문서번호 APCC-출장-17-1181(2017-10-16)

TRAVEL REPORT FORM
출장보고서

결재	선임연구원	팀장	부서장	원장
	10/10 이승수	10/16 조재필	10/16 김형진	10/16 정홍상
협조				

I. Reporter 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
응용사업팀	선임연구원	이승수	10/4-10/8	

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

- 오사카 Neya 강 유역 홍수조절 시설 (Saigo-dori Regulating Pond, Sanra Shaft Structure, Fukakita Ryokuchi Retarding Basin 등) 견학
- International Workshop on Urban Inundation Mitigation in East Asian Countries under Extreme Climate Conditions 참석 및 발표 (발표 주제 : Why Hybrid Parallel Computing is Essential for 1D-2D coupled Urban Inundation Modelling?)
- 향후 공동 연구를 위한 간담회 참석

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- 본 세미나는 일본 교토대학 산하 방재연구소에서 주최 하여 개최된 세미나임.
- 세미나에 초청된 발표자는 대만, 중국, 한국, 일본에서 활동하는 연구자들 이었으며 도시침수와 관련된 다양한 연구를 수행하는 연구자들이었음
- 비슷한 기후대를 가진 한/중/일 연구자들이 한 자리에 모여 도시침수를 예방하기 위한 수행한 다양한 연구 발표를 들을 수 있었으며 인적 네트워크를 만들 수 있는 좋은 기회 였음.
- 향후 센터에서도 해외사업 추진에 있어서 현지 연구기관과의 교류를 통한 연구역량 확대를 위한 노력이 필요할 것으로 판단됨.

III. References 참고사항

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

1. Presented and Collected Materials 주요 수집자료

발표 자료 및 참석자 명함.

2. Suggestions and Remarks 건의사항

Why Hybrid Parallel Computing is Essential for 1D-2D coupled Urban Inundation Modelling?

Seungsoo Lee, Research Fellow, APCC

[2017. 10. 6]

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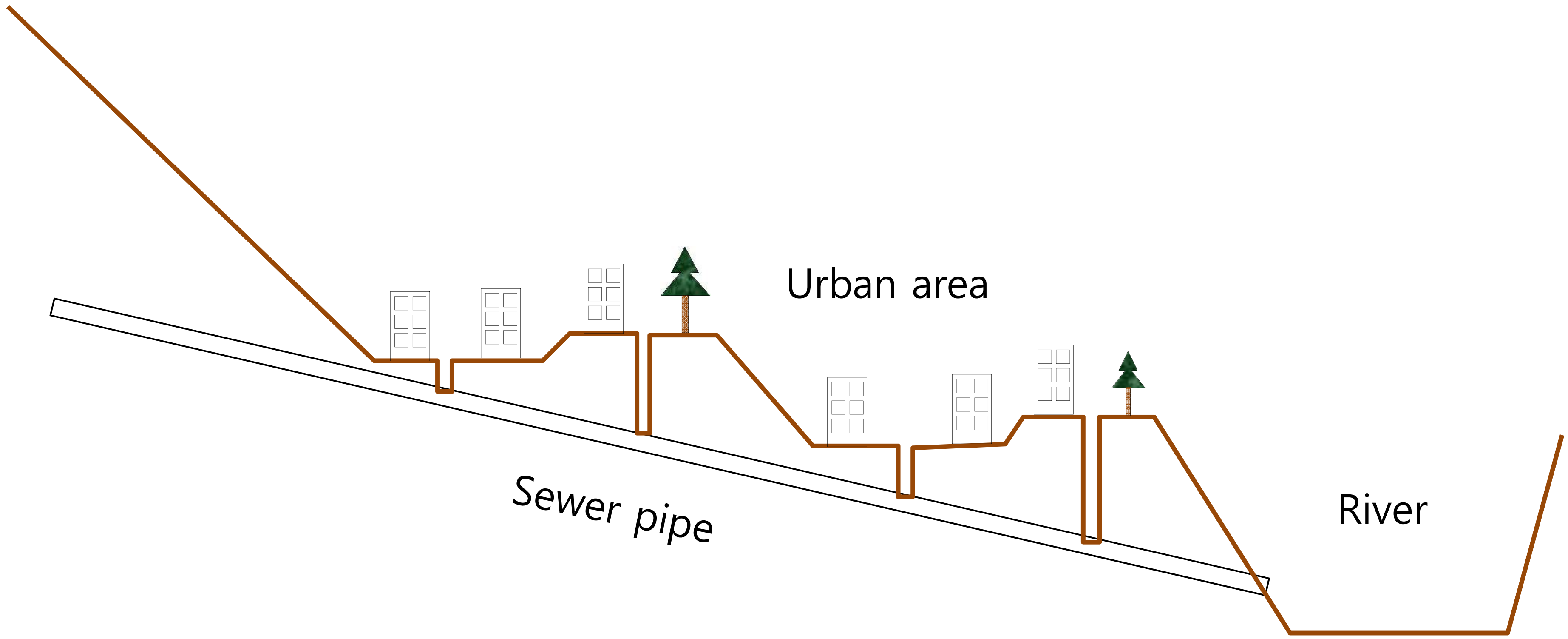
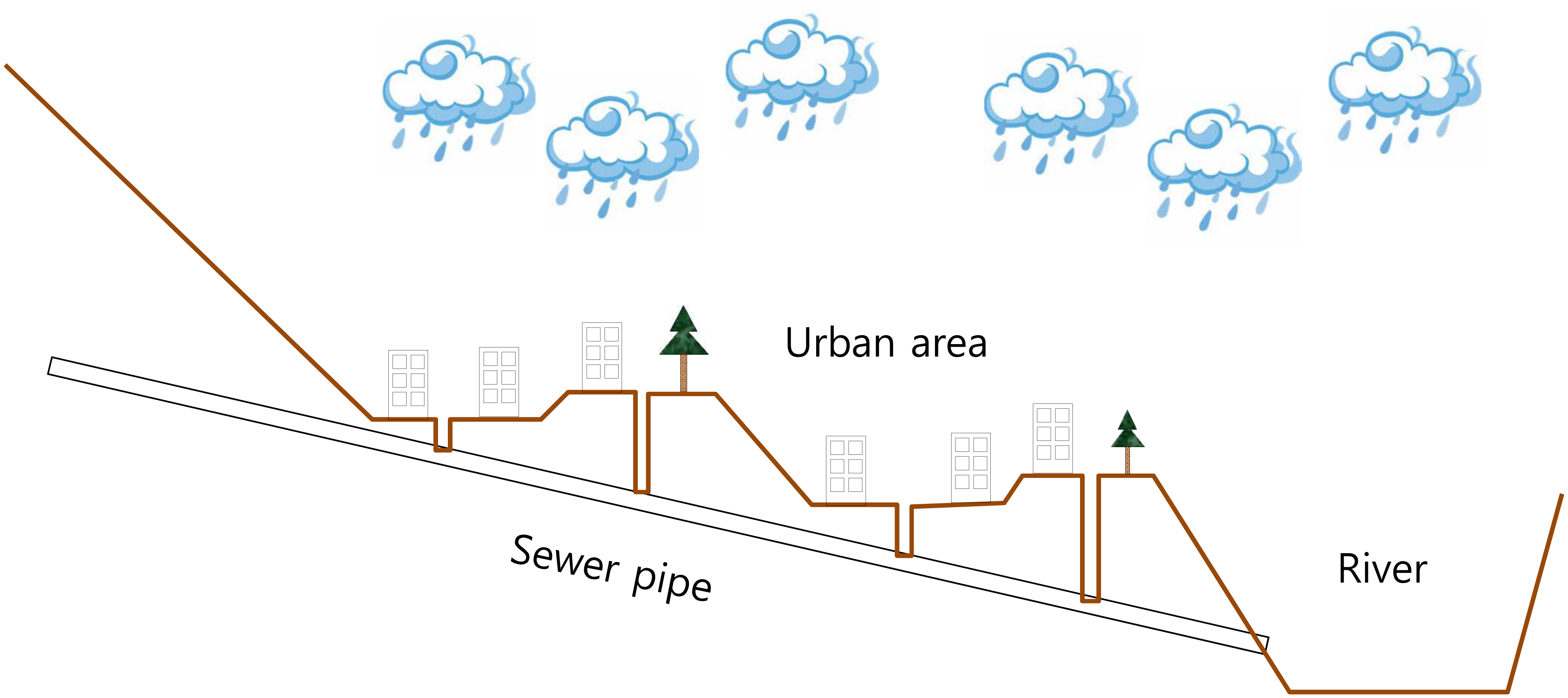
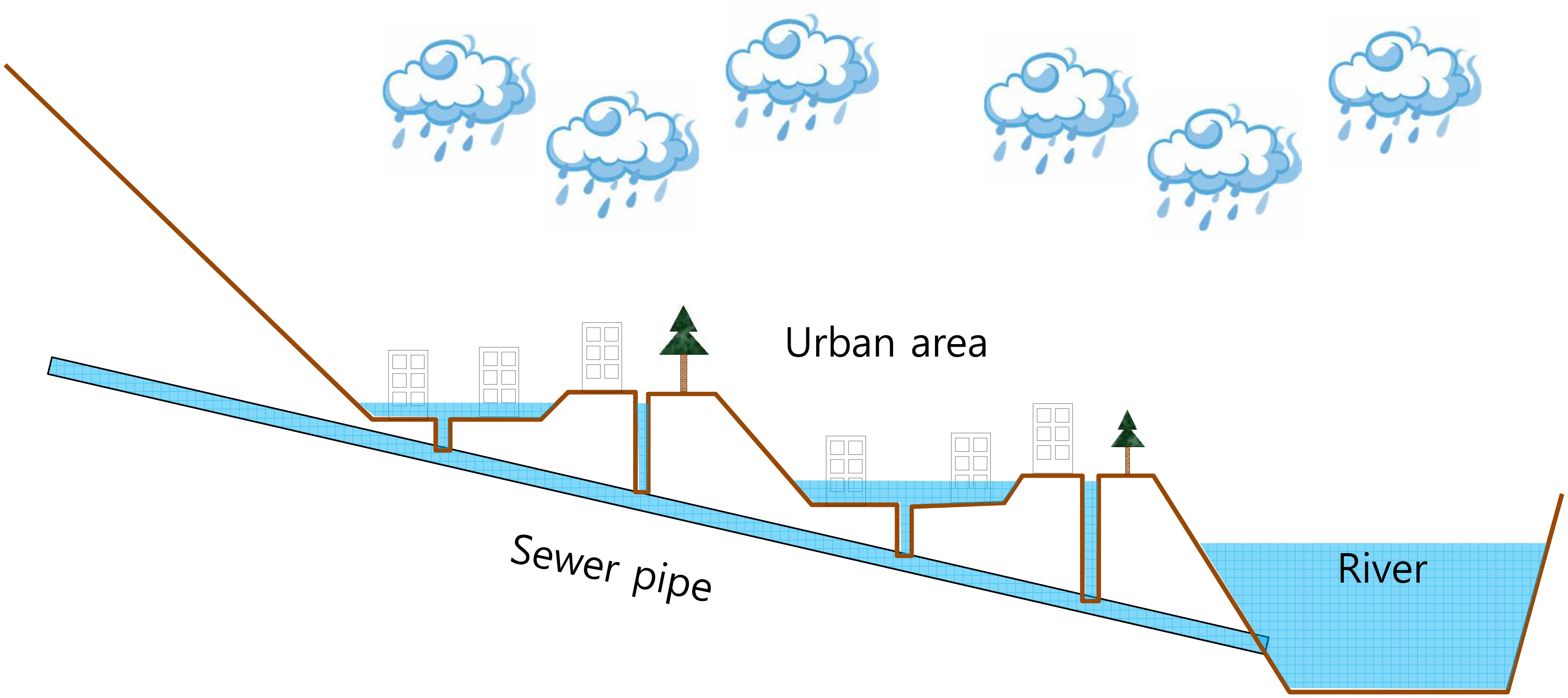
Cross-section of urban area



Cross-section of urban area



Cross-section of urban area



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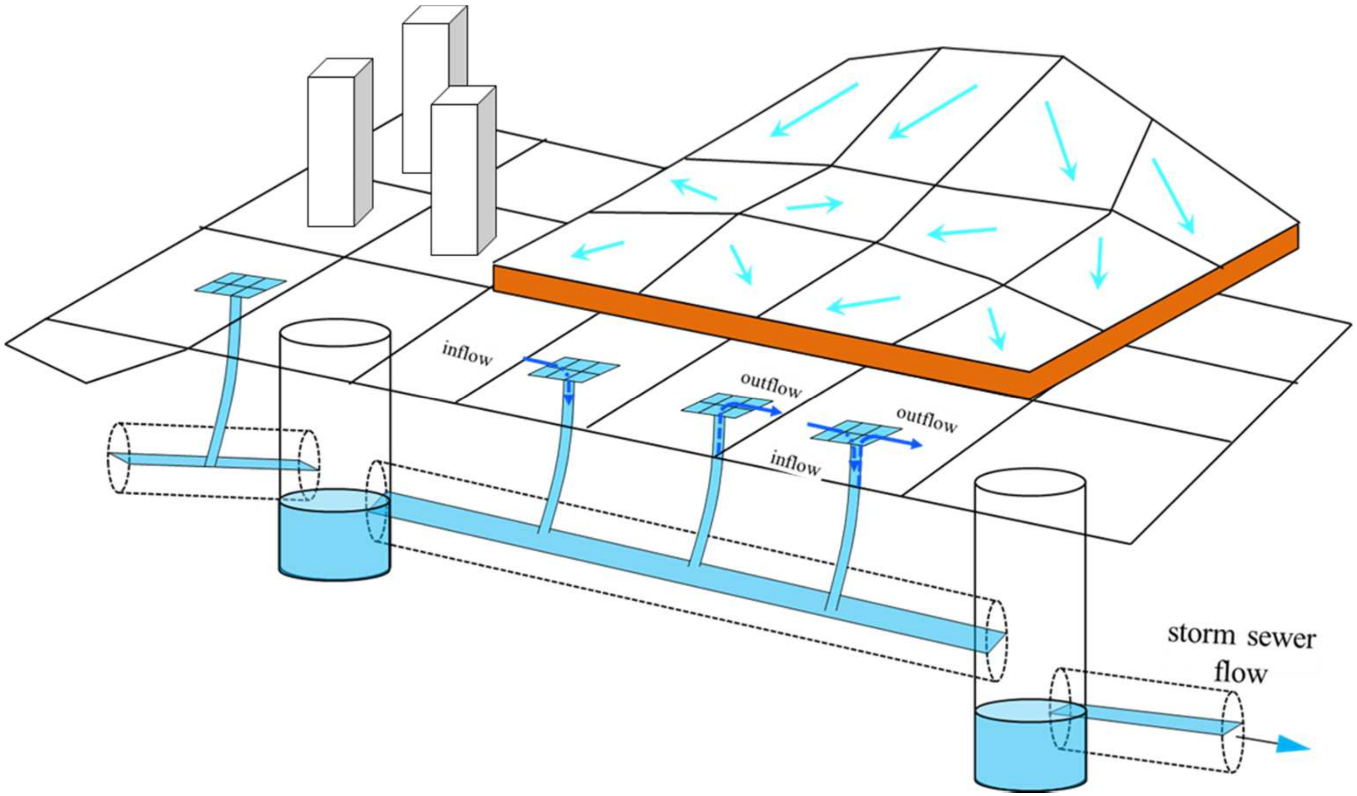
➢ 1D-2D coupled modelling



2D overland flow

+

Interaction

+

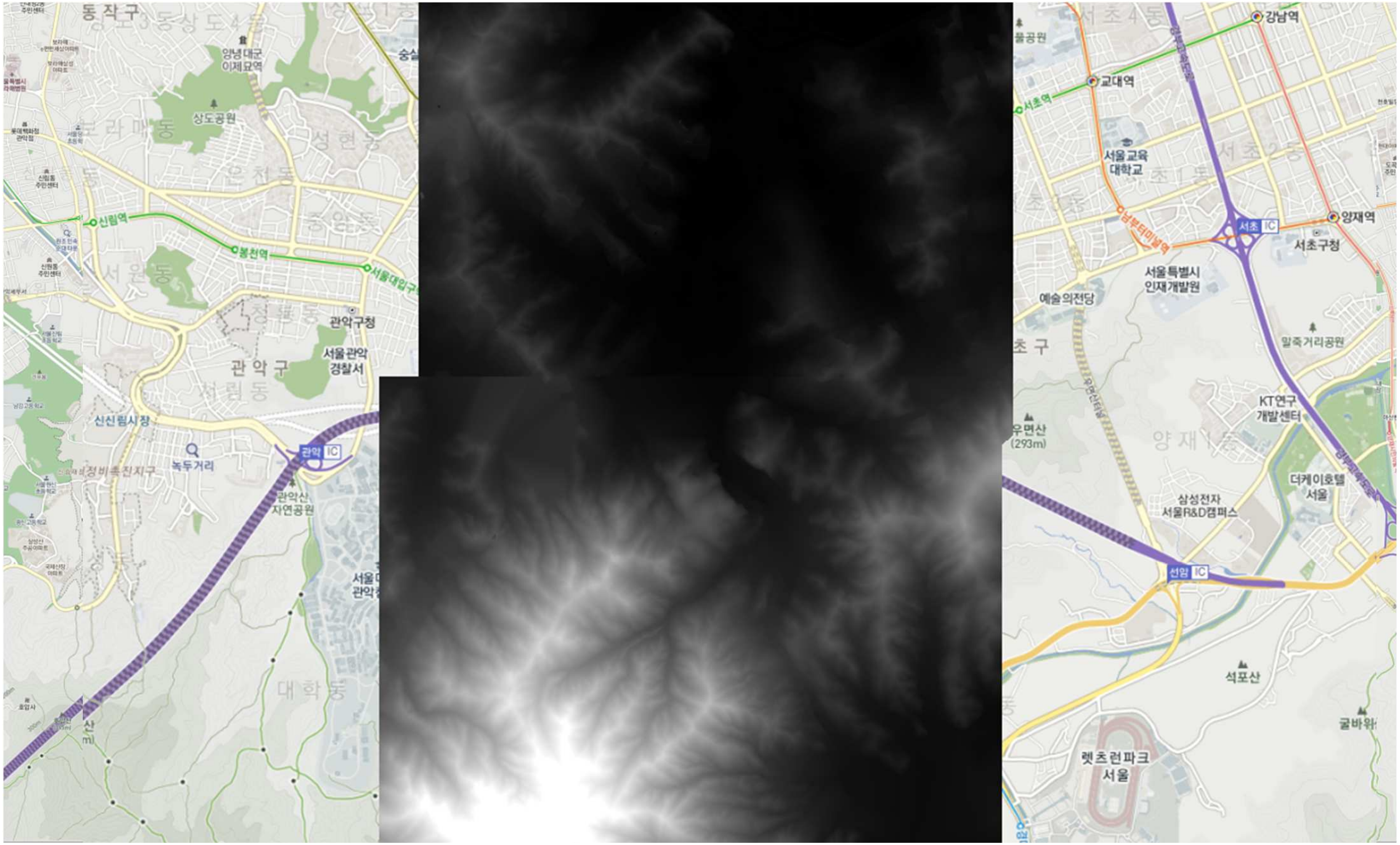
1D pipe flow

Challenging

Challenging

- How to select surface domain and sewer system data?

July 27, 2017


동작구
양녕대군 이제묘역
상도공원
신림역
봉천역
서울대입구역
관악구청
서울관악경찰서
관악구
신신림시장
녹두거리
관악 IC
관악산 자연공원
대학동
강남역
교대역
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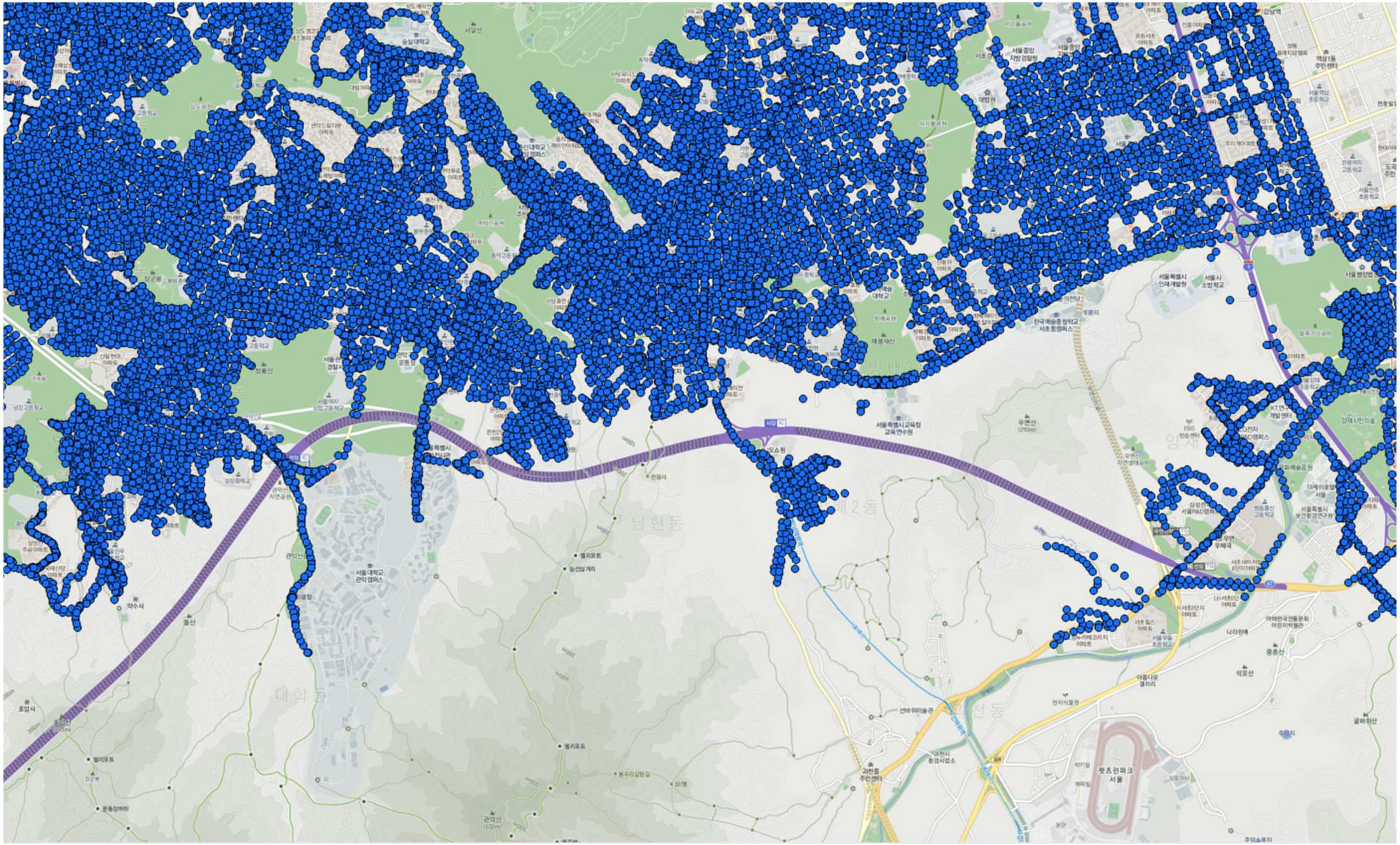
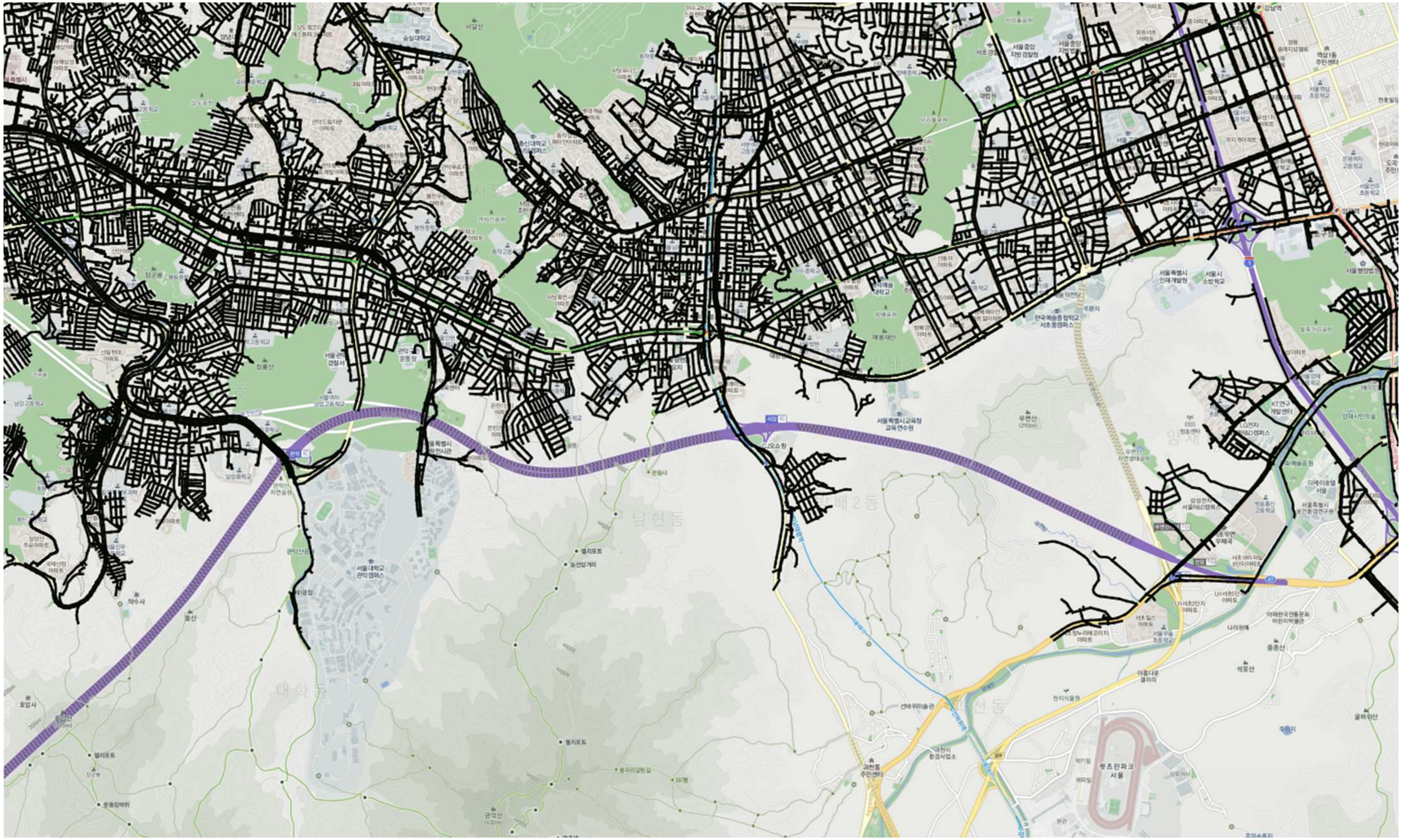
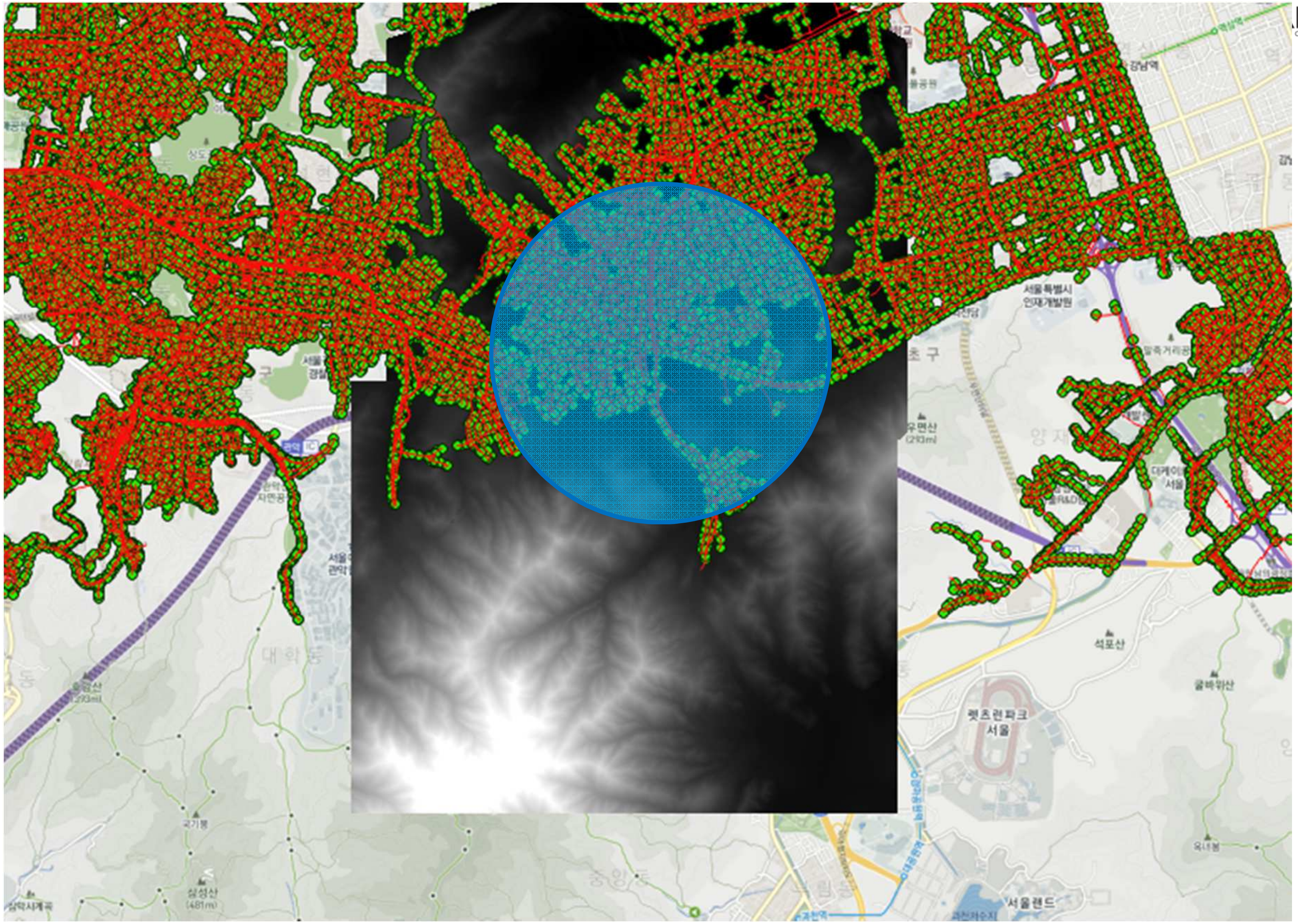
서울교육대학교
서초 IC
양재역
서초구청
서울특별시 인재개발원
예술의전당
말죽거리공원
우면산 (293m)
KT연구 개발센터
양재1동
더케이호텔 서울
삼성전자 서울R&D캠퍼스
선암 IC
석포산
굴바위
렛츠런파크 서울



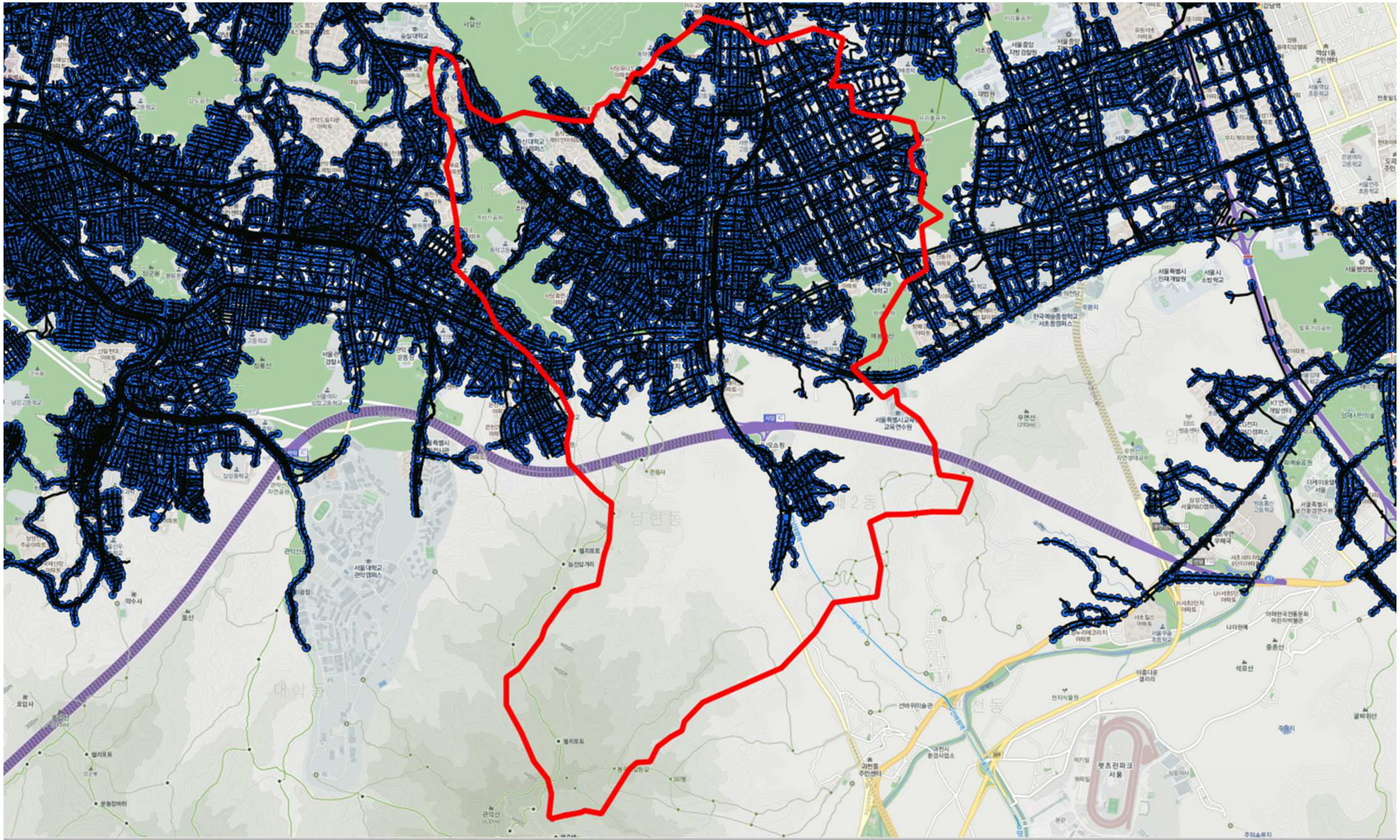


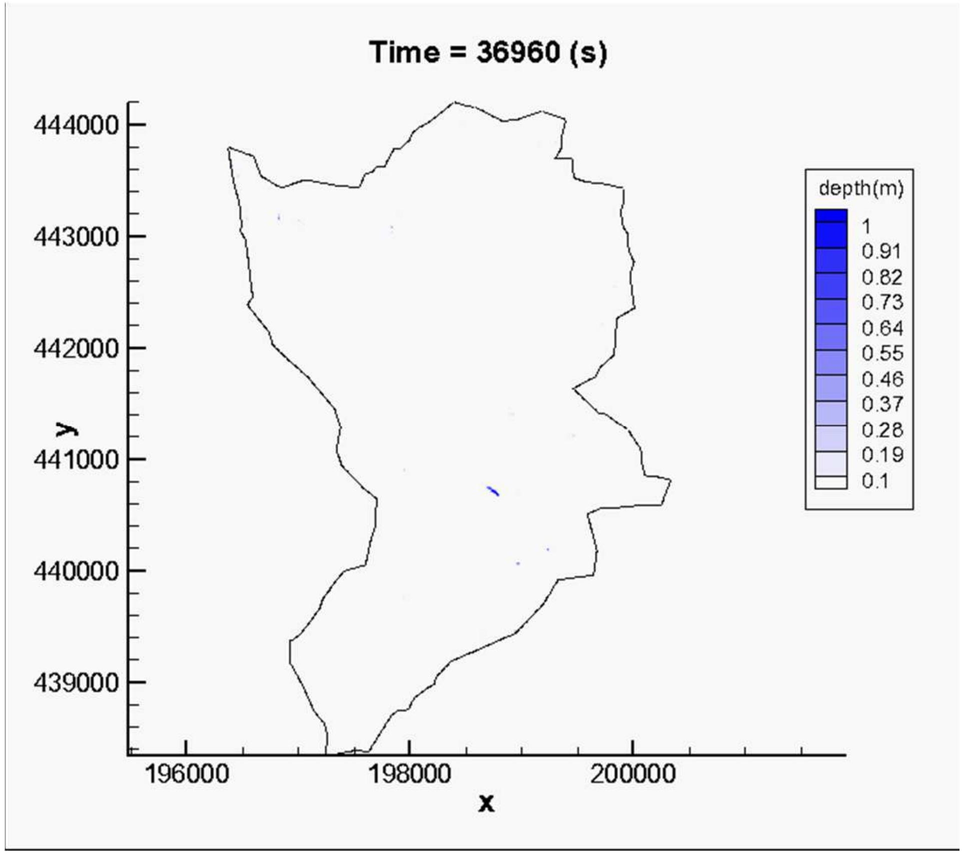

서울특별시
인재개발원
석포산
렛츠런파크
서울
서울랜드

Solution

- How to select surface domain and sewer system data?

  : Basin scale

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y
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198000
200000
x
depth(m)
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0.82
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0.46
0.37
0.28
0.19
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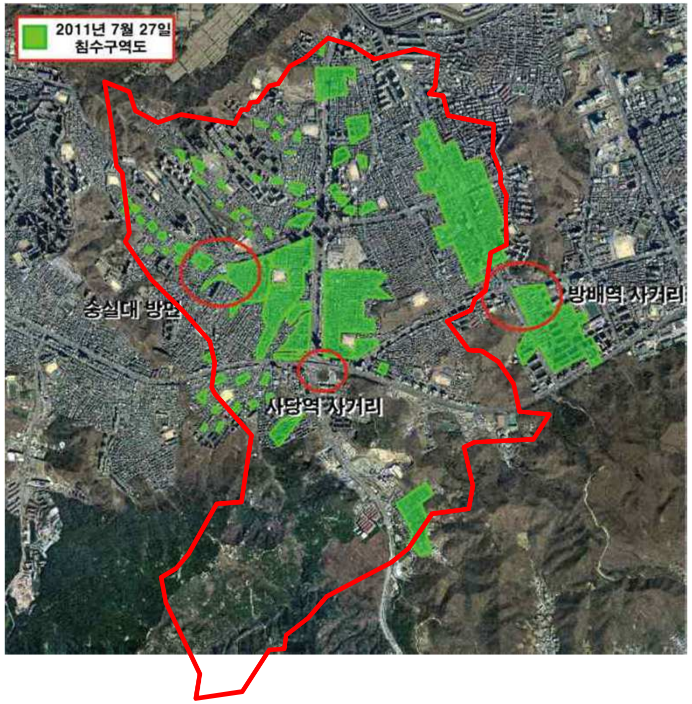
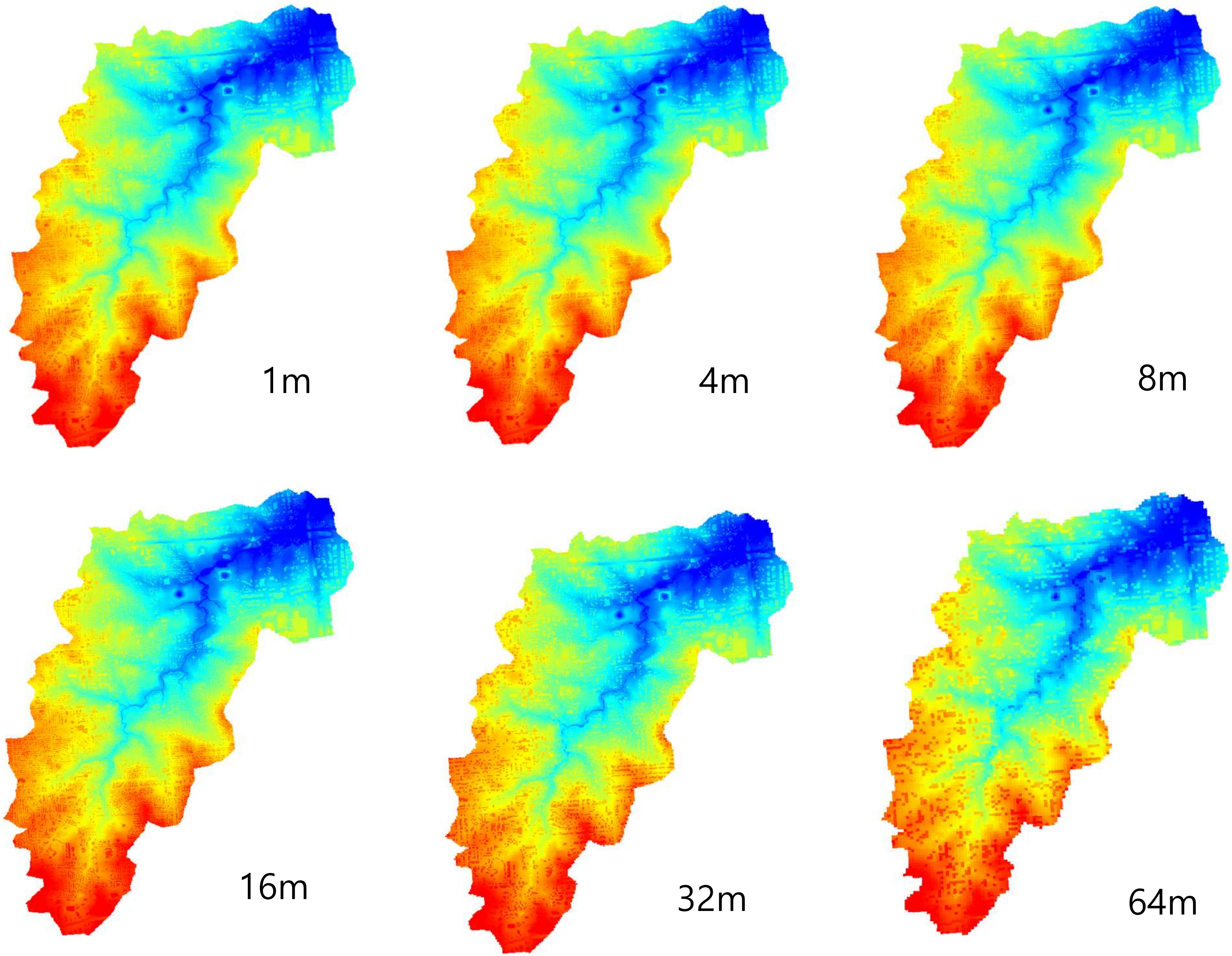

2011년 7월 27일
침수구역도
숭실대 방면
방배역 사거리
사당역 사거리

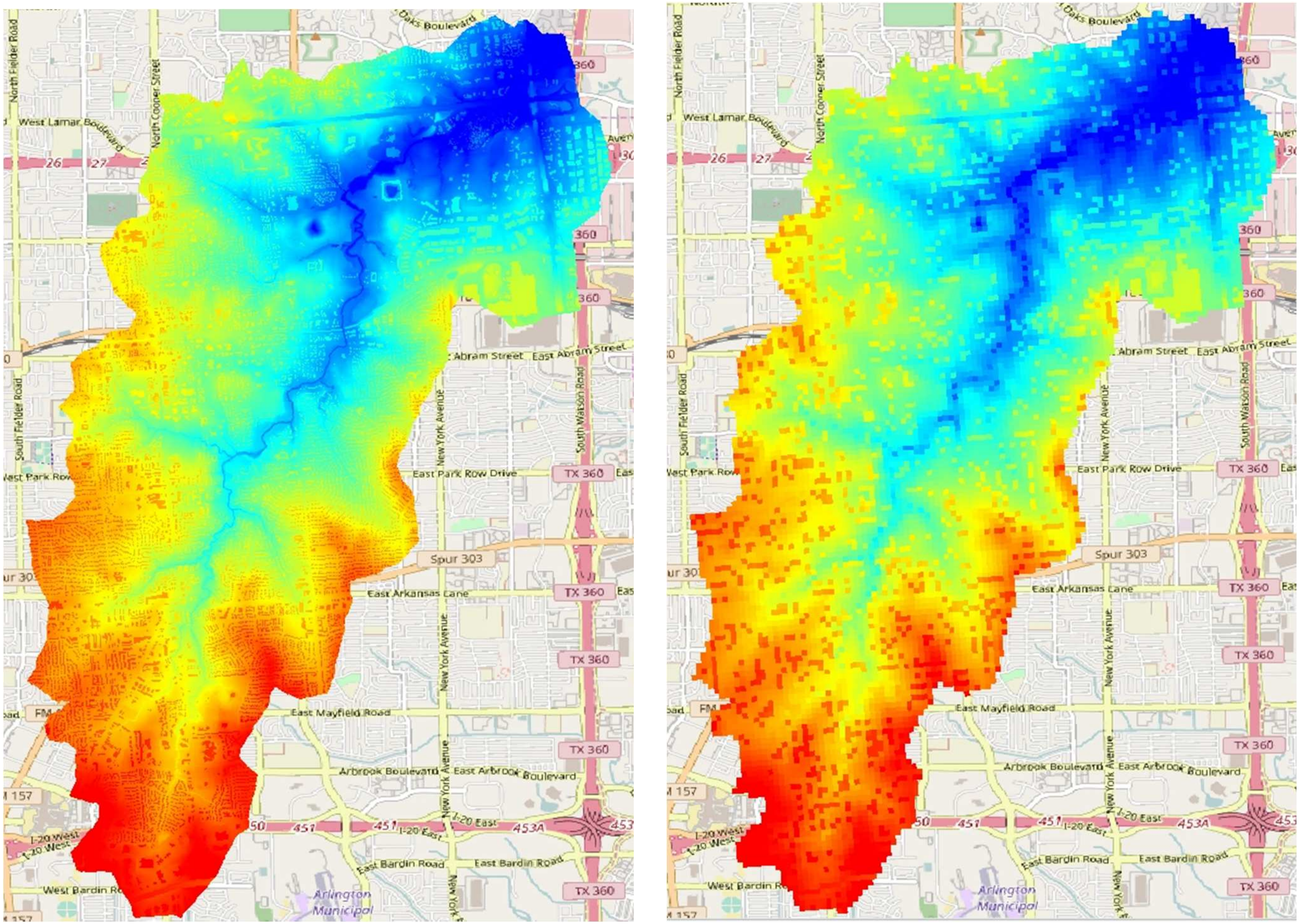
Challenging

- How to select surface domain and sewer system data?

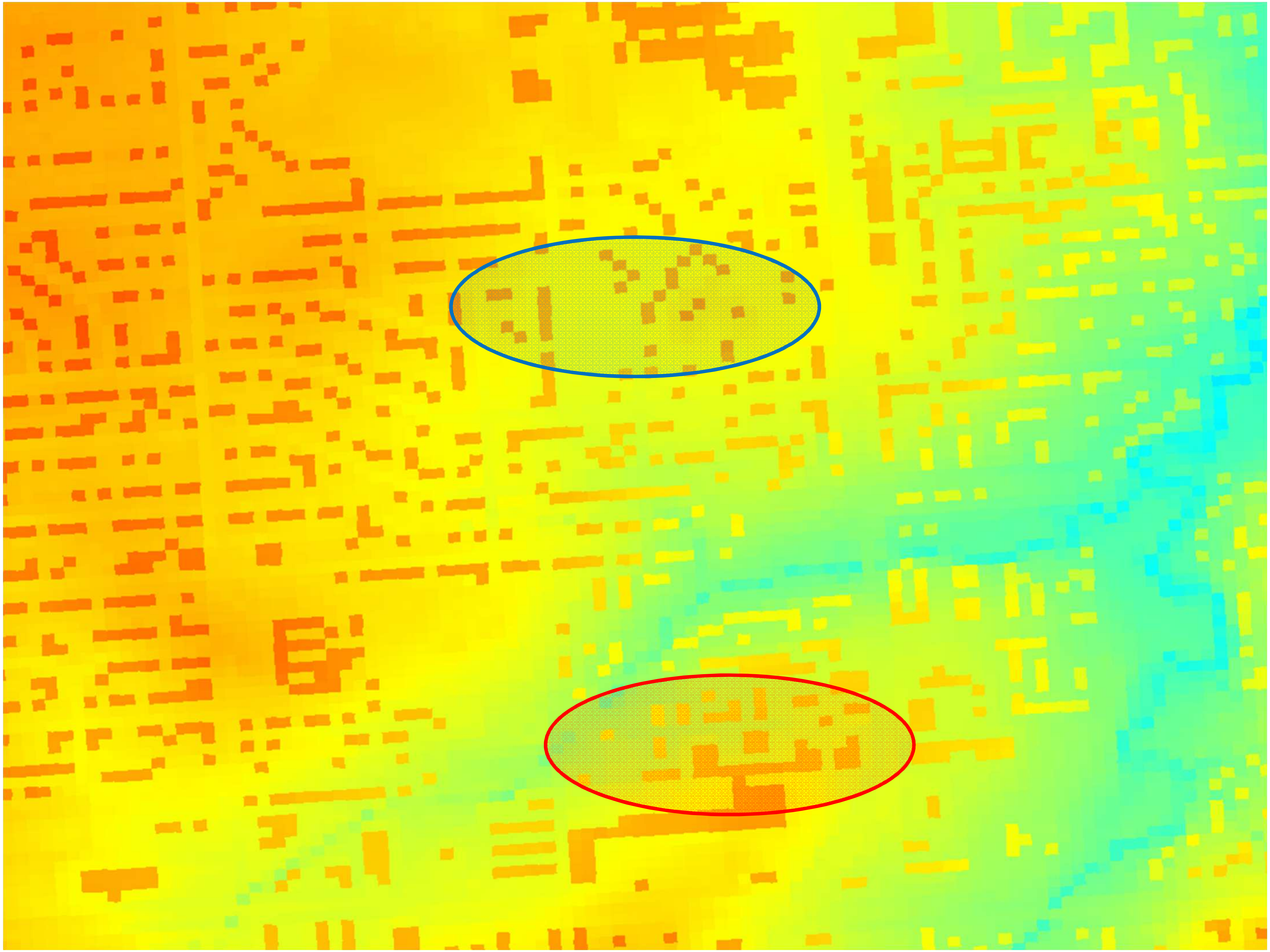
  : Basin scale

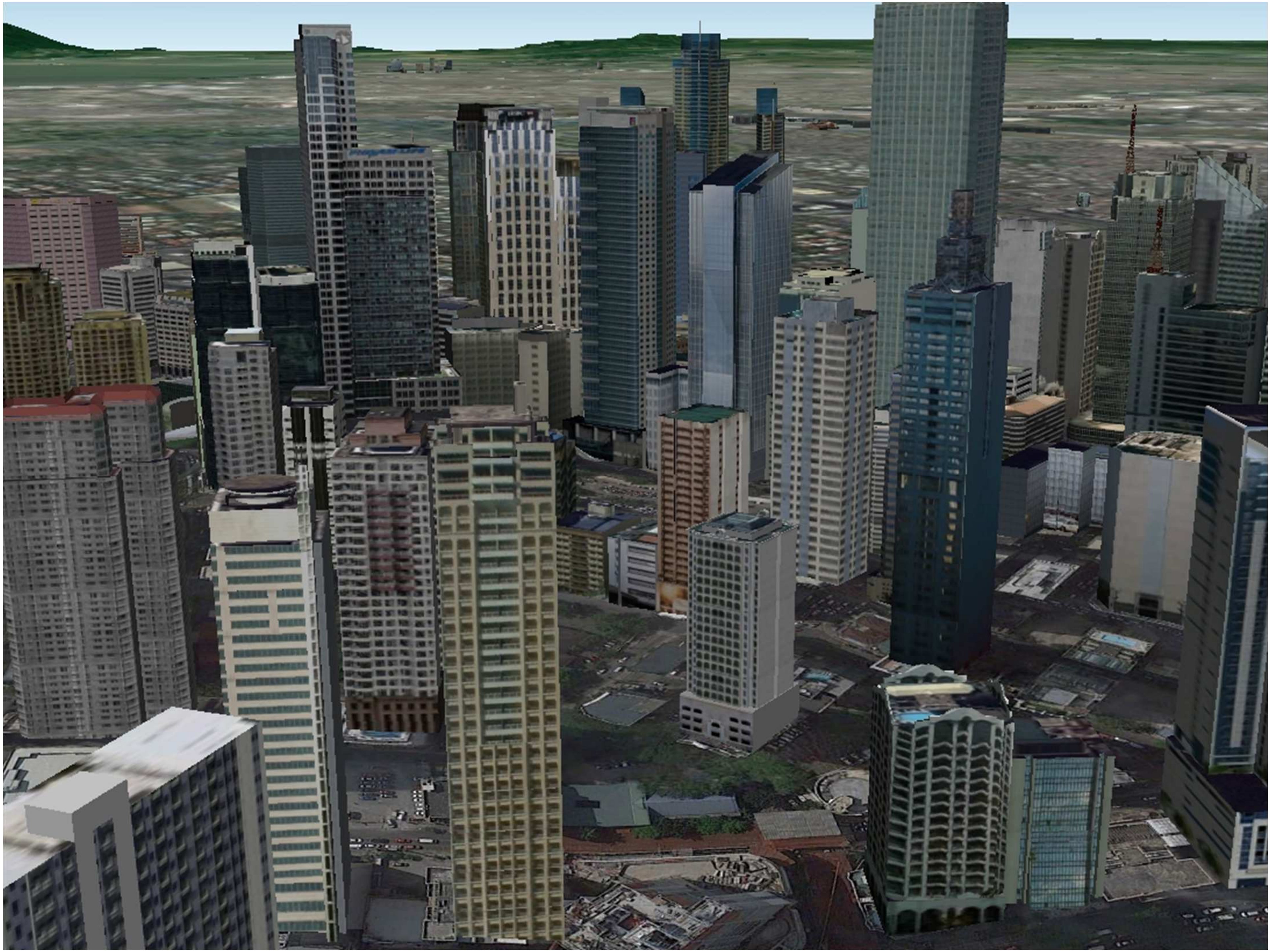
- How to depict urban structures?

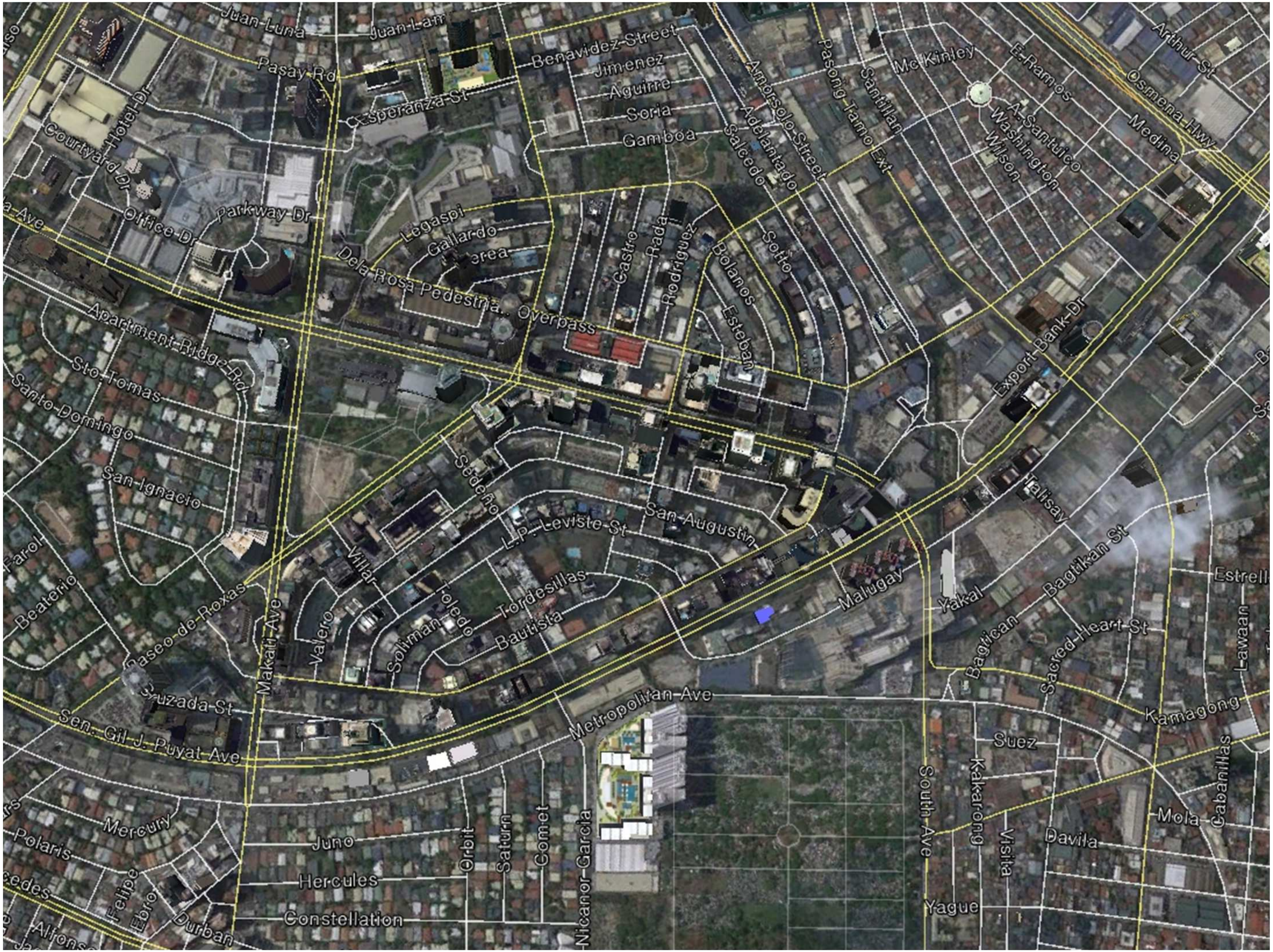

1m
4m
8m
16m
32m
64m



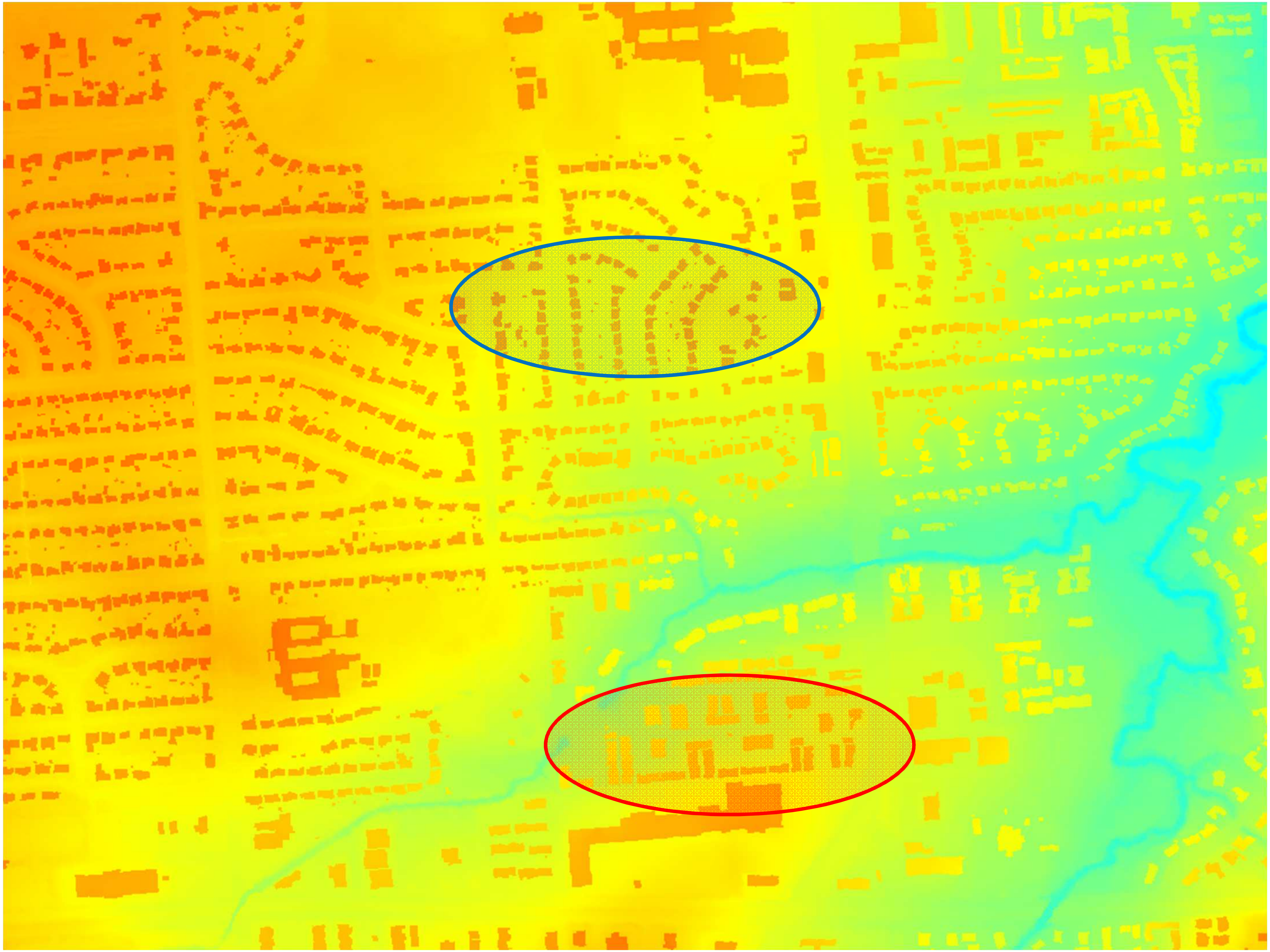
North Fielder Road
North Cooper Street
Oaks Boulevard
West Lamar Boulevard
Abram Street
East Abram Street
South Fielder Road
New York Avenue
South Watson Road
West Park Row
East Park Row Drive
TX 360
Spur 303
East Arkansas Lane
East Mayfield Road
Arbrook Boulevard
East Arbrook Boulevard
I-20 West
I-20 East
East Bardin Road
West Bardin Road
Arlington Municipal







Juan Luna
Pasay Rd
Benavidez Street
Jimenez
Aguirre
Soria
Gamboa
Esperanza St
Hotel Dr
Courtyard Dr
Parkway Dr
Office Dr
Legaspi
Gallardo
Dela Rosa Pedestria.. Overpass
Castro
Rada
Rodriguez
Bolanos
Esteban
Sotto
Salcedo
Adelantado
Amorsolo Street
Pasong Tamo Ext
Santillan
Mc Kinley
E Ramos
A Santuico
Washington
Wilson
Arthur St
Osmena Hwy
Medina
Export Bank Dr
Apartment Ridge Rd
Sto.Tomas
Santo Domingo
San Ignacio
Farol
Beaterio
Paseo de Roxas
Makati Ave
Sedeño
Villar
L.P. Leviste St
San Augustin
Valero
Soliman
Toledo
Tordesillas
Bautista
Malugay
Talisay
Yakal
Bagtikan St
Bagtican
Sacred Heart St
Lawaan
Cruzada St
Sen. Gil J. Puyat Ave
Metropolitan Ave
Kamagong
Suez
South Ave
Kakarong
Visita
Davila
Mola
Cabanillas
Yague
Mercury
Polaris
Juno
Hercules
Constellation
Orbit
Saturn
Comet
Nicanor Garcia
Felipe
Ebro
Durban



Solution

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- How to select surface domain and sewer system data?

  : Basin scale

- How to depict urban structures?

  : High resolution DEM

Challenging

- How to select surface domain and sewer system data?

  : Basin scale

- How to depict urban structures?

  : High resolution DEM

- How to depict river in urban area

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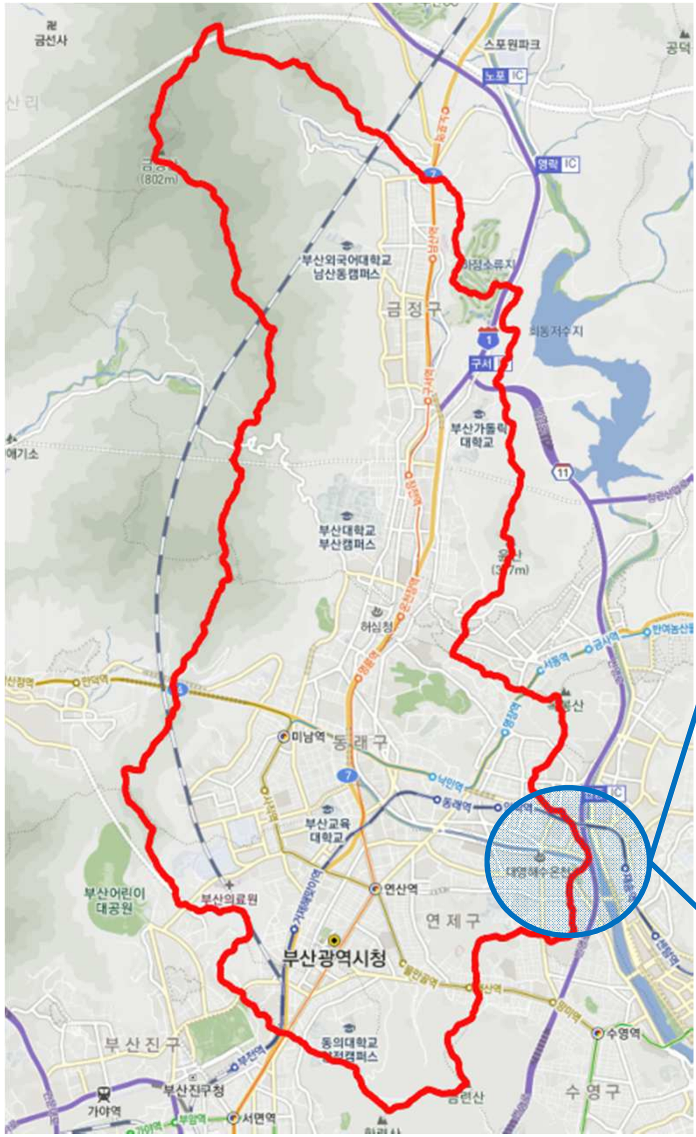
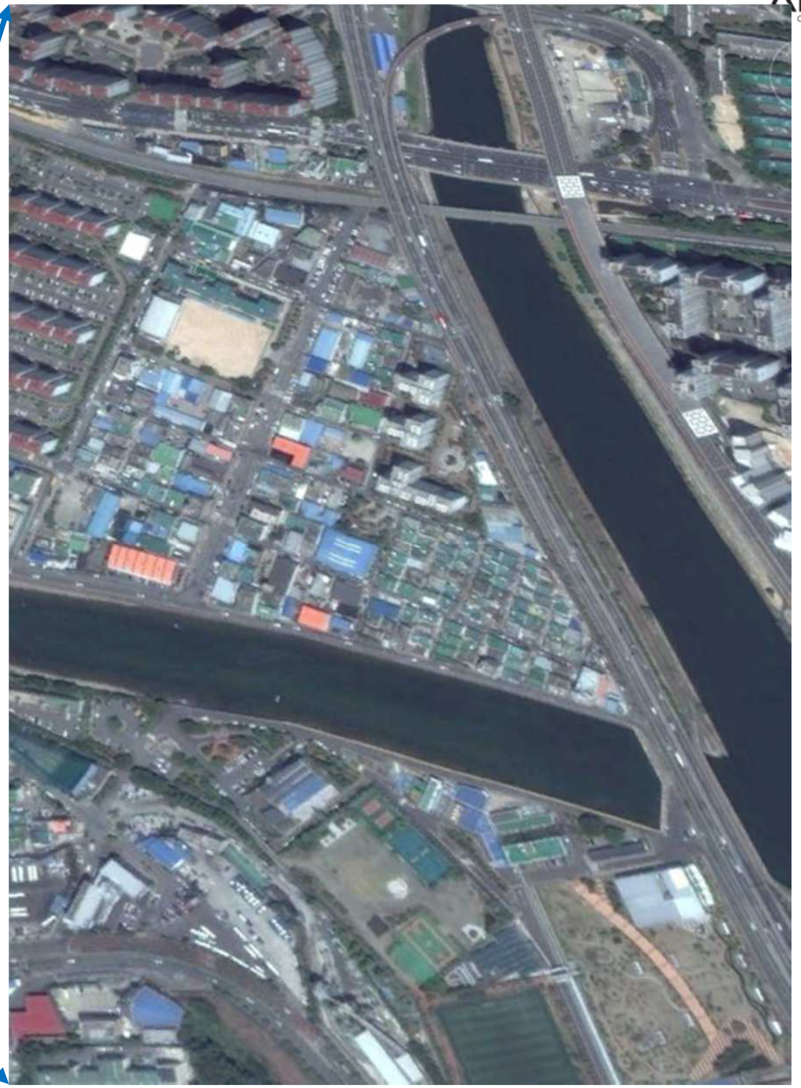
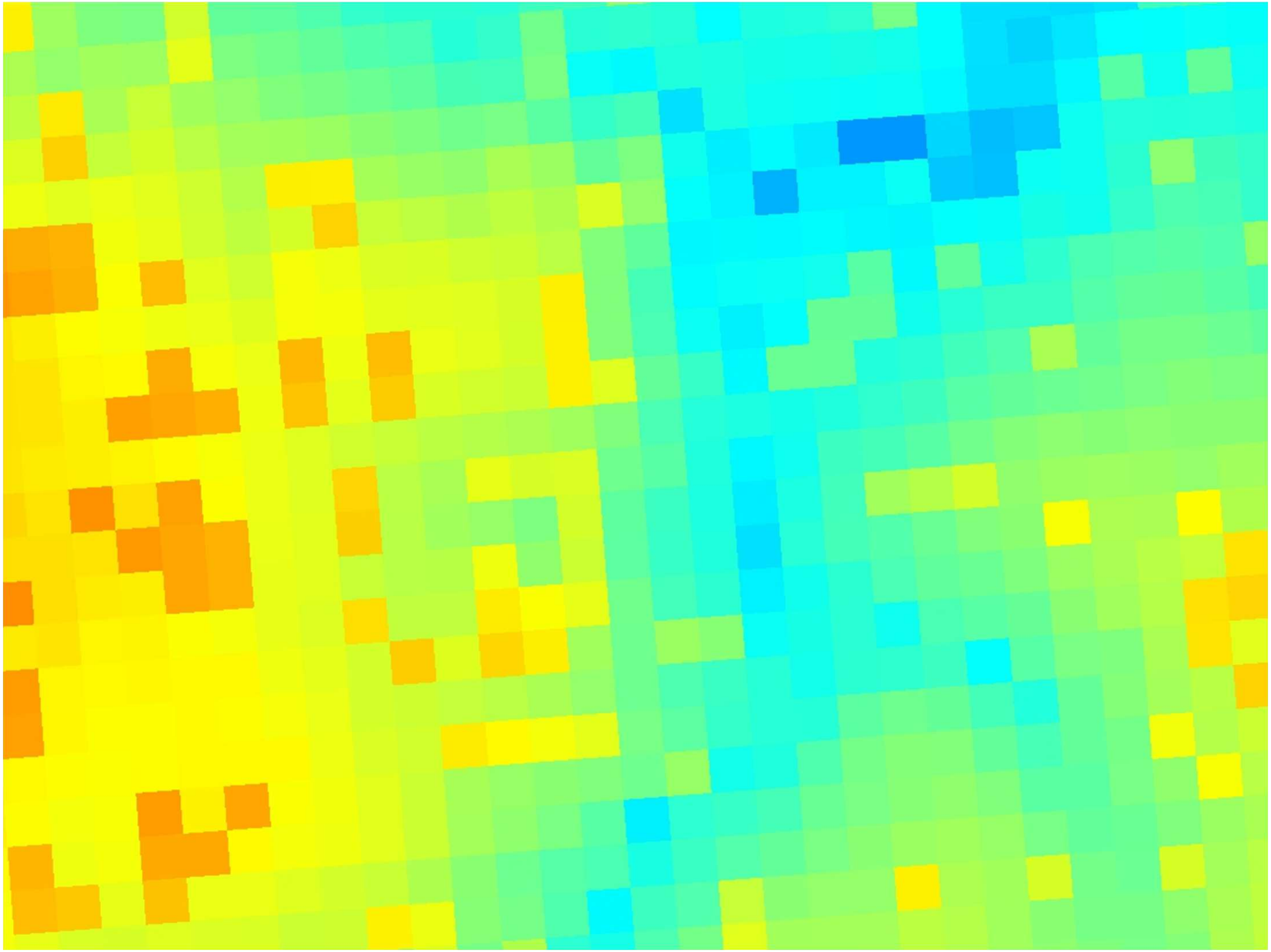
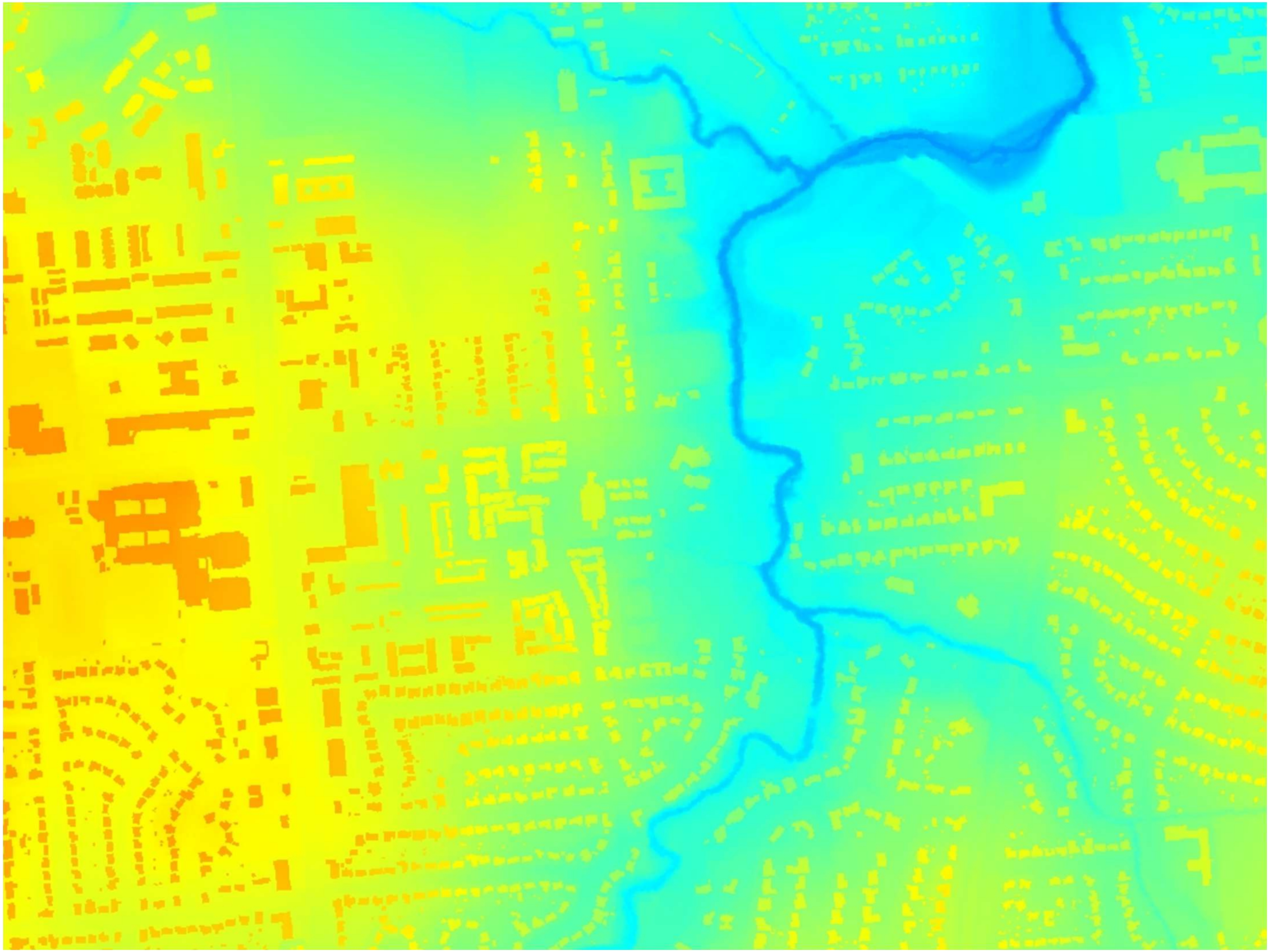








Solution

- How to select surface domain and sewer system data?

  : Basin scale

- How to depict urban structures?

  : High resolution DEM

- How to depict river in urban area

  : Cross-section data into DEM

Another Challenging

Challenging

- How to select surface domain and sewer system data?

  : Basin scale

- How to depict urban structures?

  : High resolution DEM

- How to depict river in urban area

  : Cross-section data into DEM

- Huge computational load

Area : 100,210km²

1,603,360 (250m×250m)

Area : 377,962km^2

6,047,392 (250m×250m)

Area : 7km × 7km = 49km^2

49,000,000 (1m×1m)

Challenging

- How to select surface domain and sewer system data?

  : Basin scale

- How to depict urban structures?

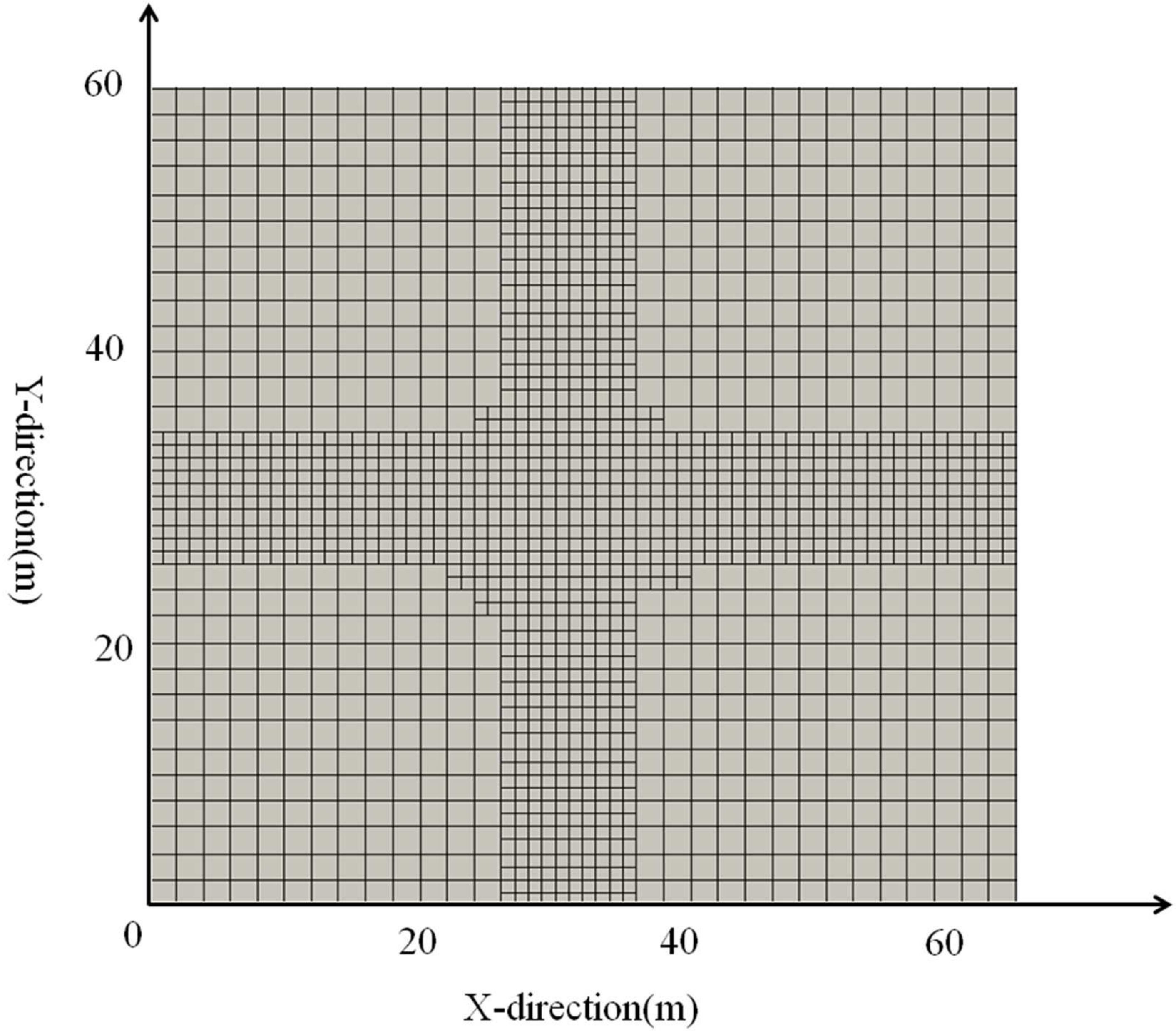
  : High resolution DEM

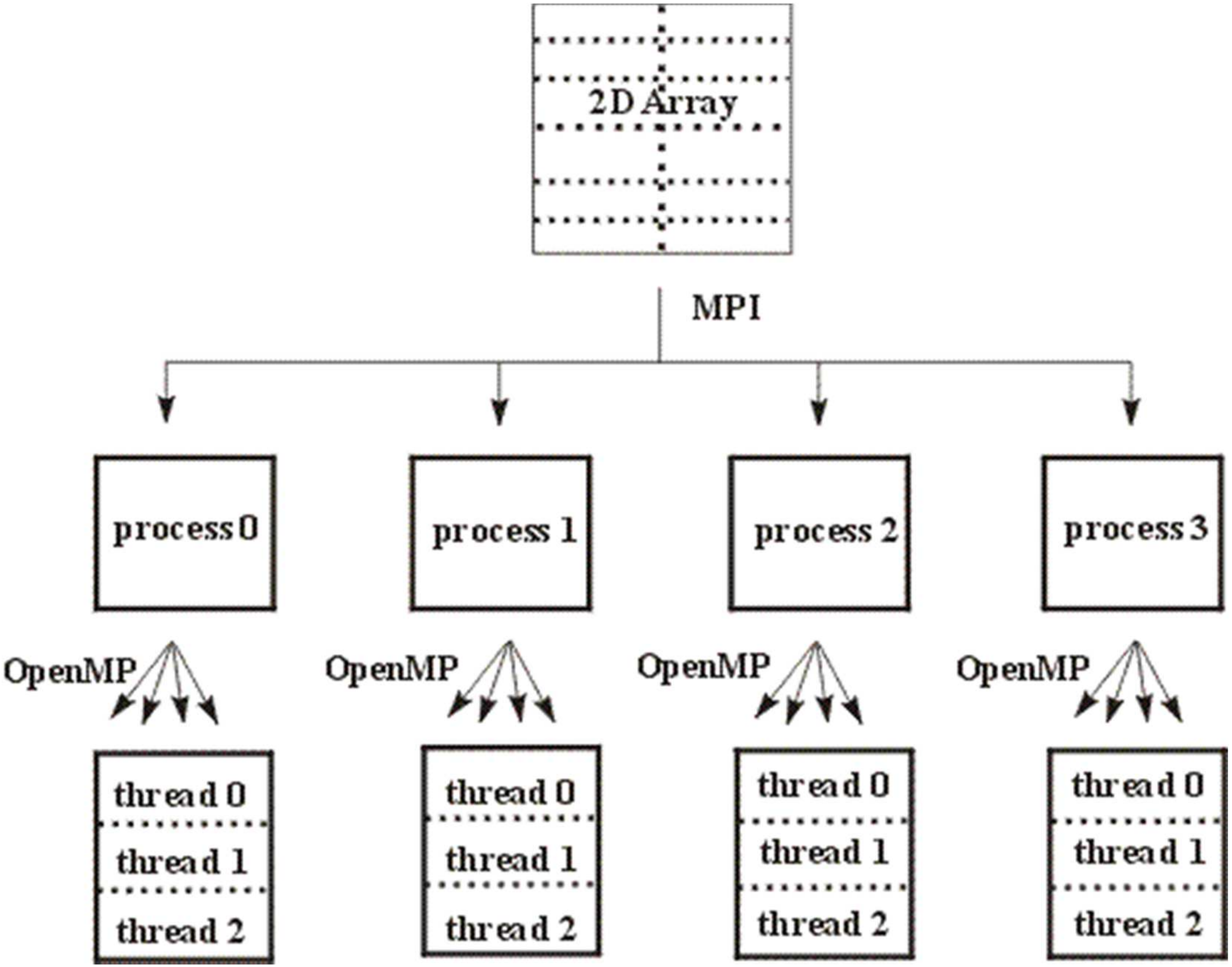
- How to depict river in urban area

  : Cross-section data into DEM

- Huge computational load

  : Adaptive mesh + Parallel computing


60
40
20
0
Y-direction(m)
20
40
60
X-direction(m)


2D Array
MPI
process 0
process 1
process 2
process 3
OpenMP
OpenMP
OpenMP
OpenMP
thread 0
thread 1
thread 2
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thread 1
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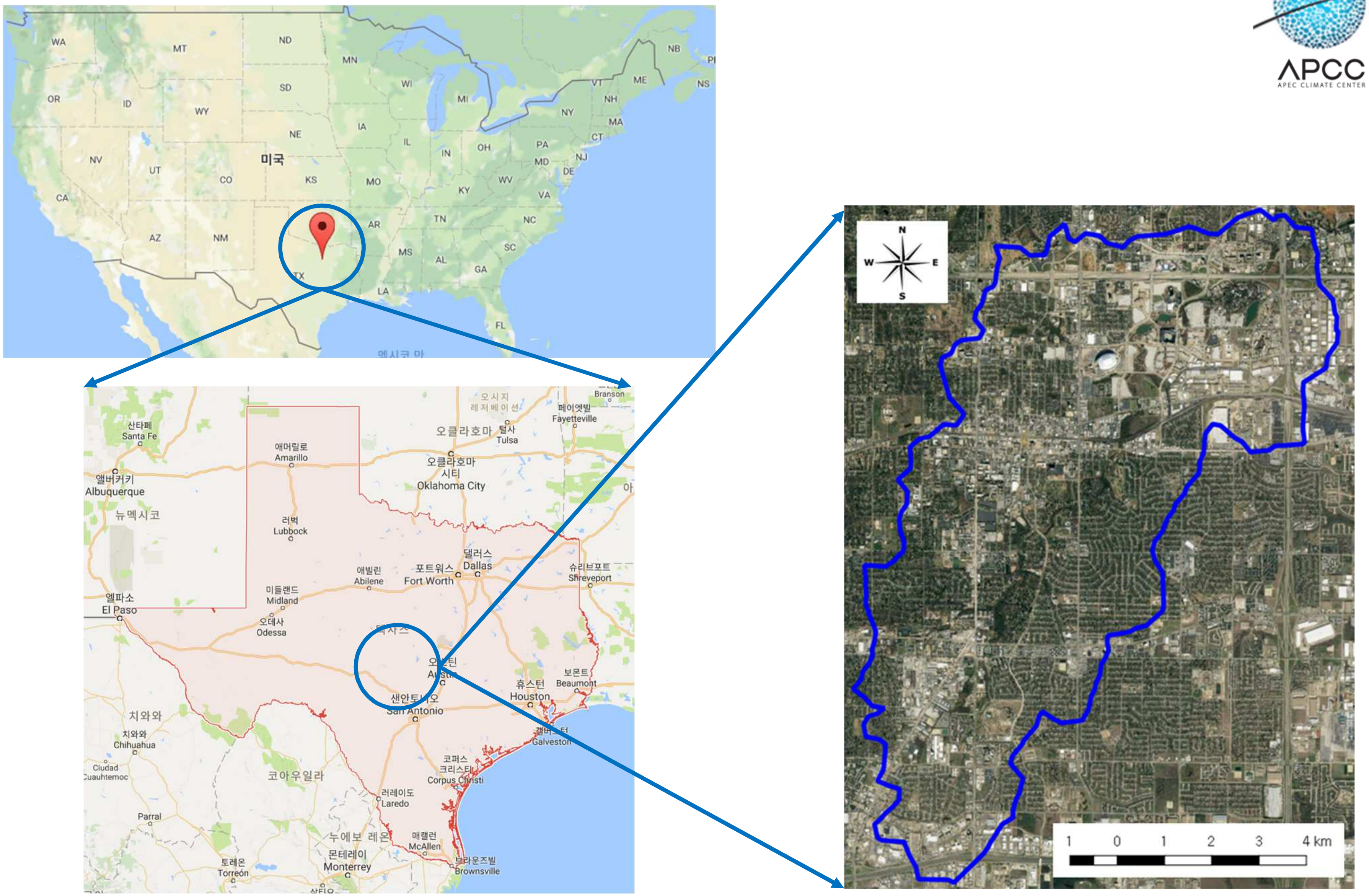
thread 0
thread 1
thread 2

Application


WA
MT
ND
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OR
ID
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OH
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AZ
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AR
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ME
VT
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CT
NJ
MD
DE
NS
산타페
Santa Fe
애머릴로
Amarillo
오클라호마
털사
Tulsa
오클라호마 시티
Oklahoma City
페이엣빌
Fayetteville
Branson
앨버커키
Albuquerque
뉴멕시코
러벅
Lubbock
애빌린
Abilene
포트워스
Fort Worth
댈러스
Dallas
슈리브포트
Shreveport
엘파소
El Paso
미들랜드
Midland
오데사
Odessa
휴스턴
Houston
보몬트
Beaumont
샌안토니오
San Antonio
Galveston
치와와
Chihuahua
코아우일라
코퍼스 크리스티
Corpus Christi
러레이도
Laredo
Parral
매캘런
McAllen
몬테레이
Monterrey
토레온
Torreón
브라운즈빌
Brownsville
N
W
E
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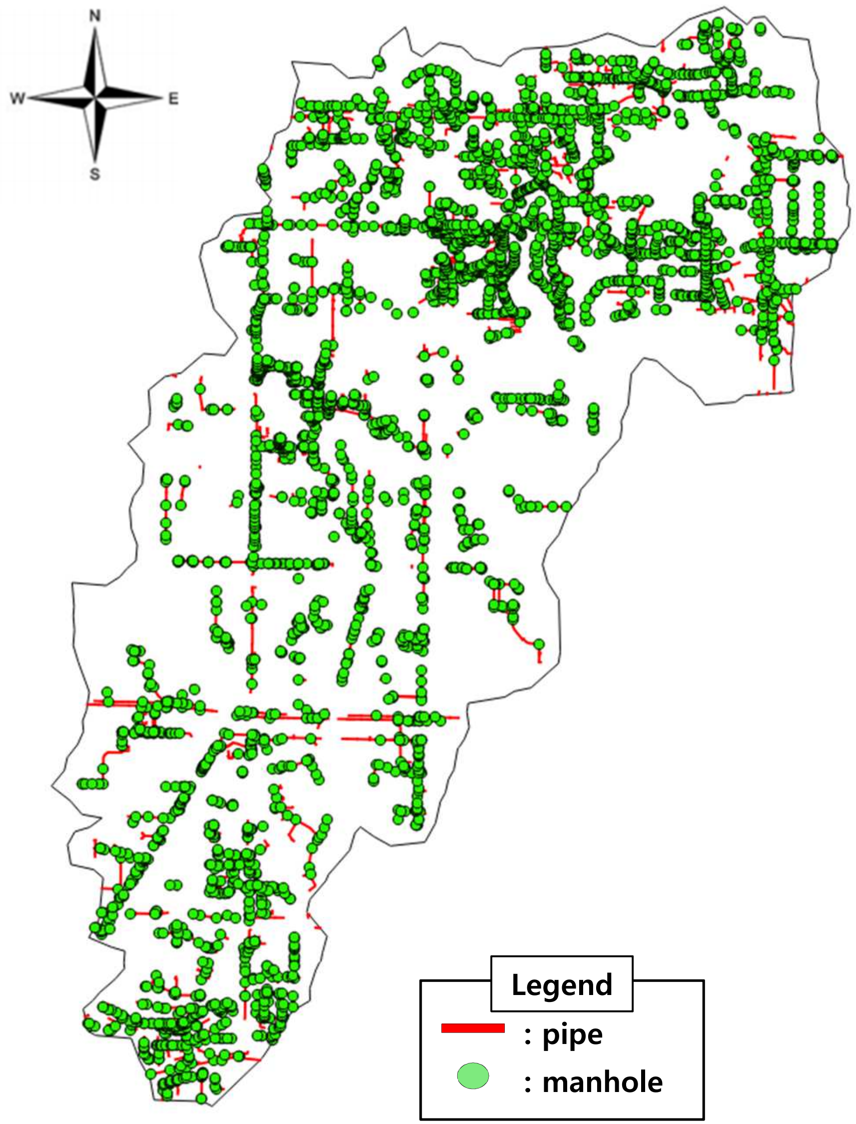
1 0 1 2 3 4 km



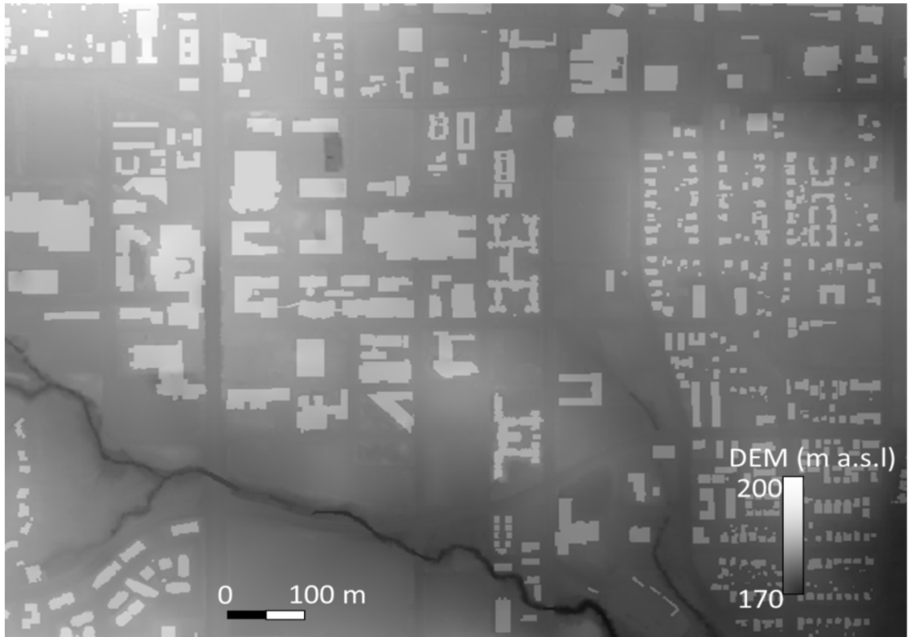
Arlington basin, TX, UAS

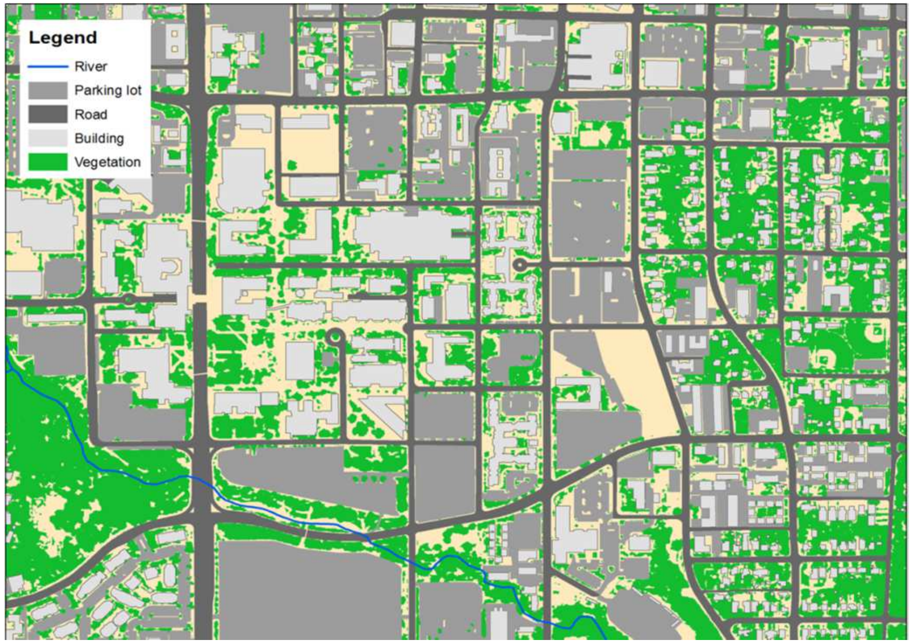
manholes : 4,217

pipes : 7,566

area : 40.2km^2

➢Land use data





Land cover	Road	Building	Parking lot	Vegetation	Bare ground	Water body
Runoff coeff.	0.9	0.9	0.9	0.5	0.6	1.0

➢Coupled 1D-2D urban flood model (2D)

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=\alpha \cdot r_e - q_{ex}$$

$$\frac{\partial M}{\partial t}+\frac{\partial (uM)}{\partial x}+\frac{\partial (vM)}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{gn^2 M\sqrt{u^2+v^2}}{h^{4/3}}$$

$$\frac{\partial N}{\partial t}+\frac{\partial (uN)}{\partial x}+\frac{\partial (vN)}{\partial y}=-gh\frac{\partial H}{\partial y}-\frac{gn^2 N\sqrt{u^2+v^2}}{h^{4/3}}$$

q_{ex} : flow discharge from the surface to the sewer system per unit surface area
r_e : rainfall intensity, α: runoff coefficient for each land use

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Coupled 1D-2D urban flood model (1D)

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q_{man}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial (uQ)}{\partial x}=-gA\frac{\partial H_p}{\partial x}-gn^2\frac{Q|Q|}{R^{4/3}A},$$

q_{man} (Q_{man}/dx_{sw}) : flow discharge from the manhole to the sewer pipe per unit pipe length,
Q_{man} : interactive flow discharge from the manhole to the sewer pipe

Manholes and street inlets are used connection spot between surface and sewer system.
Weir and orifice equations are for calculation of exchange discharge (Lee et al., 2016)

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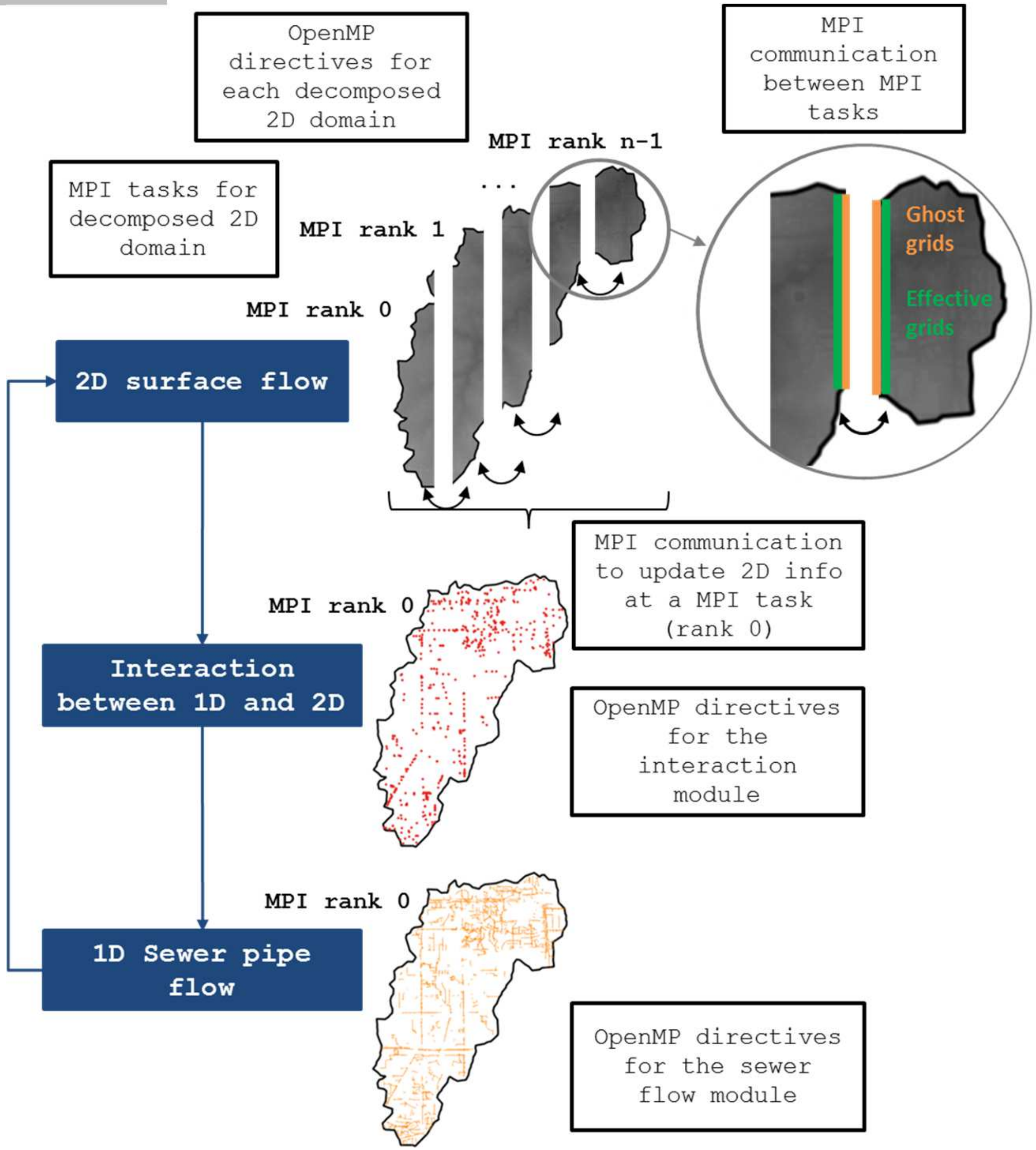
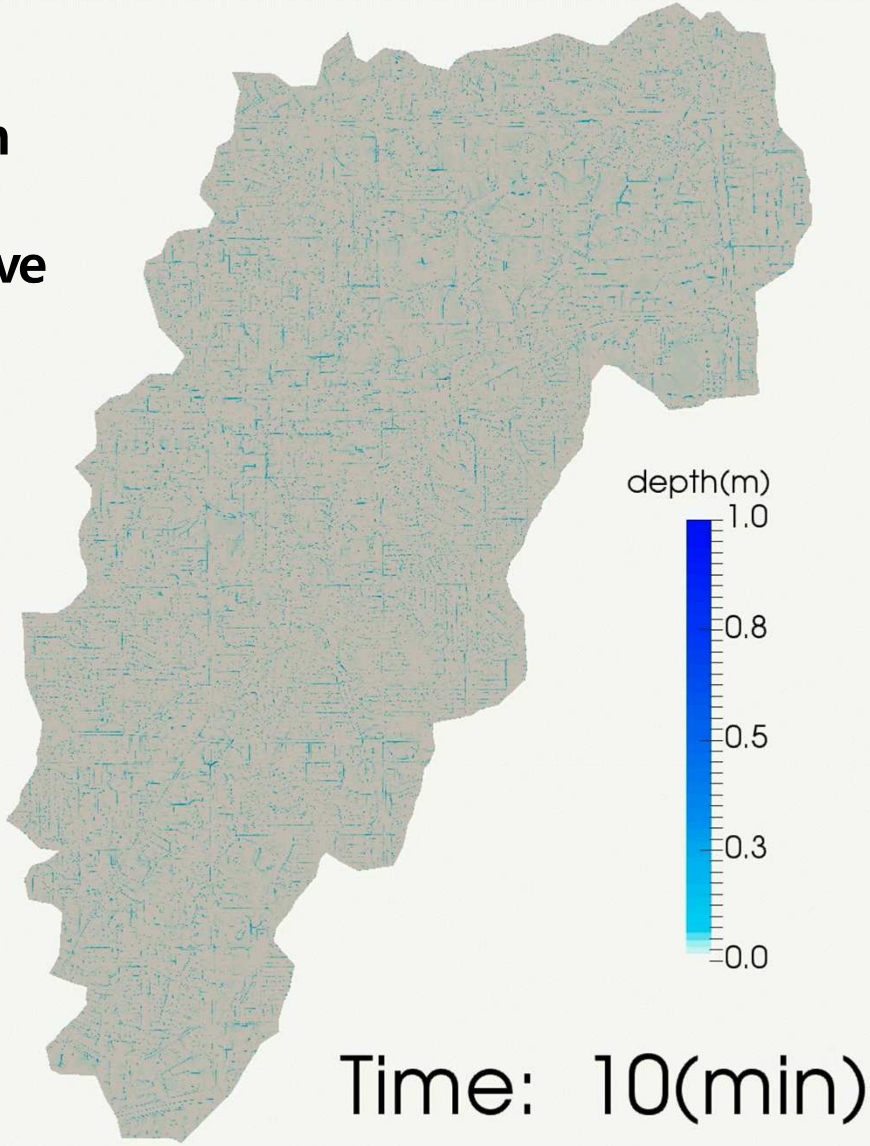
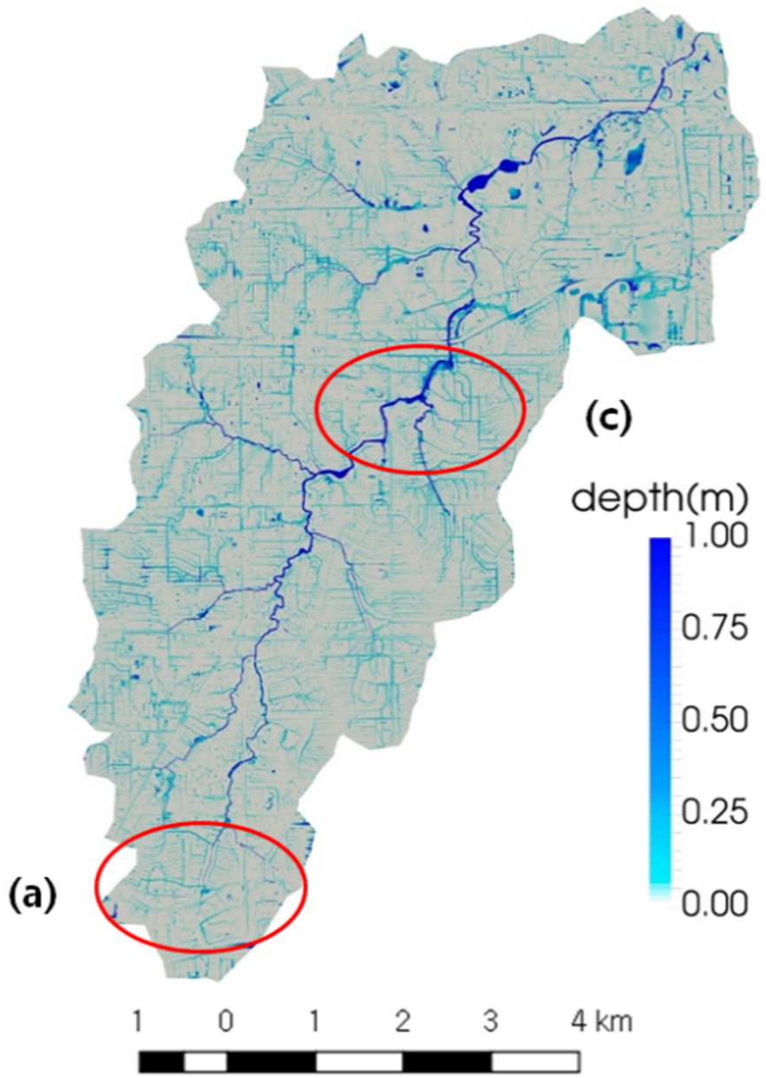
Resolution	Surface domain	Sewer domain		
		Pipe	Manhole	Inlet
1 m	13,998,516	7,017	549	3,615
2 m	3,667,558			
4 m	995,839			
8 m	284,768			


OpenMP directives for each decomposed 2D domain
MPI communication between MPI tasks
MPI tasks for decomposed 2D domain
MPI rank n-1
...
MPI rank 1
MPI rank 0
Ghost grids
Effective grids
2D surface flow
MPI communication to update 2D info at a MPI task (rank 0)
MPI rank 0
Interaction between 1D and 2D
OpenMP directives for the interaction module
MPI rank 0
1D Sewer pipe flow
OpenMP directives for the sewer flow module

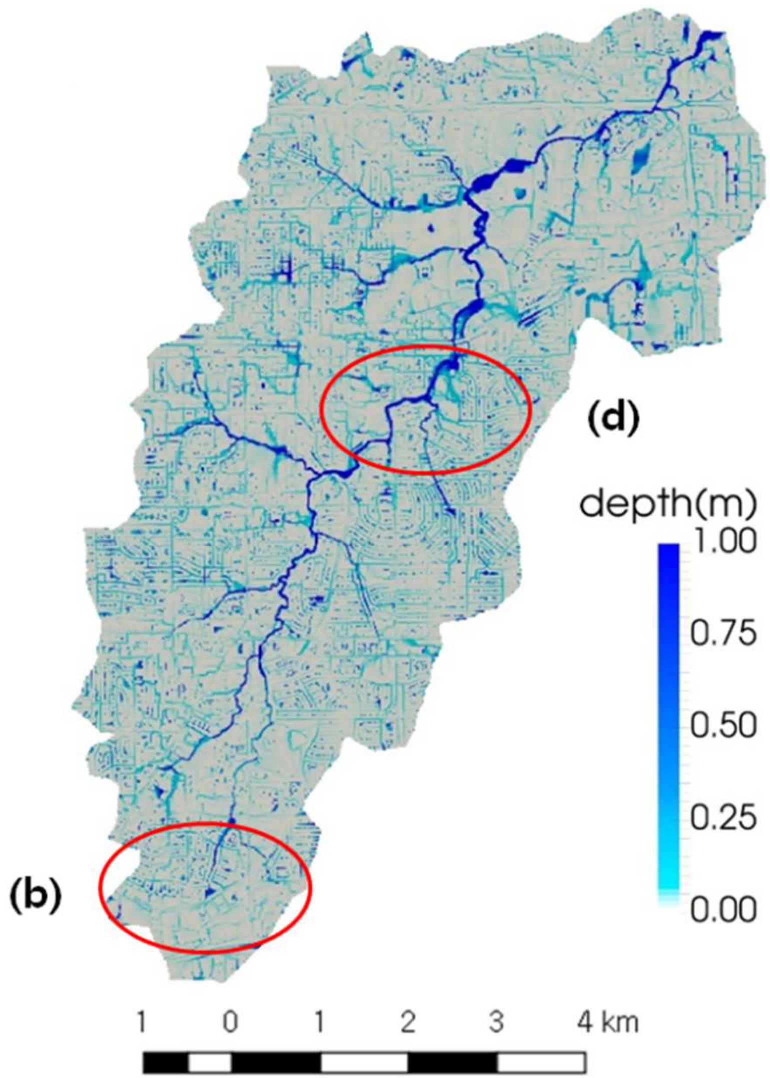
- 1-m lidar elevation data
- building, vegetation resolved
- 1D-2D dynamic wave
- Hybrid parallel computing (MPI, Open MP)



Noh et al. (2016)

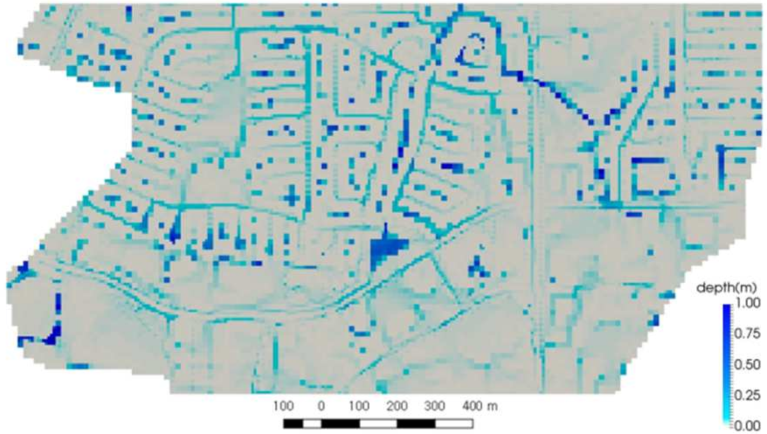


1m resolution

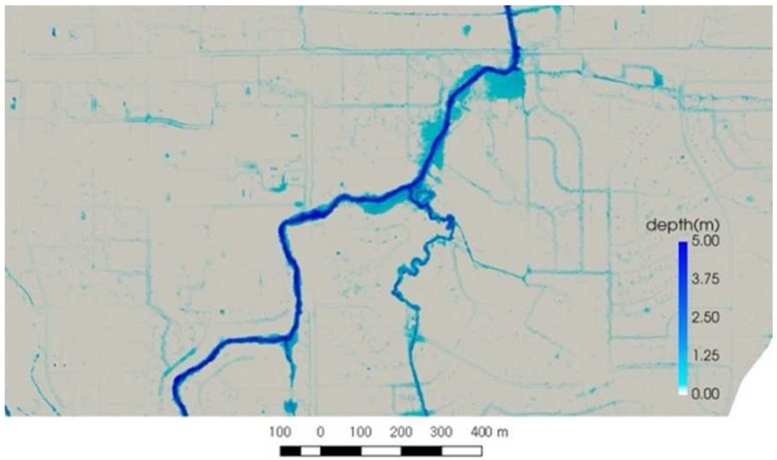


8m resolution

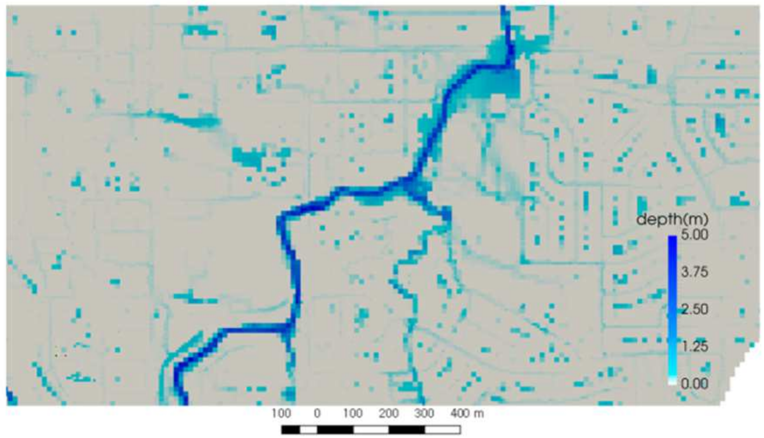
(a) 1m resolution(90min)



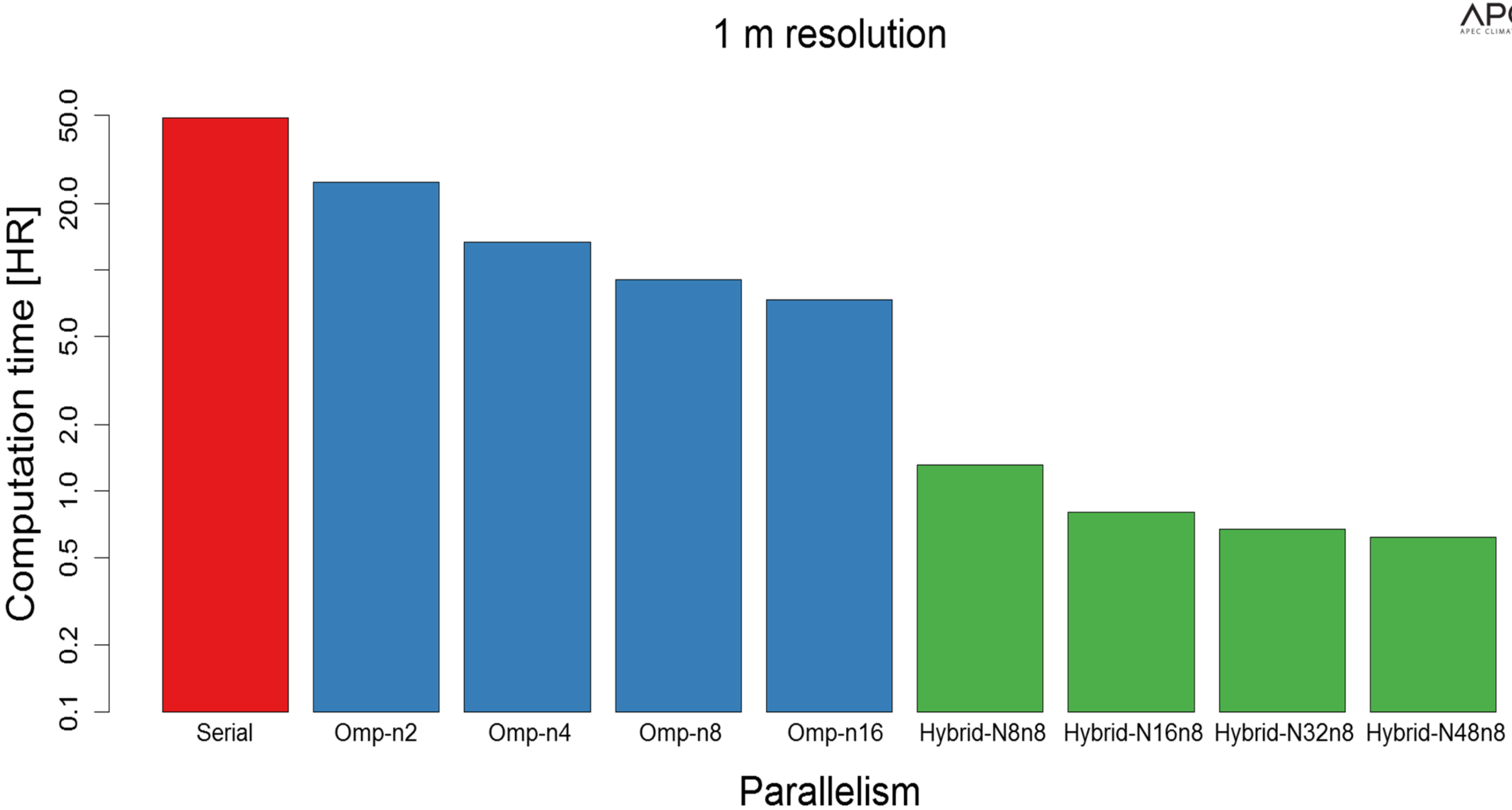
(b) 8m resolution(90min)



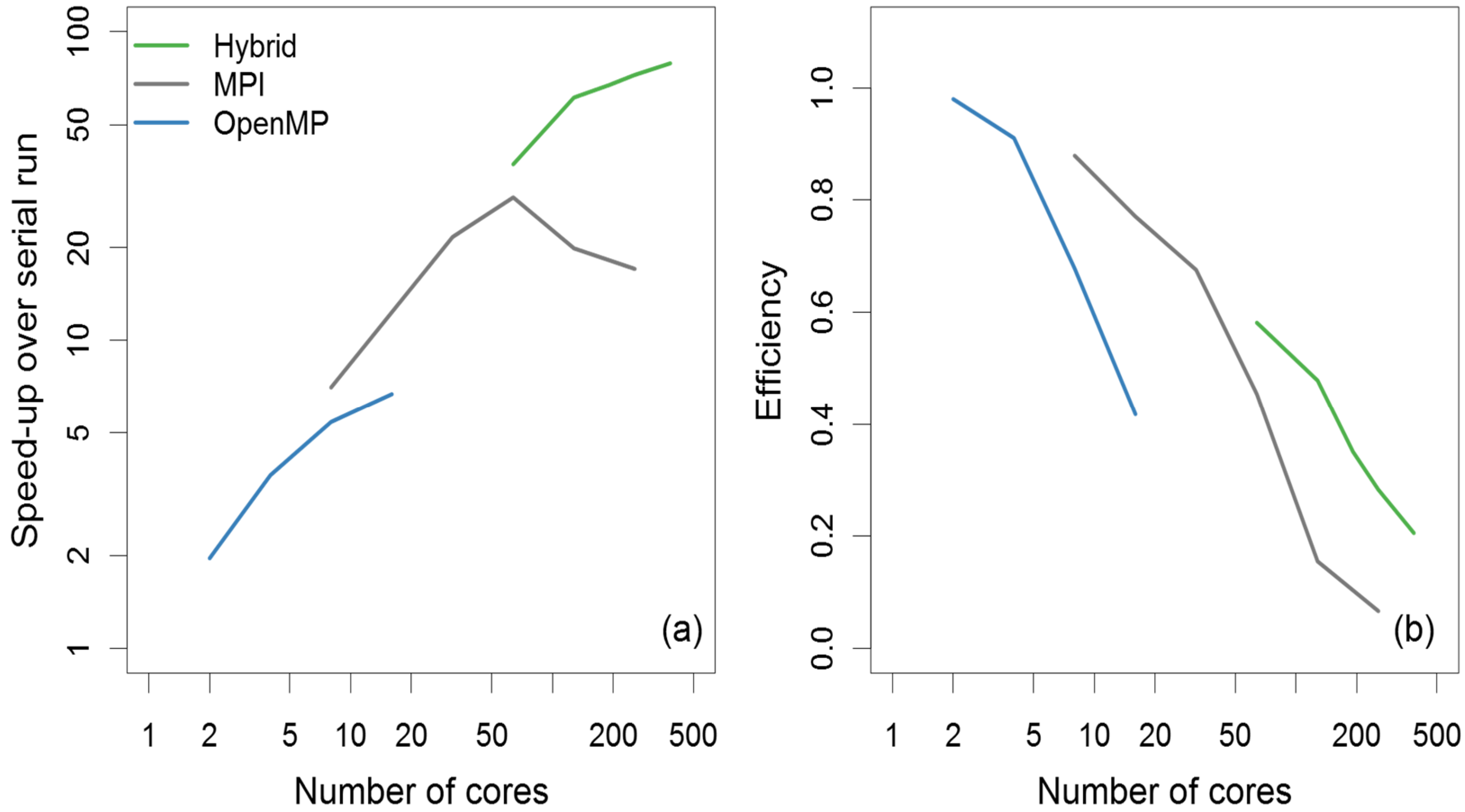
(a) 1m resolution(120min)



(a) 8m resolution(120min)



N' and 'n' denote the number of MPI tasks and openMP threads used for computation.



$$\text{Speedup} = \frac{\text{Serial run time}}{\text{Parallel run time}}$$

$$\text{Efficiency} = \frac{\text{Speedup}}{\text{Number of CPU cores}}$$

Summary

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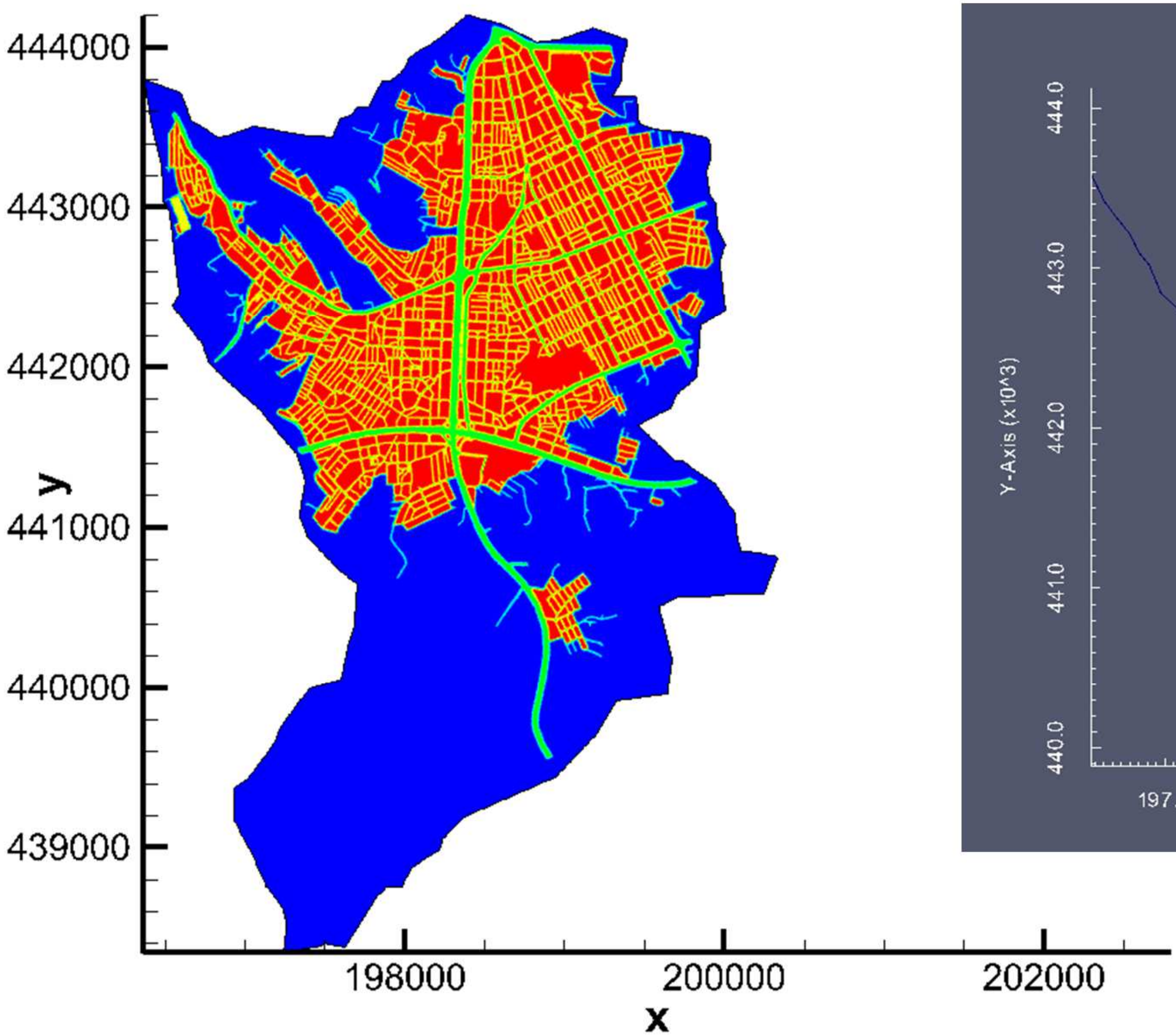
- High resolution & basin scale modelling is a crucial change in urban inundation analysis .
- High resolution modelling needs huge amount of calculation capacity and it causes demand of parallel computation skill.
- OpenMP and MPI techniques satisfy the demand.
- Hybrid parallel computing technique shows best performance.

Thank You for Your Attention!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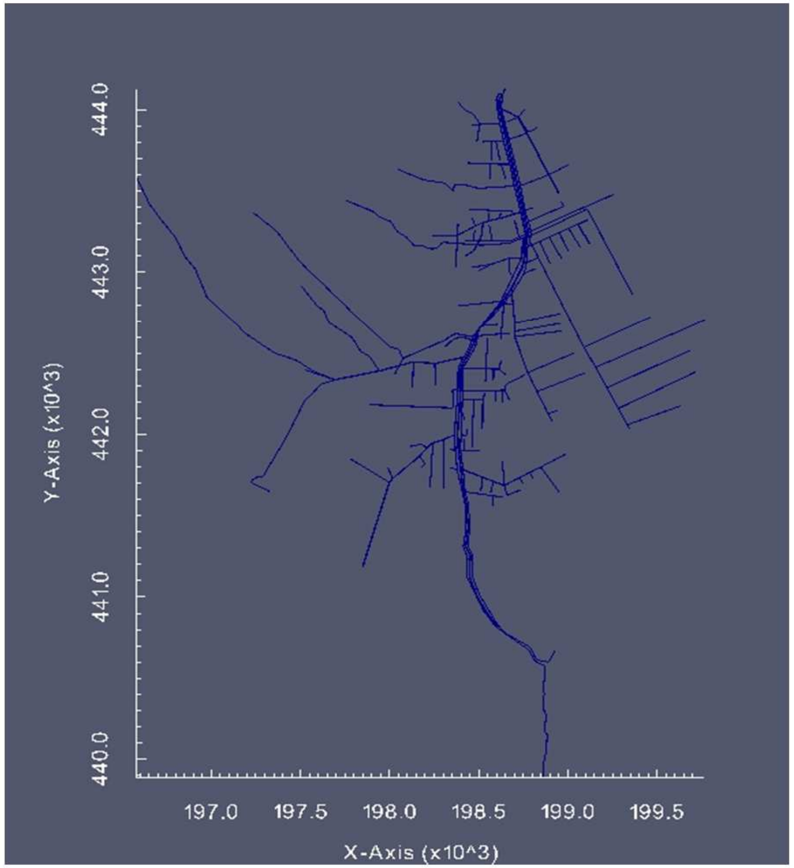
442000
441000
440000
439000
y
198000
200000
202000
x


444.0
443.0
442.0
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440.0
Y-Axis (x10^3)
197.0
197.5
198.0
198.5
199.0
199.5
X-Axis (x10^3)