Common Ground:

Bridging 3D Subsurface Information Models and Climate Adaptation Design

Double Degree Graduation (Geomatics + Urbanism) P5, 17th June 2024

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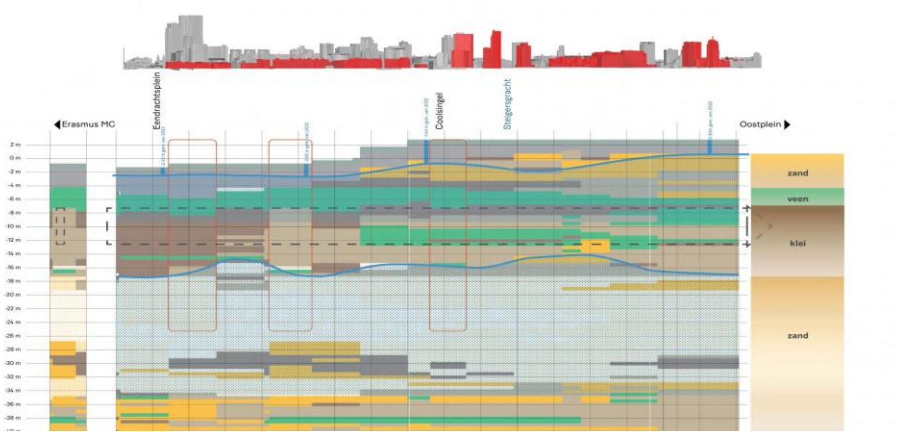
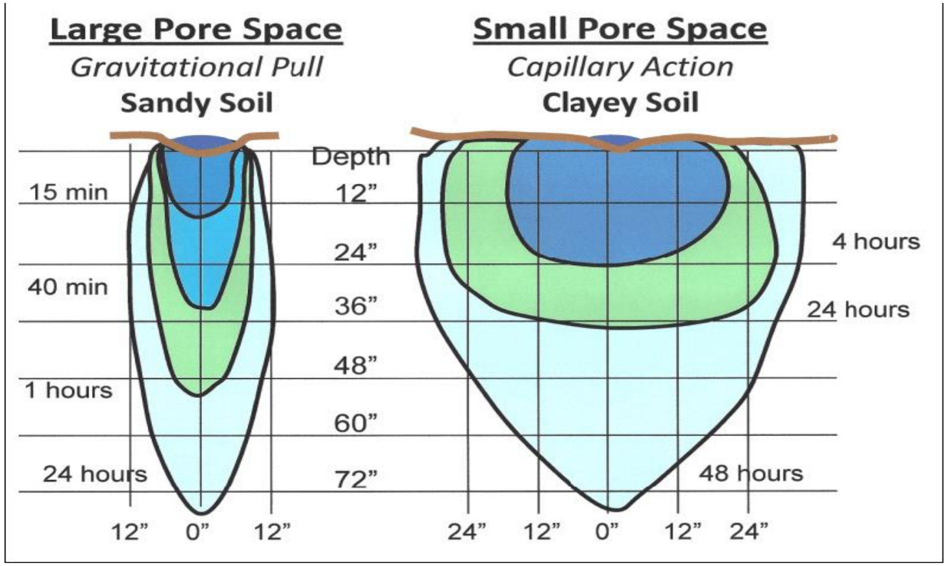
Mentors External: Rob van der Krogt (TNO), Wilfred Visser (TNO)

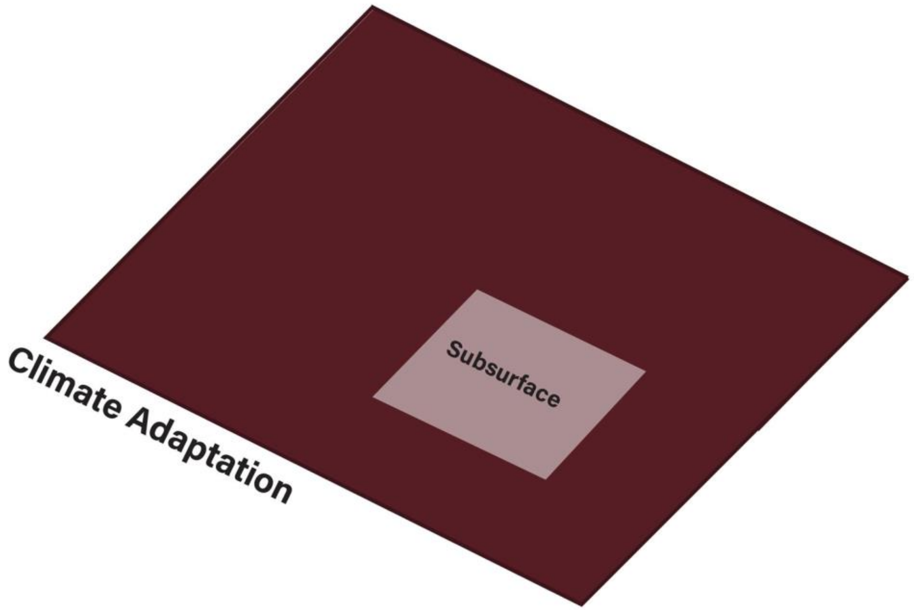
I. Problem Statement

Climate Adaptation and Subsurface

It is known that natural climate adaptation is related to different subsurface properties, such as soil type and groundwater levels.







Climate Adaptation Design and Subsurface

This is particularly interesting for Dutch climate adaptation design. Cabinet 2022 defined **water and soil guiding** as the main principle for Dutch spatial planning. **But this is often too abstract.**

Longread

'Water and soil guiding' calls for a broad perspective

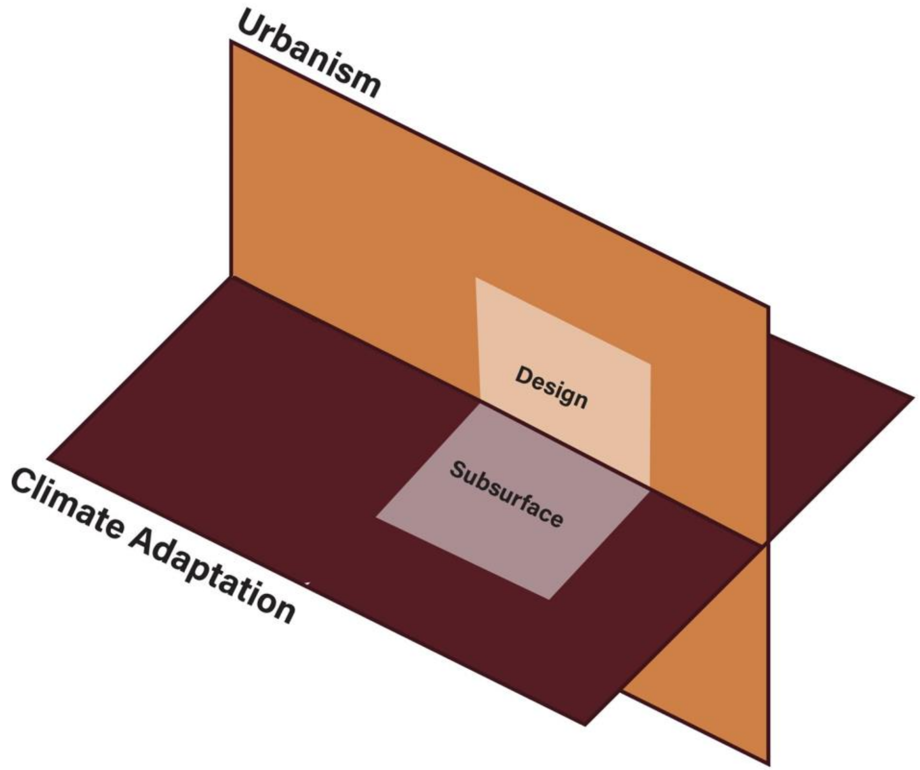
15 minuten

June 27, 2023

Response from Delta Commissioner Peter Glas to Cabinet decision about the leading role of water and soil

News item | 25-11-2022 | 09:24

"The limits of the water and soil system are coming into view more and more often and in more and more locations," states Delta Commissioner Peter Glas in response to the Cabinet decision about the leading role of water and soil. "Clearly, this demands a profound change in our thinking and actions."



Climate Adaptation Design and Models

One way to support concrete climate adaptation design is through the use of subsurface information models. The Netherlands has multiple (3D) subsurface models. **But are they are underused.**

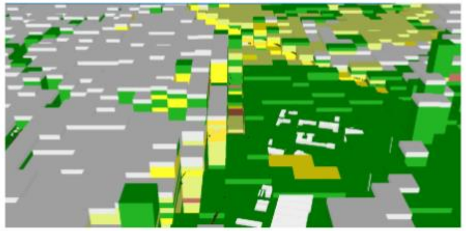


Figure 3.1: GeoTOP Voxels

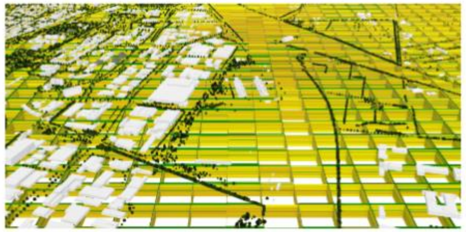
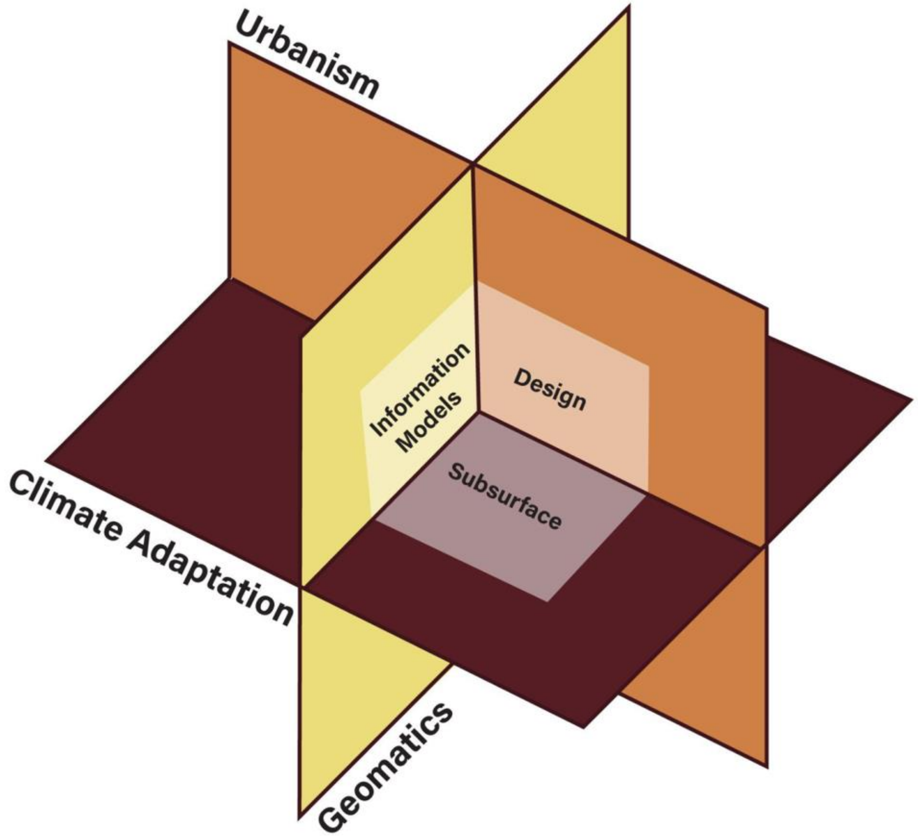


Figure 3.2: GeoTOP Fence Diagram

Figure 3.3: REGIS II

Figure 3.4: Geotechnisch and Grondwater



Research Question:

How can 3D data subsurface information models support standardized local climate adaptation design?

Hypothesis:

Through a theoretical and practical interdisciplinary approach: a *common ground.*

Common Ground:

Bridging Subsurface Information Models and Climate Adaptation Design

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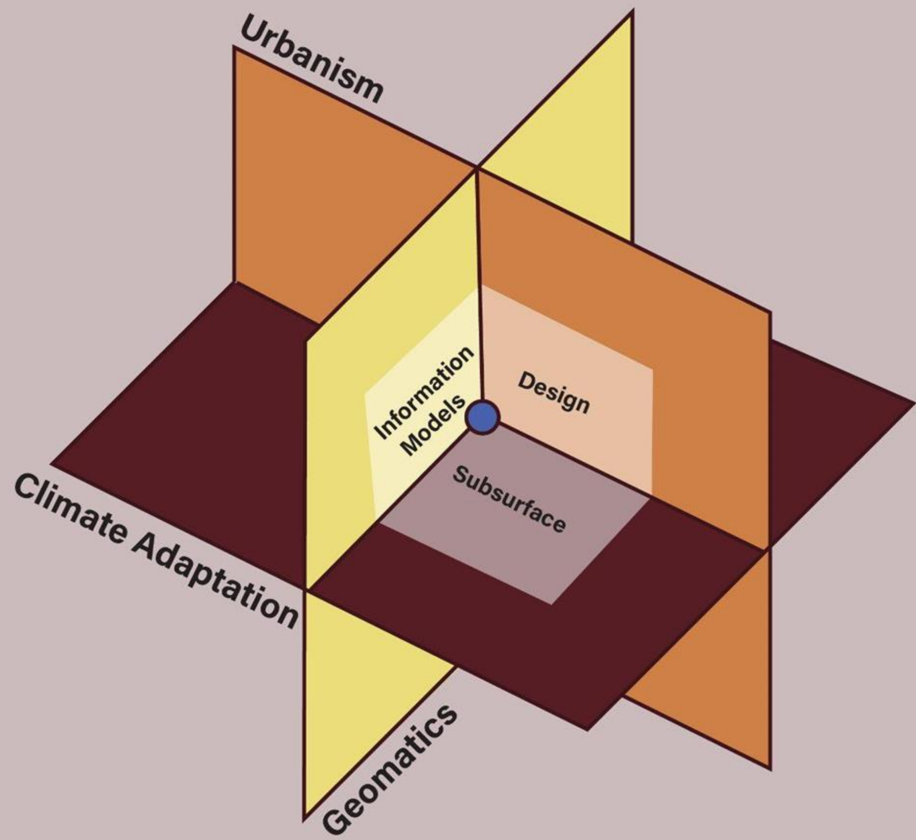


TU Delft

TNO innovation for life

II. Methodology

Methodology Overview

This thesis explores how can subsurface information models enhance urban climate adaptation by:

1. **Literature Review** for a theoretical foundation.
2. **Theoretical Assessment** of current 2D/3D subsurface models.
3. **Design Proposal** to understand information requirements and **Practical Assessment** of existing models.
4. **Creation of Tools** for information integration → UML diagram, LADM Part 5 subclasses, Online Catalog (CLIMACAT)

Goal = theoretical and practical foundations for better integrating subsurface information models into climate adaptation design.

Standards And Models Overview

As highlighted by the Delta Program, **to achieve concrete results it is important to reach an agreement through standardization.**

Standardized Climate Adaptation Design:

Leidraad 2.0, Maatlat, Klimaateffectatlas, and Klimaatadaptieve Maatregelen are used to define climate themes and design.

bouw adaptief

Klimaateffectatlas

GROENBLAUWE NETWERKEN
voor veerkrachtige steden

Maatregelen klimaatadaptief en natuurinclusief bouwen en renoveren

Standardized Subsurface Information Models:

Key Registry for the Subsurface, and other subsurface data models from the province and the municipality of Utrecht were used for suitability assessment.

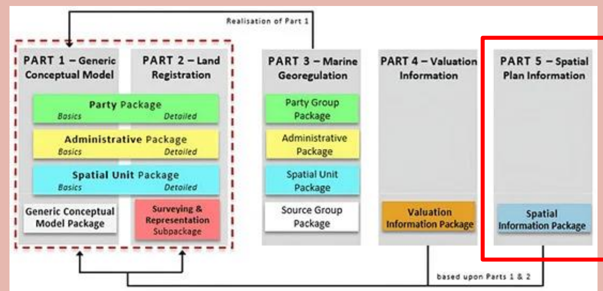
ATLAS
PROVINCIE UTRECHT

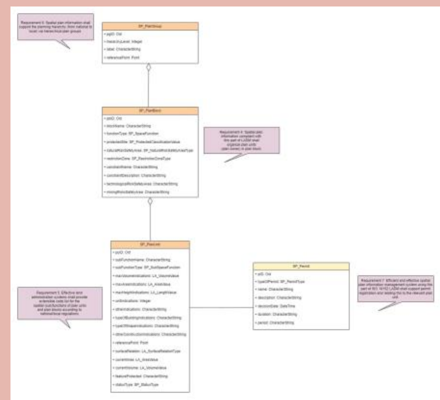
Gemiddelde Hoogste Grondwaterstand - huidig

Gemeente Utrecht
3D Utrecht

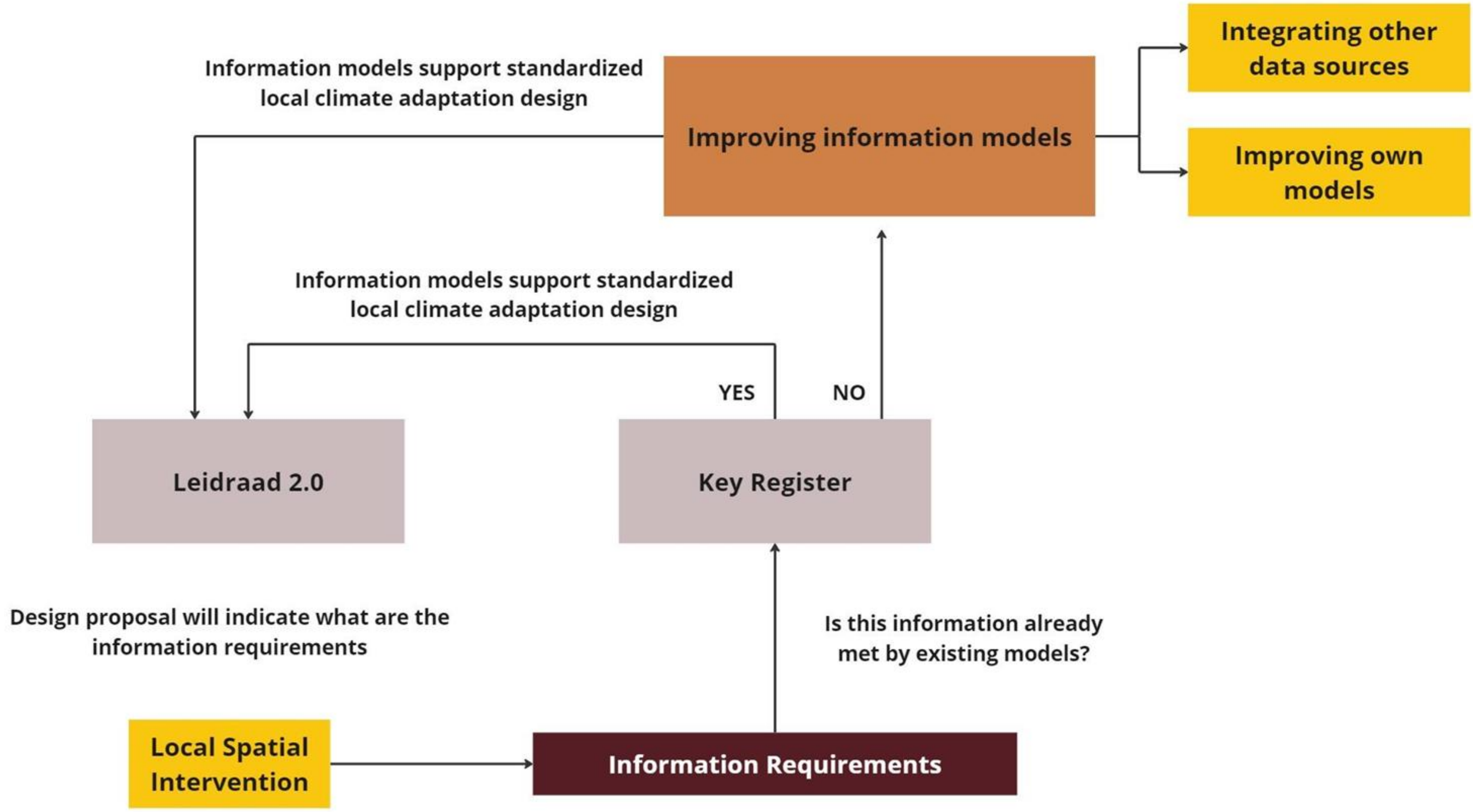
Standardized Urban Plans:

LADM Part 5 is used to define the exchange of urban planning information and potentially of local climate design interventions.

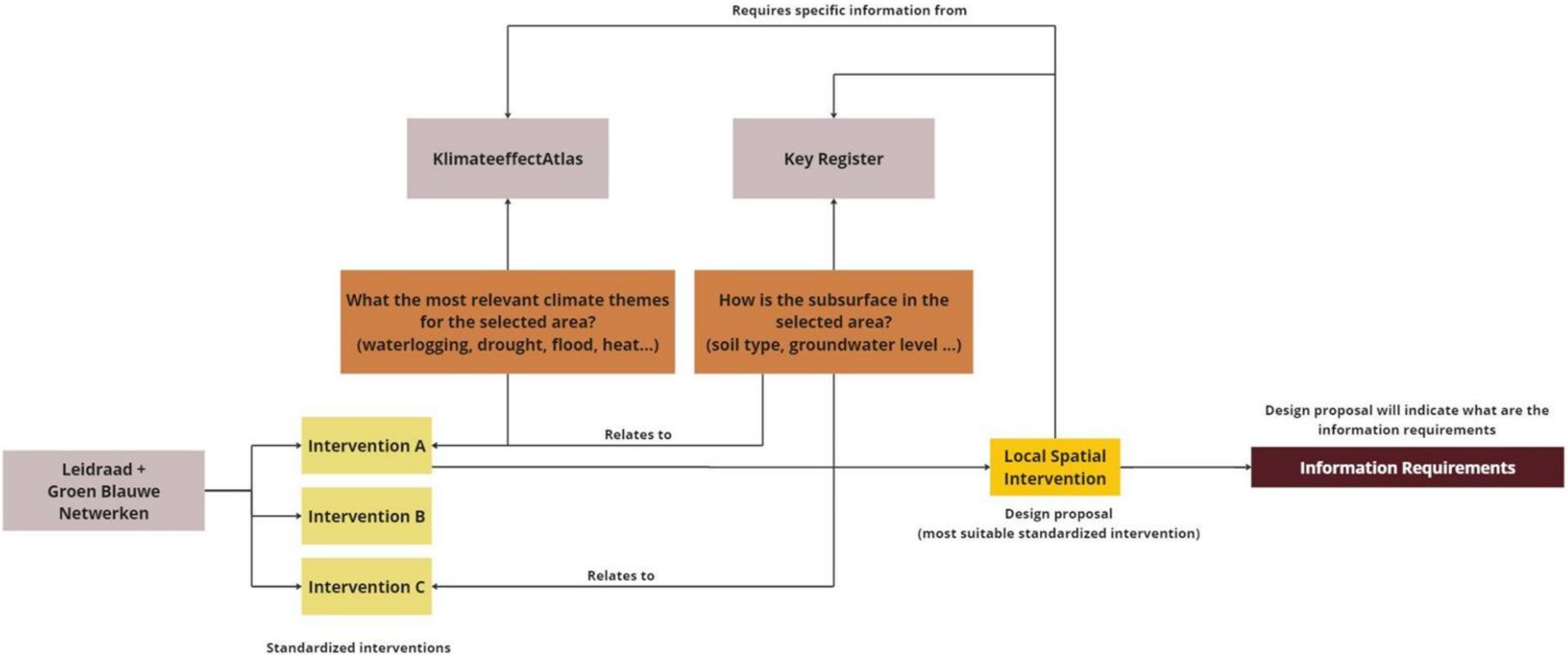




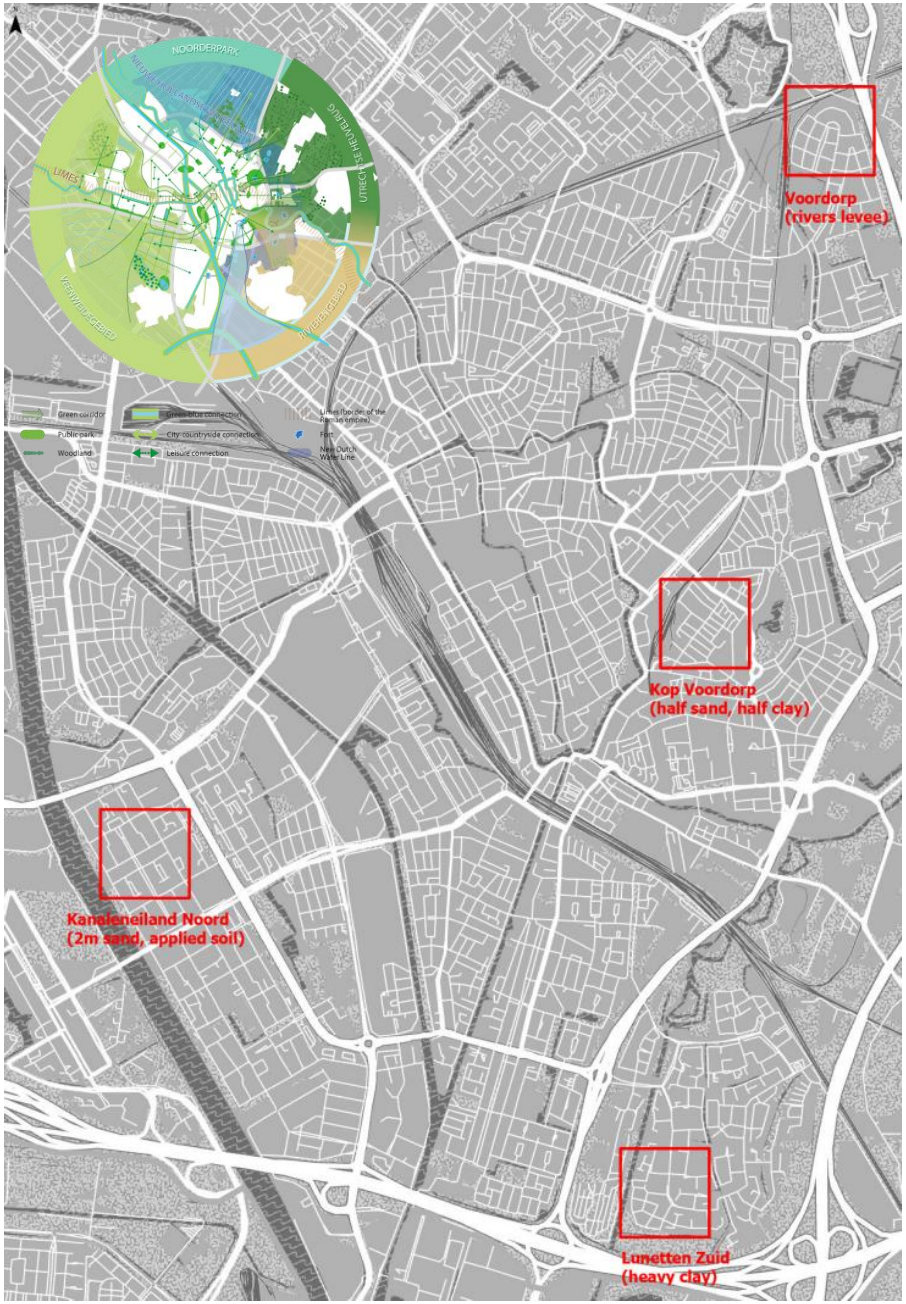
Methodology Geomatics

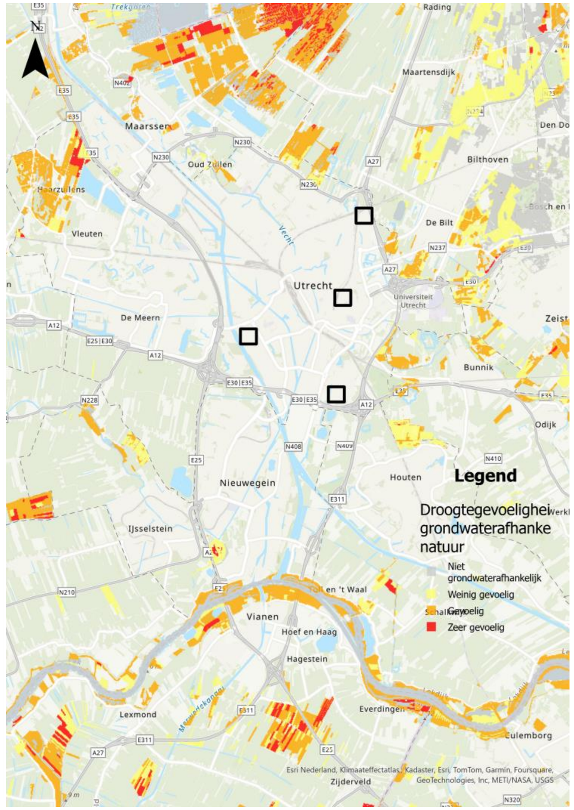


Methodology Urbanism



Methodology Design (Locations and Scenarios)





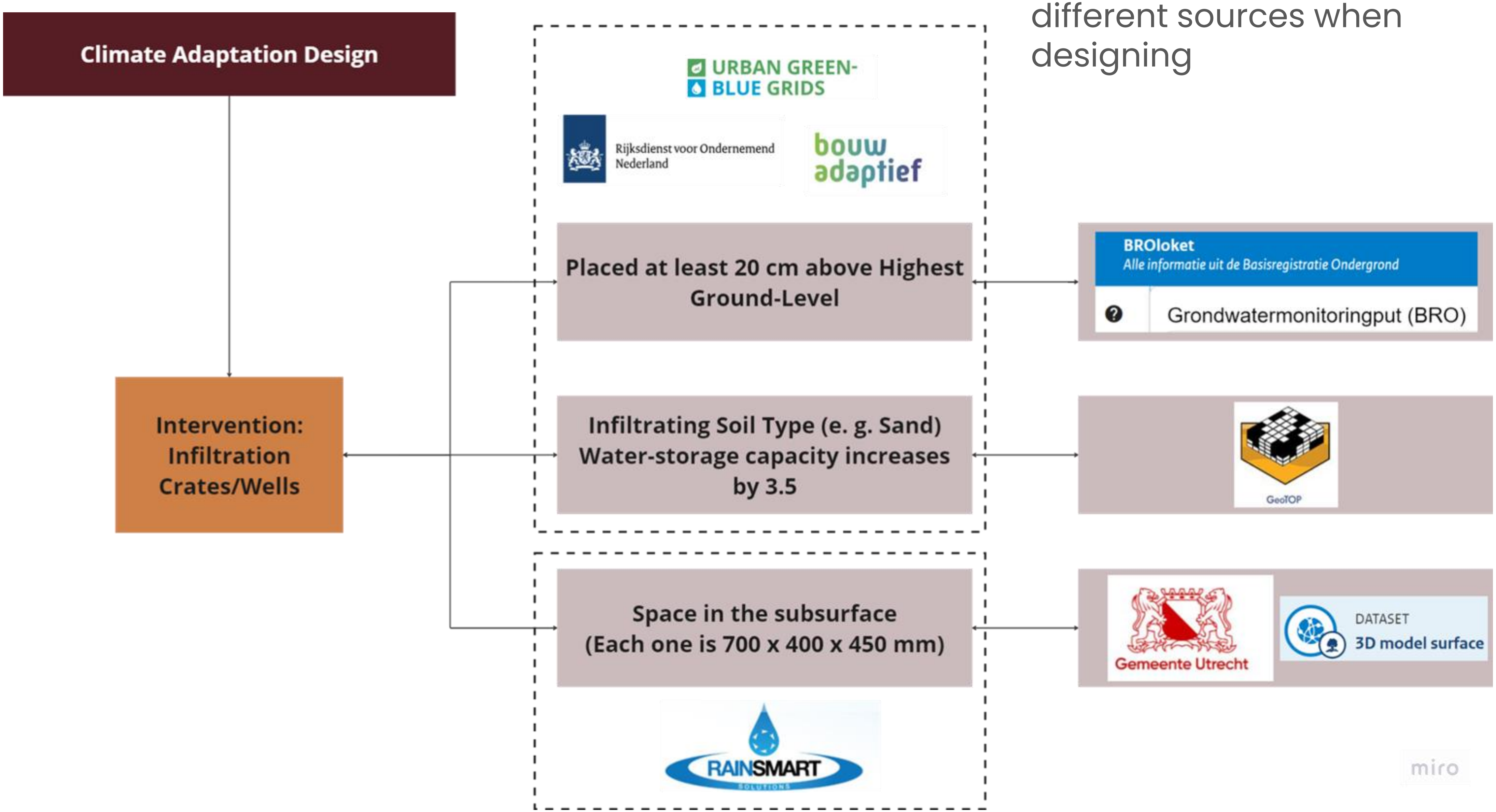
Two storm events (from Deltares and based on Leidraad and Klimateffectatlas) were used for the purpose of the spatial interventions consist of:

- **A shower of 140 mm in two hours (or 70 mm/hour)**
- **A shower of 70 mm in two hours.**

Storm events are particularly relevant due to infiltration. However, for each area, **the most relevant climate themes** were mapped and taken into consideration.

Design As A Methodology

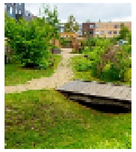
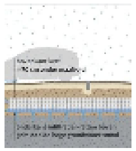
Need for combining different sources when designing



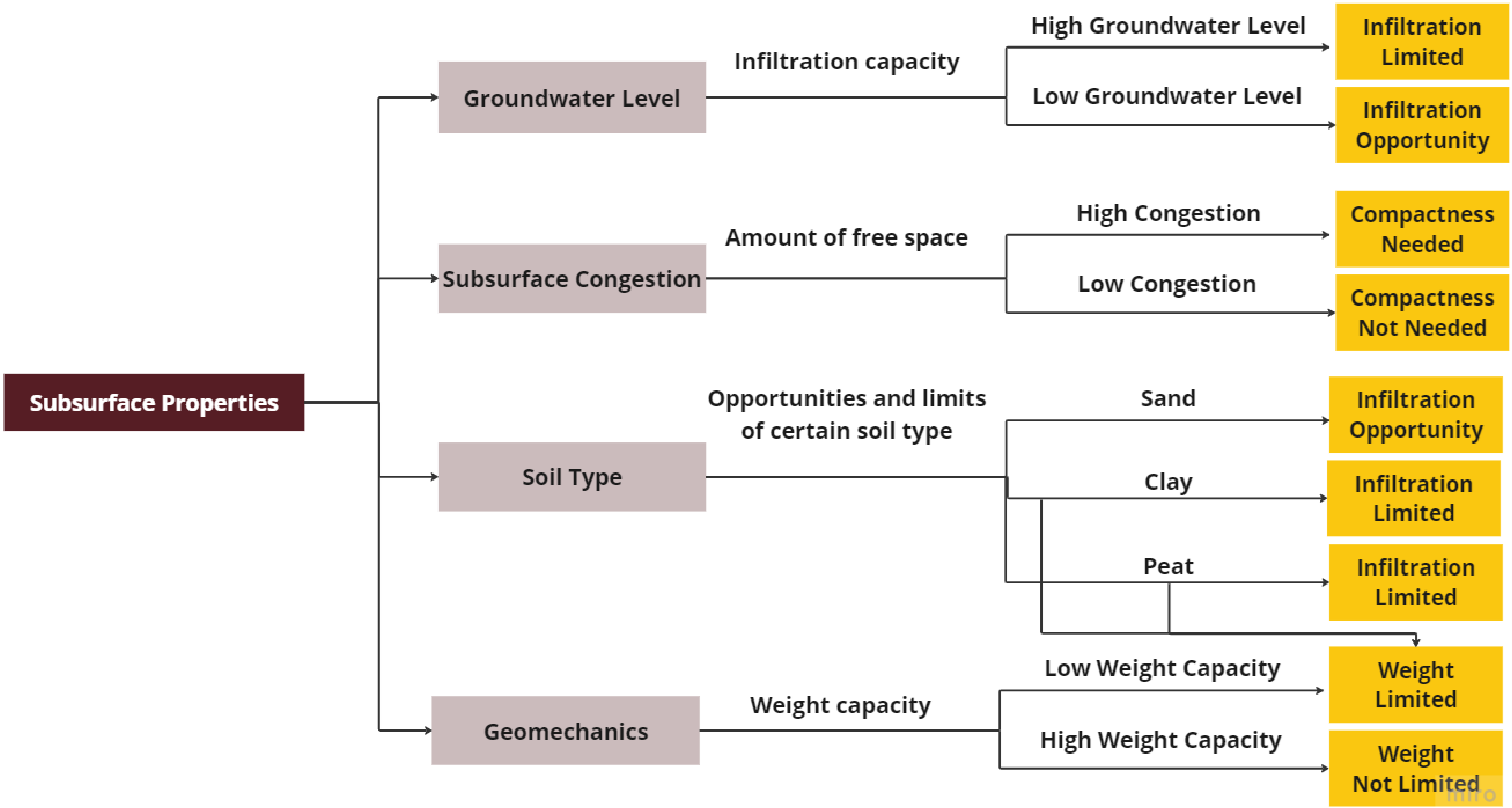
III. Theoretical Foundation

Which interventions are mostly used in NL?

** Medium intervention

Climate-adaptive measure		Application	Indicative investment costs	Indicative management and maintenance costs	Soil type	Points
GREEN ROOF			€2,500-€5,000 per home, roof garden €5,000-€10,000 per home	€4 /m^2 for extensive green roof, €6 /m^2 for polder roof/roof garden	N/a.	In the case of new construction, weight calculation must be determined in advance. Maintenance 4 times a year. Extensive and intensive vegetation possible. Existing construction: not always possible due to the load-bearing capacity of the roof.
COOL PLACES			-	Limited increase	All	See also Basic MRA safety requirements: Minimum 200 m^2 and within walking distance (300m).
SHADOW ROUTES			€150-€220 /m2	Limited increase	All	See also Basic Safety Requirements MRA, Programme of Requirements for ConstructionAdaptive Zuid-Holland: at least 30% shade for important slow traffic routes and places to stay during the highest sun position in the summer.
NATURAL PLAYGROUND			€500-€12,000 per playground	€3 - 6 /m^2	All	Whether or not in combination with local water collection (nature-friendly wadi).
(NATURE-FRIENDLY) WADIS			€100-€145 /m^3	€0,37 /m^2	High sandy soils, riverbeds	Space demand, especially for existing buildings; Especially applicable at low groundwater levels. Grass swale requires regular mowing in the summer, nature-inclusive swale biennial maintenance.
APPLYING (MORE) SURFACE WATER			€160 /m3 incl. sheeting	No increase	All	Demand for space when widening.
INFILTRATION CRATES AND WELLS UNDER (UN)PAVED SURFACE			€330-€400 /m3 for paved, €165 /m3 for unpaved surface	-	-	Pay attention to maintenance: risk of clogging. Low groundwater level necessary: max. 20cm above GHG. The water storage capacity of the subsoil increases by a factor of 3.5. Existing building: apply to refurbishment / maintenance.
WATER STORAGE UNDER (UN)PAVED SURFACE			€120 /m3	-	-	For example, hollow constructions under roads, water storage in granulate. Existing building: apply in refurbishment / renovations.

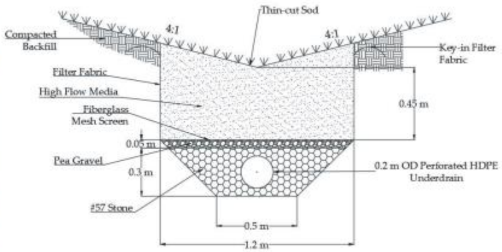
How do they relate to the subsurface?



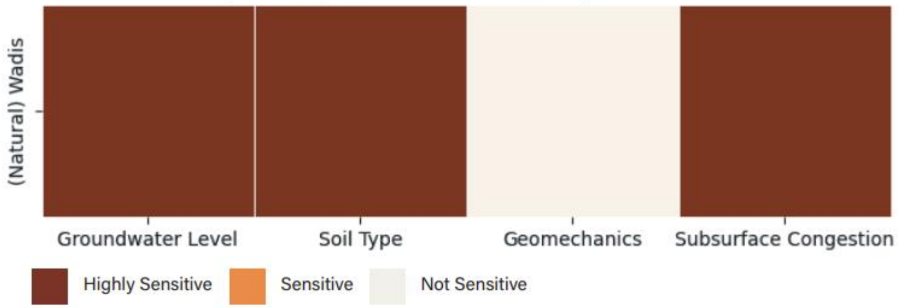
Which are their information requirements?

(Natural) Wadis

Adaptation: Biodiversity, Waterlogging, Drought



Source (left to right): NACTO, KOED

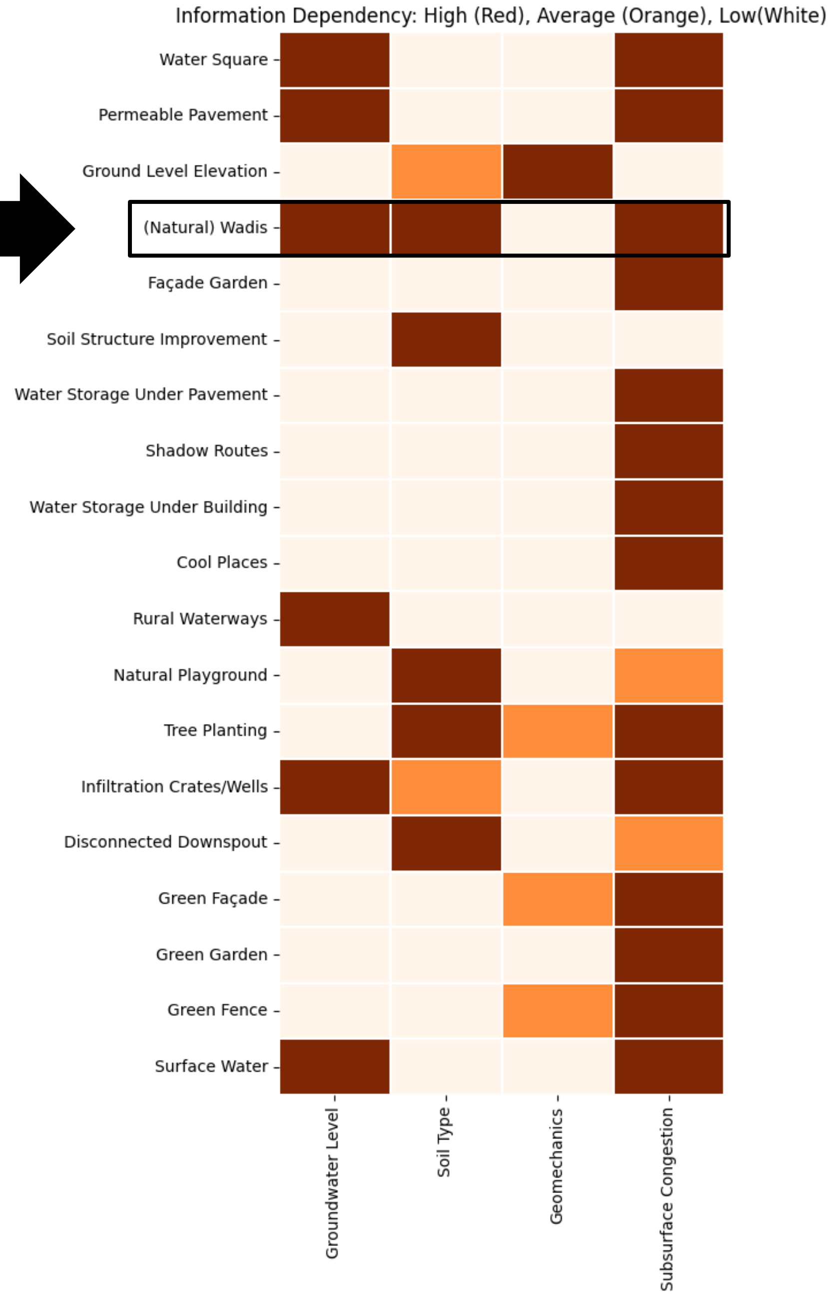


Soil Type: Wadis usually take advantage of infiltrating soil, such as sand. For this reason, accuracy is needed regarding the soil type. A wrong and less infiltrating soil type will have negative consequences.

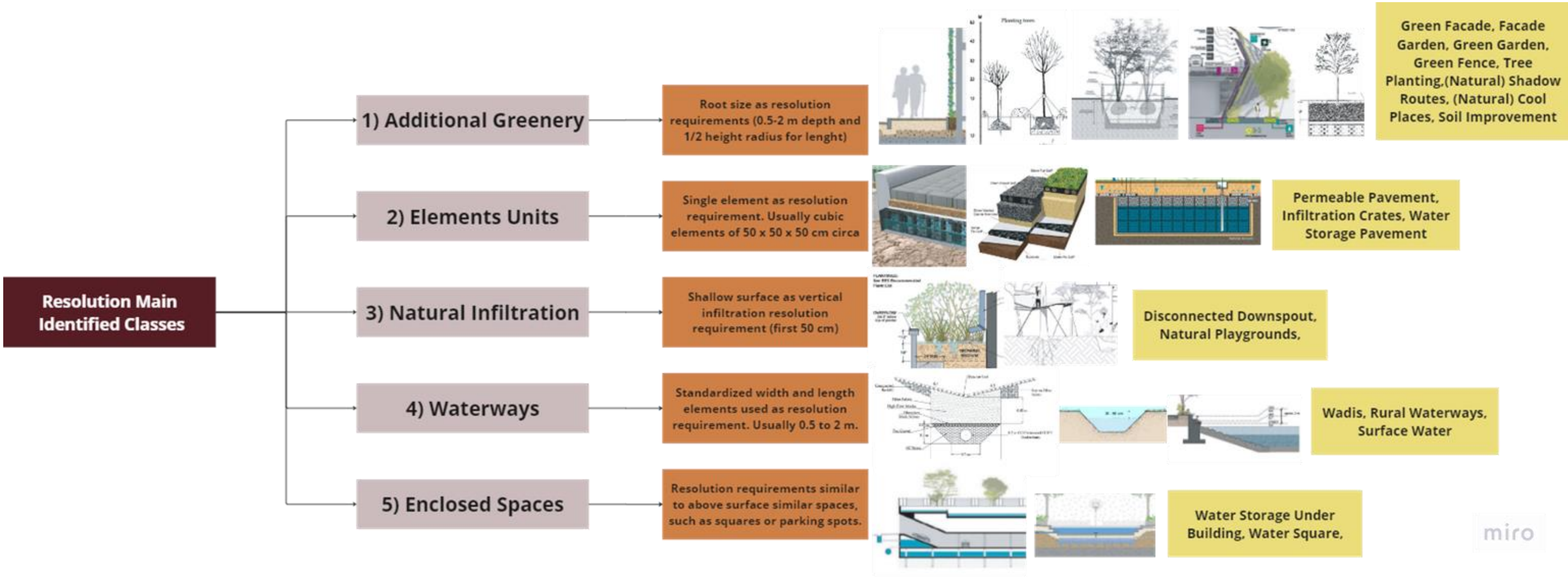
Groundwater Level: A wadi may replenish groundwater by inifiltration. For this reason, accuracy is necessary regarding the groundwater level.

Subsurface Congestion: A wadi requires space underground, often for a continuous long route. Space underground is thus required.

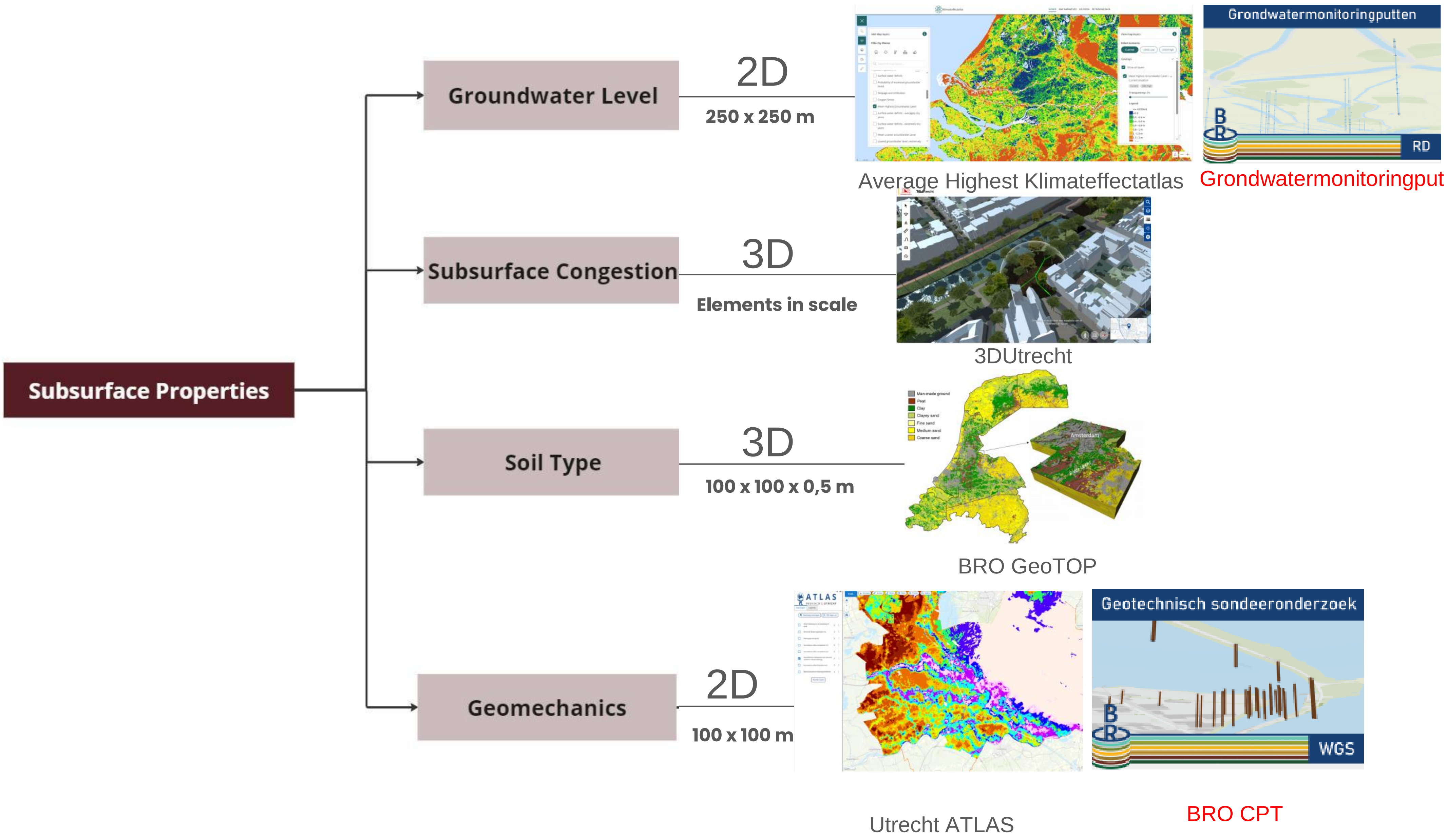
Resolution Requirement: Wadis have on average a depth of one meter and can be divided roughly into two parts of half a meter. Resolution should have 50 cm vertically. Horizontally this solution also is on average one meter wide and would benefit from this level of detail.



Which are their resolution requirements?



What are the existing subsurface models?



IV. Combining Information

Visualizing relationships: UML Diagram

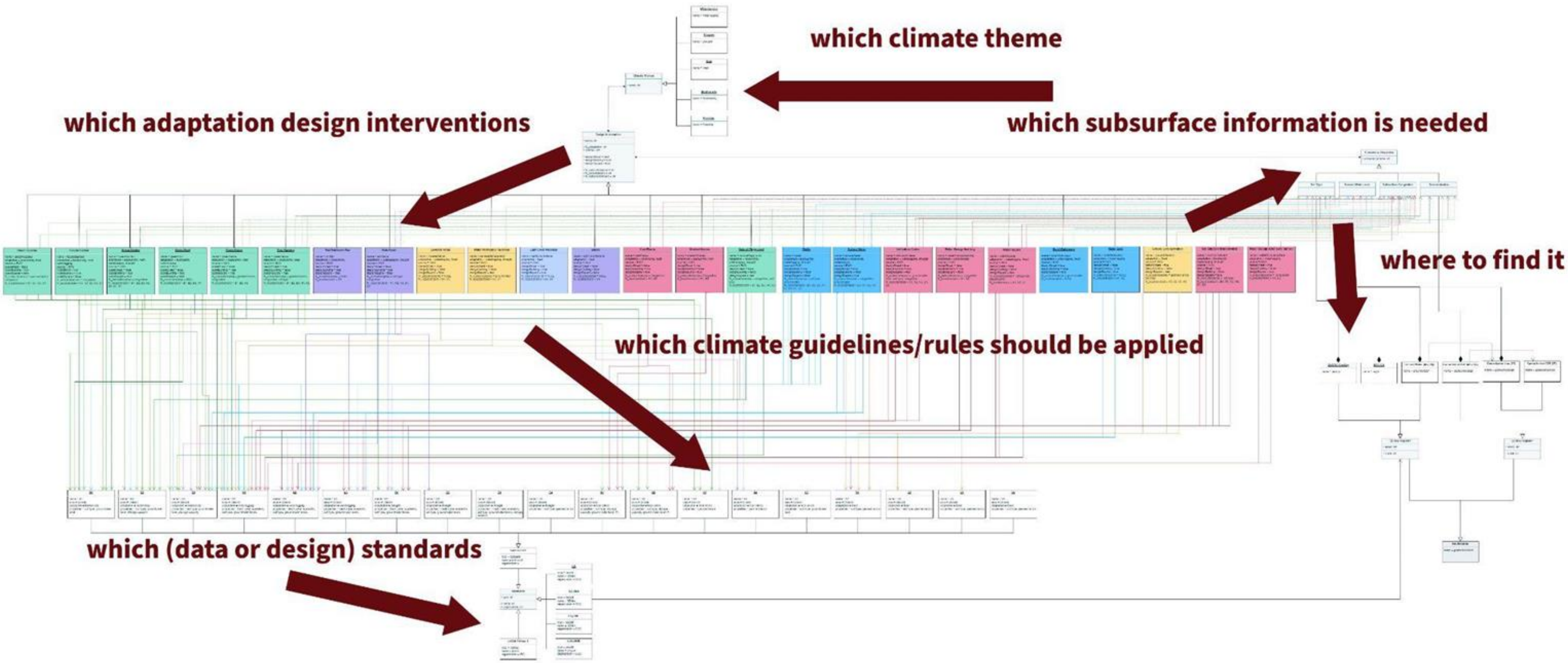
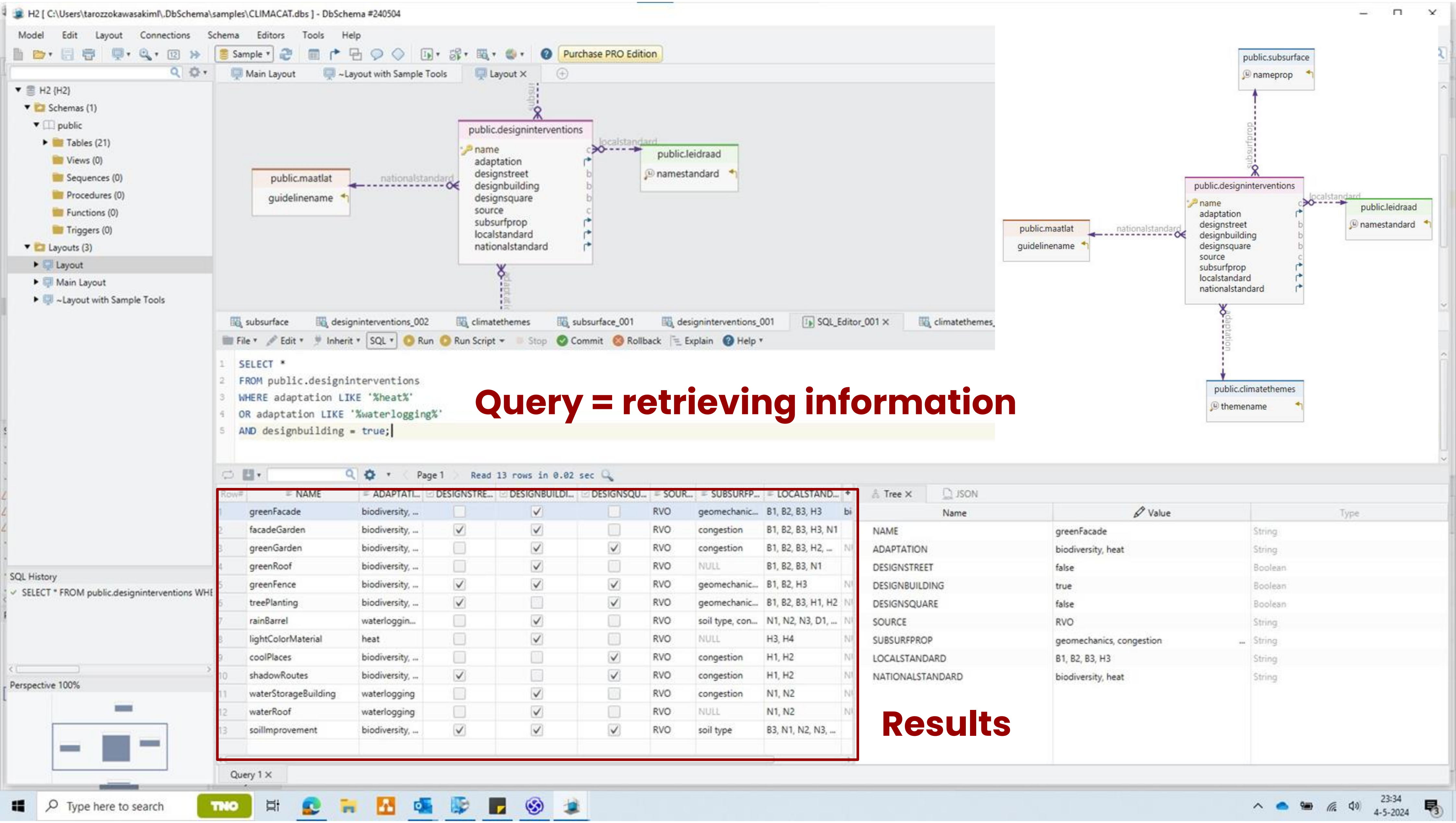


Diagram = "Roadmap" for users

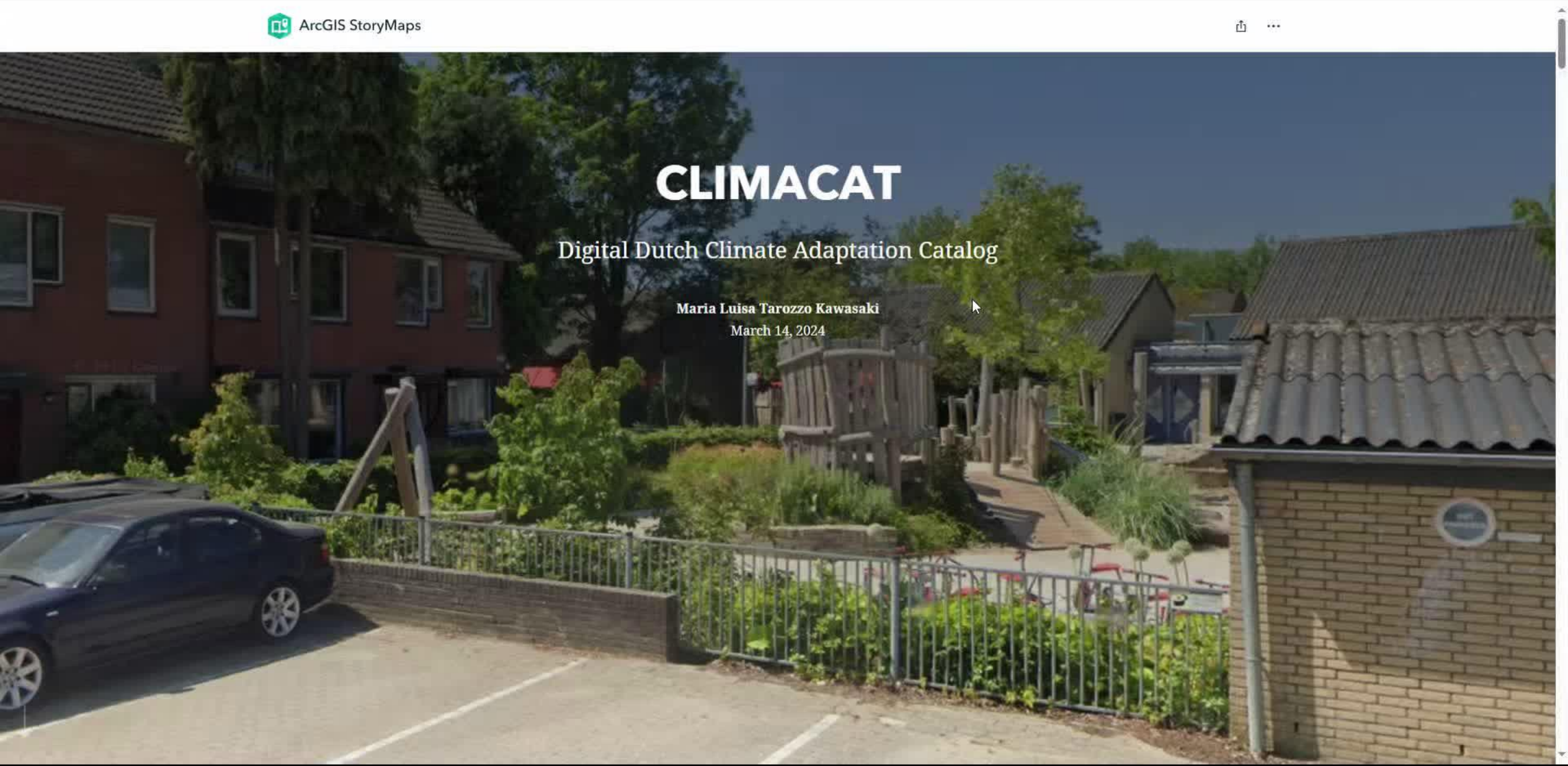
Retrieving information: Relational databases



Query = retrieving information

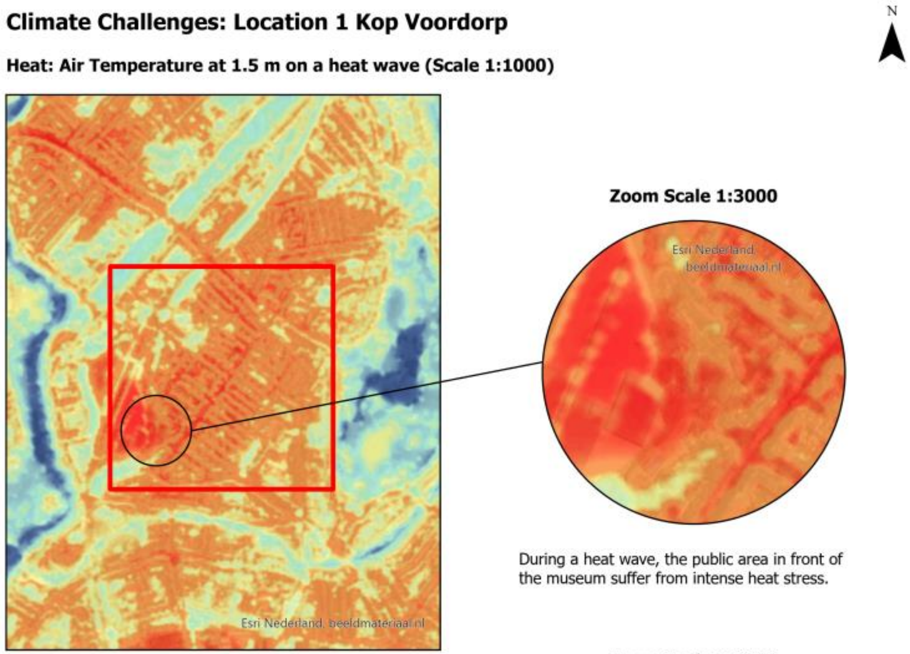
Results

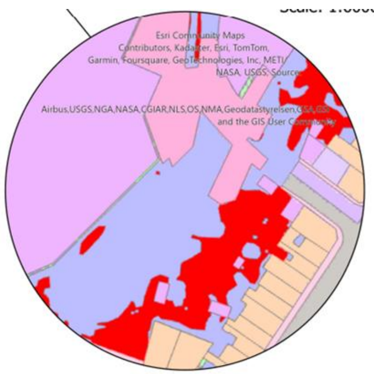
Online Catalog: CLIMACAT



V. Design Proposals

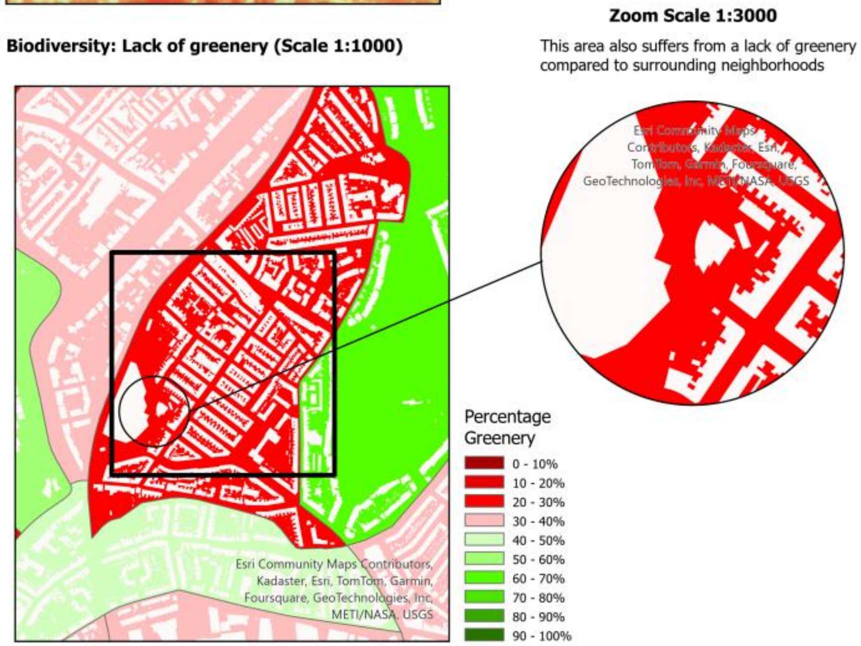
1) Kop Voordop: Context





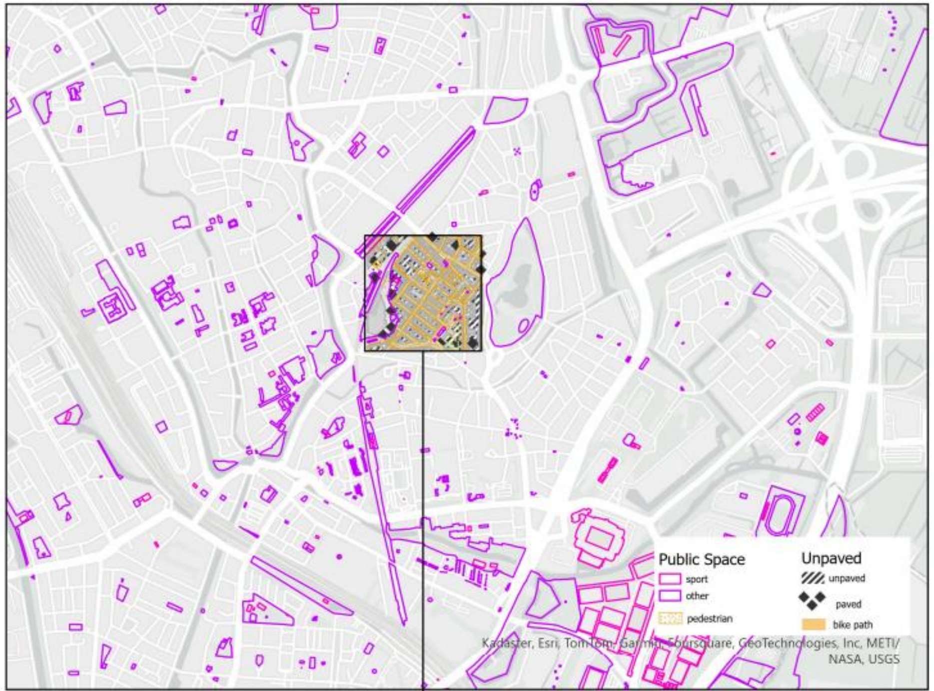
Museum public area

Scale: 1:1000

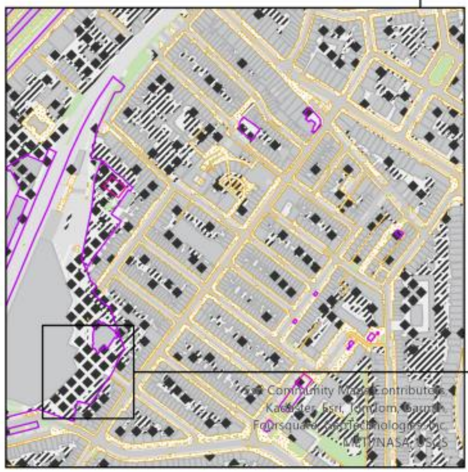


1) Kop Voordop: Social/Ecological Context

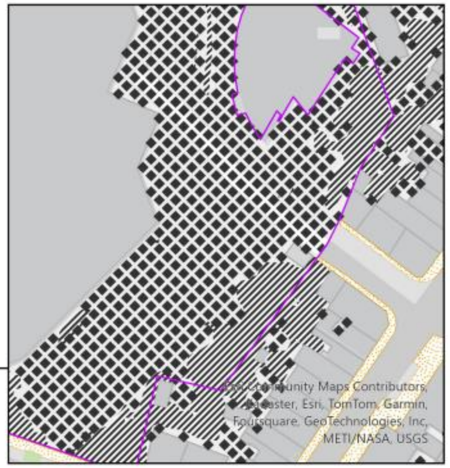
Public And Unpaved Spaces: Location 1 (Kop Voordorp)



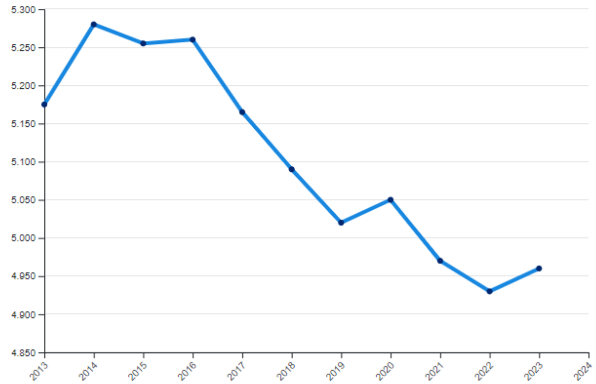
Public/Unpaved Spaces Level Macro (Scale: 1:20000)



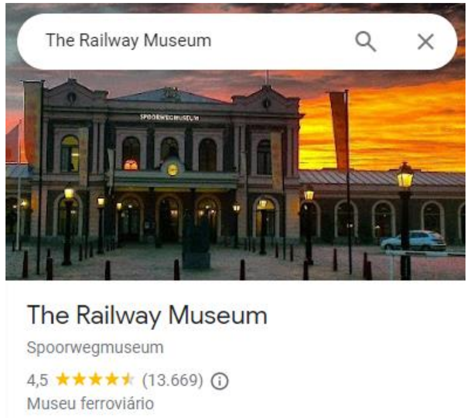
Public/Unpaved Spaces 500x500m (Scale: 1:5000)



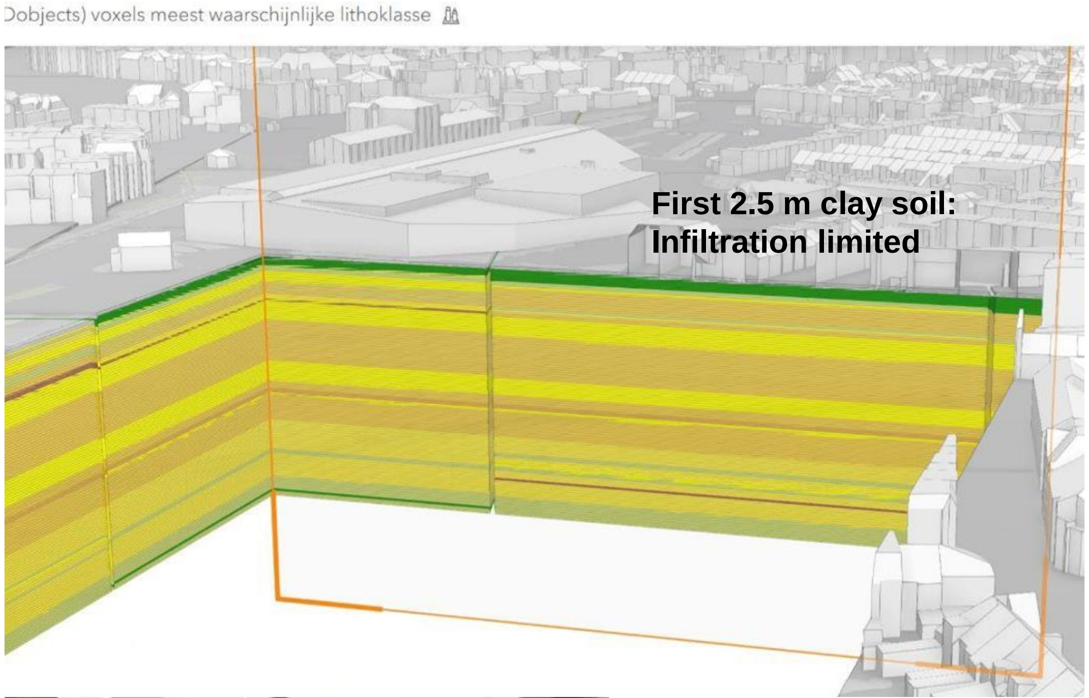
Public/Unpaved Spaces design area (Scale: 1:1000)

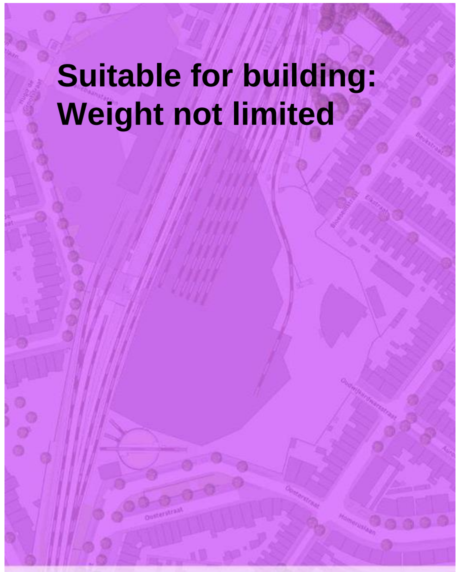


Population numbers in neighbourhood Oudwijk in Utrecht in the Netherlands for the years 2013 thru 2023.

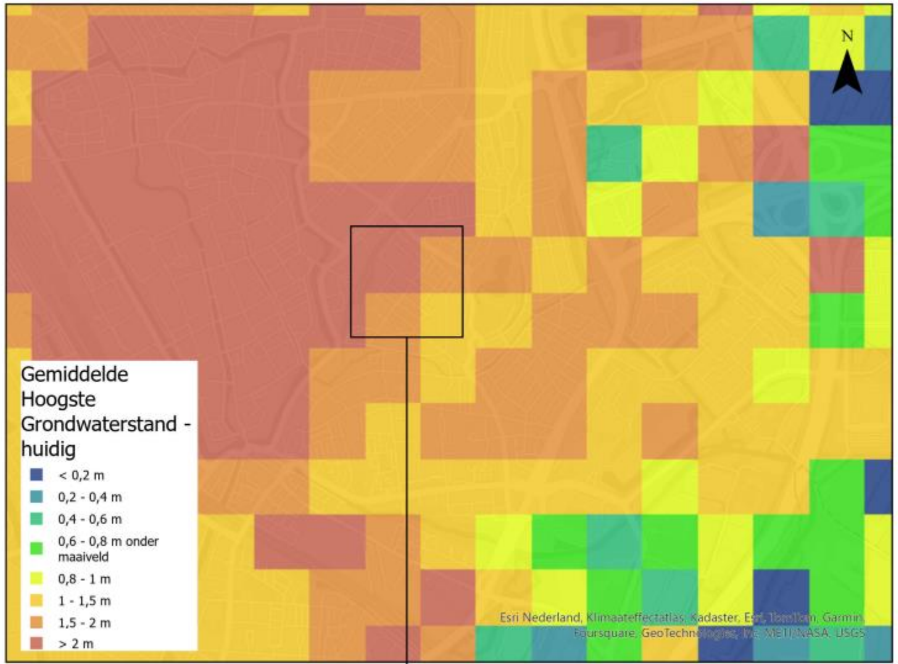


1) Kop Voordop: Subsurface Properties

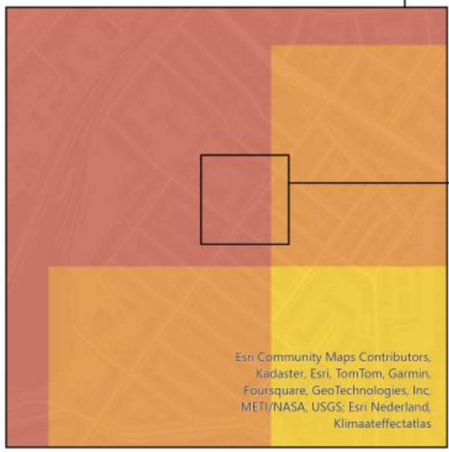




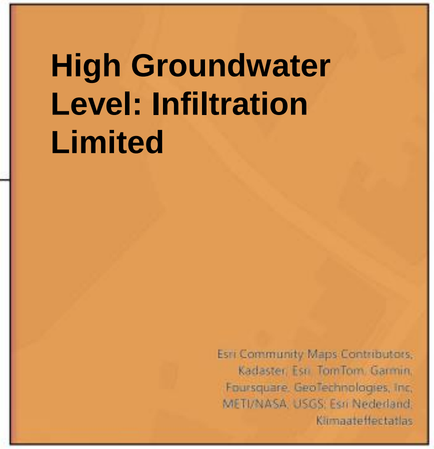
Mean Highest Groundwater Level - Current: Location 1 (Kop Voordorp)



Mean Highest Groundwater Level Macro (Scale: 1:20000)

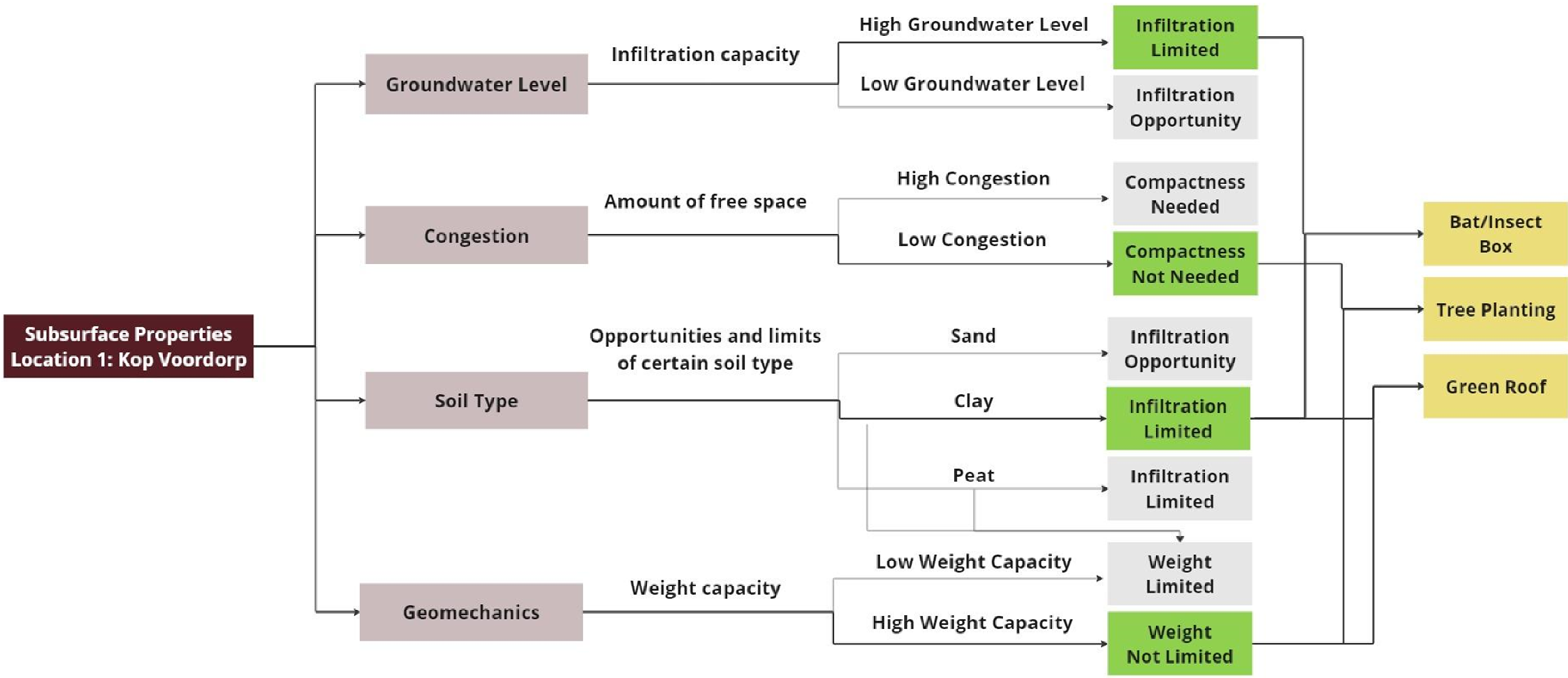


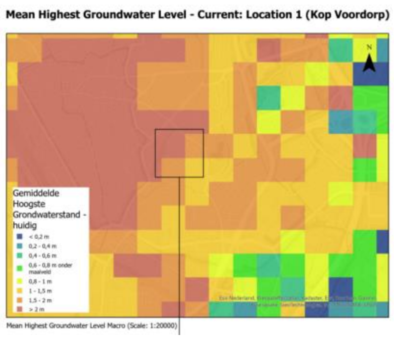
Mean Highest Groundwater Level 500x500m (Scale: 1:5000)

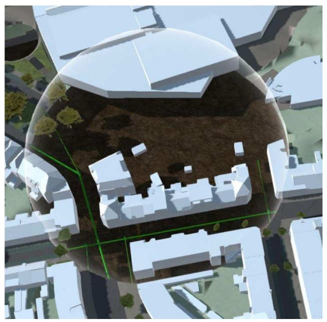


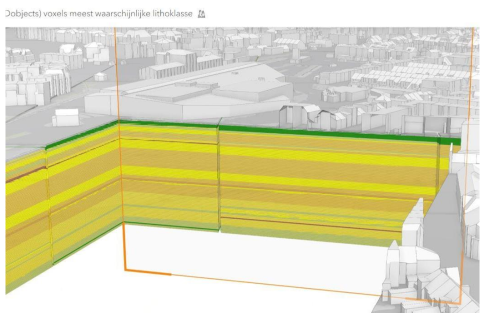
Mean Highest Groundwater Level design area (Scale: 1:1000)

1) Kop Voordop: Design Decision Tree

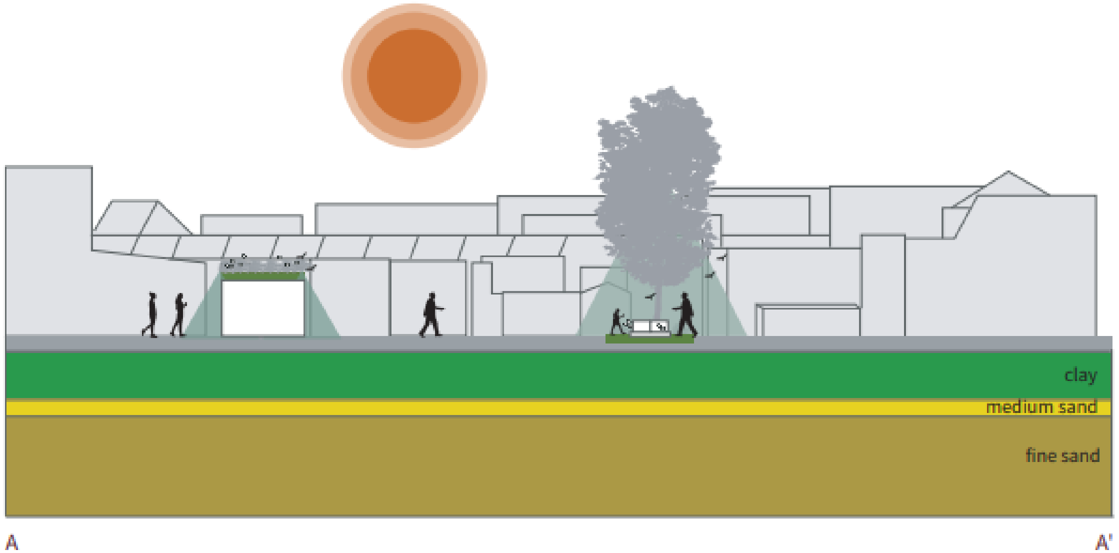








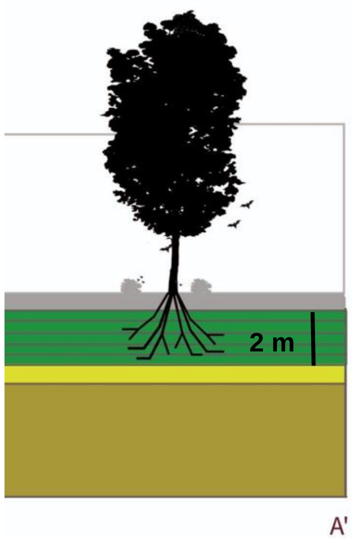
1) Kop Voordop: Design Proposal




Green Roof


Tree Planting

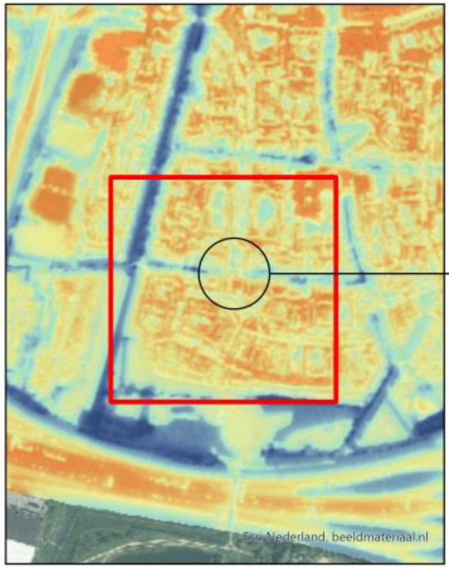

Bird/Bat/Insect Box



2) Lunetten Zuid: Context

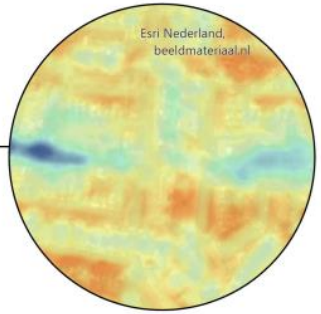
Climate Challenges: Location 2 Lunetten Zuid

Heat: Air Temperature at 1.5 m on a heat wave (Scale 1:1000)



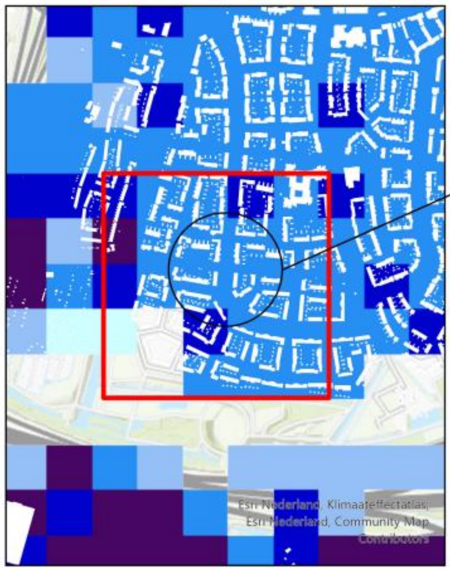
During a heat wave, the air temperature is low only where greenery is present: the main parks and roads with high number of trees.

Zoom Scale 1:3000

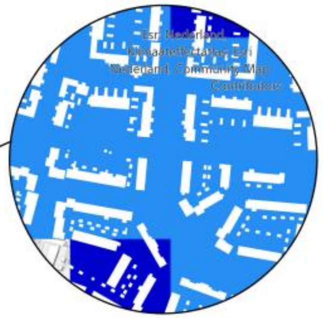


The selected project area includes an intersection with lower temperature horizontally, and higher temperatures vertically.

Flooding: Flood depth average probability (Scale 1:1000)



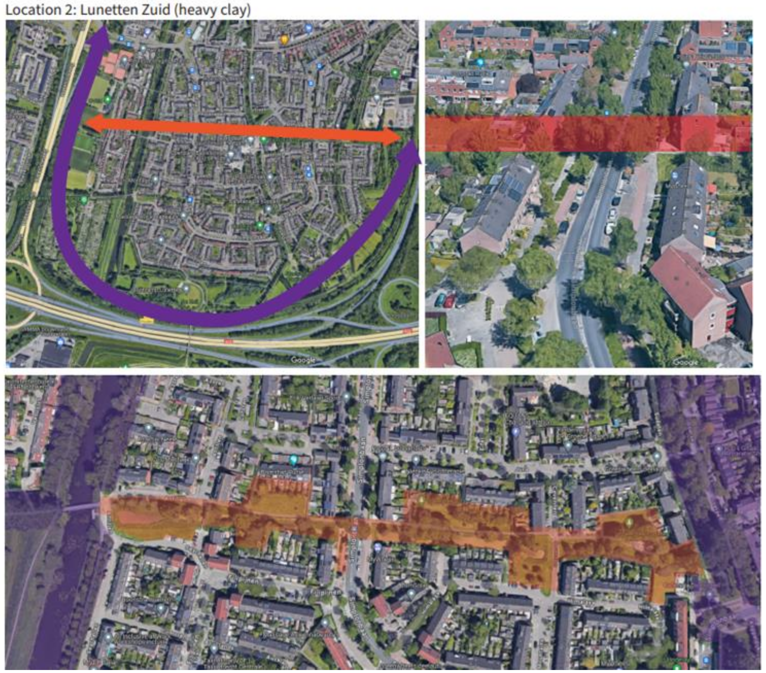
Zoom Scale 1:4500

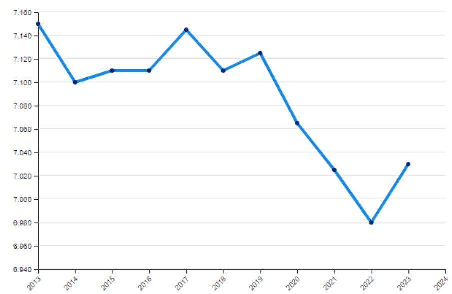


Moreover, the selected area is between spots where flood depth can get to up to 2 meters.

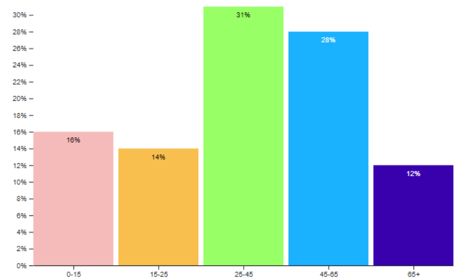
- < 0.5 meter
- 0.5 - 1 meter
- 1 - 1.5 meter
- 1,5 -2 meter
- 2 - 5 meter
- >5 meter

Location 2: Lunetten Zuid (heavy clay)





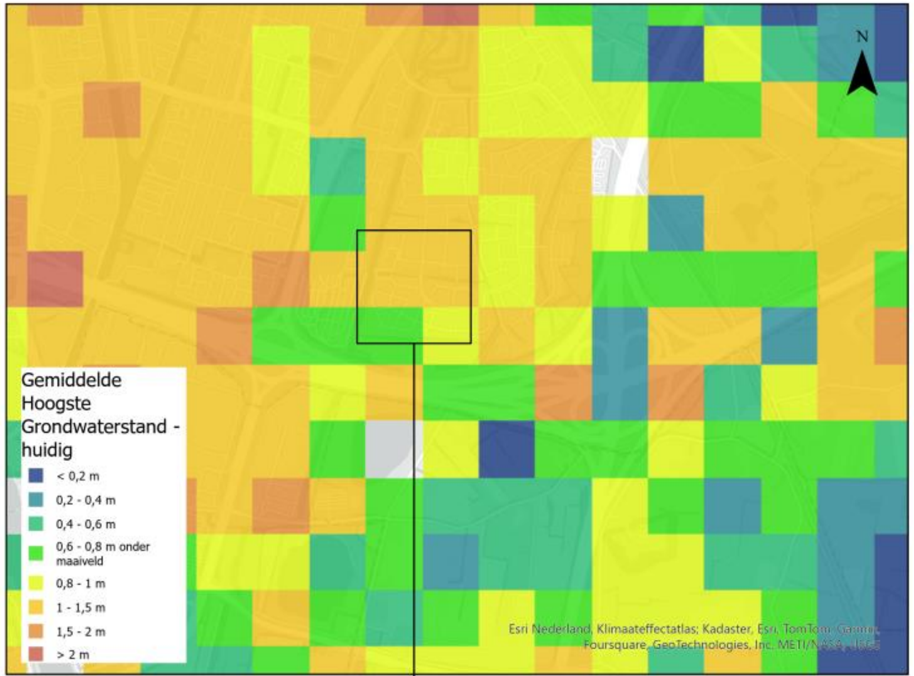
Population numbers in neighbourhood Lunetten-Zuid in Utrecht in the Netherlands for the years 2013 thru 2023.



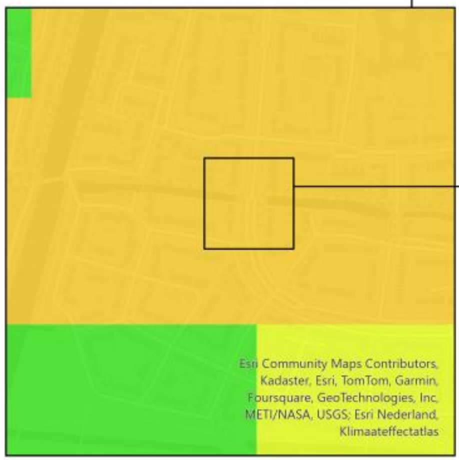
Neighbourhood Lunetten-Zuid, 2023, age groups.

2) Lunetten Zuid: Subsurface

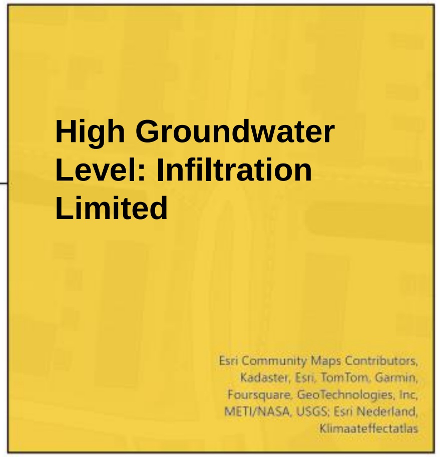
Mean Highest Groundwater Level - Current: Location 2 (Lunetten Zuid)



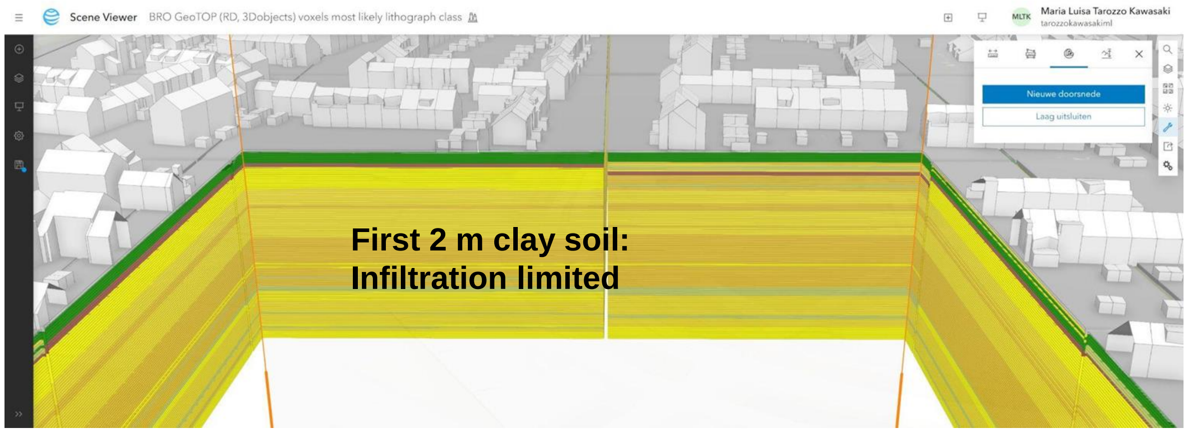
Mean Highest Groundwater Level Macro (Scale: 1:20000)

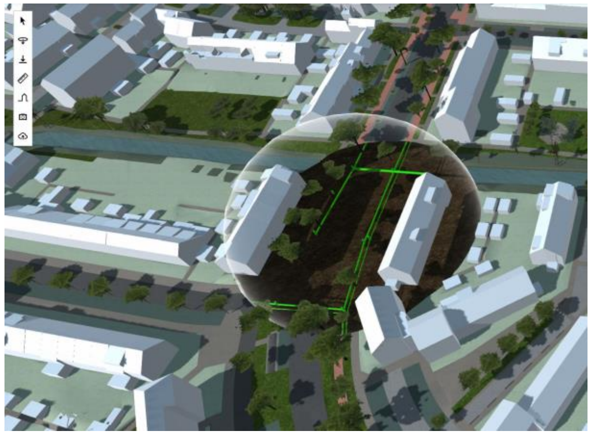


Mean Highest Groundwater Level 500x500m (Scale: 1:5000)



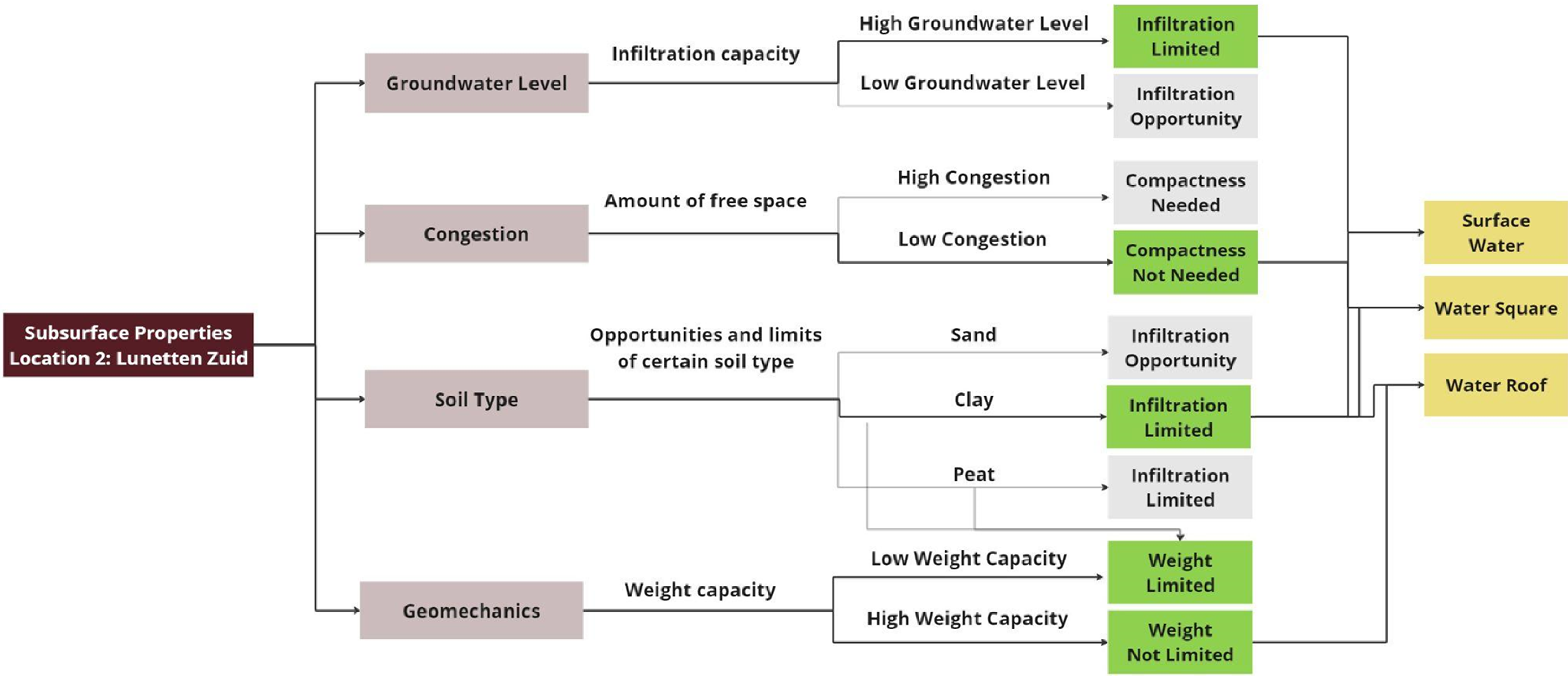
Mean Highest Groundwater Level design area (Scale: 1:1000)





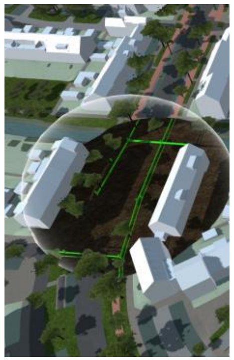
Low Congestion: Compactness not needed

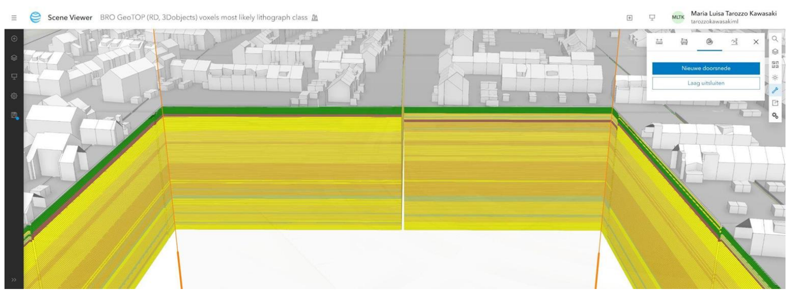
2) Lunetten Zuid: Design Decision Tree



Mean Highest Groundwater Level - Current: Location 2 (Lunetten Zuid)

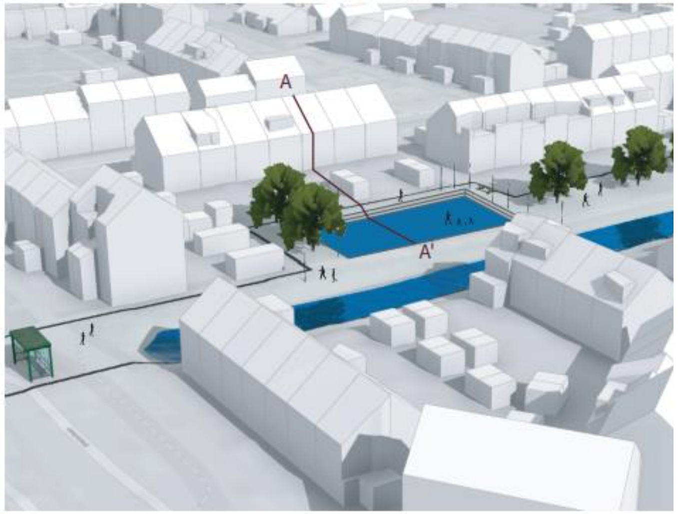
Mean Highest Groundwater Level Macro (Scale: 1:20000)

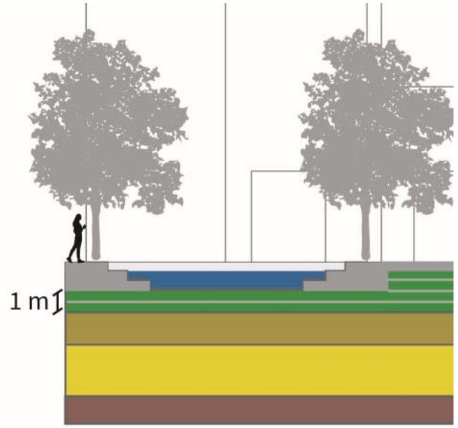




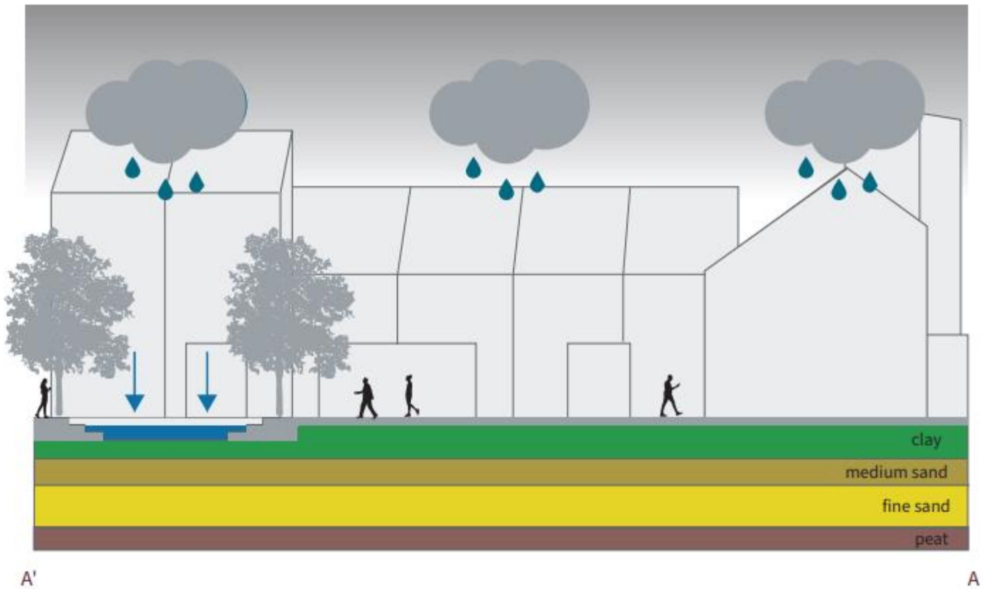
2) Lunetten Zuid: Design Proposal

Area 2 (Lunetten Zuid): Adaptation to Flood (Water Square)

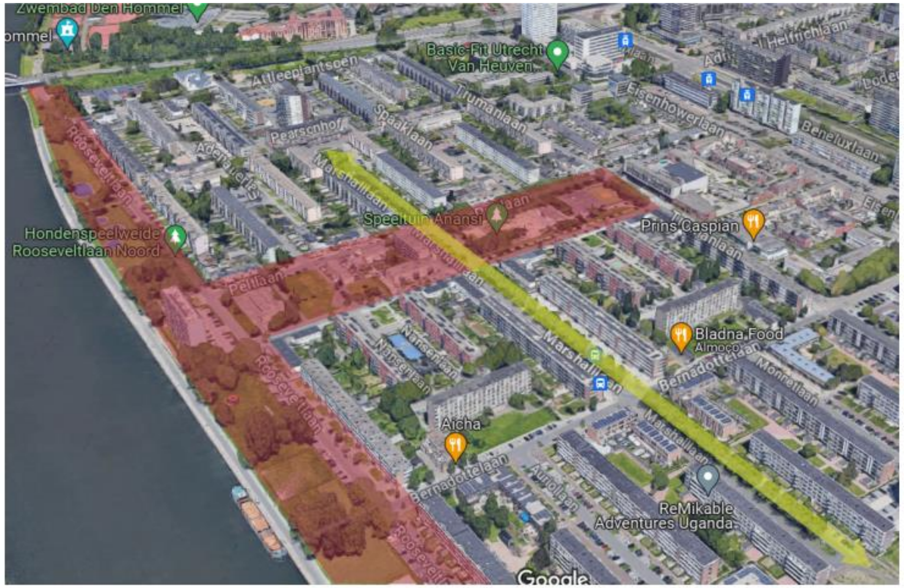




Area 2 (Lunetten Zuid): Adaptation to Flood (Water Square)

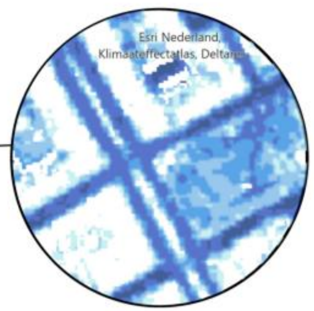


3) Kanaleneiland Noord: Context



Waterlogging: Shower of 140 mm/2 hours (Scale 1:1000)

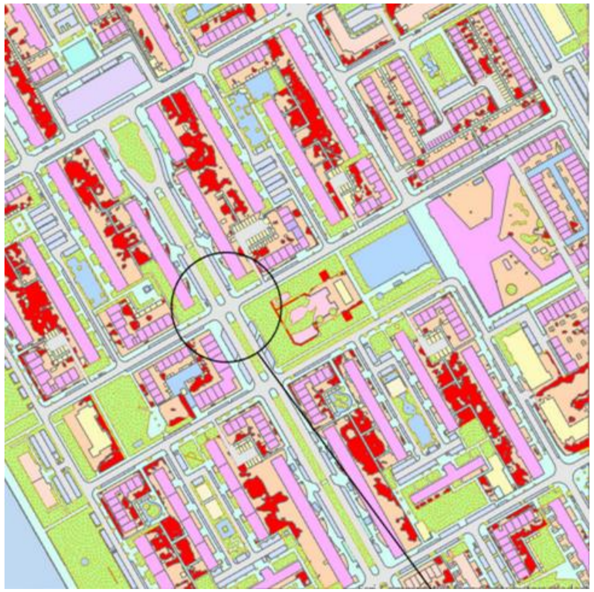
Zoom Scale 1:3000

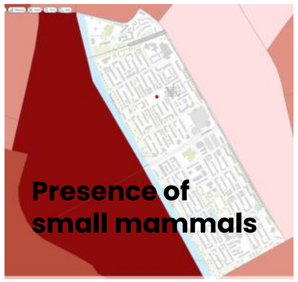


During a shower that occurs once every 1000 years, the play area suffers from waterlogging

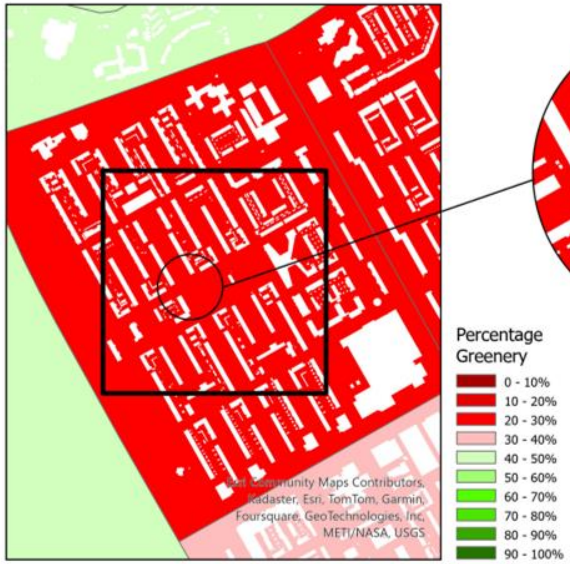
Zoom Scale 1:3000

This area also suffers from a lack of greenery compared to surrounding neighborhoods



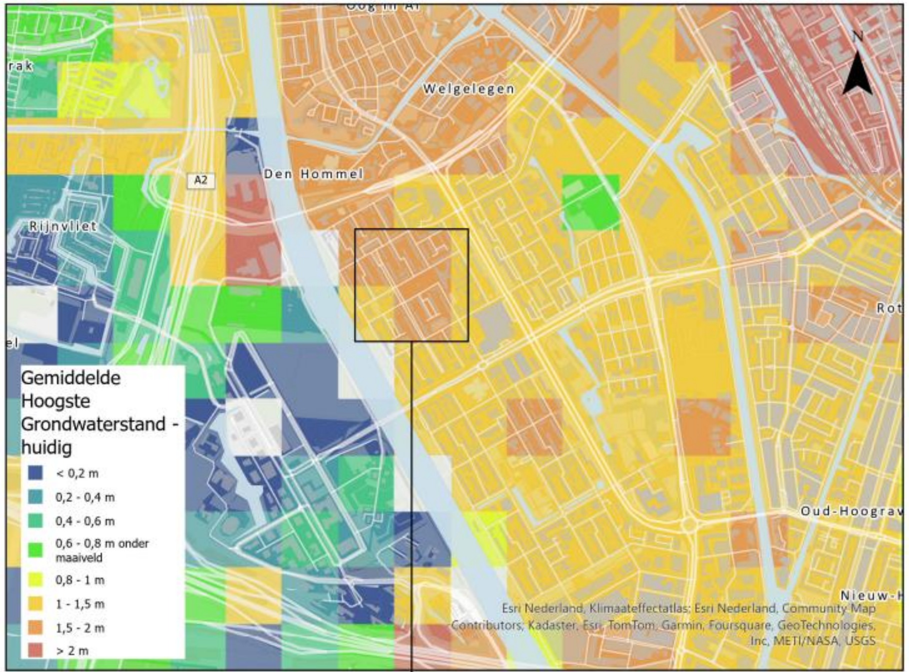


Biodiversity: Lack of greenery (Scale 1:1000)



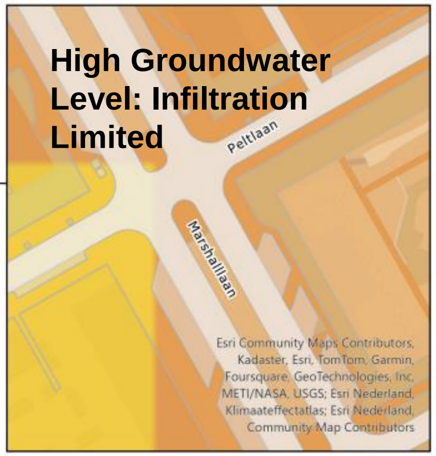
3) Kanaleneiland Noord: Subsurface

Mean Highest Groundwater Level - Current: Location 3 (Kanaleneiland)

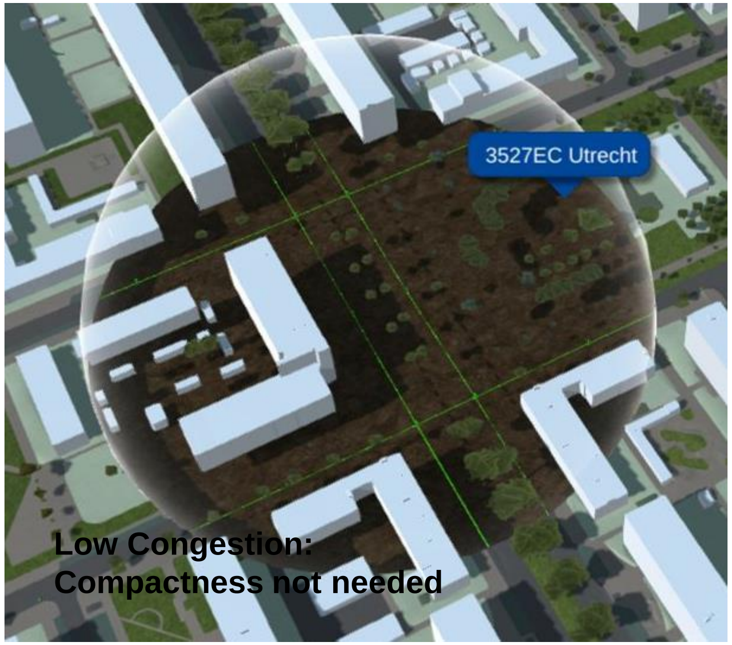


Mean Highest Groundwater Level Macro (Scale: 1:20000)

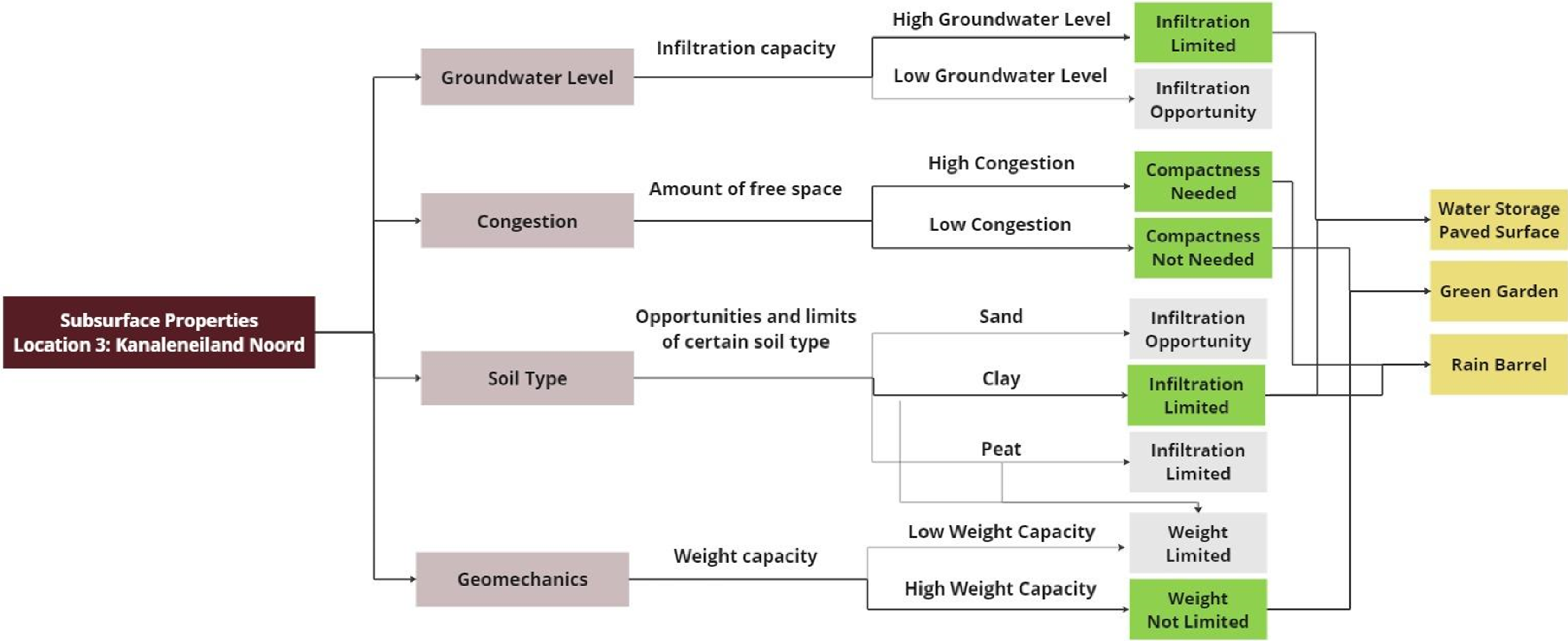
Mean Highest Groundwater Level 500x500m (Scale: 1:5000)

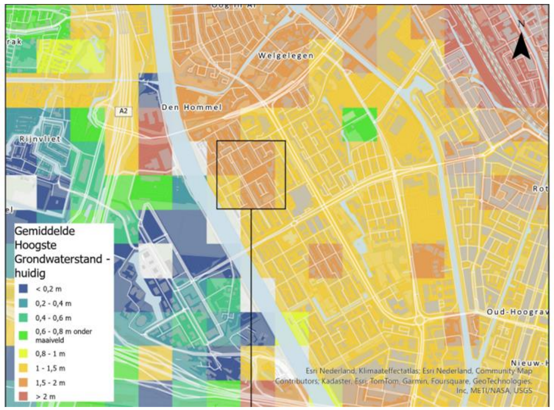


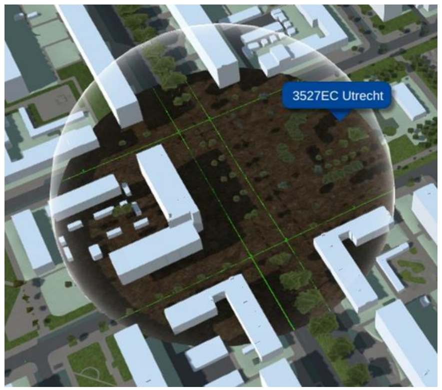
Mean Highest Groundwater Level design area (Scale: 1:1000)

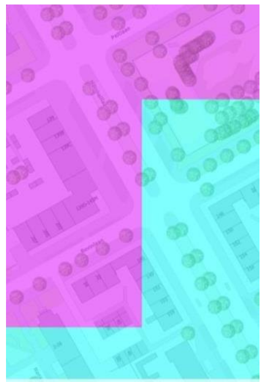


3) Kanaleneiland Noord: Design Decision Tree









3) Kanaleneiland Noord: Design Proposal

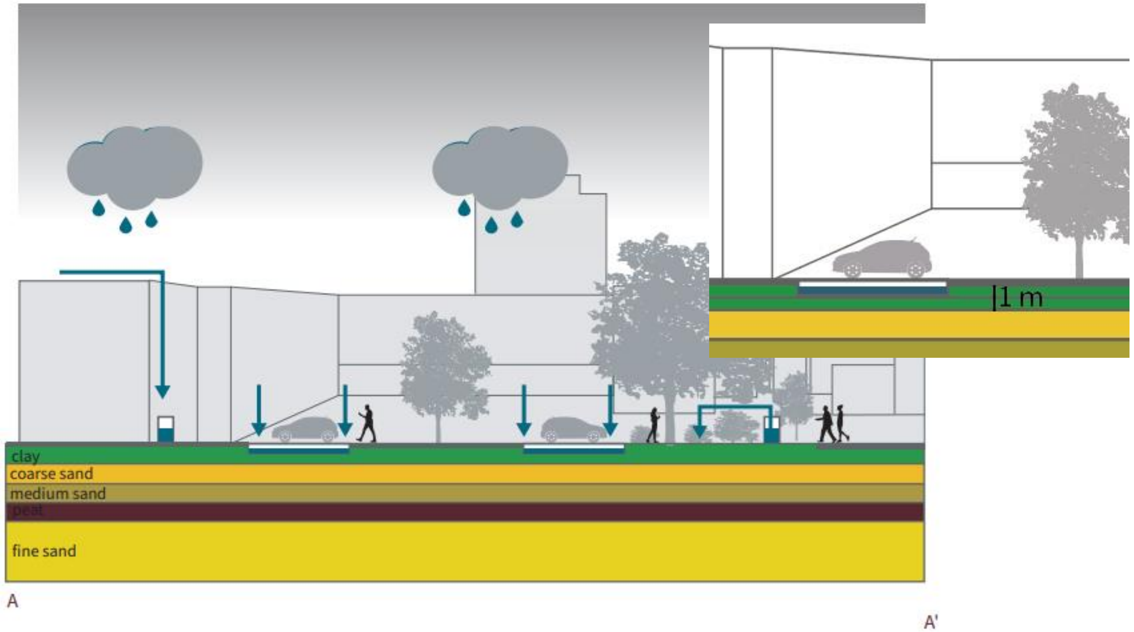
Area 3 (Kanaleneiland Noord): Adaptation Design Impression

Water Storage Under (Un)paved Surface

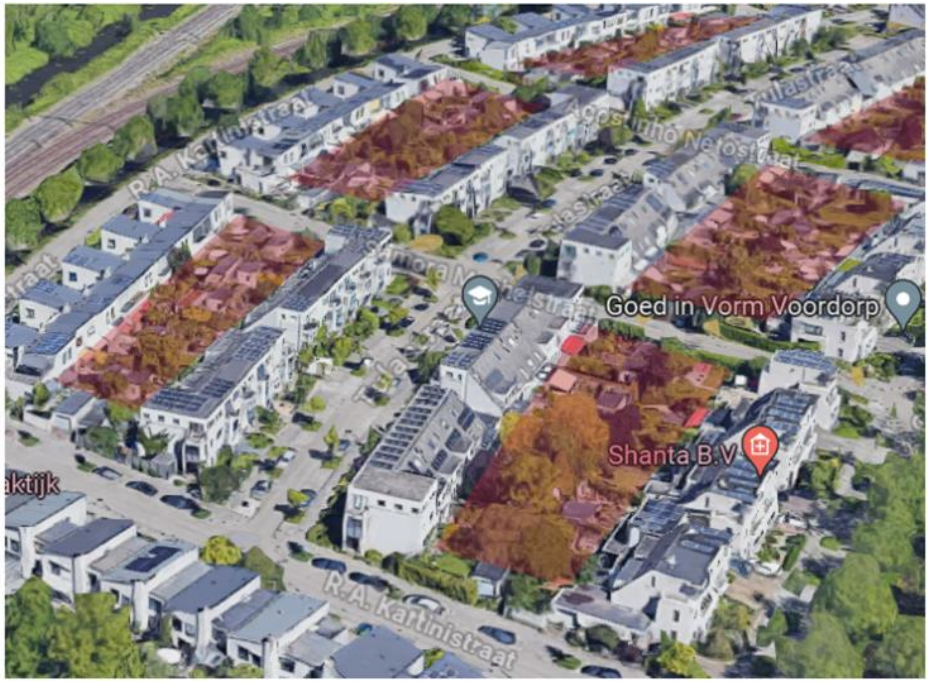
Green Garden

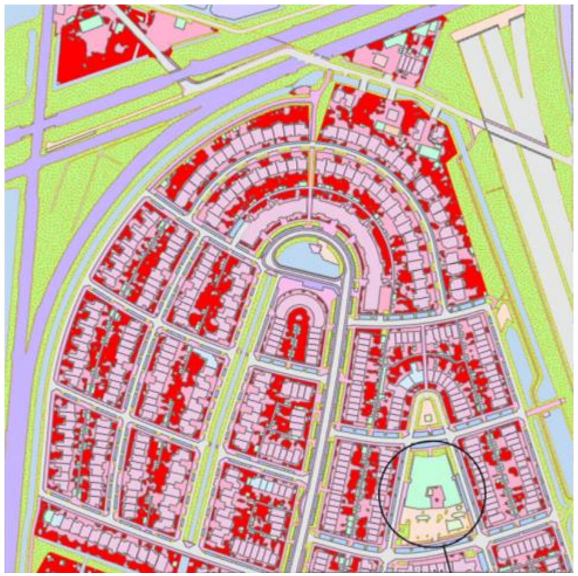
Rain Barrel

Area 3 (Kanaleneiland Noord): Adaptation to Waterlogging and Lack of Biodiversity

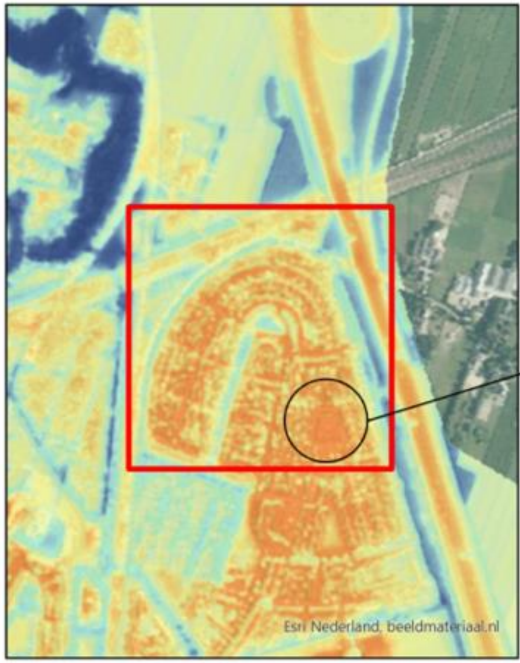


4) Voordorp: Context



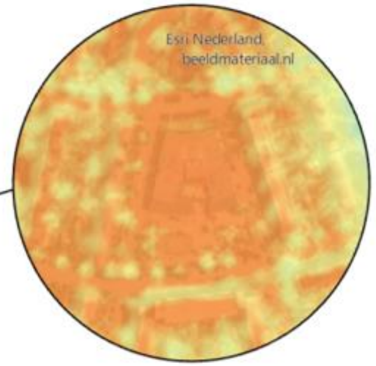


Heat: Air Temperature at 1.5 m on a heat wave (Scale 1:1000)



During a heat wave, the air temperature is higher on the public space around the local public school, the playground and the sports field.

Zoom Scale 1:3000



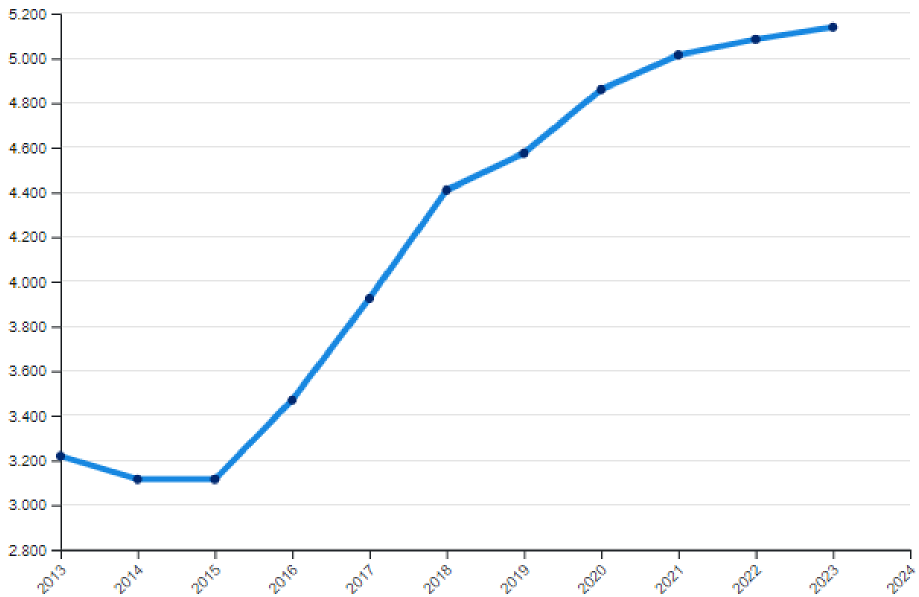
This higher air temperature is due to a lack of greenery in the area compared to the greenery from private gardens in the surrounding.

Waterlogging: Shower of 140 mm/2 hours (Scale 1:1000)

Zoom Scale 1:4500

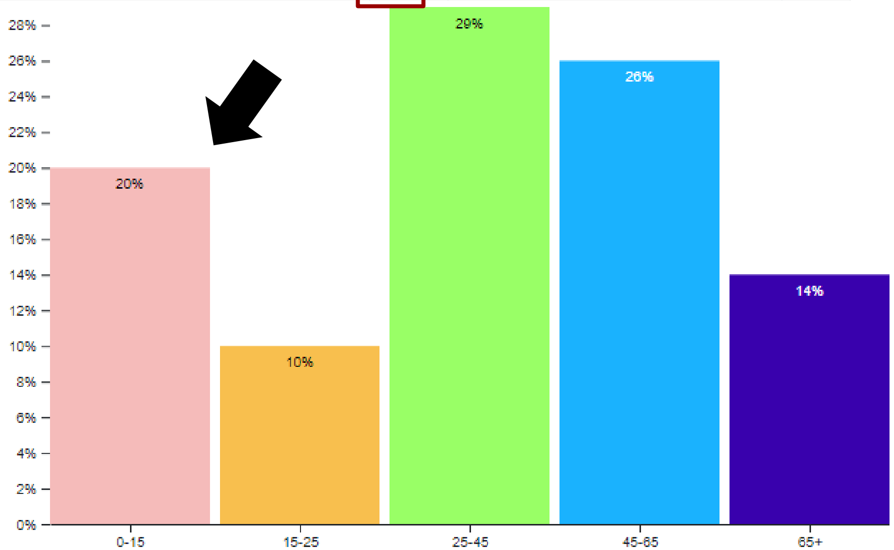
For the same reason, there is a waterlogging problem in the streets surrounding the local public school. This is aggravated by a tendency for waterlogging in the main street on the left.

4) Voordorp: Social



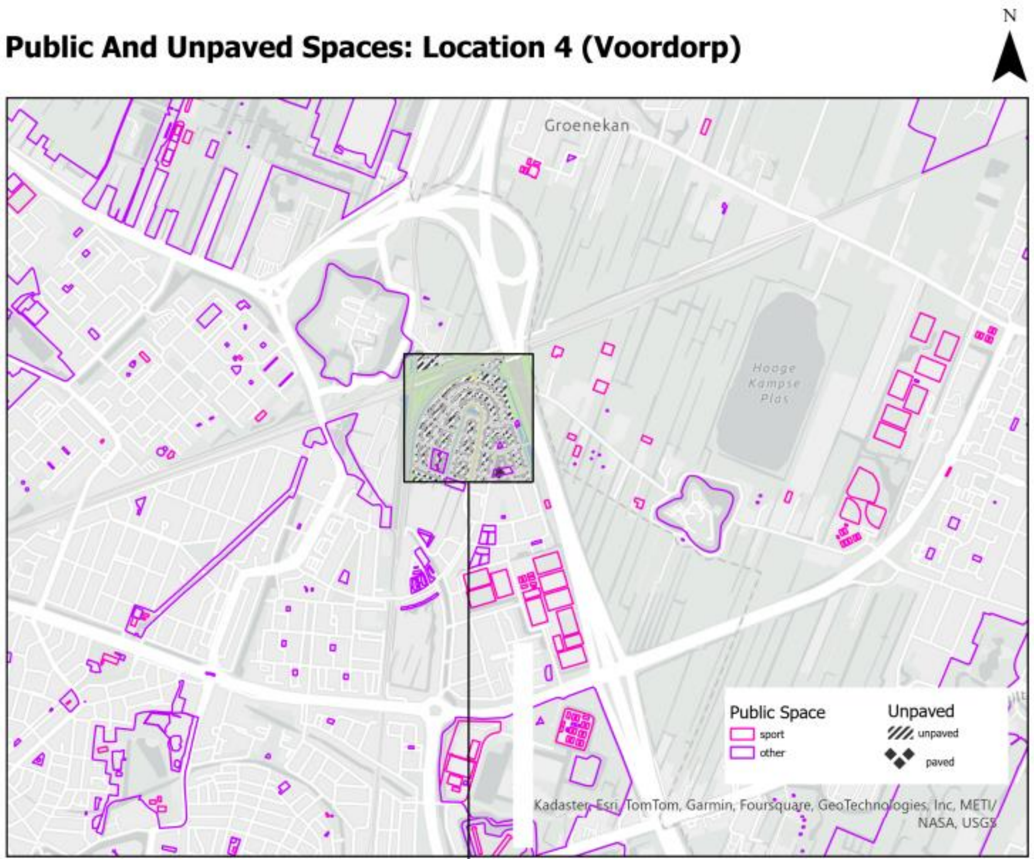
Population numbers in neighbourhood Voordorp en Voorveldsepolder in Utrecht in the Netherlands for the years 2013 thru 2023.

Births	85	number	2021
Births relative	17	number per 1000 inhabitants	2021

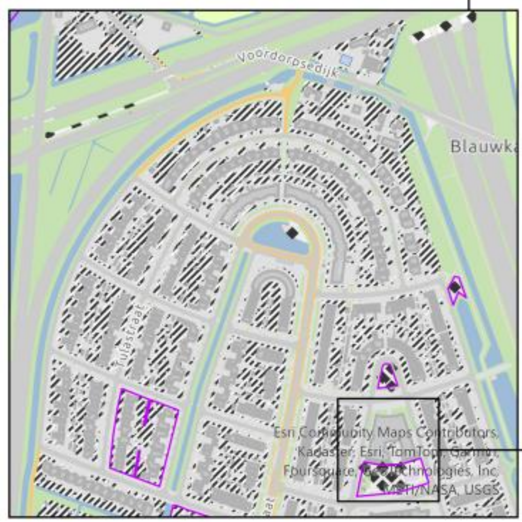


Neighbourhood Voordorp en Voorveldsepolder, 2023, age groups.

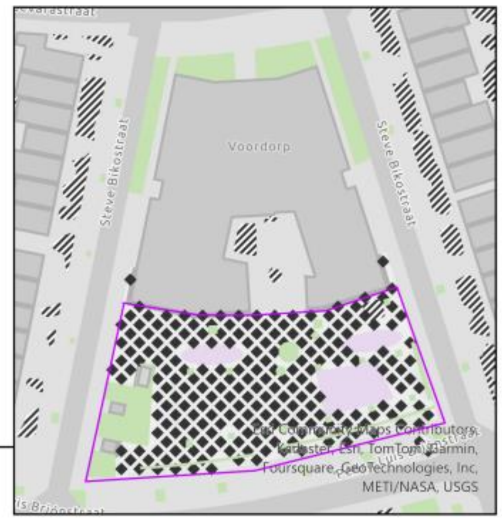
Public And Unpaved Spaces: Location 4 (Voordorp)



Public/Unpaved Spaces Level Macro (Scale: 1:20000)

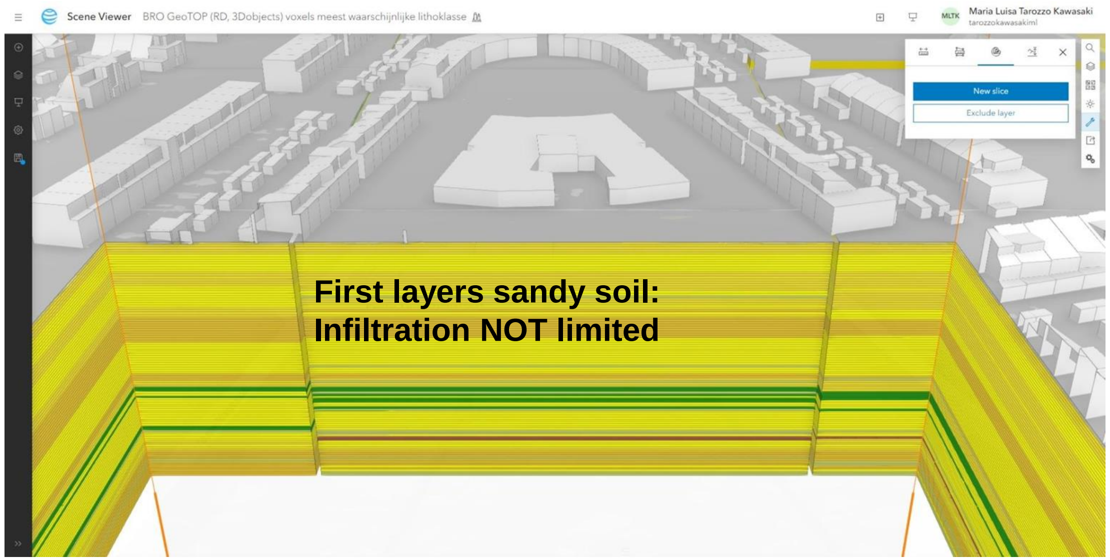


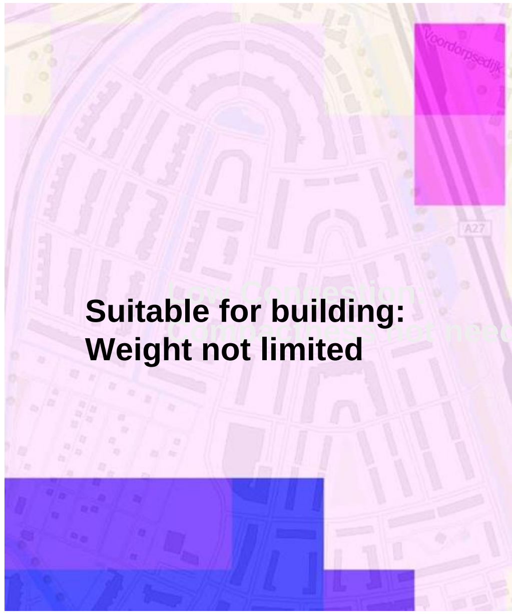
Public/Unpaved Spaces 500x500m (Scale: 1:5000)



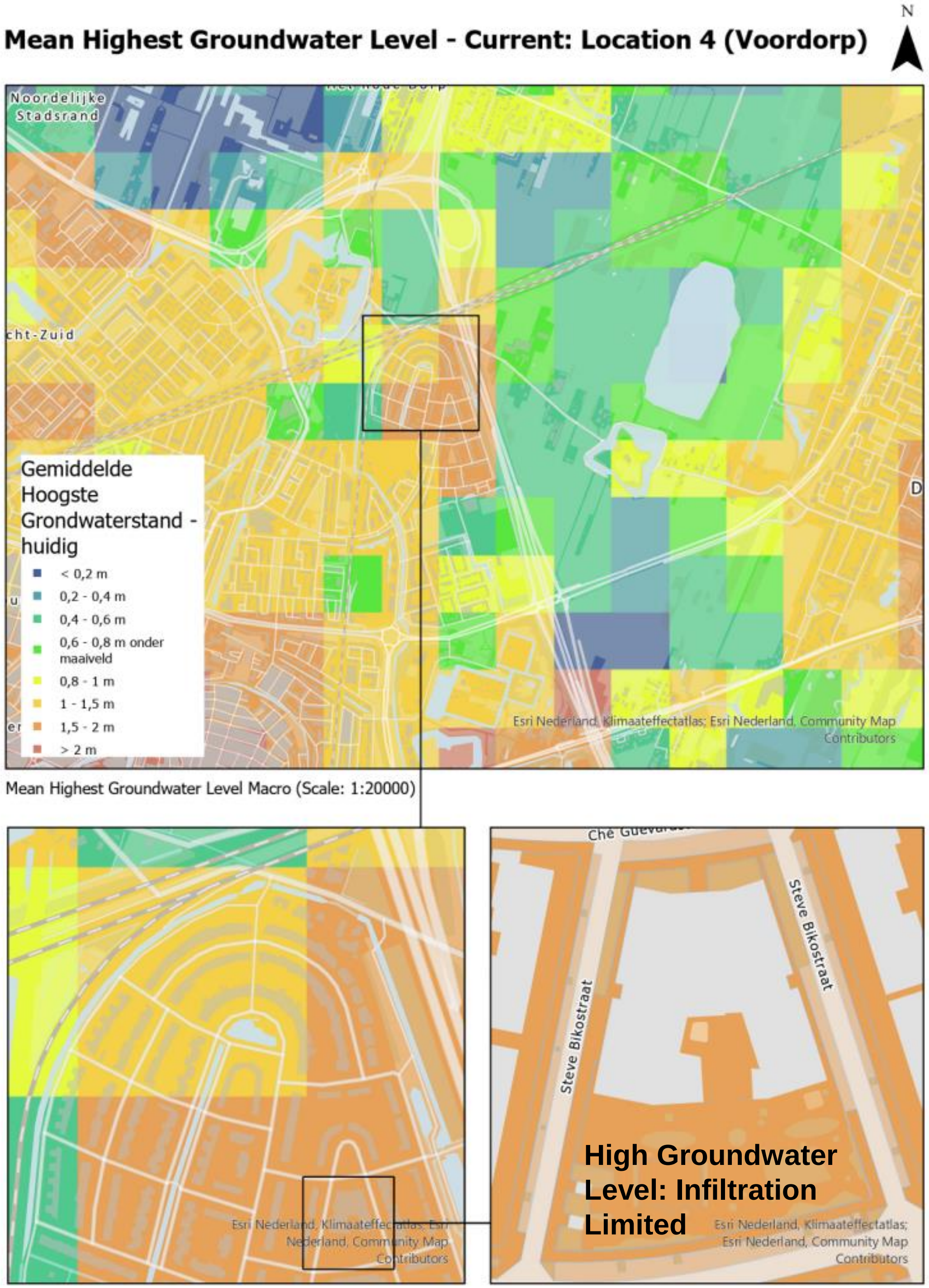
Public/Unpaved Spaces design area (Scale: 1:1000)

4) Voordorp: Subsurface





Mean Highest Groundwater Level - Current: Location 4 (Voordorp)

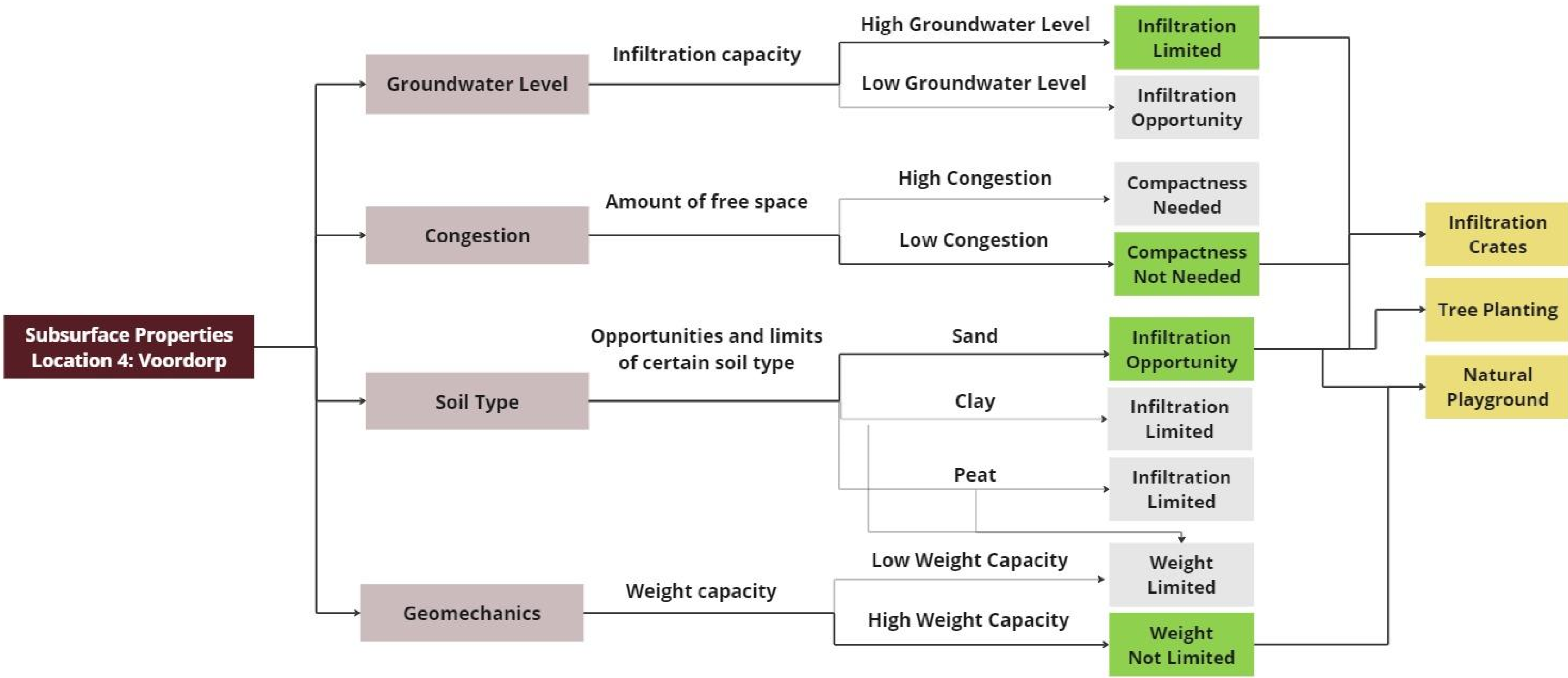


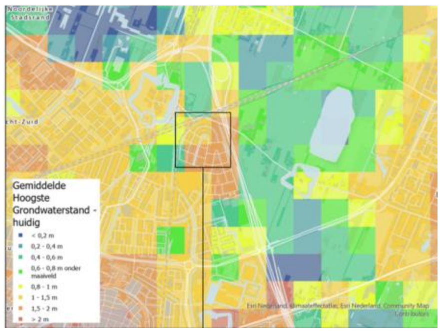
Mean Highest Groundwater Level Macro (Scale: 1:20000)

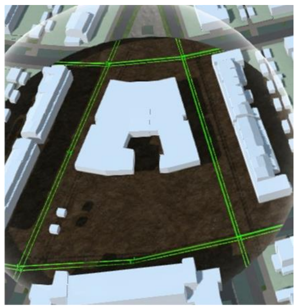
Mean Highest Groundwater Level 500x500m (Scale: 1:5000)

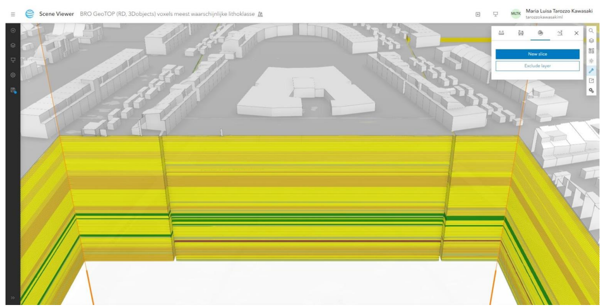
Mean Highest Groundwater Level design area (Scale: 1:1000)

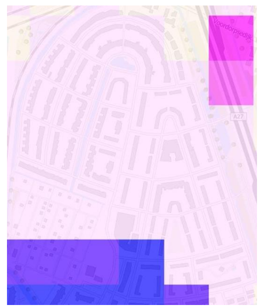
4) Voordorp: Design Decision Tree





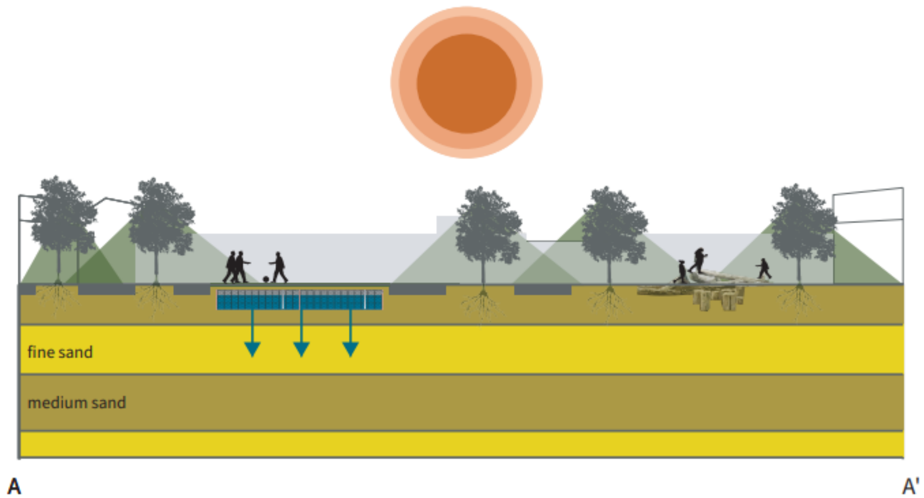






4) Voordorp: Design Proposal

Area 4 (Voordorp): Adaptation to Heat Stress

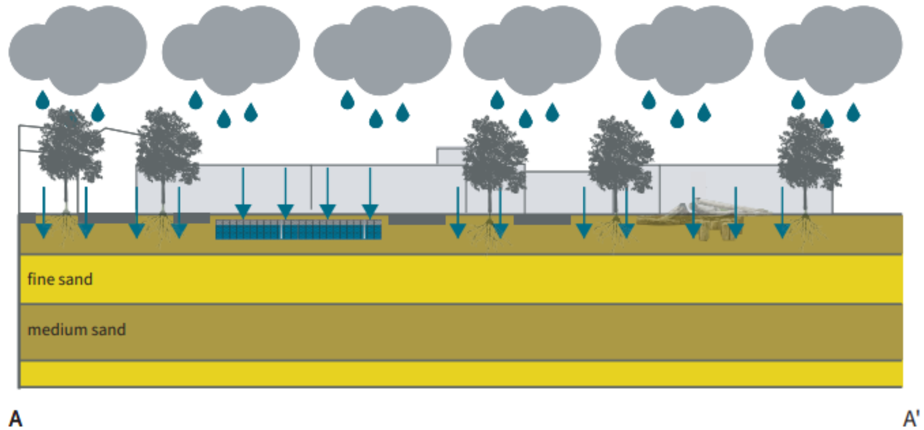


Tree Planting

Natural Playground

Infiltration Crates

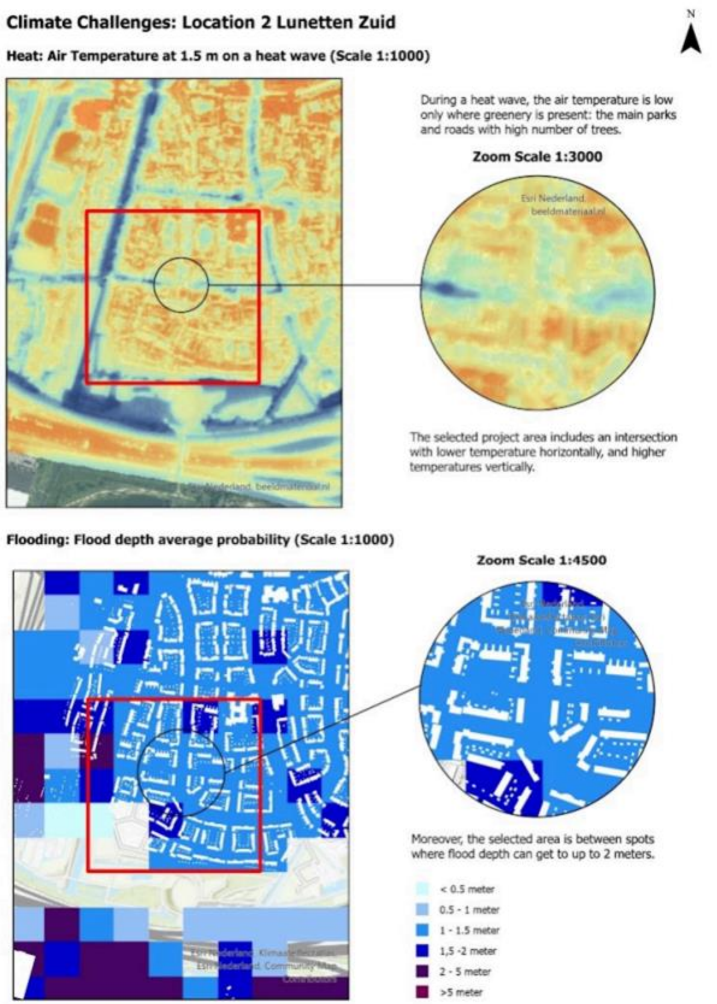
Area 4 (Voordorp): Adaptation to Waterlogging



VI. Design Evaluation

Online Survey

4. Considering that this area suffer from heat stress and tendency for flooding, which interventions would your climate adaptation design include? *
Choose 3 interventions.



Marque todas que se aplicam.

☐ Green Façade

☐ Façade Garden

☐ Green Garden

☐ Green Roof

☐ Green Fence

☐ Tree Planting

☐ Bird/Bat/Insect Box

☐ Rain Barrel

16 design proposal collected

10 students
6 professionals

Requested:

1) Select standardized interventions for design

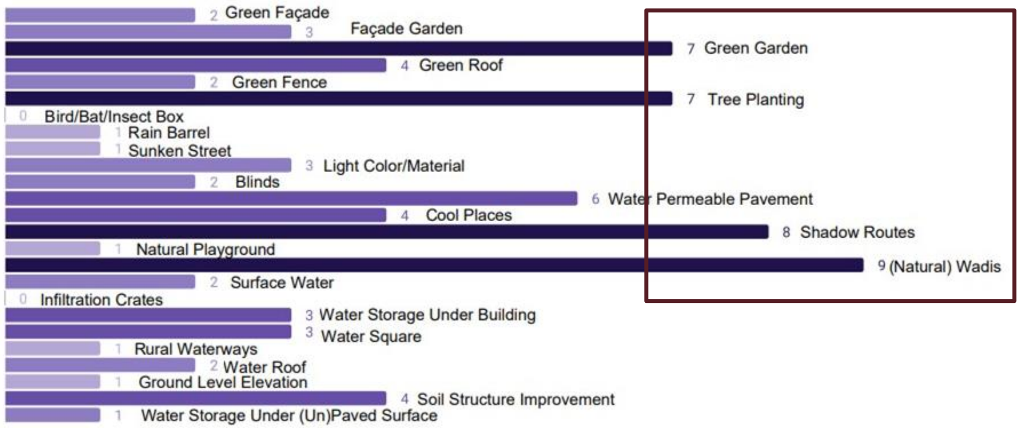
2) Justify selection

3) Identify information needs

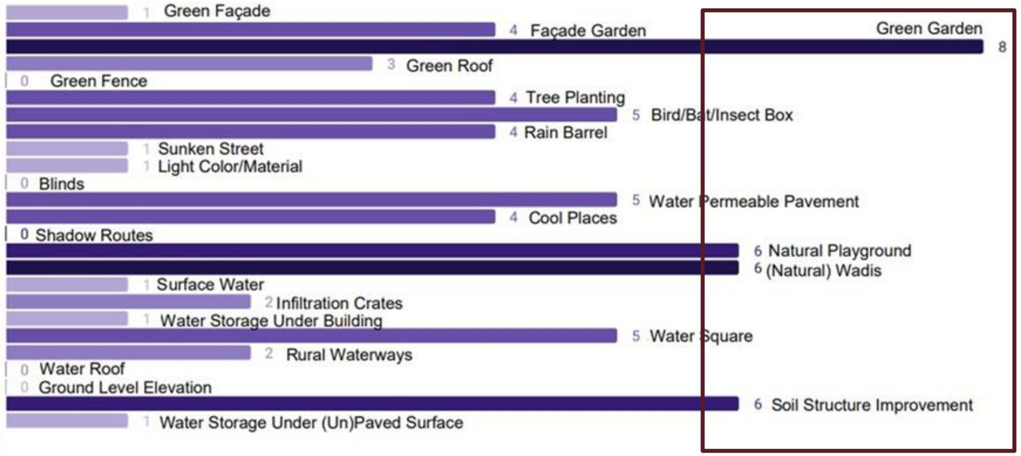
Survey Results

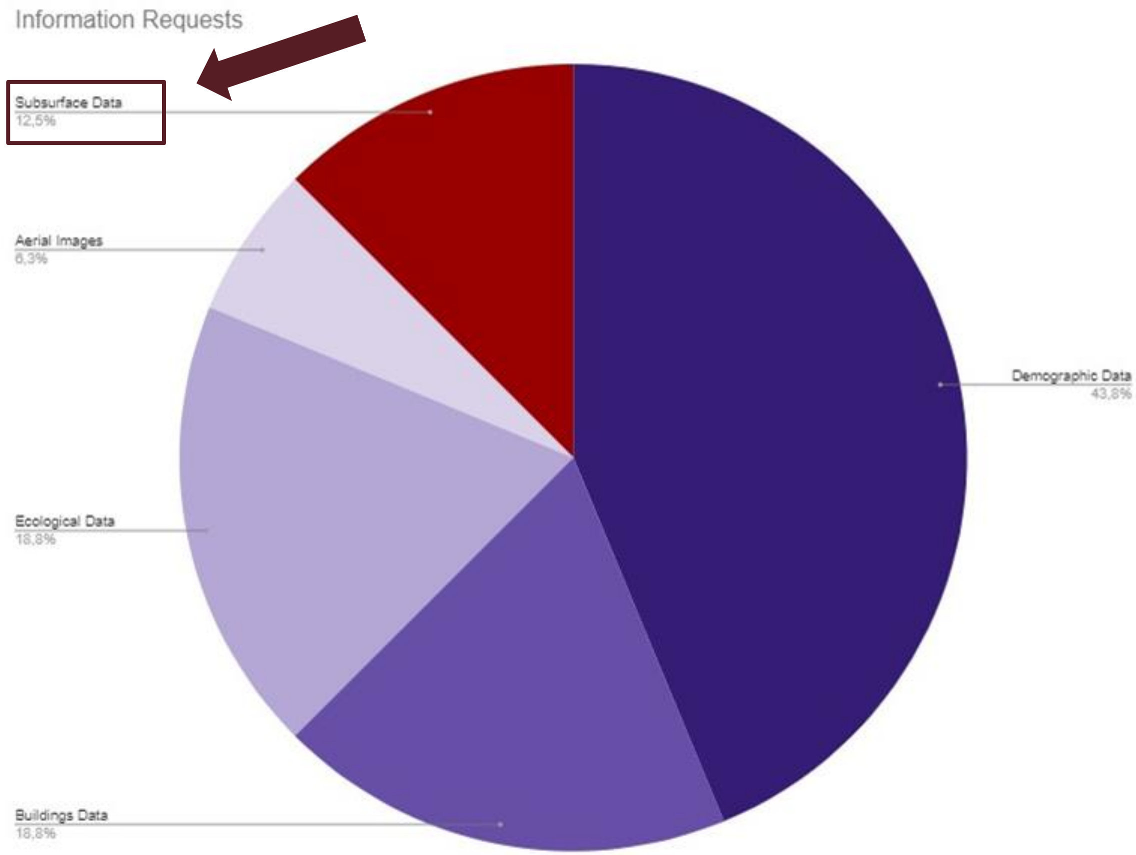
Only 12.5% of designs recognized the need for subsurface information

Results Lunetten Zuid



Results Kanaleneiland Noord





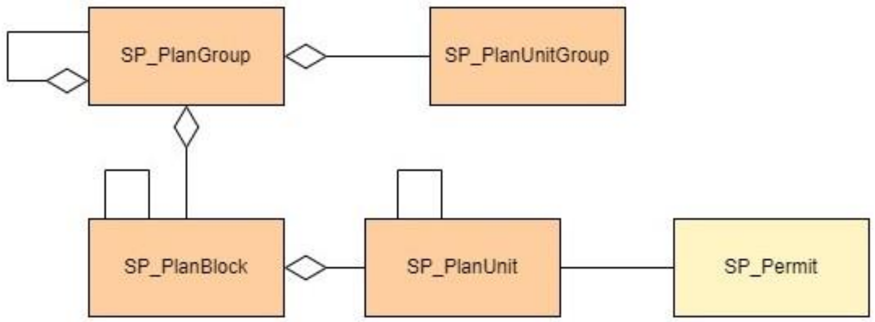
Increase greenery for natural infiltration but infiltration capacity is very low → Artificial Infiltration is more suitable

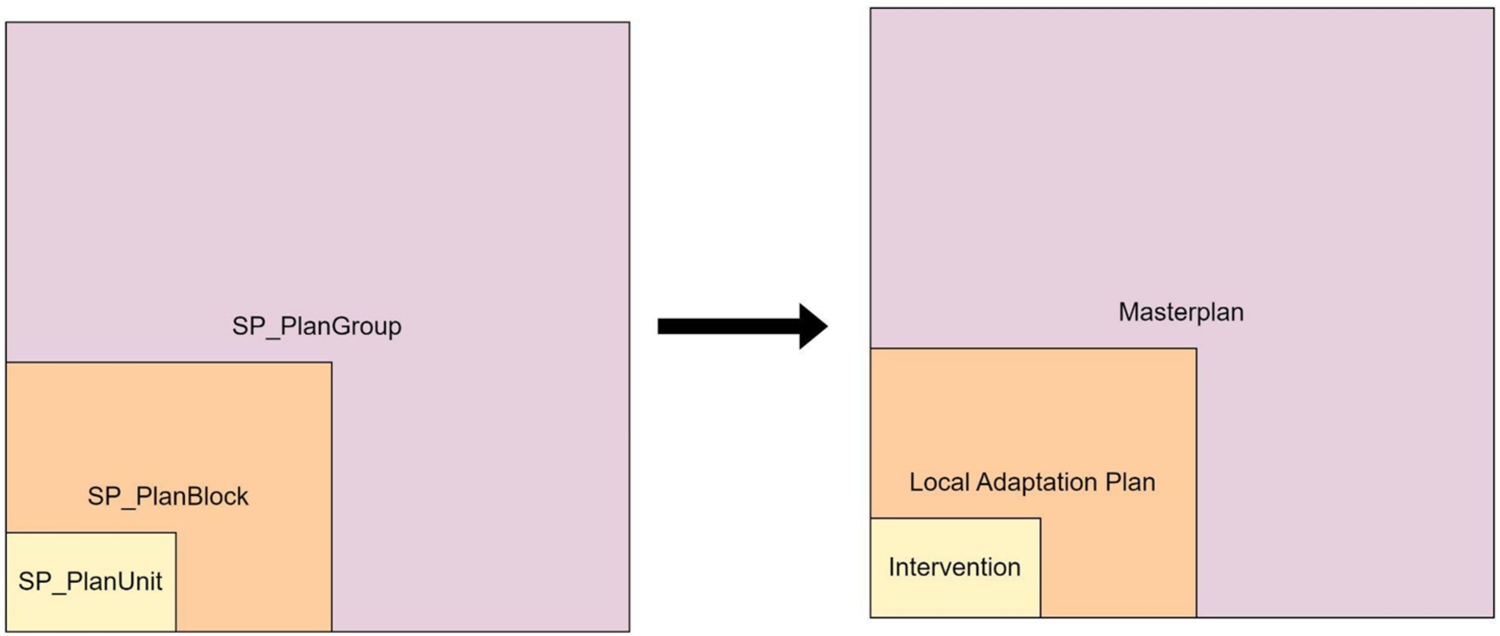
Increase trees for shadowing but trees require subsurface information → Artificial shadowing

Soil structure improvement NEEDS soil information→ Basic information need not provided

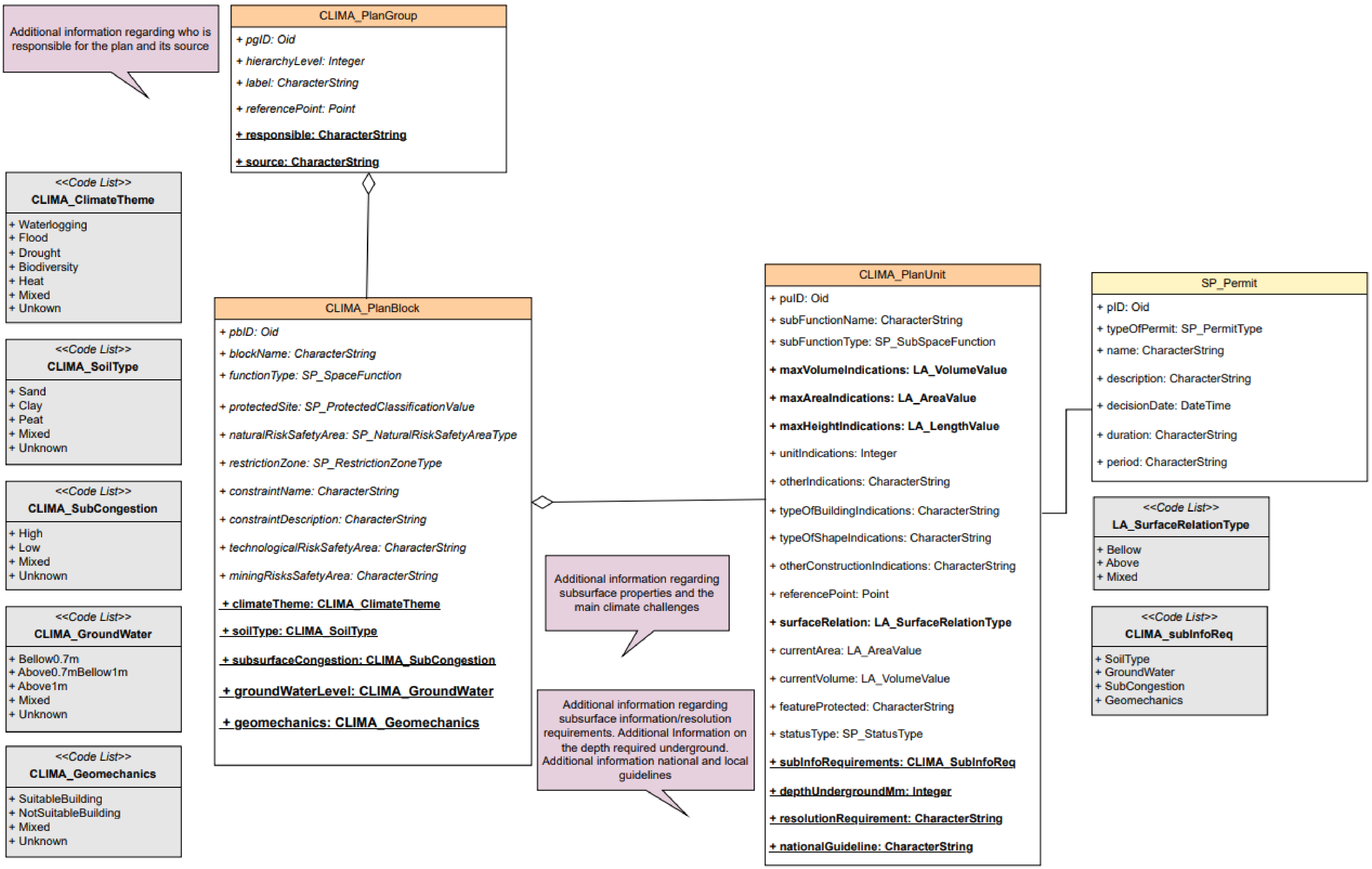
VII. Design Standardization

LADM Part 5 Climate Adaptation Subclasses





LADM Part 5 Climate Adaptation Subclasses



LADM Part 5 Climate Adaptation Subclasses

1) Storing masterplans (hierarchy) → CLIMA Plan Group

pgid	hierarchylevel	label	referencepoint	responsible	source
MU2040	1	Utrecht2040		Municipality Utrecht	Utrecht 2040

2) Storing local plans (made of interventions) → CLIMA Plan Block

pbid	blockname	functiontype	p...	naturalrisk...	r...	c...	c...	t...	m..	climatetheme	soiltype	su...	ground...	geomechanics	plangr...
UVoord001	VoordorpPlan001	cultivationPublicFacility		stormRiskZone						Waterlogging Heat	Sand	Low	Above1m	SuitableBuilding	MU2040

3) Storing climate adaptation interventions → CLIMA Plan Unit

puid	subfunctionname	subfun...	maxvol...	maxarea...	maxhei...	u...	o	t.	t.	o	r.	surfacerelation	currenta...	currentvol...	f.	statustype	subinforequirements	depthundergroundmm	resolutionrequirement	nationalguideline	localguideline	planblock_id
InfiltrationCrates	underPlayground	education	190	159	1							Bellow	159	0		inUse	GroundWater SoilTyp...	1000	0.5x0.5x0.5	Maatlat	N1 N2 N3 D1 D2	UVoord001
TreePlanting	treePlayground	education	1	1	10							Mixed	0	0		inUse	Geomechanics SoilTy...	1500	0.5x0.5x0.5	Maatlat	B1 B2 B3 H1 H2	UVoord001
NaturalPlayground	naturalPlayground	education	250	120	3							Mixed	120	232		inUse	SoilType SubCongesti...	500	0.5x0.5x0.5	Maatlat	B1 B2 B3 N1 D1	UVoord001

VIII. Conclusion

Conclusions

WHY?

1) Climate adaptation strategies **rely heavily on subsurface information**, in particular nature-based adaptation.

2) Four main subsurface properties: **groundwater level, subsurface congestion, soil type and geomechanics.** They can be used as basis for model suitability assessment.

3) Subsurface models always present **uncertainty.**

Theory

WHAT?

4) Interventions with **water infiltration almost always require information regarding the soil type**

5) Interventions that are a **3D element** benefit from **a model of underground in 3D** (simulate placement).

6) Potential improvement of the existing models is related to the **resolution** and the **necessity of interpretation**.

7) Some **subsurface properties benefit more from 3D instead of 2D.** The benefits of a 3D for properties with dependency of sections vs. singular numerical value.

8) The **existing information models were sufficient**, but only for preliminary design.

Assessment

HOW?

9) **Standards** are useful to integrate different models and to exchange information.

10) **LADM Part 5 subclasses** can support climate adaptation design.

11) **Relational diagrams and databases** are useful to represent relationships (roadmap), for selecting elements with specific properties (query), and to store information.

12) The same is true for the use of an **online catalog**, which combines different information in one single place.

13) Designers still underestimate the necessity for subsurface information in climate adaptation design.

Tools

Recommendations

1. The thesis points to **potential new tools and models** tailored for climate adaptation design.

2. **CPT data interpretation methods** can be used to increase data resolution and accuracy.

3. The average highest groundwater level can be modeled using interpolation and added as **3D layer into the soil type model** (relevant for water infiltration) or as a separate model.

4. Using LADM Part 5 subclasses **information of a real plan** (geometry) can be loaded using tools such as FME

5. The inclusion of **3D buildings** is very helpful for models tailored for design purposes.

6. Web viewers are useful to users with few/none GIS experience to interact with the models.

Reflection

The primary constraint of this study is related to its potential: its ***interdisciplinary nature****. It showcases not only the benefits and drawbacks of an interdisciplinary approach to climate adaptation, but also of an interdisciplinary thesis.*

Thank you!

Thesis in a nutshell:

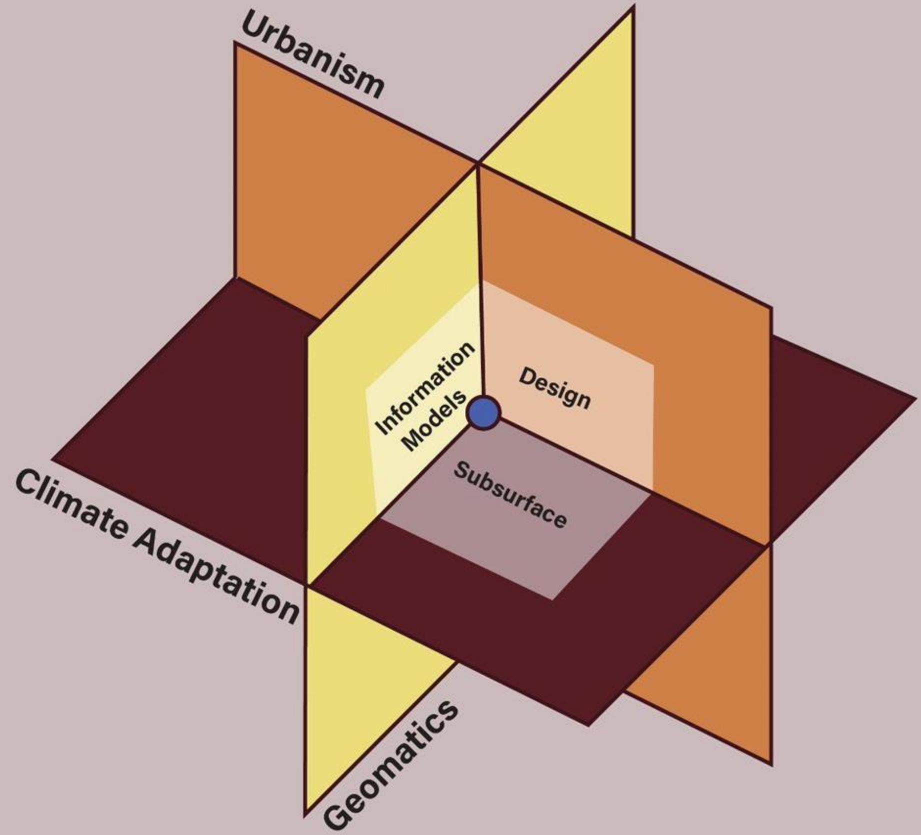
1. Subsurface (3D) information models can support standardized local climate adaptation design.
2. This thesis provides **theoretical and practical foundation** for this integration. → **Common Ground**
3. It **assesses** the suitability of existing models through **theory and design**.
4. It **provides tools** to support integration: **UML Diagram, Relational Databases, LADM Part 5 Subclasses and Online Catalog**.
5. **Four design proposals** in the city of Utrecht are used to **exemplify** this integrated approach.

Common Ground:

Bridging Subsurface Information Models and Climate Adaptation Design

Double Degree Graduation Thesis (Geomatics and Urbanism)

Maria Luisa Tarozzo Kawasaki (5620341)
Mentors TU Delft: Peter van Oosterom (Geomatics), Ulf Hackauf (Urbanism), Alex Wandl (Urbanism)
Mentors External: Rob van der Krogt (TNO), Wilfred Visser (TNO)



TU Delft

TNO innovation for life