

P5

Towards Living with Water

In search of new perspectives towards living with the increasing risk of flooding in the densifying outer dike area of the urban center of Rotterdam

J.E.H. Grevink

Architectural Engineering

2020-2021

Under supervision of:

Delft University of Technology

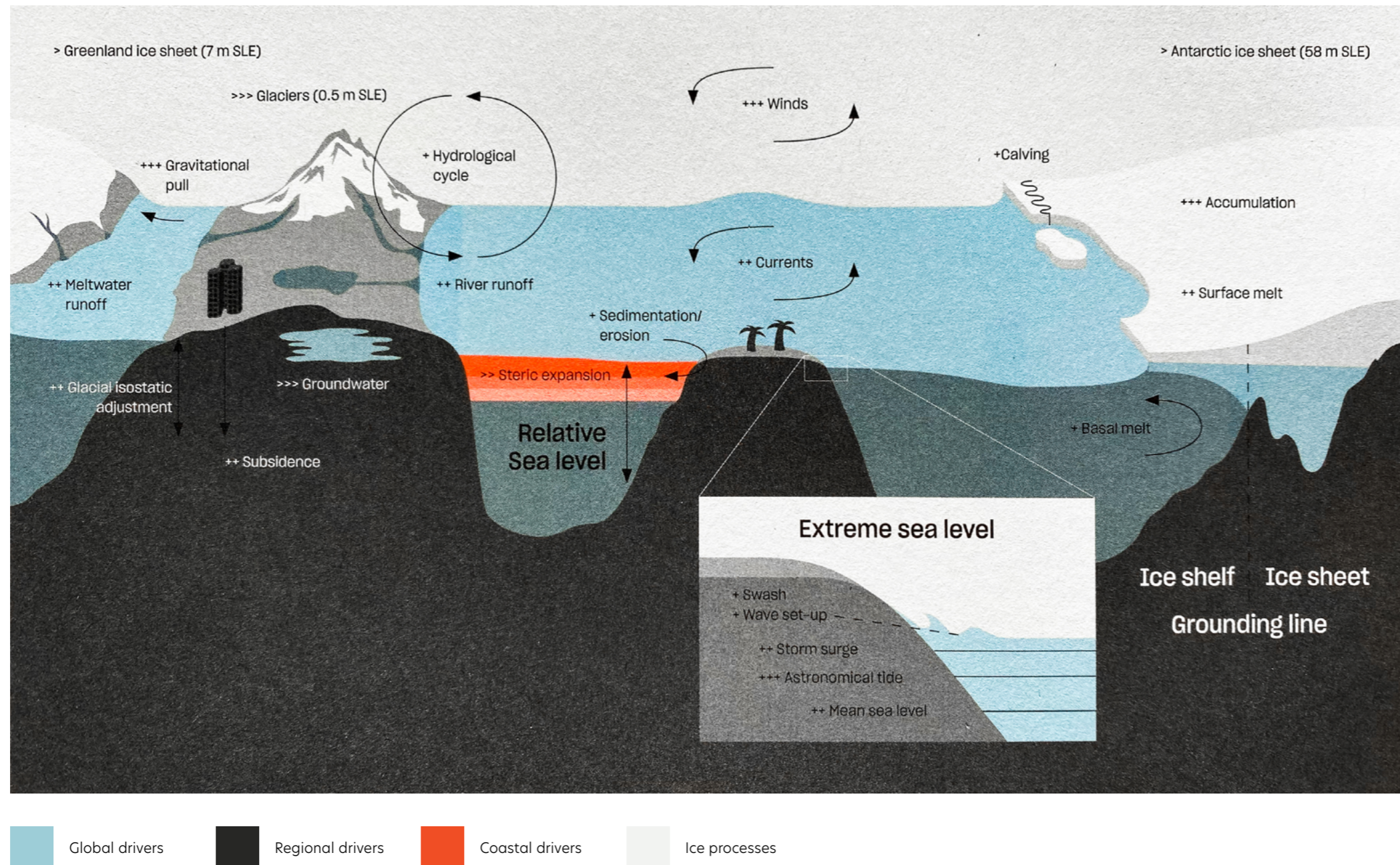
Dr. F.L. Hooimeijer / M. Parravicini / Ir. P.L. Tomesen / Ir. E.J. van der Zaag





1. Kiribati, Oceania, 2012. © Kadir van Lohuizen / NOOR

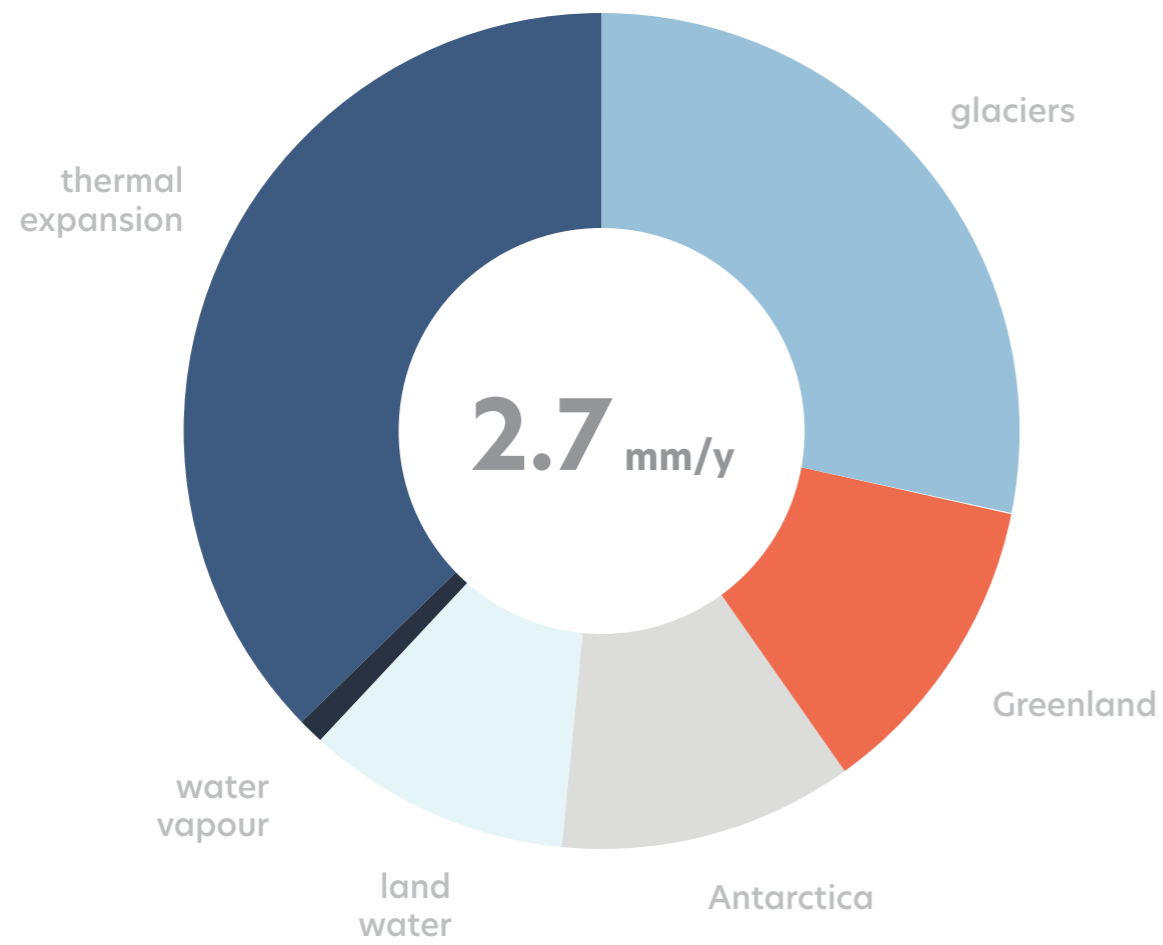
GLOBAL CAUSES



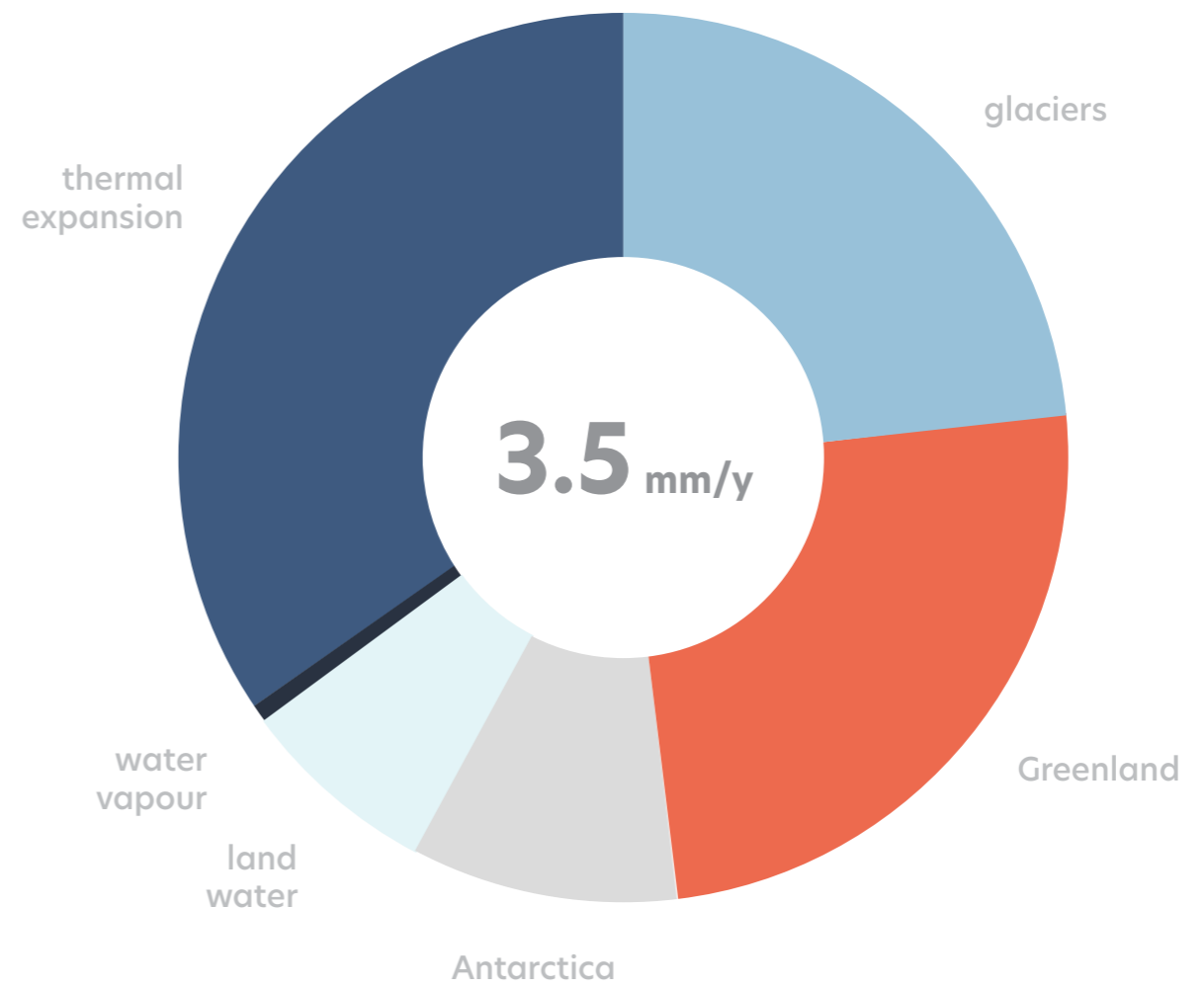
2. Schematic illustration of the climate and non-climate driven processes that can influence global, regional, relative and extreme sea level events along coasts (Oppenheimer et al., 2019)

ANNUAL SEA LEVEL RISE

1993 - 2004



2004 - 2015



3. Sea level rise contributors, own illustration based on (World Meteorological Organization, 2018)

Bangladesh



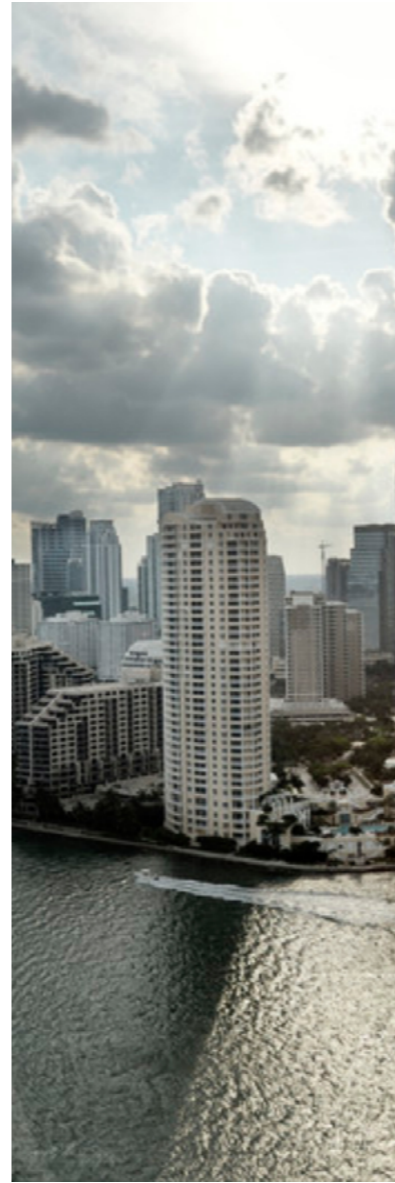
Fiji | Kiribati



SIDS
(small island development states)



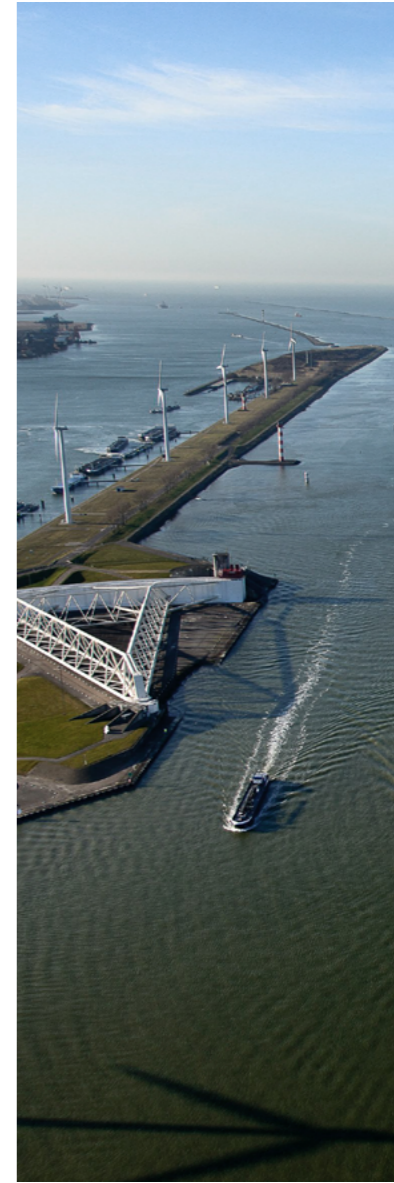
United States
(east coast)



United Kingdom



The Netherlands



The New York Times

The Dutch Have Solutions to Rising Seas. The World Is Watching.



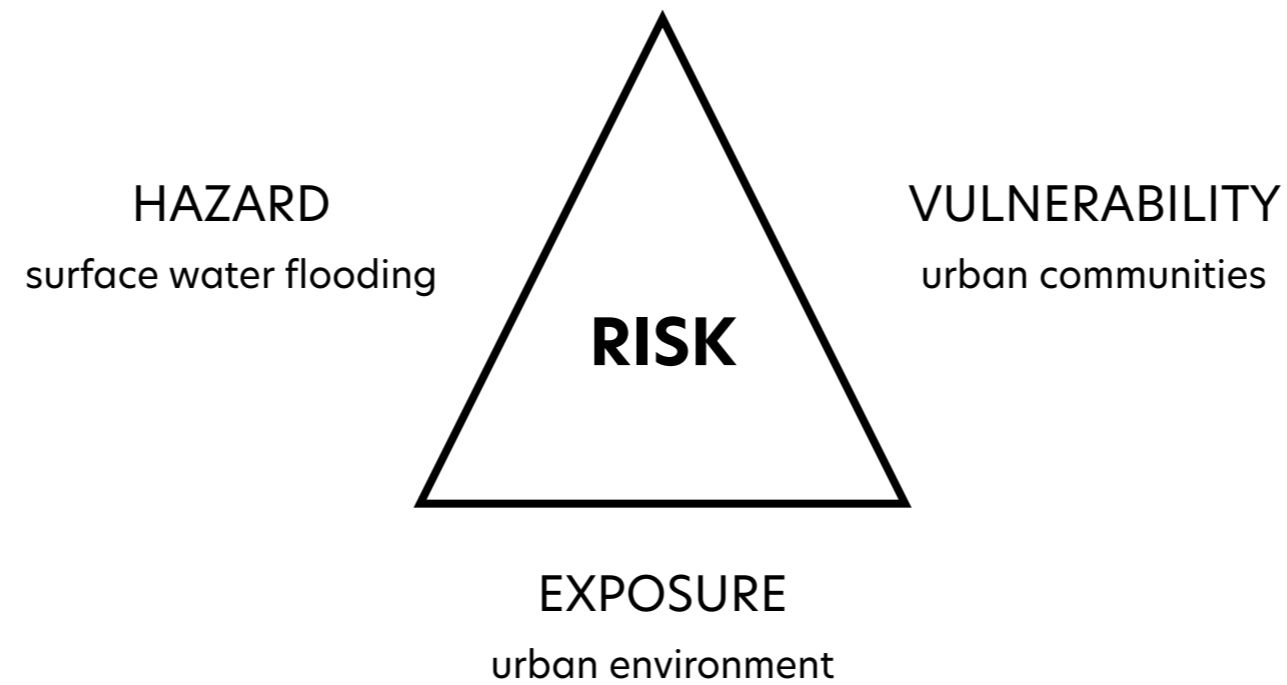
In the waterlogged Netherlands, climate change is considered neither a hypothetical nor a drag on the economy. Instead, it's an opportunity.

By MICHAEL KIMMELMAN, Photographs by JOSH HANER
JUNE 15, 2017

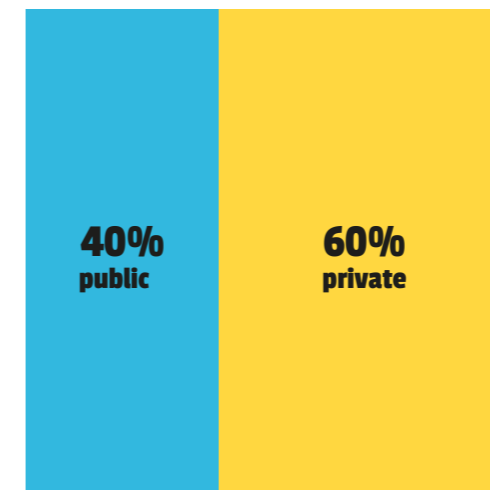
ROTTERDAM, the Netherlands — The wind over the canal stirred up whitecaps and rattled cafe umbrellas. Rowers strained toward a finish line and spectators hugged the shore. Henk Ovink, hawkish, wiry, head shaved,

$$R = C \cdot P$$

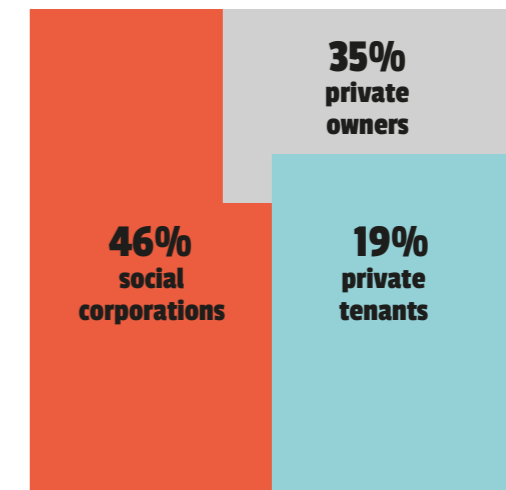
$$\text{FLOOD RISK} = \text{VALUES AT RISK | VULNERABILITY} \cdot \text{PROBABILITY}$$



$$R = C \cdot P \quad \text{FLOOD RISK} = \text{VALUES AT RISK | VULNERABILITY} \cdot \text{PROBABILITY}$$



Ownership in Rotterdam

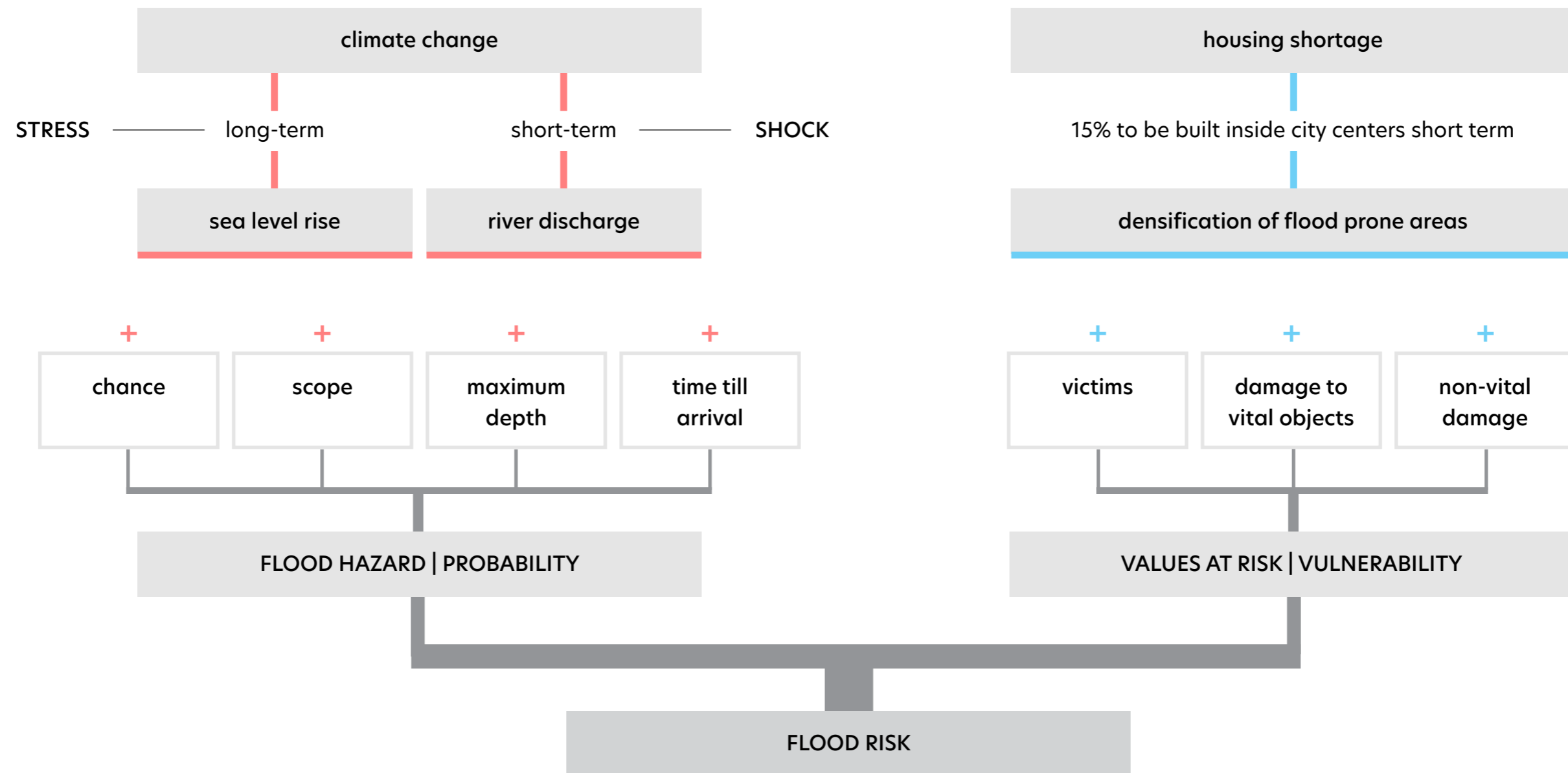


Home ownership in Rotterdam

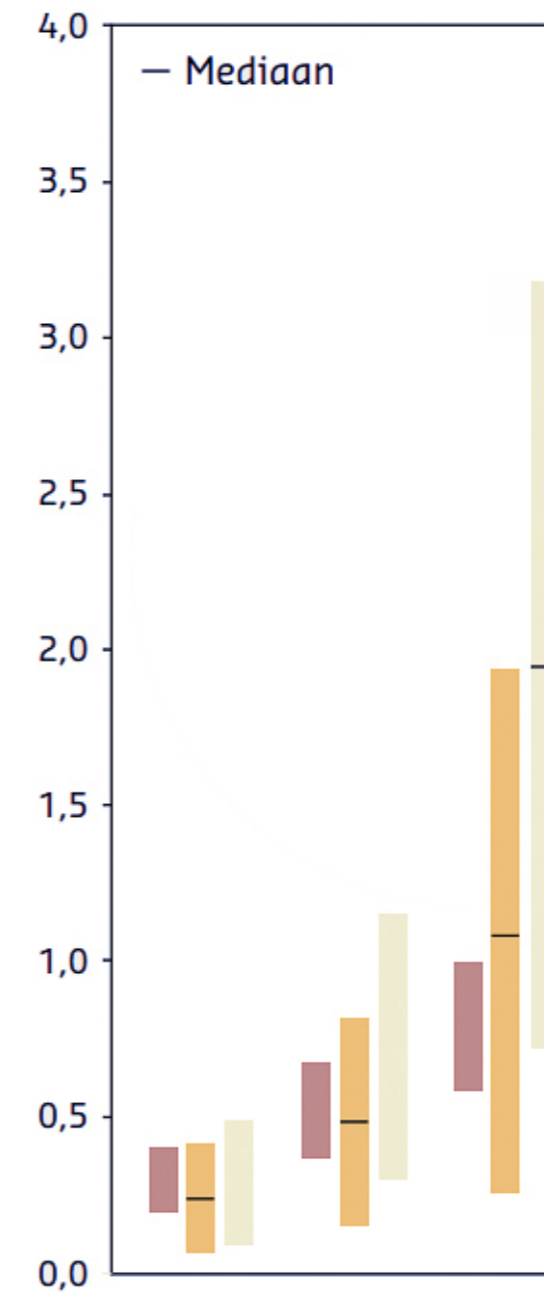
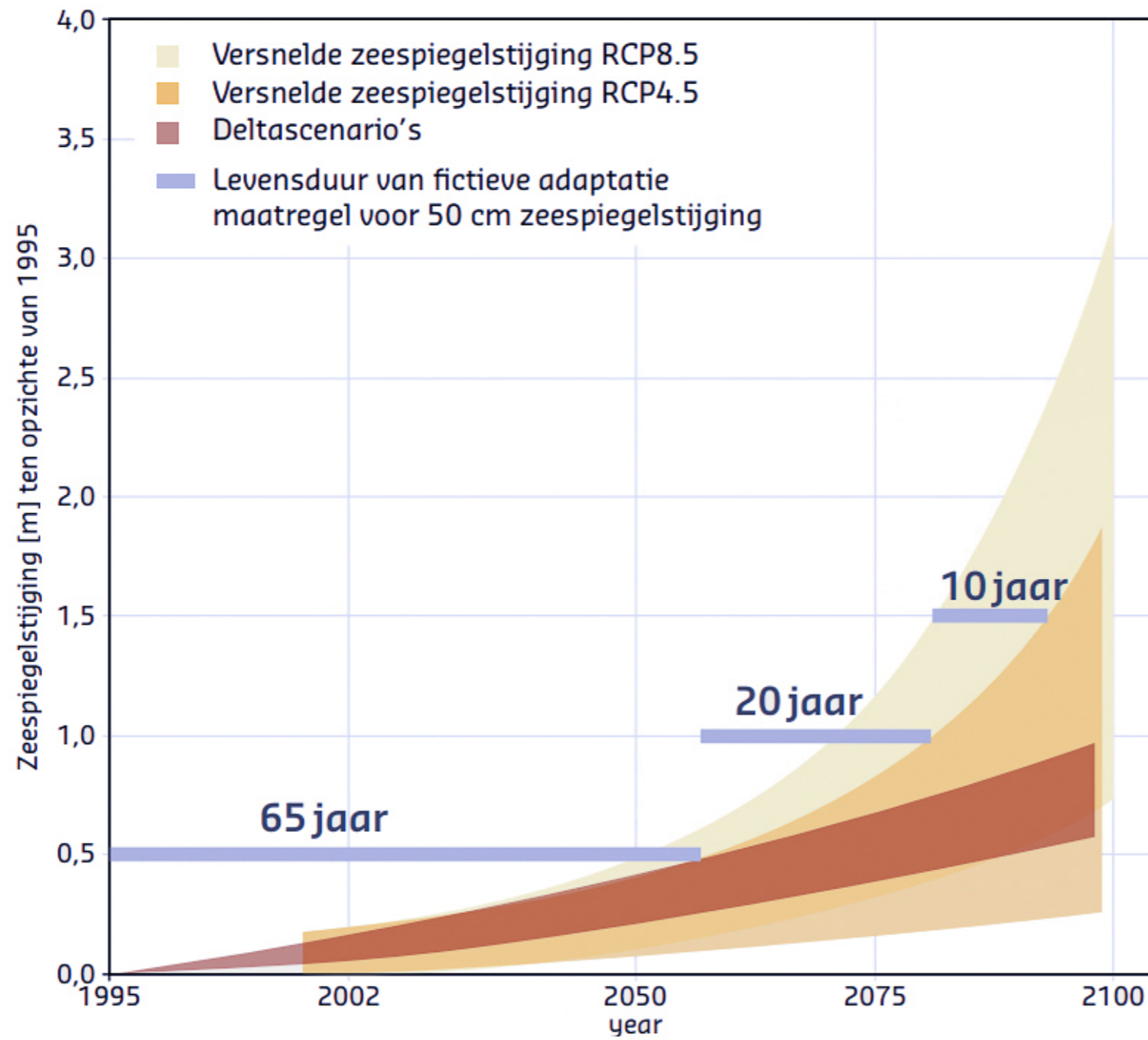
7. Partnership for risk reduction, illustration edited from (Kron, 2005)

8. Proportion of public and private ownership in Rotterdam (Gemeente Rotterdam, 2020)

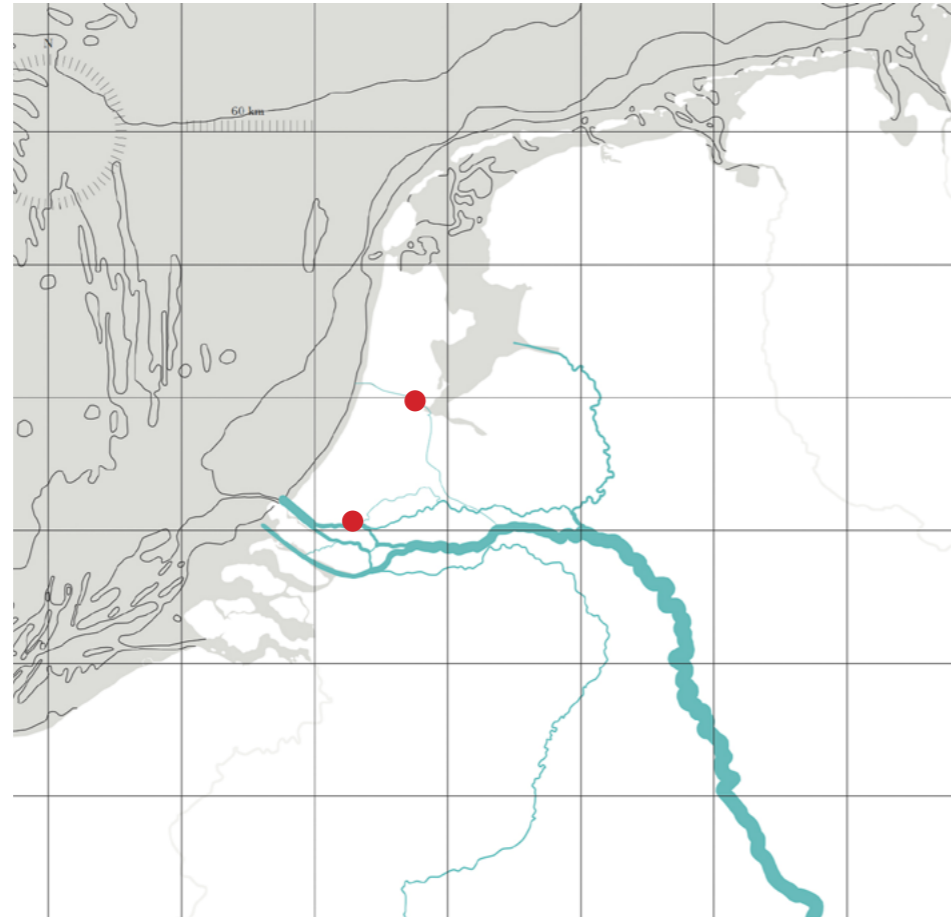
DEPENDENCIES INFLUENCING FLOOD RISK



FUNCTIONAL LIFESPAN OF ADAPTATION MEASURES



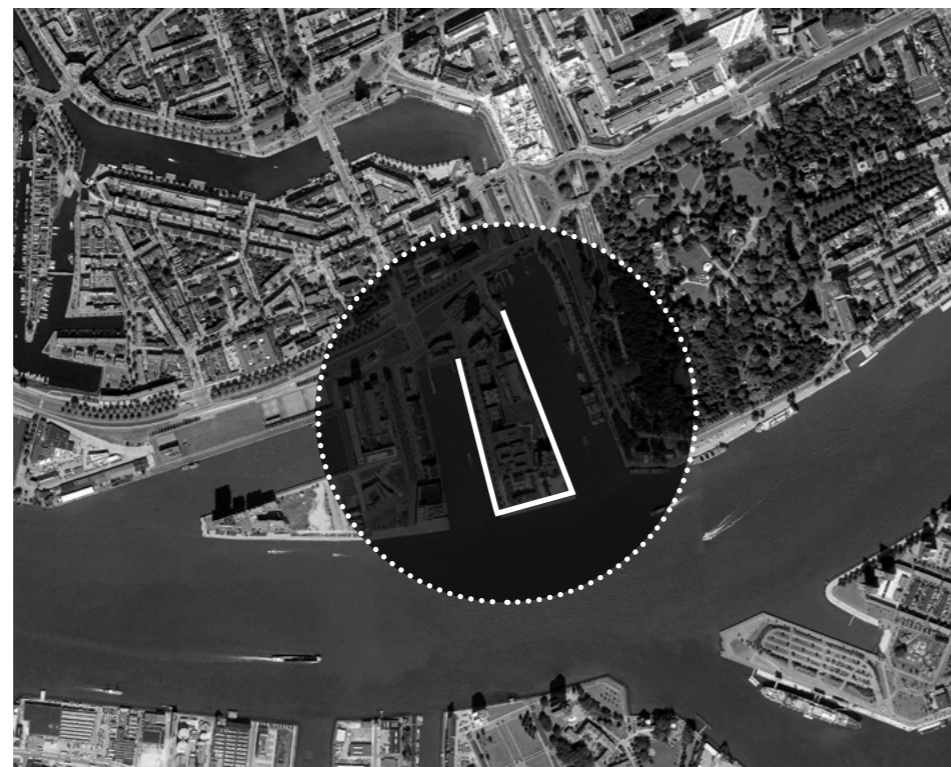
9. Reduction of the functional lifespan of adaptation measures to 0.5 m sea level rise (Haasnoot, 2018)



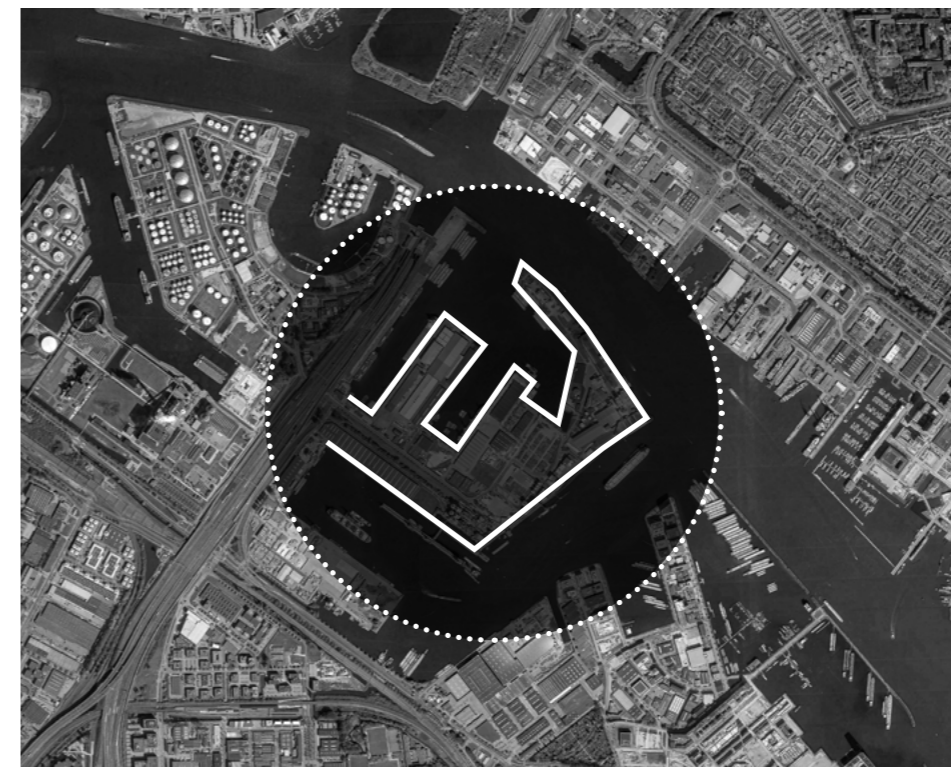
10. Distribution of river water discharge in The Netherlands, edited from (van der Meulen, 2018)

Functioneel woningmarktgebied	Binnenstedelijk			Aandeel binnenstedelijk in totaal aantal woningen in plannen		
	2020 t/m 2024	2025 t/m 2029	2020 t/m 2029	2020 t/m 2024	2025 t/m 2029	2020 t/m 2029
	Groningen	12.700	2.400	15.200	70%	36%
Leeuwarden	nb	nb	nb	nb	nb	nb
Heerenveen	nb	nb	nb	nb	nb	nb
Emmen	nb	nb	nb	nb	nb	nb
Zwolle	nb	nb	3.500	nb	nb	33%
Enschede	nb	nb	4.900	nb	nb	64%
Lelystad	6.300	4.600	14.200	100%	100%	87%
Apeldoorn	nb	nb	6.000	nb	nb	62%
Doetinchem	nb	nb	2.300	nb	nb	67%
Arnhem	nb	nb	8.800	nb	nb	77%
Nijmegen	1.500	500	9.300	74%	72%	51%
Ede	nb	nb	11.000	nb	nb	62%
Amersfoort	nb	nb	17.100	nb	nb	80%
Utrecht	nb	nb	78.800	nb	nb	95%
Alkmaar	22.600	10.600	33.200	92%	92%	92%
● Amsterdam	119.400	93.500	215.200	95%	94%	95%
Gouda	9.900	1.200	11.600	84%	29%	68%
Leiden	13.700	2.100	15.900	75%	35%	65%
Den Haag	44.600	14.400	59.000	91%	85%	89%
● Rotterdam	42.900	16.100	58.900	90%	80%	87%
Dordrecht	6.900	1.200	8.100	95%	81%	92%
Middelburg	8.500	2.700	11.200	98%	98%	98%
Roosendaal	5.200	2.500	7.700	76%	79%	77%
Breda	10.600	5.000	15.600	77%	75%	76%
Tilburg	9.400	2.300	11.700	73%	48%	66%
's Hertogenbosch	6.900	2.600	10.700	67%	49%	57%
Oss	6.500	1.400	7.900	59%	39%	54%
Eindhoven	20.400	7.100	27.600	71%	59%	67%
Venlo	nb	nb	10.800	nb	nb	94%
Sittard	nb	nb	5.900	nb	nb	98%
Maastricht	nb	nb	4.100	nb	nb	99%
Nederland	348.200	170.400	686.700	86%	81%	83%

11. Amount and share of inner-city plans by functional housing market area, from 2020 till 2029, edited from (Groenemeijer et al., 2020)



12. Soon to be redeveloped inner-city port area of the Parkhaven/Sint Jobshaven, Rotterdam, edited from (Google Earth, 2020)



13. Soon to be redeveloped inner-city port area of the Coenhaven, Amsterdam, edited from (Google Earth, 2020)



14. Watervilla IJburg 2, Amsterdam (Waterstudio, 2008)



15. Havenlofts Nassouhaven, Rotterdam (PDA, 2020)



16. Schoonschip, Amsterdam (Schoonschip, 2020)

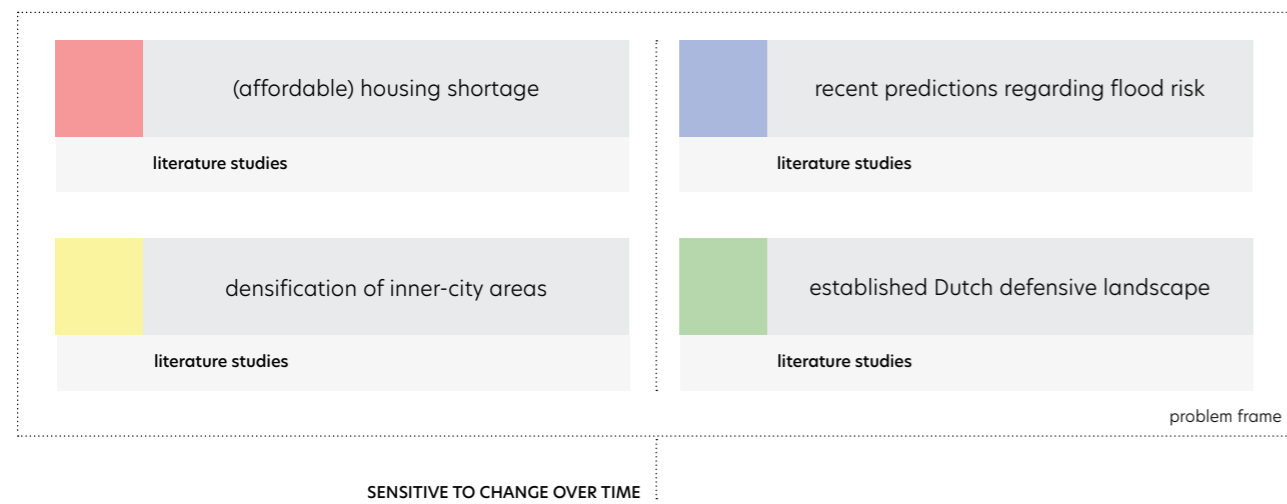


17. Waterwoningen IJburg, Amsterdam (Rohmer, 2008)



18. Schoonschip, Amsterdam (Schoonschip, 2020), Top-Up Amsterdam (FRANTZEN et al, 2020)

RESEARCH



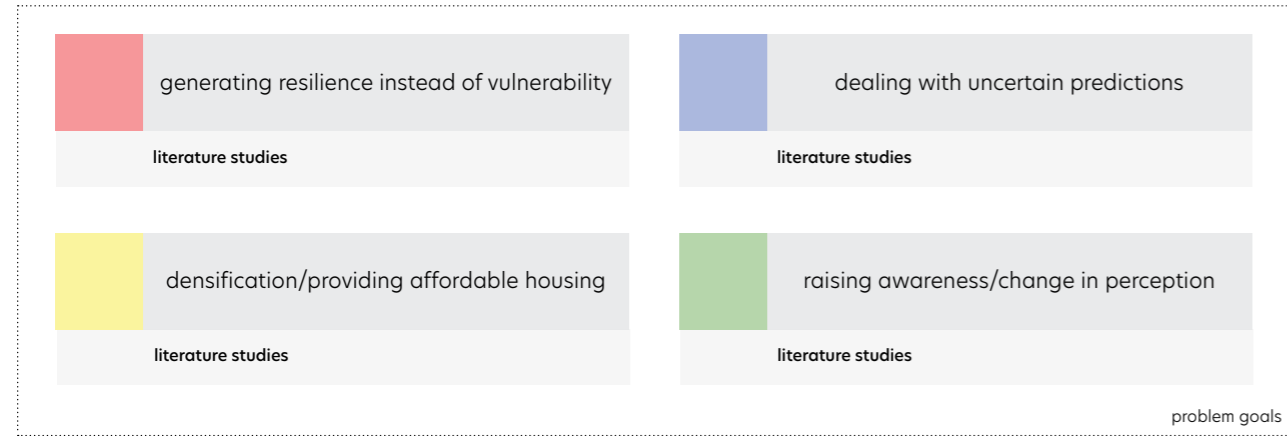
21. Simplified research structure diagram, own illustration based on the creative strategy introduced by Cross and the time-based approaches introduced by van den Dobbelsteen (Cross, 2006), (van den Dobbelsteen et al., 2006)

RESEARCH

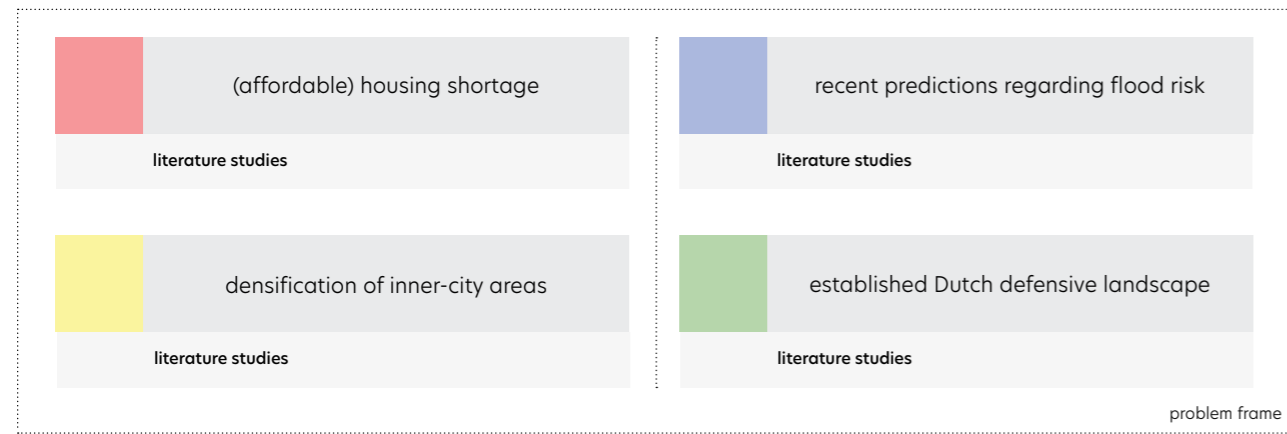


21. Simplified research structure diagram, own illustration based on the creative strategy introduced by Cross and the time-based approaches introduced by van den Dobbelsteen (Cross, 2006), (van den Dobbelsteen et al., 2006)

RESEARCH



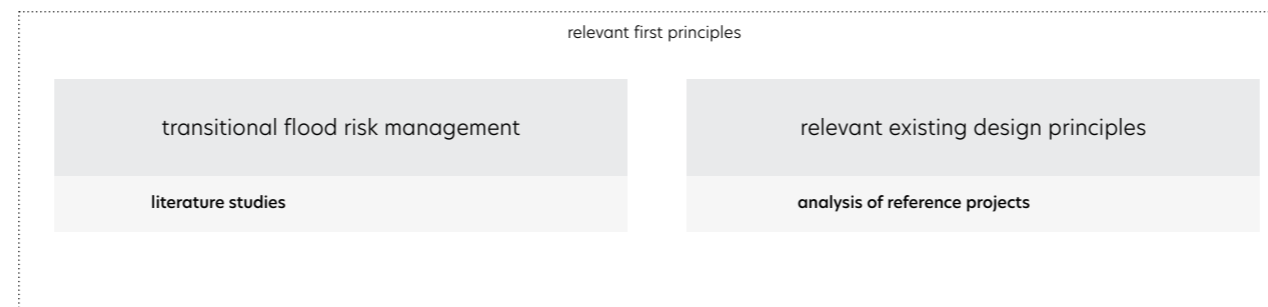
↓ EXPLORED TO ESTABLISH



SENSITIVE TO CHANGE OVER TIME

↓ USED TO IDENTIFY

ACHIEVED BY USING



21. Simplified research structure diagram, own illustration based on the creative strategy introduced by Cross and the time-based approaches introduced by van den Dobbelsteen (Cross, 2006), (van den Dobbelsteen et al., 2006)

RESEARCH

DESIGN



21. Simplified research structure diagram, own illustration based on the creative strategy introduced by Cross and the time-based approaches introduced by van den Dobbelsteen (Cross, 2006), (van den Dobbelsteen et al., 2006)

RESEARCH

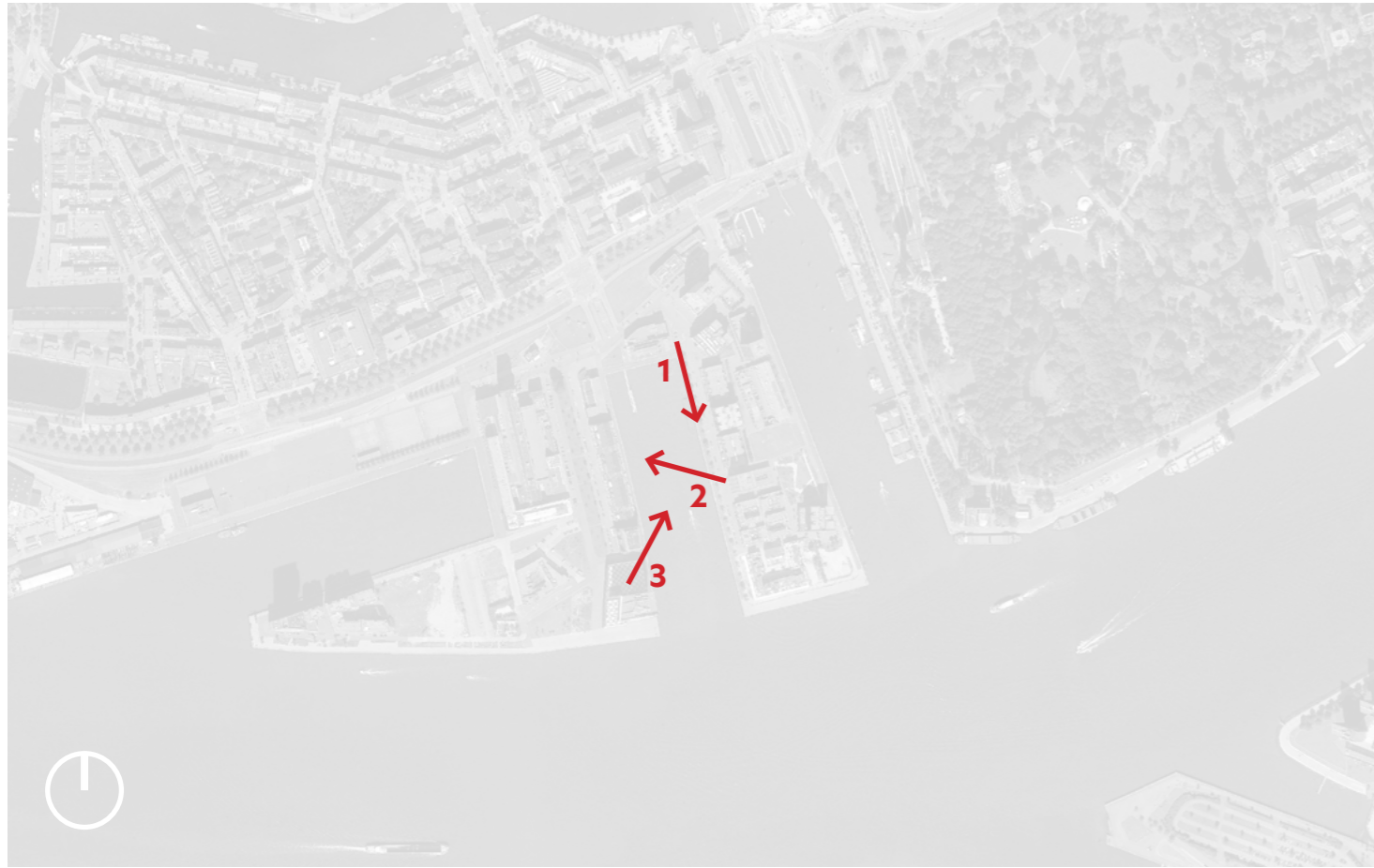
DESIGN



21. Simplified research structure diagram, own illustration based on the creative strategy introduced by Cross and the time-based approaches introduced by van den Dobbelsteen (Cross, 2006), (van den Dobbelsteen et al., 2006)



Rotterdam, The Netherlands, own illustration edited from (Google Earth, 2021), height measurement (AHN, 2020)



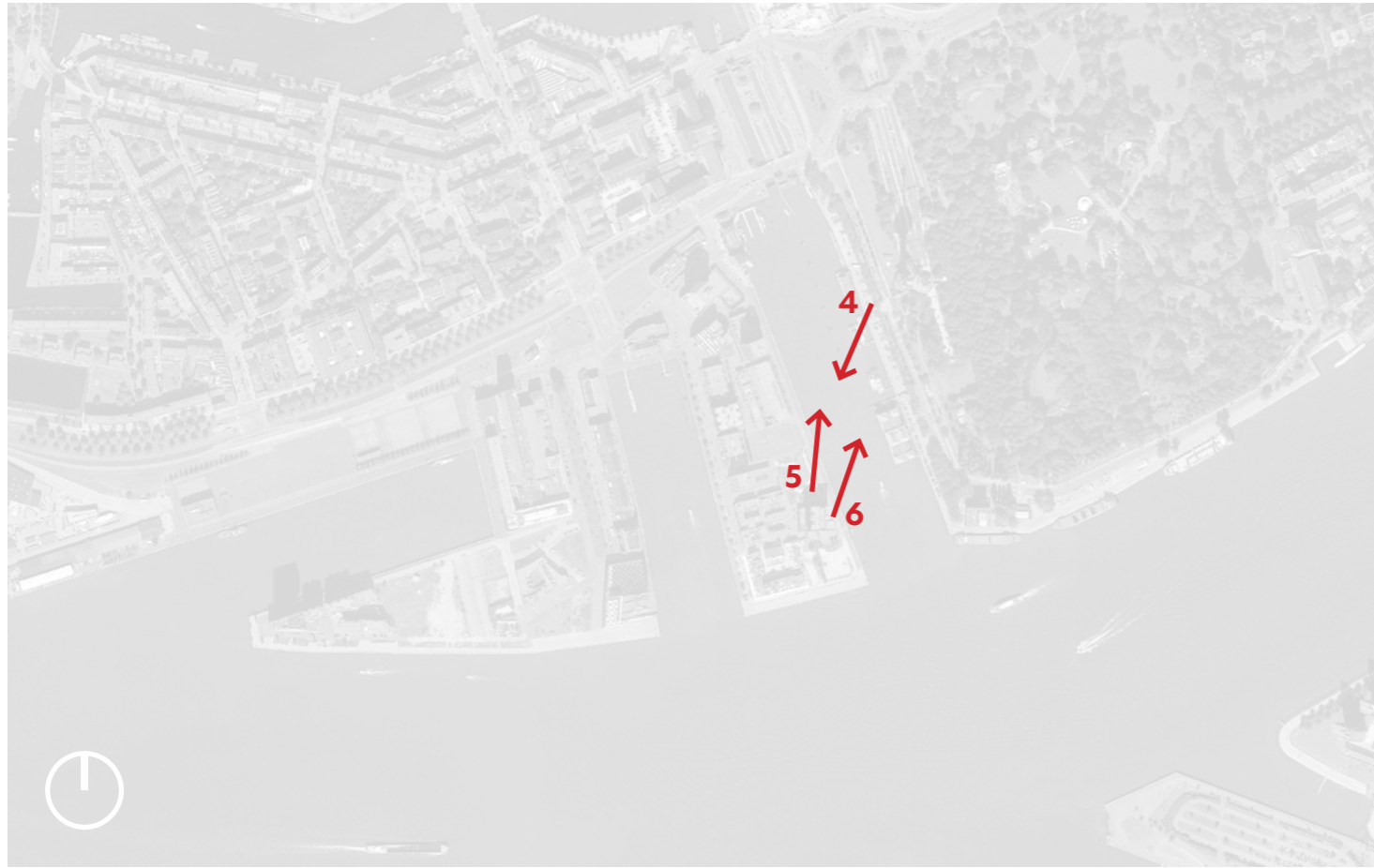
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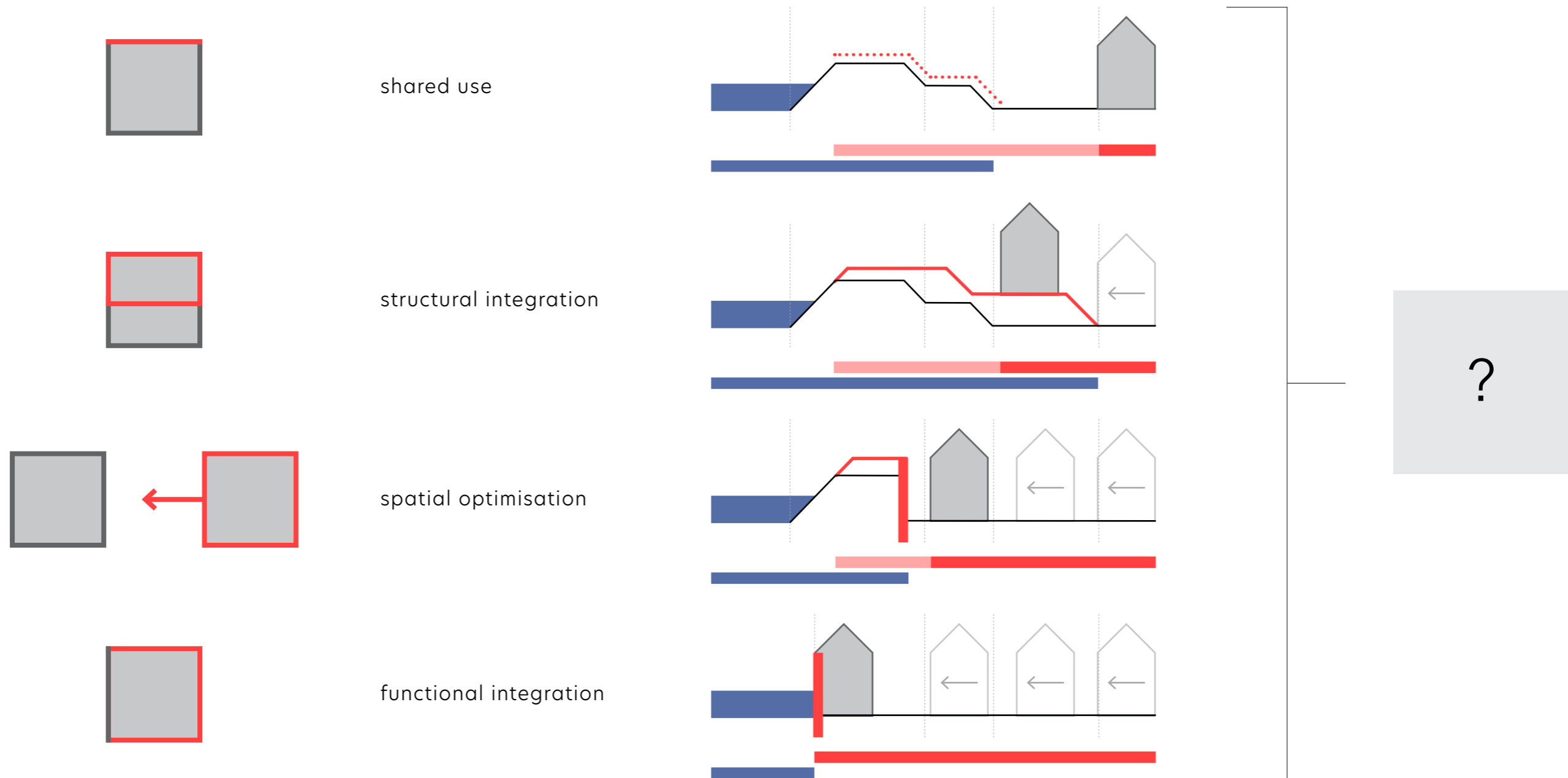


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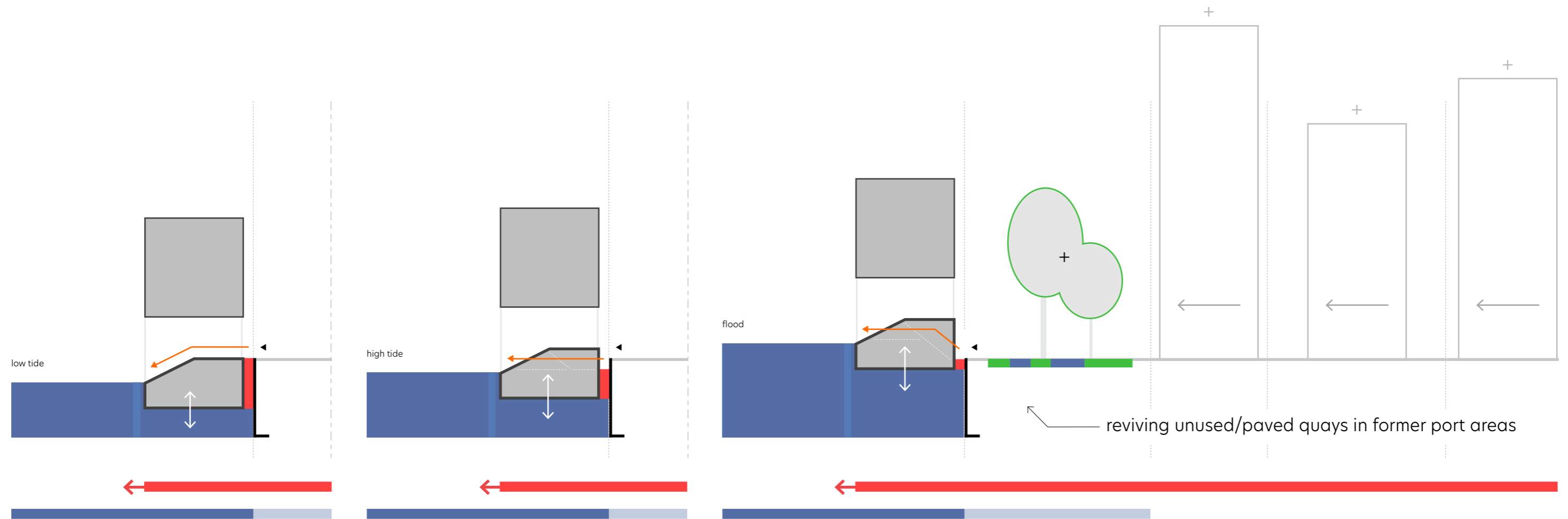


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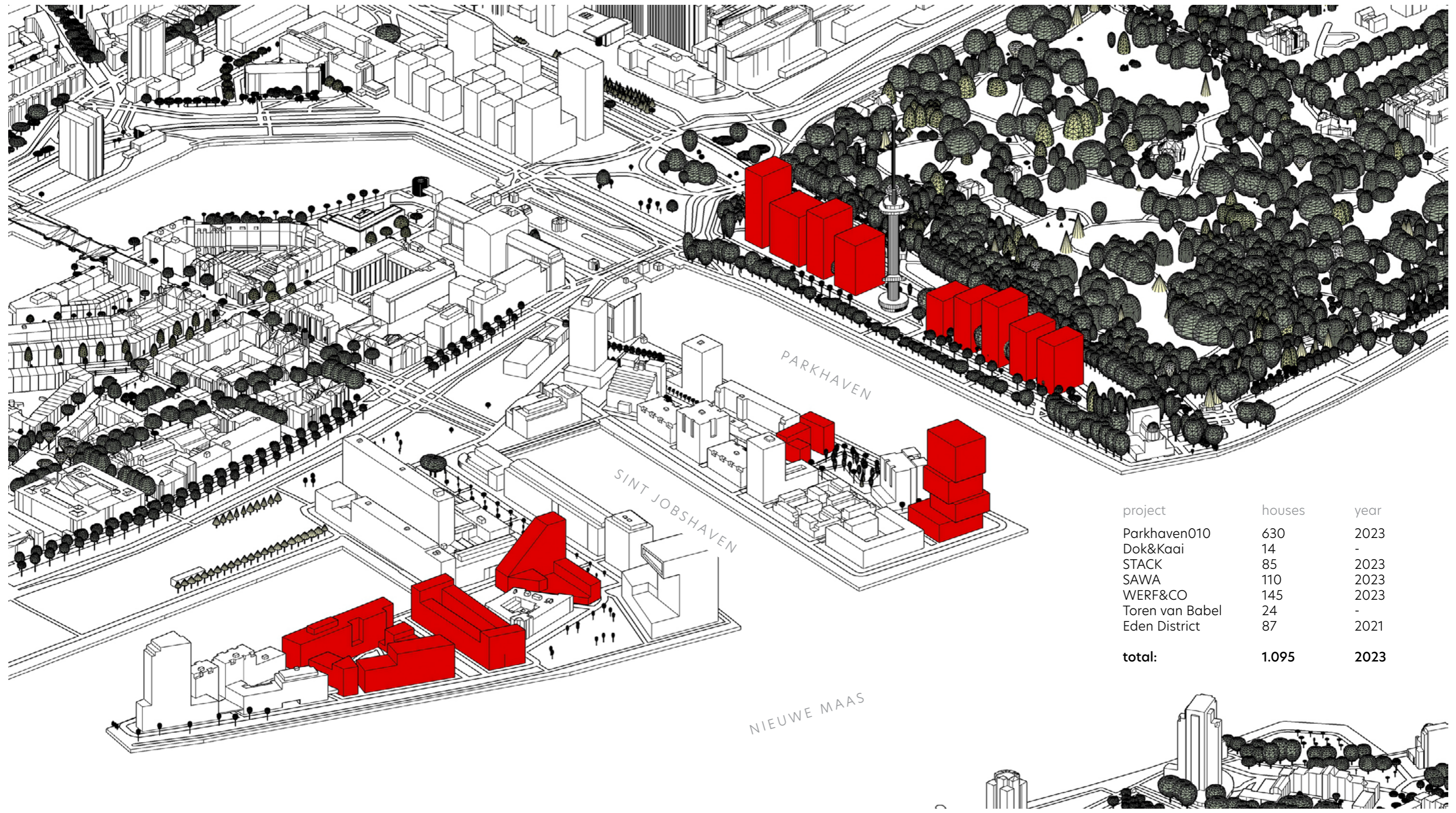
DEGREES OF SPATIAL INTEGRATION



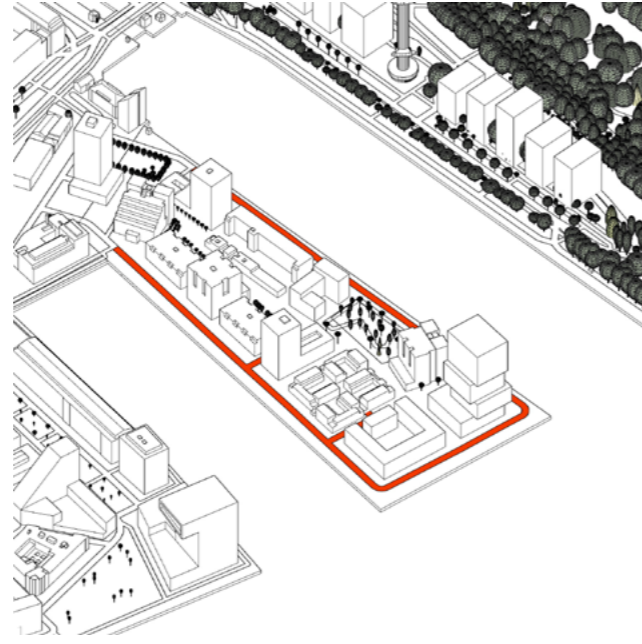
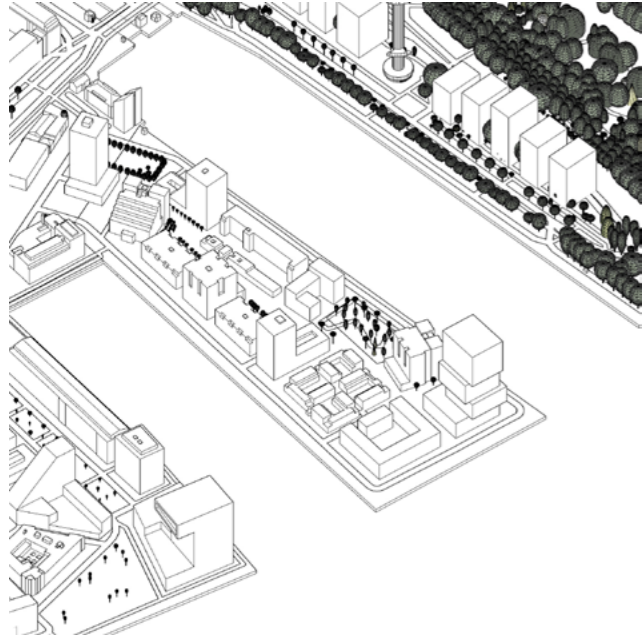
PROPOSAL TO INTEGRATE FURTHER

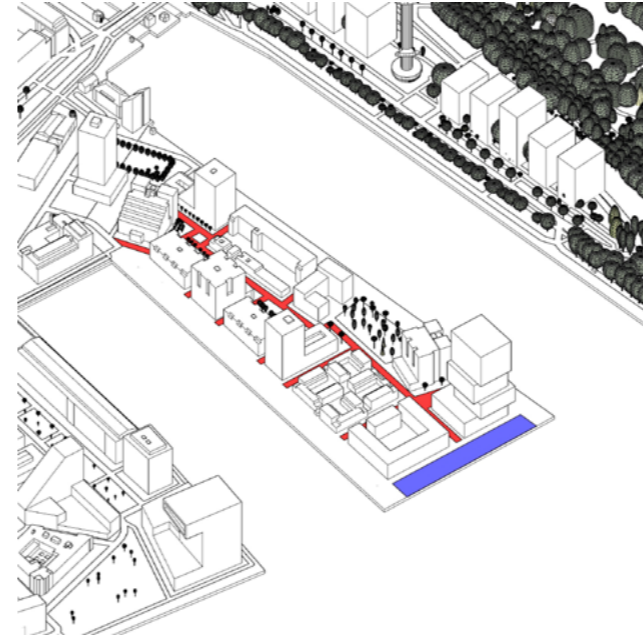
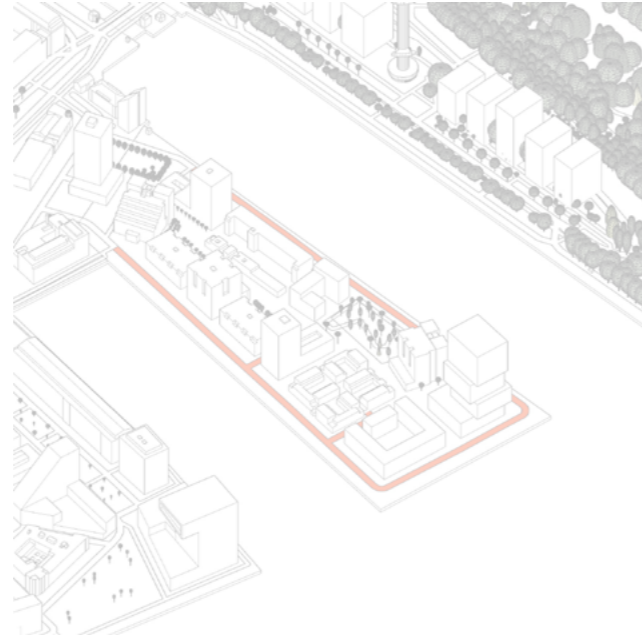
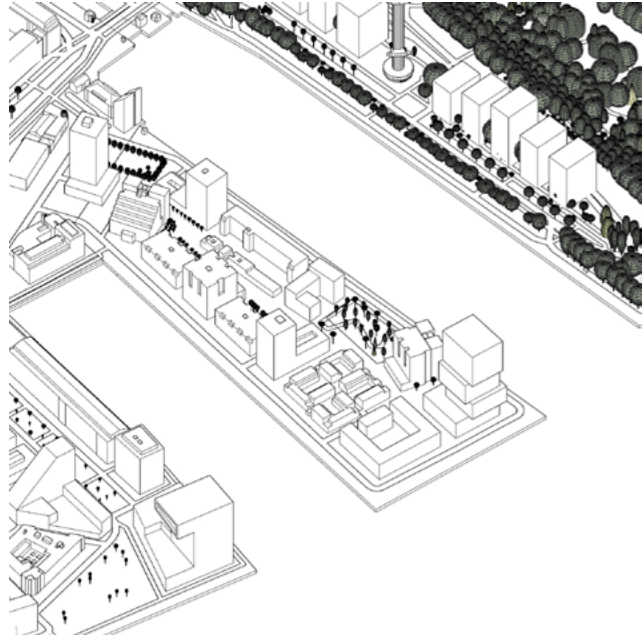


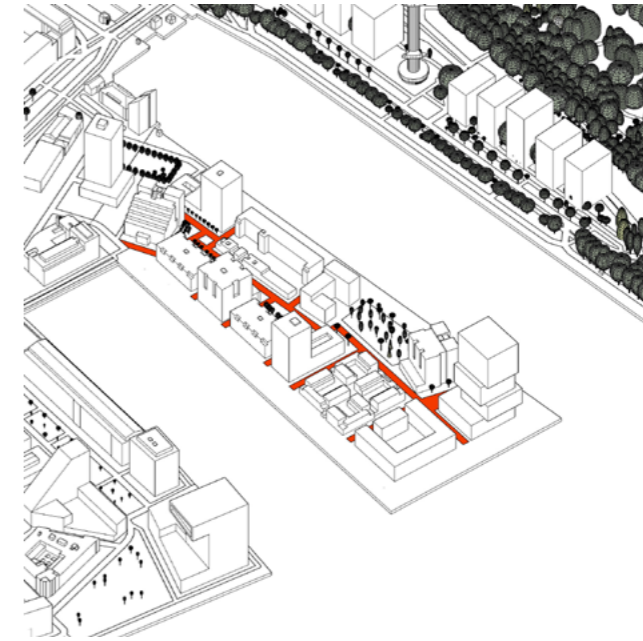
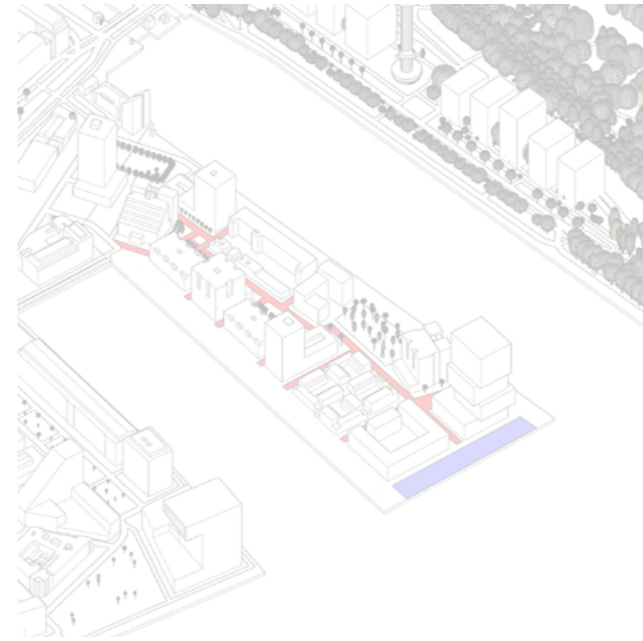
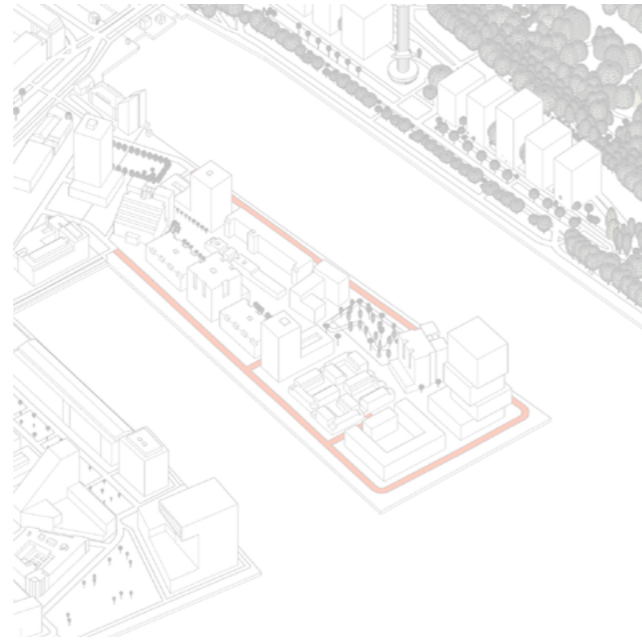
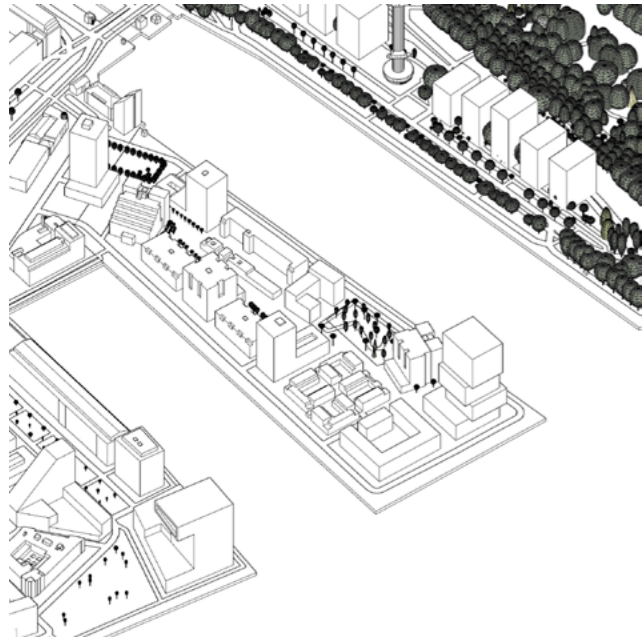
23. Example of a schematic proposal for a hydraulic building typology along currently vacant quays combining shared use, structural, spatial and functional integration, own illustration



project	houses	year
Parkhaven010	630	2023
Dok&Kaai	14	-
STACK	85	2023
SAWA	110	2023
WERF&CO	145	2023
Toren van Babel	24	-
Eden District	87	2021
total:	1.095	2023

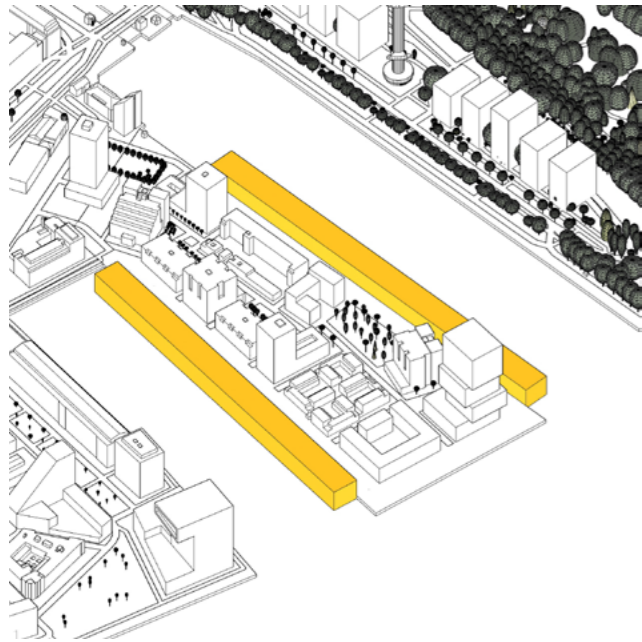
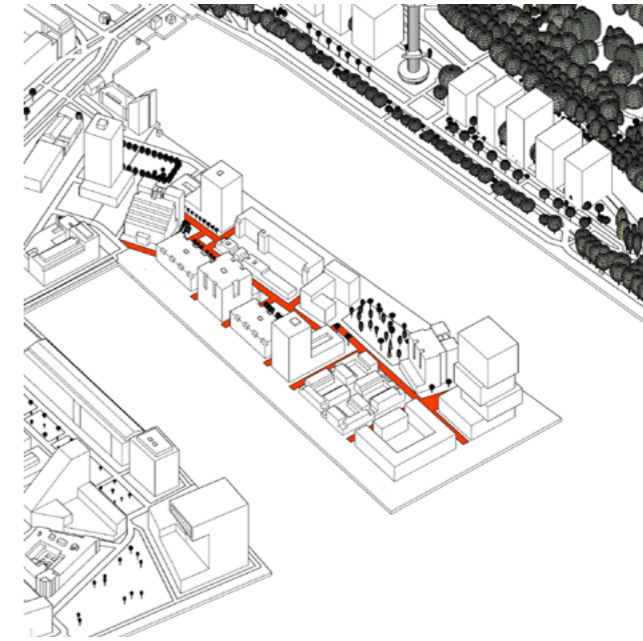
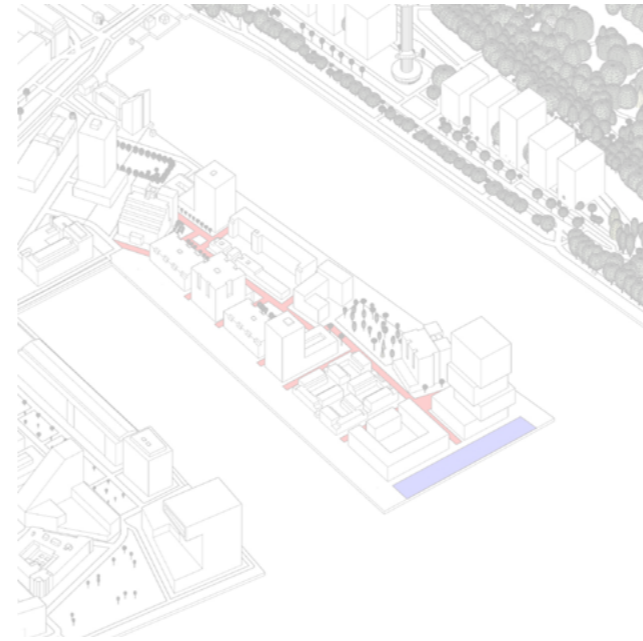
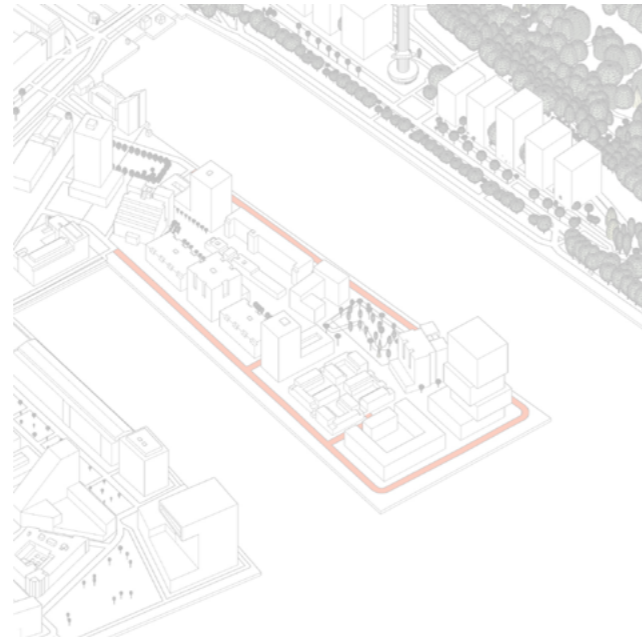
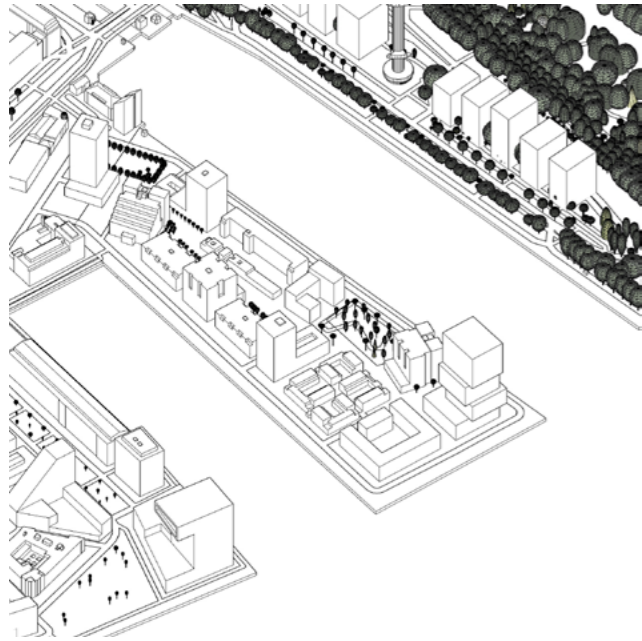






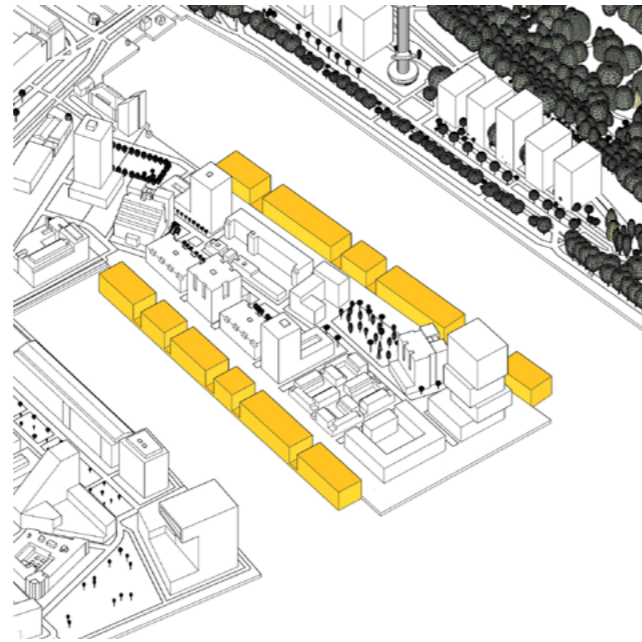
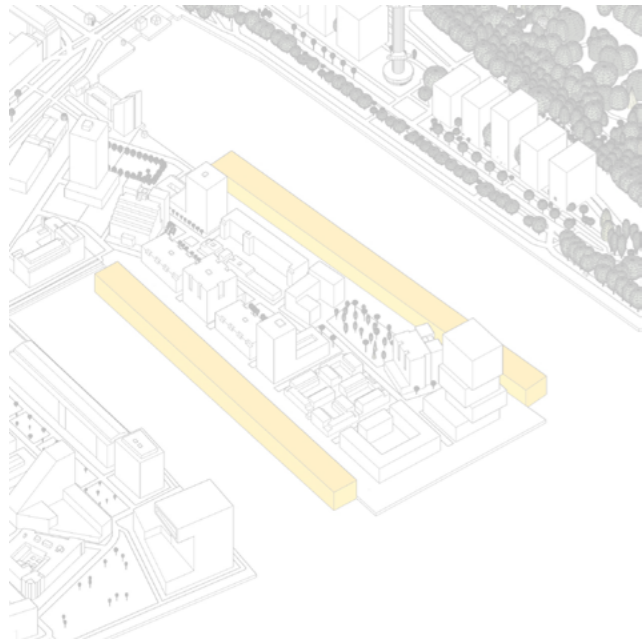
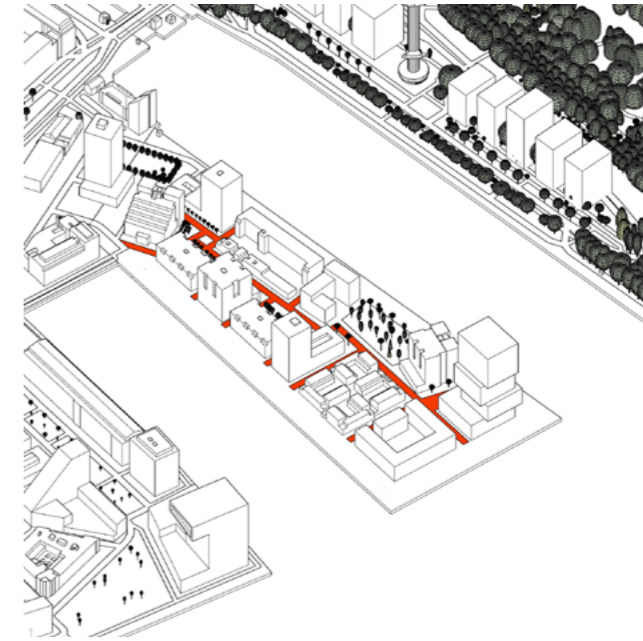
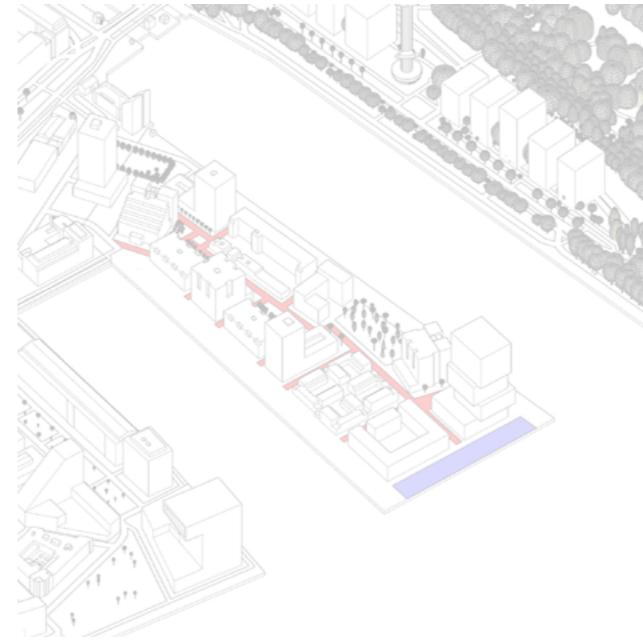
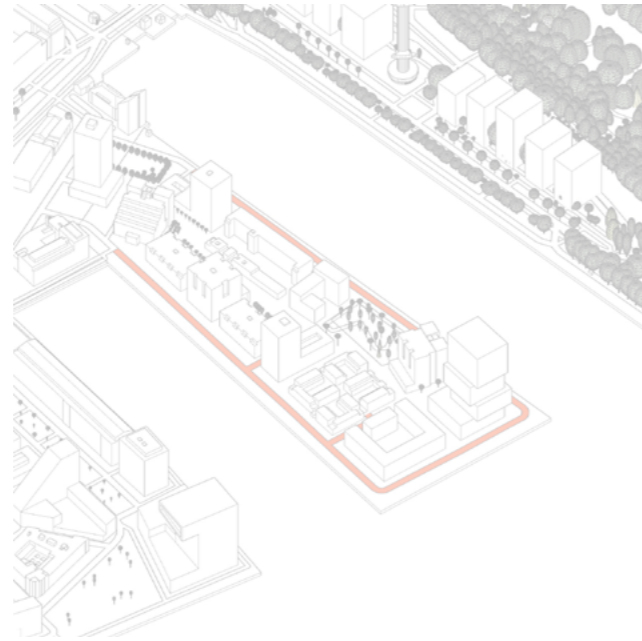
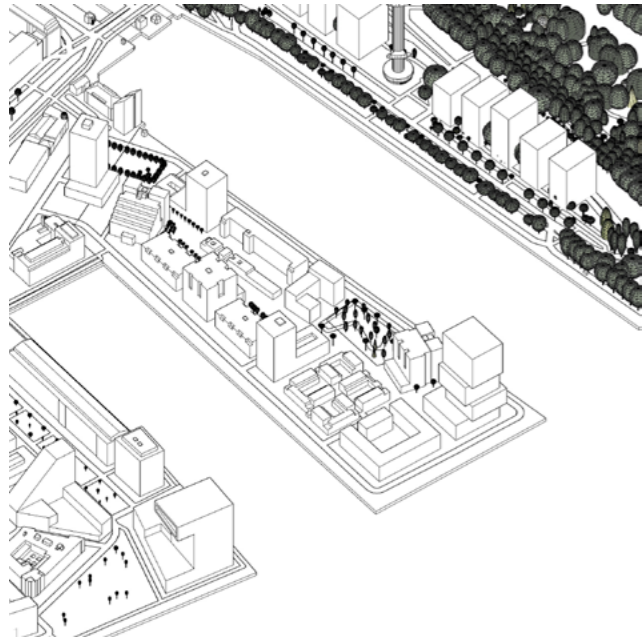
Infrastructure

**Spatial
optimisation**



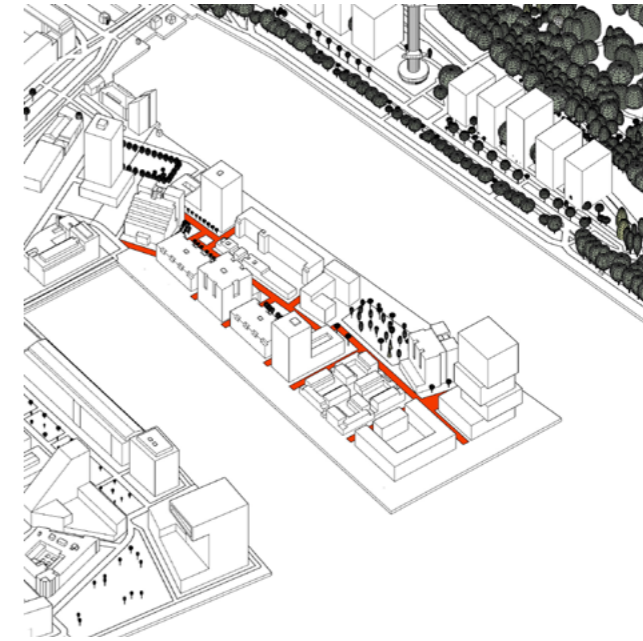
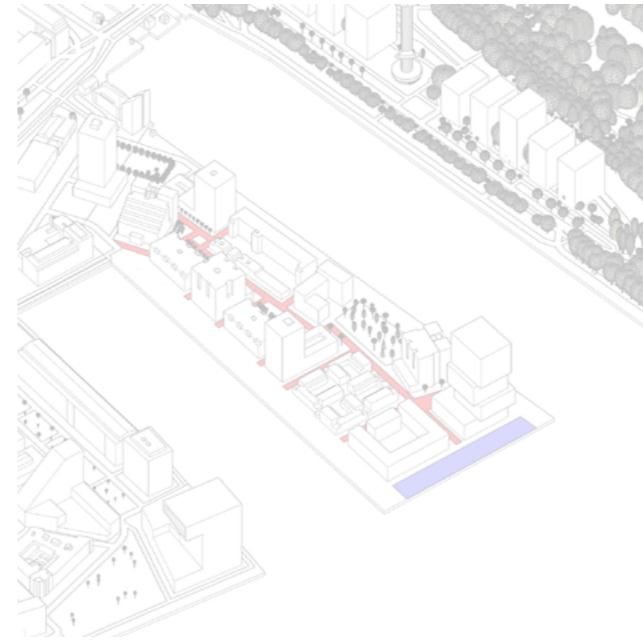
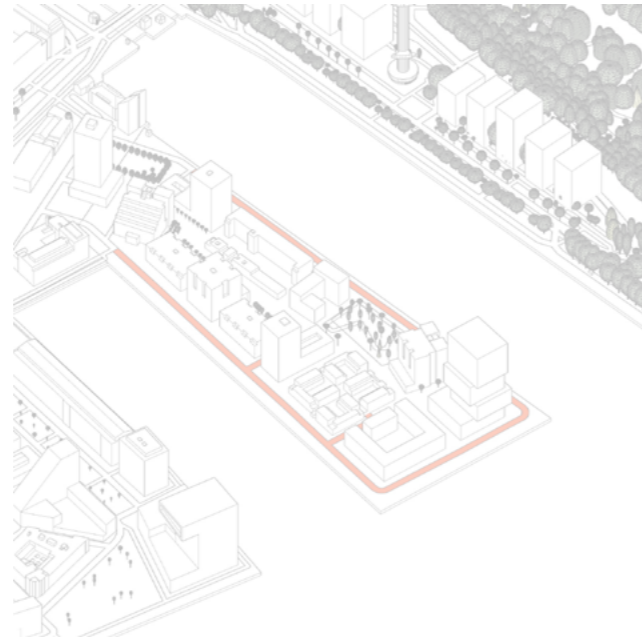
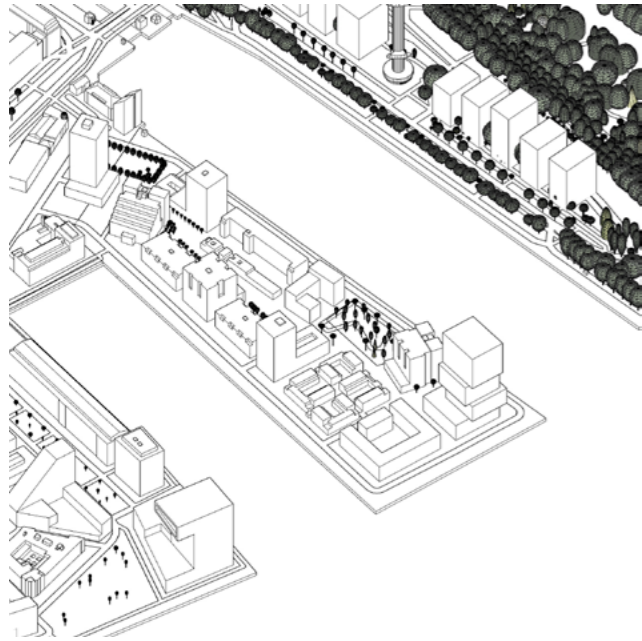
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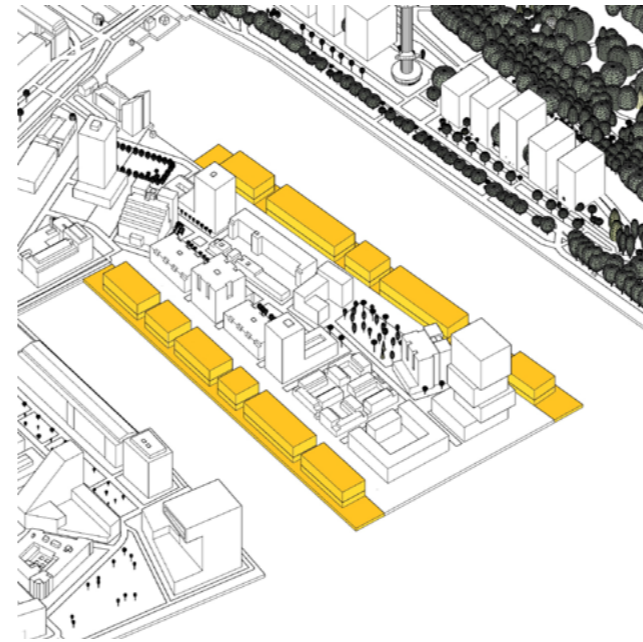
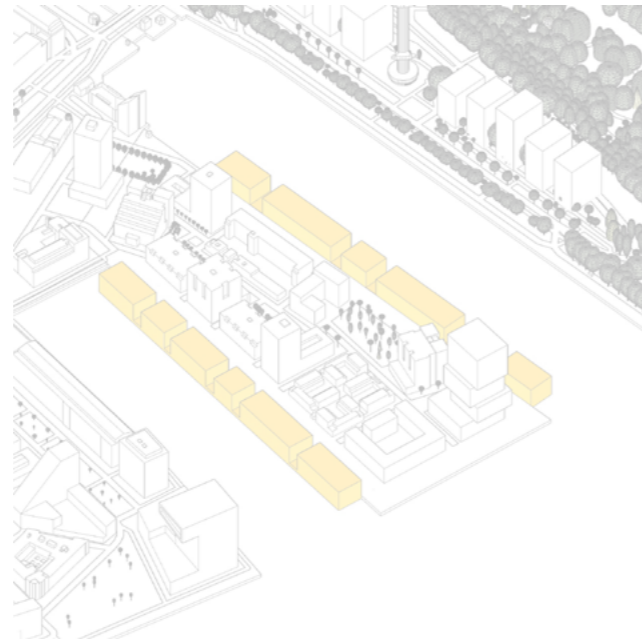
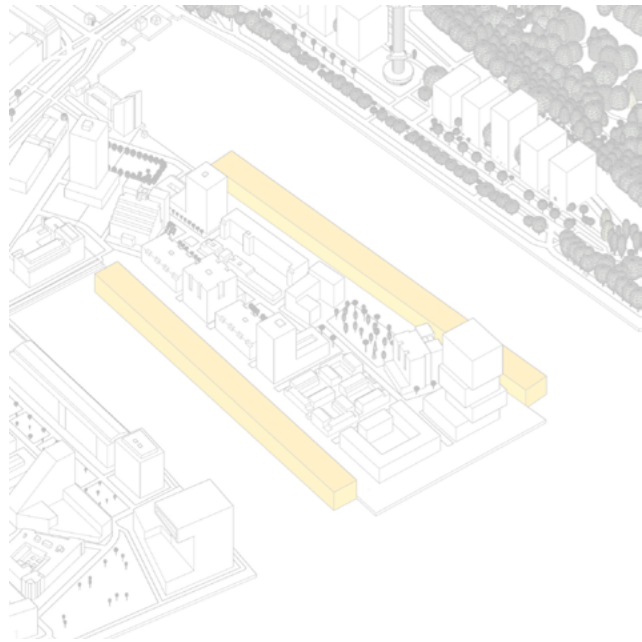
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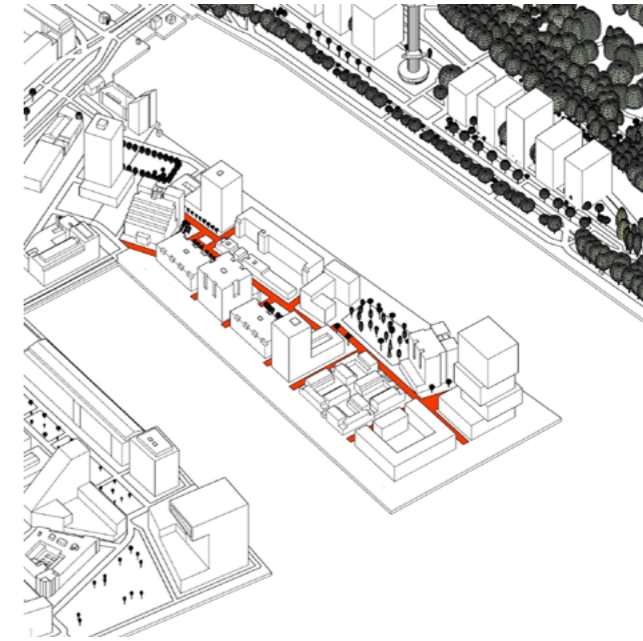
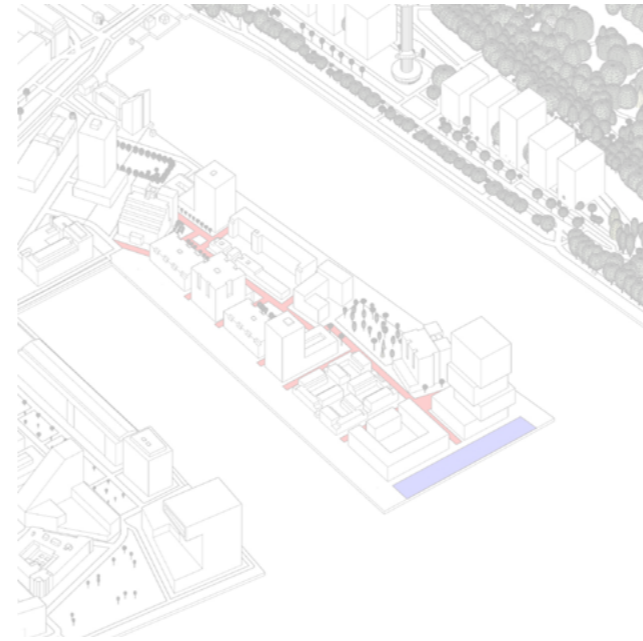
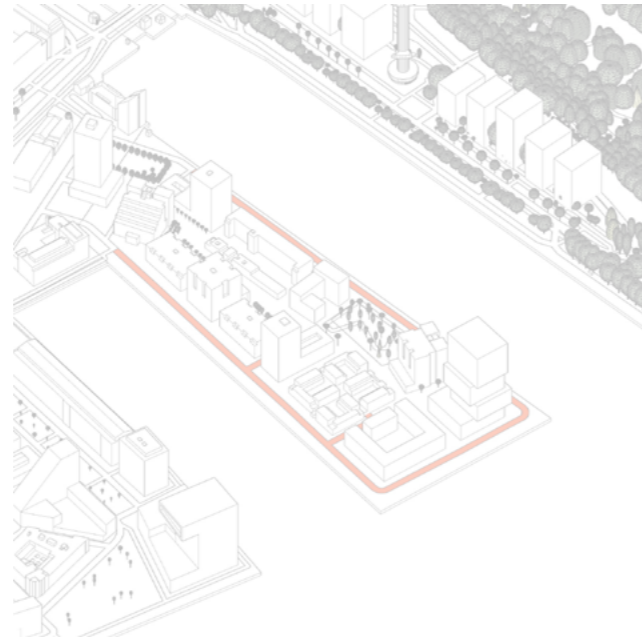
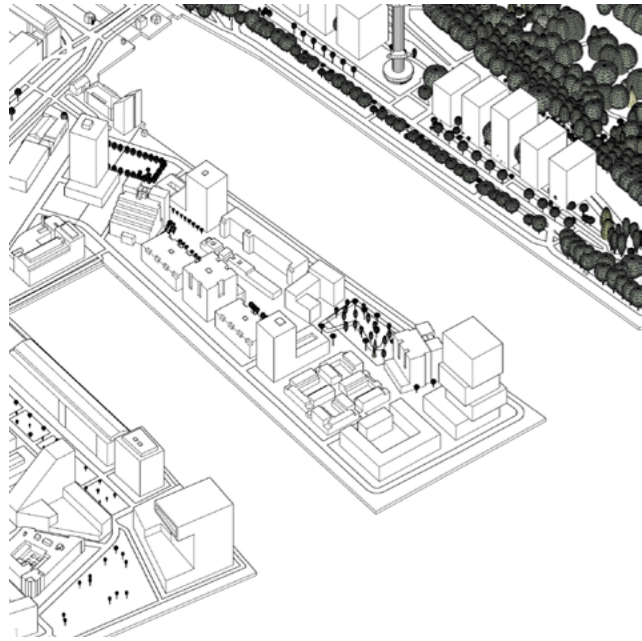
**Spatial
optimisation**



Infrastructure

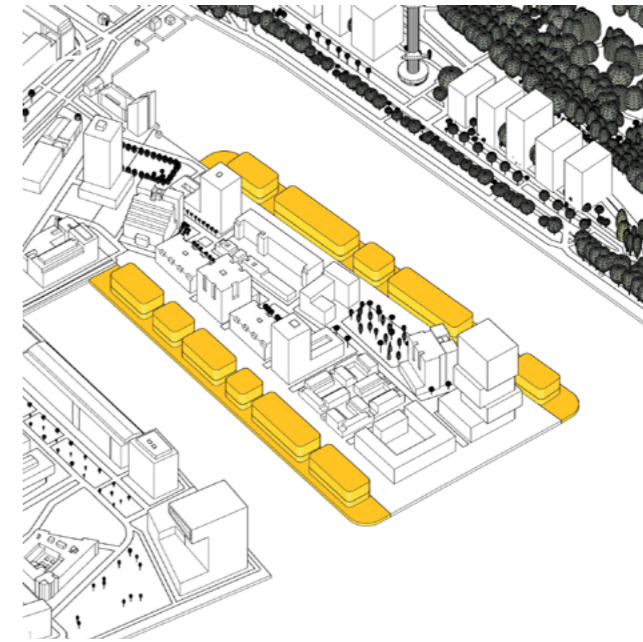
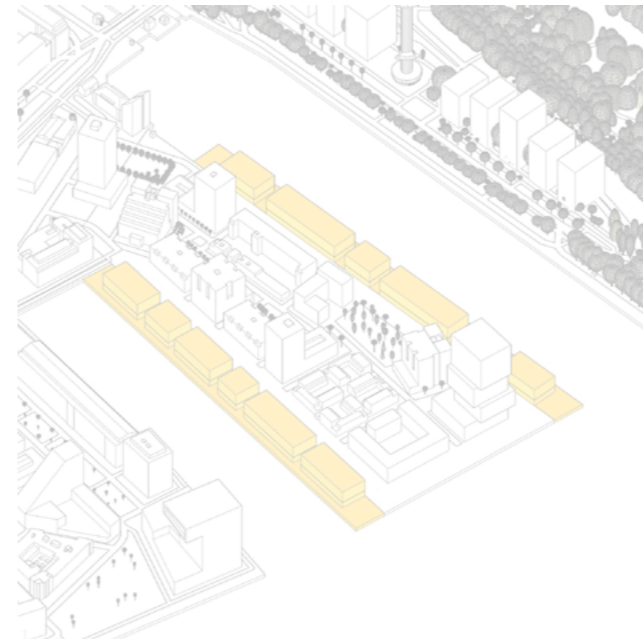
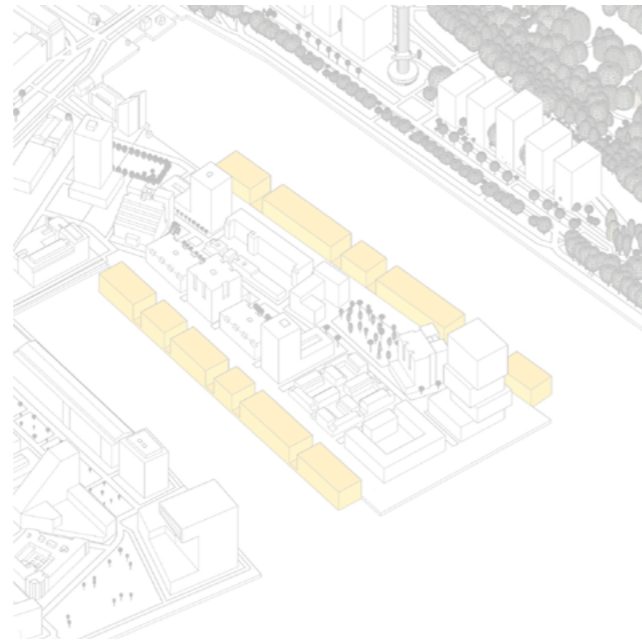
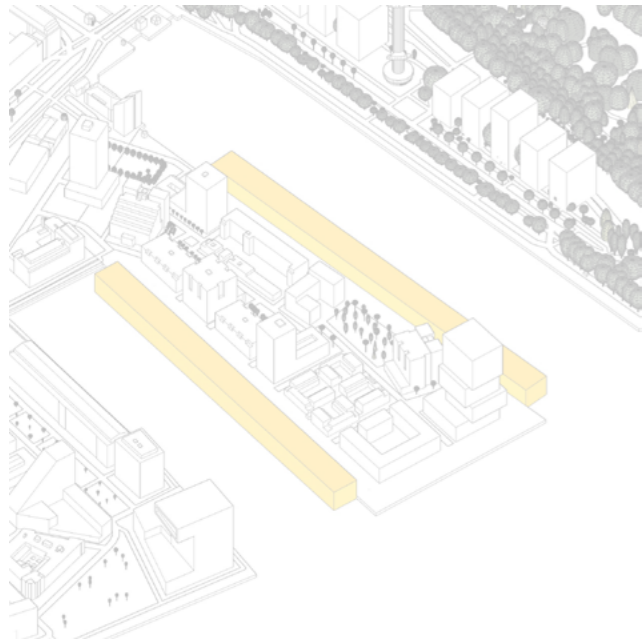
**Spatial
optimisation**





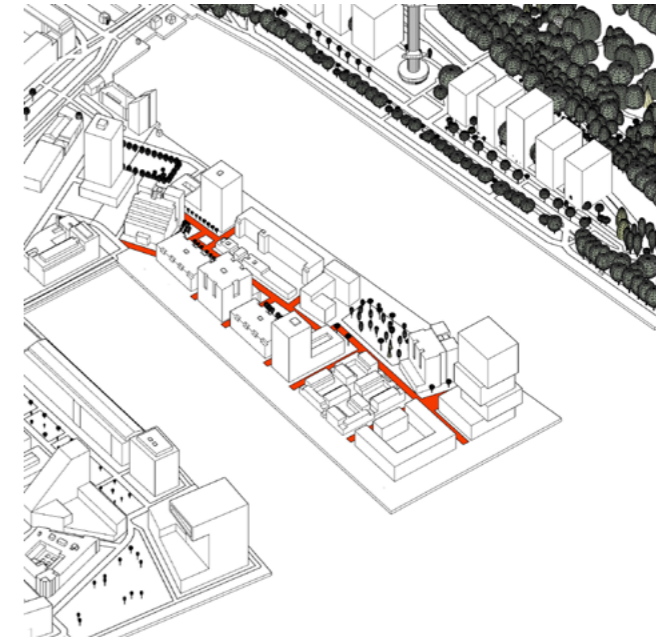
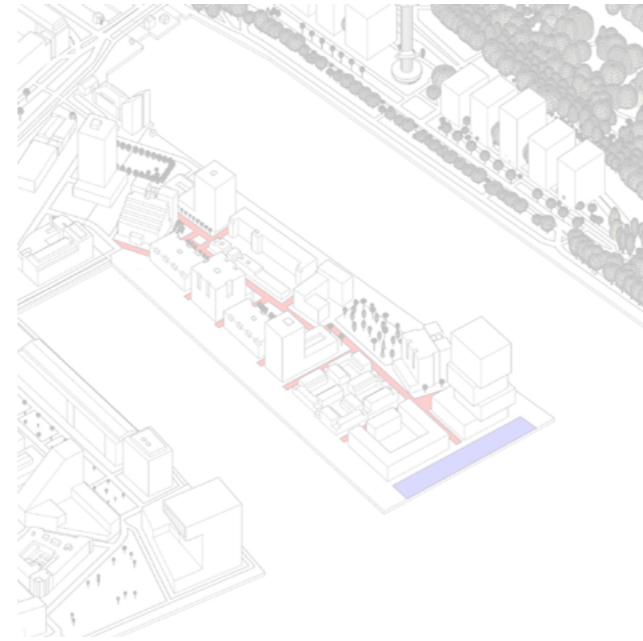
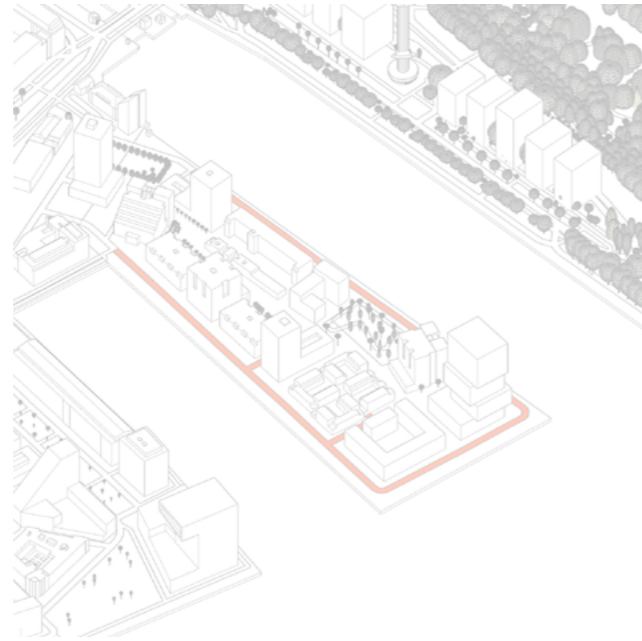
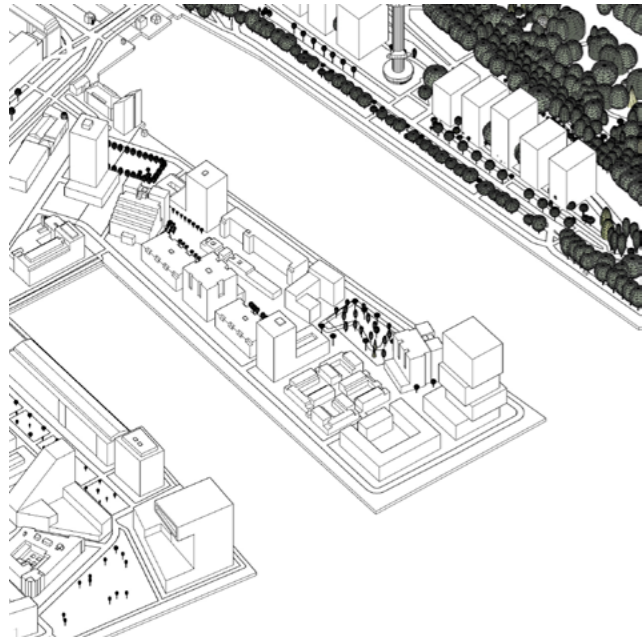
Infrastructure

**Spatial
optimisation**



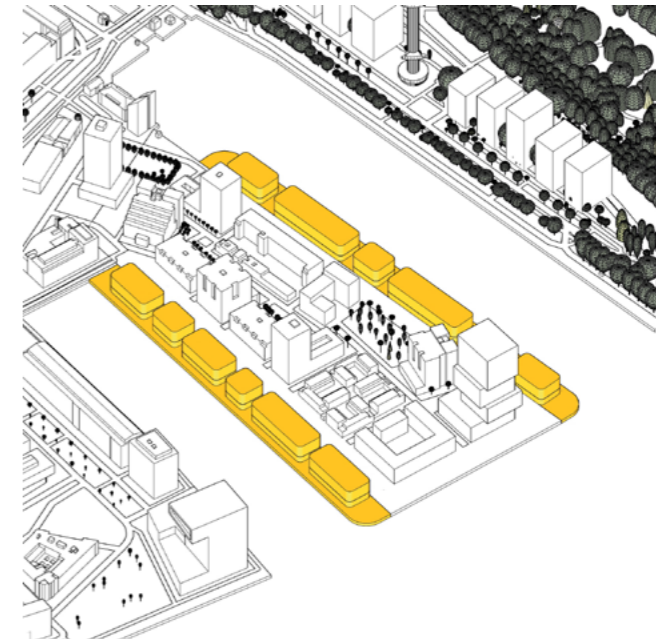
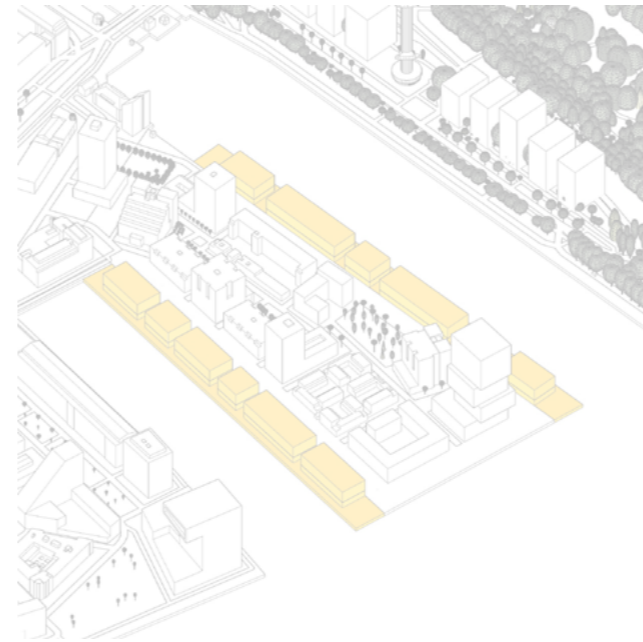
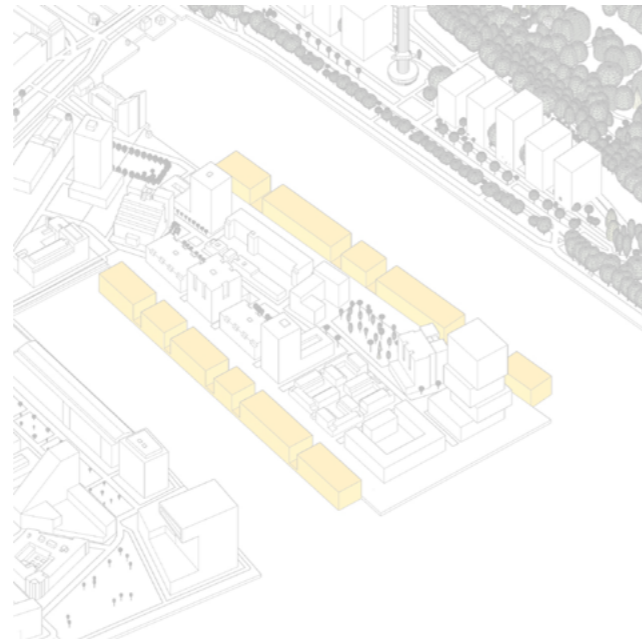
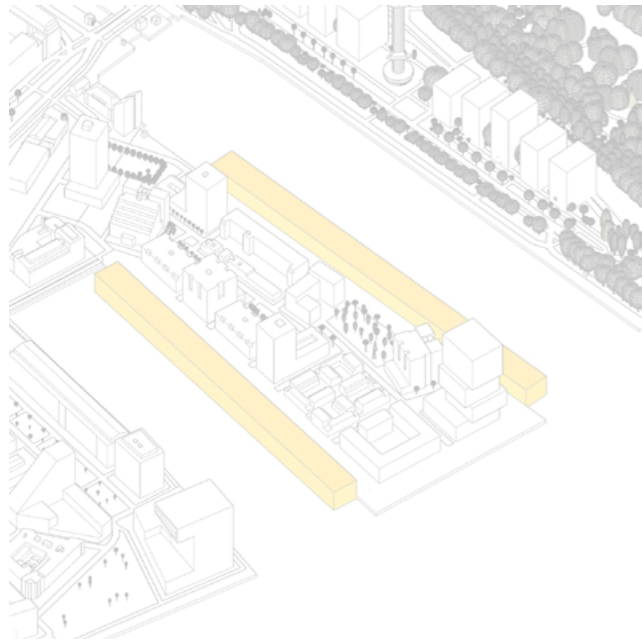
Building Volumes

**Spatial
Functional
Structural
integration**



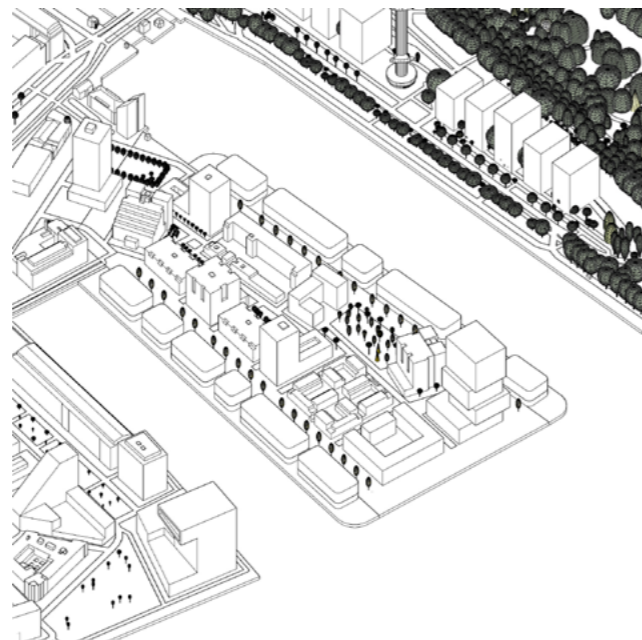
Infrastructure

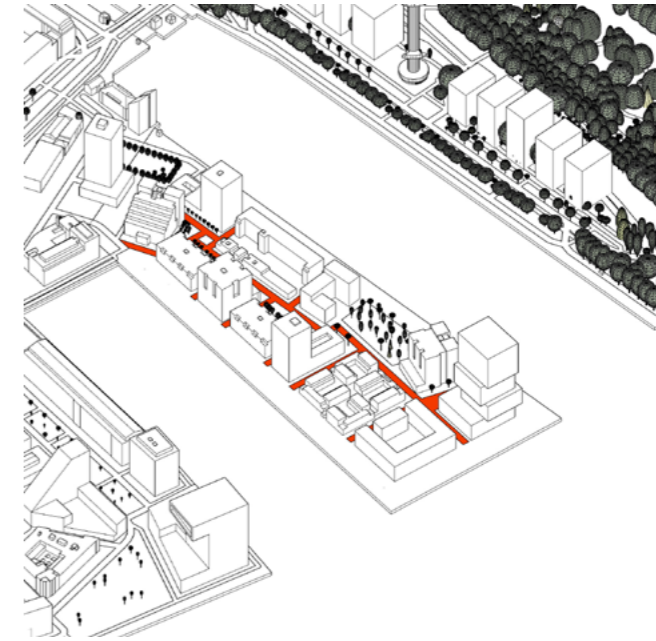
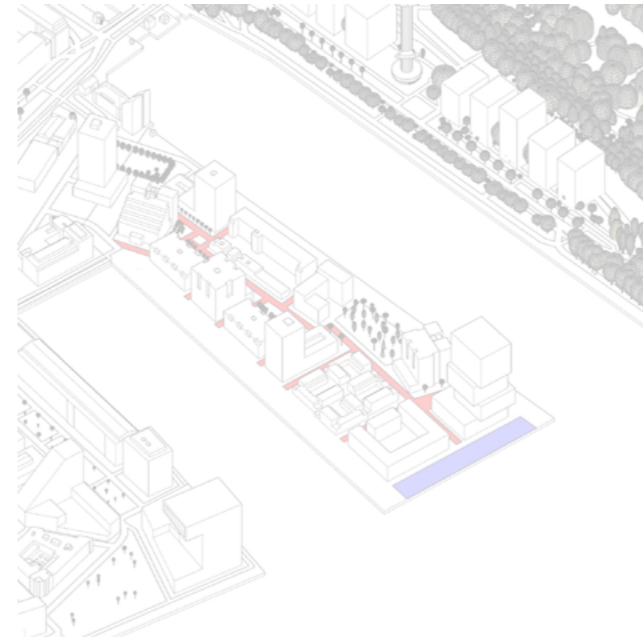
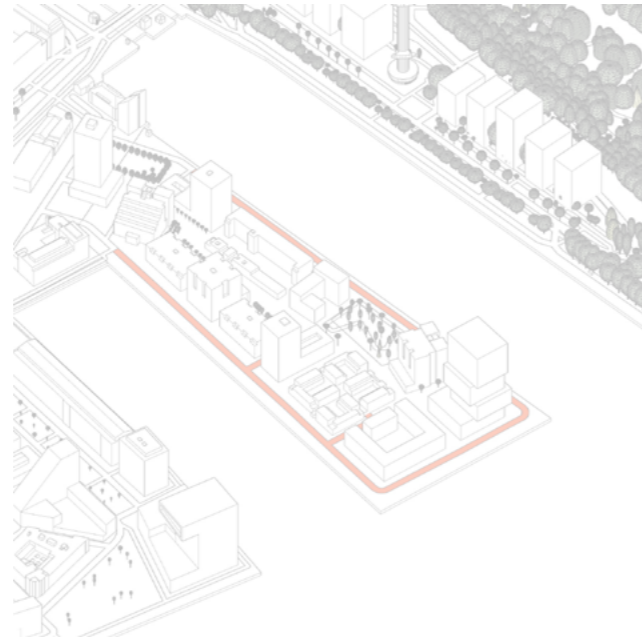
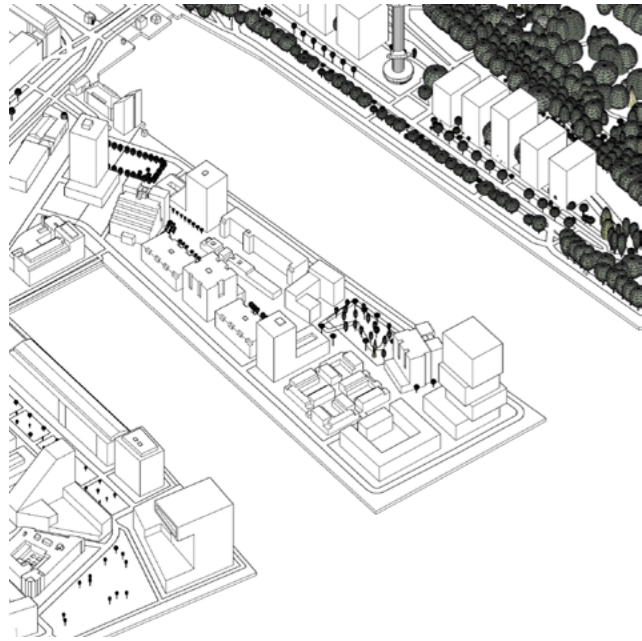
**Spatial
optimisation**



Building Volumes

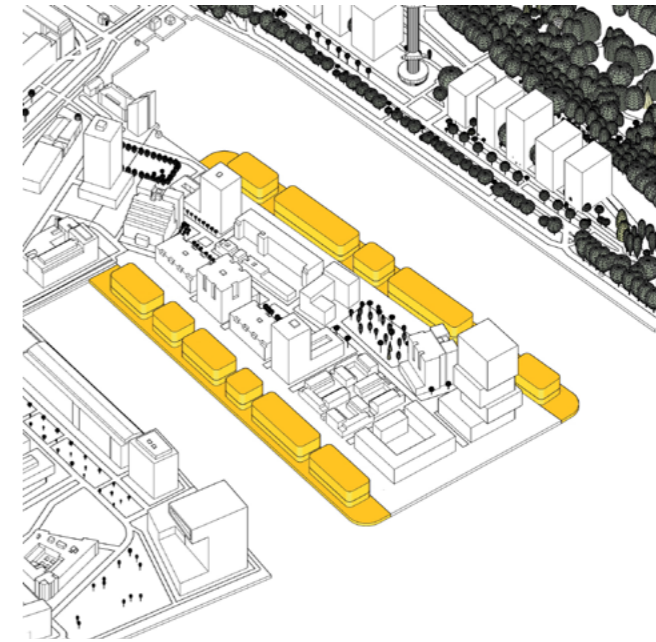
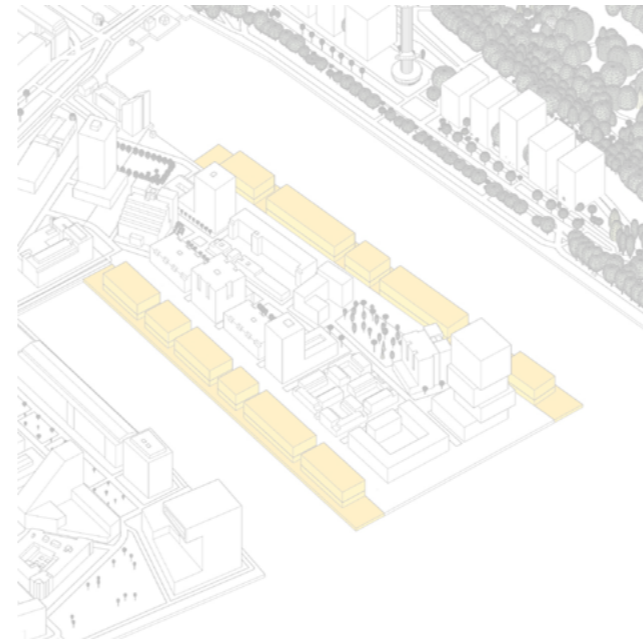
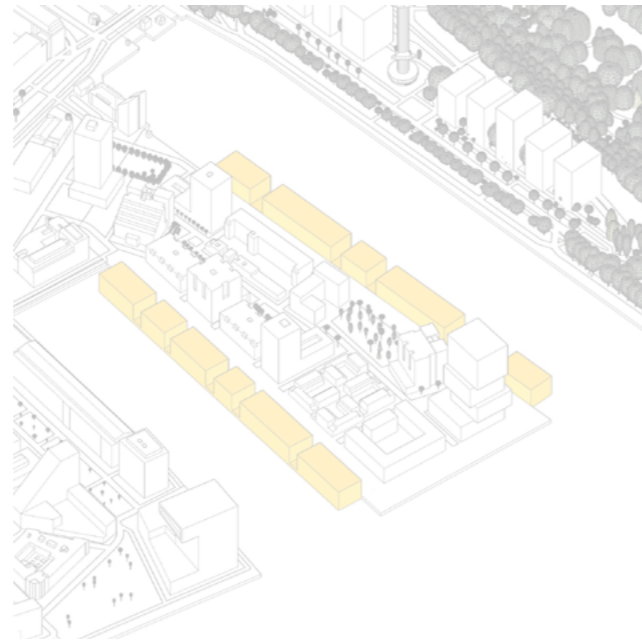
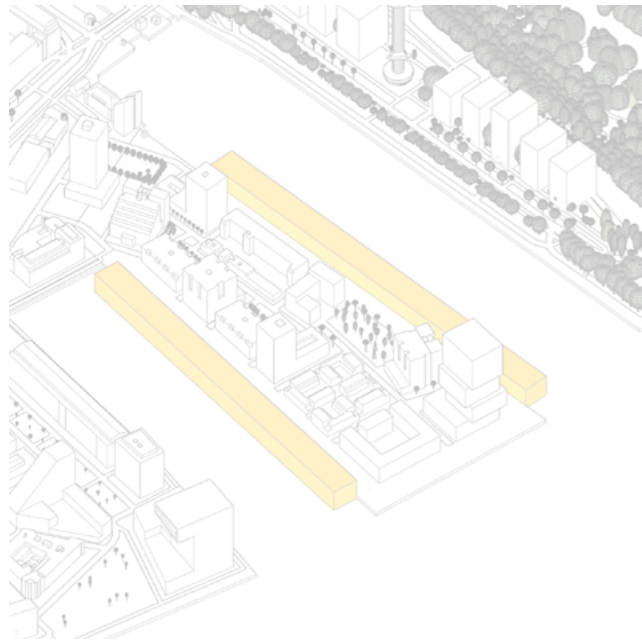
**Spatial
Functional
Structural
integration**





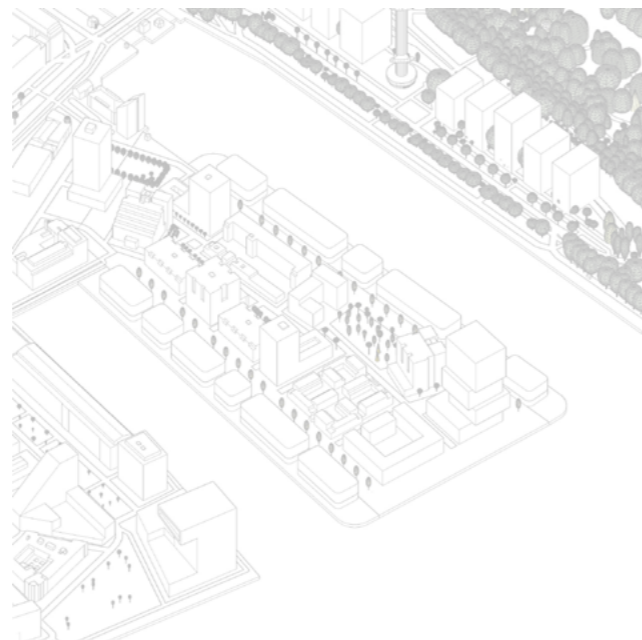
Infrastructure

**Spatial
optimisation**



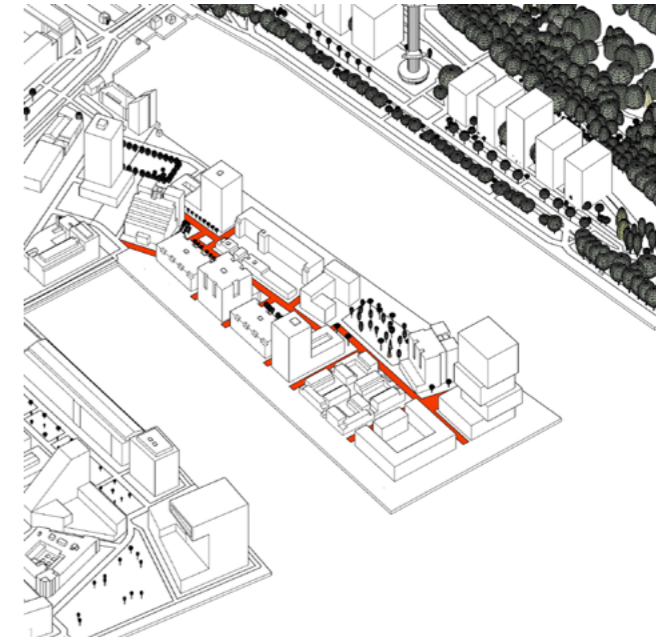
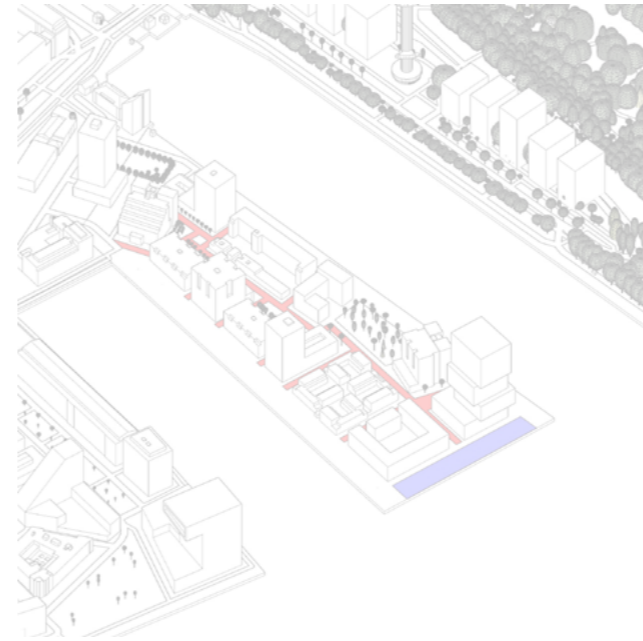
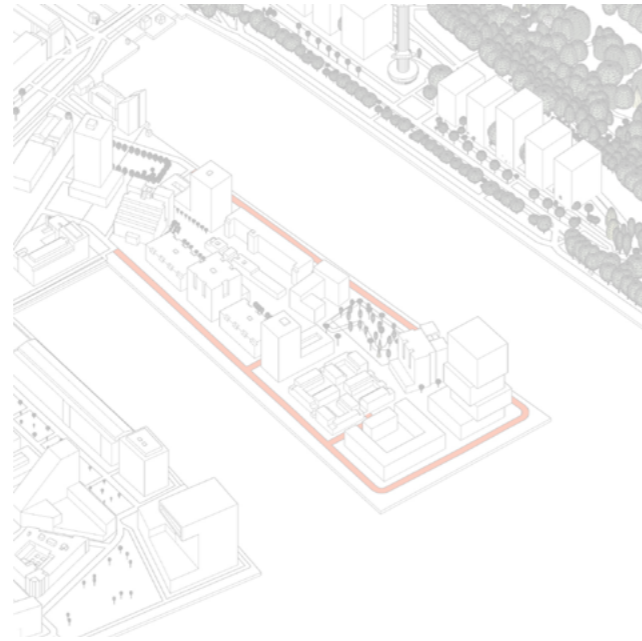
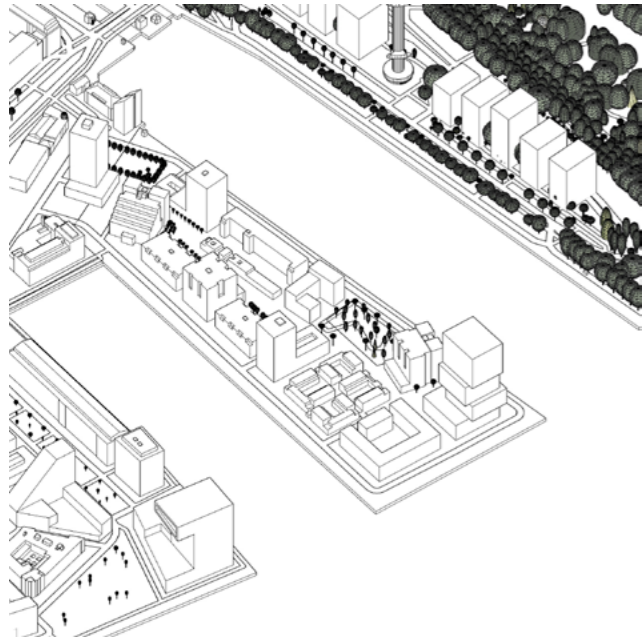
Building Volumes

**Spatial
Functional
Structural
integration**



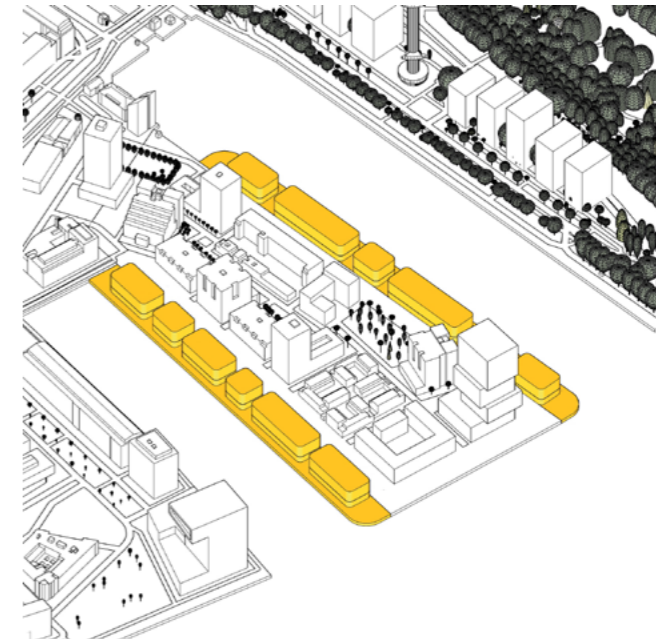
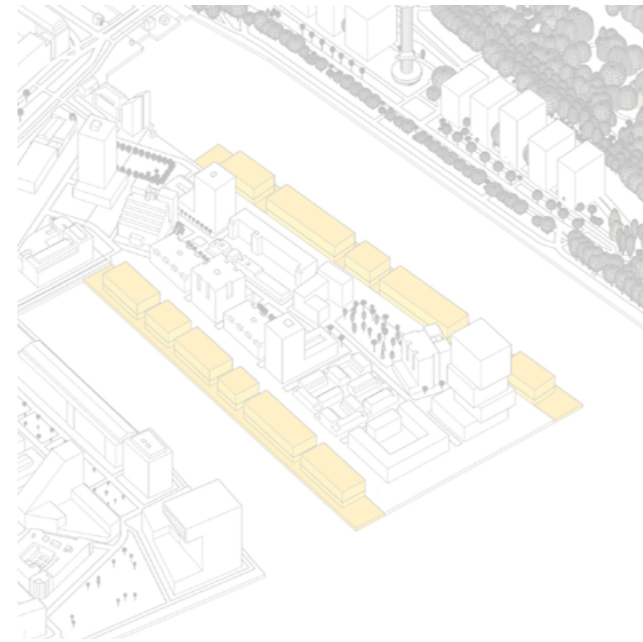
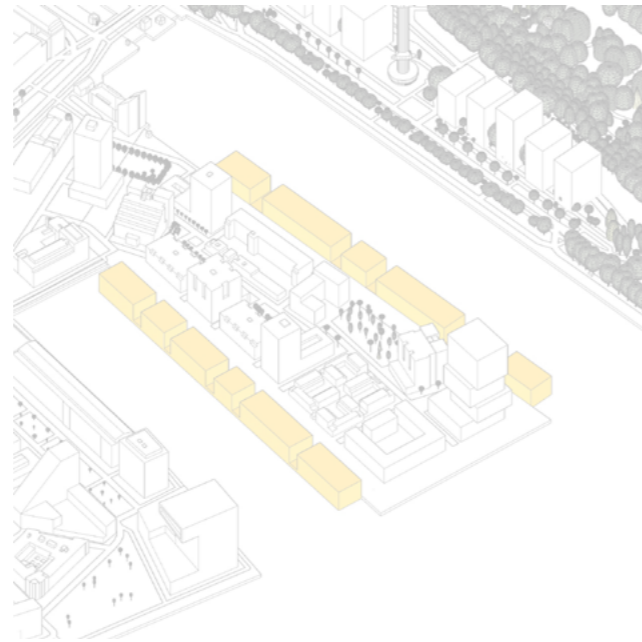
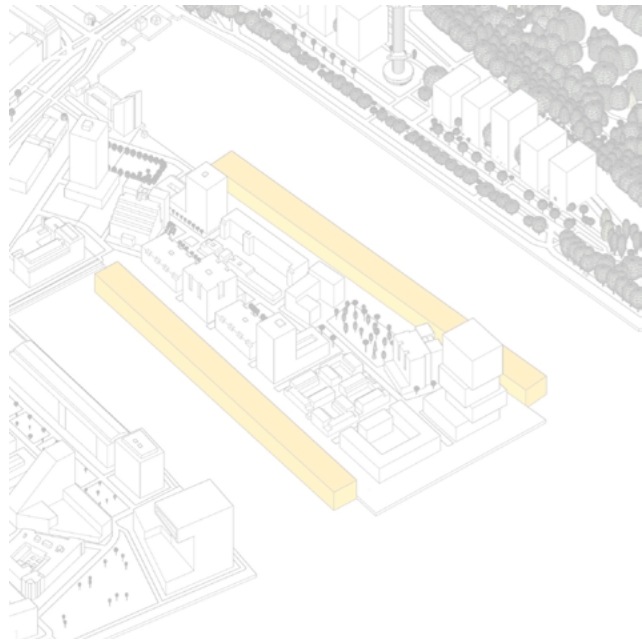
Public Park

Shared use



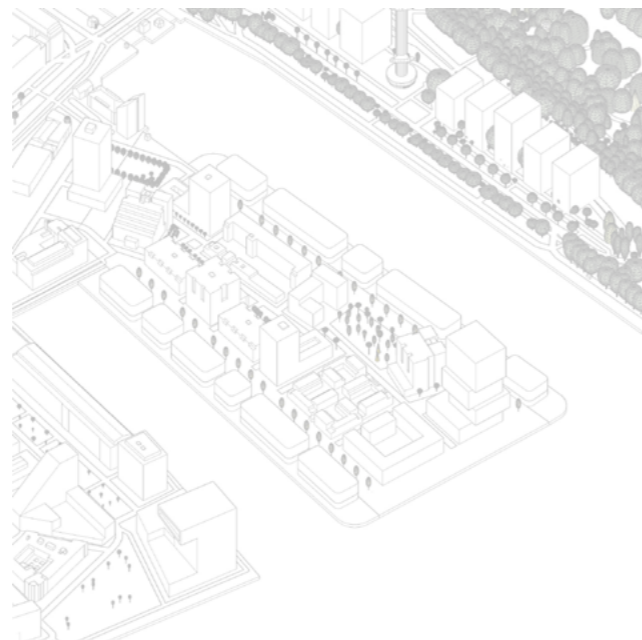
Infrastructure

**Spatial
optimisation**



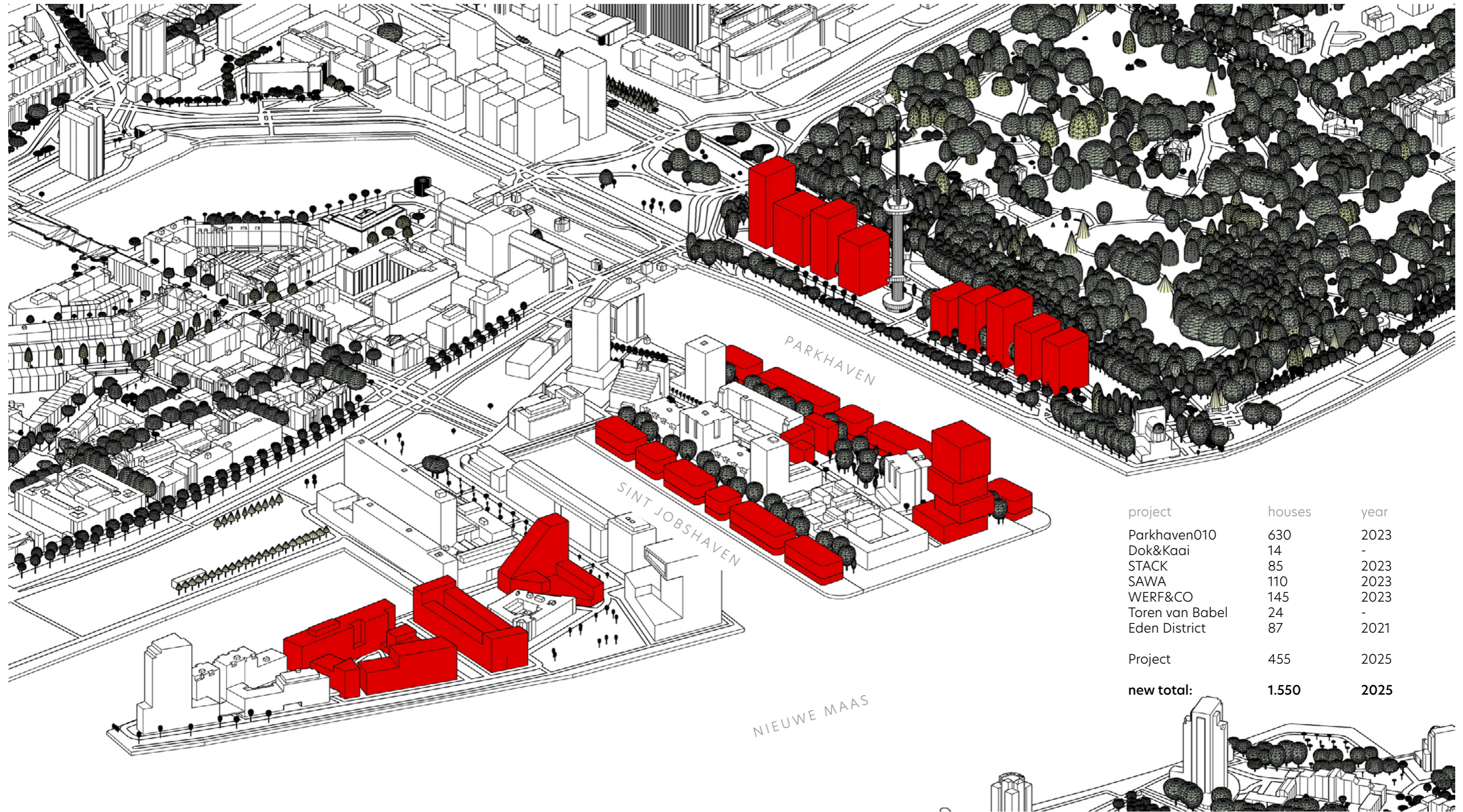
Building Volumes

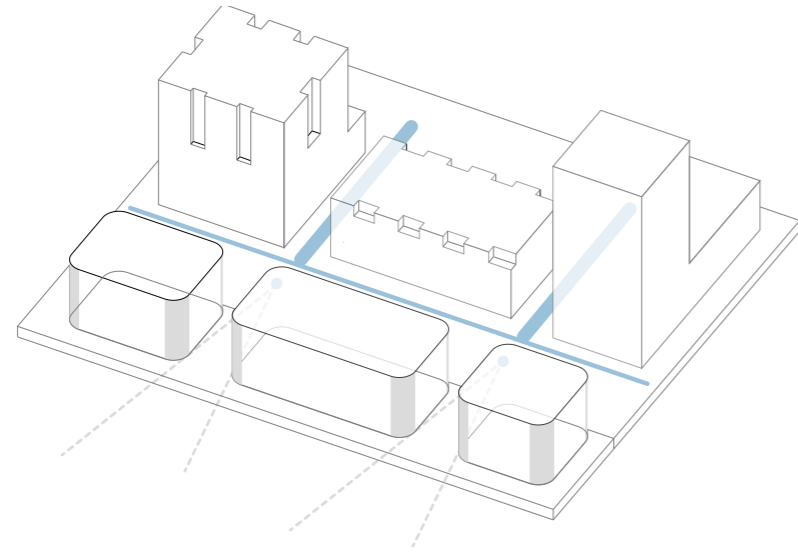
**Spatial
Functional
Structural
integration**



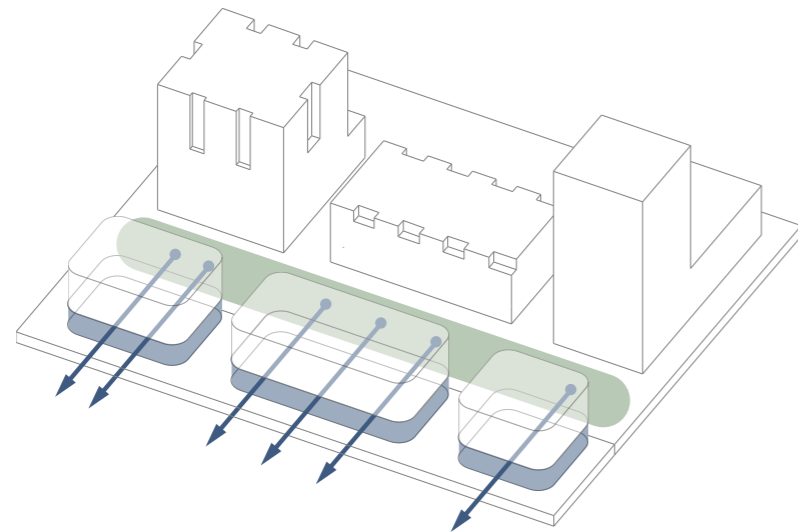
Public Park

Shared use



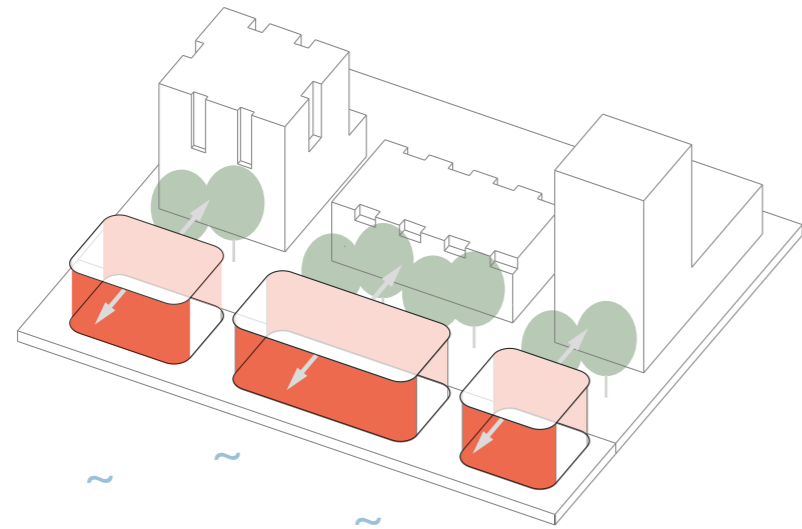


**STREETS WITH DIRECT
VIEW ON WATERSIDE**

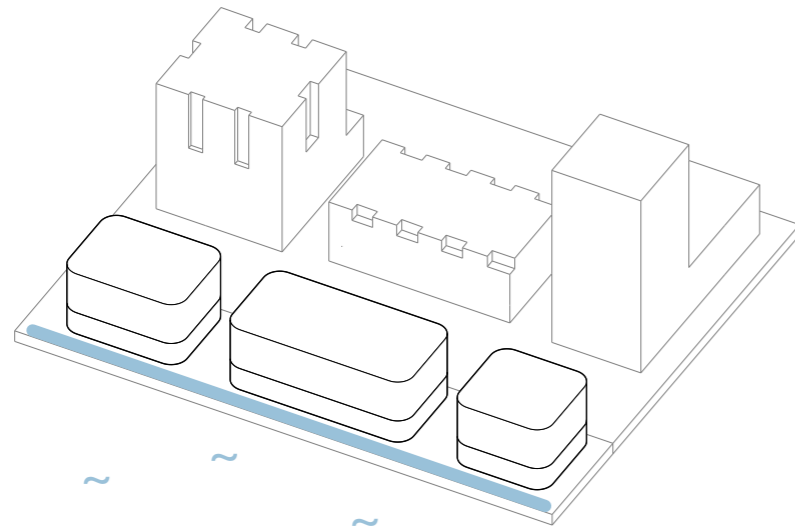


**PUBLIC FUNCTIONS IN PLITH PROVIDING
ACCESSIBILITY AND TRANSPARENCY**



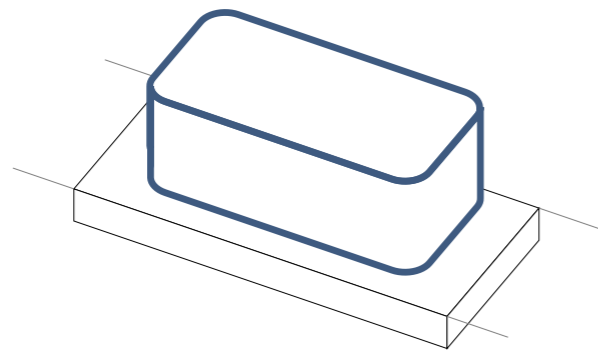


FRONT ON BOTH WATER-
AND PARKSIDE

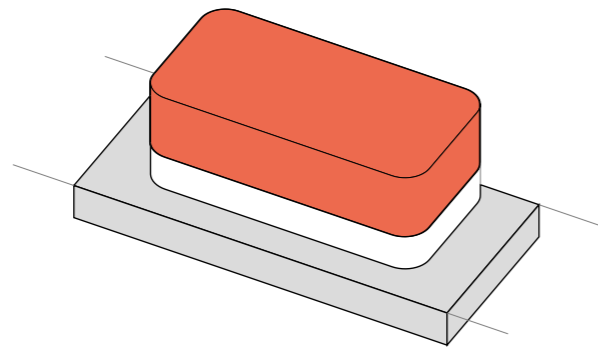


PROMENADE CONNECTING THE
VARIOUS VOLUMES

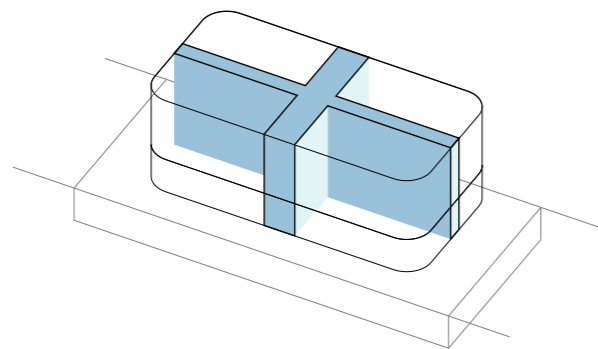




EVEN WEIGHT DISTRIBUTION TO
MAINTAIN STABILITY



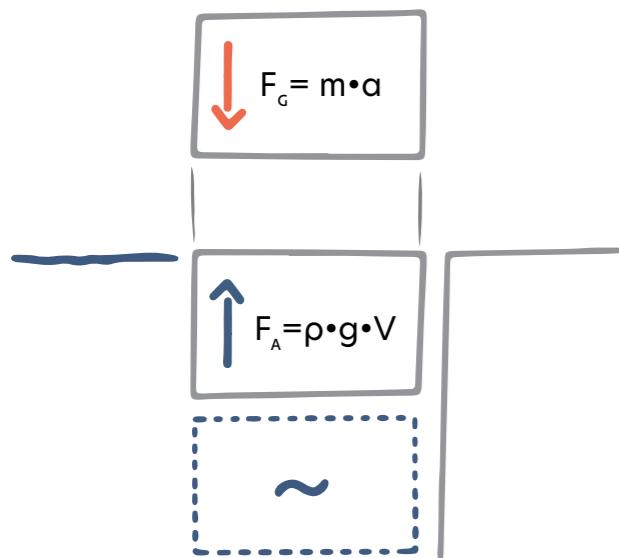
UTILITIES INSIDE FLOATING FOUNDATION
FLEXIBLE HOUSING INFILL ON TOP



CENTRAL HALLWAY PROVIDING
STABILITY, LOGISTICS AND DAYLIGHT



FLOATING FOUNDATION PRINCIPLES



UPWARD FORCE EQUAL TO
WEIGHT OF DISPLACED WATER

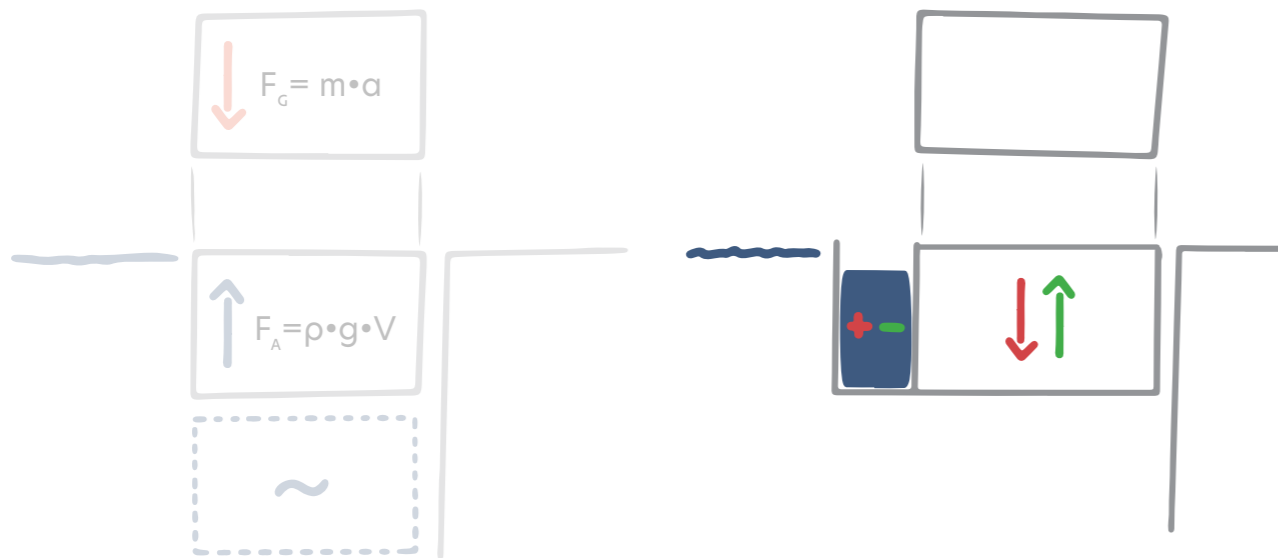
(LAW OF ARCHIMEDES)

MAESLANTKERING



24. Hydraulic engineering references, Maeslantkering and Stormvloedkering Ramspol (Rijkswaterstaat, 2014)

FLOATING FOUNDATION PRINCIPLES



UPWARD FORCE EQUAL TO WEIGHT OF DISPLACED WATER

(LAW OF ARCHIMEDES)

INTERNAL WATER BUFFER

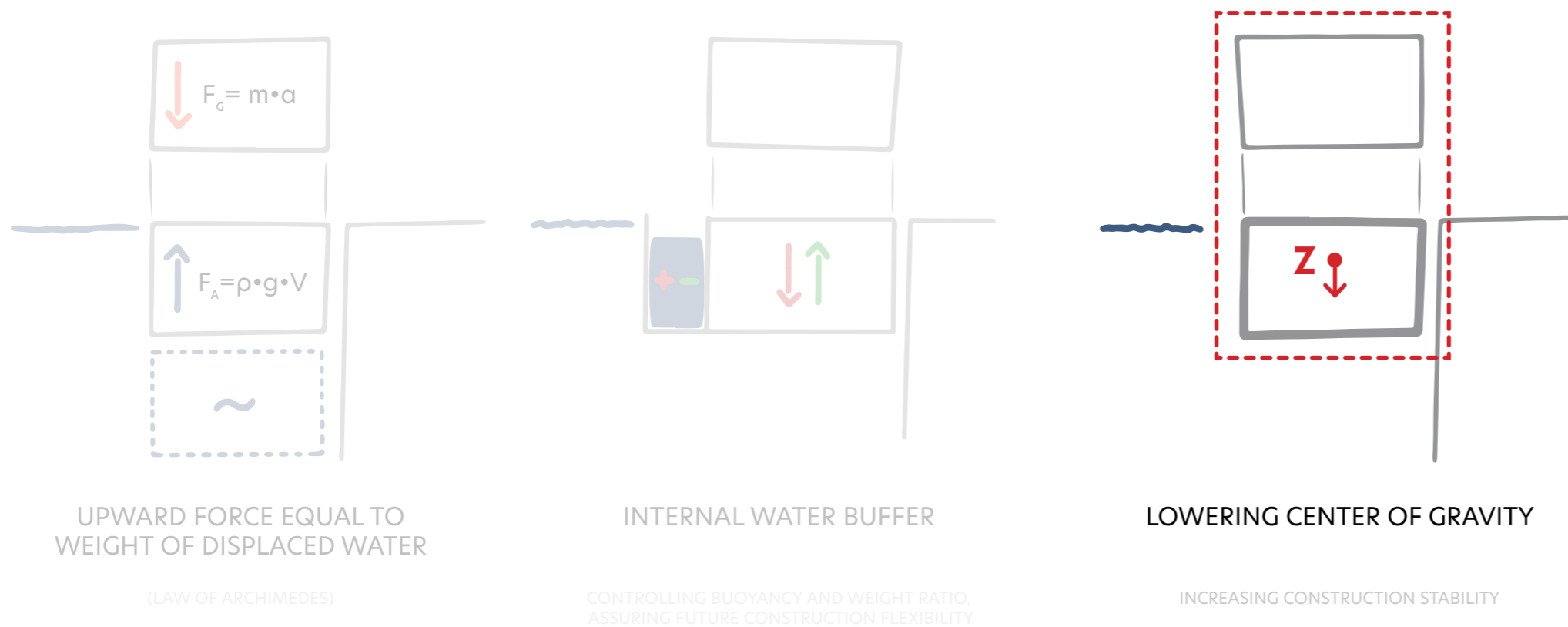
CONTROLLING BUOYANCY AND WEIGHT RATIO, ASSURING FUTURE CONSTRUCTION FLEXIBILITY

MAESLANTKERING



24. Hydraulic engineering references, Maeslantkering and Stormvloedkering Ramspol (Rijkswaterstaat, 2014)

FLOATING FOUNDATION PRINCIPLES



MAESLANTKERING

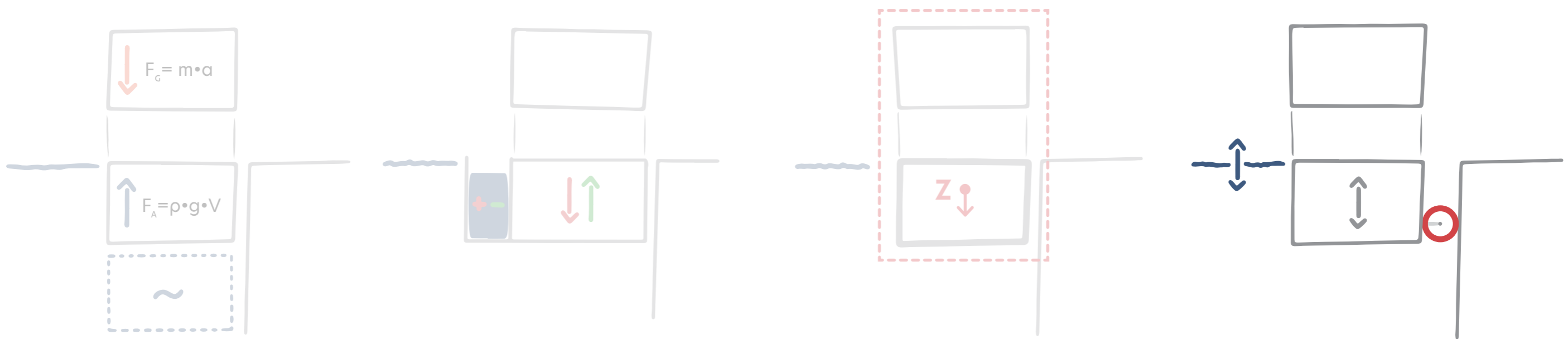


STORMVLOEDKERING RAMSPOL



24. Hydraulic engineering references, Maeslantkering and Stormvloedkering Ramspol (Rijkswaterstaat, 2014)

FLOATING FOUNDATION PRINCIPLES



UPWARD FORCE EQUAL TO WEIGHT OF DISPLACED WATER

(LAW OF ARCHIMEDES)

INTERNAL WATER BUFFER

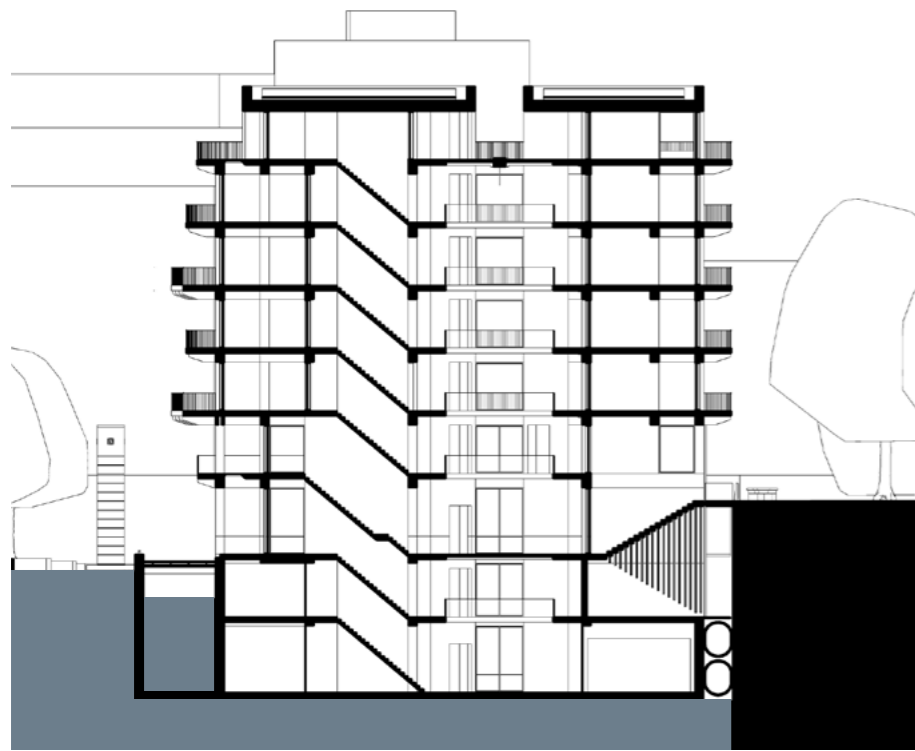
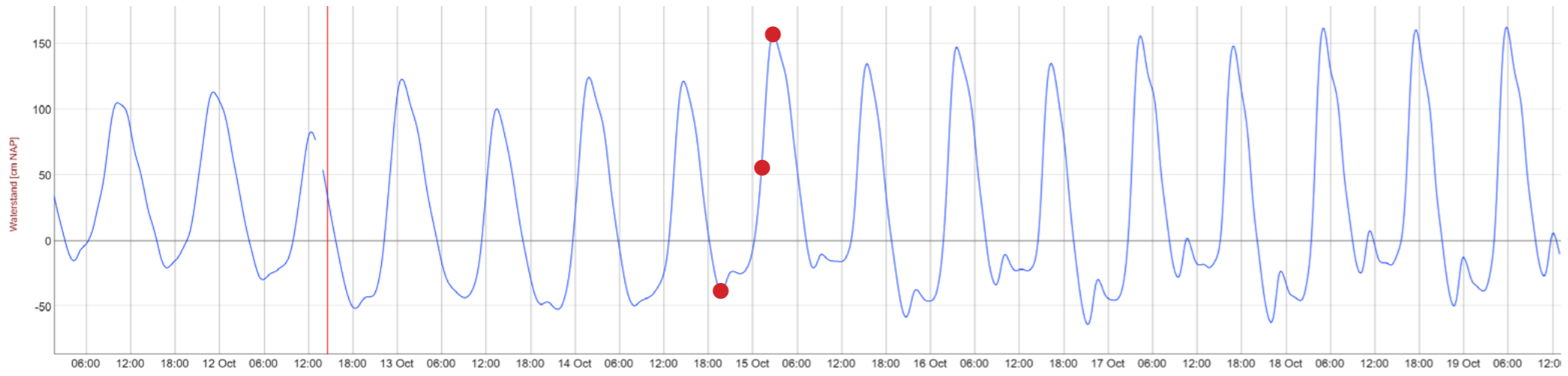
CONTROLLING BUOYANCY AND WEIGHT RATIO, ASSURING FUTURE CONSTRUCTION FLEXIBILITY

LOWERING CENTER OF GRAVITY

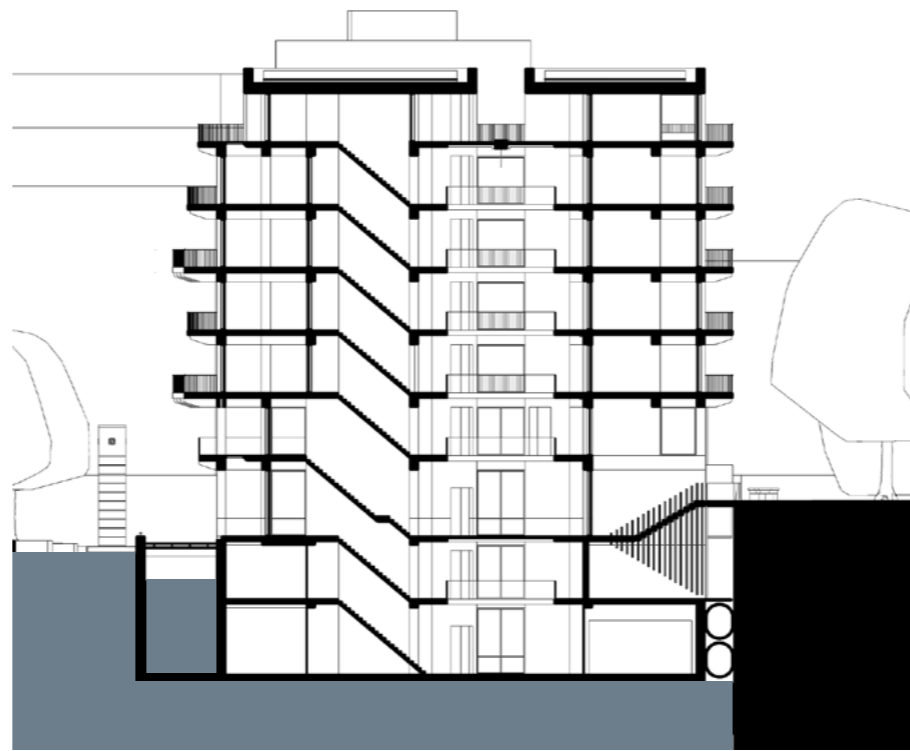
INCREASING CONSTRUCTION STABILITY

INFLATABLE WATERTIGHT ROLLER

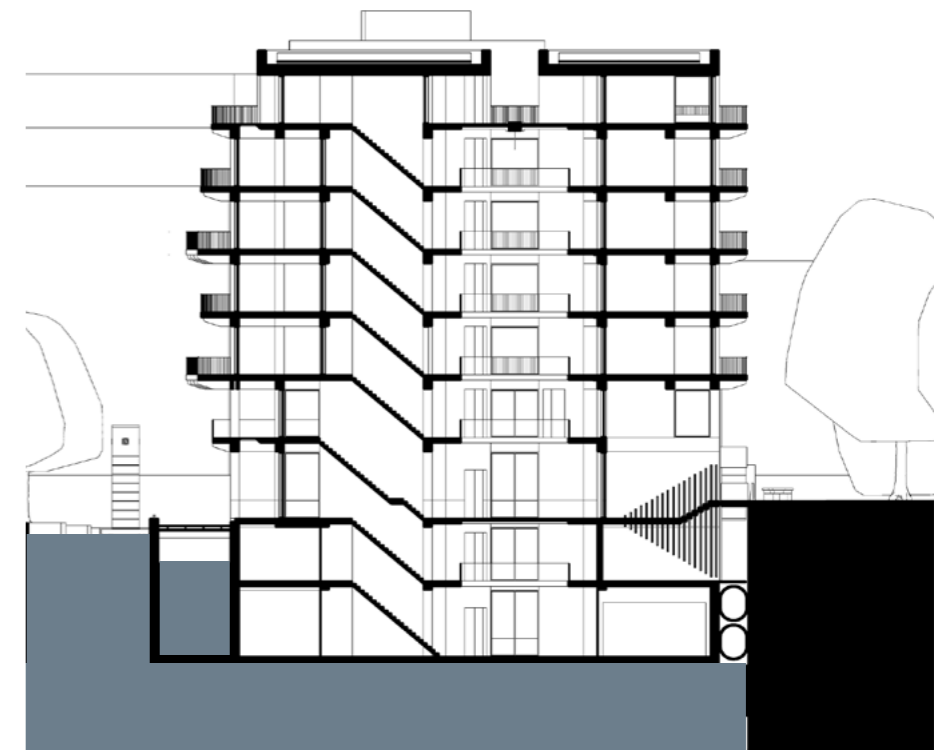
FUNCTIONING AS FLOOD BARRIER



low tide | NAP -0.4m



mid tide | NAP +0.5m

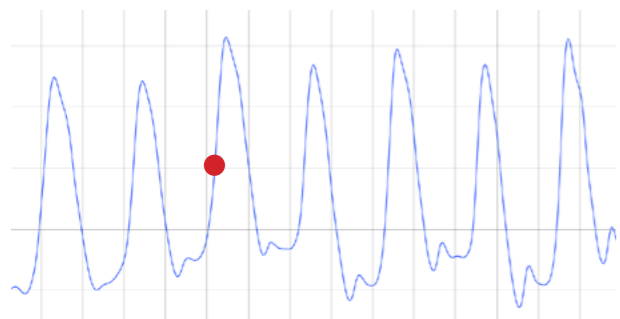


high tide | NAP +1.5m



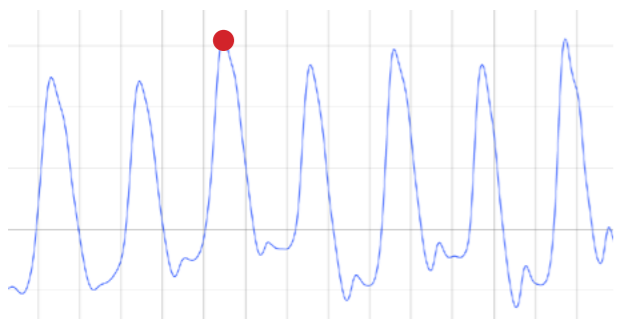
low tide | NAP -0.4m

4:00 PM



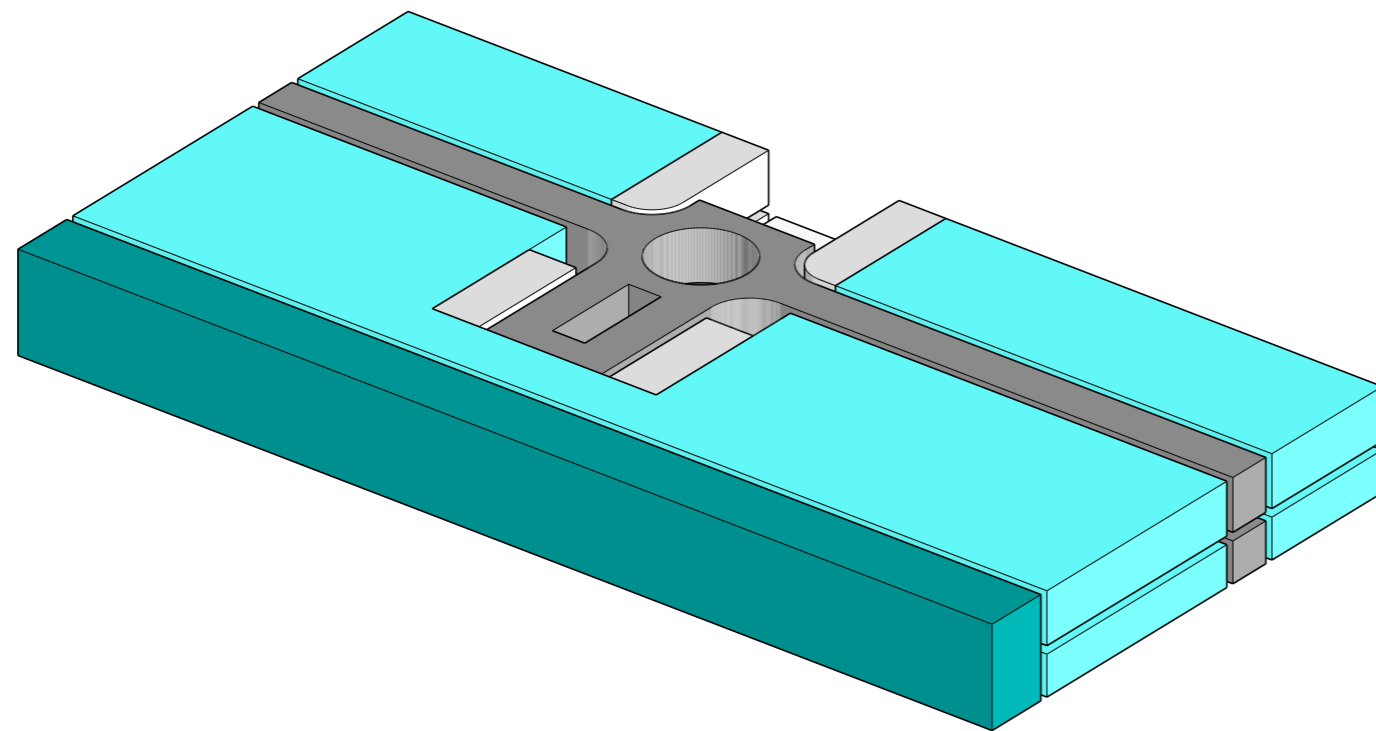
mid tide | NAP +0.5m






7:00 PM

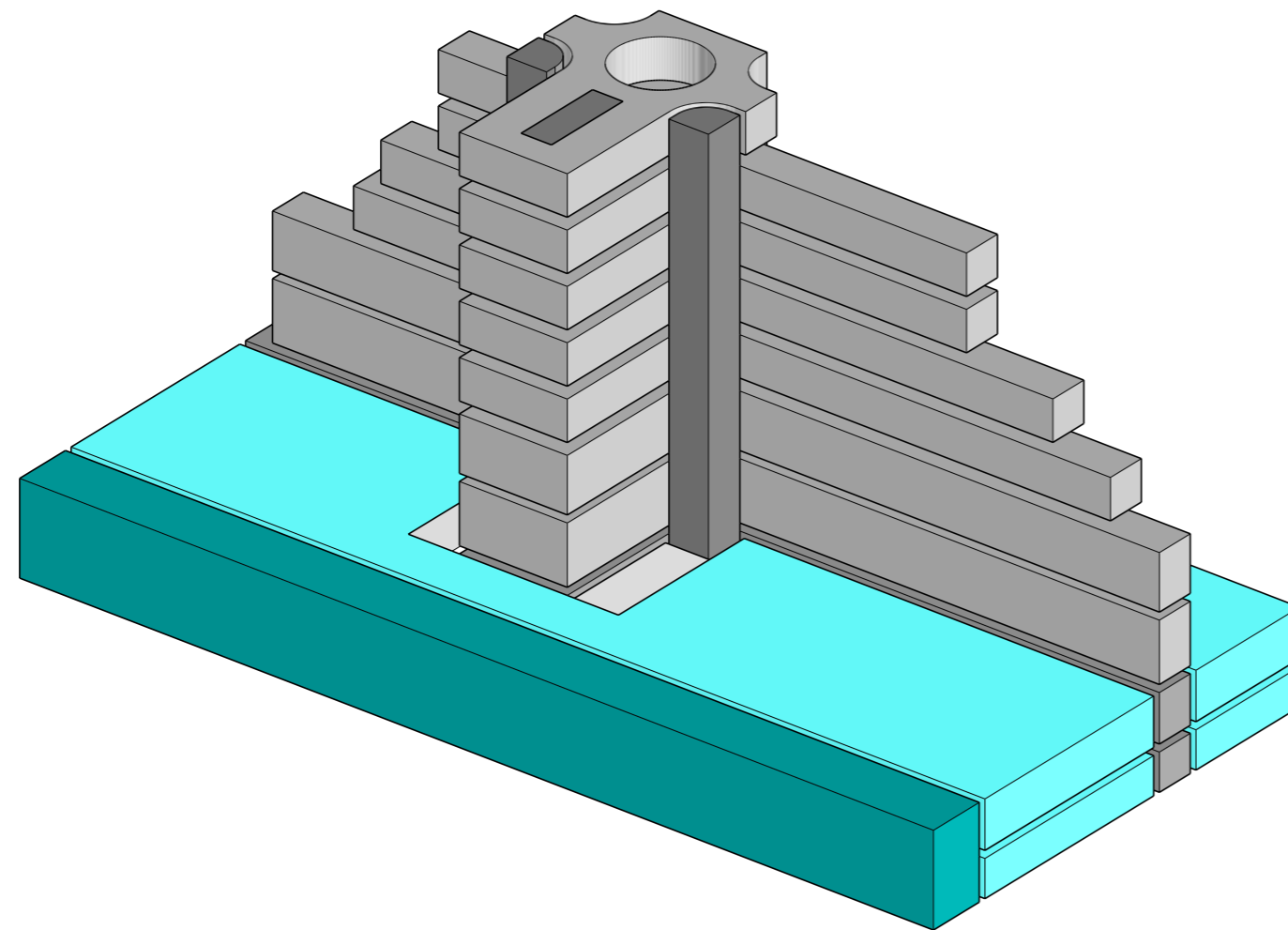


high tide | NAP +1.5m

10:00 PM

**Utilitarian****3070 m²**

	parking	76 spots	2.060
	hallway		510
	installations	4	100
	storage (housing)	26	150
	water buffer	1650 m ³	250

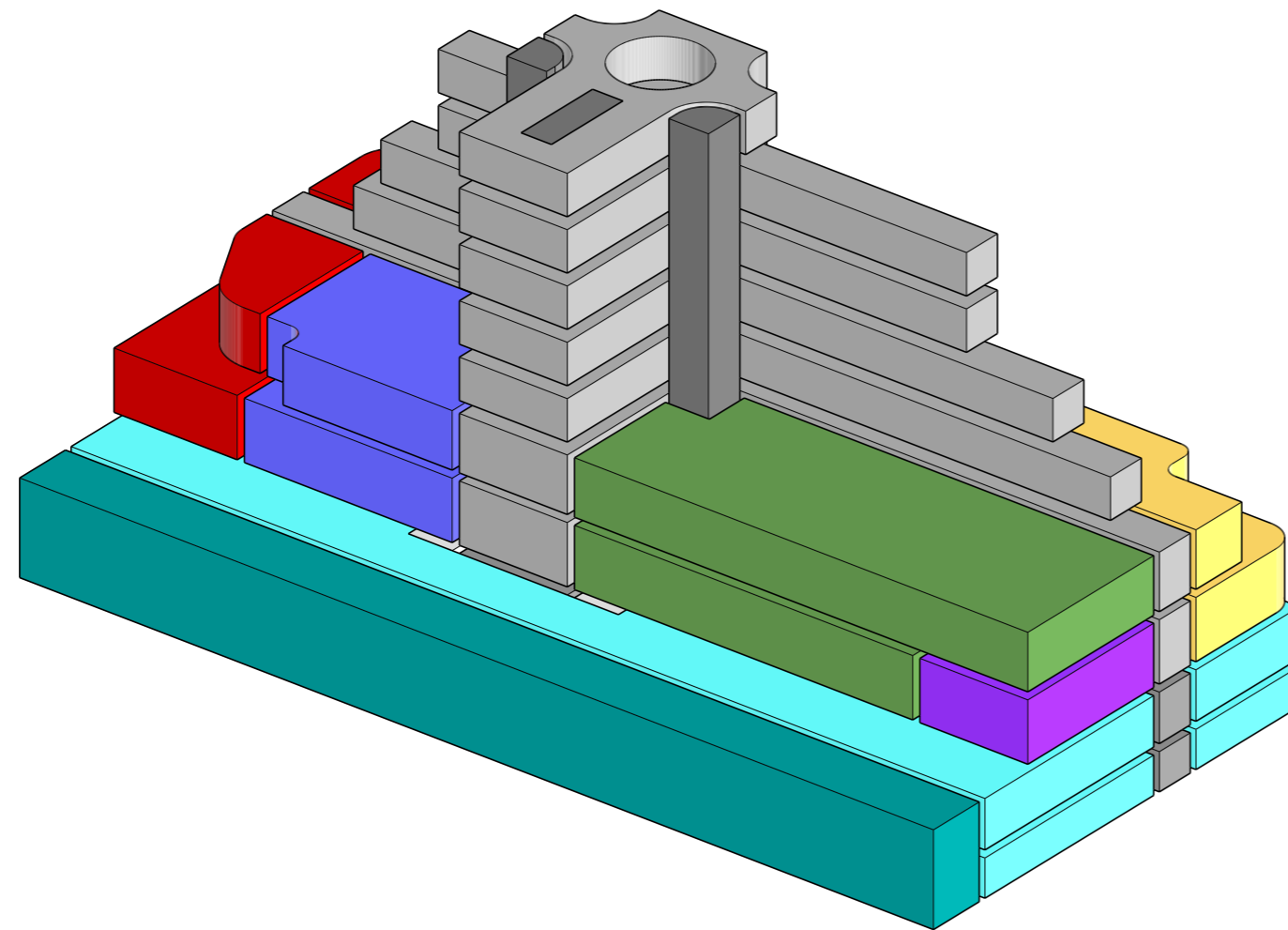


Logistics **1185 m²** **12 %**

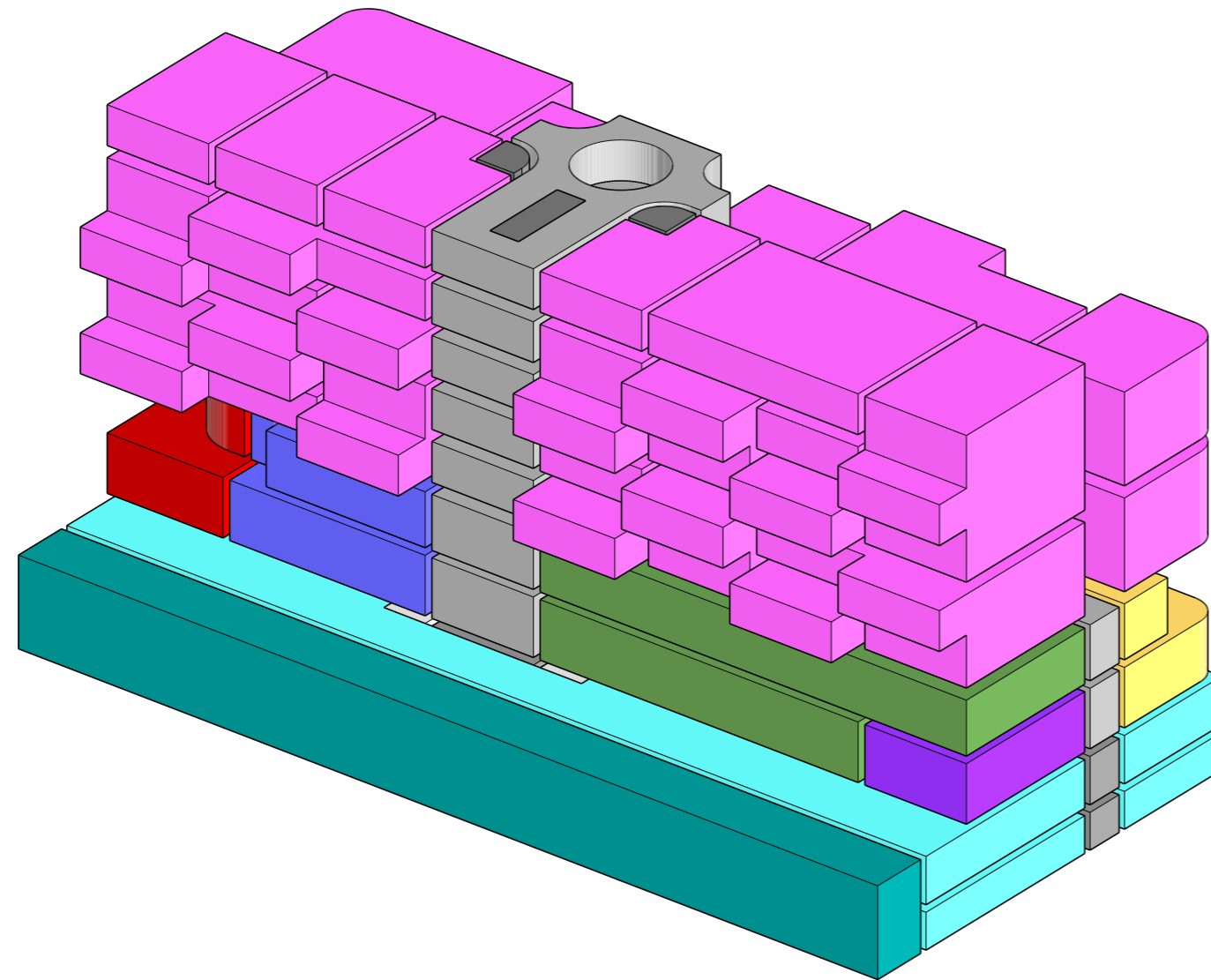
■	hallway		950
■	staircase	1	170
■	elevator	2	65

Utilitarian **3070 m²**

■	parking	76 spots	2.060
■	hallway		510
■	installations	4	100
■	storage (housing)	26	150
■	water buffer	1650 m ³	250



Public		2180 m²	24%
■	library	630	
■	flexwork area	585	
■	cafe restaurant	124	
■	meeting space	270	
■	gym	305	
■	local shops	2	265
Logistics		1185 m²	12 %
■	hallway	950	
■	staircase	1	170
■	elevator	2	65
Utilitarian		3070 m²	
■	parking	76 spots	2.060
■	hallway		510
■	installations	4	100
■	storage (housing)	26	150
■	water buffer	1650 m ³	250



Private 4880 m² 55 %

■ housing units	38	4880
< 80 m ²	21	
80/160 m ²	12	
> 160 m ²	5	

Public 2180 m² 24%

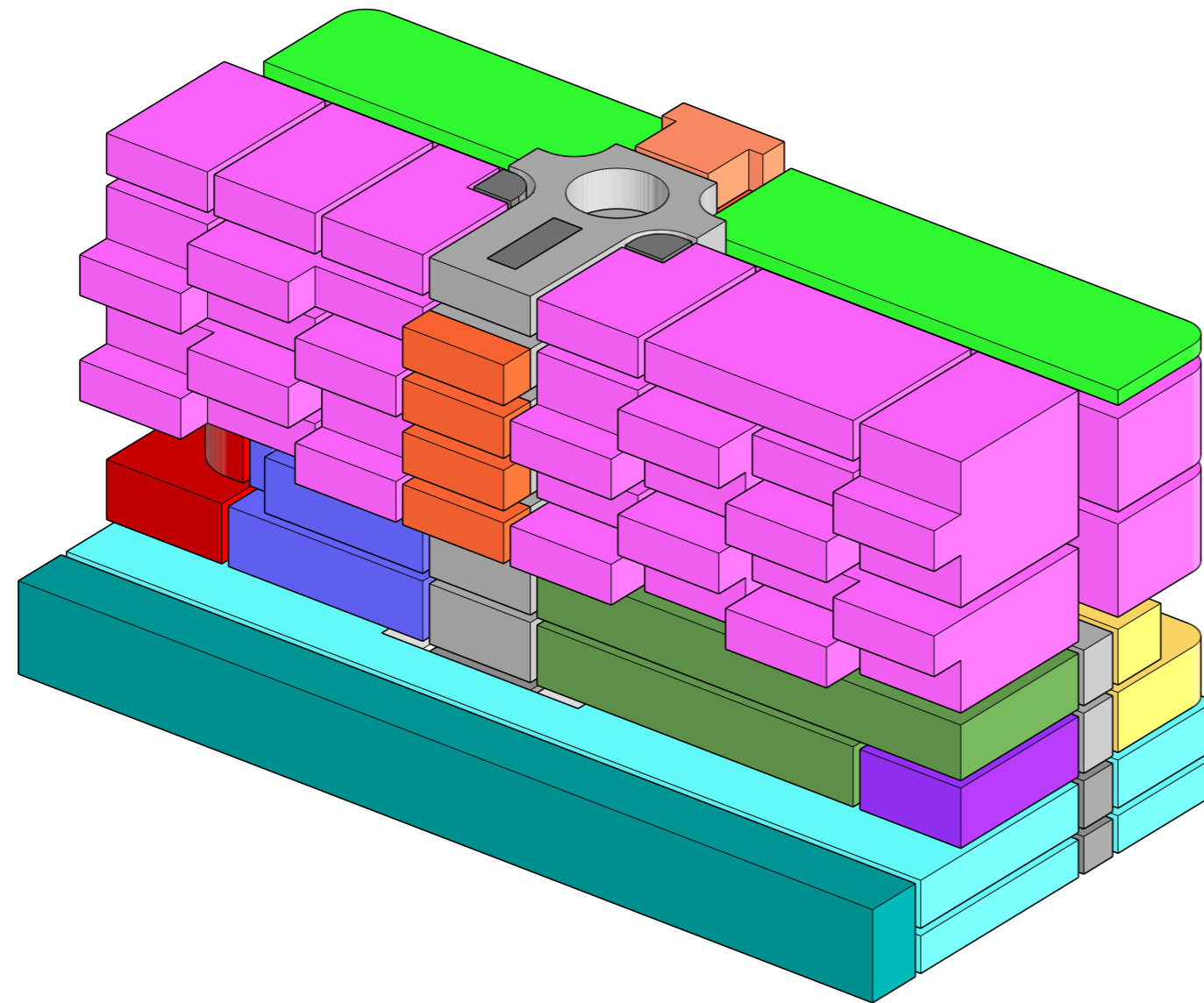
■ library		630
■ flexwork area		585
■ cafe restaurant		124
■ meeting space		270
■ gym		305
■ local shops	2	265

Logistics 1185 m² 12 %

■ hallway		950
■ staircase	1	170
■ elevator	2	65

Utilitarian 3070 m²

■ parking	76 spots	2.060
■ hallway		510
■ installations	4	100
■ storage (housing)	26	150
■ water buffer	1650 m ³	250



Shared 810 m² 9 %

■	roof garden terrace		530
■	workshop		40
■	home offices	8	240

Private 4880 m² 55 %

■	housing units	38	4880
	< 80 m ²	21	
	80/160 m ²	12	
	> 160 m ²	5	

Public 2180 m² 24 %

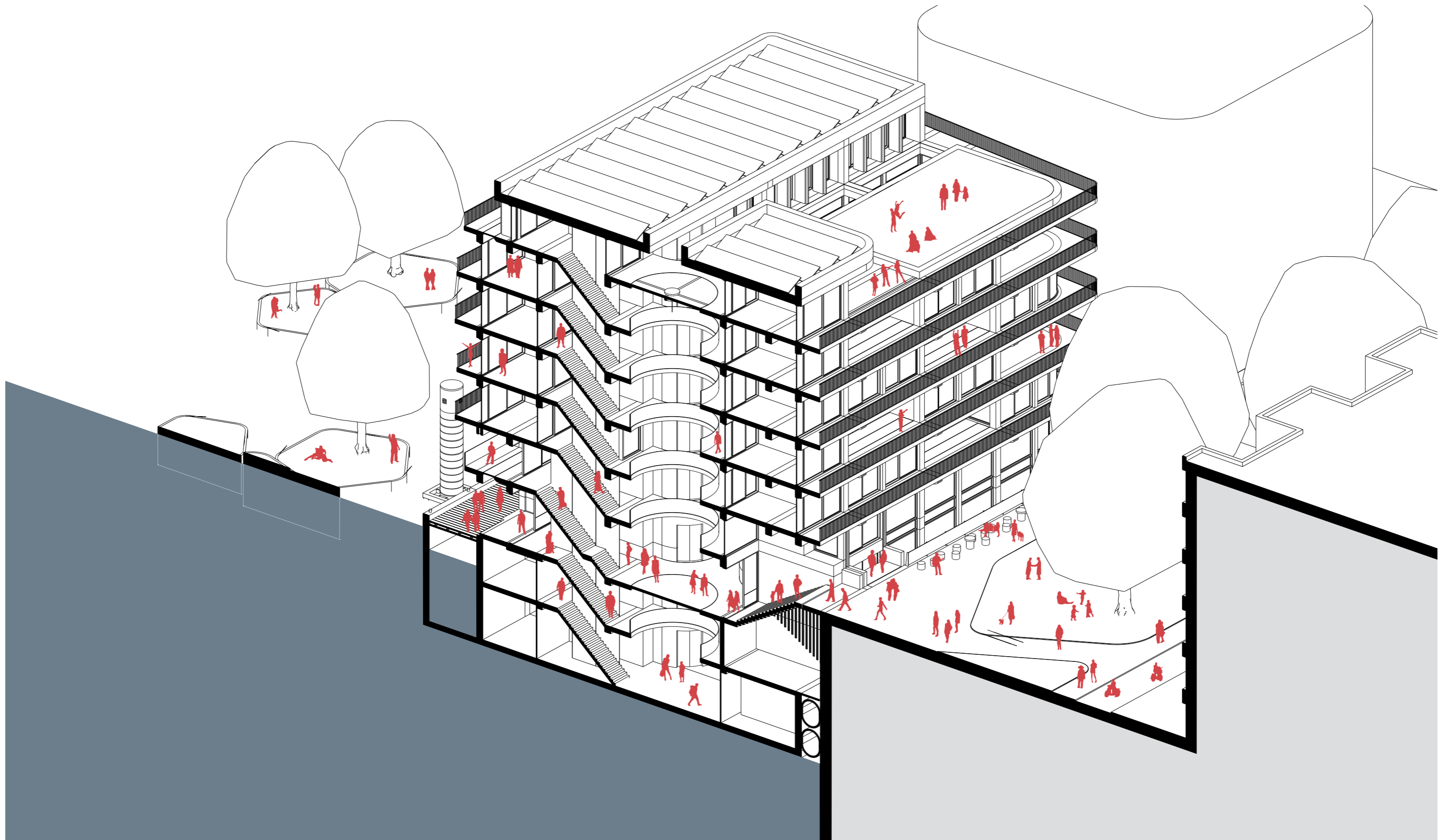
■	library		630
■	flexwork area		585
■	cafe restaurant		124
■	meeting space		270
■	gym		305
■	local shops	2	265

Logistics 1185 m² 12 %

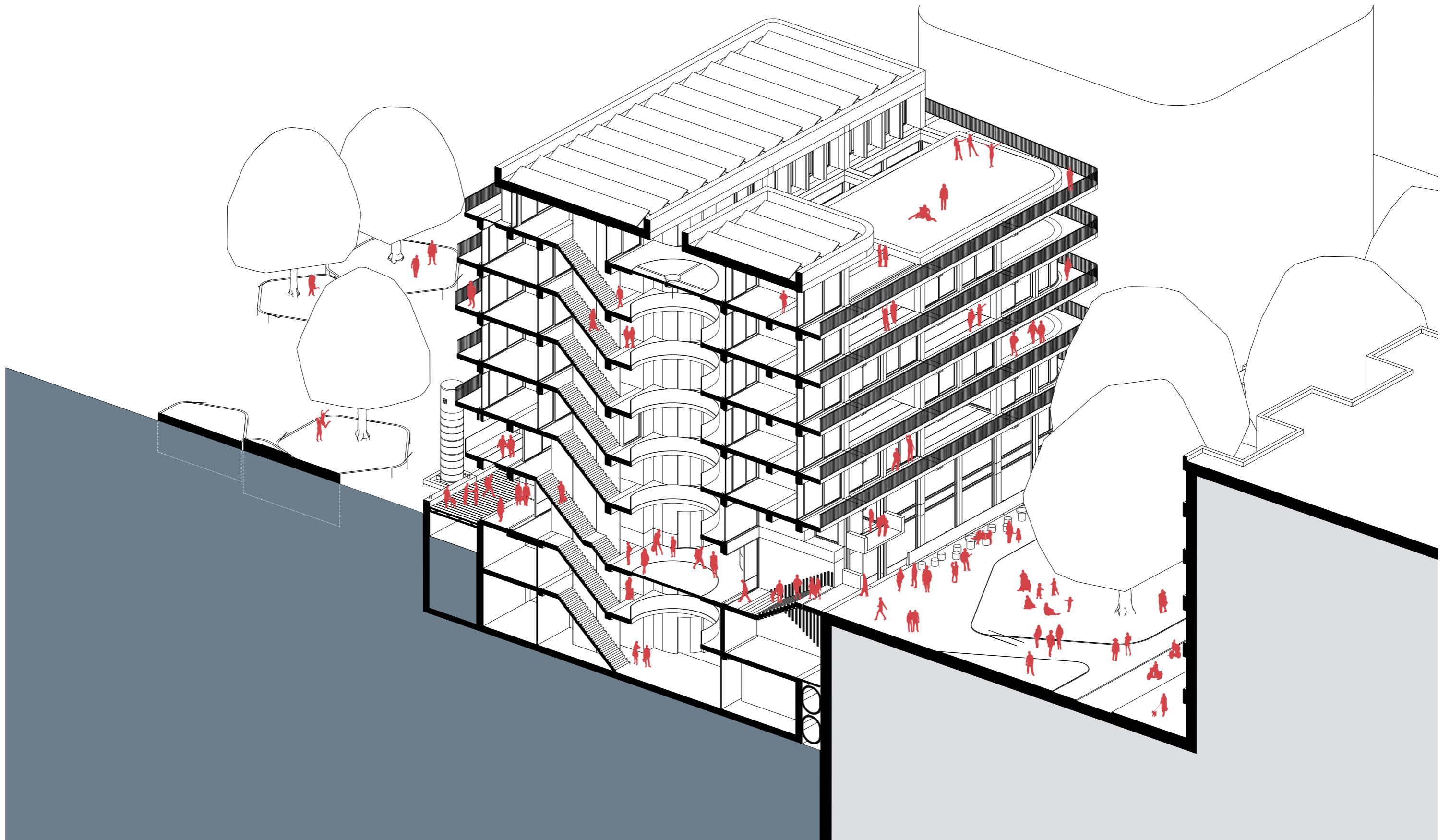
■	hallway		950
■	staircase	1	170
■	elevator	2	65

Utilitarian 3070 m²

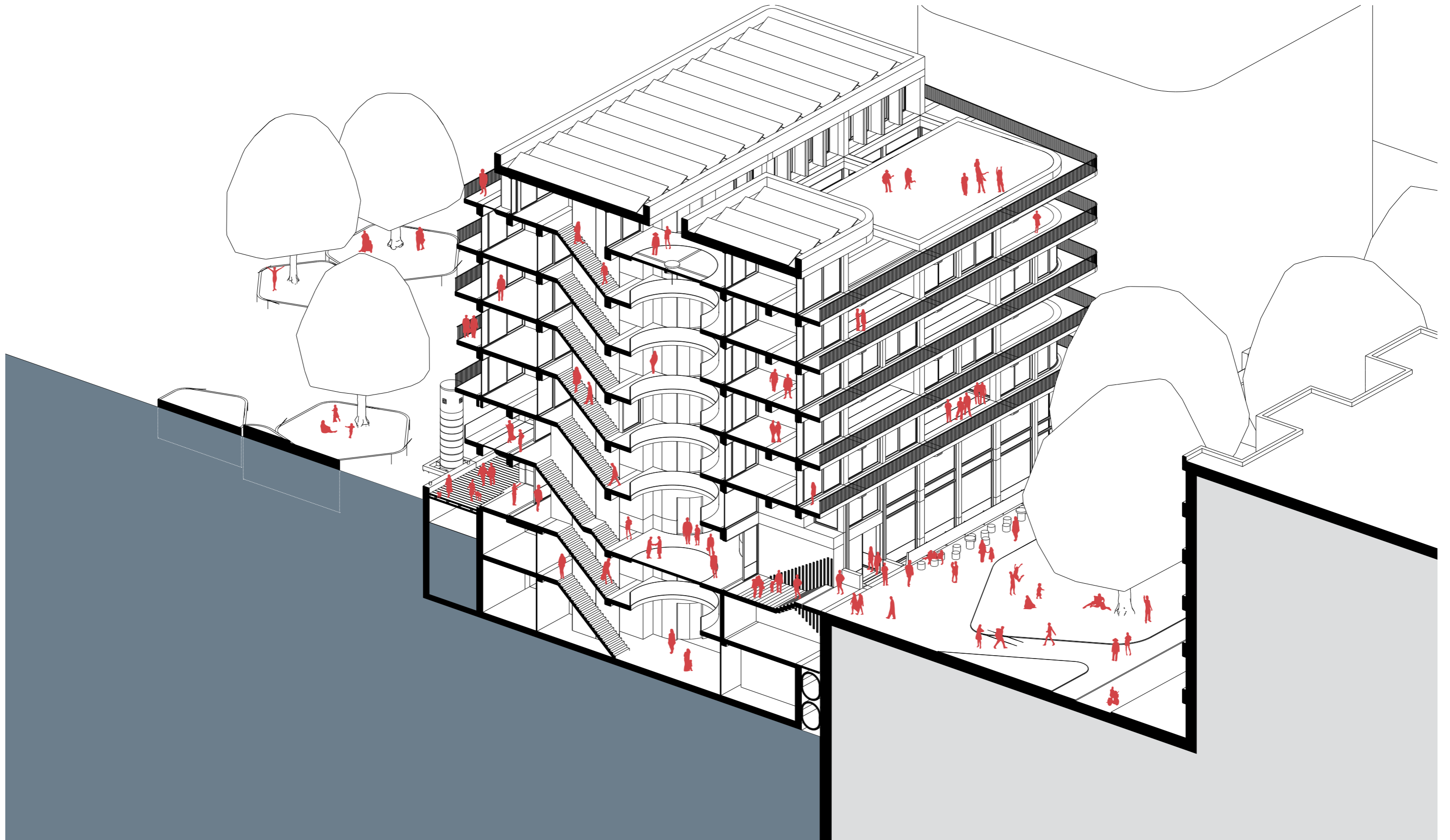
■	parking	76 spots	2.060
■	hallway		510
■	installations	4	100
■	storage (housing)	26	150
■	water buffer	1650 m ³	250



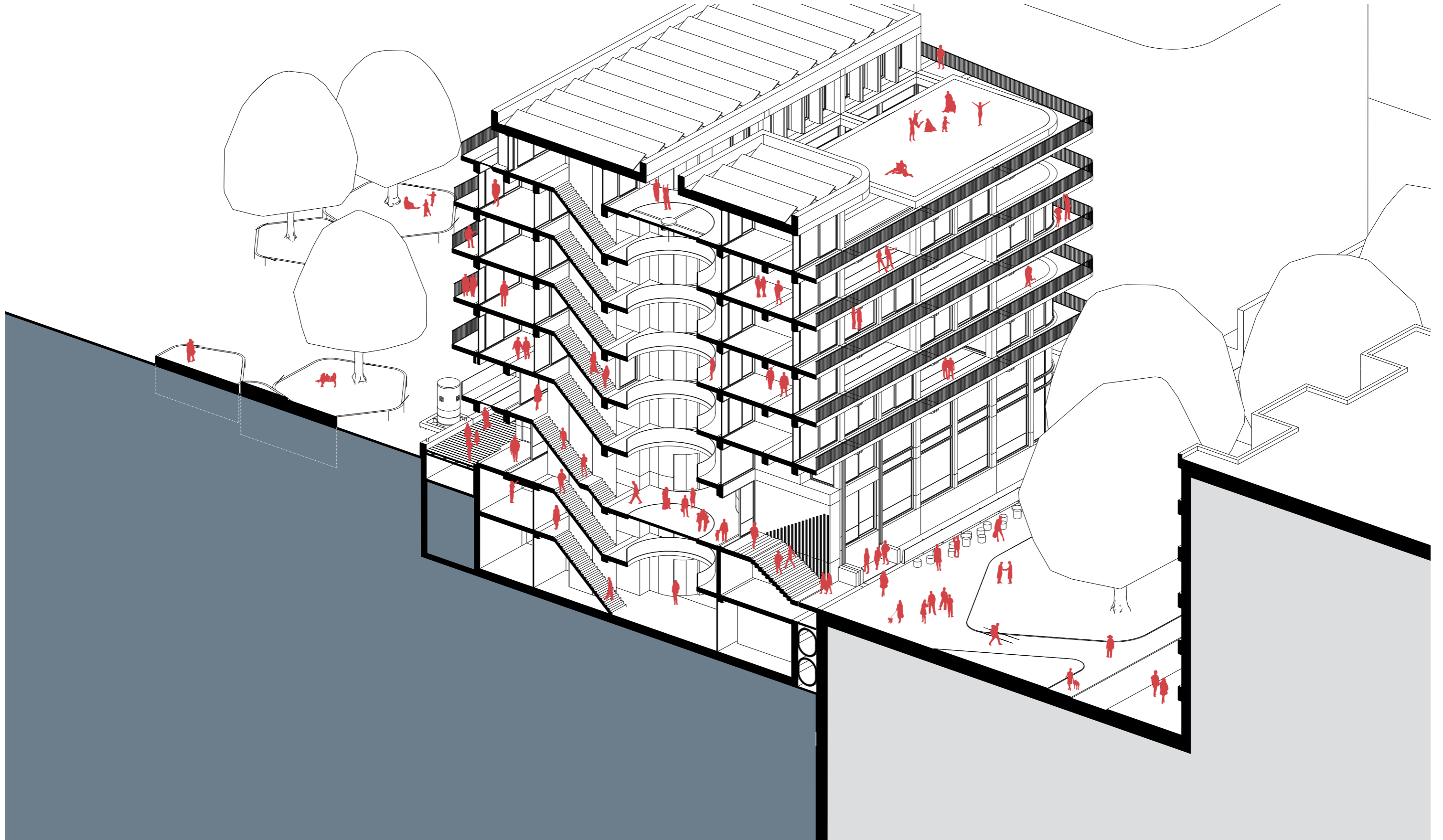
low tide | NAP -0.4m



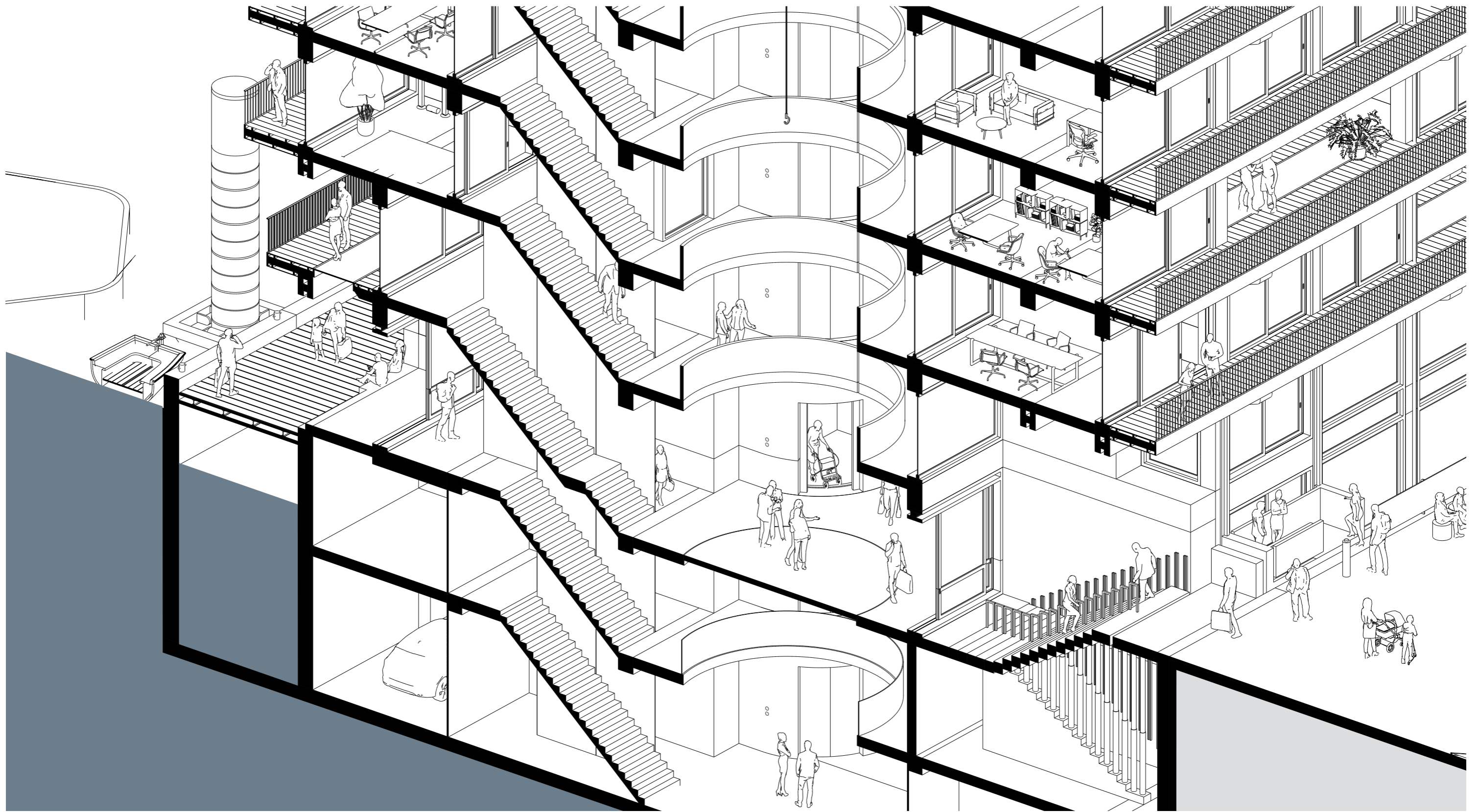
mid tide | NAP +0.5m



high tide | NAP +1.5m



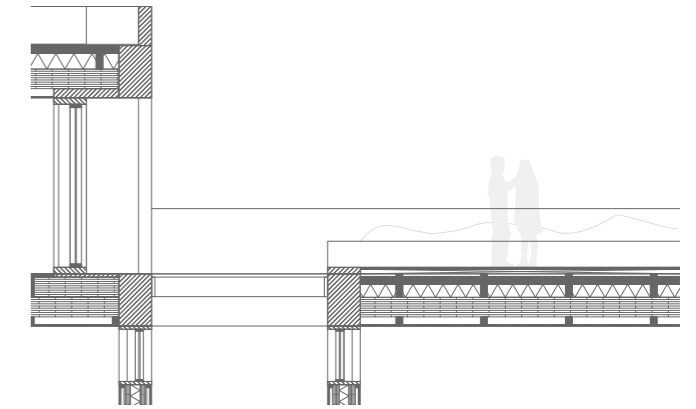
flood | NAP + >3.0m



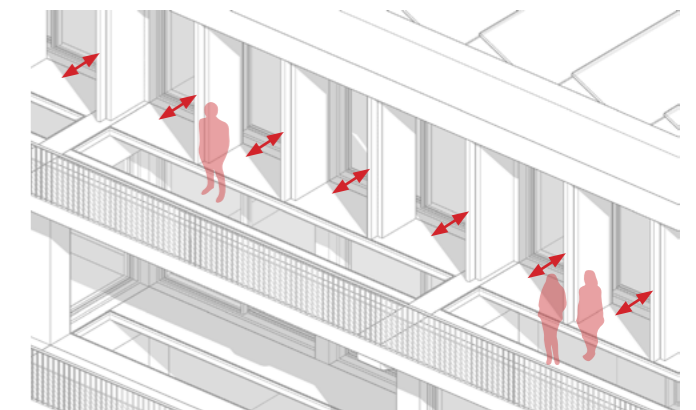
mid tide | NAP +0.5m



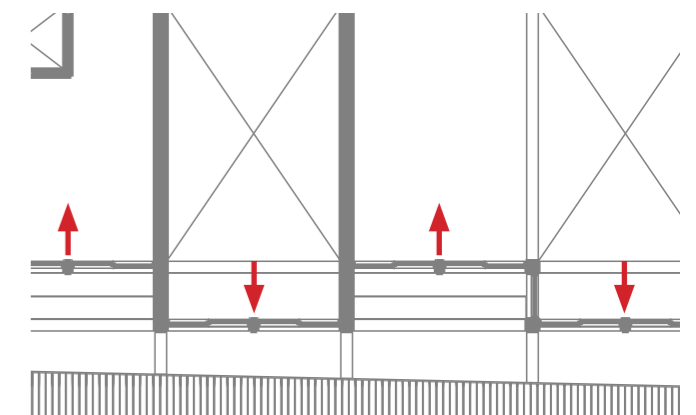
shared rooftop garden/terrace



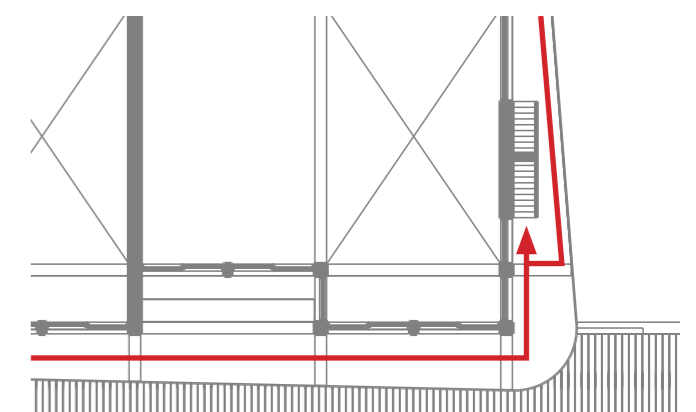
slidable shading/privacy louvres



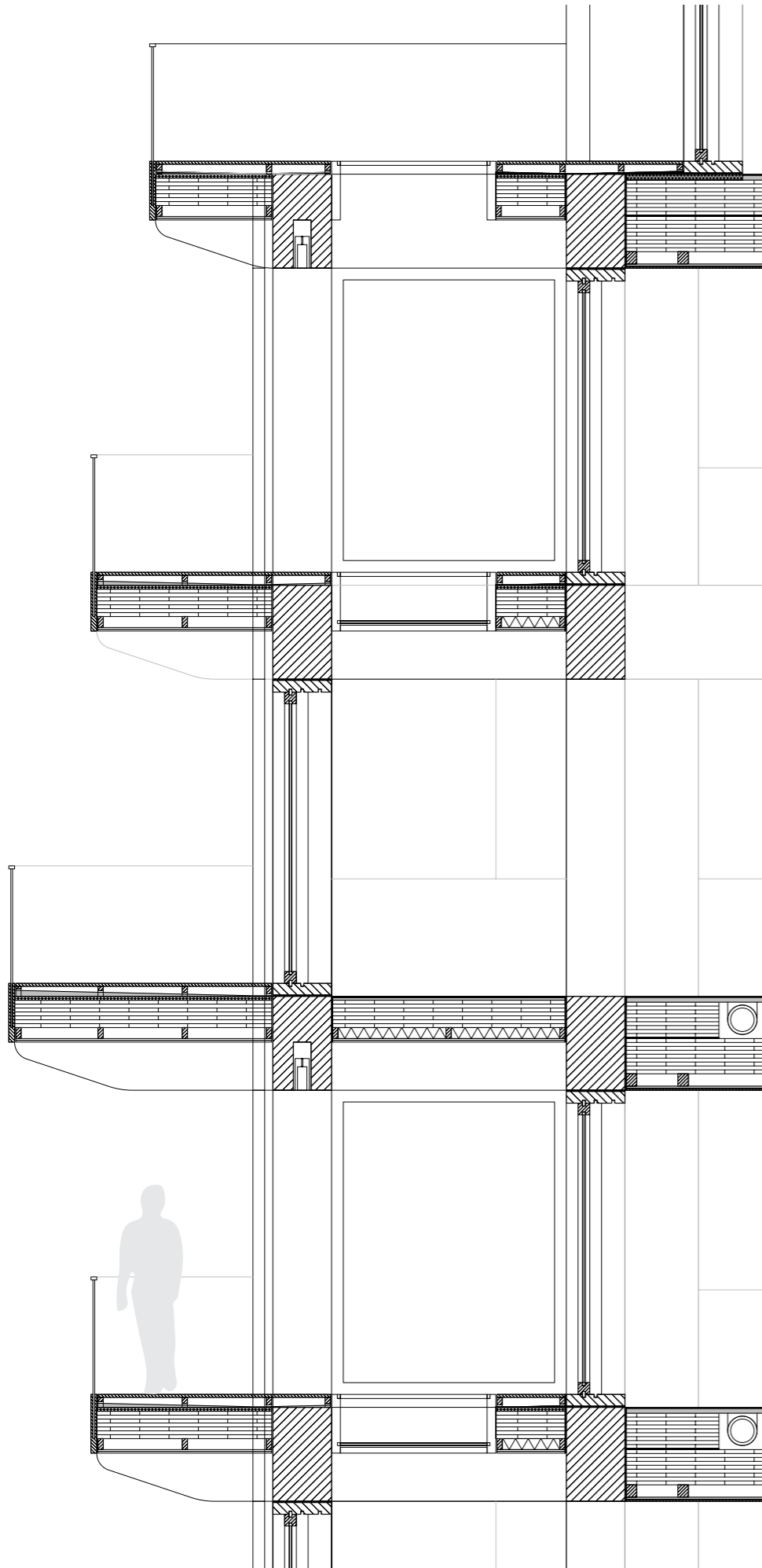
semi private balconies



fire staircase/exit through balconies

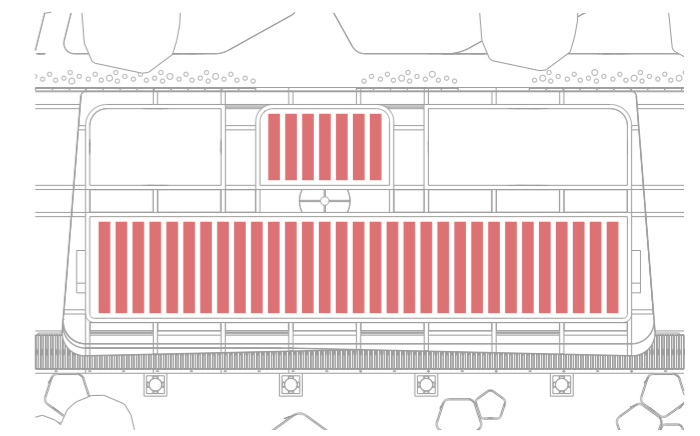




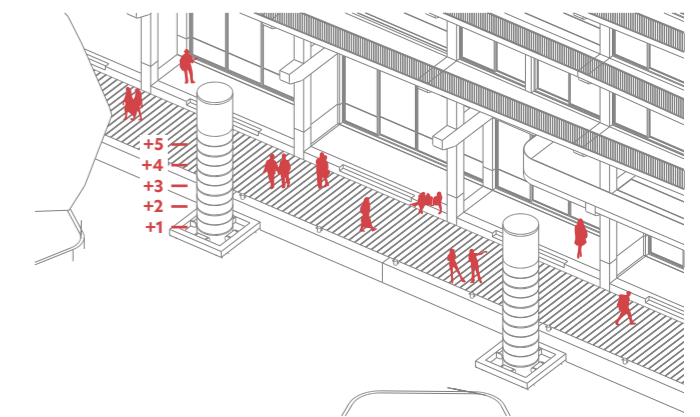




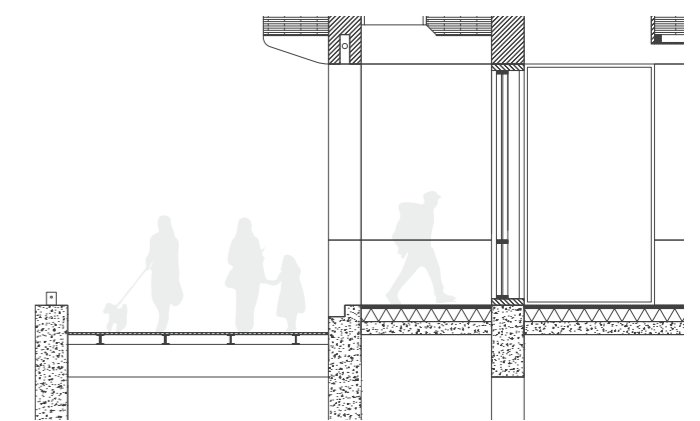
solar panels | 580 m² | 15m²/household



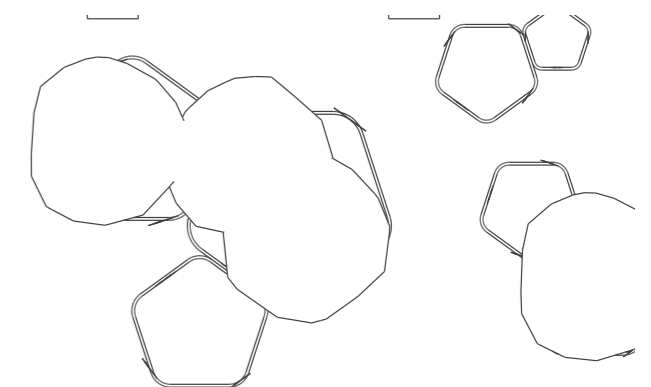
functional mooring poles/lighting



promenade above water buffer



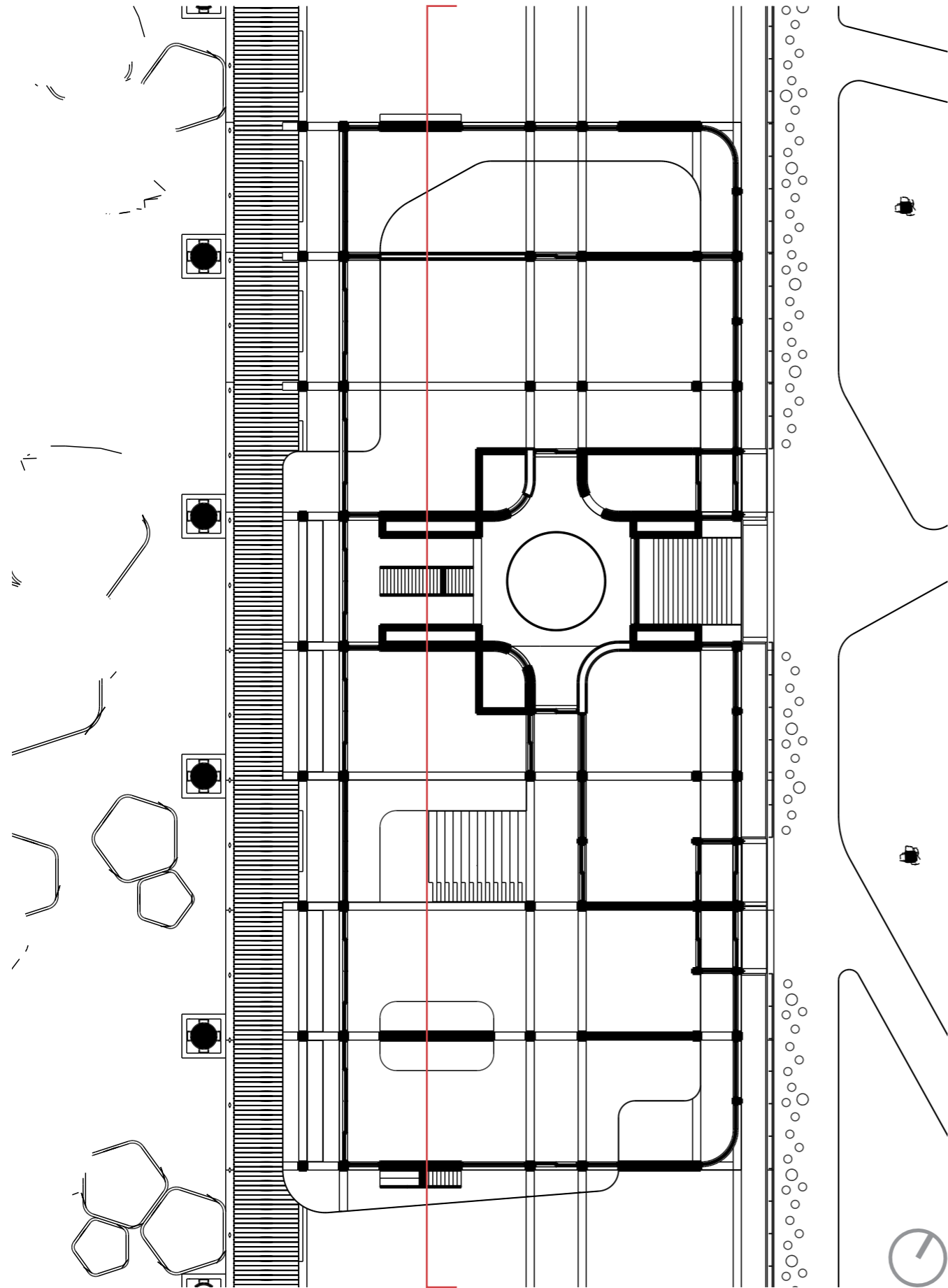
floating park elements





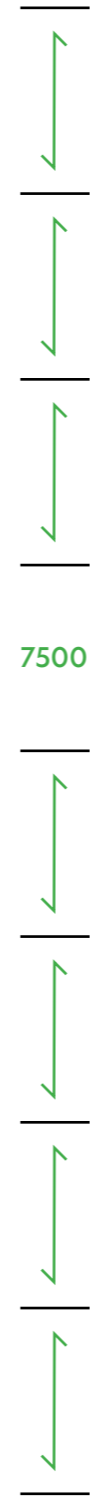
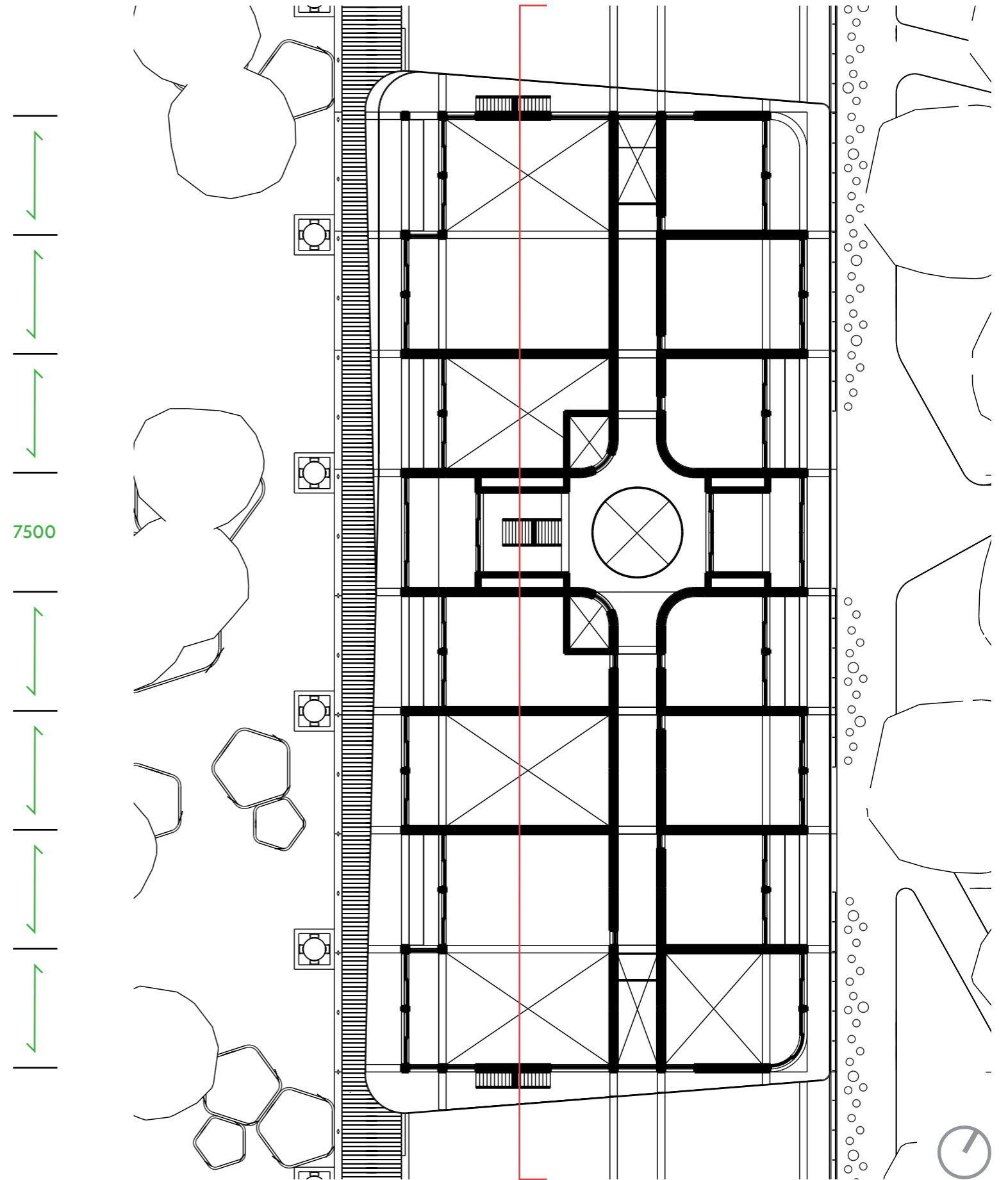
PUBLIC FUNCTIONS

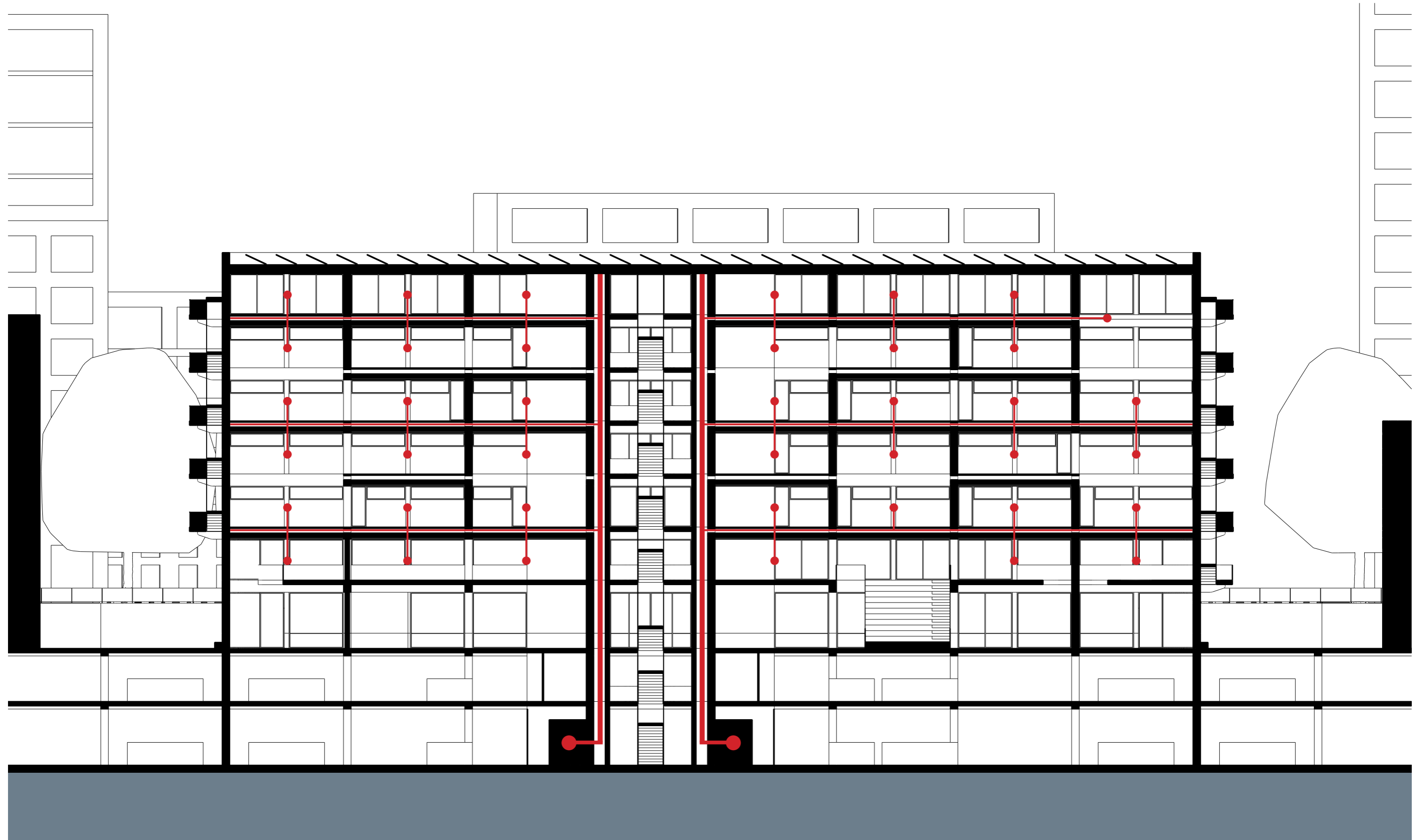
first floor

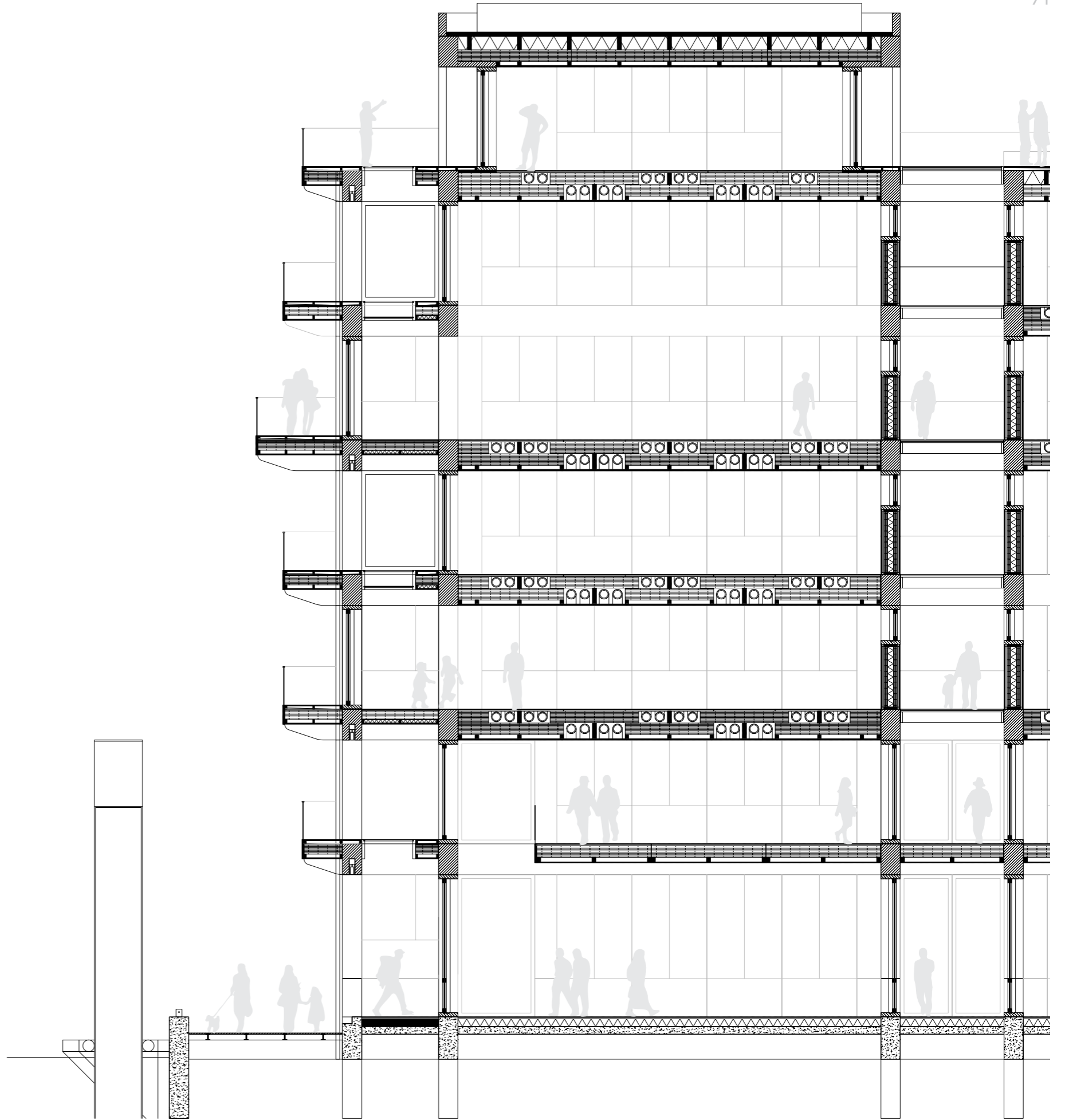
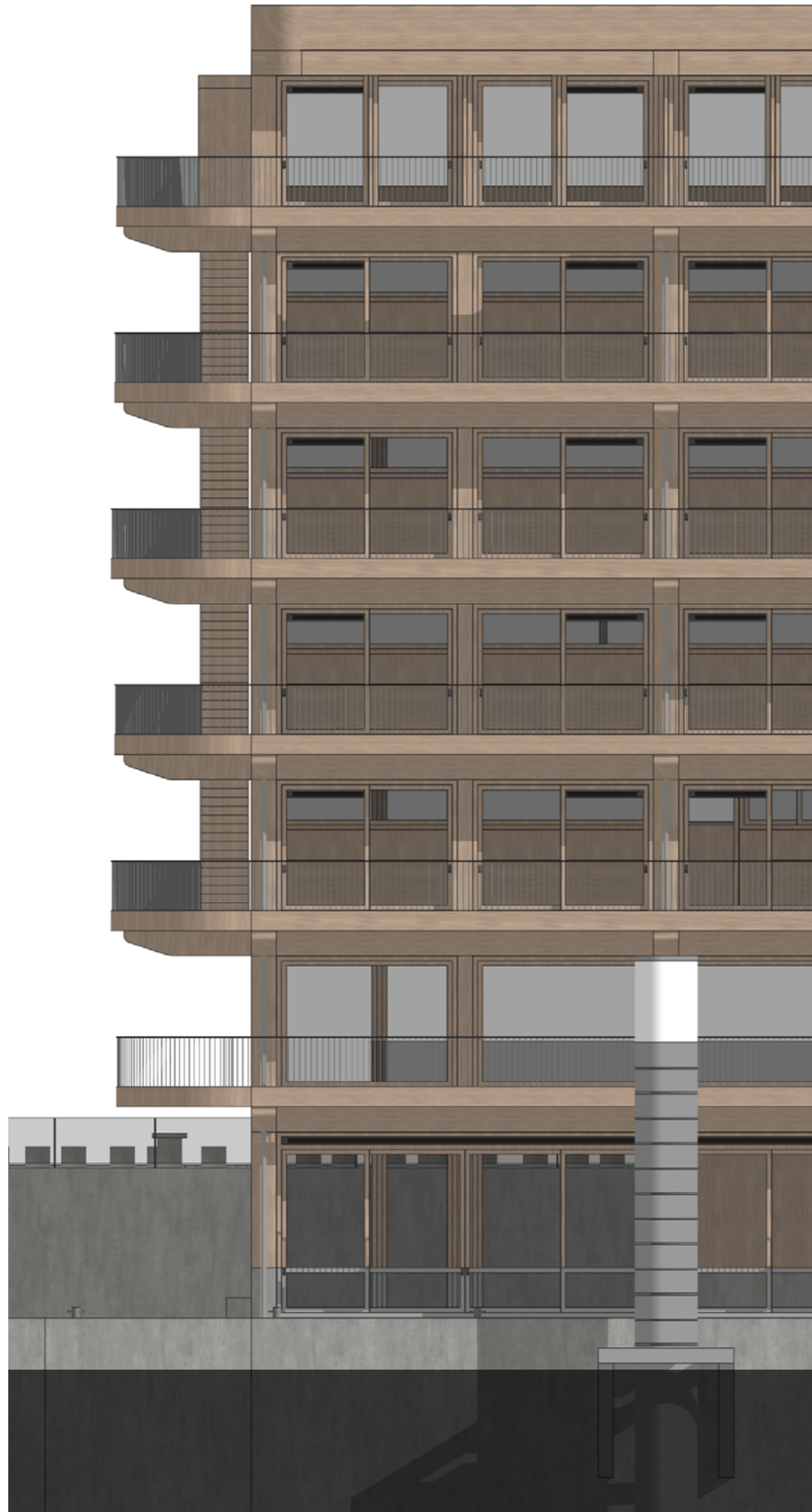


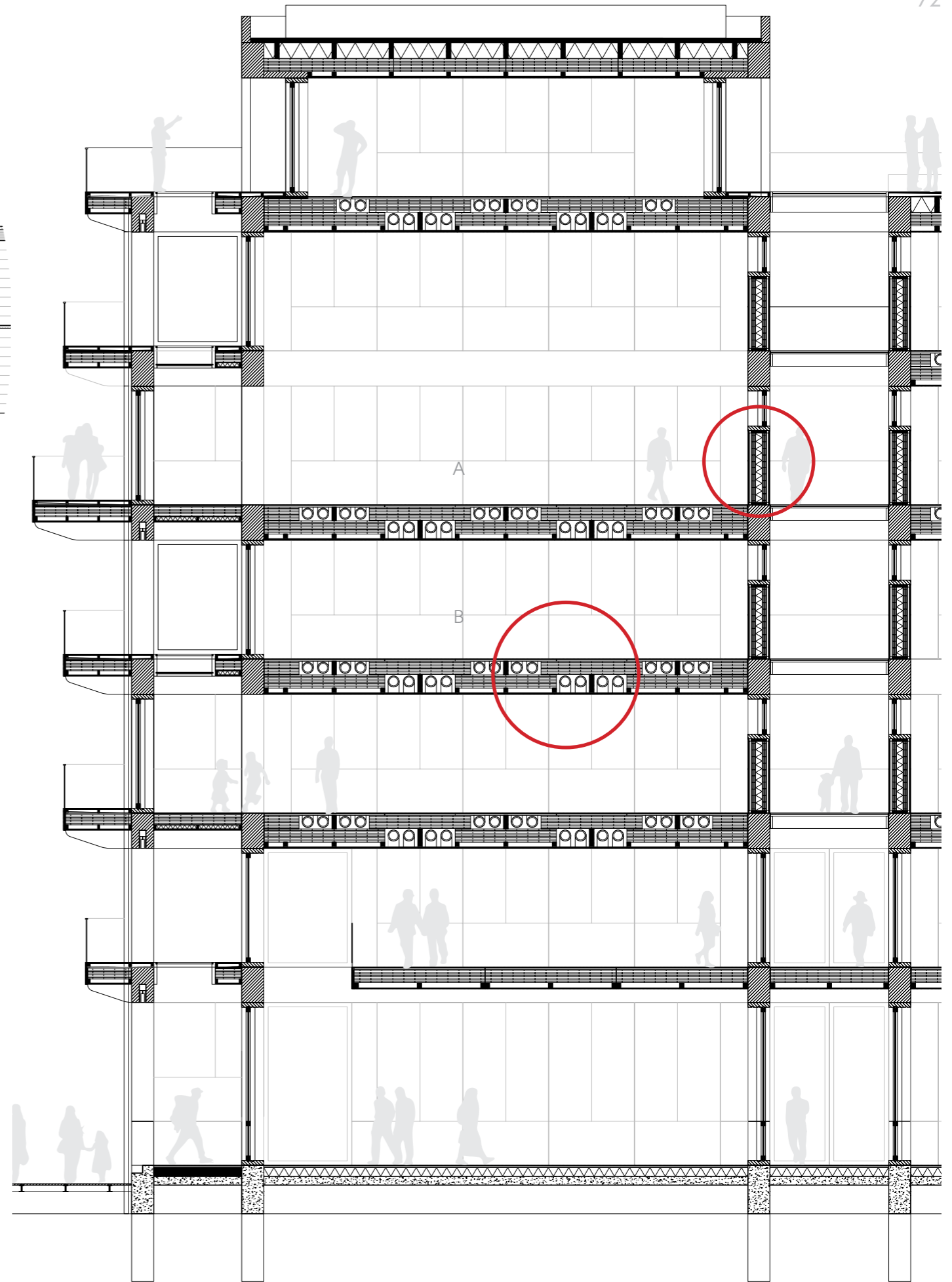
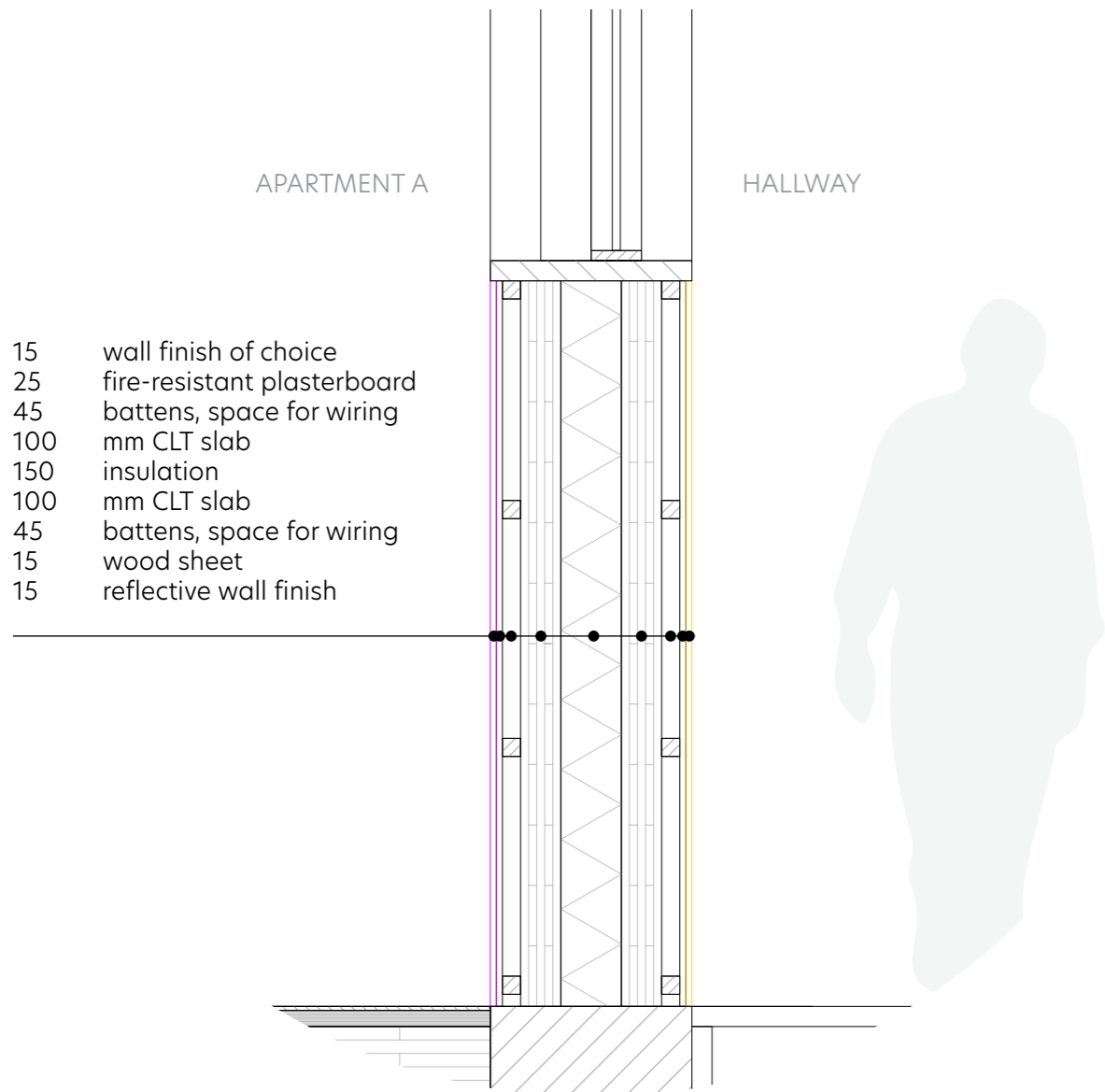
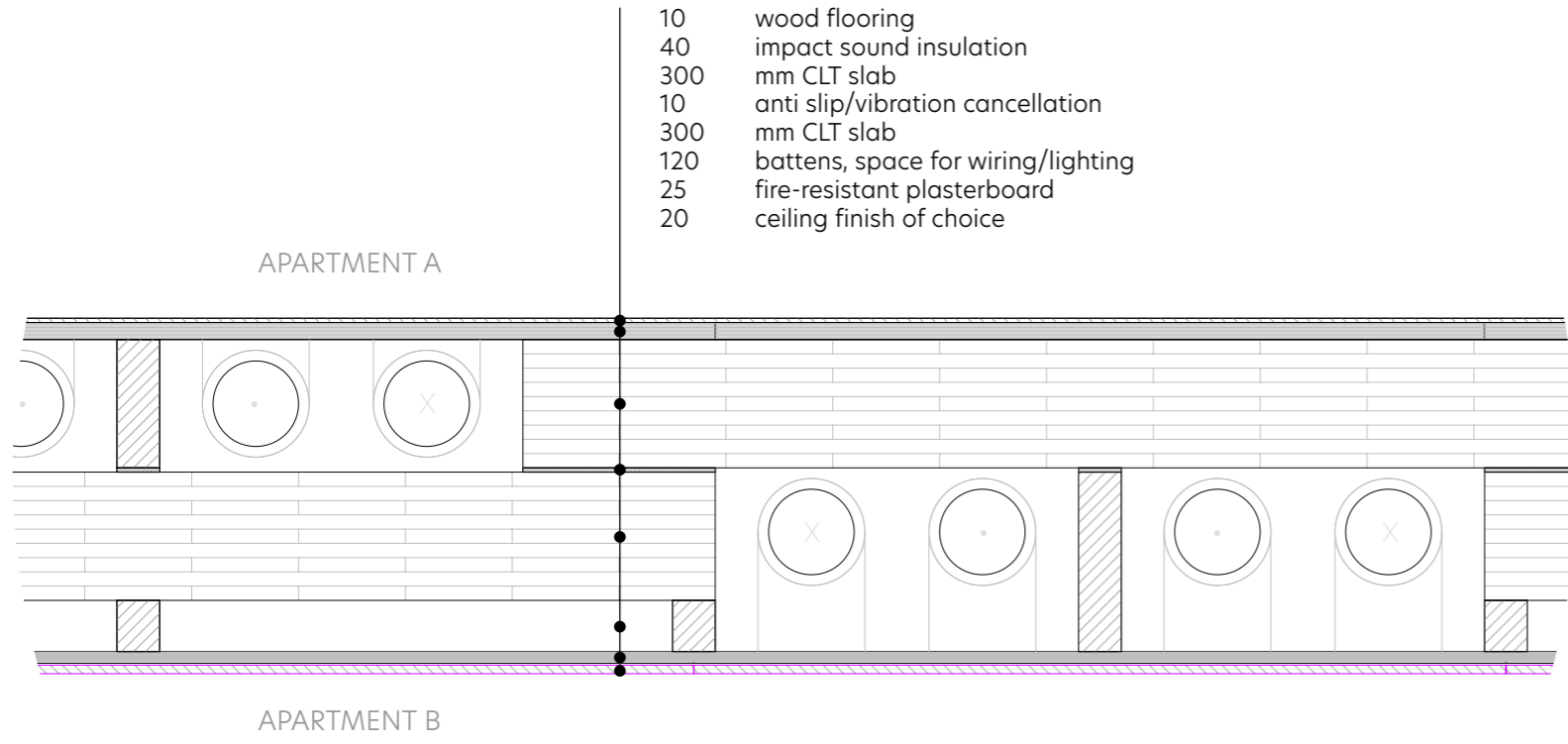
HOUSING

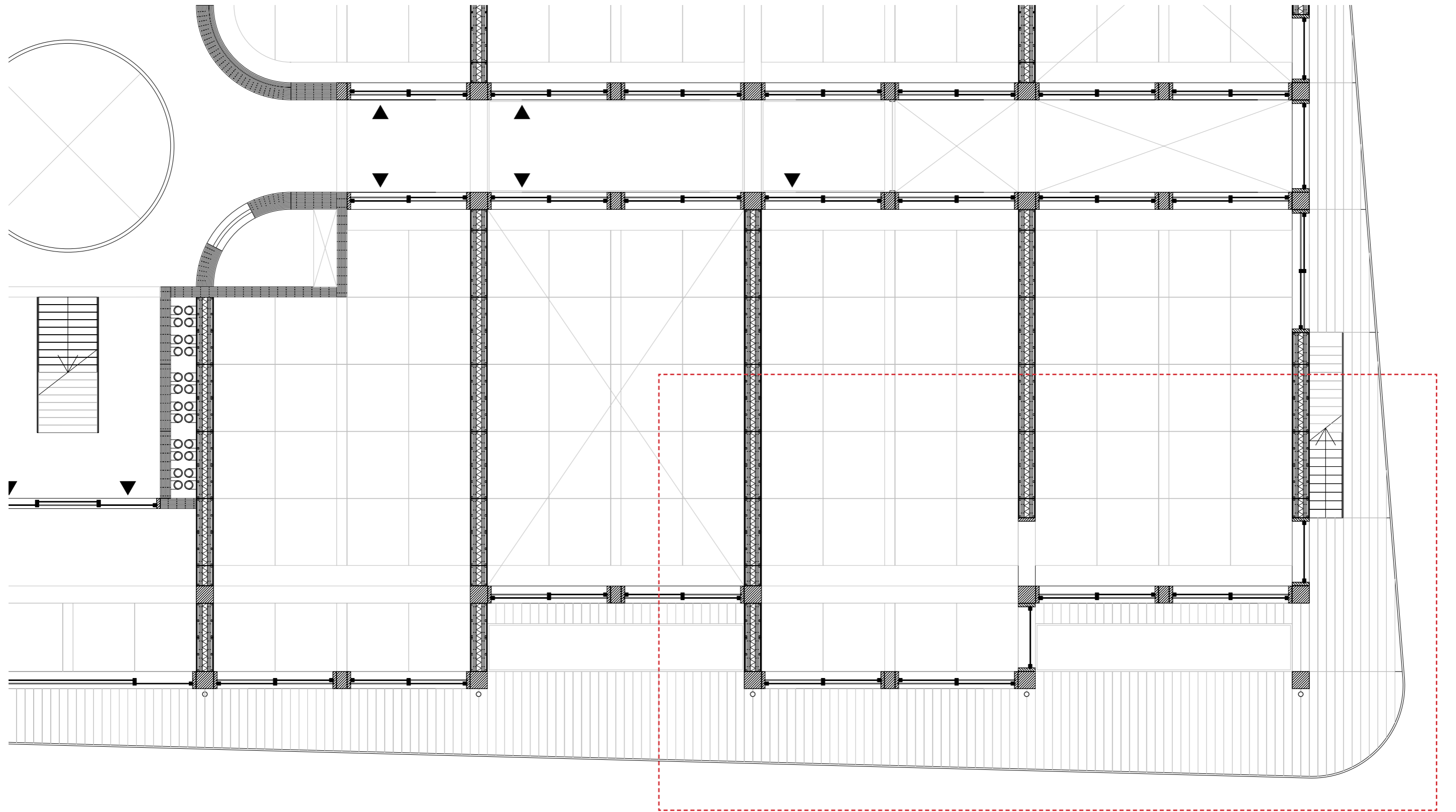
third floor

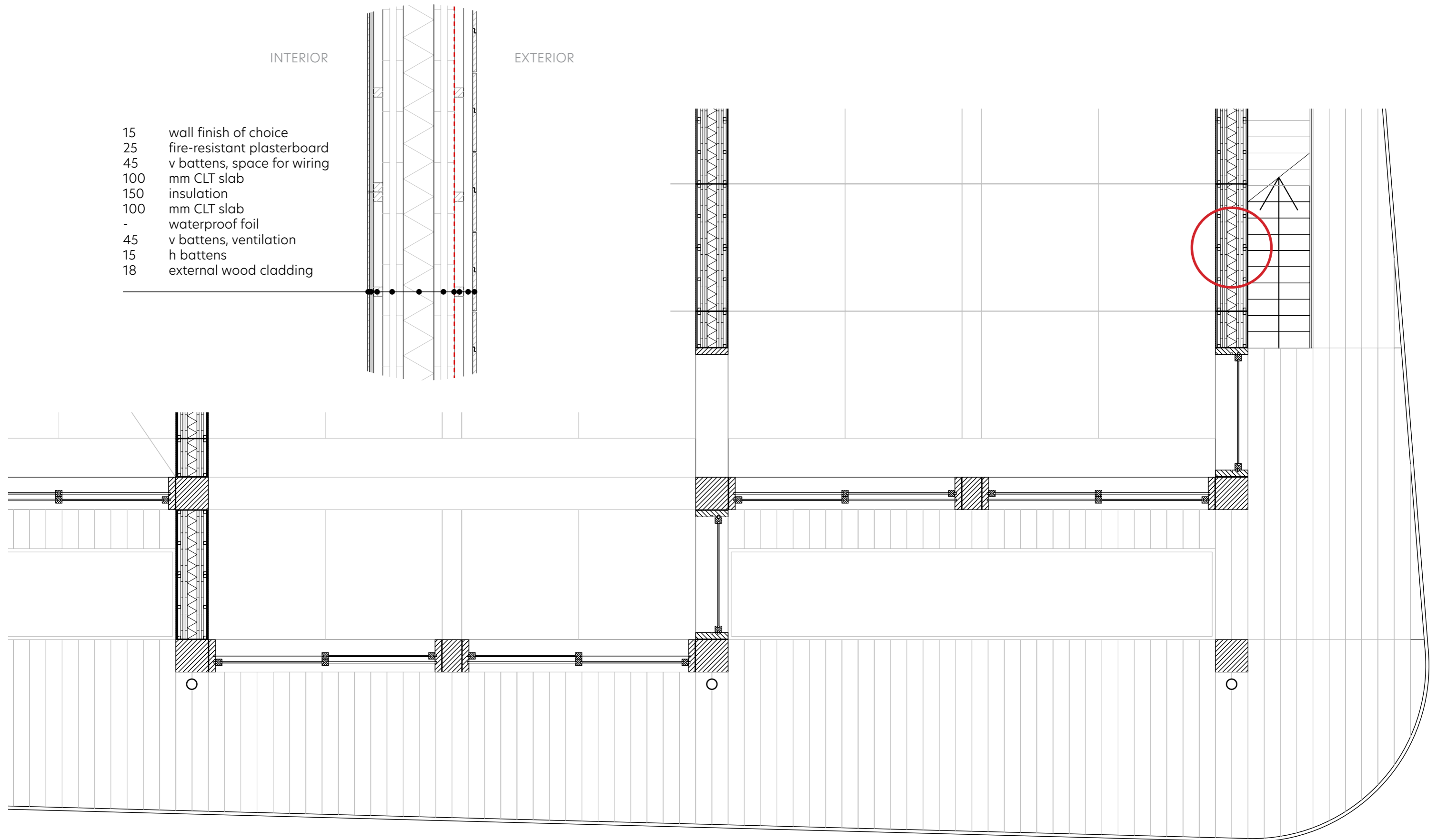






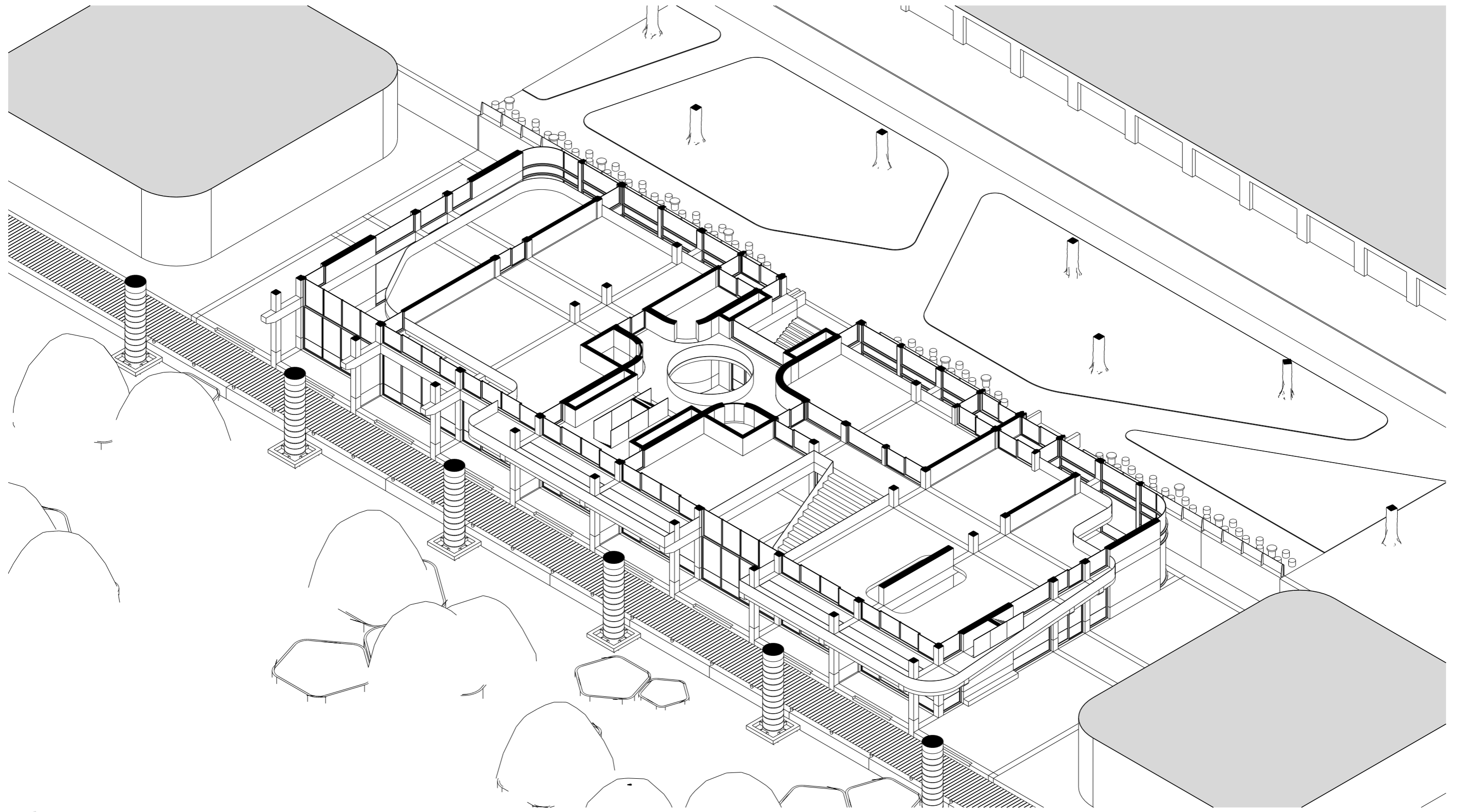




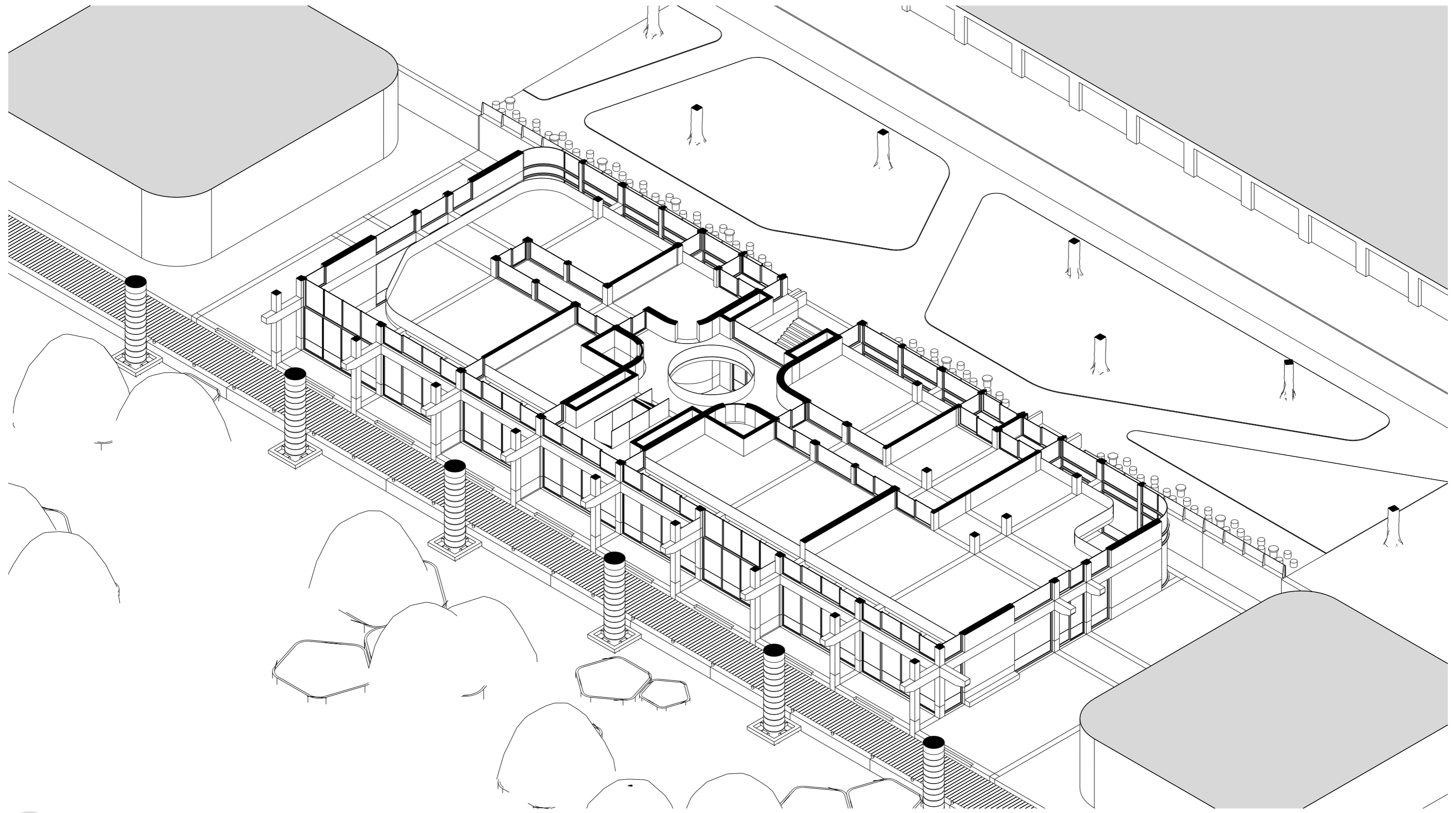


- 15 wall finish of choice
- 25 fire-resistant plasterboard
- 45 v battens, space for wiring
- 100 mm CLT slab
- 150 insulation
- 100 mm CLT slab
- waterproof foil
- 45 v battens, ventilation
- 15 h battens
- 18 external wood cladding

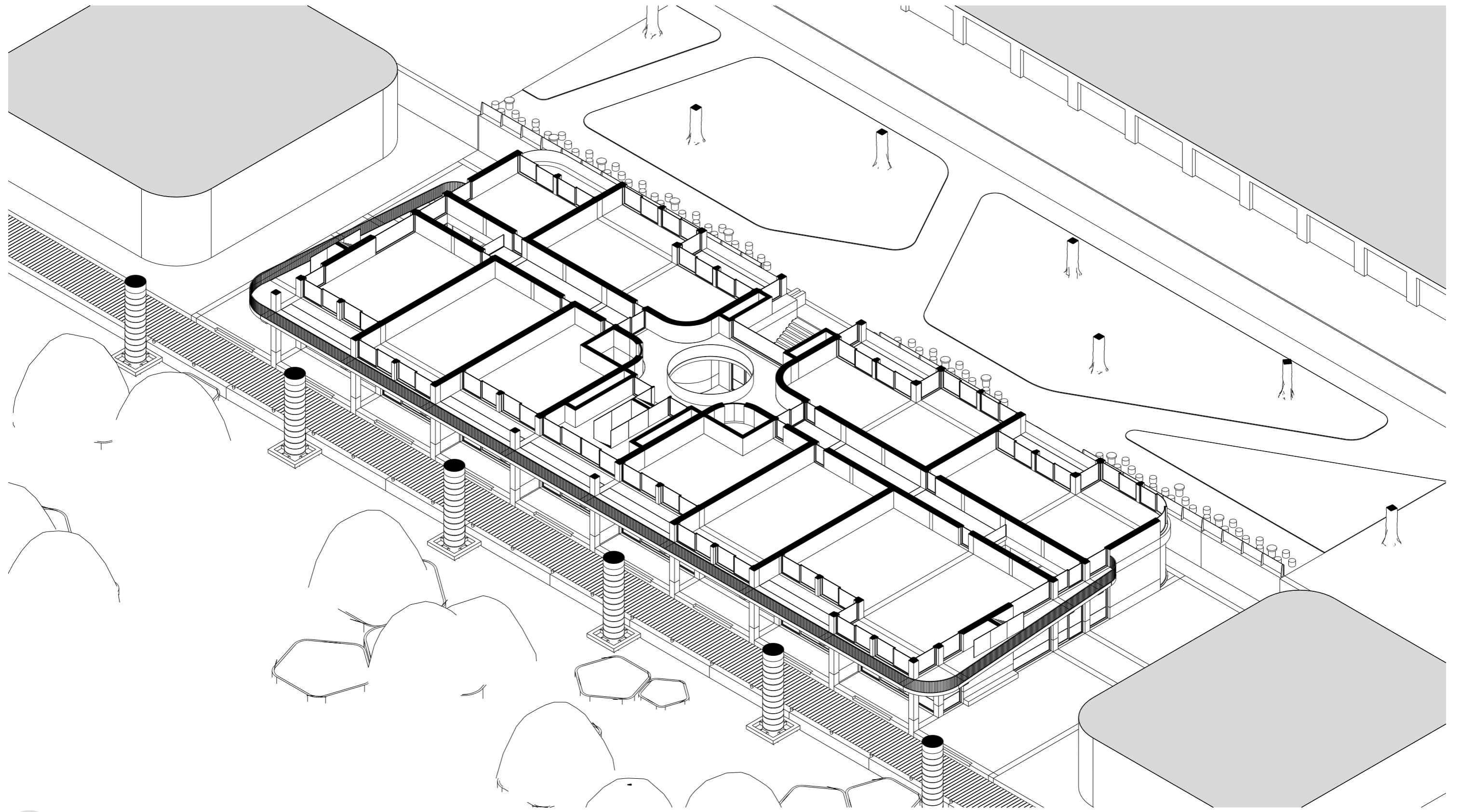




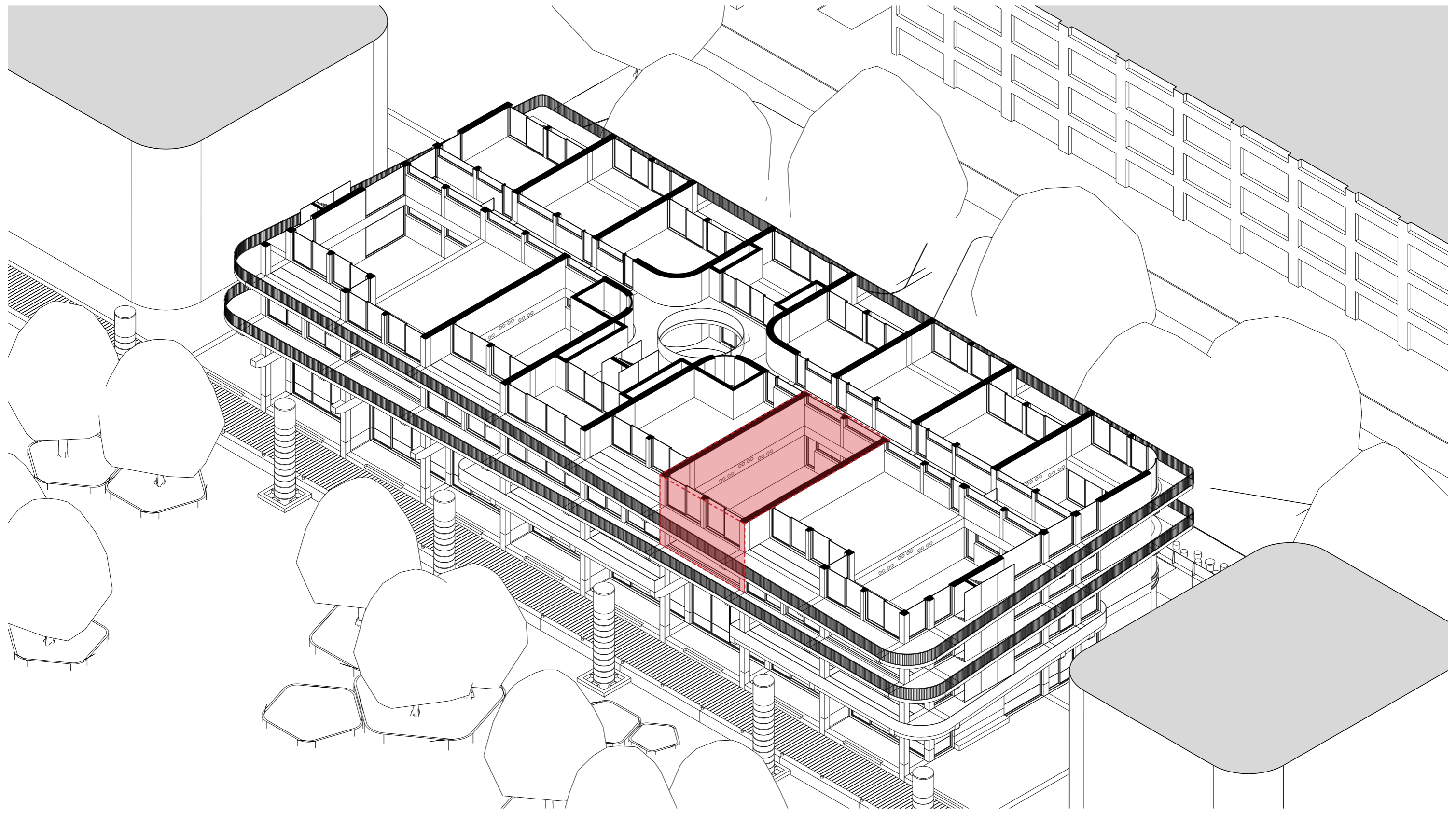
1 library | flexwork spaces | gym | cafe

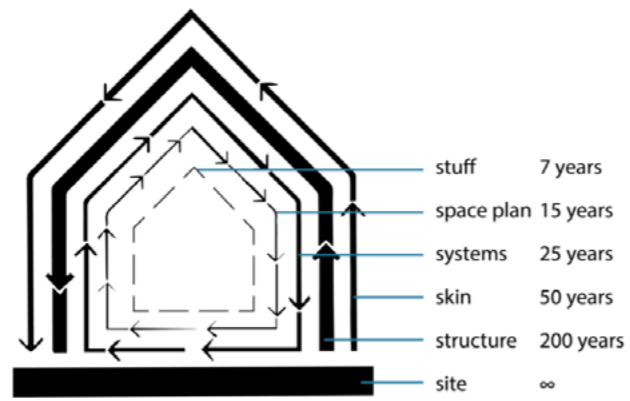


2 event space | small businesses | flex office | restaurant

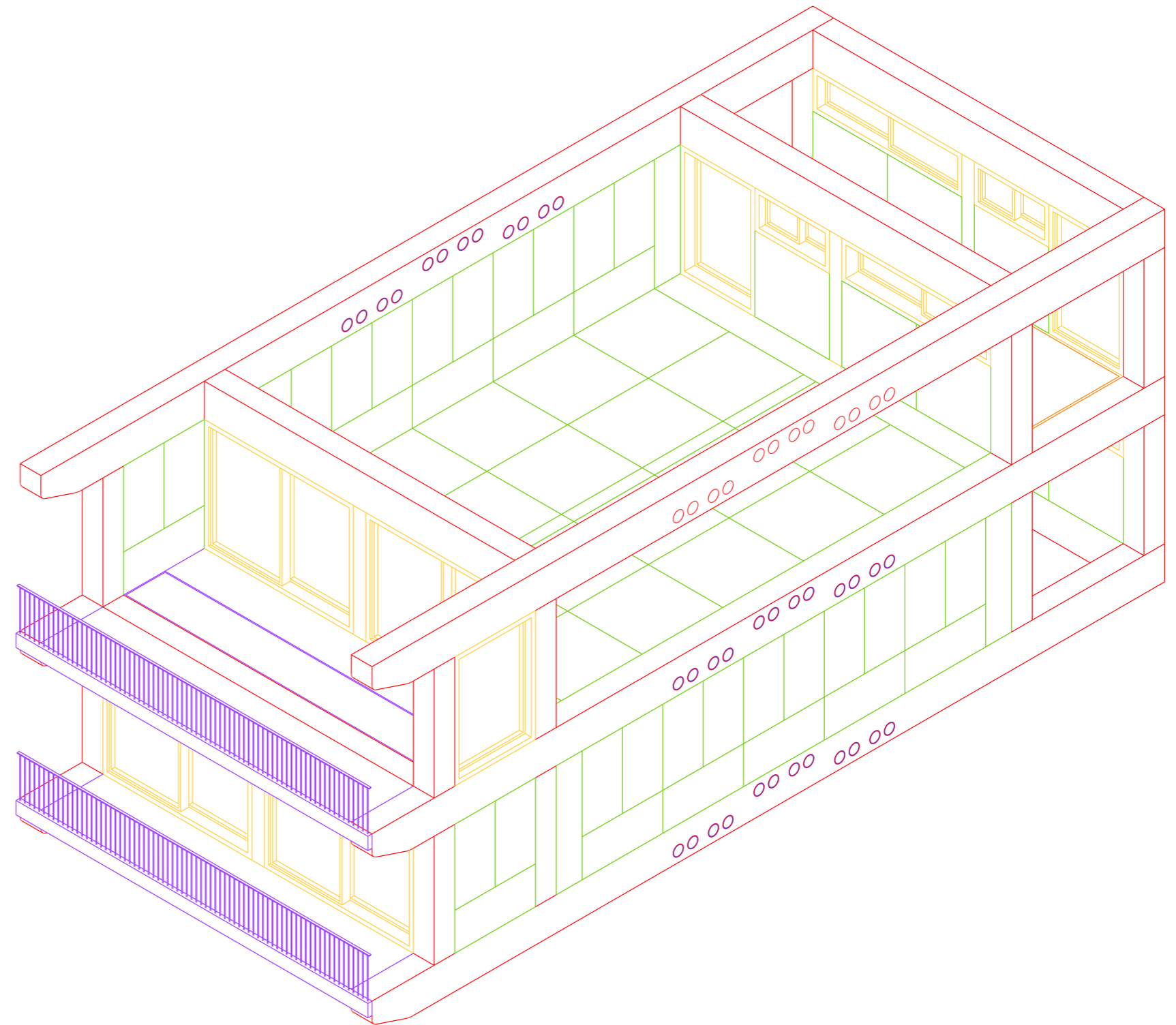


3 public functions transform into housing





25. Open building principle, Shearing layers of change (Brand, 1994)

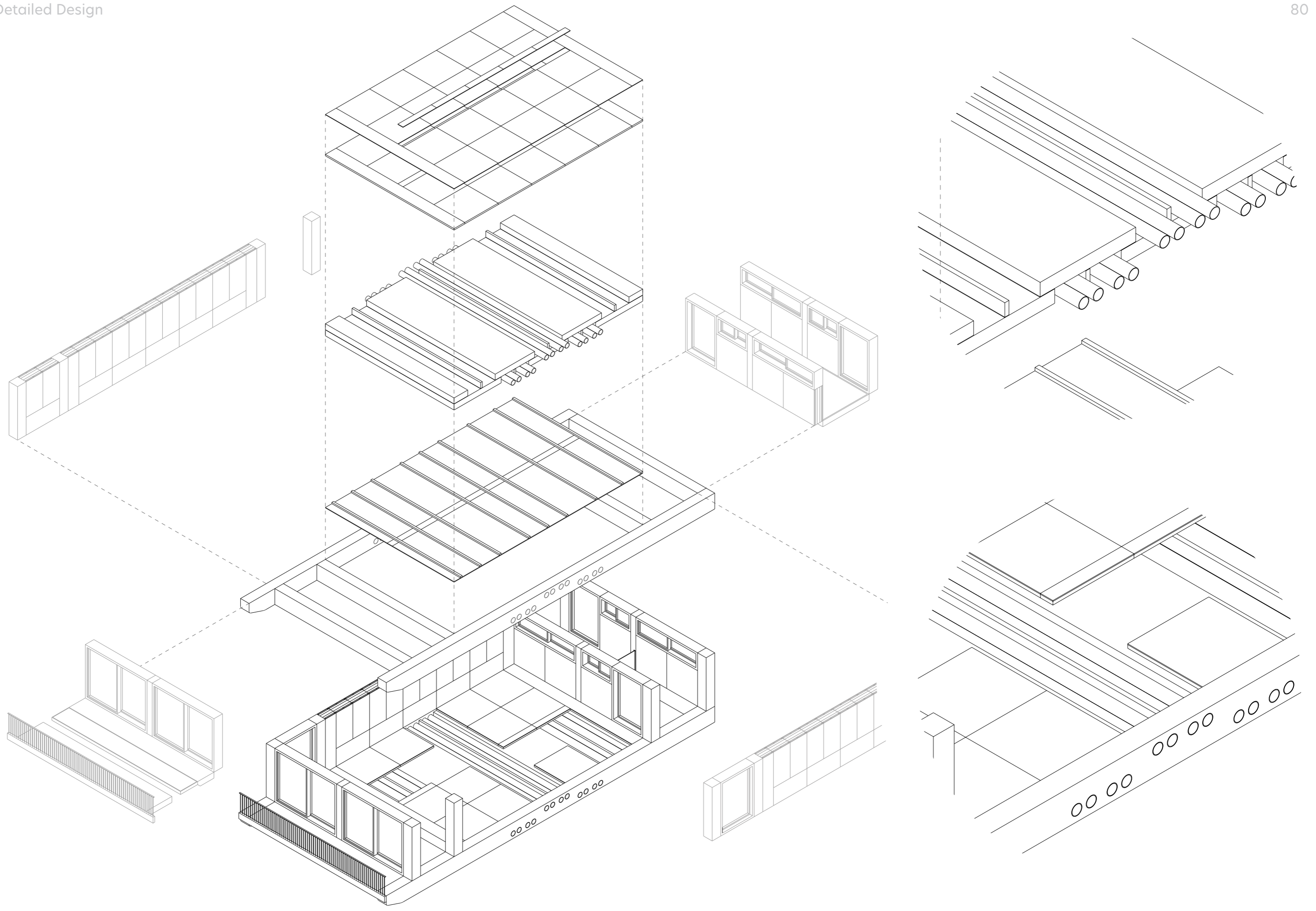


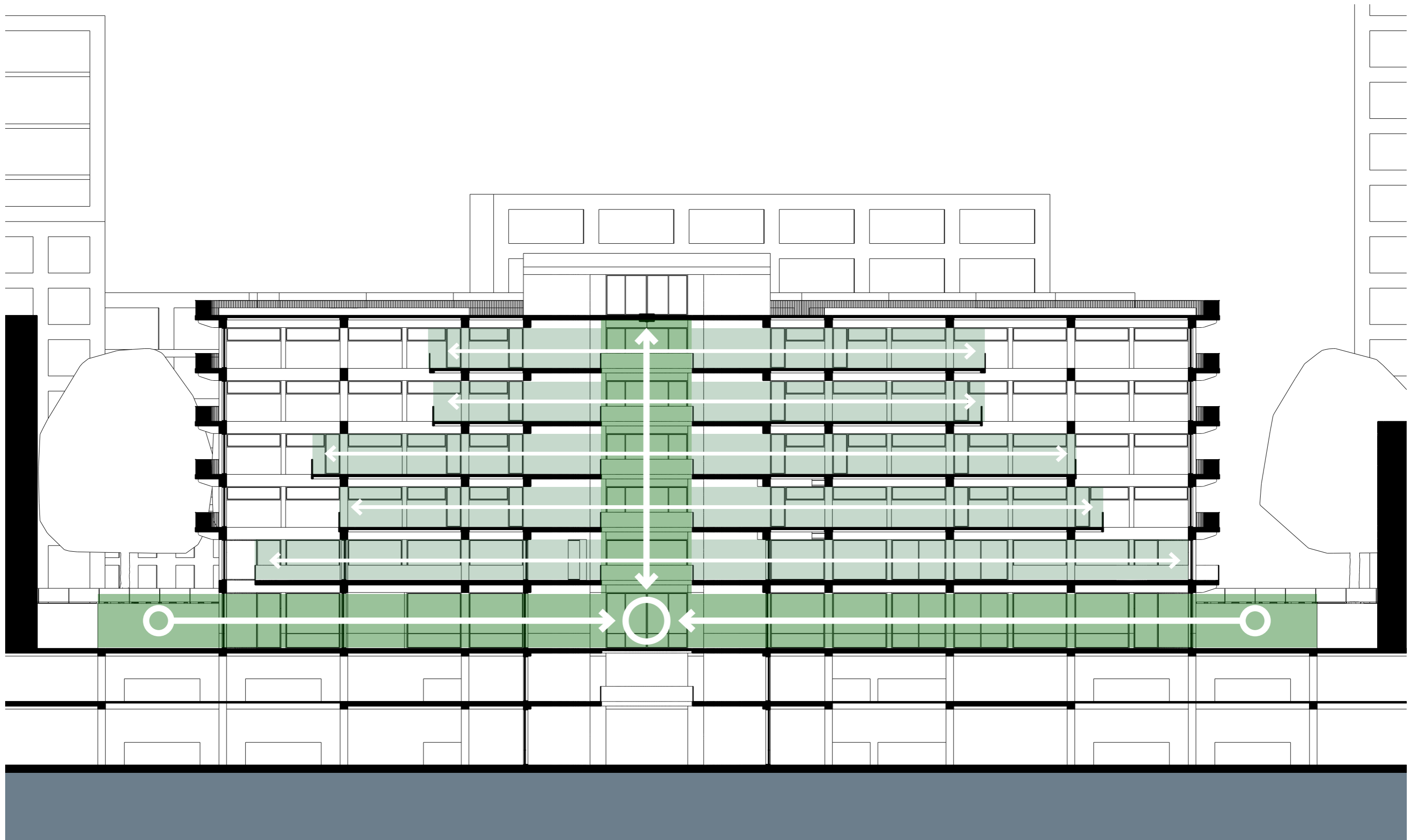
LAYERS																			
SUPPORT	<table border="1"> <tr> <td>■</td> <td>STRUCTURE</td> <td>200 years</td> </tr> </table>	■	STRUCTURE	200 years															
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INFILL	<table border="1"> <tr> <td>■</td> <td>SKIN</td> <td>50 years</td> </tr> <tr> <td>■</td> <td>OUTDOOR SPACE</td> <td>50 years</td> </tr> <tr> <td>■</td> <td>ACCESS</td> <td>50 years</td> </tr> <tr> <td>■</td> <td>SYSTEMS</td> <td>25 years</td> </tr> <tr> <td>■</td> <td>SPACE PLAN</td> <td>15 years</td> </tr> <tr> <td>■</td> <td>INTERIOR INFILL</td> <td>10 years</td> </tr> </table>	■	SKIN	50 years	■	OUTDOOR SPACE	50 years	■	ACCESS	50 years	■	SYSTEMS	25 years	■	SPACE PLAN	15 years	■	INTERIOR INFILL	10 years
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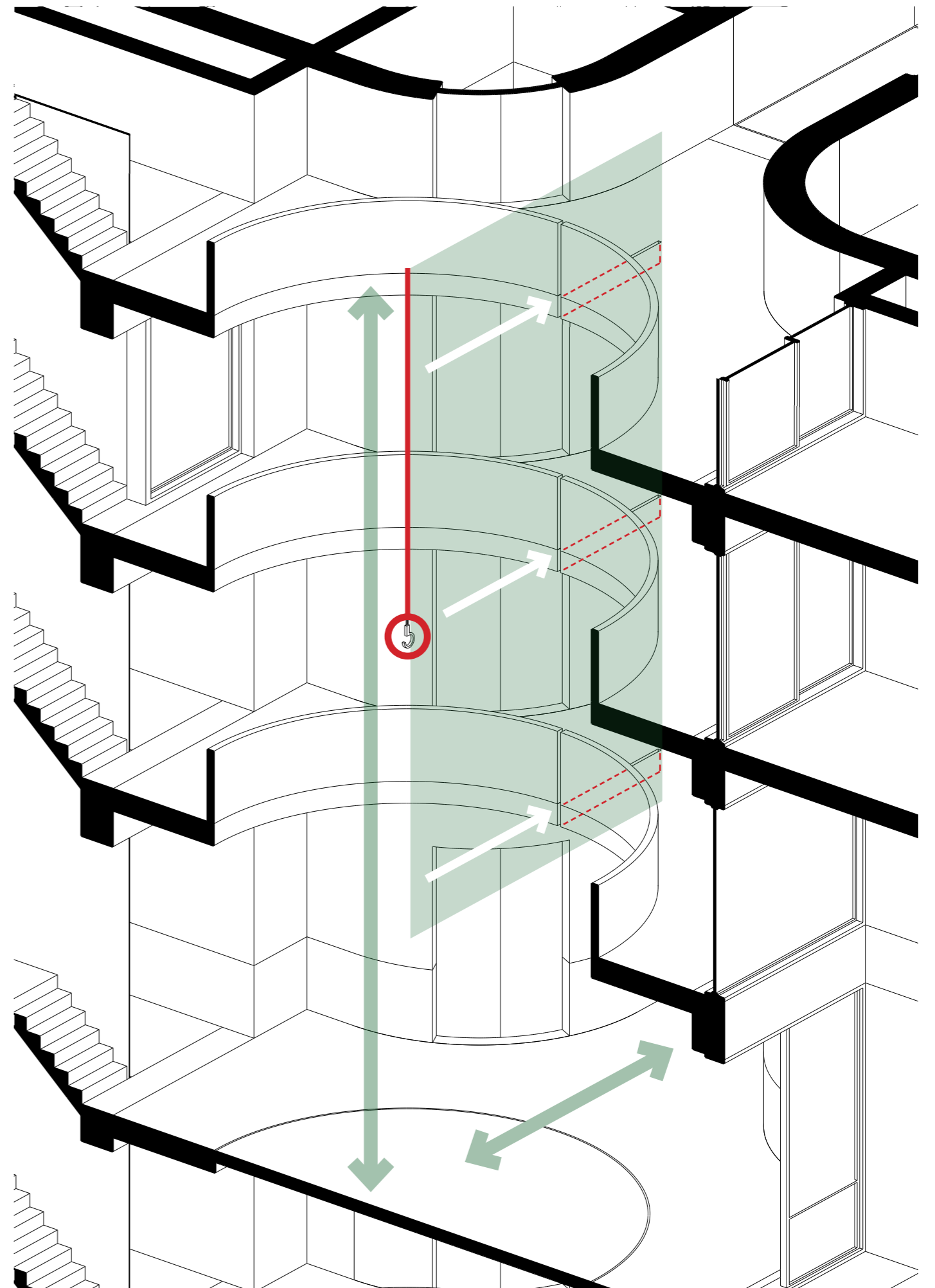
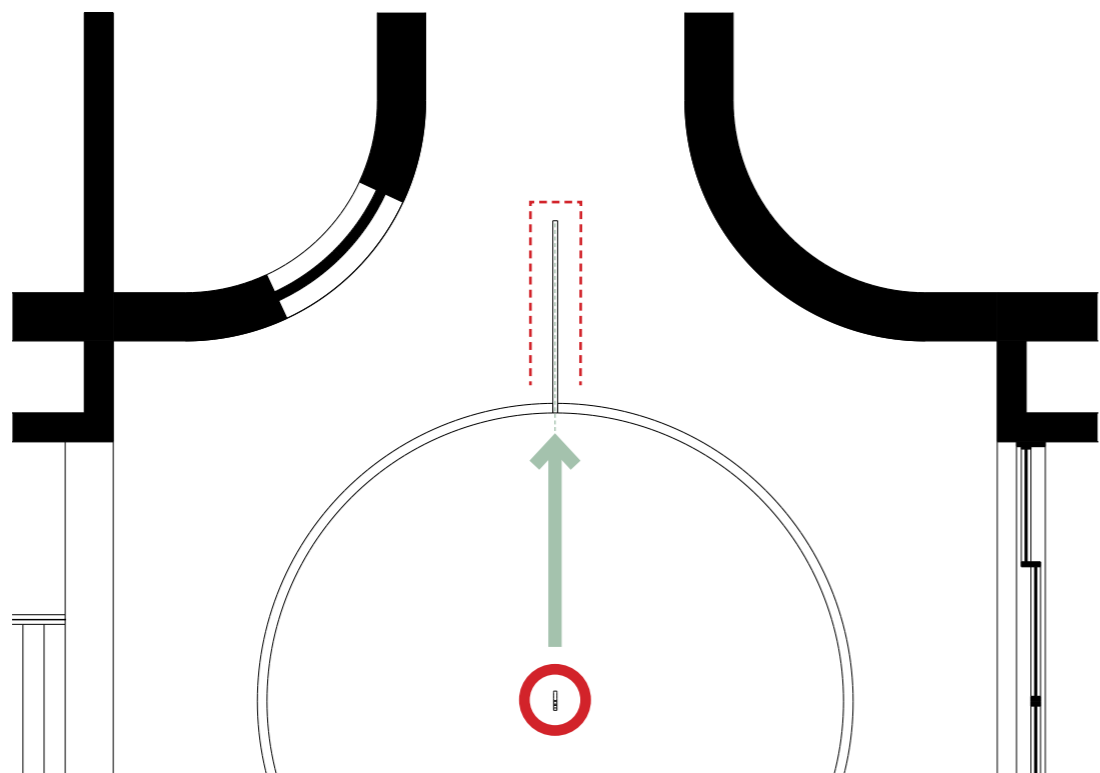
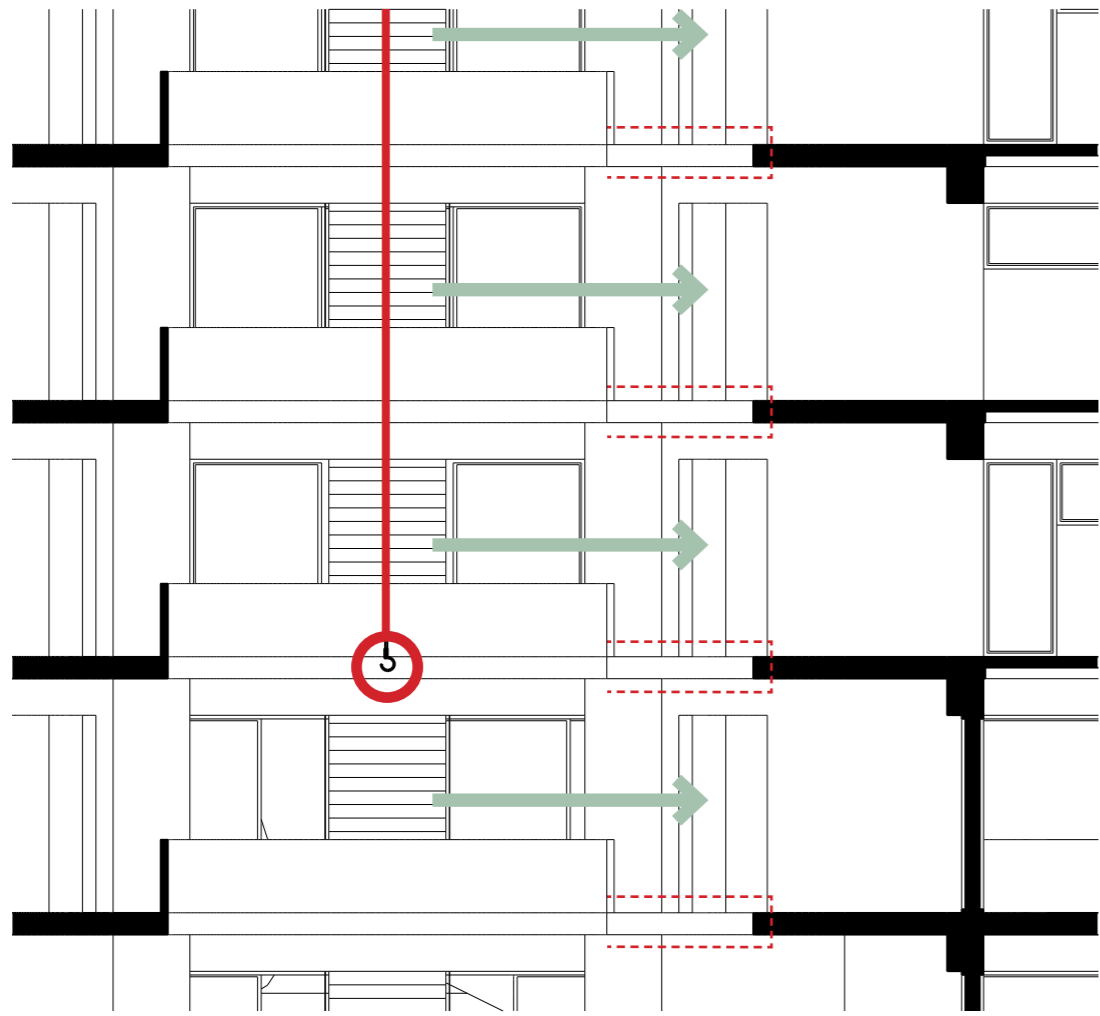
REQUIREMENTS

DRY CONNECTIONS BETWEEN:

- SUPPORT AND INFILL LAYER
- SEPARATE INFILL LAYERS
- COMPONENTS INSIDE INFILL LAYER



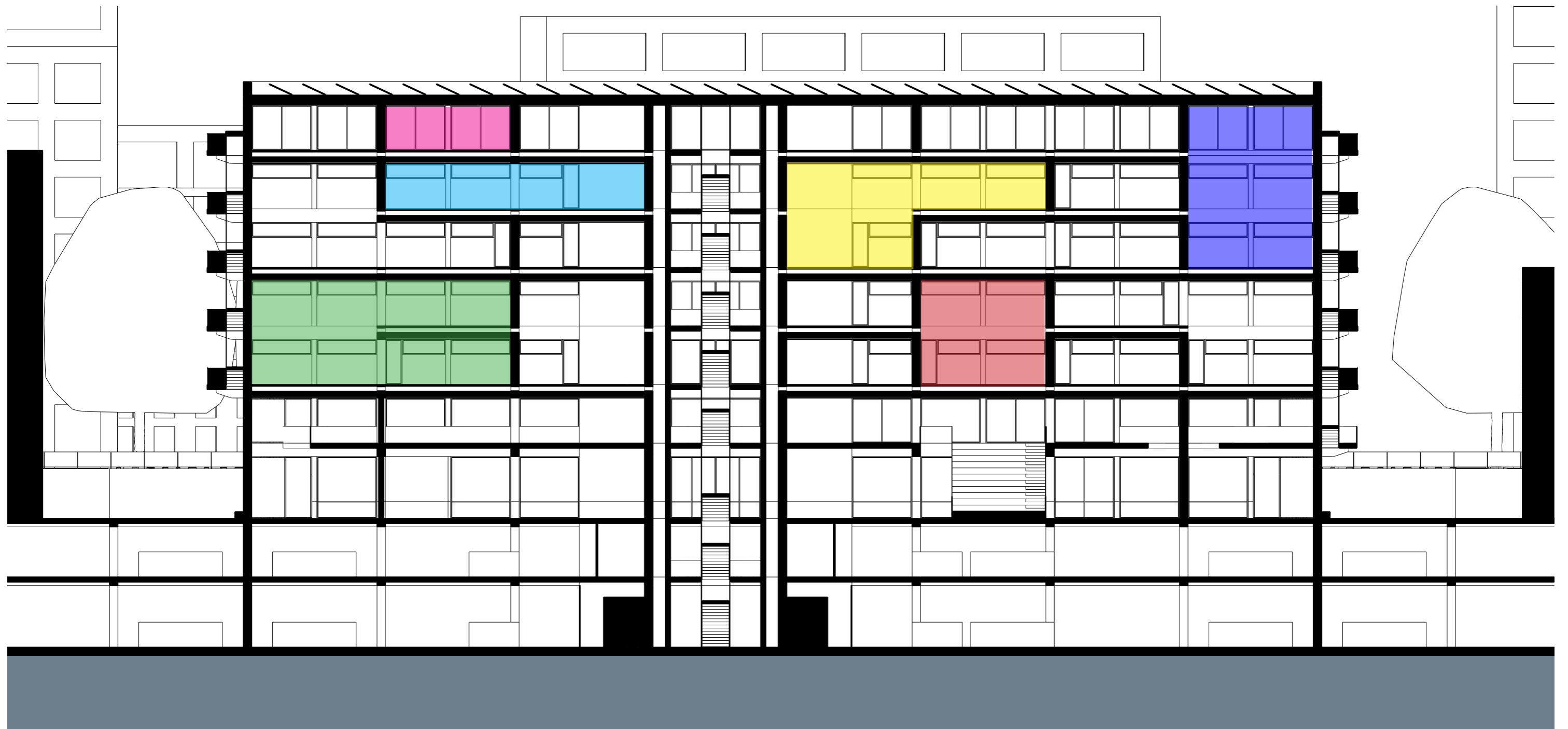


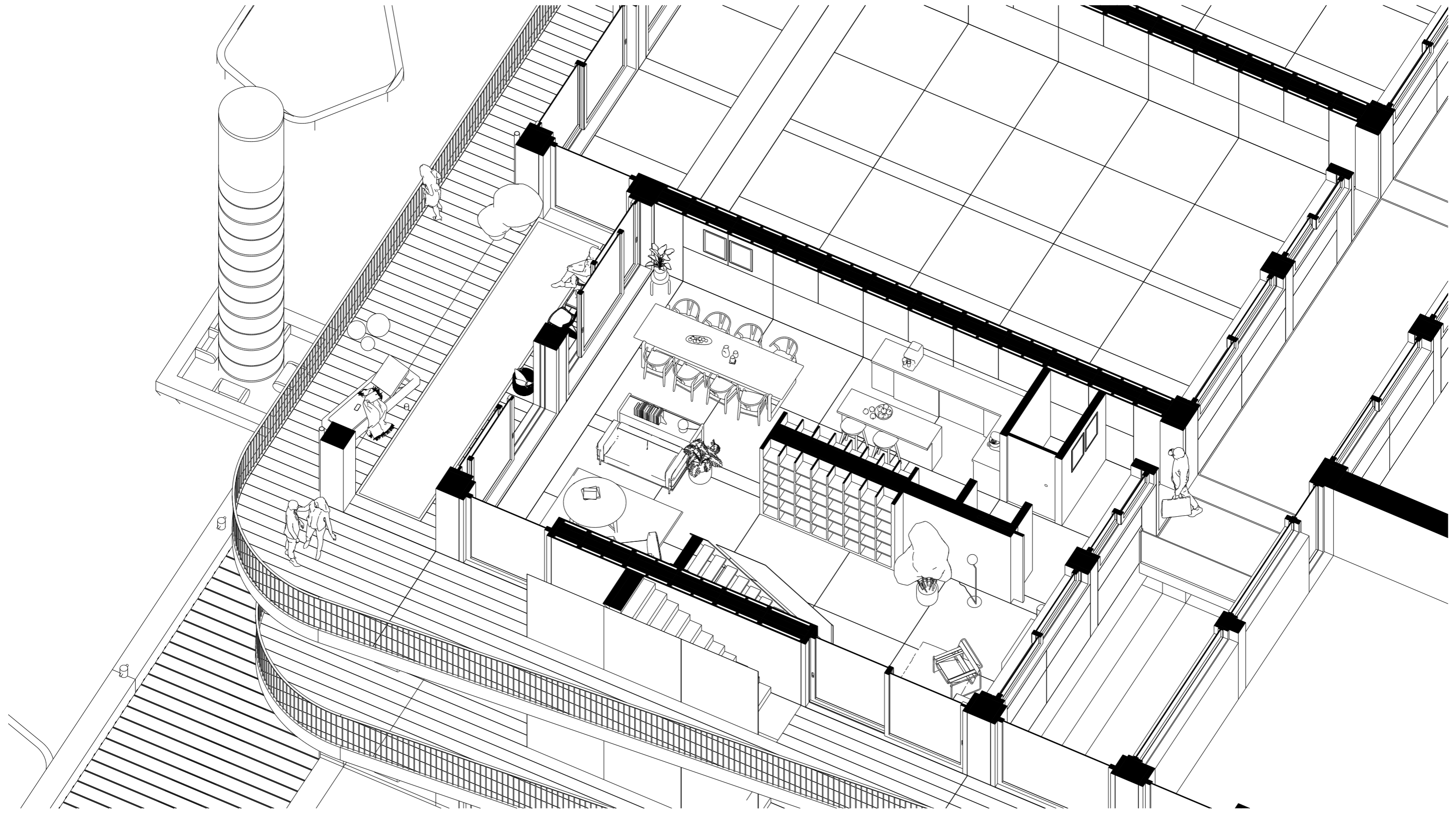


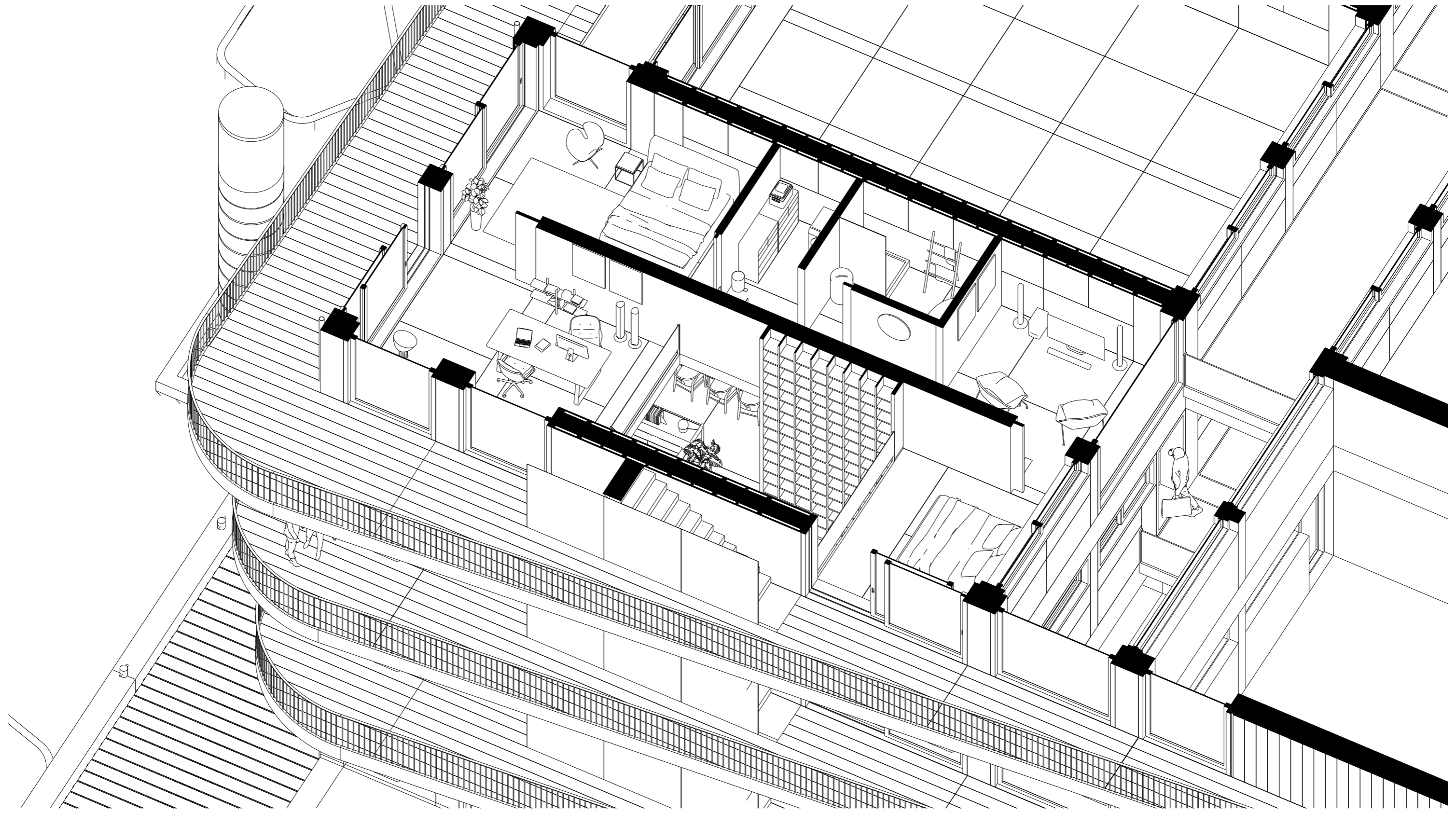
1 co-living for starters/group of friends

2 2 small studio's turn into 1 medium sized apartment

3 single family house expanding along with changing needs



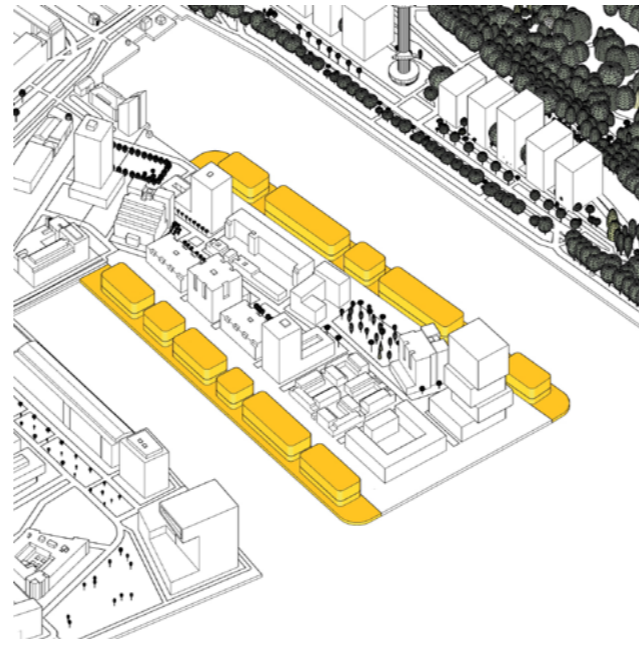




1 infrastructure



2 building volumes



3 public park



1 spatial optimisation of infrastructure | current situation



1 spatial optimisation of infrastructure | proposal



1 spatial optimisation of infrastructure | building plots

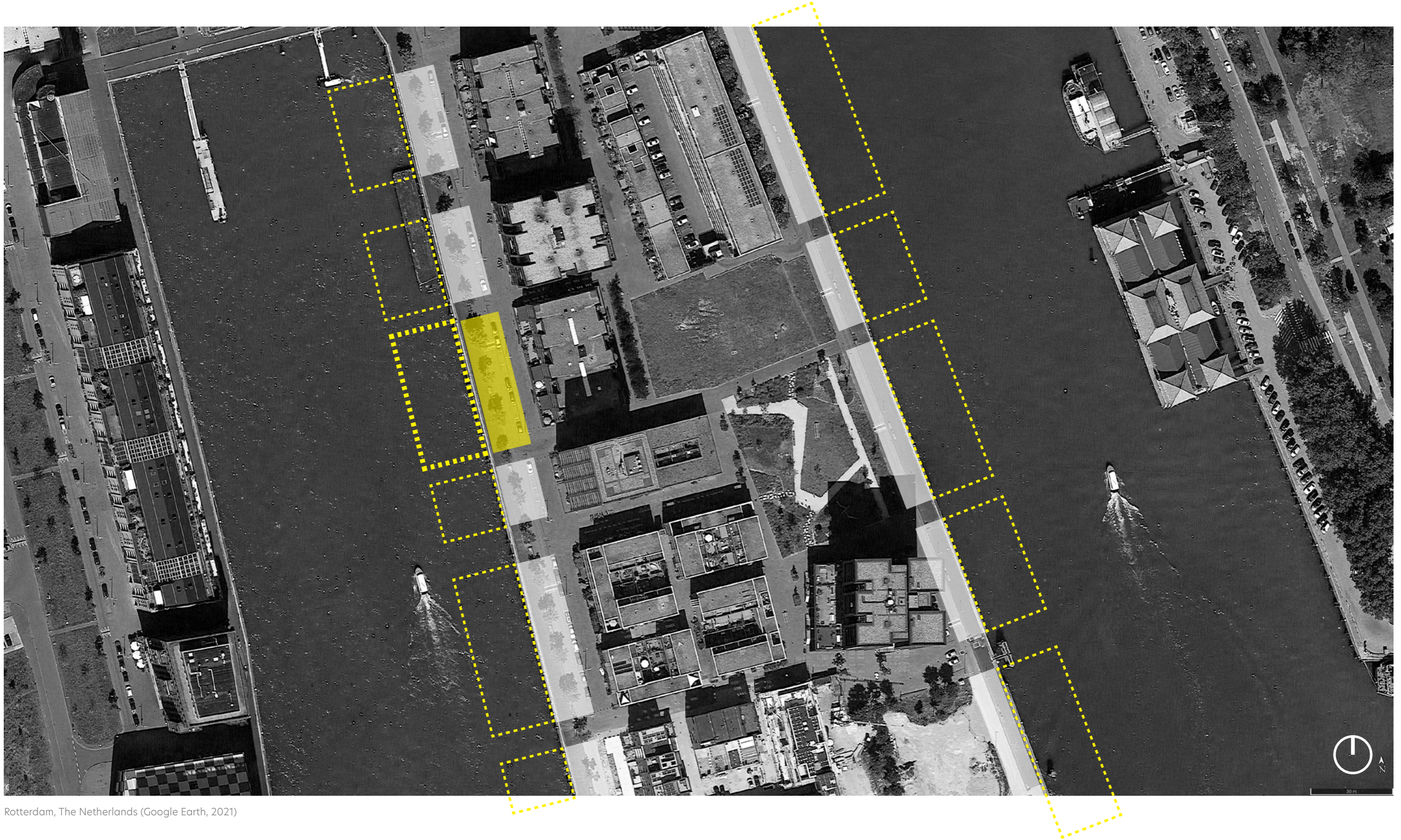


Rotterdam, The Netherlands (Google Earth, 2021)

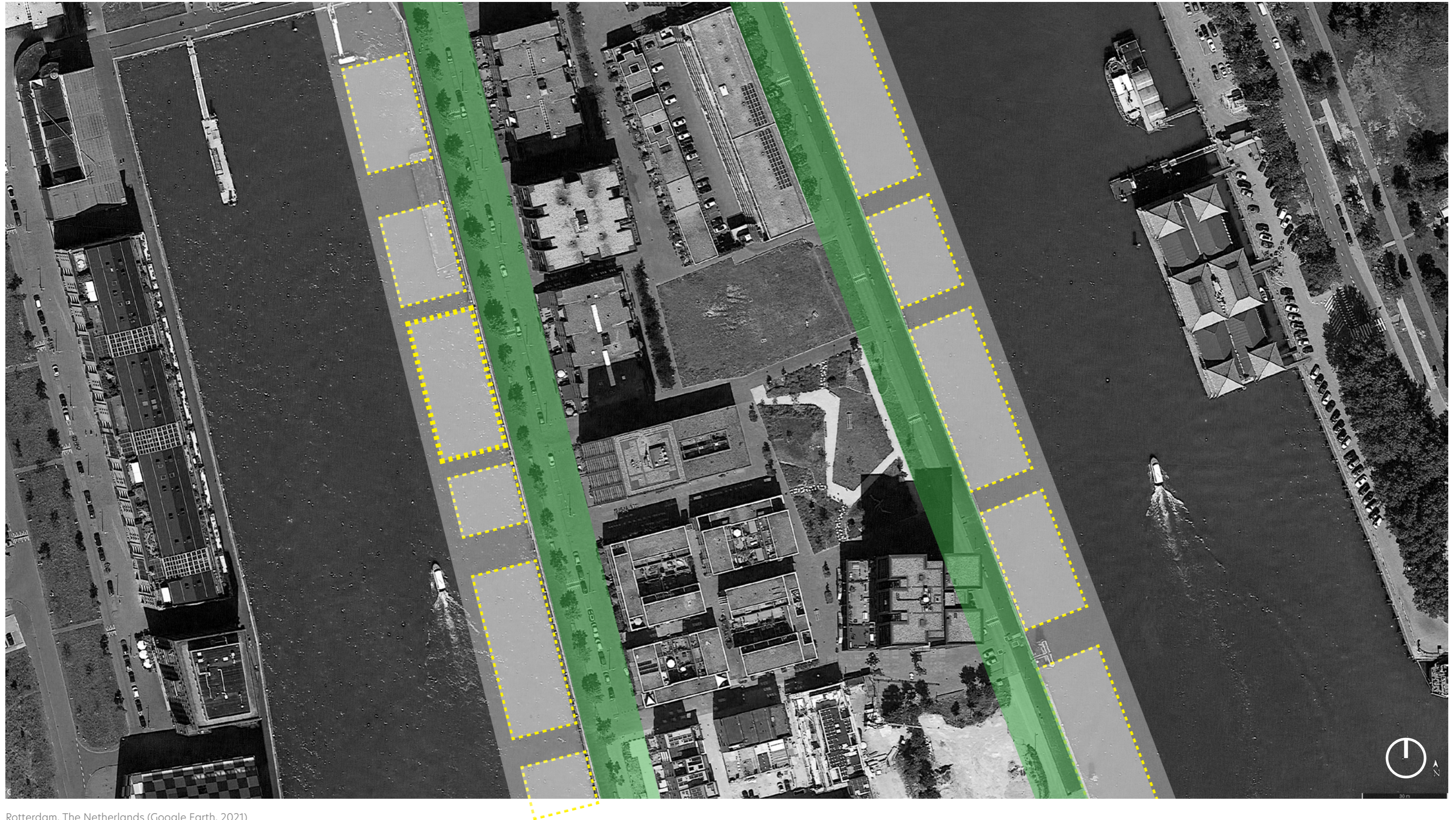
2 building volumes | floating foundation | assembly and transport



2 building volumes | installing prefab wooden superstructure | on site



3 public park on former construction site







P5

Towards Living with Water

In search of new perspectives towards living with the increasing risk of flooding in the densifying outer dike area of the urban center of Rotterdam

J.E.H. Grevink

Architectural Engineering

2020-2021

Under supervision of:

Delft University of Technology

Dr. F.L. Hooimeijer / M. Parravicini / Ir. P.L. Tomesen / Ir. E.J. van der Zaag

