Inundation analysis using a 2-dimensional flood model

- Application of the G2D model -

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https://github.com/floodmodel/References

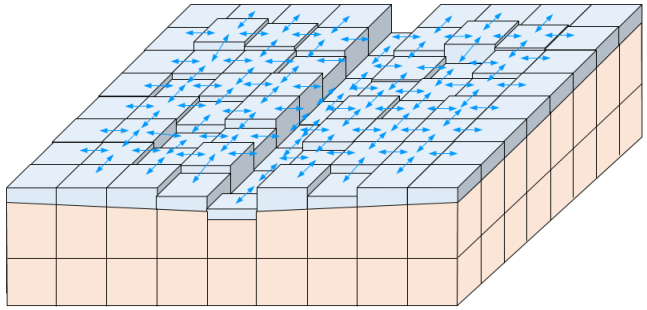
Nov., 2020

Contents

개요

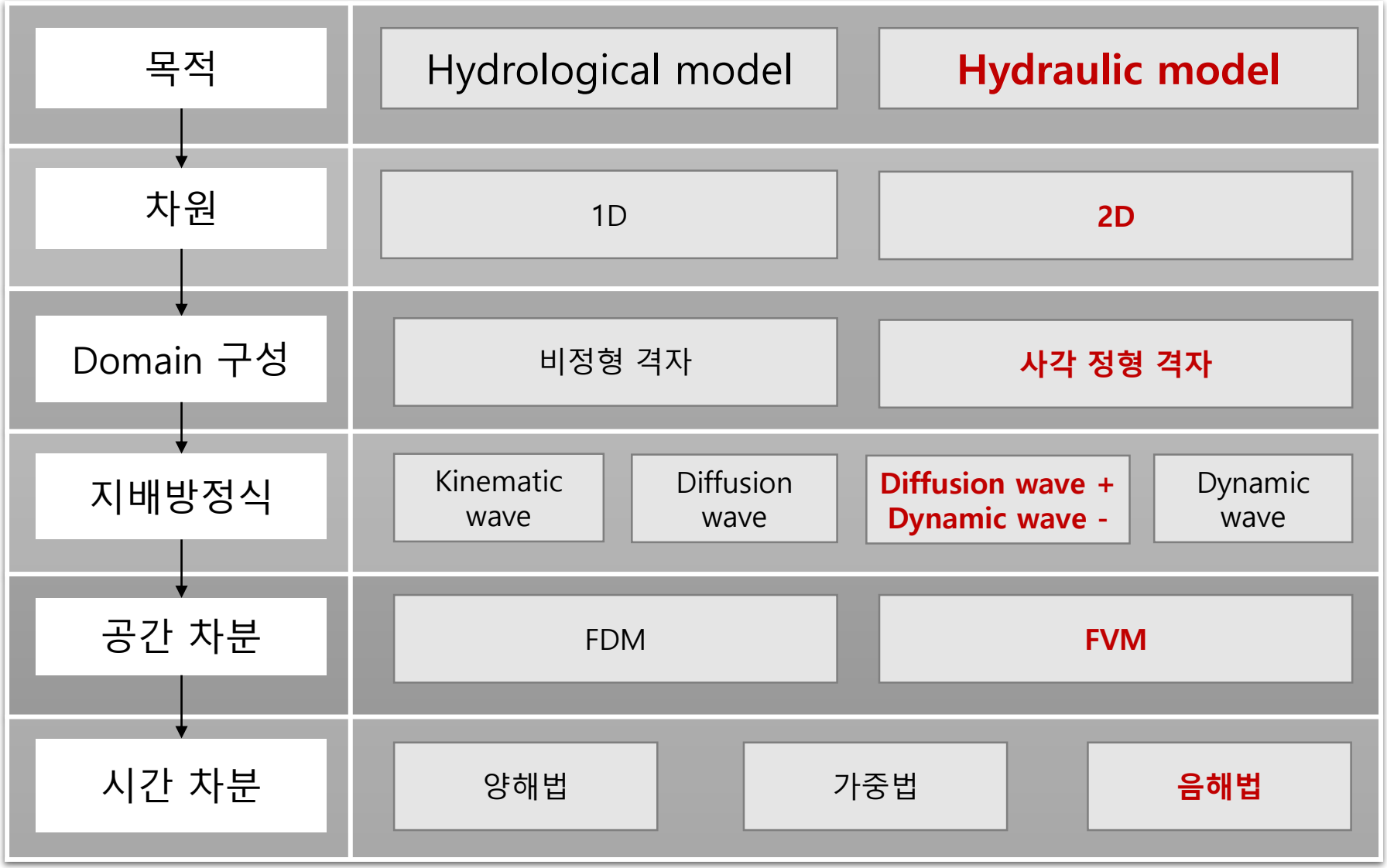
- **모형 목적**
  - 최소한의 자료(DEM, 토지피복 등)를 이용, 쉽고 빠르게 지표면 침수해석
  - 격자기반 모형 , 분포형 강우-유출 모형(GRM)과 연계된 침수해석(G2D) 체계 구축
  - OpenGIS 기반 홍수해석 기술 개발 및 배포(QGIS기반 GRM+G2D)

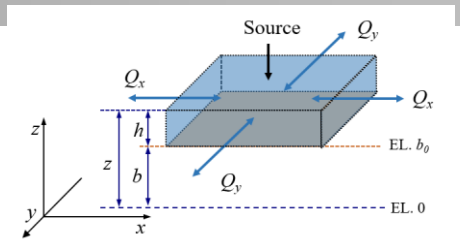
- **방법**
  - 정형 사각 격자 기반의 2차원 침수해석 모형
  - 운동량 방정식에서 이송가속도항 제외(DWE-)
  - 유한체적법, 음해법 적용



- **History**
  - 2017.12 : G2D v2017
  - 2018.06 : G2D v2018 (안정성, 속도 향상)
  - 2019.05 : QGIS Plug-in GUI(QGIS-G2D) 배포 (QGIS 2.18)
  - 2019.12 : QGIS Plug-in GUI(QGIS-G2D) 배포 (QGIS 3.8, 후처리 기능 추가)
  - 2020.05 : 기존 C#을 이용한 모델을 C++를 이용하여 재개발

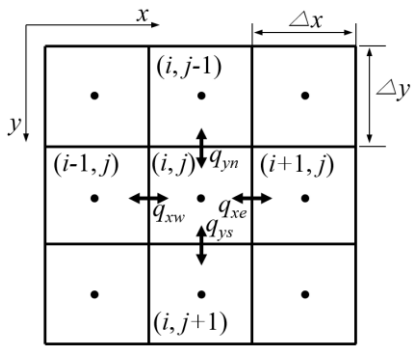
모형의 분류(개략적 분류)


목적
Hydrological model
Hydraulic model
차원
1D
2D
Domain 구성
비정형 격자
사각 정형 격자
지배방정식
Kinematic wave
Diffusion wave
Diffusion wave +
Dynamic wave -
Dynamic wave
공간 차분
FDM
FVM
시간 차분
양해법
가중법
음해법



● 지배방정식 및 해법

- 2차원, 연속방정식 + 운동량방정식(이송가속도항 무시)
- 연속방정식에서의 Source term : 강우, 유량
- 경계조건 : 수위, 유량



- 연속방정식 : $\frac{\partial h}{\partial t}+\frac{\partial (uh)}{\partial x}+\frac{\partial (vh)}{\partial y}=s$
- 운동량방정식 : $\frac{\partial (uh)}{\partial t}+\frac{gh\partial z}{\partial x}+\frac{gn^2(uh)^2}{h^{7/3}}=0$ (x-dir.)

※ Dynamic wave eq. :

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}+g\frac{\partial h}{\partial x}-g(S_b-S_f)=0$$

여기서, u : x방향 유속, v : y방향 유속, h : 수심, t : 시간, $s[LT^{-1}]$: source term, b : 지면표고, z : 수위(= $h+b$), g : 중력가속도

- 유한체적법, 음해법 적용
- 계산시간 간격 : Courant-Friedrich-Lewy (CFL) 조건

$$\Delta t \leqq \frac{C\times \Delta x}{V}$$

여기서, C : Courant number, V : 유속, Δx : 격자 크기

※ von Neumann stability condition 적용 가능

$$\Delta t=\frac{\Delta x^2}{4}min\left(\frac{2n}{h_f^{5/3}}\left|\frac{\Delta z}{\Delta x}\right|^{1/2},\frac{2n}{h_f^{5/3}}\left|\frac{\Delta z}{\Delta y}\right|^{1/2}\right)$$

● 모델 소프트웨어 개발

- 개발환경 : C++, 텍스트 및 xml 파일 이용, 콘솔 exe, QGIS Plug-in GUI
- 모형 프로젝트 파일(*.g2p)을 이용한 실행
- 입력자료

자료	형식	용도	필수여부
DEM 1개	ASCII raster	Domain 설정, 고도, 지면 경사 설정	O
DEM n개	ASCII raster	모의 진행 중에 Domain 변경	X
토지피복도	ASCII raster	지표면 조도계수 설정	X
강우	Text, ASCII raster	강우량 설정(source term)	X
유량	Text	유량 (source term)	X
유량, 수심, 수위	Text	경계조건 설정	X
수심	ASCII raster	초기조건 설정	X

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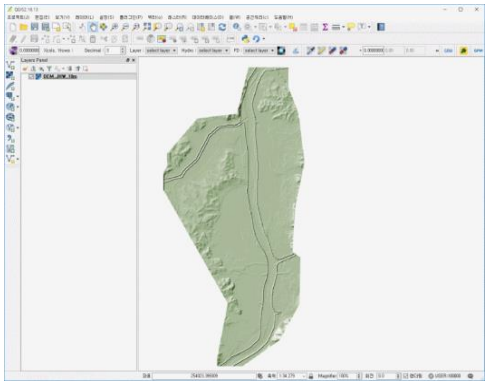
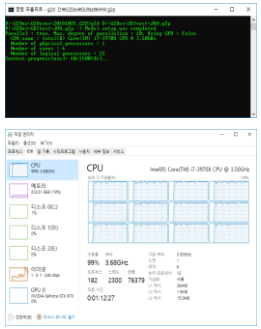
<MakeImgFile>false</MakeImgFile>
<WriteLog>false</WriteLog>
</ProjectSettings>

<.g2p 파일 사례>

- 출력자료

자료	형식	설명
수심	ASCII raster	모든 셀 수심
수위	ASCII raster	모든 셀 수위
유속	ASCII raster	셀 별 4방향 중 최대 유속
유량	ASCII raster	셀 별 4방향 중 최대 유량
침수 셀 개수	Text	임의 수심 이상의 셀 개수





G2D 검증

● 모델 검증 절차

개발

↓

해석해

↓

수치실험

↓

실제 지역 적용

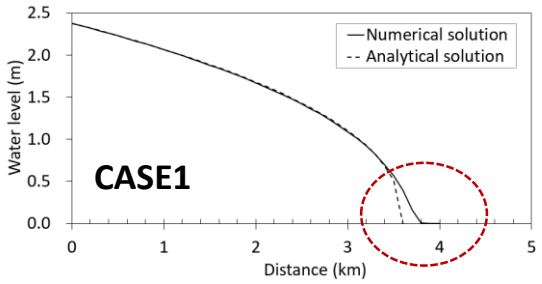
● 해석해 검증

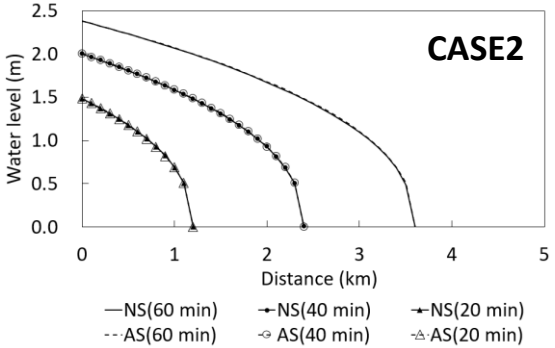
▪ Hunter et al.(2005)에서 제시된 해석해 적용

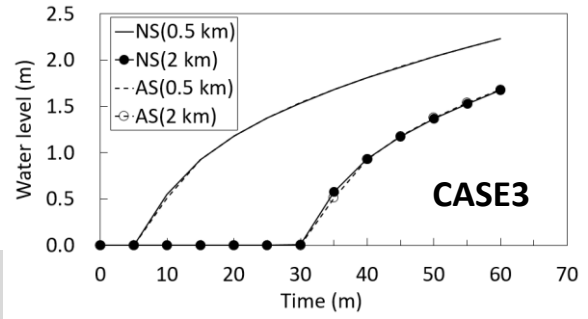
$$h(x,t) = \left[\frac{7}{3}\{C - n^2u^3(x-ut)\}\right]^{3/7}$$

▪ 계산조건 및 결과 : 격자크기 100m, 조도계수 0.03, 지면경사 0

Comparison contents	CASE	Boundary condition cell location	Output cell		Output time(min)	RMSE (m)	NSE	CC
			Location	Distance from the left side (km)				
Water surface profile	CASE1	(0, 0)	All	All	60	0.07	0.99	1.00
	CASE2	(36, 0)			20, 40, 60	0.01	1.00	1.00
The changes of water depth in a cell	CASE3	(0, 0)	(5, 0)	0.5	From 0 to 60	0.01	1.00	1.00
			(20, 0)	2.0		0.02	1.00	1.00





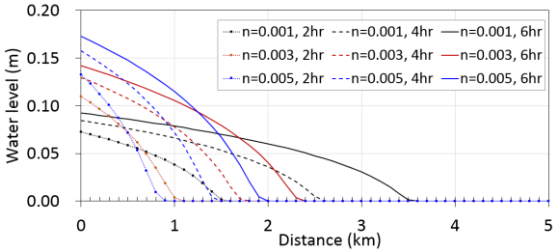


G2D 검증

● 수치실험

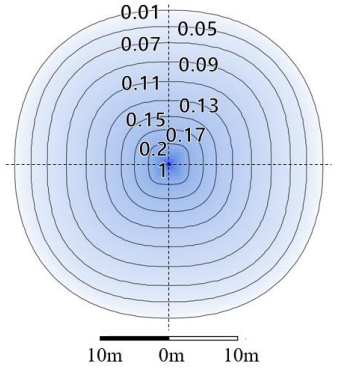
- 경계조건(수위, 유량), 해상도(100m, 10m)
- 방향성 검토 : x 방향(1 X N), y 방향(N X 1), xy 방향(N X N), 대칭성
- 지면경사 (bed slope =0 and ≠ 0), 조도계수, 장애물

▪ 조도계수 영향 검토



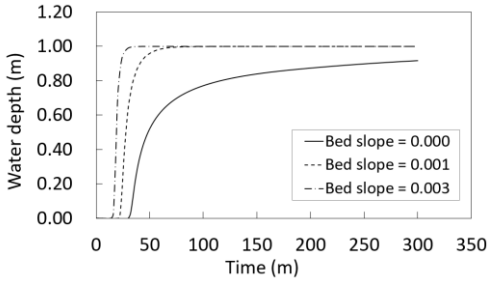
▪ xy 방향, 대칭성 검토

- 중심부에 수심 1m 경계조건 부여

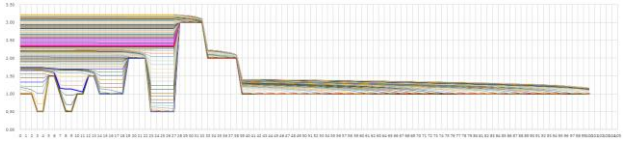


▪ 경사

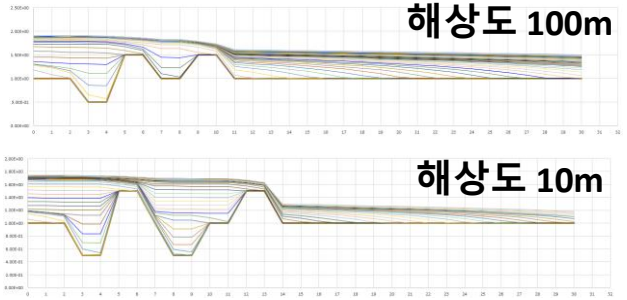
- (0, 0)에서 2km 위치에서의 수심 변화



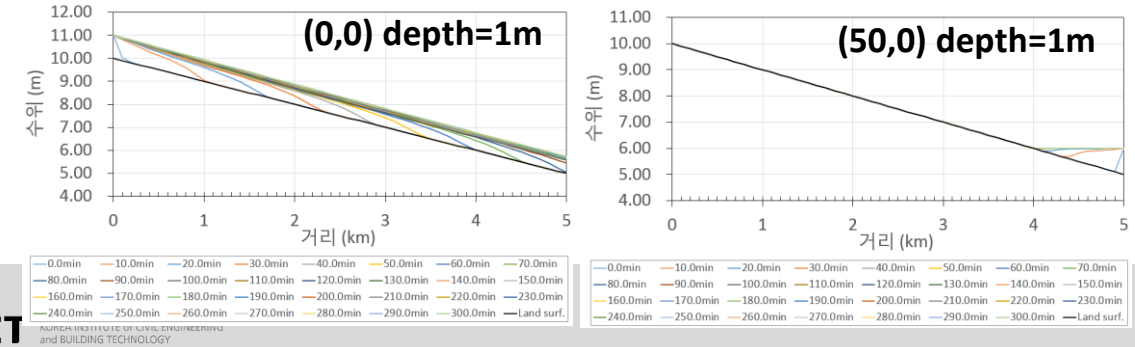
▪ 장애물 조건 안정성



▪ 해상도 안정성

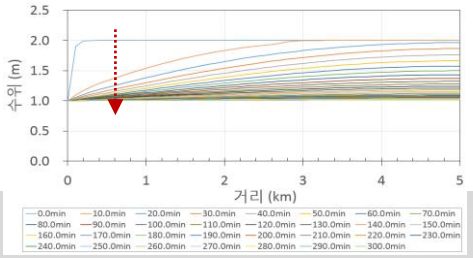


▪ 1 방향 경사지면, 좌우 경계조건



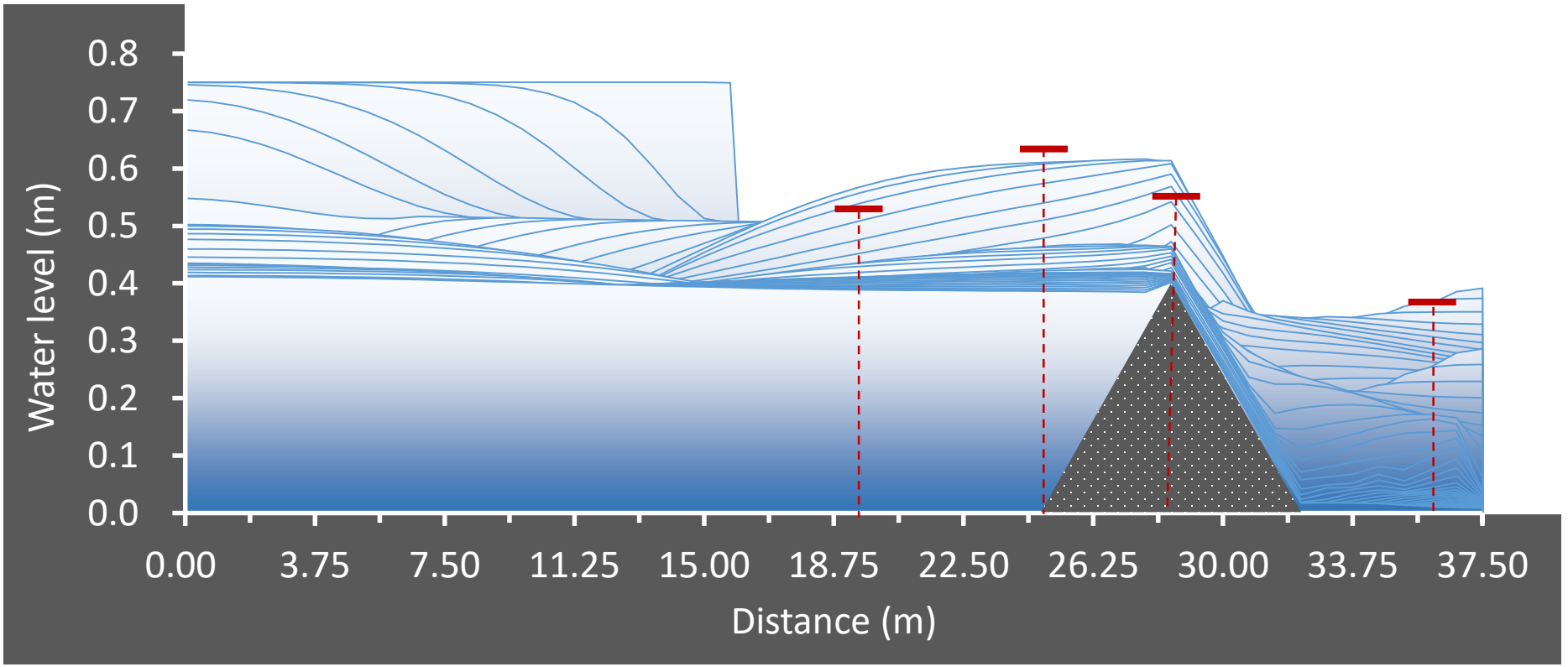
▪ 낮은 수위 경계조건

- 초기조건 2m, (0,0) 경계조건 1m



G2D 검증

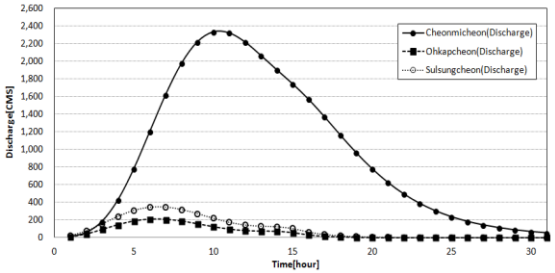
- **수치실험**
  - CADAM 실험 데이터 (Zhou et al., 2004) 와 비교
    - Domain : 37.5m 수로, x=28.5m에 장애물, 상류단은 닫힌 경계조건, 하류단은 자유수면 유출
    - 초기 조건 : X=15.5m 까지 0.75m 수심, 장애물을 지나서 0.15m 수심, 모델 정밀 보정 하지 않음
    - 관성, 최고 수심은 어느정도 재현 가능, 급격한 수심변화(처오름, 도수 등) 모의에 한계를 보임

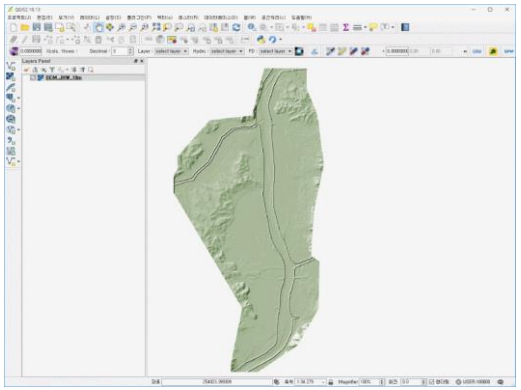


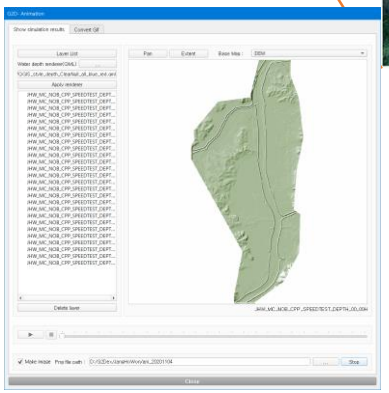
G2D 적용 사례(청미천 장호원)

- **대상 지역 및 자료**
  - 분석범위 : 청미천 장호원읍 (홍수위험지도 구축 구간)
    파제지점1(CM1)과 하도(유효면적 약 18㎢)
  - DEM : Lidar / 해상도 : 10m (287,040개 셀)
  - 파제폭 : 90m, 파제후 지면고 : 64.75m

- 홍수사상 : 100년 빈도 설계홍수량





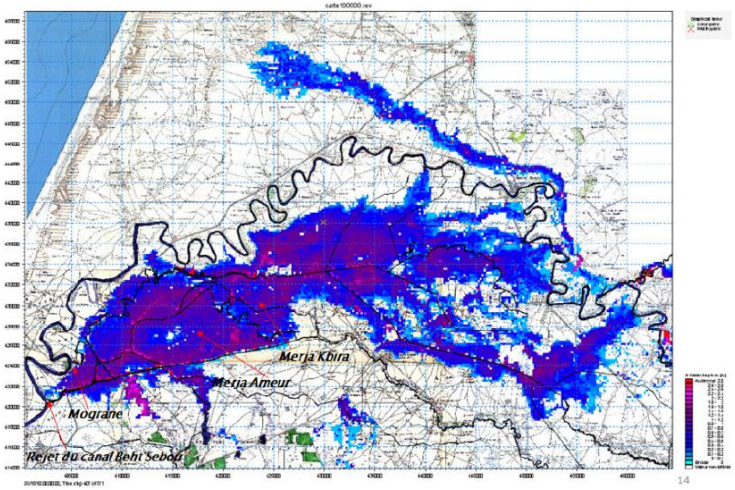


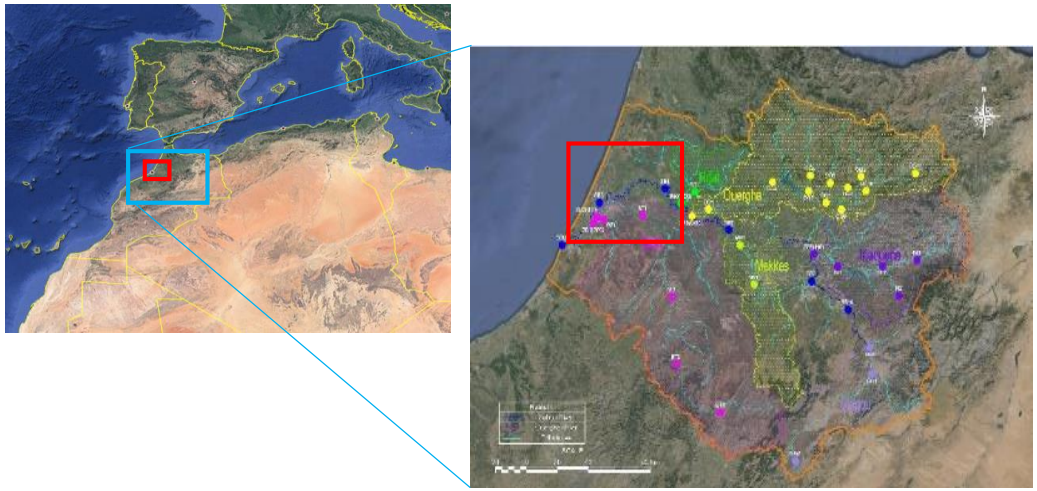
<홍수위험지도
(FLUMEN) 침수범위>

G2D 적용 사례(모로코 Sebou 강 지역)

● 대상 지역 및 자료

- 분석 범위 : 모로코 Sebou 강 중하류 지역
  (유효면적 약 3,000 ㎢)
- DEM : STRM / 해상도 : 90m (423,185개 셀)
- 홍수사상 : 2010.1.6 ~ 1.18

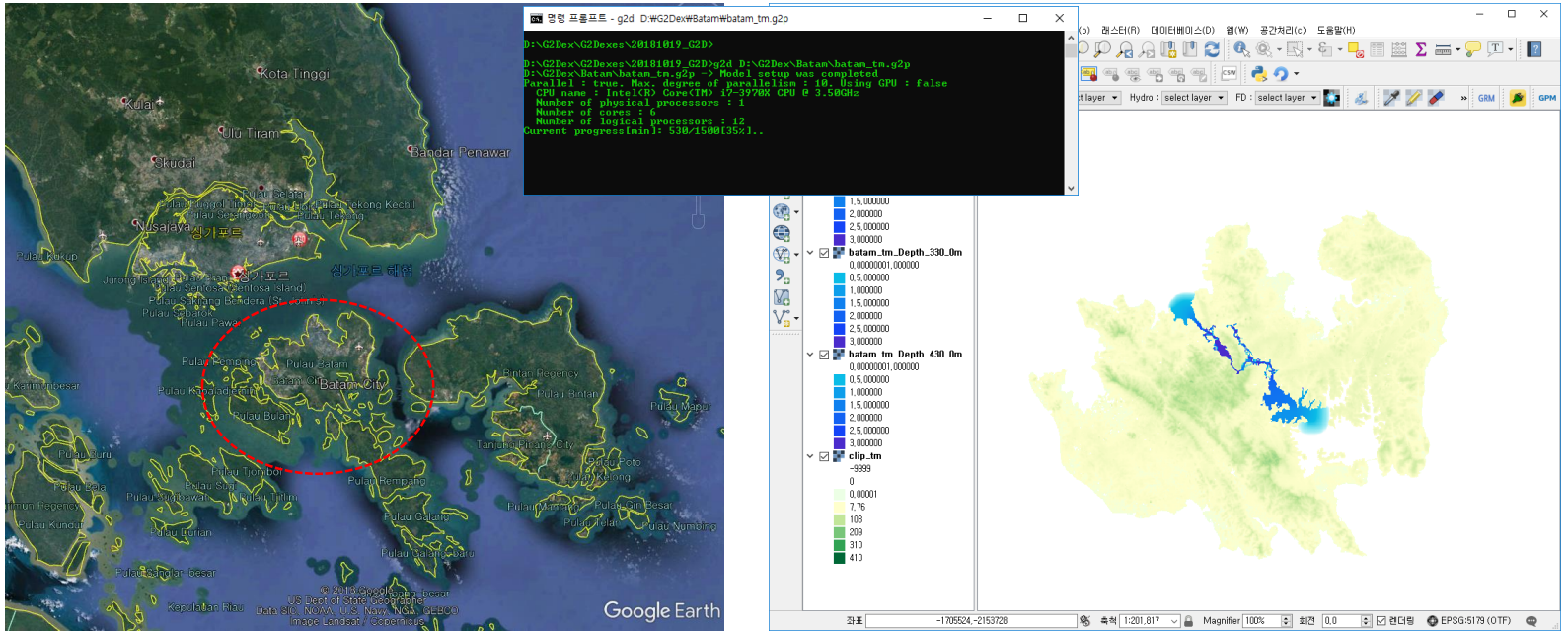




<모로코 Sebou강 유역 홍수방지 마스터플랜(2015), KOICA>

G2D 적용 사례(인도네시아)

- 사업명 : 클라우드 기반 동남아시아 맞춤형 물재해 관리시스템 개발
- 기간 / 참여기관 : 2017.4.5-2019.12.31/ KAIA, (주)로커스솔루션
- 적용 내용 : 인도네시아에 대해 강우 규모별 침수지역 모의

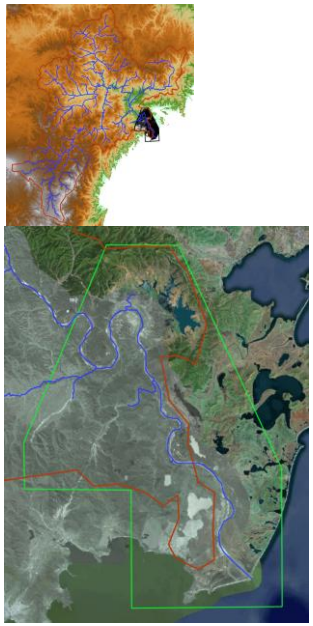


G2D 적용 사례(북한)

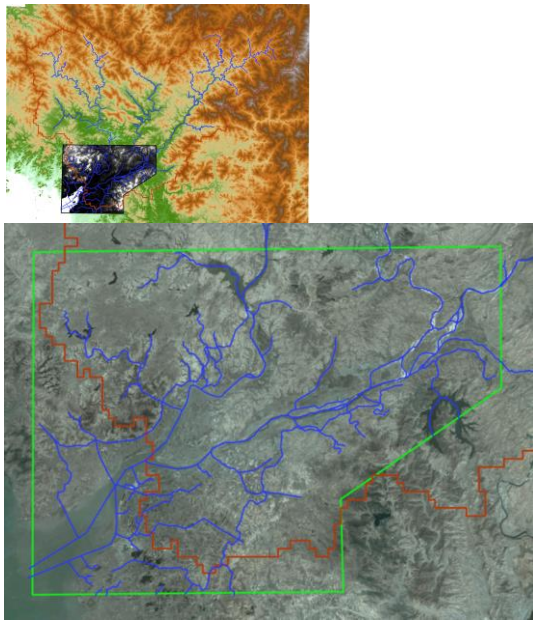
- 사업명 : 위성자료를 이용한 북한 홍수범람 분석 기술 개발
- 기간 / 참여기관 : 2018.5.1-2020.12.31/ 과학기술정보통신부, 한국건설기술연구원
- 적용 내용 : 북한 5대 하천 빈도별 개략적 침수지역 모의

예성강

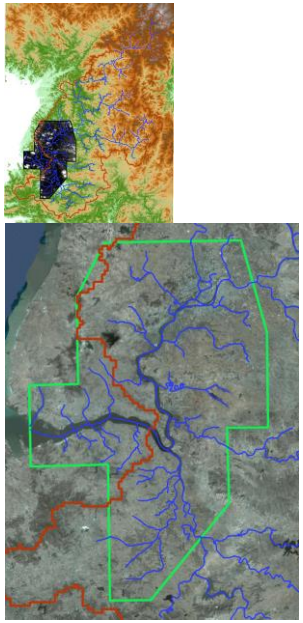
두만강



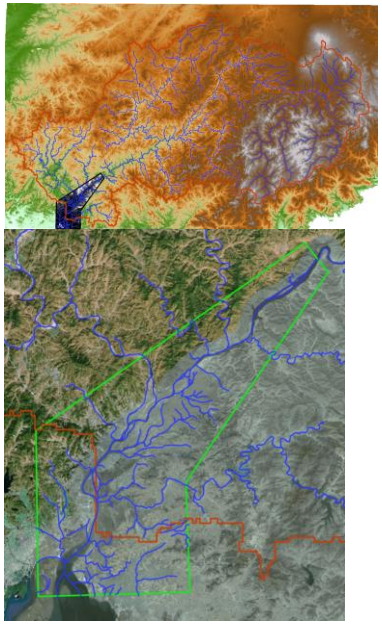
청천강



대동강

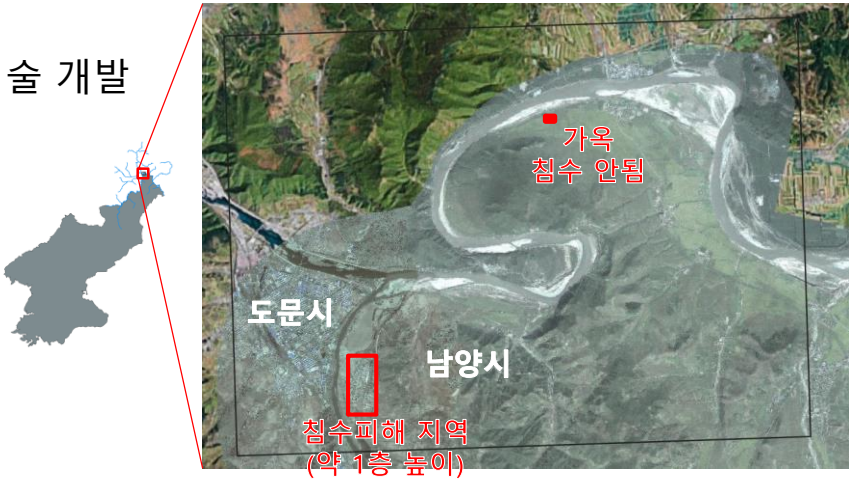


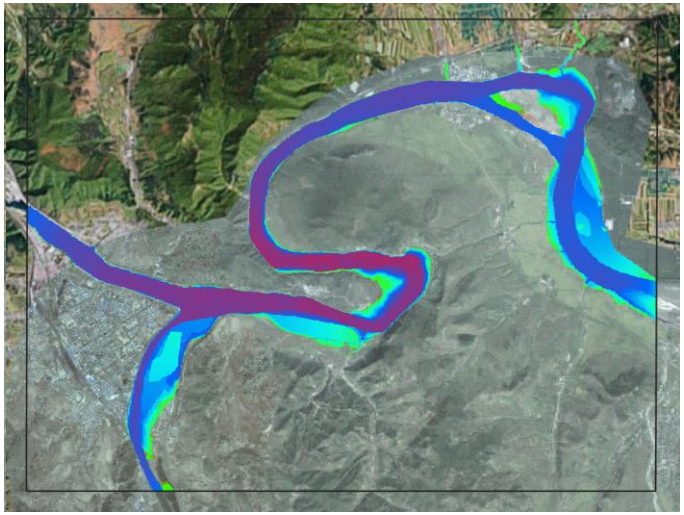
압록강

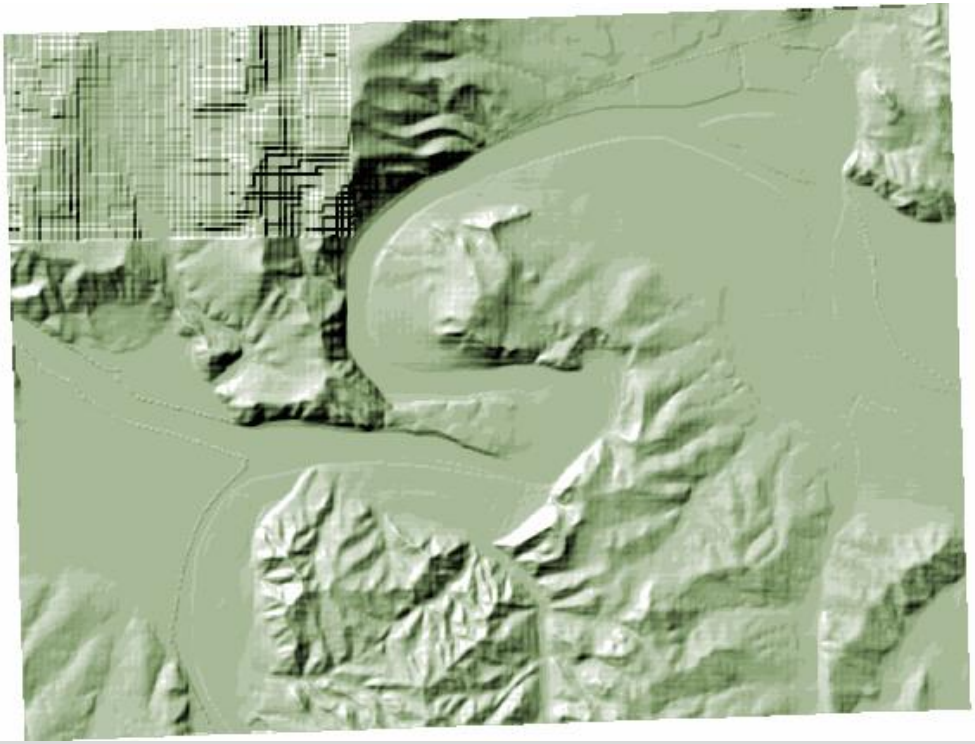


G2D 적용 사례(북한)

- 사업명 : 위성자료를 이용한 북한 홍수범람 분석 기술 개발
- 기간 / 참여기관 : 2018.5.1-2020.12.31
  / 한국건설기술연구원
- 적용 내용
  중국과 북한 접경지인 두만강 도문/남양 침수해석
  (2016년 태풍 라이언록)







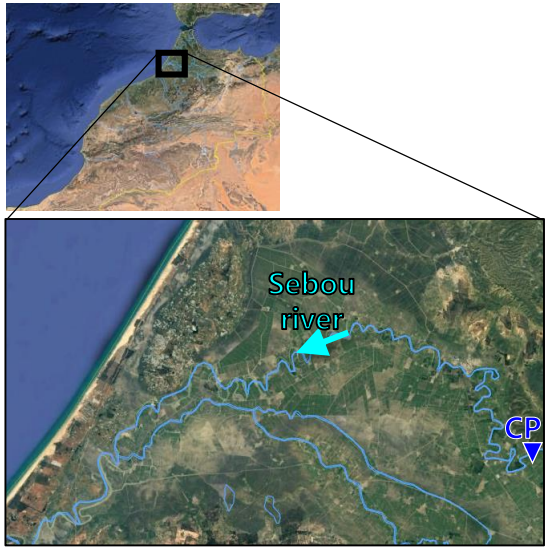
실행시간

- 런타임 평가 환경

구분	장호원	모로코 Sebou 강
해상도(m)	10 X 10	90 X 90
셀개수	368 X 780 (287,040 개)	791 X 535 (423,185 개)
출력 시간 간격	1 hr	1 hr
모의 기간	24 hr	480 hr
컴퓨터 사양	Windows10 Enterprise 64bit, Intel Core i9-7900X, 3.3GHz, 10 Core 20 Threads	

[장호원 지역]

[모코토 Sebou 강 지역]

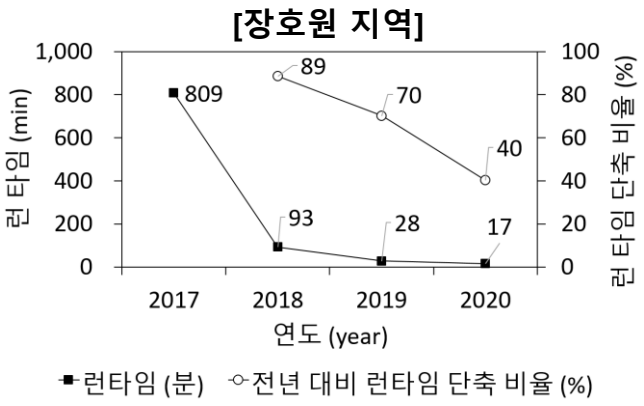


● 실행 시간

** CLF(CAESAR-Lisflood) CASE1, CASE2는 매개변수(Courant number 등)를 각기 달리 설정한 실행시간을 나타냄

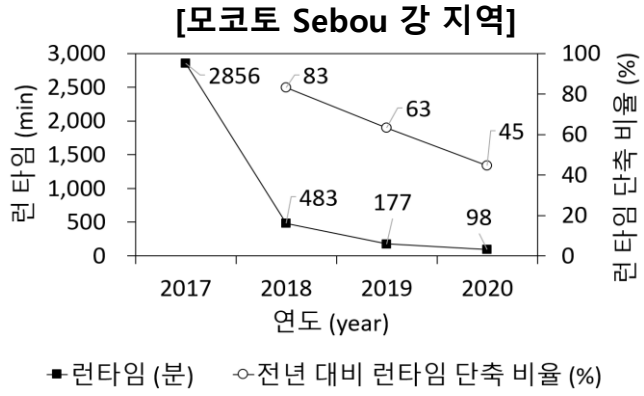
장호원 지역 실행 시간(분)

모의 시간 (hr)	1	6	12	18	24
CLF CASE1	0.16	6.57	21.49	35.77	45.99
CLF CASE2	0.05	2.14	6.97	11.48	14.58
G2D(2017)	13.29	132.78	341.78	573.24	808.59
G2D(2018)	0.61	8.01	44.59	74.95	92.92
G2D(2019)	0.25	4.49	13.13	21.55	28.03
G2D(2020)	0.08	2.60	7.72	12.77	**16.57**



모로코 Sebou 강 지역 실행 시간(분)

모의 시간 (hr)	24	120	240	360	480
CLF CASE1	0.01	10.39	89.59	190.23	289.17
CLF CASE2	0.03	3.03	25.74	54.71	83.21
G2D(2017)	69.20	484.33	1208.98	2027.95	2856.26
G2D(2018)	5.37	59.45	210.86	350.86	482.68
G2D(2019)	2.09	22.29	78.74	129.66	177.41
G2D(2020)	1.08	16.38	51.22	76.15	**98.35**

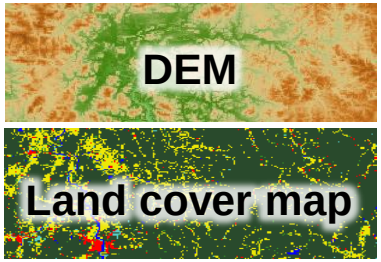


- **Application process**

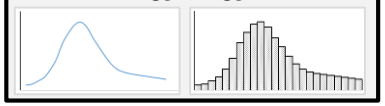
Prepare model input data
- QGIS
- Cell Value Edit plug-in
- Multi-Cell Value Edit plug-in

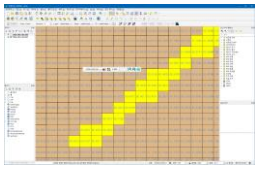
Make model project file(.g2p)
- QGIS-G2D
- Text editor

Original data



Discharge
Water depth
Water level
Rainfall





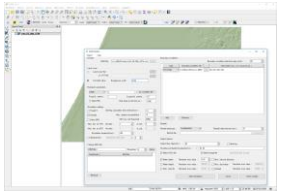
G2D input data

DEM for simulation domain

DEM to replace during simulation

Land cover

Initial condition
Boundary condition
Source term

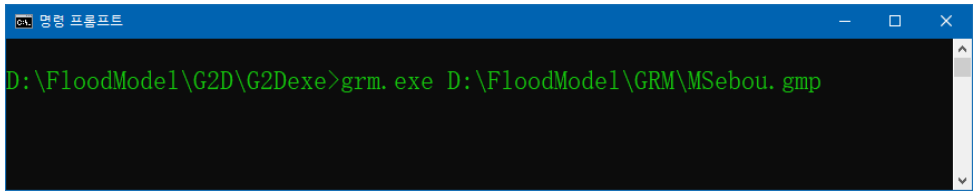


G2D project file (.g2p)
Run G2D

```
<?xml version="1.0" standalone="yes"?>
<projectds xmlns="http://tempuri.org/projectds.xsd">
  <ProjectSettings>
    <DEMFile>D:/G2Dex/Morocco_SBR/Domain/srtm_R2_90m_UTM.asc</DEMFile>
    <LandCoverFile />
    <LandCoverVatFile />
    <CalculationTimeInterval_sec>1.0</CalculationTimeInterval_sec>
    <IsFixedDT>false</IsFixedDT>
    <IsParallel>true</IsParallel>
    <MaxDegreeOfParallelism>10</MaxDegreeOfParallelism>
    <UsingGPU>false</UsingGPU>
    <EffCellThresholdForGPU>45000</EffCellThresholdForGPU>
    <MaxIterationAllCellsOnCPU>7</MaxIterationAllCellsOnCPU>
    <MaxIterationACellOnCPU>5</MaxIterationACellOnCPU>
    <MaxIterationAllCellsOnGPU>7</MaxIterationAllCellsOnGPU>
    <MaxIterationACellOnGPU>5</MaxIterationACellOnGPU>
    <SimulationDuration_hr>240</SimulationDuration_hr>
    <PrintoutInterval_min>60</PrintoutInterval_min>
    <StartDateTime>0</StartDateTime>
    <RainfallDataType>TextFileMAP</RainfallDataType>
    <RainfallDataInterval_min>10</RainfallDataInterval_min>
    <RainfallFile />
    <BCDataInterval_min>60</BCDataInterval_min>
    <FloodingCellDepthThresholds_cm>1, 30, 50</FloodingCellDepthThresholds_cm>
    <OutputDepth>true</OutputDepth>
    <OutputHeight>false</OutputHeight>
```

● The G2D model project file (~.g2p)

➢ The G2D model run using an argument of a project file



➢ G2D project file

- Text xml format with the extension of '.g2p'.
- Includes input file info., modeling options, the model parameters, etc.
- Text editor or QGIS-G2D GUI can be used to make a project file

```
<?xml version="1.0" standalone="yes"?>
<projectds xmlns="http://tempuri.org/projectds.xsd">
  <ProjectSettings>
    <DEMFile>C:₩G2D₩SampleData₩domain₩DEM_JHW_10m.asc</DEMFile>
    <LandCoverFile>C:₩G2D₩SampleData₩domain₩LC_JHW.asc</LandCoverFile>
    <LandCoverVatFile>C:₩G2D₩SampleData₩domain₩LC_JHW.VAT</LandCoverVatFile>
    <CalculationTimeStep_sec>0.01</CalculationTimeStep_sec>
    <IsFixedDT>false</IsFixedDT>
    <MaxDegreeOfParallelism>20</MaxDegreeOfParallelism>
    <UsingGPU>false</UsingGPU>
    <EffCellThresholdForGPU>0</EffCellThresholdForGPU>
    <MaxIterationAllCellsOnCPU>7</MaxIterationAllCellsOnCPU>
    <MaxIterationACellOnCPU>5</MaxIterationACellOnCPU>
    <MaxIterationAllCellsOnGPU>7</MaxIterationAllCellsOnGPU>
    <MaxIterationACellOnGPU>5</MaxIterationACellOnGPU>
    <PrintoutInterval_min>60</PrintoutInterval_min>
    <SimulationDuration_hr>25</SimulationDuration_hr>
    <StartDateTime>0</StartDateTime>
    <RainfallDataType>TextFileMAP</RainfallDataType>
    <RainfallDataInterval_min>10</RainfallDataInterval_min>
    <RainfallFile></RainfallFile>
    <BCDataInterval_min>60</BCDataInterval_min>
    <FloodingCellDepthThresholds_cm>10,20,50</FloodingCellDepthThresholds_cm>
    <OutputDepth>true</OutputDepth>
    <OutputHeight>false</OutputHeight>
    <OutputVelocityMax>false</OutputVelocityMax>
    <OutputFDofMaxV>false</OutputFDofMaxV>
    <OutputDischargeMax>false</OutputDischargeMax>
    <OutputBCData>false</OutputBCData>
    <OutputRFGrid>false</OutputRFGrid>
    <DepthImgRendererMaxV>3</DepthImgRendererMaxV>
    <HeightImgRendererMaxV>200</HeightImgRendererMaxV>
    <VelocityMaxImgRendererMaxV>10</VelocityMaxImgRendererMaxV>
    <DischargeImgRendererMaxV>10000</DischargeImgRendererMaxV>
    <RFImgRendererMaxV>30</RFImgRendererMaxV>
    <MakeASCFile>true</MakeASCFile>
    <MakeImgFile>false</MakeImgFile>
    <WriteLog>false</WriteLog>
  </ProjectSettings>
```

실행

- **The QGIS-G2D GUI** (Make G2D project file and run the model)

Domain file 설정

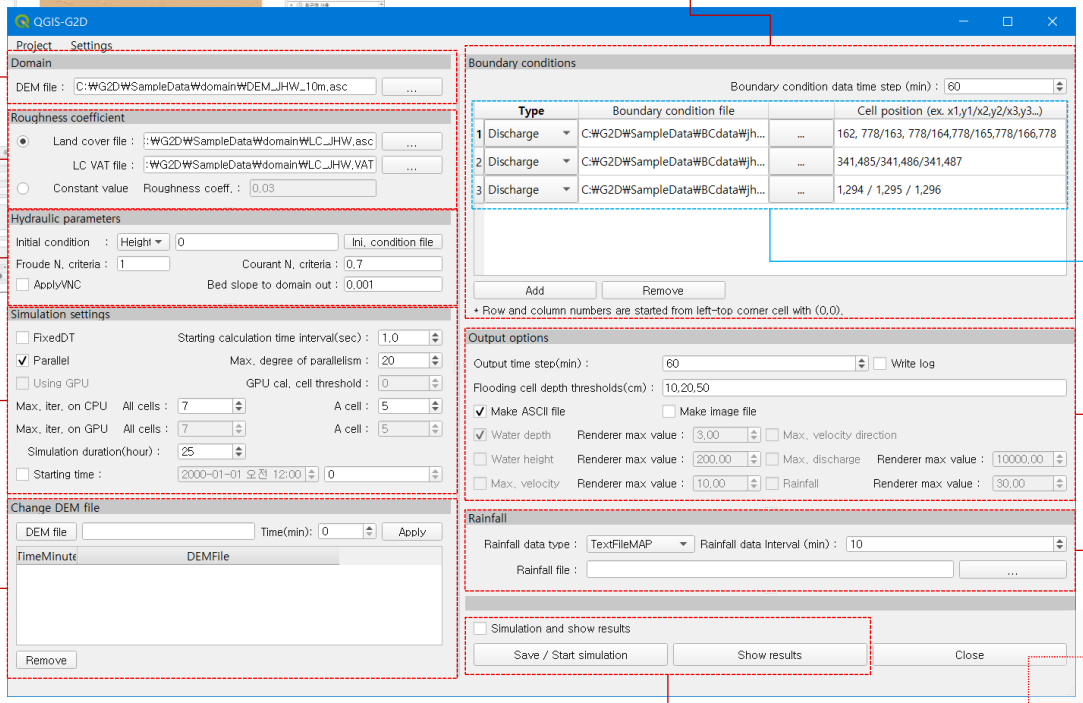
조도계수 설정

매개변수 설정

모의 환경변수 설정

DEM 수정 설정

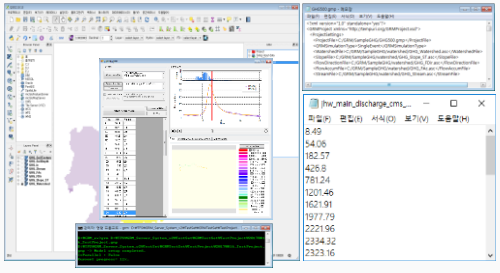
경계조건 설정



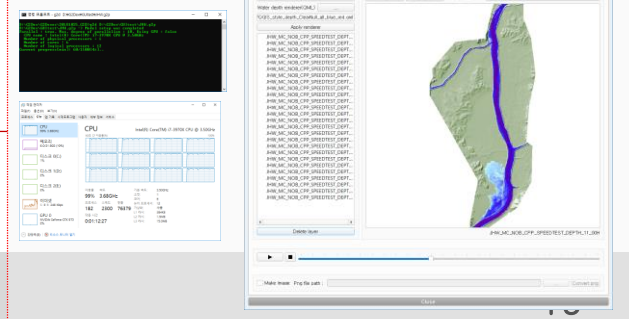
출력 옵션 선택

강우자료 설정

경계조건(GRM 모의 결과 등) 입력



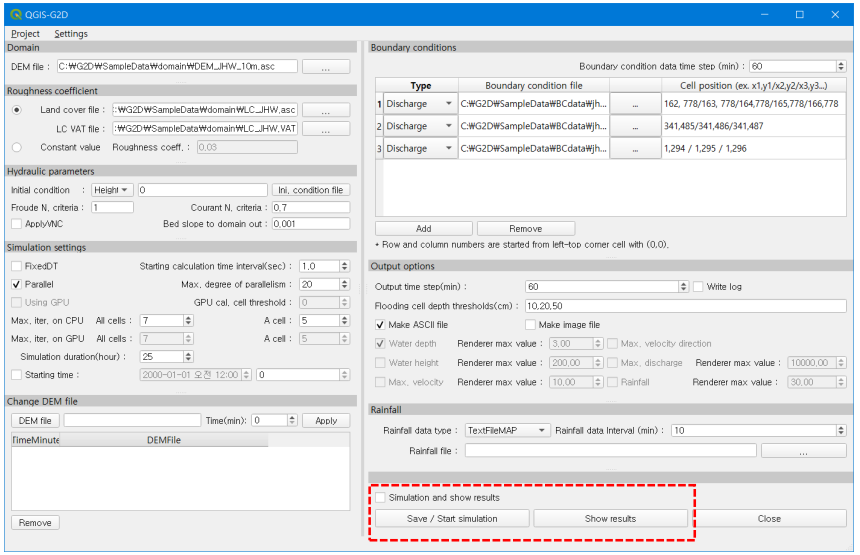
모의 실행, 모의 결과 후처리 과정 실행



● How to run the G2D model

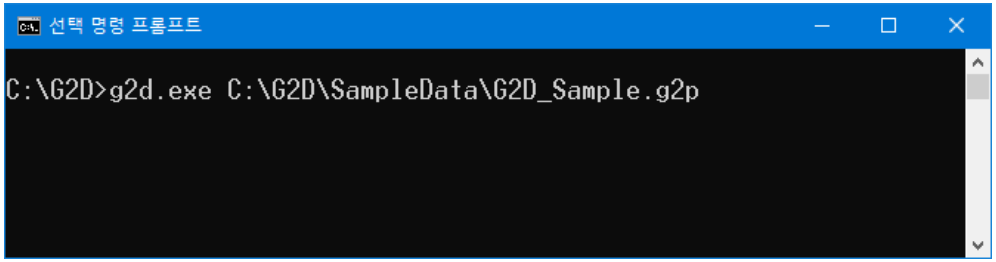
➢ Using QGIS-G2D GUI

- Click "Save / Start simulation" button on GUI
- Check "Simulation and show results" to run post processing while simulation



➢ Using G2D.exe in console window

- Run G2D.exe using a project file argument in console window
- Example: C:₩G2D₩SampleData₩G2D_Sample.g2p



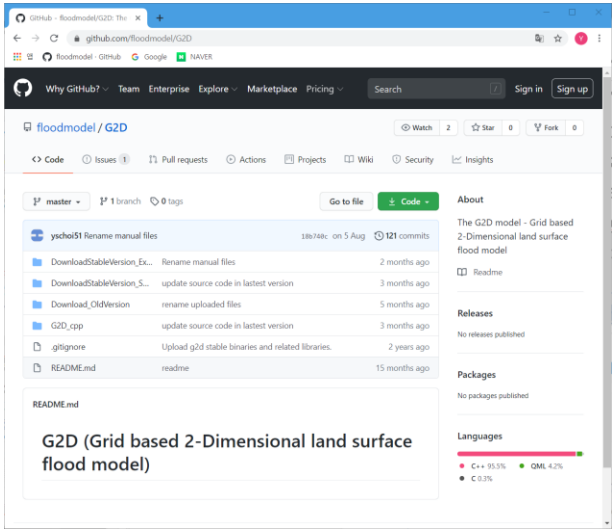
다운로드 및 설치

- **How to get the softwares**
  - Softwares : G2D, QGIS-G2D plug in
  - Contents : Source codes, executable files(exe), manuals, sample data, etc.
  - Searching web site
    - Search Google (https://www.google.com)

      or GitHub (https://github.com)

      using keywords "floodmodel", "github floodmodel",

      "floodmodel g2d", "floodmodel qgis-g2d"



  - GitHub website
    - G2D : https://github.com/floodmodel/G2D
  - QGIS plug-in repository location (QGIS 3.8.X)
    - https://raw.githubusercontent.com/floodmodel/repository_QGIS3.8/master/plugins.xml
    - Install QGIS-G2D using "Plugins>Manage and Install Plugins" menu of QGIS

Thank you!!