HERL Hydro-Environmental Research Laboratory Hongik University

Applying RCP scenarios on inundation due to levee breach with SCHISM : Saemangeum Basin, Korea

2017 APCC

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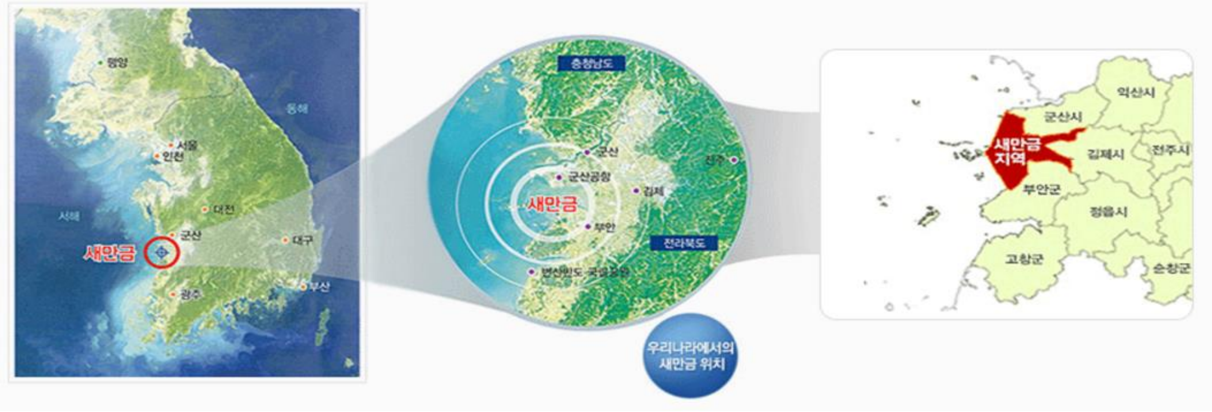
Introduction

□ Background of Saemangeum Basin

- Location : Central part of west coast (Gunsan city, Jeollabuk do, Gimje city, Buan-gun)
- On November 28, 1991, after the start of the anti-corrosion business April 21, 2006 complete the construction work.
- The Saemangeum Basin consists of the Mangyeong River and the Dongjin River
- Research on the Saemangeum Basin has been conducted in many areas (Prediction of long-term bed variation , Prediction of flood elevation etc.)
- Reference : Saemangeum Development and Investment Agency



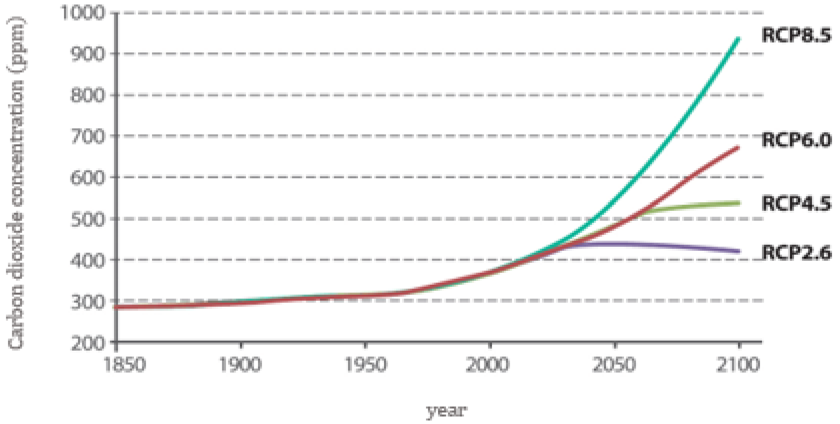
Introduction

□ Climate Change (RCP Scenario)

→ RCP (Representative Concentration Pathways)

→ Setting the greenhouse gas concentration value, it calculates the scenario of climate change and decides the policy of reduction of green house gas emission by society and economy sector as a result.

Classification	Feature	Remarks (Carbon dioxide concentration)
RCP 2.6	The earth itself can recover the effects of human activities.	420 ppm
RCP 4.5	The greenhouse gas reduction policy is implemented fairly.	540 ppm
RCP 6.0	The greenhouse gas reduction policy realized to some extent.	670 ppm
RCP 8.5	The greenhouse gas emissions without reduction	940 ppm



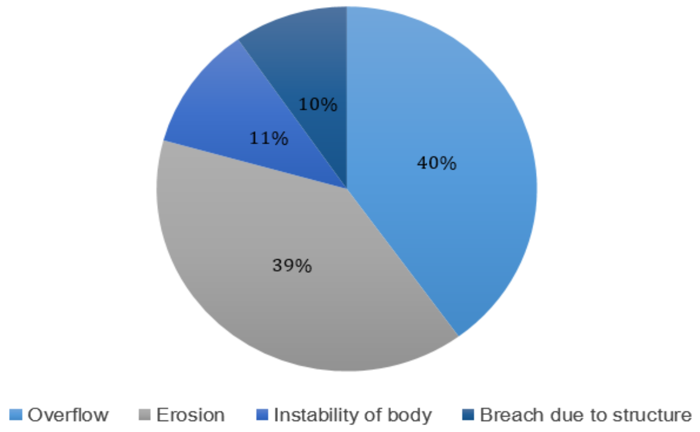
Reference : KACCC (Korea Adaptation Center for Climate Change

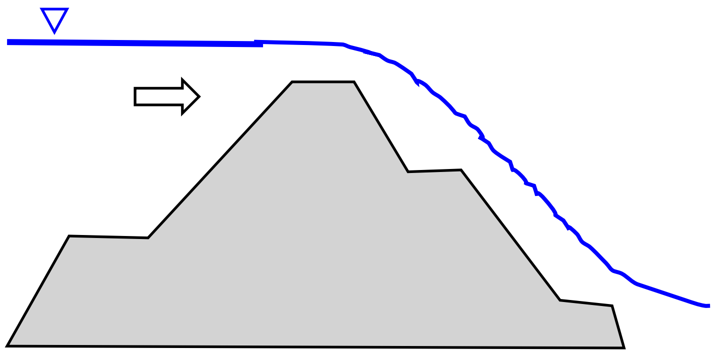
❖ RCP 8.5 scenarios were applied to calculate the flood discharge by frequency of Jeonju stream

Introduction

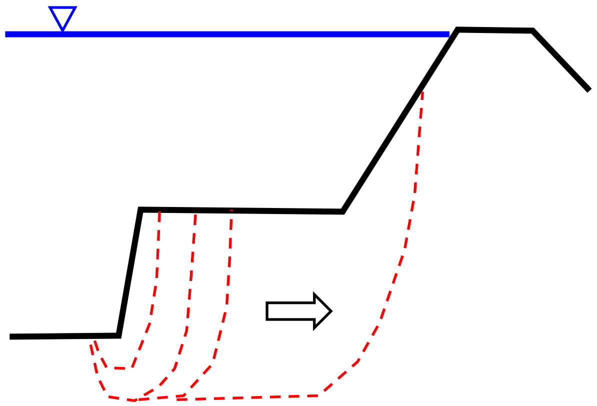
☐ Mechanism of Levee breach

- Overflow
  - → Lack of levee height , Underestimation of design flood
- Scour
  - → Steepness of river , Excessive flow velocity & Narrow width of river
- Instability of body
  - → Piping
- Breach due to structure

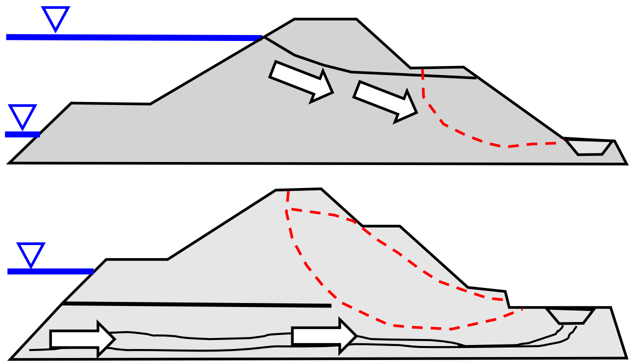




Overflow



Erosion

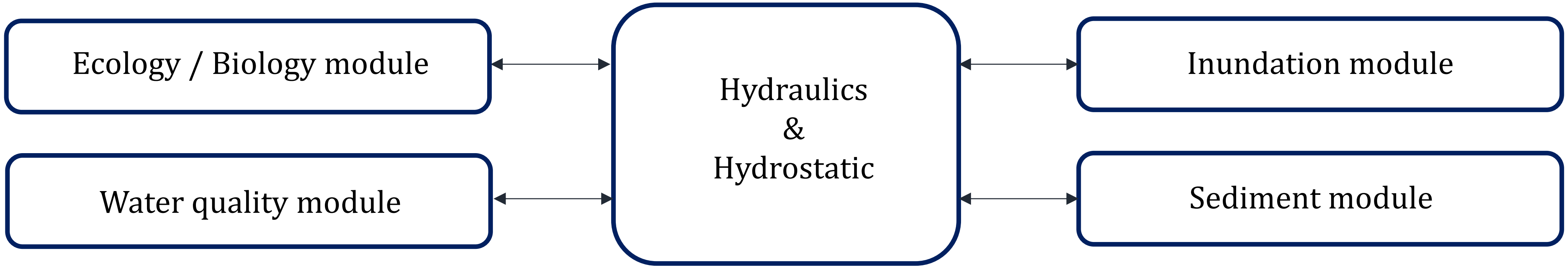


Piping

Introduction-SCHISM

□ Model description

- **SCHISM: Semi-implicit Cross-scale Hydroscience Integrated System Model**
- A derivative product of SELFE v3.1 , developed by Dr. Zhang in Virginia Institute of Marine Science
- Distributed with open-source Apache v2 license , Operationally tested and proven (DWR, NOAA etc.)
- Finite-element and finite-volume approach : unstructured grids (Mixed grids : tri-quads)
- Semi-implicit time stepping : large time step and no splitting errors
- Eulerian-Lagrangian method(ELM) for momentum advection : more efficiency & robustness
- MPI (Message Passing Interface) is available.



SCHISM modeling system

Detailed in SCHISM

□ Model description

○ **Using module**

→ Hydraulics module & Inundation module

○ **Governing Equation**

→ The SCHISM model follows the Navier-Stokes equation for incompressible fluids under the Boussinesq assumption.

→ Continuity Equation : $\nabla \cdot \mathrm{u} + \frac{\partial \mathrm{w}}{\partial \mathrm{z}} = 0$ ---- (1) , $\frac{\partial \eta}{\partial t} + \nabla \cdot \int_{-h}^{\eta} u dz = 0$ ---- (2)

(where, u : horizontal velocity , w : vertical velocity , h : bathymetric depth , η : free-surface elevation)

→ Momentum Equation : $\frac{\mathrm{D}u}{\mathrm{Dt}} = \frac{\partial}{\partial z}\left(\nu \frac{\partial u}{\partial z}\right) - g\nabla\eta + f$ ---- (3)

(where, ν : eddy viscosity , g : gravity acceleration , f : component of horizontal viscosity , air pressure etc.)

○ **Wet / Dry Condition**

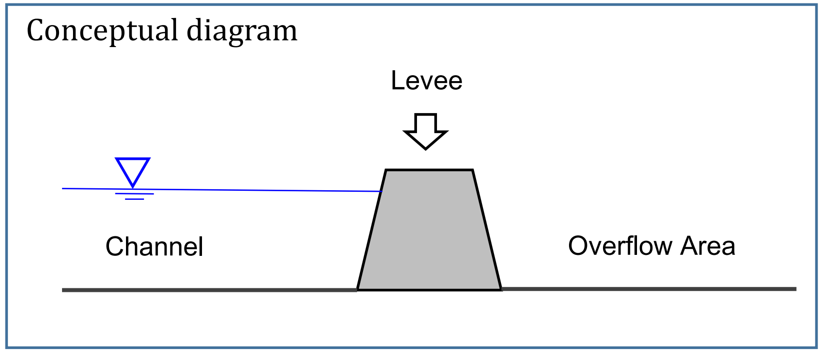
→ Set up the threshold depth

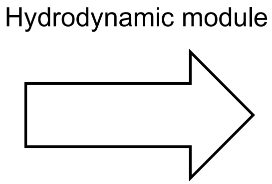
→ If one of the nodes is dry , the elements should be set as dry

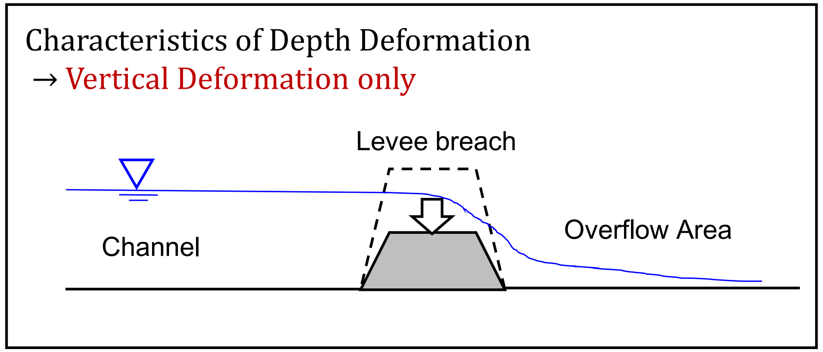
Detailed in SCHISM

□ Inundation module in SCHISM model

- Inundation module
  - → In order to use the Inundation module in the SCHISM model, the terrain depth value should be changed with time in conjunction with the Hydrodynamic module.
- Deformation process of Terrain Depth







- → In the SCHISM model, the terrain can be transformed over time using the bdef.gr3 file and the ibdef variable.
- → The bdef.gr3 is a file that gives the node a transformation value, in which negative values are descending and positive Integers are rising
- → The ibdef parameter is the number of time step required to change the terrain, and the time step value can be used to specify the rate of decay of the bank

Detailed in SCHISM

□ Geometry mesh Workflow

1) Export xyz Data

→ Because surve[illegible]ta about Saemangeum basin is 20 m interval, interpolation work is required between data.

2) Interpolation Data

→ To perform terrain interpolation, Surfer 8.0 program was used in this study and interpolation was performed by the Krigging method.

3) Mesh creation.

→ To generate mesh file, SMS program was used in this study and the grid spacing and mesh type can be set through the SMS program.

→ Building information and Contour of Jeonju were reproduced using Arc GIS program

Applications of SCHISM

□ Previous Research with SCHISM

- SCHISM which has a wet / dry function is suitable to simulate inundation modeling.
- Through inundation simulation, information on inundation area, flood wave velocity and inundation direction can be checked.
- Zhang et. Al (2008) simulated tsunami propagation and inundation using SELFE model.
- Forunato et. Al (2013) simulated the coastal flooding due to storm surges using SCHISM model.
- Chen et. Al (2013) simulated the coastal inundation in Massachusetts to examine the impact of current-wave interaction on storm-induced inundation and confirmed the inundated areas.

➢ Most inundation studies using SCHISM were focused on the coastal region but inundation on the river was insufficient.

➢ In this study, we performed inundation simulation in ideal open channels without or with uniform flow and field cases, Saemangeum Basin in Korea for several flood conditions.

Numerical Implementation for Ideal Cases

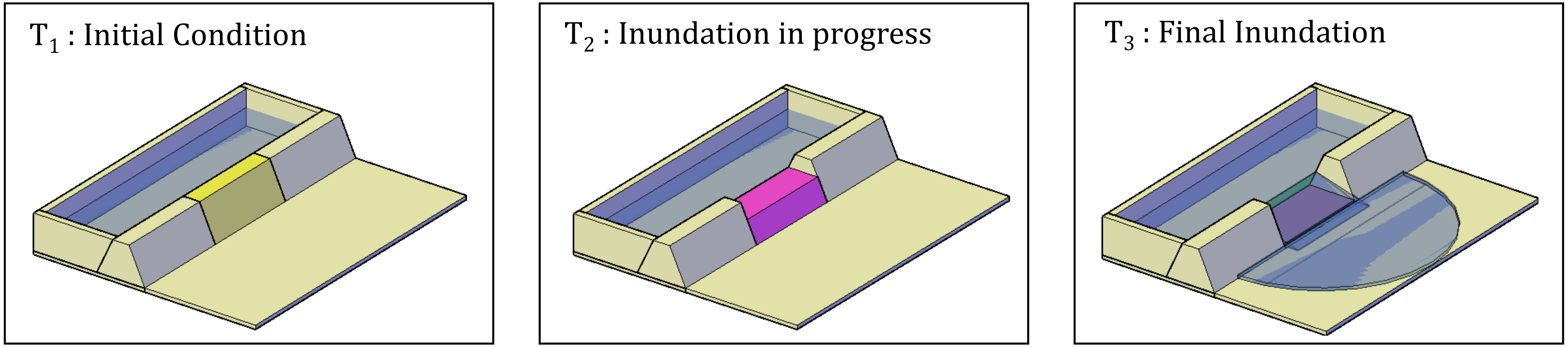
1. Dam break case
2. Uniform flow case
3. Confluence case

Numerical Simulation Implementation #1

- Purpose
  - Ensure whether the wet / dry conditions in the SCHISM model are applied well or not.
- Classification
  - Still water case & uniform flow case with mesh dependence.
- Topography
  - Inundation simulation was implemented in ideal channel.
  - Dam break Case : Ideal channel was constructed with a width of 500 m and a length of 2000 m and levee slope is 1:2
  - Uniform flow Case : Ideal channel was constructed with a width of 15 m and a length of 50 m and levee slope is 1:2
  - Levee collapse width & shape : 100 m & rectangular

Numerical Simulation Implementation #1

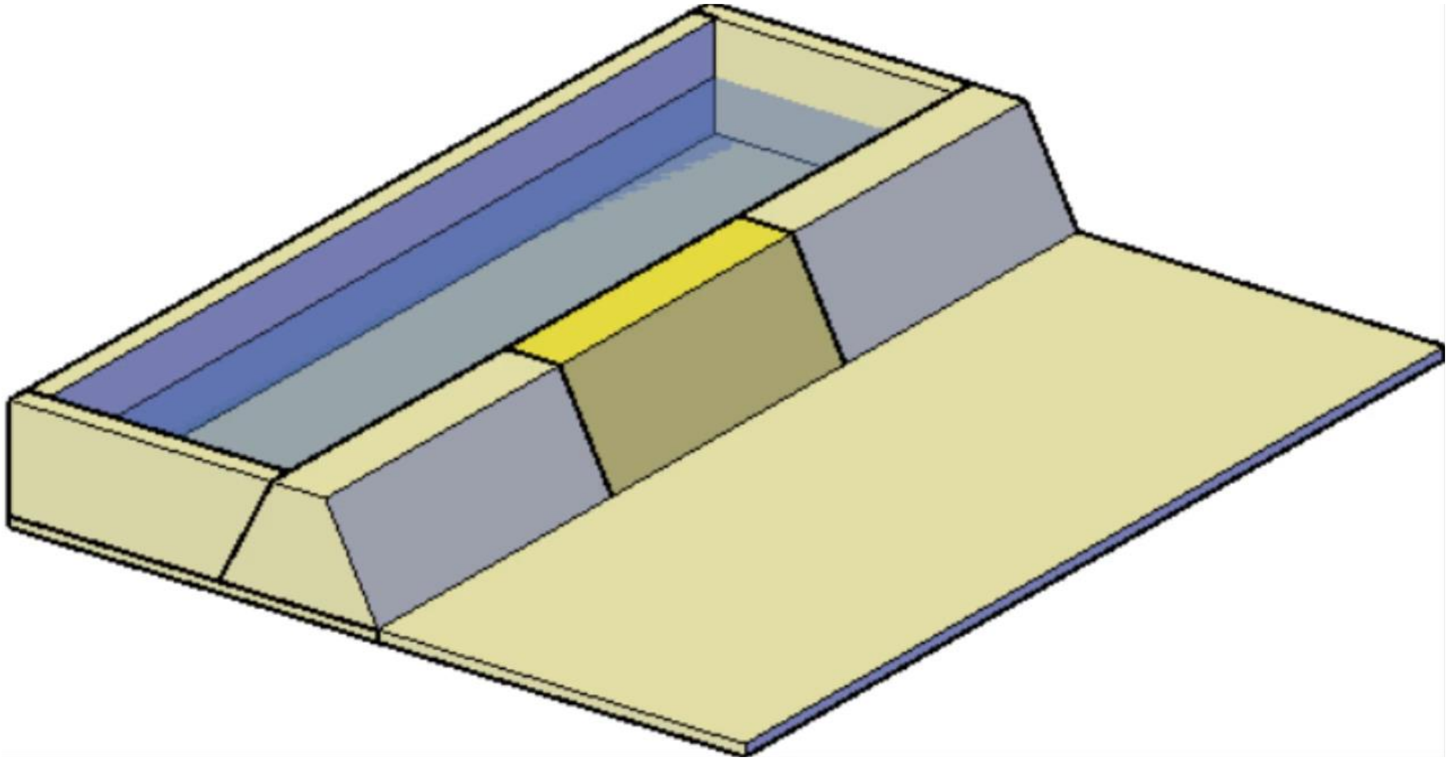
- Still water Case
  - Flow Chart



- Configuration
  - Check the propagation range , flood wave velocity after levee breach in stationary state
  - Compare the results according to mesh type effect (Rectangular vs. Triangular)

Numerical Simulation Implementation #1

- Dam break Case
  - Inundation Process (animation)



Numerical Simulation Implementation #1

□ Model setup

○ Grid & Time step

→ Total 216000 elements, 216941 nodes (quads grids) & Total 500068 elements, 250975 nodes (triangular grids)

→ Grid spacing is 5 m & Time step is 5 seconds (CFL number = 1.5)

→ CFL (Courant-Friedrichs-Lewy condition) number

CFL number = $\frac{u \cdot \Delta t}{\Delta x}$ (where, u = flow velocity , Δx = grid spacing , Δt = time step)

○ Boundary Condition & Initial Condition

	Boundary Condition	Initial Condition
Box Container	Discharge (No output)	Wet condition (Constant Elevation value)
Interior floodplain	Elevation	Dry condition

Numerical Simulation Implementation #1

□ Model setup

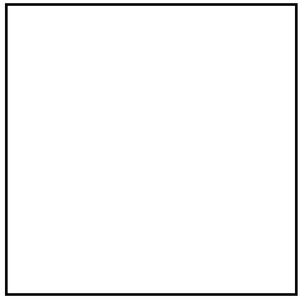
○ Levee Information

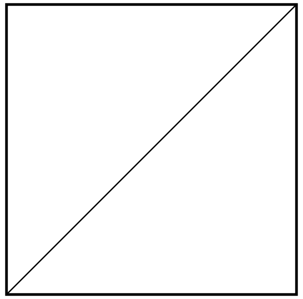
→ Collapse Shape is Rectangular (Collapse Width : 100 m , Collapse Time : 80 min)

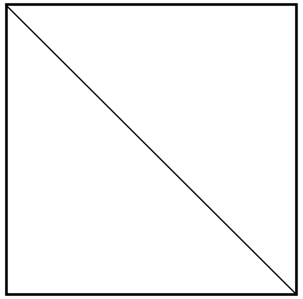
○ Numerical Simulation Case

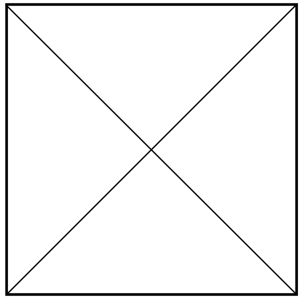
→ Total 2 Case according to mesh type

Case	1	2	3	4
Mesh Type	Rectangular	L-Triangular	R-Triangular	Triangular


Mesh Type 1


Mesh Type 2


Mesh Type 3

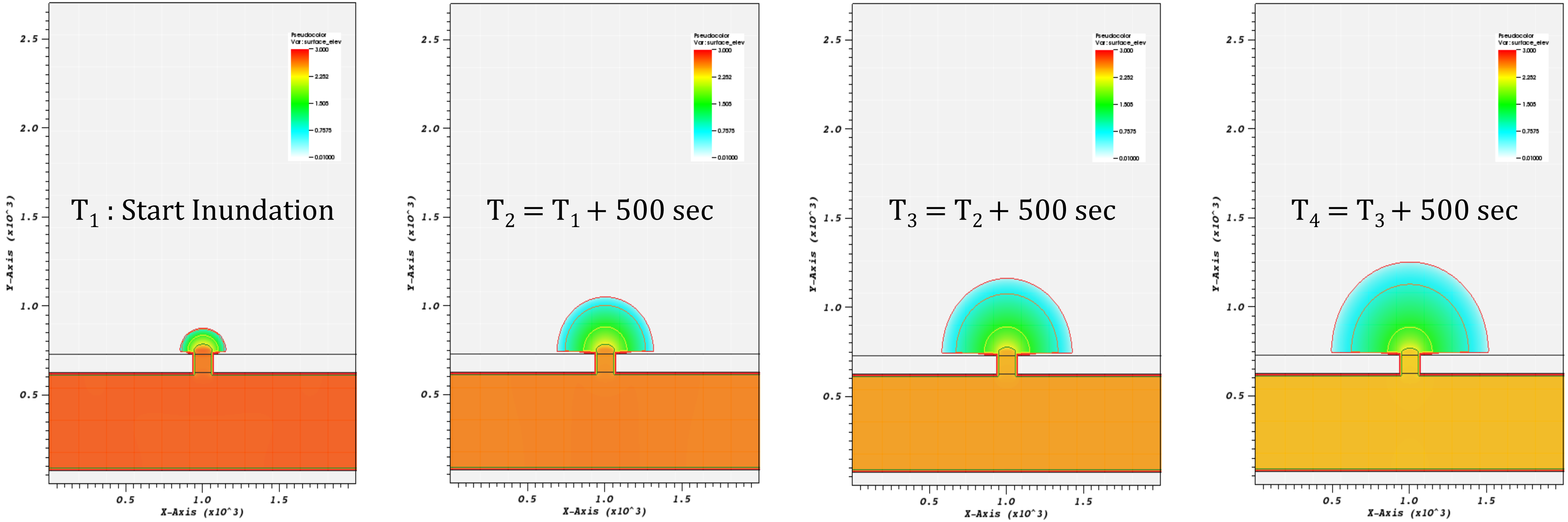

Mesh Type 4

Numerical Simulation Implementation #1

Results

- Inundation Process (Rectangular mesh)

  → Surface elevation results (Time history)

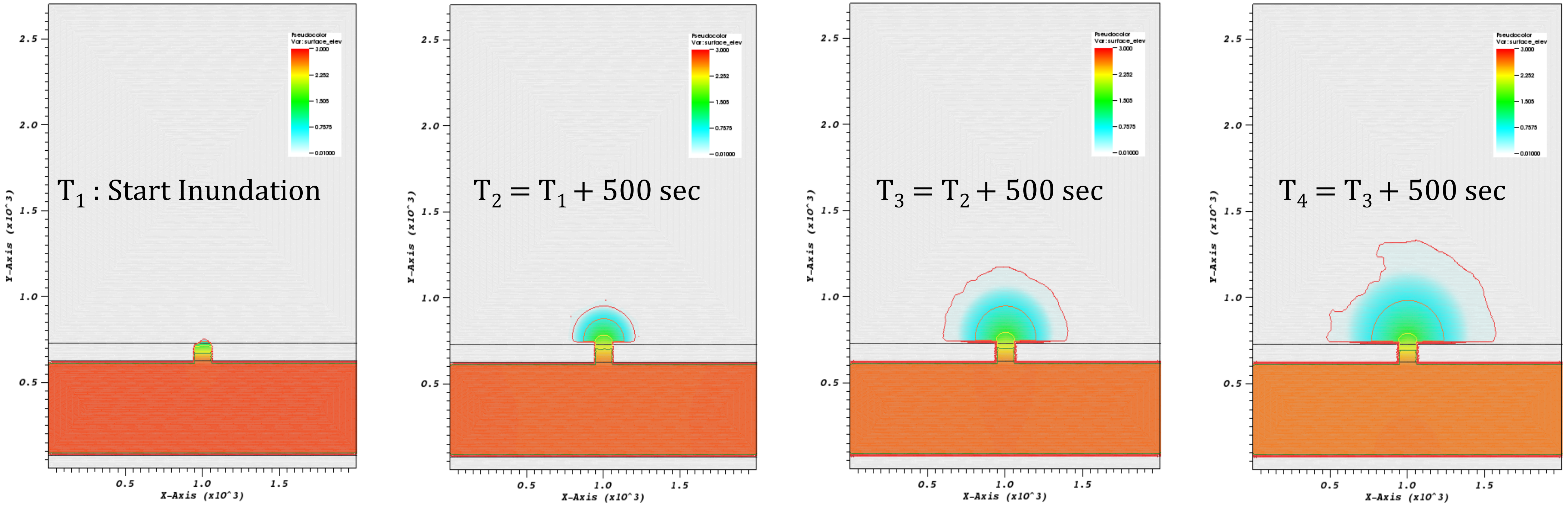


Numerical Simulation Implementation #1

□ Results

- Inundation Process (Triangular mesh)

  → Surface elevation results (Time history)

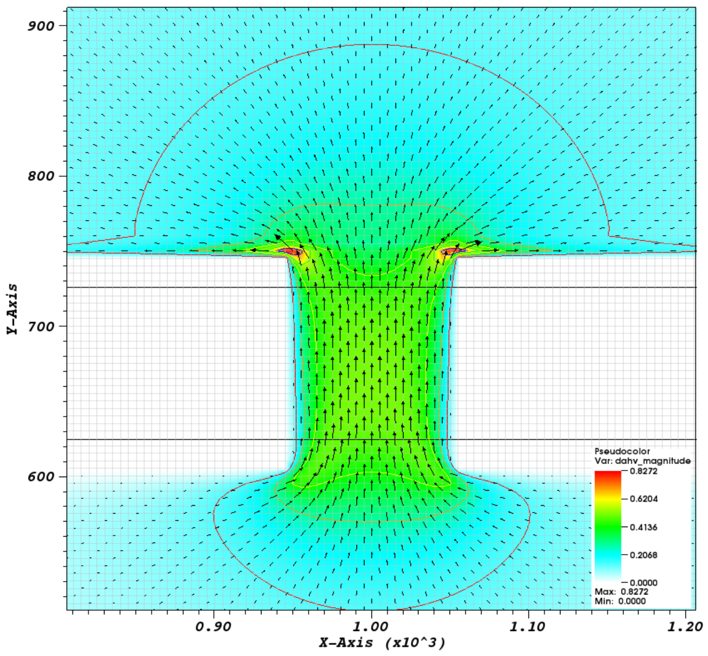


Numerical Simulation Implementation #1

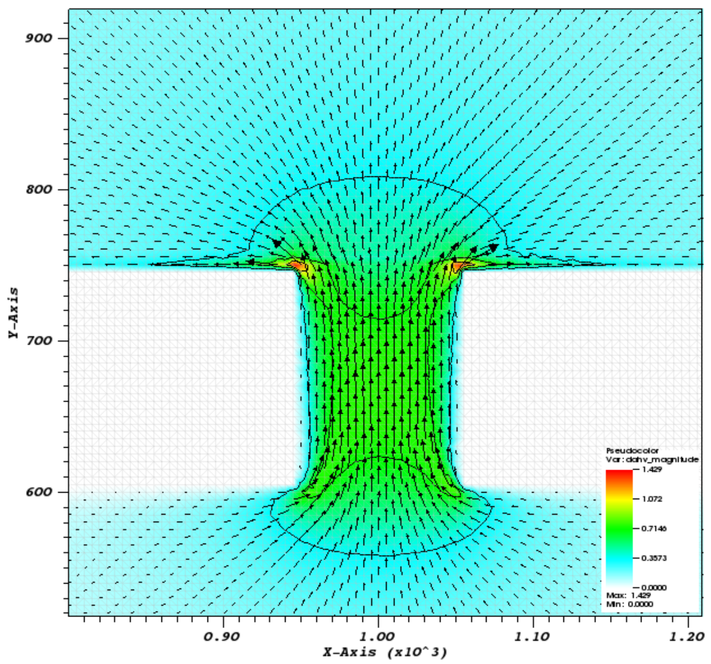
□ Results

- Inundation Process (Rectangular & Triangular mesh)

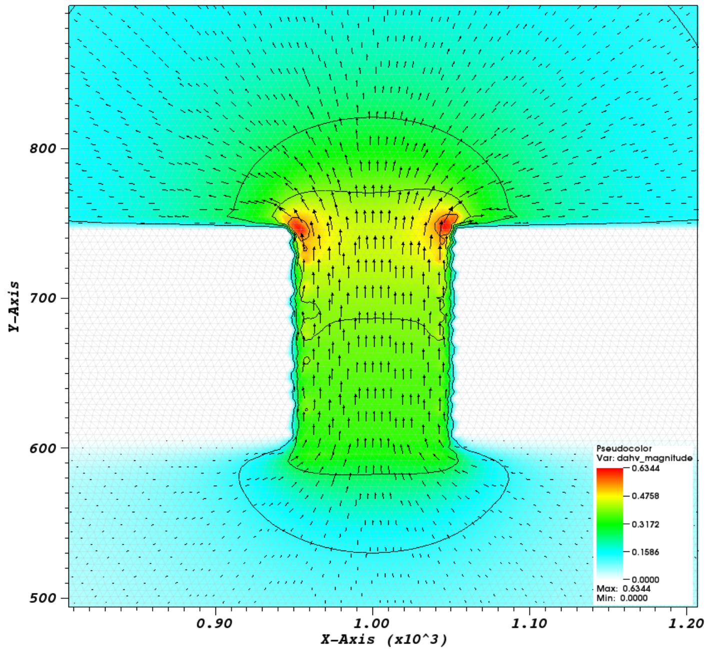
  → Depth averaged velocity & velocity vector (at $T = T_4$)



Mesh Type 1
(Rectangular)



Mesh Type 2 & 3
(L- and R-triangular)



Mesh Type 4
(Triangular)

Numerical Simulation Implementation #1

□ Results Analysis from Dam break case

- The wet / dry condition is well applied in the SCHISM model.
- However, after the levee breach, the propagation patterns of the flood waves were different according to mesh type
- The maximum flow velocity appears at the same point, but the magnitude of flow velocity becomes different according to mesh type maybe due to the density of mesh

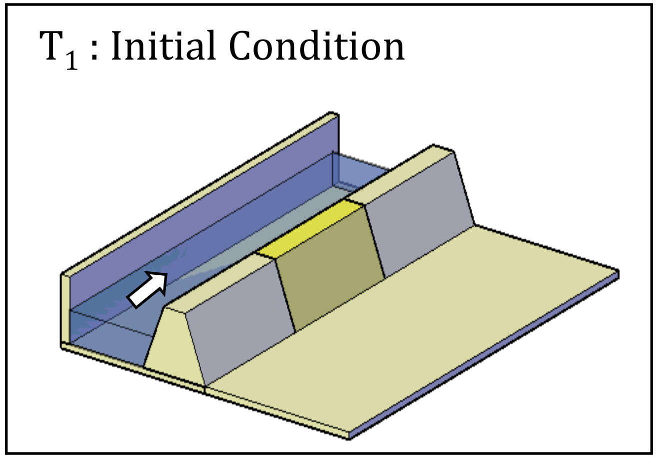
➢ Results from SCHISM model such as propagation patterns and flow velocity are strongly influenced by the mesh type, which is highly dependent the direction of flow.

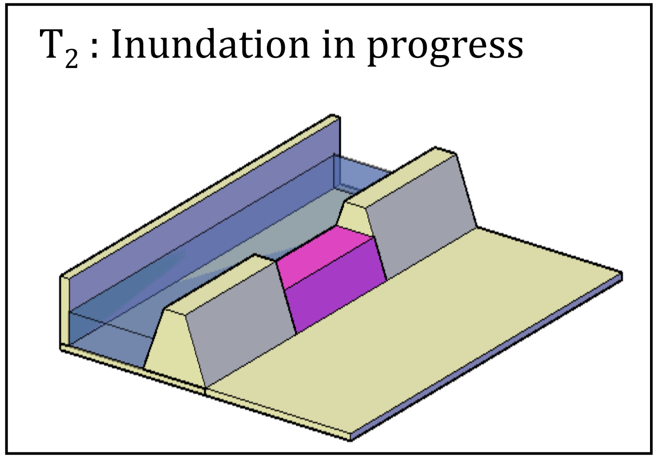
➢ Therefore, results from the SCHISM simulation for inundation should be examined in terms of the mesh type and mesh orientation.

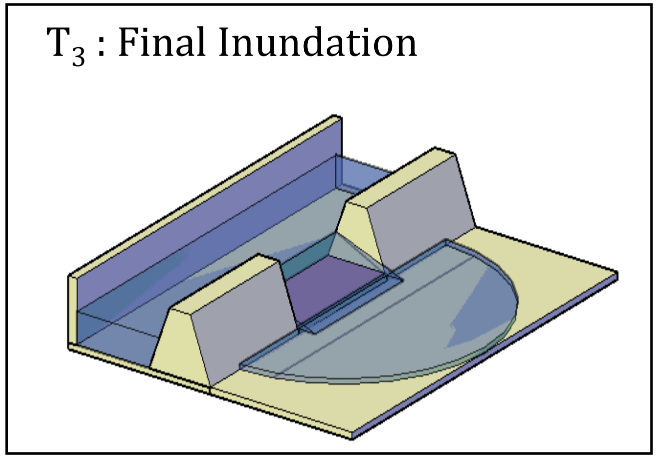
Numerical Simulation Implementation #2

☐ Uniform flow Case

- Flow Chart





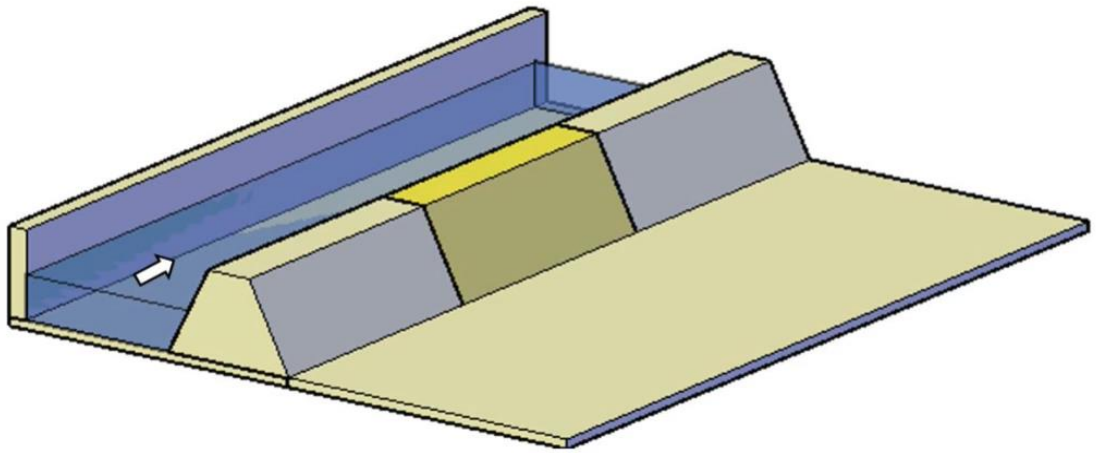


☐ Configuration

- Check the propagation range , flood wave velocity after levee breach in flow state
- Compare the results according to mesh orientation (4 case)

Numerical Simulation Implementation #2

- Uniform flow Case
  - Inundation Process (animation)



Numerical Simulation Implementation #2

□ Model setup

○ Grid & Time step

→ Total 1280 elements, 693 nodes (triangular grids) ,

→ Grid spacing is 2.5 m & Time step is 5 seconds (CFL number = 1.5)

→ CFL (Courant-Friedrichs-Lewy condition) number

CFL number = $\frac{u \cdot \Delta t}{\Delta x}$ (where, u = flow velocity , Δx = grid spacing , Δt = time step)

○ Boundary Condition & Initial Condition

	Boundary Condition	Initial Condition
Upstream	Discharge	Wet condition (Constant Elevation value)
Downstream	Elevation	Wet condition (Constant Elevation value)
Interior floodplain	Elevation	Dry condition

Numerical Simulation Implementation #2

□ Model setup

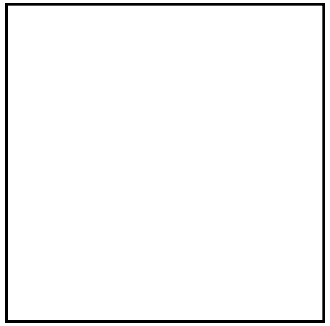
○ Levee Information

→ Collapse Shape is Rectangular (Collapse Width : 2.5 m , Collapse Time : 20 min)

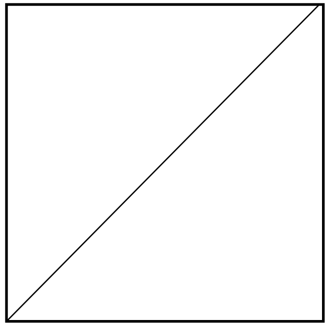
○ Numerical Simulation

→ Total 4 Cases according to mesh orientation

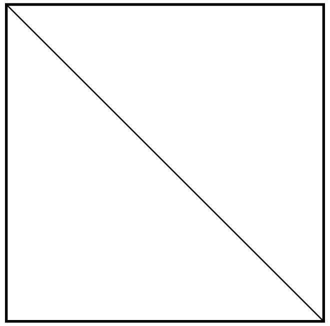
→ Mesh configurations are as below:



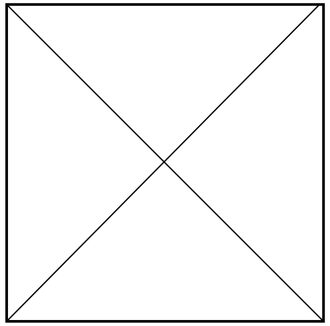
Type 1



Type 2



Type 3



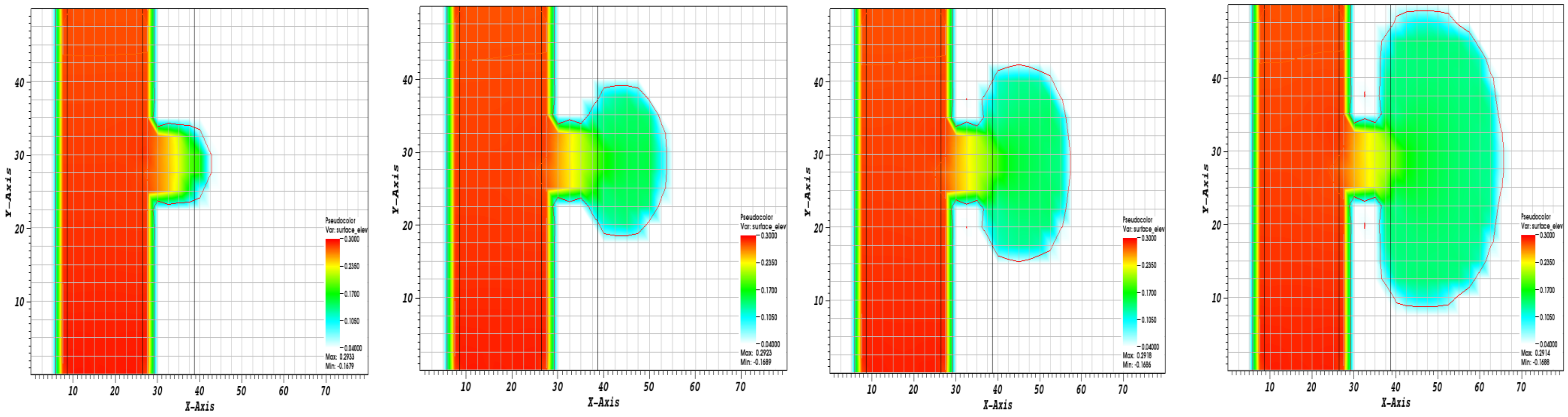
Type 4

Numerical Simulation Implementation #2

□ Results

- Inundation Process (□ type mesh)

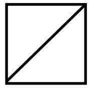
  → Surface elevation results (Time history)



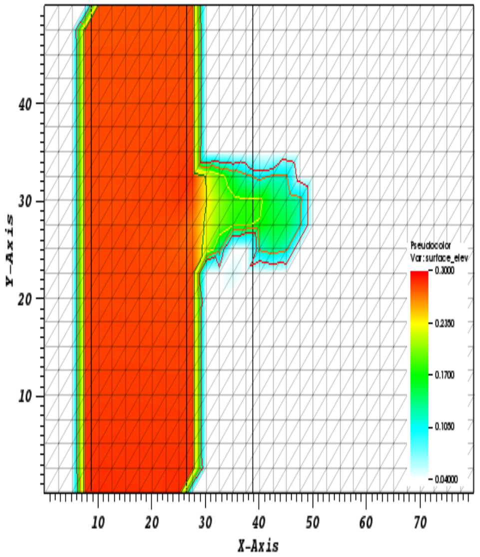
T_1 : Start Inundation $\qquad T_2 = T_1 + 10$ sec $\qquad T_3 = T_2 + 10$ sec $\qquad T_4 = T_3 + 10$ sec

Numerical Simulation Implementation #2

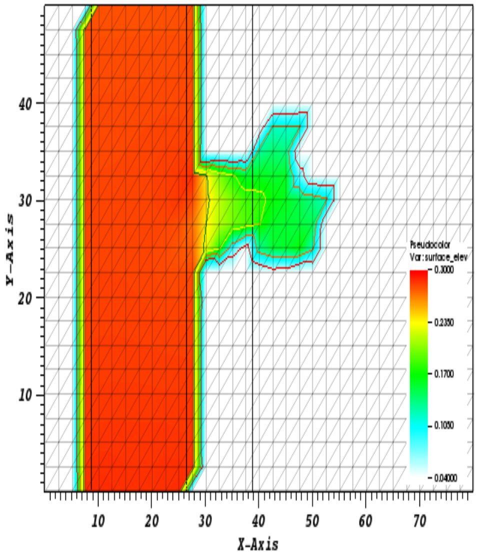
□ Results

- Inundation Process ( type mesh)

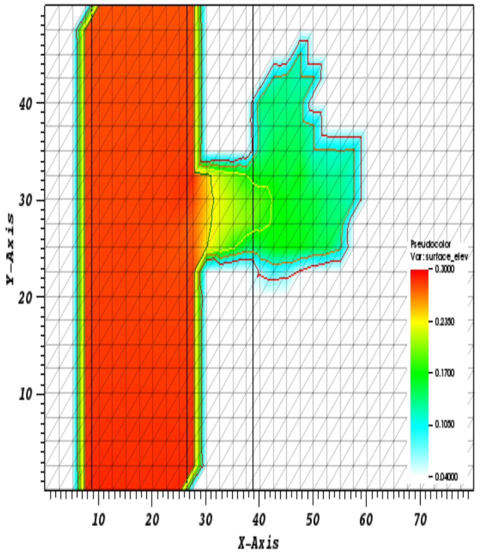
  → Surface elevation results (Time history)



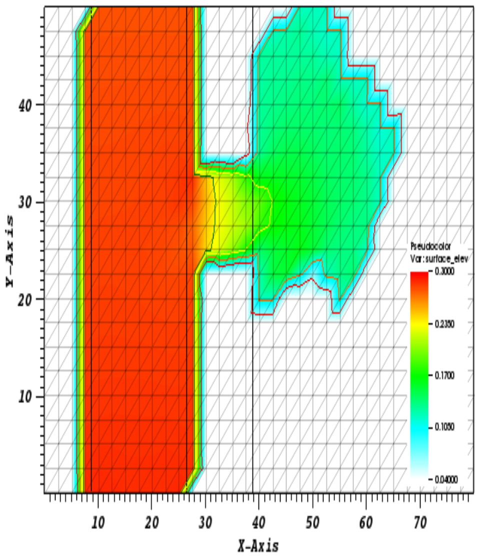
T_1 : Start Inundation



$T_2 = T_1 + 10$ sec



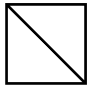
$T_3 = T_2 + 10$ sec



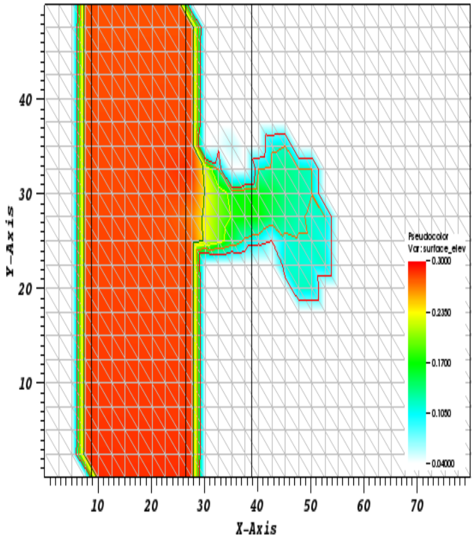
$T_4 = T_3 + 10$ sec

Numerical Simulation Implementation #2

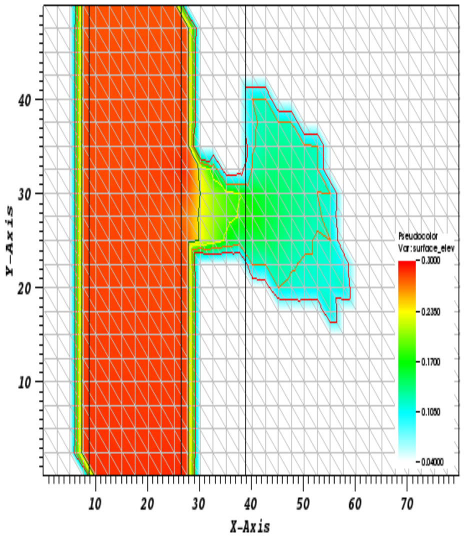
□ Results

- Inundation Process ( type mesh)

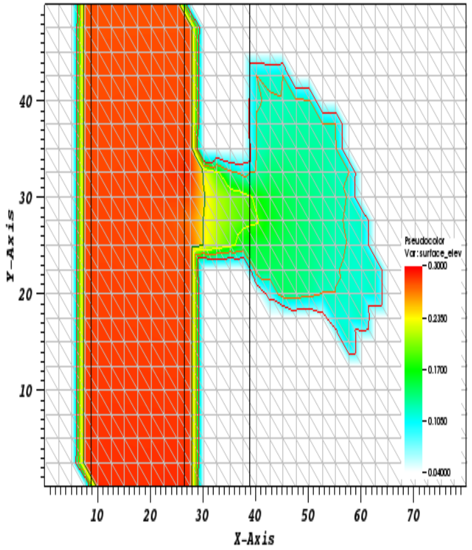
→ Surface elevation results (Time history)



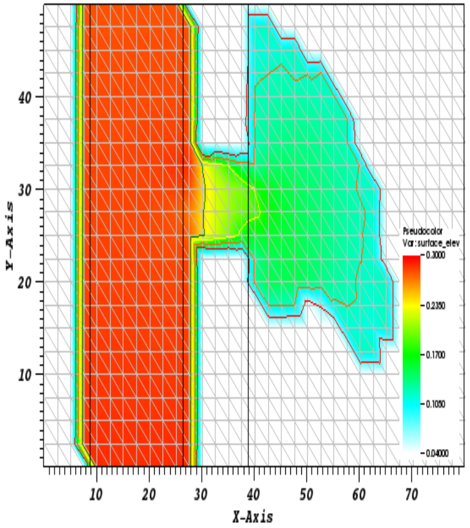
T_1 : Start Inundation



$T_2 = T_1 + 10$ sec



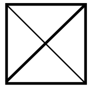
$T_3 = T_2 + 10$ sec



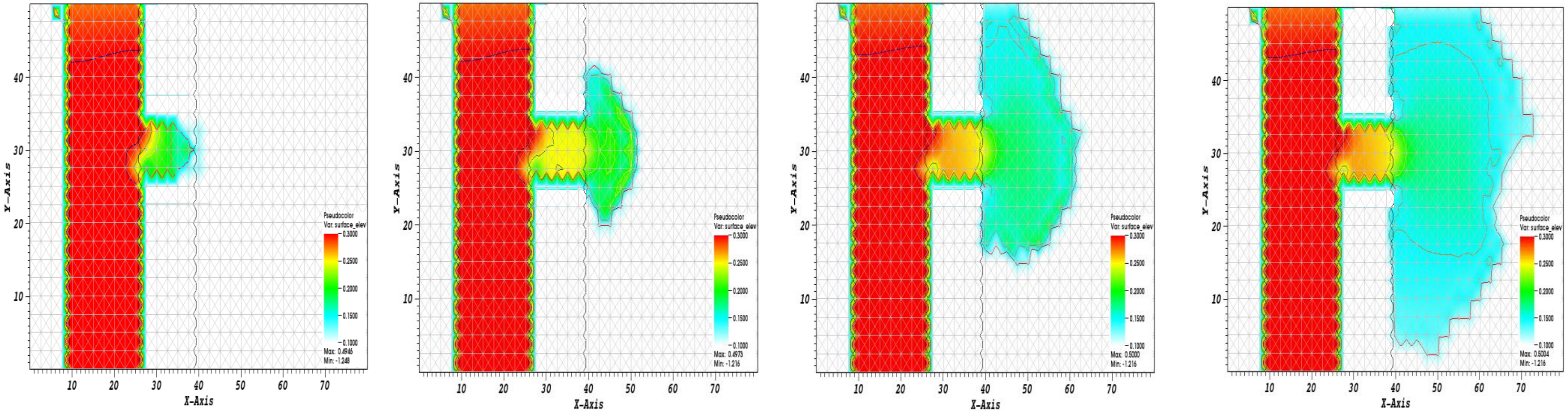
$T_4 = T_3 + 10$ sec

Numerical Simulation Implementation #2

□ Results

- Inundation Process ( type mesh)

  → Surface elevation results (Time history)



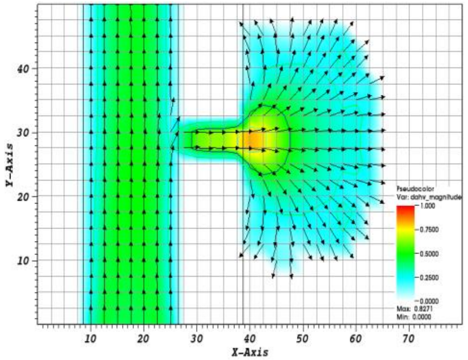
T_1 : Start Inundation $T_2 = T_1 + 10$ sec $T_3 = T_2 + 10$ sec $T_4 = T_3 + 10$ sec

Numerical Simulation Implementation #2

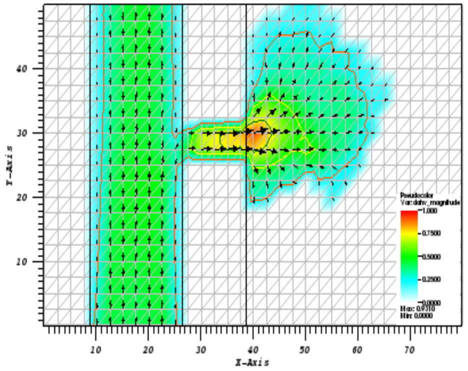
□ Results

- Inundation Process (Rectangular & Triangular mesh)

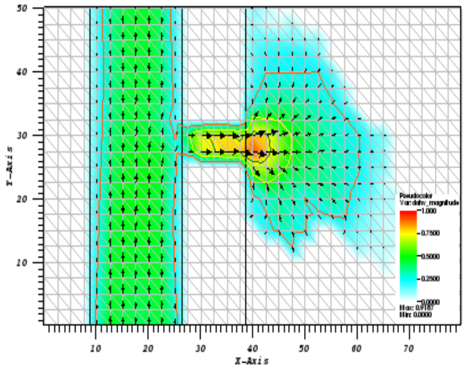
  → Depth averaged velocity & velocity vector (at $T = T_4$)



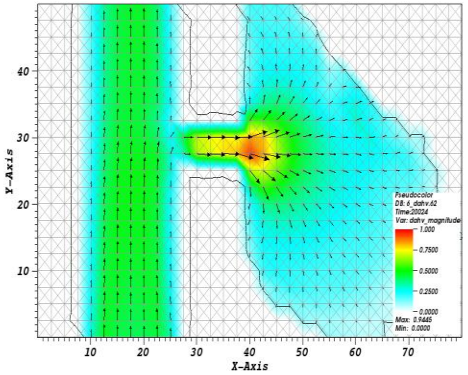
(a) Rectangular



(b)L-triangular



(c)R-triangular



(d)x-triangular

Numerical Simulation Implementation #2

- Results Analysis from uniform flow case
  - Through sensitivity analysis, the SCHISM model is affected by the mesh orientation.
  - After the levee breach, the propagation patterns of the flood waves were different according to mesh orientation
  - In case of mesh type 3, the flow velocity is faster than the other grid type and Maximum velocity also occurred elsewhere in other mesh types.

➢ The results of SCHISM model such as propagation patterns , flow velocity are strongly influenced by the mesh orientation.

➢ Therefore, Understanding the flood wave characteristics and physical meaning is important to set the mesh directionality.

Numerical Simulation Implementation #3

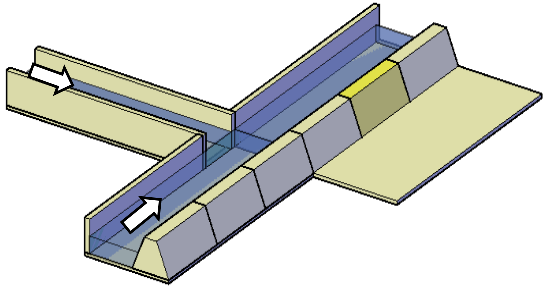
- Purpose
  - Configuration of the inundation area according to variation of tributary flow rate
  - Configuration of the direction of velocity vector and analysis of flood wave velocity according to variation of tributary flow rate
- Classification
  - River with tributary in terms of ration of discharge
- Topography
  - Inundation simulation was implemented in ideal channel.
  - Ideal channel consists of main channel which width is 500 m and length is 4,750 m, tributary channel which width is 200 m and length is 2,000 m
  - Levee height is 25 m , levee width is 50 m , levee slope is 1:2

Numerical Simulation Implementation #3

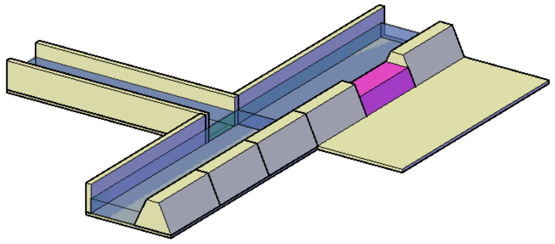
□ Tributary flow Case

○ Flow Chart

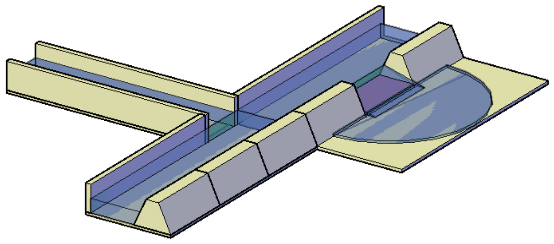
T_1 : Initial Condition



T_2 : Inundation in progress



T_3 : Final Inundation



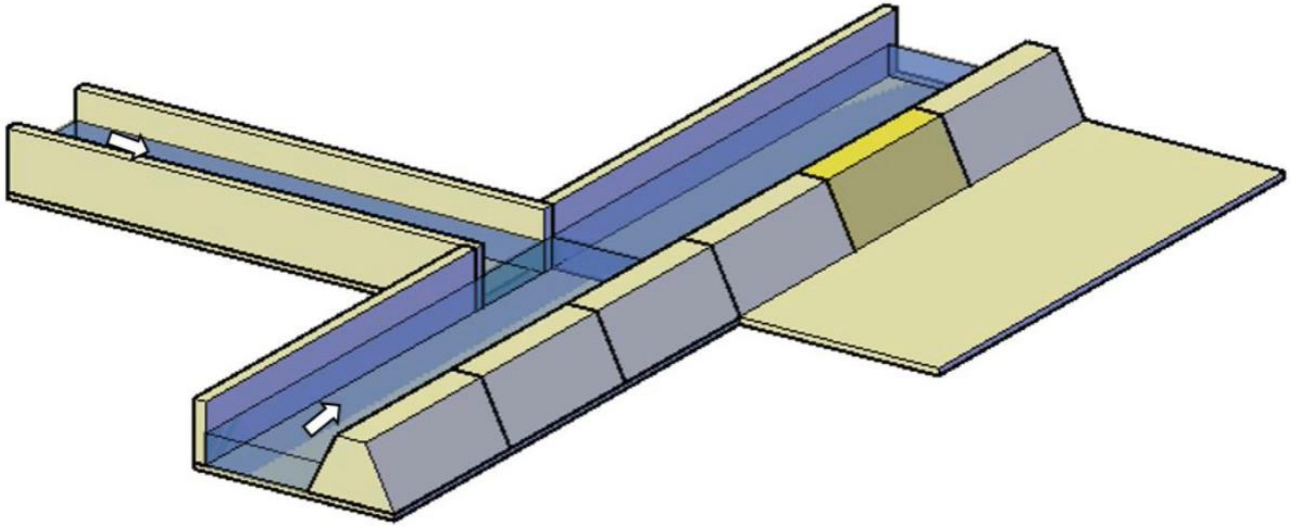
□ Configuration

○ Check the propagation range , flood wave velocity after levee breach in flow state

○ Compare the results according to variation of tributary flow rate (5 case)

Numerical Simulation Implementation #3

- Confluence flow Case
  - Inundation Process (animation)



Numerical Simulation Implementation #3

□ Model setup

○ Grid & Time step

→ Total 11800 elements, 12171 nodes (quad grids)

→ Grid spacing is 25 m & Time step is 5 seconds (CFL number = 1.5)

→ CFL (Courant-Friedrichs-Lewy condition) number

CFL number = $\frac{u \cdot \Delta t}{\Delta x}$ (where, u = flow velocity , Δx = grid spacing , Δt = time step)

○ Boundary Condition & Initial Condition

	Boundary Condition	Initial Condition
Upstream	Discharge	Wet condition (Constant Elevation value)
Downstream	Elevation	Wet condition (Constant Elevation value)
Interior floodplain	Elevation	Dry condition

Numerical Simulation Implementation #3

□ Model setup

○ Observing Points

→ Configuration of Mass Conservation → Discharge (Section 1 ~ 4)

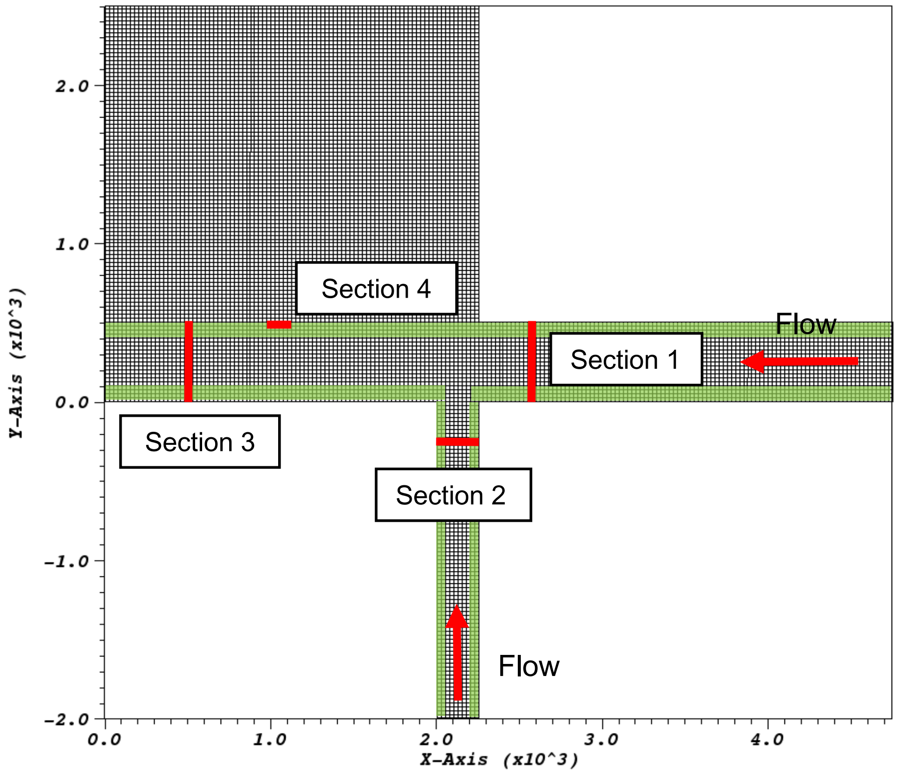
→ Configuration of velocity vector → Propagation direction

→ Configuration of flood wave velocity (maximum velocity)

○ Numerical Simulation Cases

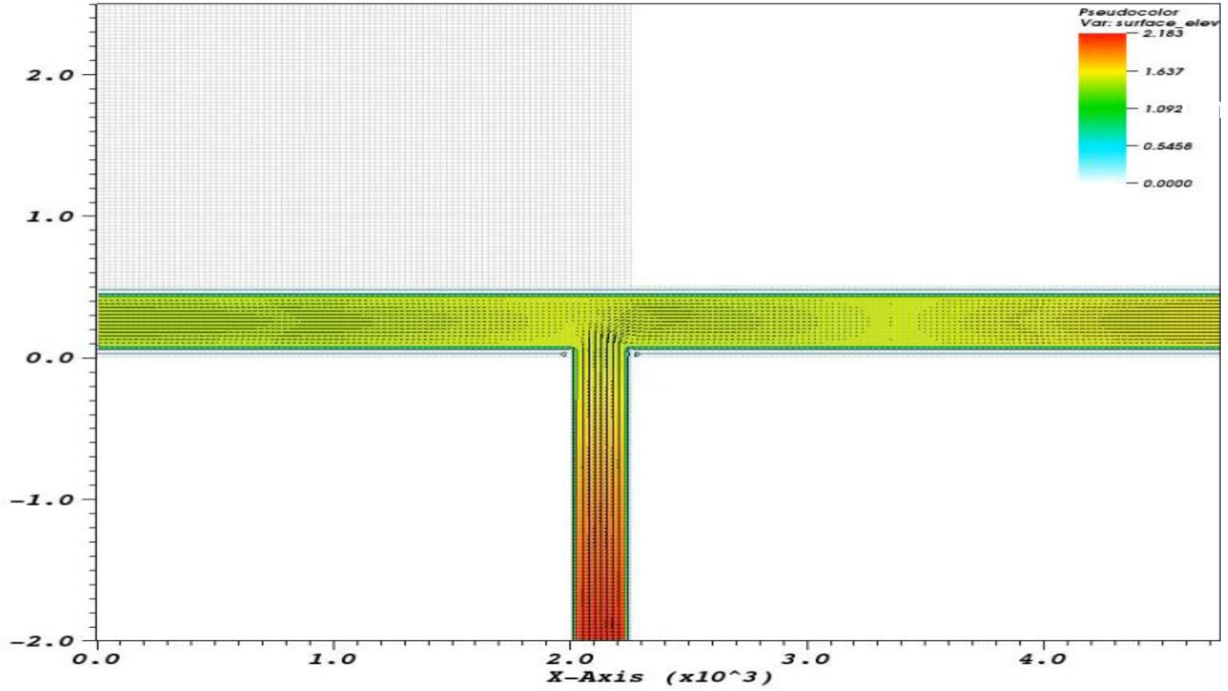
→ Q_m is main channel discharge , Q_t is tributary channel discharge

Case	1	2	3	4	5
Main Channel Discharge	400 m^3/s	400 m^3/s	400 m^3/s	400 m^3/s	400 m^3/s
Tributary Channel Discharge	200 m^3/s	320 m^3/s	400 m^3/s	480 m^3/s	600 m^3/s
Tributary flow rate (Qt/Qm)	0.5	0.8	1.0	1.2	1.5



Numerical Simulation Implementation #3

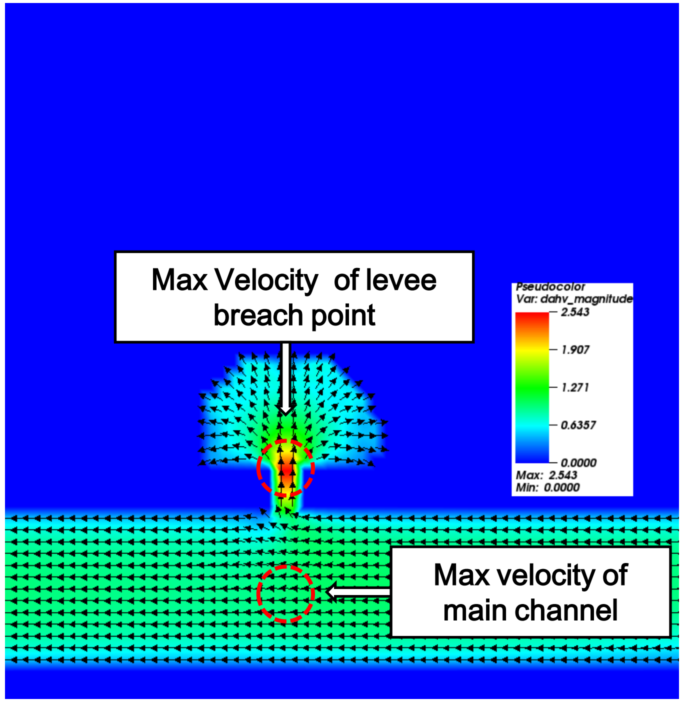
- Results
  - Froude numbers are between 0.2 and 0.27 in main channel
  - When Inundation starts , the velocity in levee breach point is maximum value
  - The collapse flow is formed perpendicular to the main channel flow

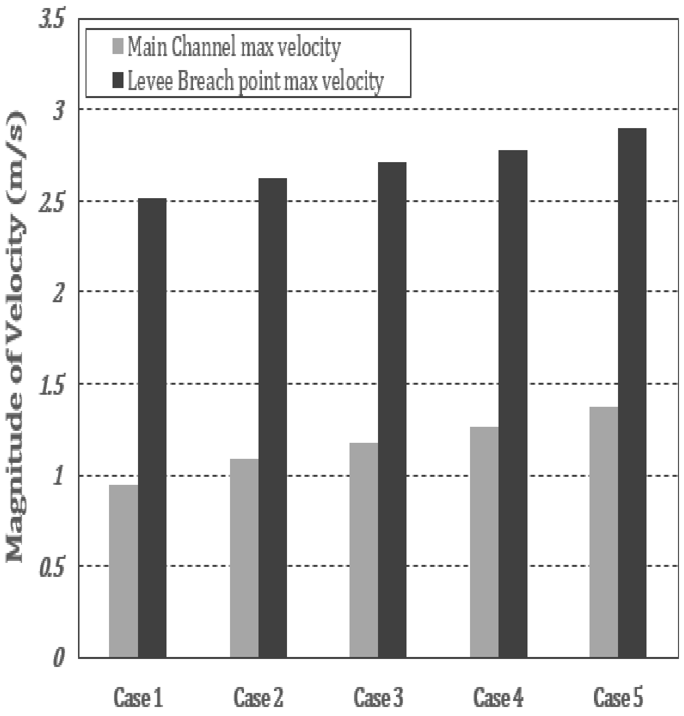


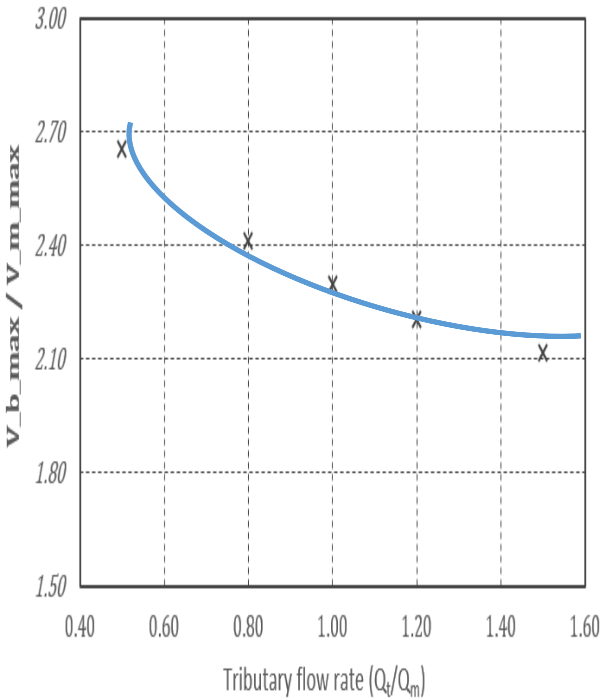
Numerical Simulation Implementation #3

□ Results

- As the tributary flow rate ratio increases, the velocity ratio of the levee breach point to the main channel decreases
- V_b_max : maximum velocity in flood plain (at nose of levee breach point in most cases), V_m_max : maximum velocity of main channel (center point in most cases)







Numerical Calibration &Verification

Numerical Calibration

□ Field Data

- Date : 2011. 08. 08 ~ 2011. 08. 14 (Total 7 days)
- Location : JeonJu Gauging Station of JeonJu-cheon
- Data Type : Discharge (m^3/s) & Water Elevation (m)
- Reference : Yeong-san River Flood Control Office

JeonJu Gauging Station

- Latitude : 35.879 °
- Longitude : 127.098 °
- River : JeonJu-cheon
- Data is present every 10 minutes.

□ SCHISM modeling of JeonJu-cheon

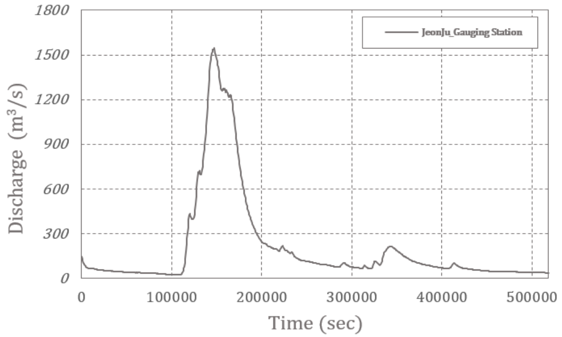
- Calibration Parameter : Roughness height (m)
- Total 12,471 elements, 13,146 nodes (quad grids)
- Hydraulic structure information (Surveying data)
- Initial Condition : Referred by "Saemangeum District Hydrological Investigation Report" , Korea Rural Community Corporation

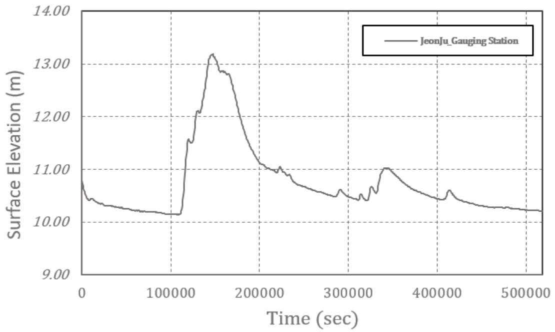
Numerical Condition

	Boundary Condition	Grid spacing	Time step
Upstream	Discharge	10 ~ 20 m	2 sec
Downstream	Elevation		

Numerical Calibration

☐ Discharge (m^3/s) & Water Elevation (m) at JeonJu Gauging Station



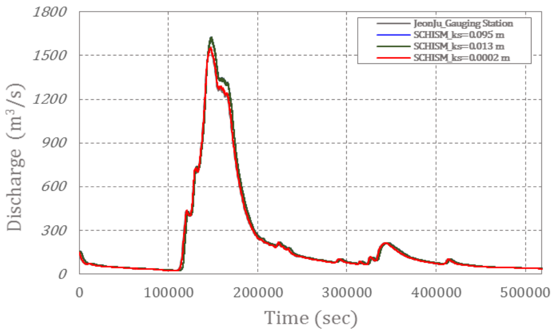


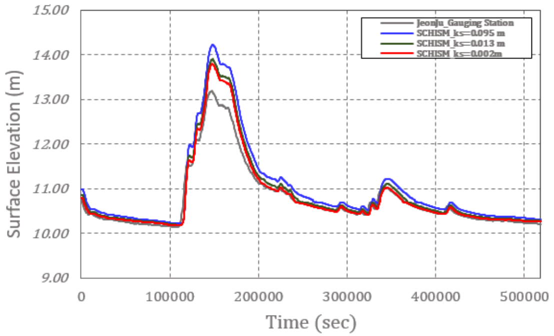
- Date : 2011. 08. 08 ~ 2011. 08. 14
- Time step : 10 min
- Maximum Discharge : 1552 (m^3/s)
- Maximum Surface Elevation : 13.2 (m)

☐ SCHISM model simulation results at JeonJu Gauging Station

○ Strickler Equation $n = 0.034 \cdot k_s^{1/6}$ (where, n : Manning Coefficient , k_s : Roughness height)

○ Total 3 Case (Roughness height : 0.095 m , 0.013 m , 0.0002 m)

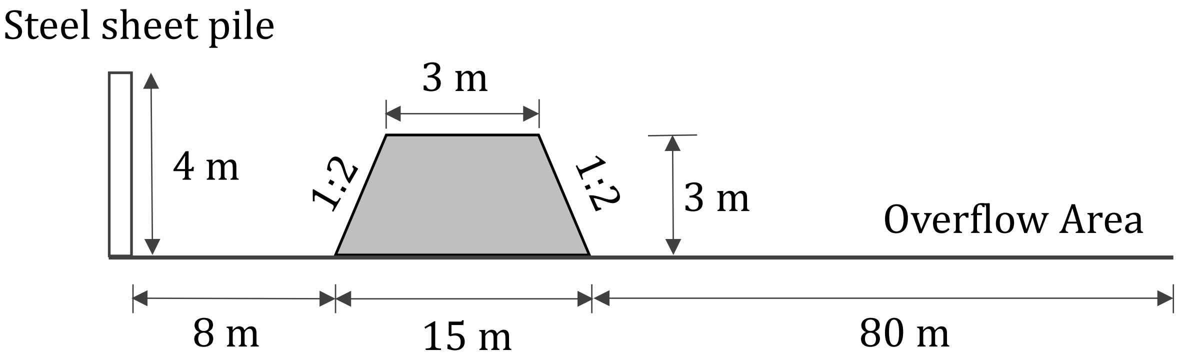




k_s	Error of Discharge (%)	Error of Water Depth(%)
0.095 m	5.05	7.84
0.013 m	4.50	5.31
0.0002 m	0.25	4.52

Numerical Verification

- Reference
  - Kakinuma et al. (2014) "Large-Scale Experiment and Numerical Modeling of a Riverine Levee Breach" , ASCE
- Experimental flume , Specification of the flume & Numerical Condition

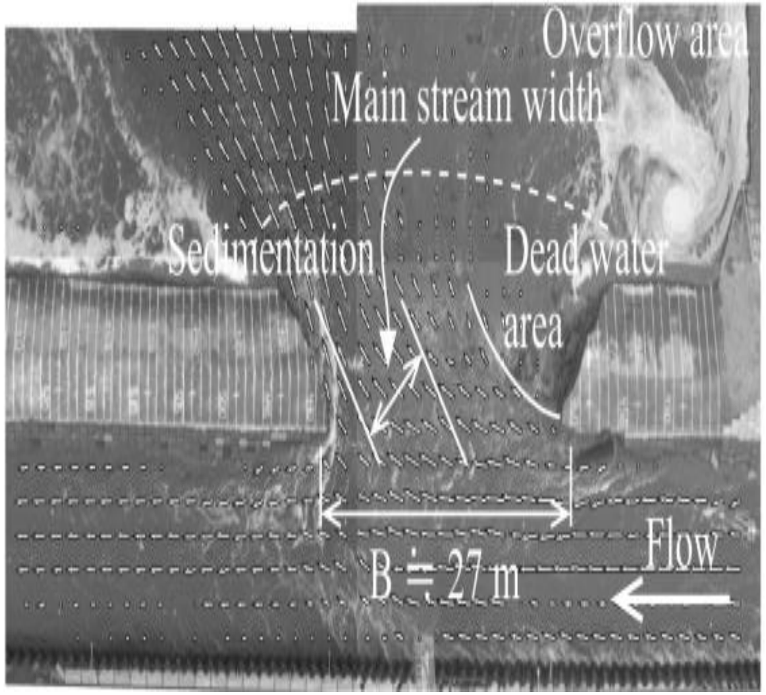


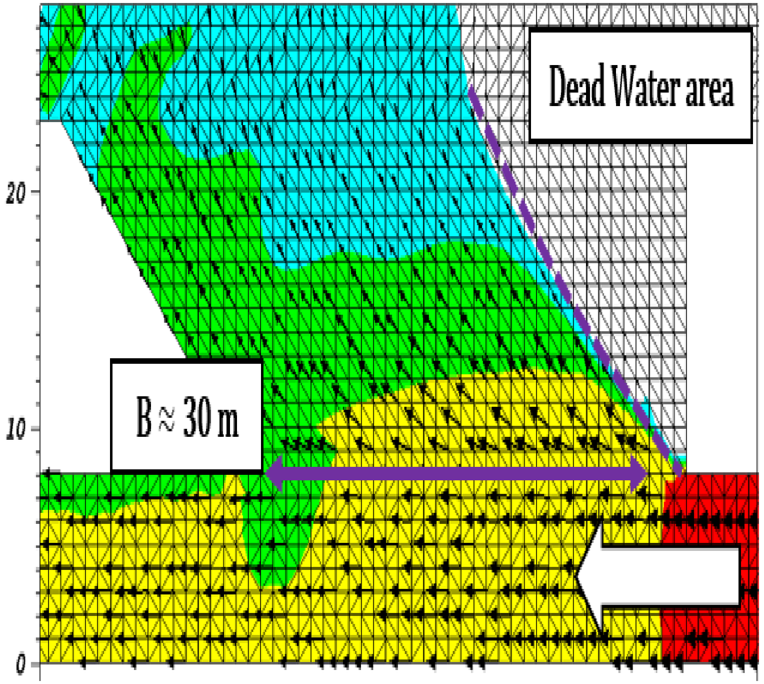
Numerical Condition

	Boundary Condition	roughness	Grid spacing	Time step
Upstream	Discharge (70 m^3/s)	0.023	1.0 m	1 sec
Downstream	Elevation			
Interior floodplain	Elevation			

Numerical Verification

- Comparison of experiment results(Kakinuma et al., 2014) & SCHISM results.
  - Check Point : Temporal Change of water level and discharge and velocity vector field near levee breach





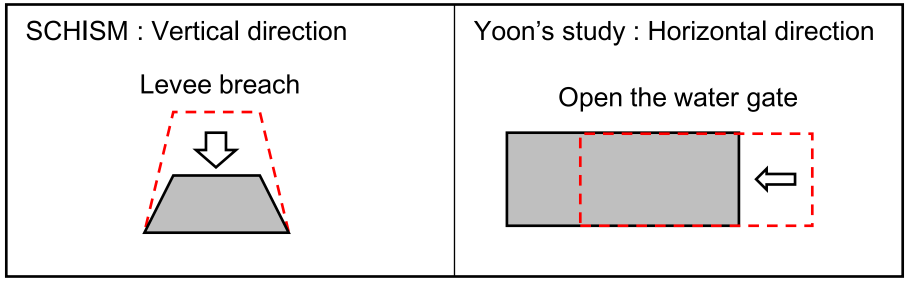
Numerical Verification

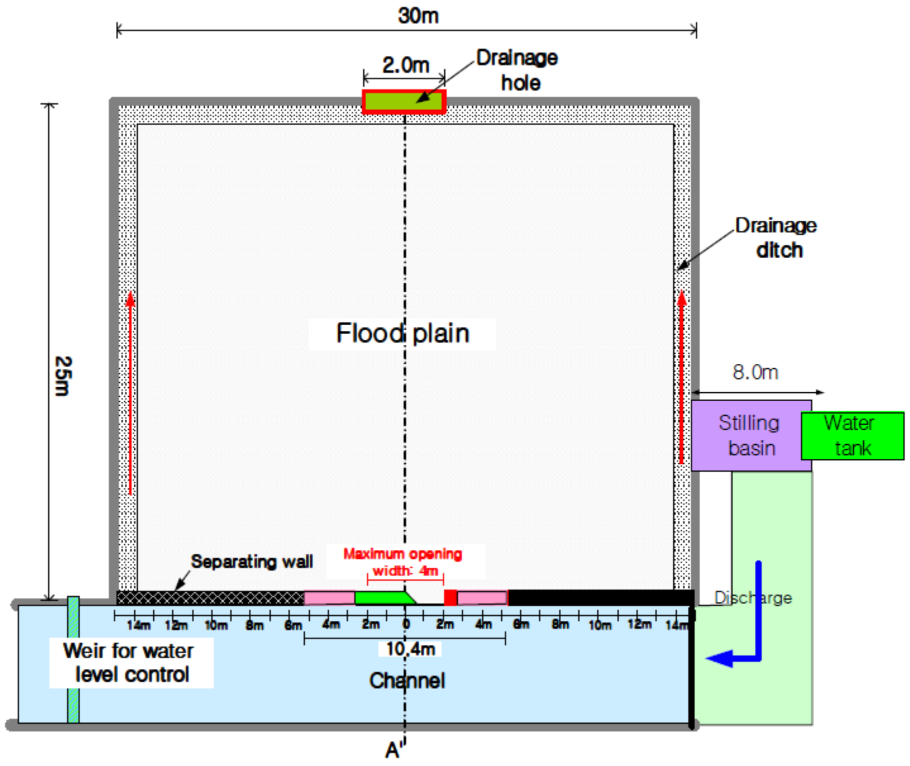
□ Reference

- Yoon K.W.(2006) “Experimental study on effects of levee breach width and duration time on floodwave behavior in floodplain” , KWRA.

□ Compared Previous Research

- Difference of SCHISM levee breach process and Yoon’s study
  - → SCHISM levee breach direction : Vertical
  - → Yoon’s study levee breach direction : Horizontal



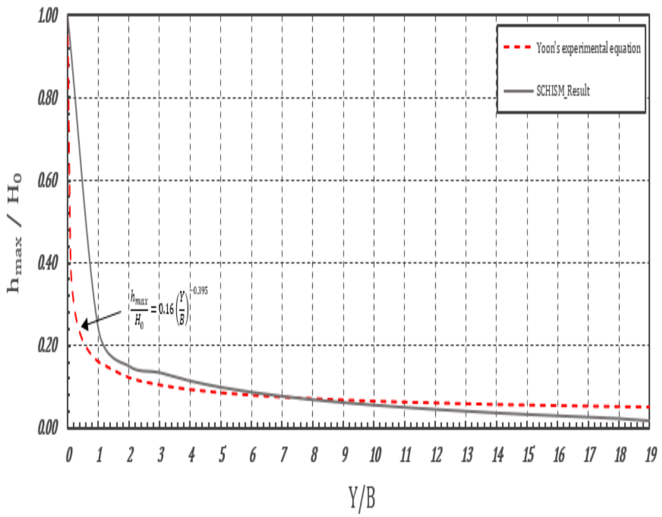


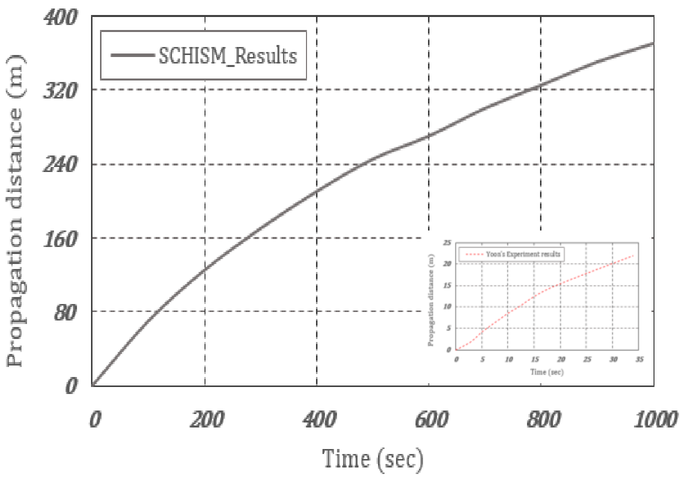
Numerical Verification

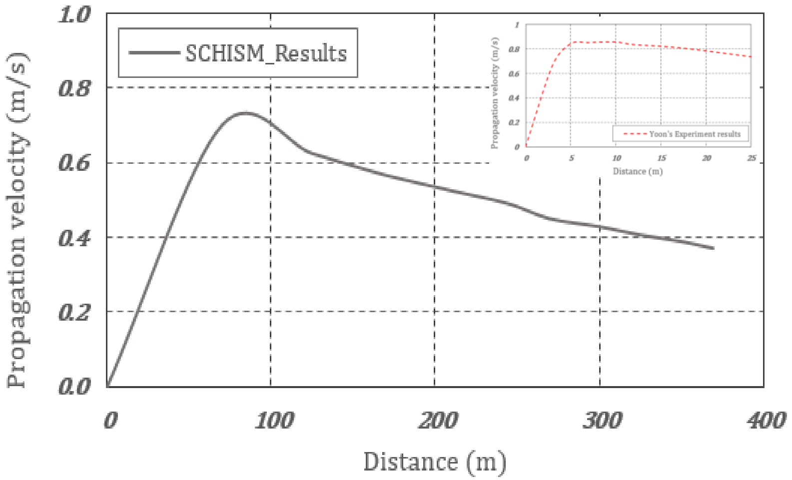
□ Comparison of Results (Yoon, 2006)

- Compare the results with the previous study using the results of the SCHISM simulation (Still water case)
- Point of Measurement is perpendicular to the flow direction
- Previous Research have shown the relationship between dimensionless propagation distance and dimensionless maximum depth

→ Dimensionless propagation distance : propagation distance (Y) / collapse width (B) Dimensionless maximum depth : maximum depth (h_{max}) / Initial Water Elevation (H_0)







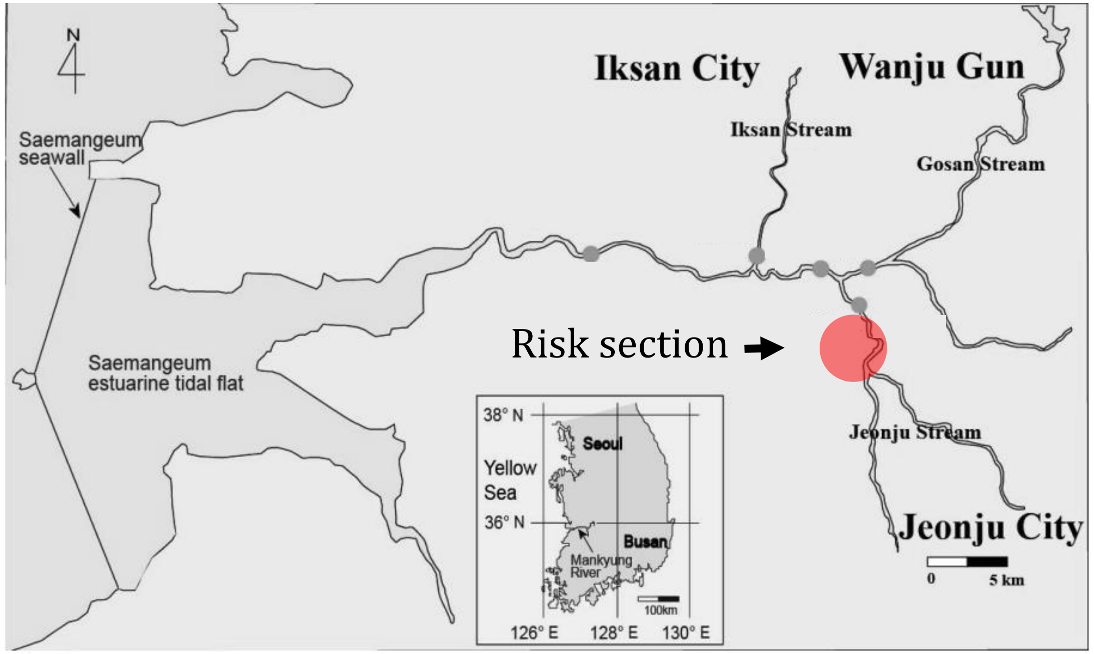
Case Study : Jeonju stream in Saemangeum Basin

Case Study

□ Study Area

- The study area is Jeonju stream in the Mangyeong River Basin in Saemangeum, Rep. of Korea
- The flooded areas in Jeonju stream are as follows.

→ Reference : Mangyeong River Flood Control Plan (2008 , Ministry of Land, Infrastructure, and Transport)



Case Study

□ Topography

○ Depth Contour

→ Using survey data about Saemangeum Basin (2011 , Ministry of Land, Infrastructure, and Transport)

→ Using shape file format data about Inland (2014 , National Geographic Information Institute)

→ Building Information (2017 , National Geographic Information Institute)

□ Model setup

○ Grid & Time step

→ Total 181,751 elements, 107,692 nodes (quad grids & Triangular grids)

→ Grid spacing is 20 m (Stream) , 2 ~ 3 m (Inland)

→Time step is 2 seconds (CFL number = 1.5)

→ The building part is expressed by removing the grid.

Case Study

□ Model setup

○ Boundary Condition & Initial Condition

	Boundary Condition	Initial Condition
Upstream	Discharge	Wet condition (Constant Elevation value)
Downstream	Elevation	Wet condition (Constant Elevation value)
Interior floodplain	Elevation	Dry condition

→ Discharge : Referred by “Stream general plan in Jeonju Stream”, MOLIT(2011 & 2012) & Chonbuk national university (2017)

→ Water surface elevation : Referred by “Saemangeum District Hydrological Investigation Report” , Korea Rural Community Corporation (2008)

(Maximum Discharge , unit : m^3/s)

Case	Steady	Unsteady	Climate Change
1 (frequency : 100 yr)	1,368	1,368	2,059
2 (frequency : 200 yr)	1,586	1,586	2,281
3 (frequency : 500yr)	1,912	1,912	2,594

Case Study

□ Model setup

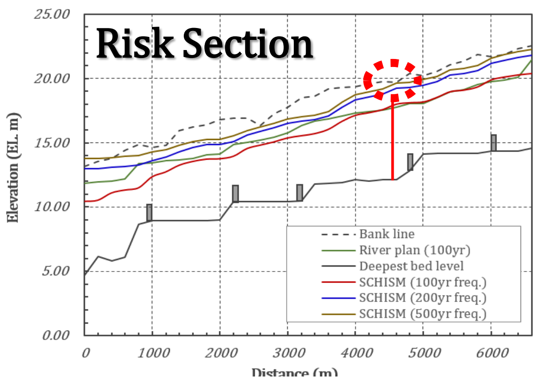
○ Assumption of Levee breach configuration

→ Collapse Shape : Rectangular

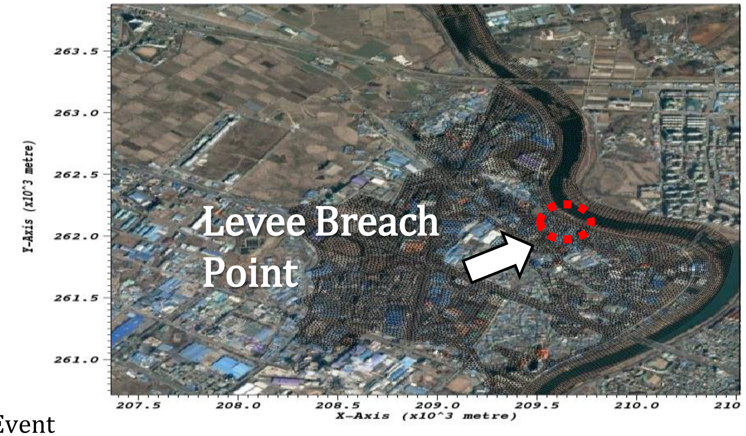
→ Collapse Width : 100 m

→ Collapse Time : 30 min

→ Collapse Position : Palbok-dong



JeonJu Stream Water Elevation according to Flood Event



→ Reference : “Analysis of Influence for Breach Flow According to Asymmetry of Breach Cross-section” (2016 , Kim)

○ Configuration

→ Comparison of flood depth and flood wave propagation range according to frequency

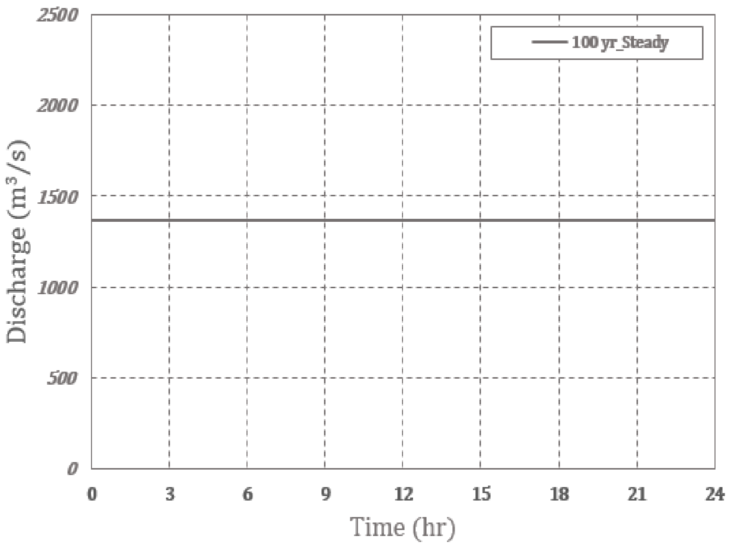
→ Identification of flood wave velocity and flow velocity vectors according to frequency

Case 1 : 100yr flood event

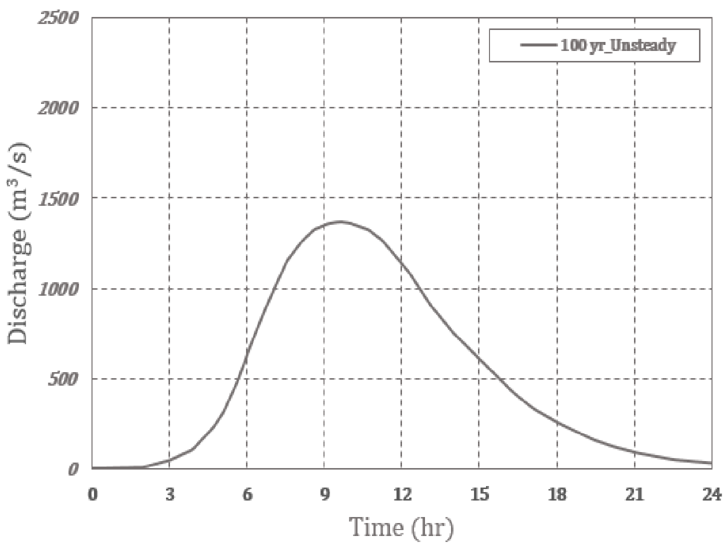
□ Hydrograph

- Total 3 Case : Steady , Unsteady , Climate change (RCP 8.5)
- Duration time : 10 hour
- Total Simulation time : 1 day

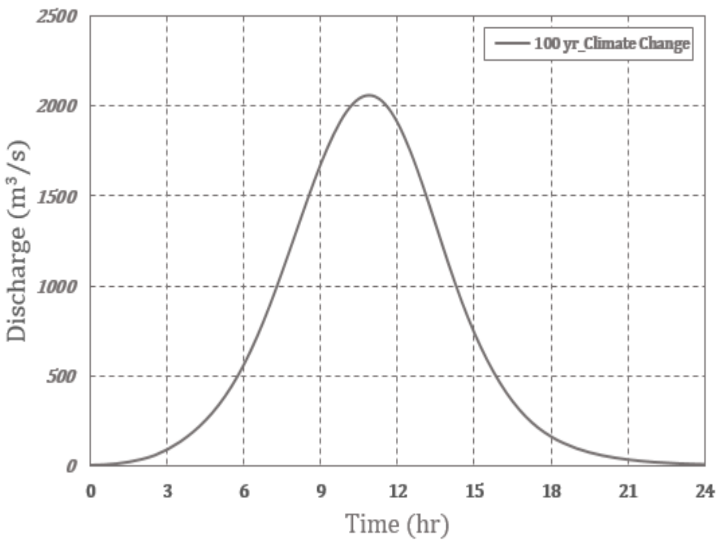
100 yr flood event (Steady)



100 yr flood event (Unsteady)



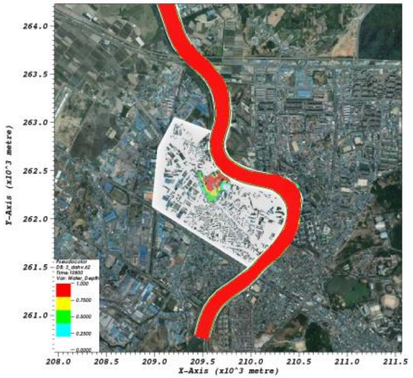
100 yr flood event (RCP 8.5)



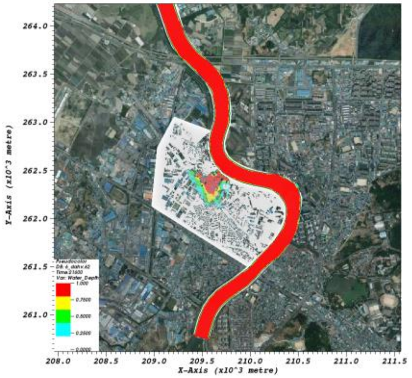
Case 1 : 100yr flood event

□ Results (Frequency : 100 year flood event – Steady)

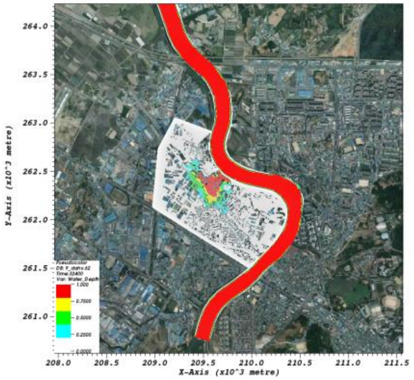
- Flood depth and wave propagation range according to frequency
- Check the results for the flood depth at 3 hour intervals.



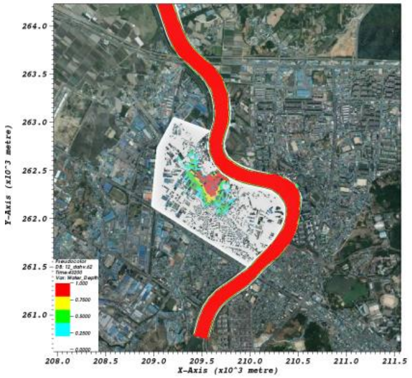
T = 3 hour



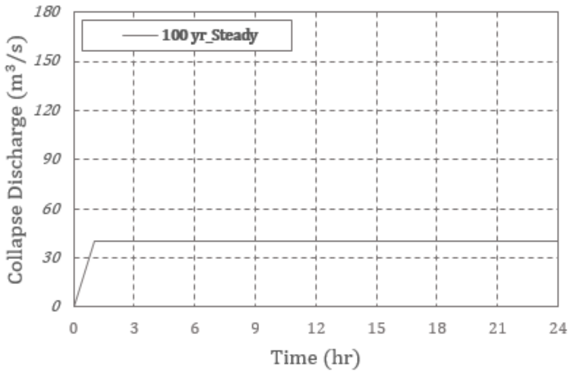
T = 6 hour

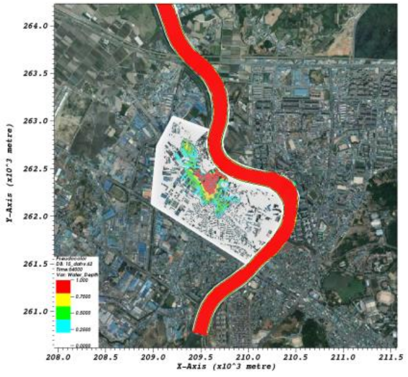


T = 9 hour

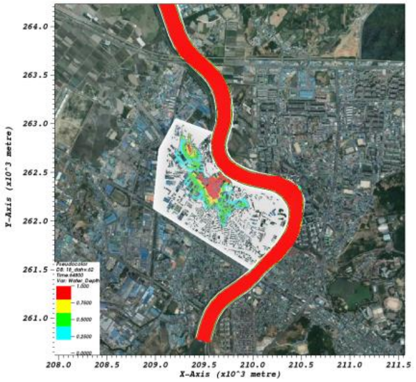


T = 12 hour

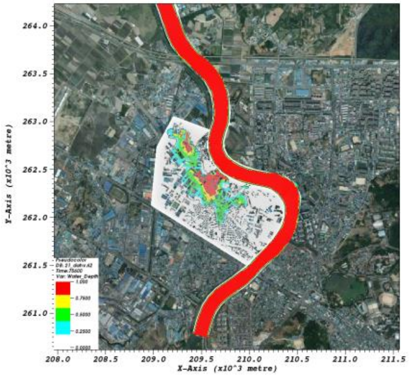




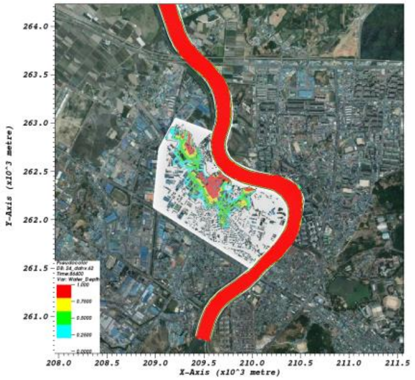
T = 15 hour



T = 18 hour



T = 21 hour



T = 24 hour

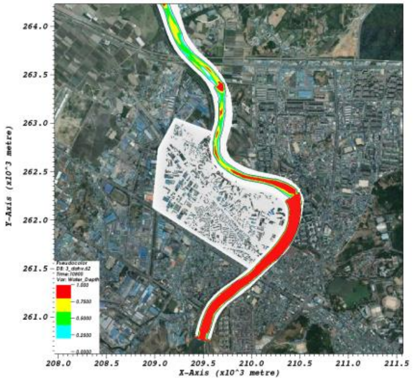
- At Time = 24 hour
- Maximum Collapse Discharge
  - 40.8 m^3/s (constant)
- Maximum Flood Depth
  - 1.35 m

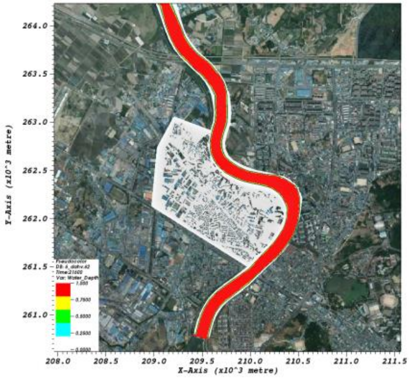
Case 1 : 100yr flood event

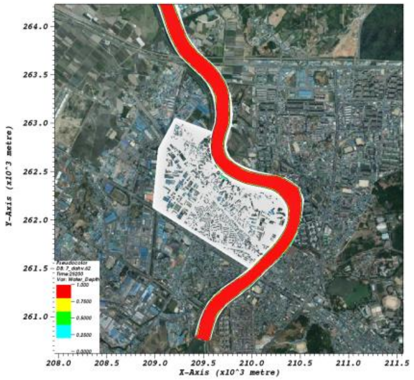
□ Results (Frequency : 100 year flood event – Unsteady)

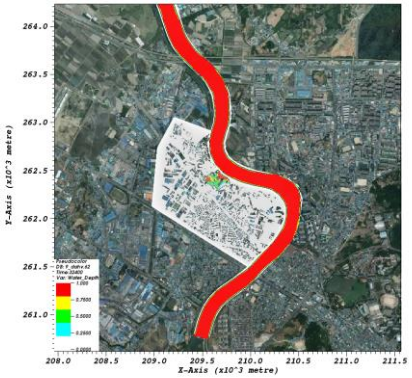
○ Flood depth and flood wave propagation range according to frequency

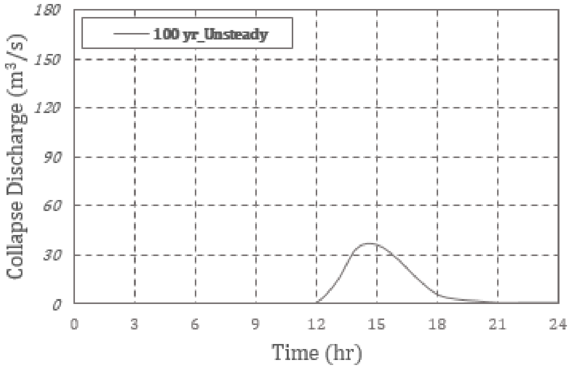
○ Check the results for the flood depth at 3 hour intervals.

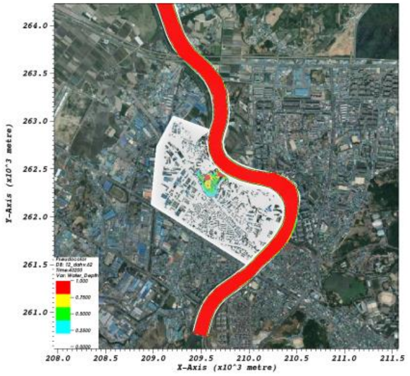

T = 3 hour

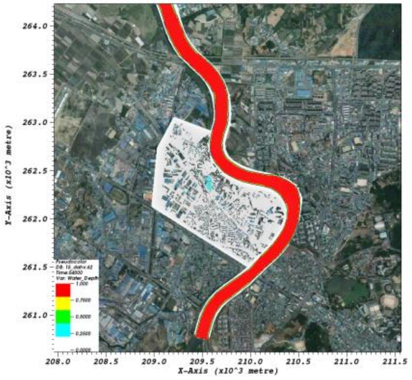

T = 6 hour

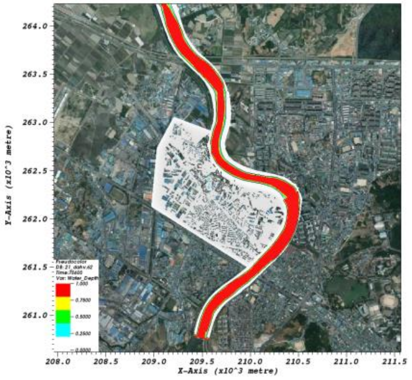

T = 9 hour

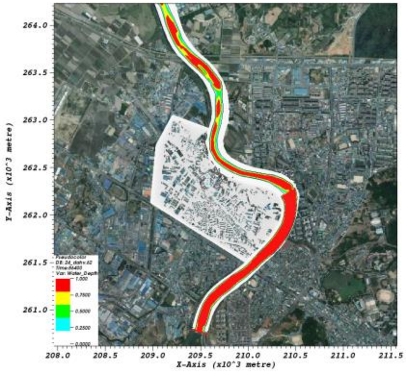

T = 12 hour




T = 15 hour


T = 18 hour

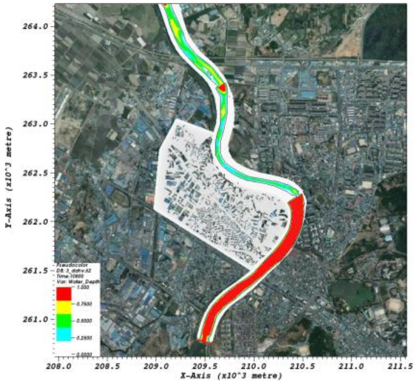

T = 21 hour


T = 24 hour

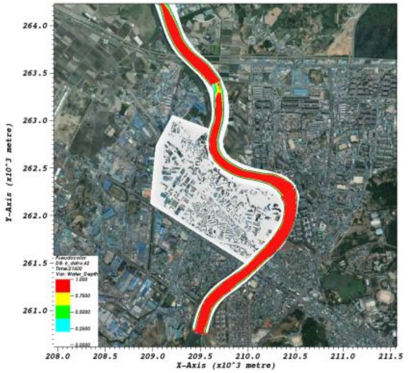
- At Time = 15 hour
- Maximum Collapse Discharge
  - 36.4 m^3/s
- Maximum Flood Depth
  - 0.96 m

Case 1 : 100yr flood event

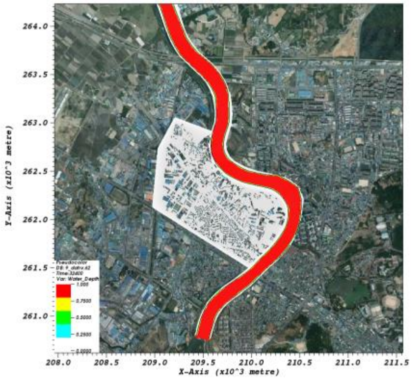
- Results (Frequency : 100 year flood event – Climate Change (RCP 8.5))
  - Flood depth and flood wave propagation range according to frequency
  - Check the results for the flood depth at 3 hour intervals.



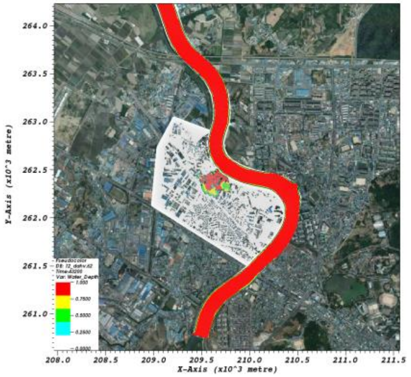
T = 3 hour



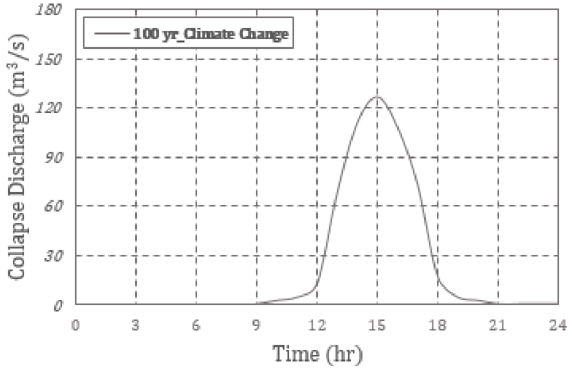
T = 6 hour

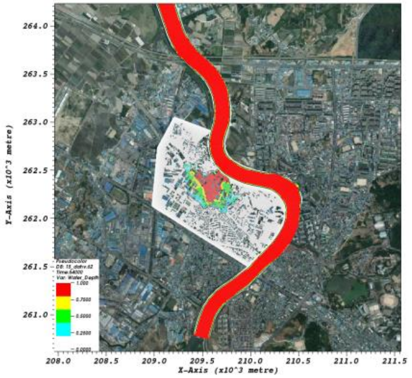


T = 9 hour

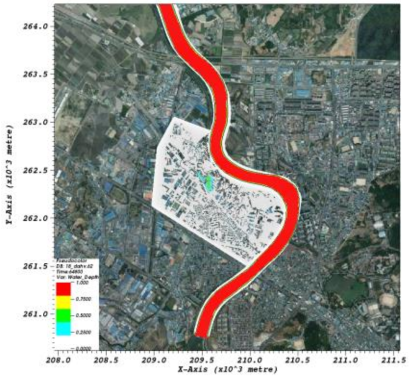


T = 12 hour

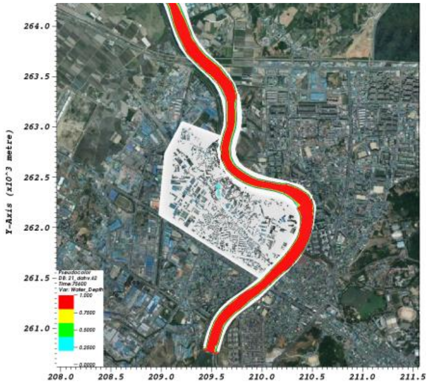




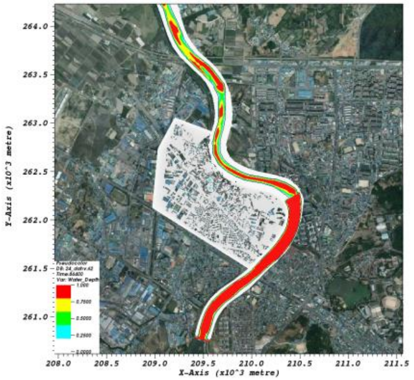
T = 15 hour



T = 18 hour



T = 21 hour



T = 24 hour

- At Time = 15 hour
- Maximum Collapse Discharge
  - $126.6m^3/s$
- Maximum Flood Depth
  - 1.60 m

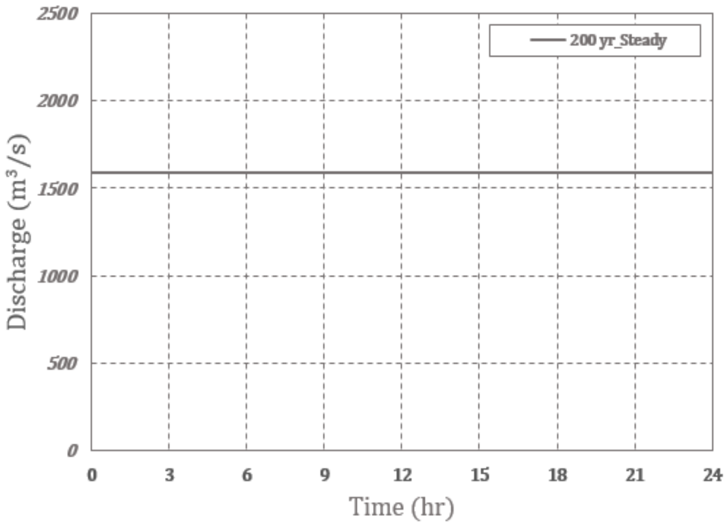
100 year flood event
(Steady)

Case 2 : 200yr flood event

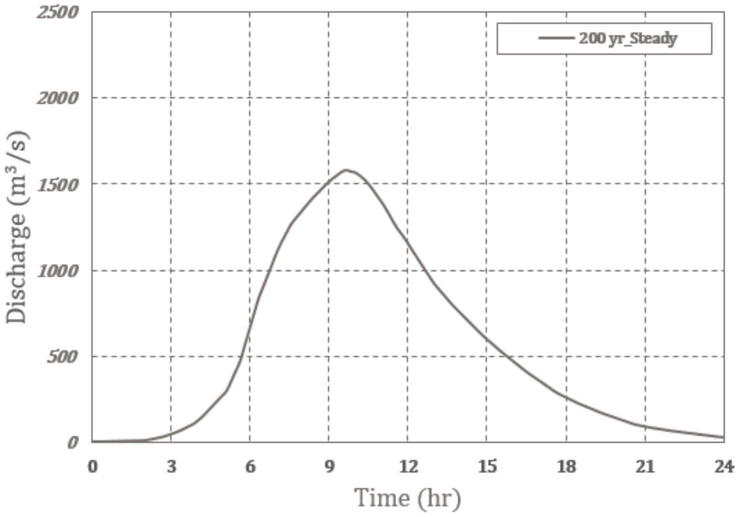
□ Hydrograph

- Total 3 Case : Steady , Unsteady , Climate change (RCP 8.5)
- Duration time : 10 hour
- Total Simulation time : 1 day

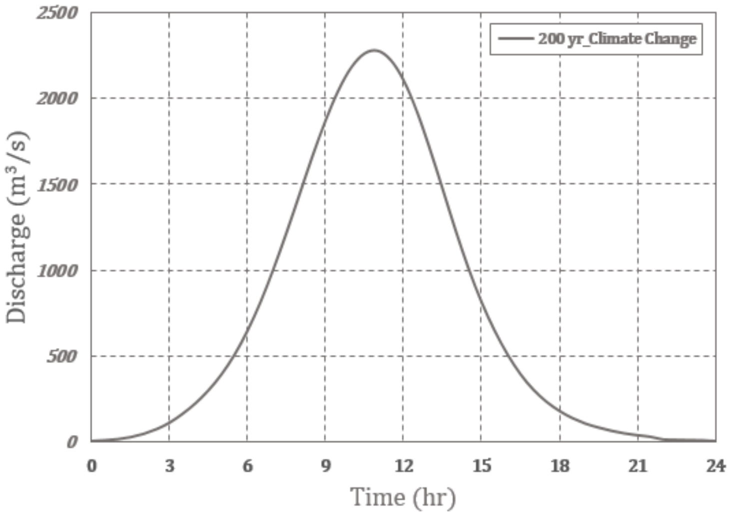
200 yr flood event (Steady)



200 yr flood event (Unsteady)



200 yr flood event (RCP 8.5)

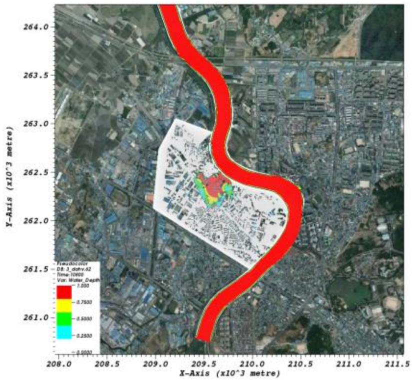


Case 2 : 200yr flood event

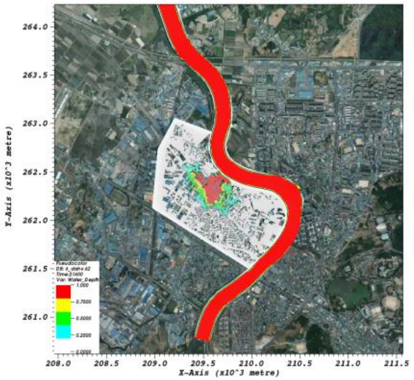
□ Results (Frequency : 200 year flood event – Steady)

○ Flood depth and flood wave propagation range according to frequency

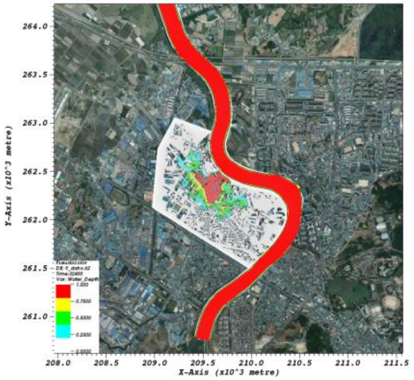
○ Check the results for the flood depth at 3 hour intervals.



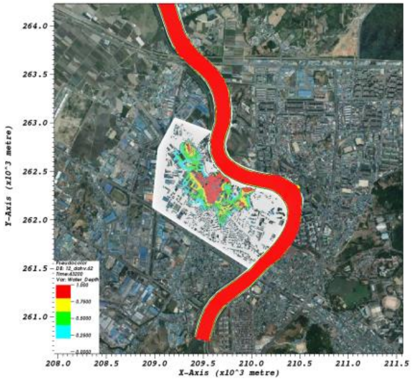
T = 3 hour



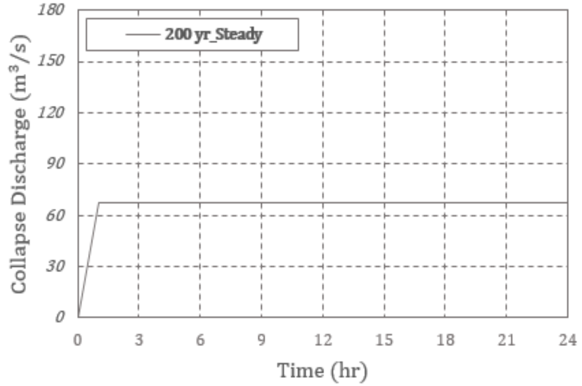
T = 6 hour

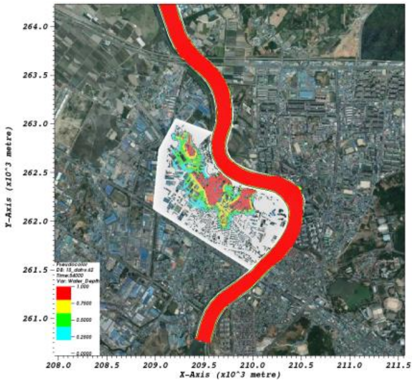


T = 9 hour

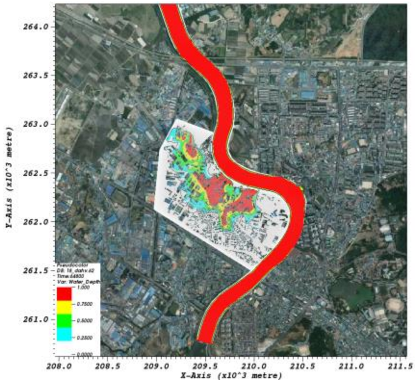


T = 12 hour

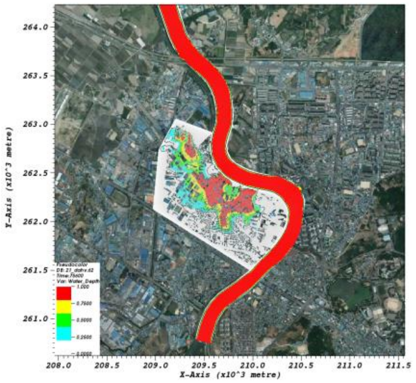




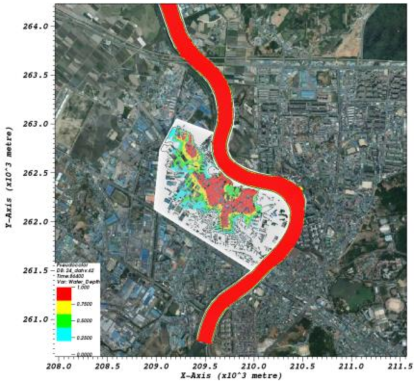
T = 15 hour



T = 18 hour



T = 21 hour



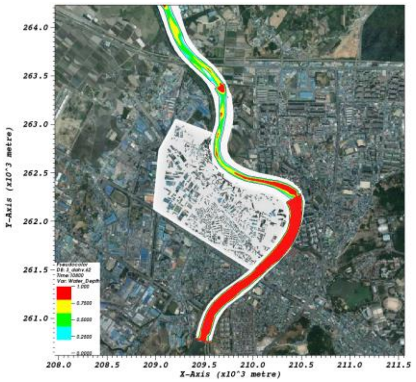
T = 24 hour

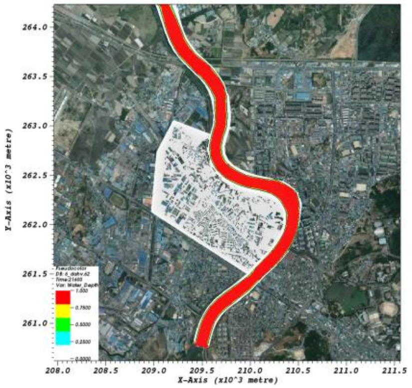
- At Time = 24 hour
- Maximum Collapse Discharge
- ➢ 67 m^3/s (constant)
- Maximum Flood Depth
- ➢ 1.62 m

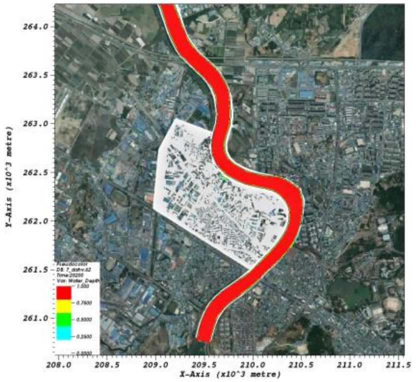
Case 2 : 200yr flood event

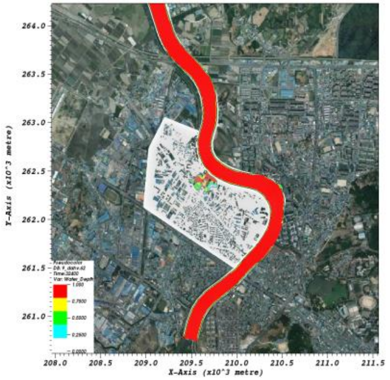
□ Results (Frequency : 200 year flood event – Unsteady)

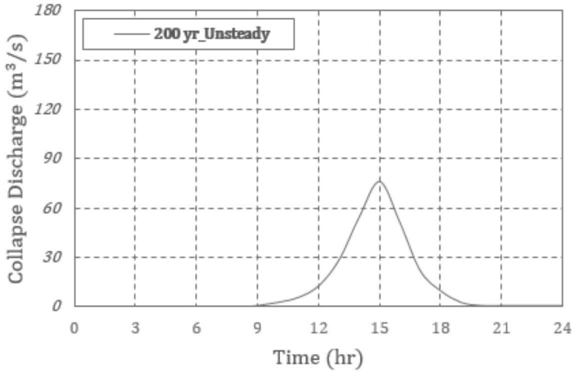
- Flood depth and flood wave propagation range according to frequency
- Check the results for the flood depth at 3 hour intervals.

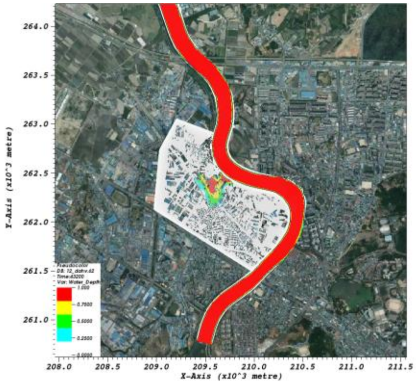

T = 3 hour

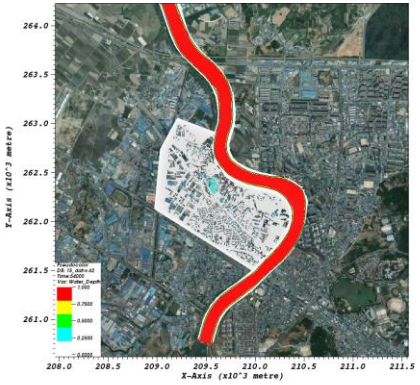

T = 6 hour

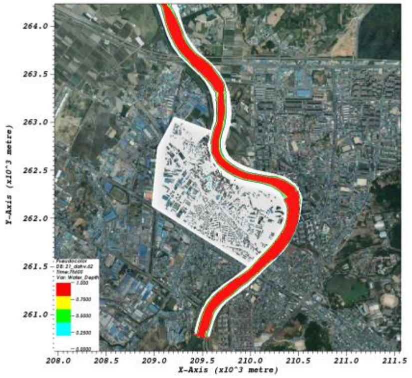

T = 9 hour

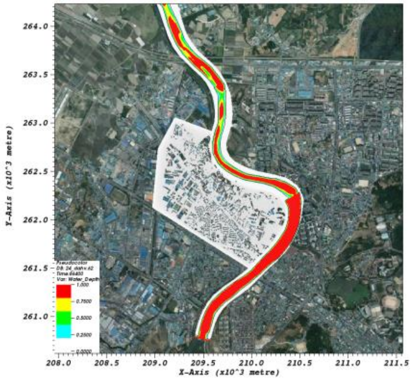

T = 12 hour




T = 15 hour


T = 18 hour


T = 21 hour


T = 24 hour

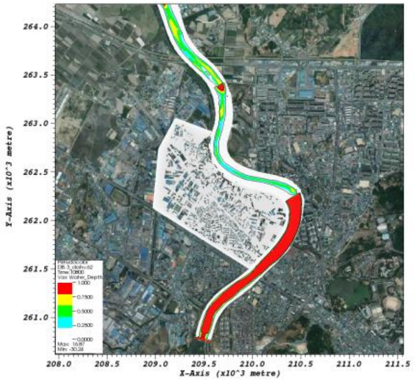
- At Time = 15 hour
- Maximum Collapse Discharge
  - 76 m^3/s
- Maximum Flood Depth
  - 1.13 m

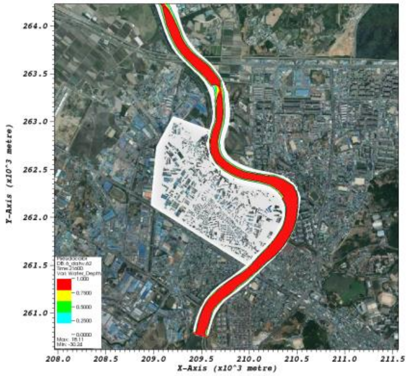
Case 2 : 200yr flood event

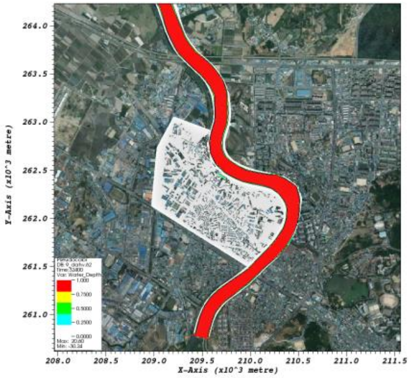
□ Results (Frequency : 200 year flood event – Climate change)

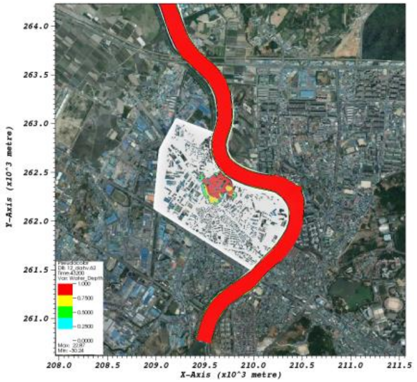
○ Flood depth and flood wave propagation range according to frequency

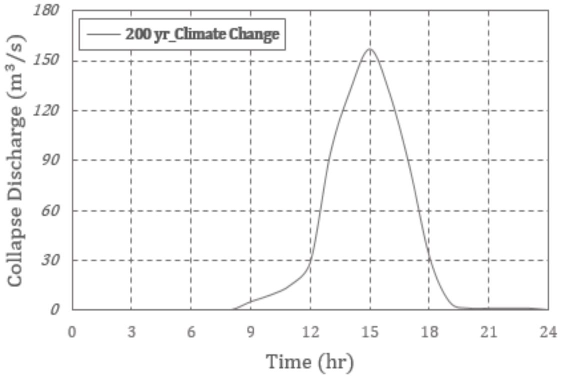
○ Check the results for the flood depth at 3 hour intervals.

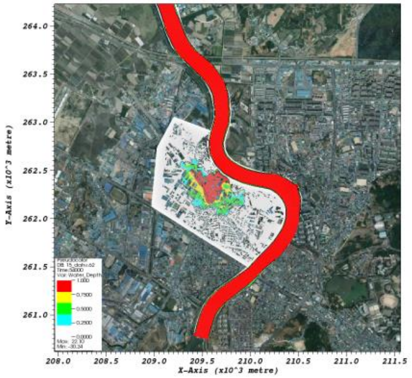

T = 3 hour

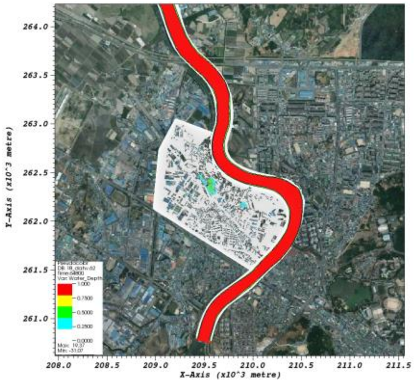

T = 6 hour

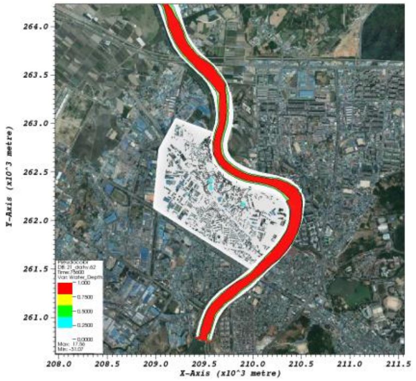

T = 9 hour

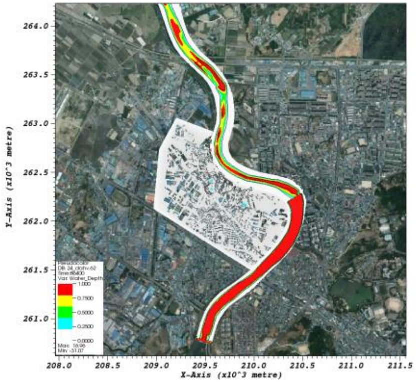

T = 12 hour




T = 15 hour


T = 18 hour


T = 21 hour


T = 24 hour

- At Time = 15 hour
- Maximum Collapse Discharge
  - ➢ 157 m^3/s
- Maximum Flood Depth
  - ➢ 1.72 m

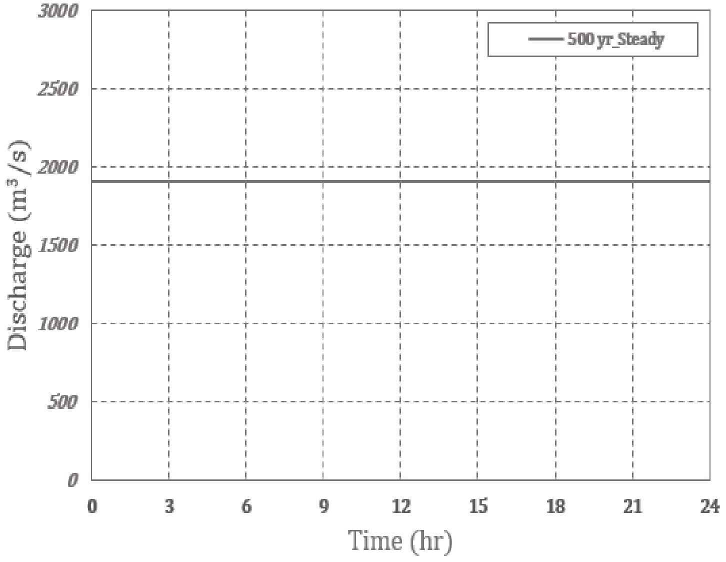
200 year flood event
(Steady)

Case 3 : 500yr flood event

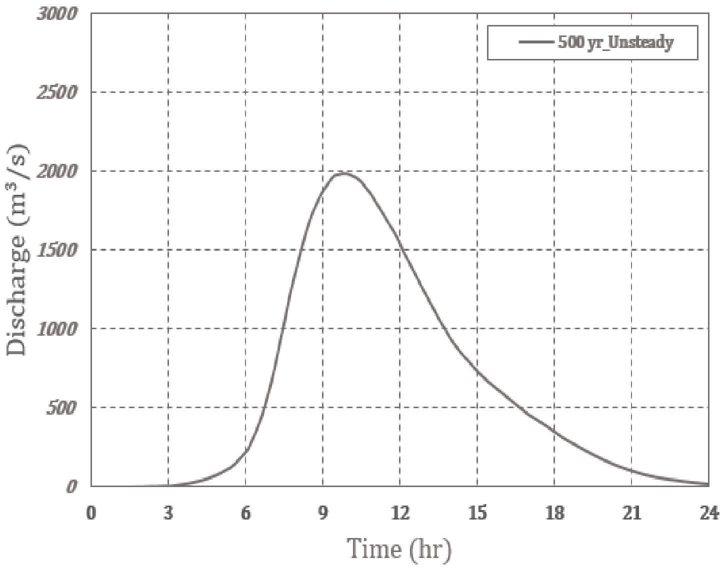
□ Hydrograph

- Total 3 Case : Steady , Unsteady , Climate change (RCP 8.5)
- Duration time : 10 hour
- Total Simulation time : 1 day

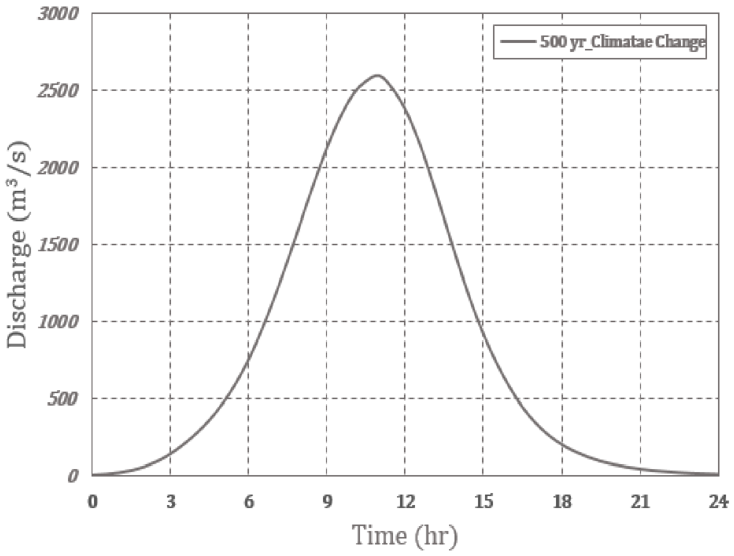
500 yr flood event (Steady)



500 yr flood event (Unsteady)



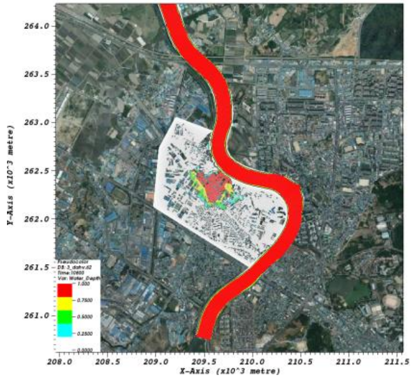
500 yr flood event (RCP 8.5)



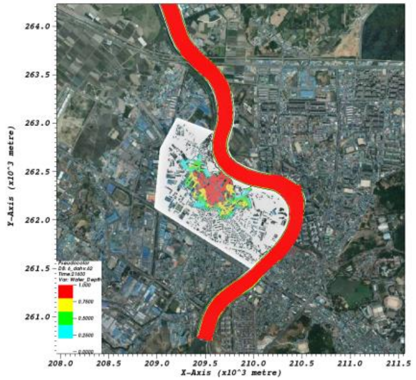
Case 3 : 500yr flood event

□ Results (Frequency : 500 year flood event – Unsteady)

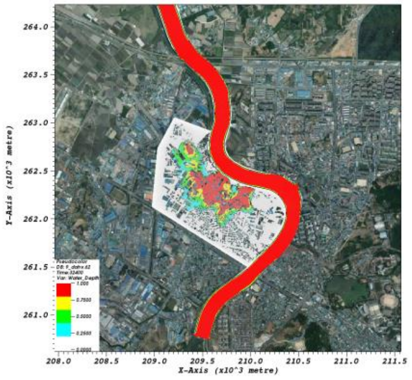
- Flood depth and flood wave propagation range according to frequency
- Check the results for the flood depth at 3 hour intervals.



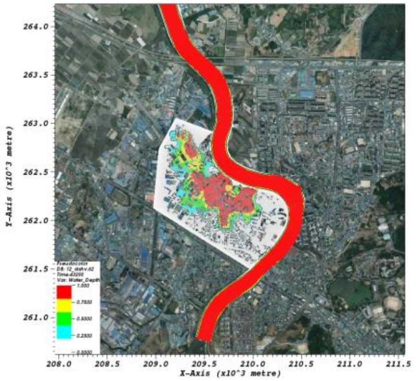
T = 3 hour



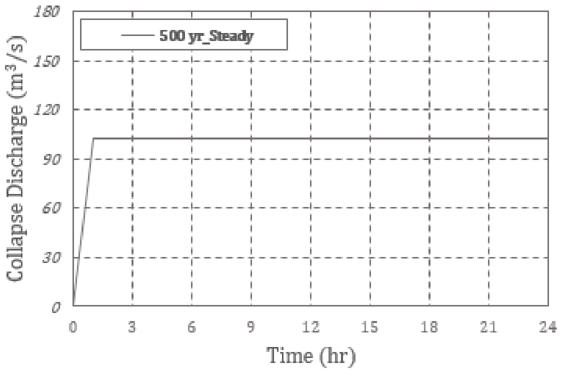
T = 6 hour

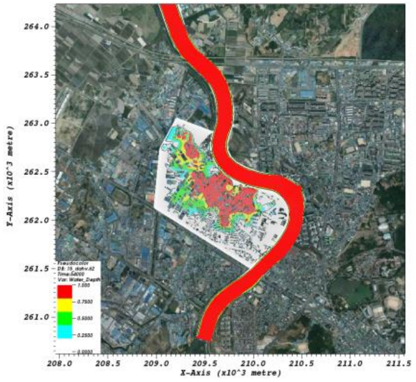


T = 9 hour

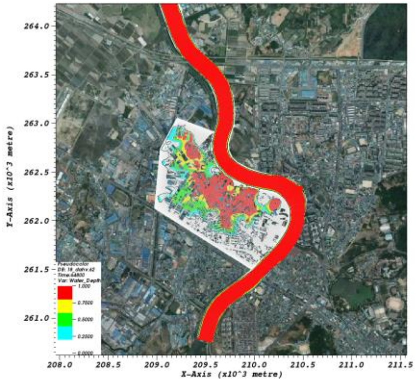


T = 12 hour

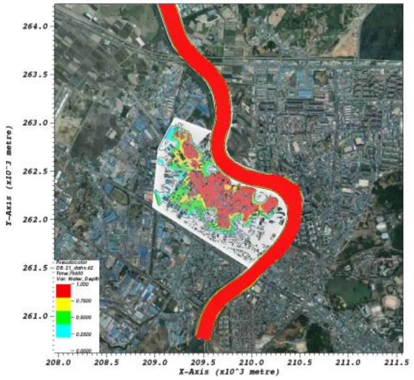




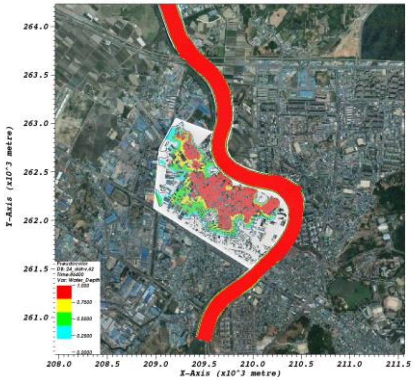
T = 15 hour



T = 18 hour



T = 21 hour



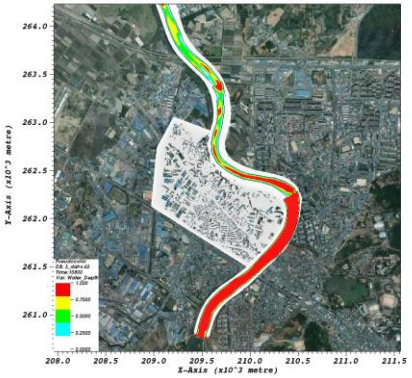
T = 24 hour

- At Time = 24 hour
- Maximum Collapse Discharge
  - $103 m^3/s$ (constant)
- Maximum Flood Depth
  - 1.89 m

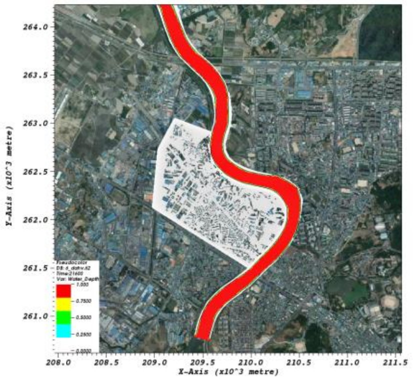
Case 3 : 500yr flood event

☐ Results (Frequency : 500 year flood event – Unsteady)

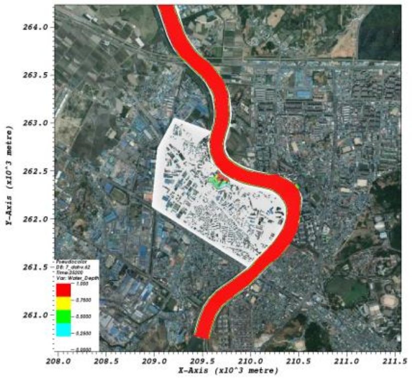
- Flood depth and flood wave propagation range according to frequency
- Check the results for the flood depth at 3 hour intervals.



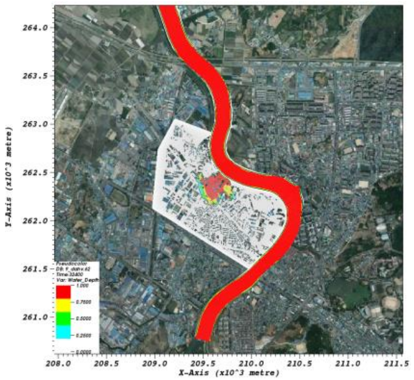
T = 3 hour



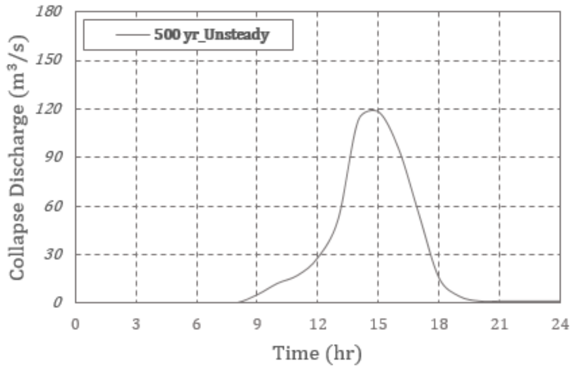
T = 6 hour

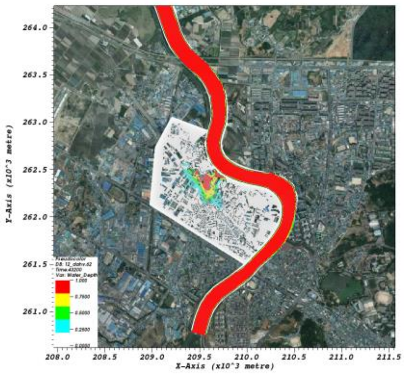


T = 9 hour

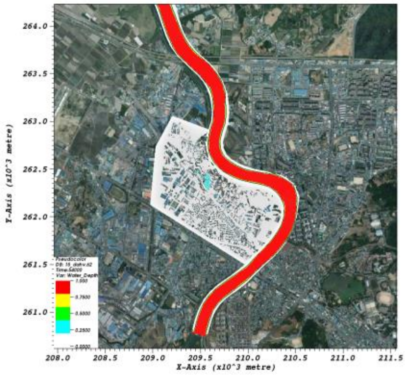


T = 12 hour

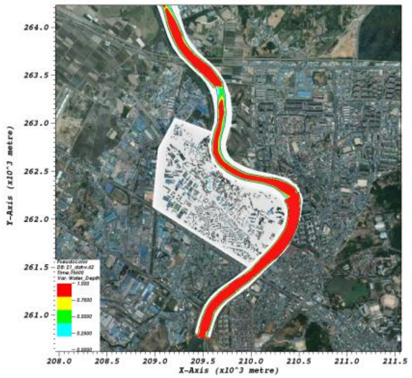




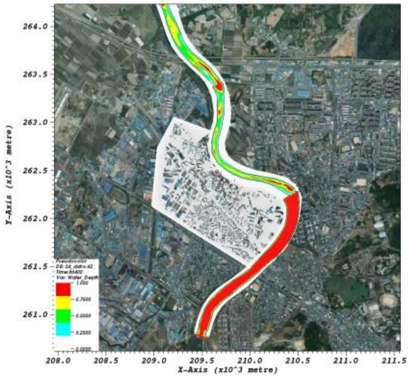
T = 15 hour



T = 18 hour



T = 21 hour



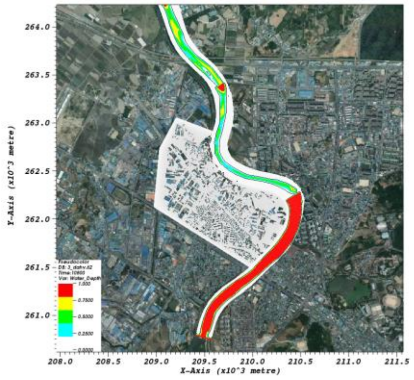
T = 24 hour

- ▪ At Time = 15 hour
- Maximum Collapse Discharge
- ➢ $118.3 m^3/s$
- Maximum Flood Depth
- ➢ 1.18 m

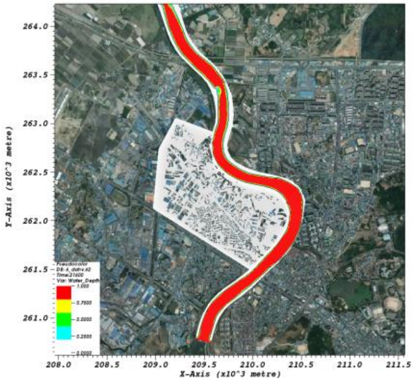
Case 3 : 500yr flood event

□ Results (Frequency : 500 year flood event – Climate Change)

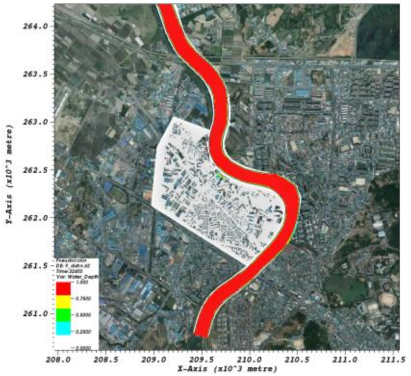
- Flood depth and flood wave propagation range according to frequency
- Check the results for the flood depth at 3 hour intervals.



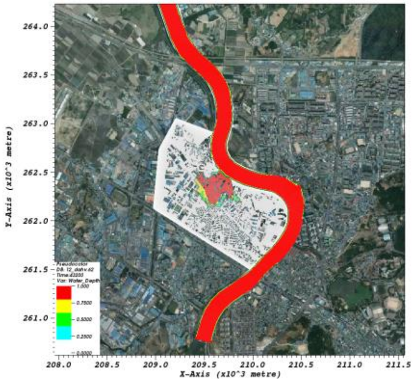
T = 3 hour



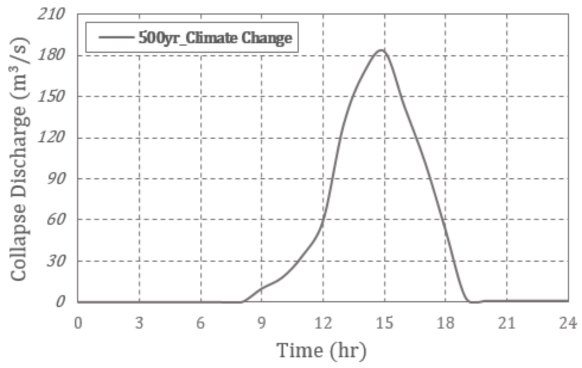
T = 6 hour

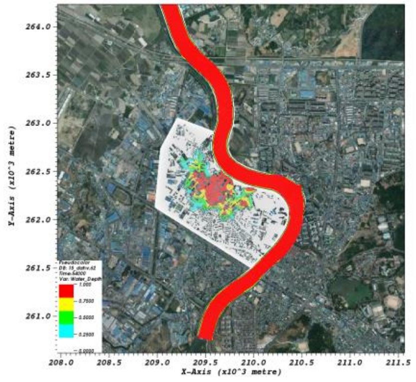


T = 9 hour

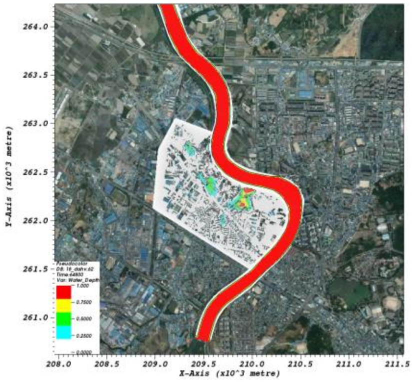


T = 12 hour

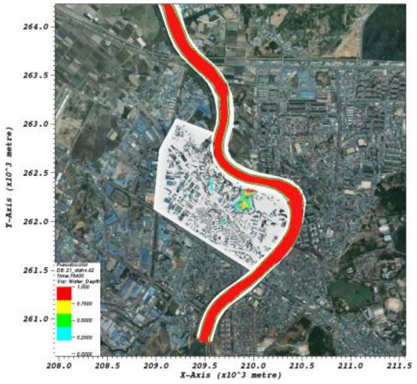




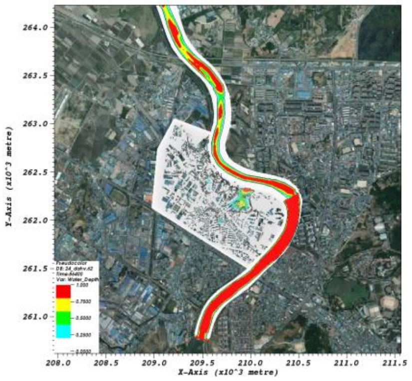
T = 15 hour



T = 18 hour



T = 21 hour



T = 24 hour

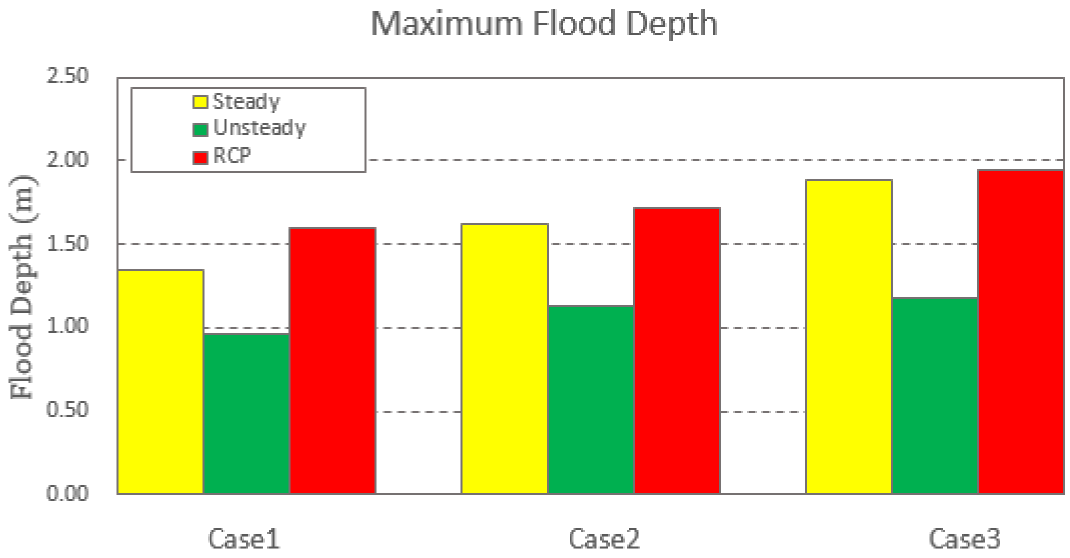
- At Time = 15 hour
  - Maximum Collapse Discharge
    - 182.6 m^3/s
  - Maximum Flood Depth
    - 1.95 m

500 year flood event
(Steady)

Application on Site : Jeonju stream

□ Results (Maximum Flood Depth)

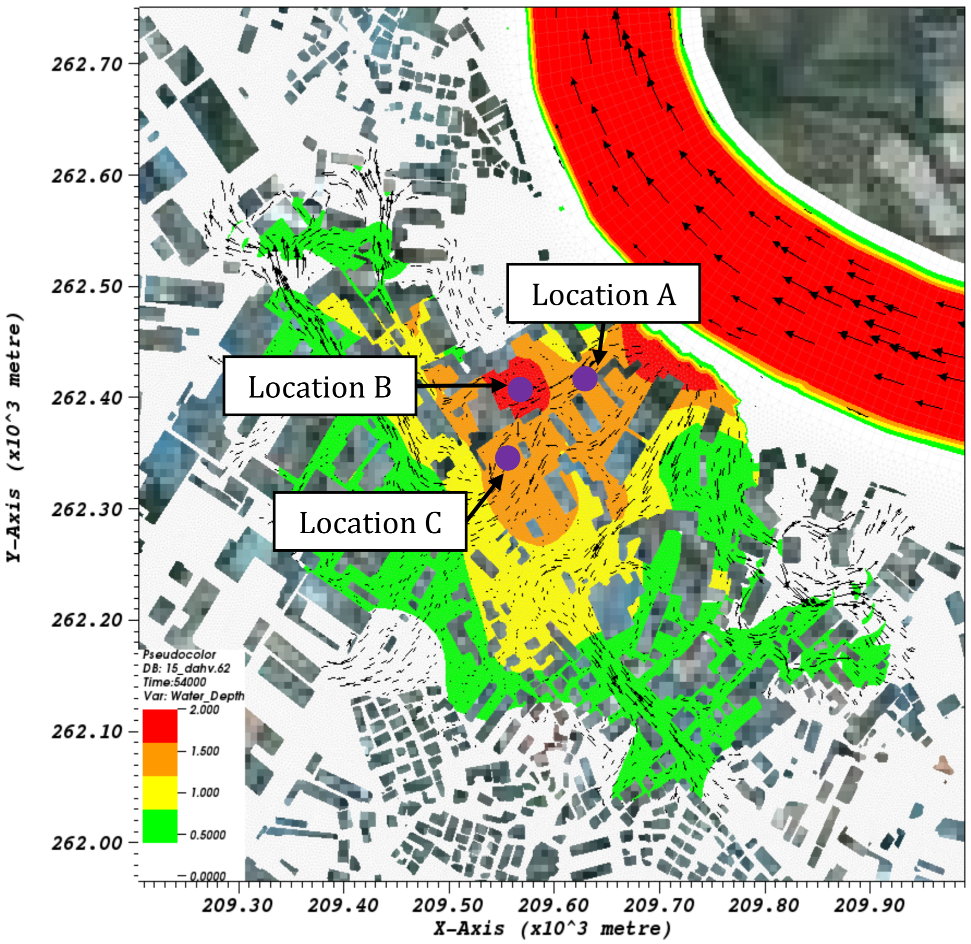
- ○ Check the maximum flood depth by flood event (Case 1 : 100 year , Case 2 : 200 year , Case 3 : 500 year)



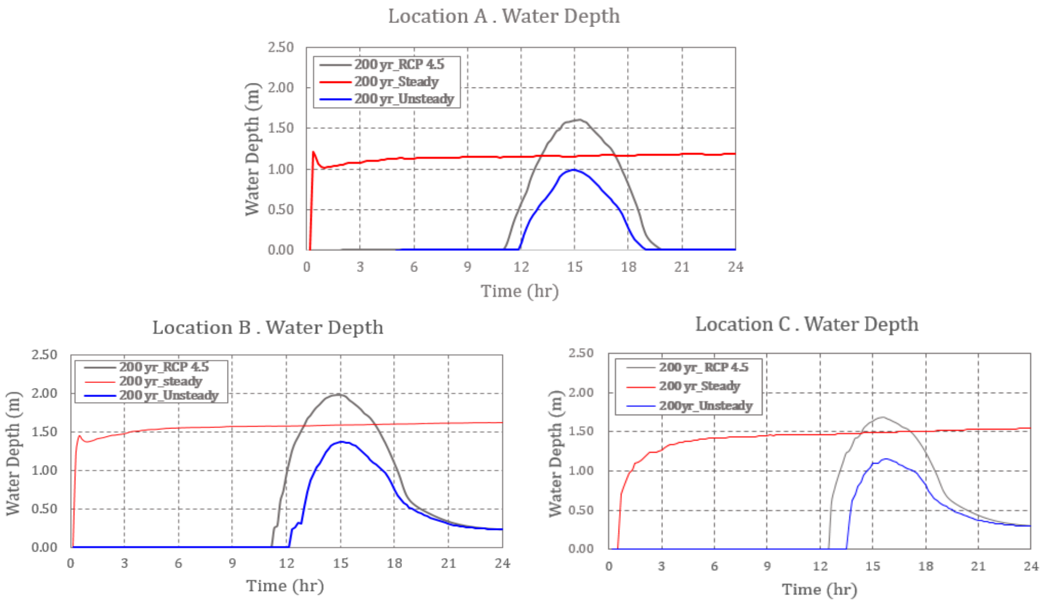
❖ The maximum water depth was represented in RCP 8.5 case

Application on Site : Jeonju stream

□ Results (Maximum Water Depth)



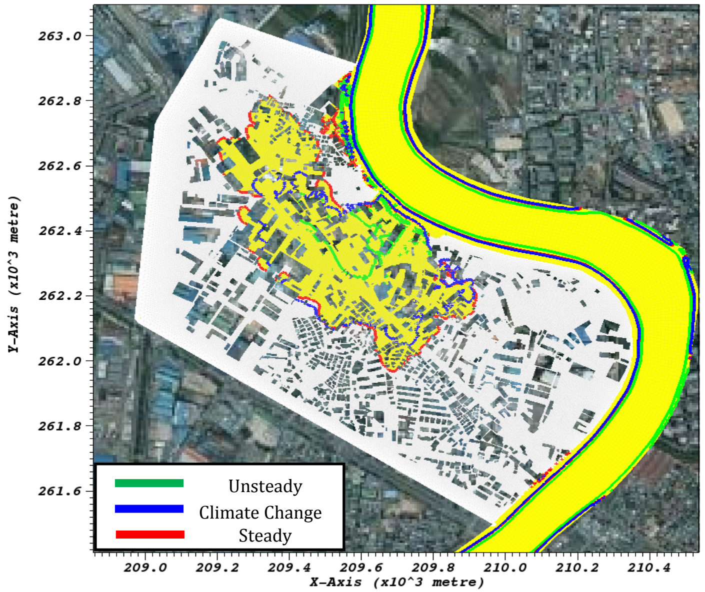
- Check for changes in water depth over time with respect to location A,B,C



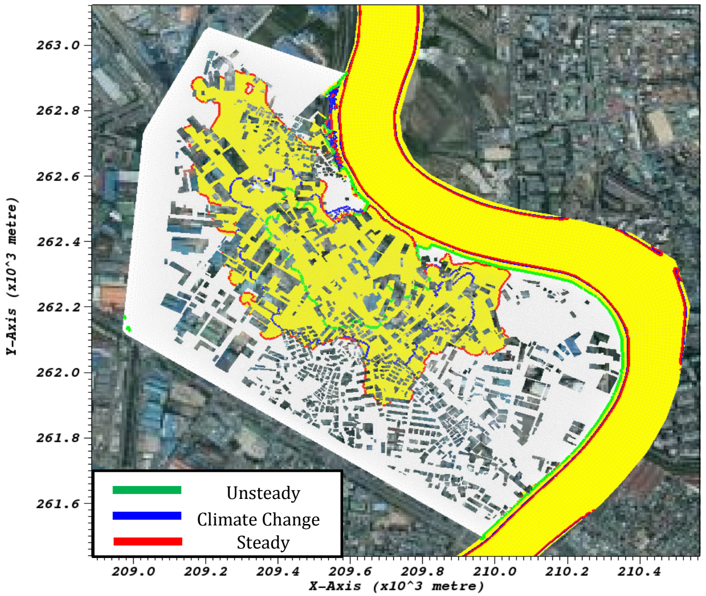
❖ The maximum water depth was represented in RCP 8.5 case

Application on Site : Jeonju stream

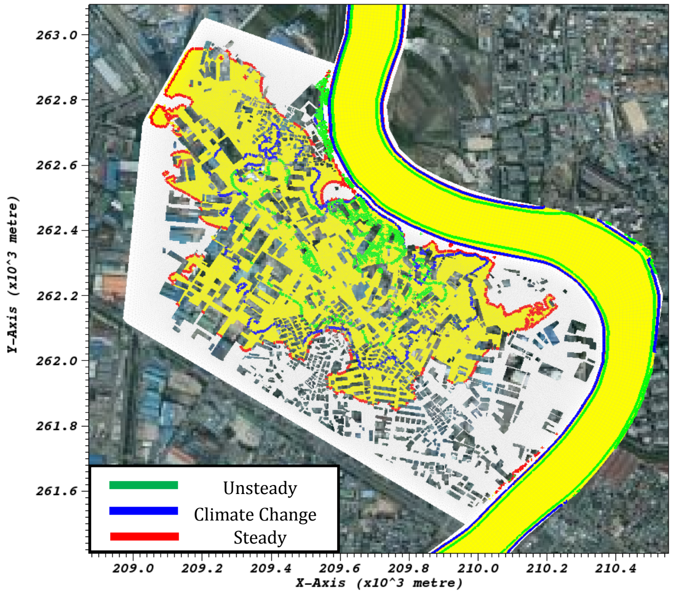
□ Results (Flood Impact)



100 yr flood event



200 yr flood event



500 yr flood event

○ Flood Impact

→ Flood Impact(FI) is an index that checked the influence of propagation area and velocity for collapse discharge

$$FI = \frac{A_{propagation} \times V_{propagation}}{Q_{collapse}}$$

(where, FI : Flood Impact , $A_{propagation}$: Maximum Area of propagation range , $V_{propagation}$: Maximum Flood Velocity , $Q_{collapse}$: Collapse Discharge)

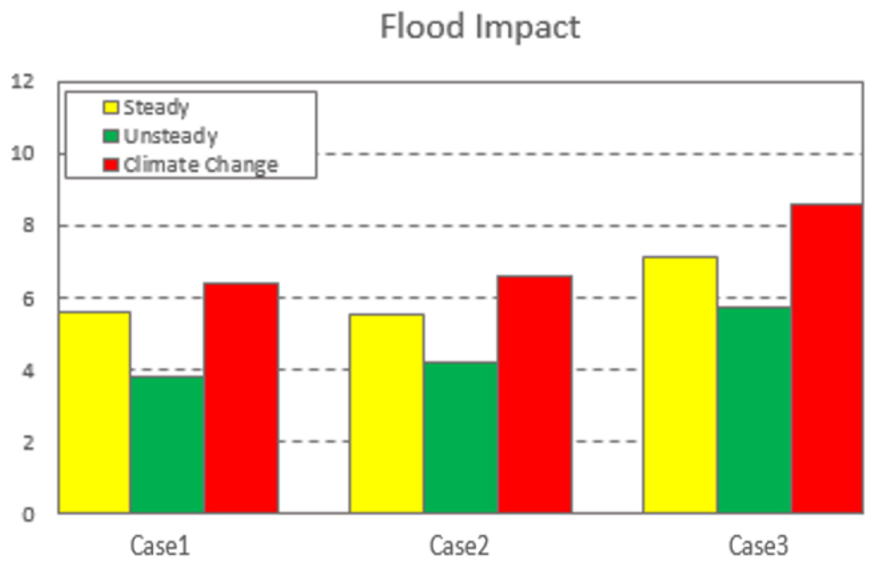
Application on Site : Jeonju stream

□ Results (Flood Impact)

Case 1 (100 year)	$A_{propagation}$	$V_{propagation}$	$Q_{collapse}$	Flood Impact
Steady	230,510 m^2	2.34 m/s	980 m^3/s	5.5×10^2
Unsteady	44,585 m^2	1.55 m/s	170 m^3/s	4.0×10^2
Climate Change	159,025 m^2	2.50 m/s	620 m^3/s	6.4×10^2

Case 2 (200 year)	$A_{propagation}$	$V_{propagation}$	$Q_{collapse}$	Flood Impact
Steady	324,000 m^2	2.71 m/s	1,608 m^3/s	5.5×10^2
Unsteady	89,460 m^2	1.78 m/s	380 m^3/s	4.2×10^2
Climate Change	184,680 m^2	2.80 m/s	785 m^3/s	6.6×10^2

Case 3 (500year)	$A_{propagation}$	$V_{propagation}$	$Q_{collapse}$	Flood Impact
Steady	612,000 m^2	2.88 m/s	2,472 m^3/s	7.1×10^2
Unsteady	199,200 m^2	2.05 m/s	710 m^3/s	5.7×10^2
Climate Change	322,000 m^2	2.94 m/s	1096 m^3/s	8.6×10^2



❖ FI of Climate Change flood event is higher than Steady state & Unsteady state.

Concluding Remarks

Concluding Remark

- ❖ Compared with the field data & experimental results in the literature, the SCHISM model can accurately reproduce and represent each inundation simulation
- ❖ The SCHISM model is well suited for inundation simulations in urban area because it can supply the deformation of geometry and well-embodied wet / dry conditions.
- ❖ When the inundation simulations were performed on the Jeonju stream in Korea, the propagation area and the maximum flood depth were affected by the flood discharges, for example, steady (designed value), unsteady (close to realized one), and climate change (RCP 8.5 scenario).
- ❖ When the RCP 8.5 scenario was applied, the water depth in inland & Flood Impact index value is higher than others, the steady and unsteady states.
- ❖ The results of inundation in urban area considering the climate change were relatively conservative in terms of design process, so it may ask higher economic cost. Thus, it would require careful consideration for flood defense works.

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Thank you for your attention

Q & A