PARK

Waterscapes

A Design Perspective of Hidden Flood Risks

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Water Resilience

Across Europe, urban waterscapes have been reshaped through centuries of intervention. Rivers have been confined, redirected and at times removed from the surface altogether. Under present climatic pressure, engineered interventions are reaching their limits. Flooding is no longer only the consequence of an external event. It also arises from the mismatch between rainfall intensity, sealed ground surfaces, constrained river corridors and infrastructure systems designed for different conditions.

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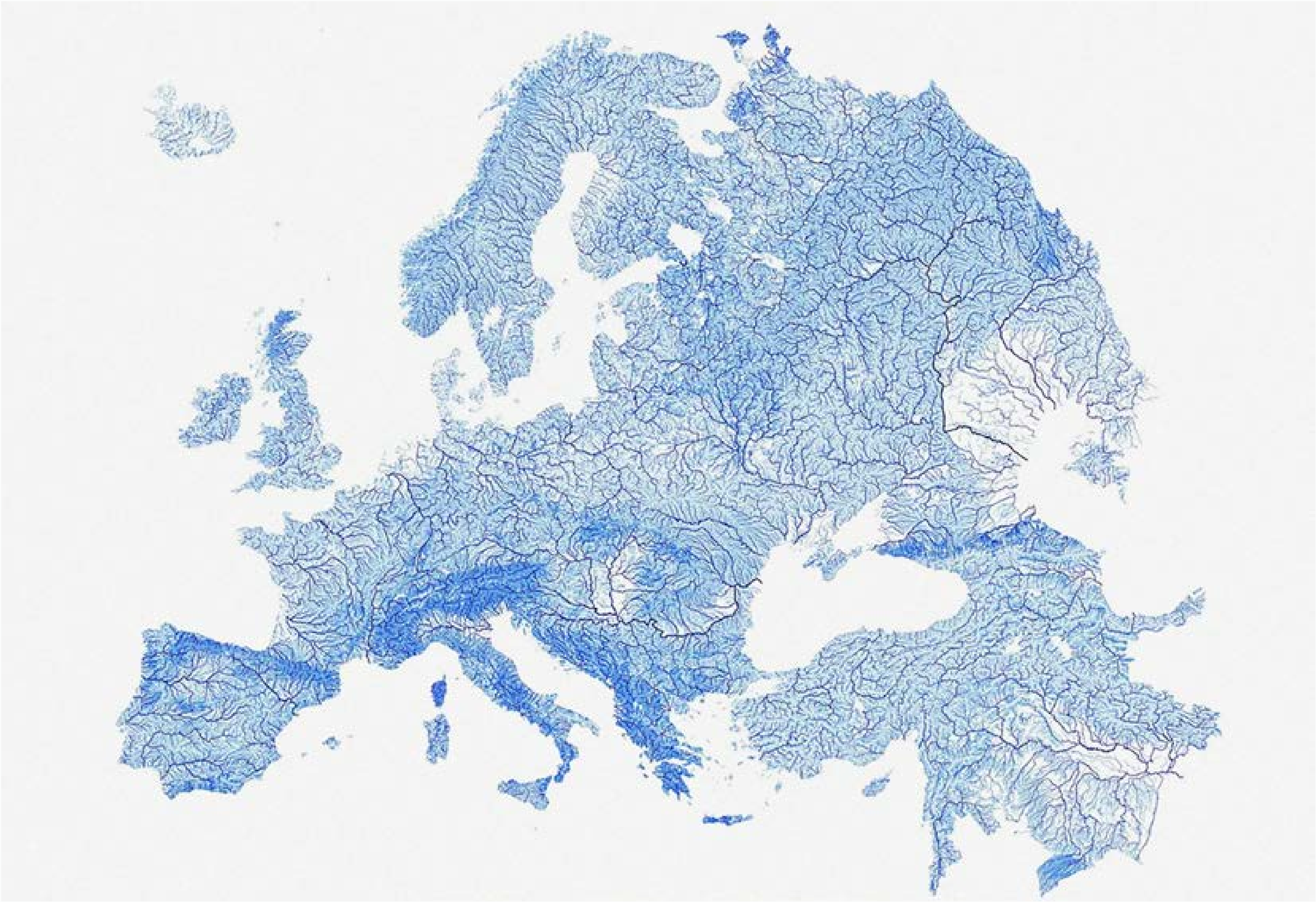
People walk on a catwalk in a flooded St. Mark's Square during a period of seasonal high water in Venice, Italy, on October 29, 2018.
Manuel Silvestri, Reuters



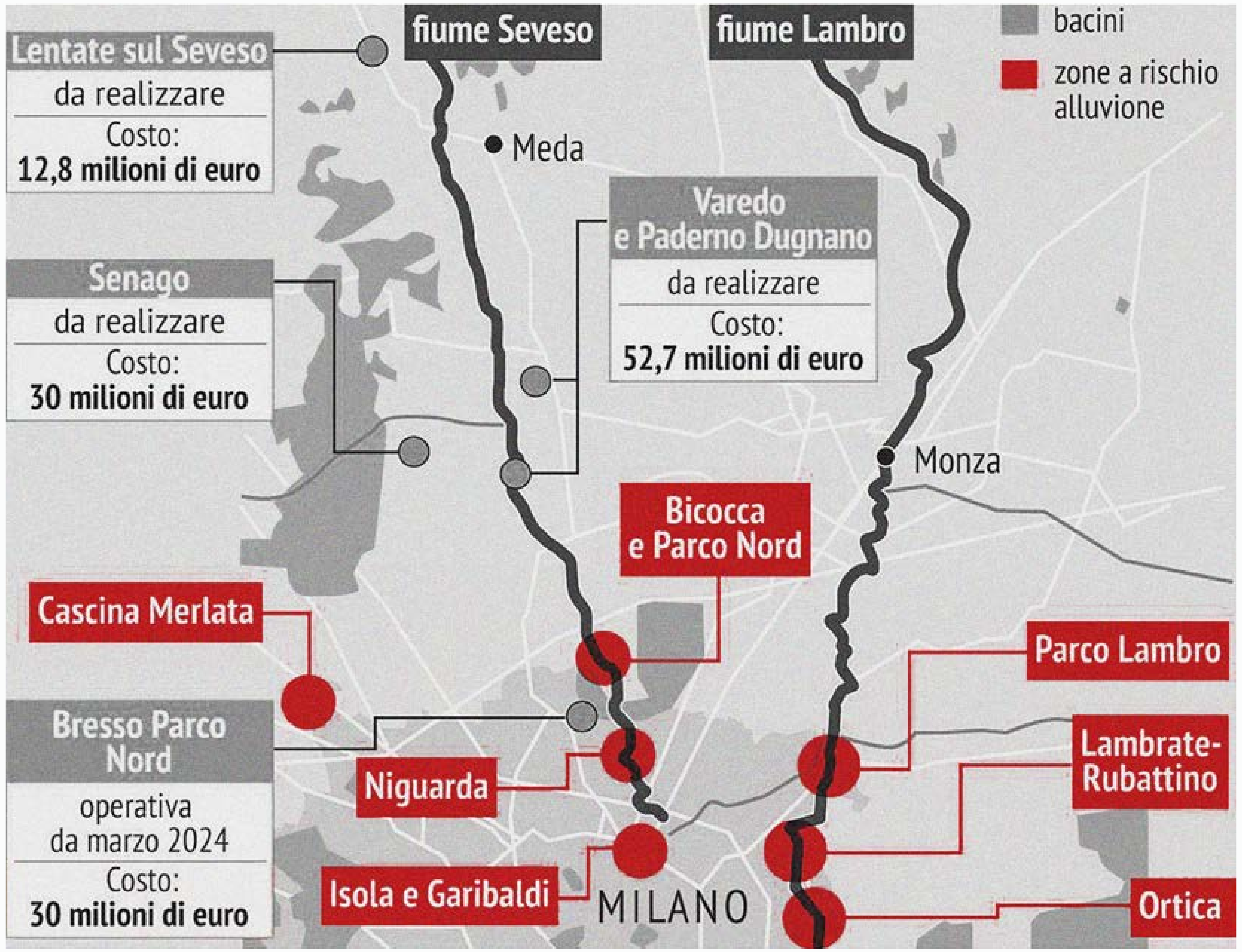
0.1 Rivers and streams of Europe

European Flood Risks

The booklet proposes a design perspective on European flood risk that treats water as a spatial system continuously produced by urban form, land management and governance choices. It links territorial exposure to the mechanisms that amplify risk in cities, showing how the interconnected conditions of urbanized environments can turn water into disruption, pollution and uneven vulnerability.

Milan's Flood Risks

The research is developed through the Milan case study, where the layered history of waterways and urban growth makes today's risks legible. From this lens, the booklet argues for a clear architectural role once water is treated as a civic and spatial condition. Flooding unfolds inside the built environment, along the thresholds, surfaces, and ground planes we design and these are the spaces where rainwater can be captured, slowed, stored, and redirected before it overwhelms the sewer system.



Milano flood risk 0.2

There is the need to shape flood risk management decisions into spatial strategies that can be designed, delivered and maintained. This contribution is intended as a small step toward clarifying how the profession can contribute, at a time when design is still too often positioned outside the decisions that shape flood risk and its consequences.

A Continent Under Pressure
Water as an European Problem

01

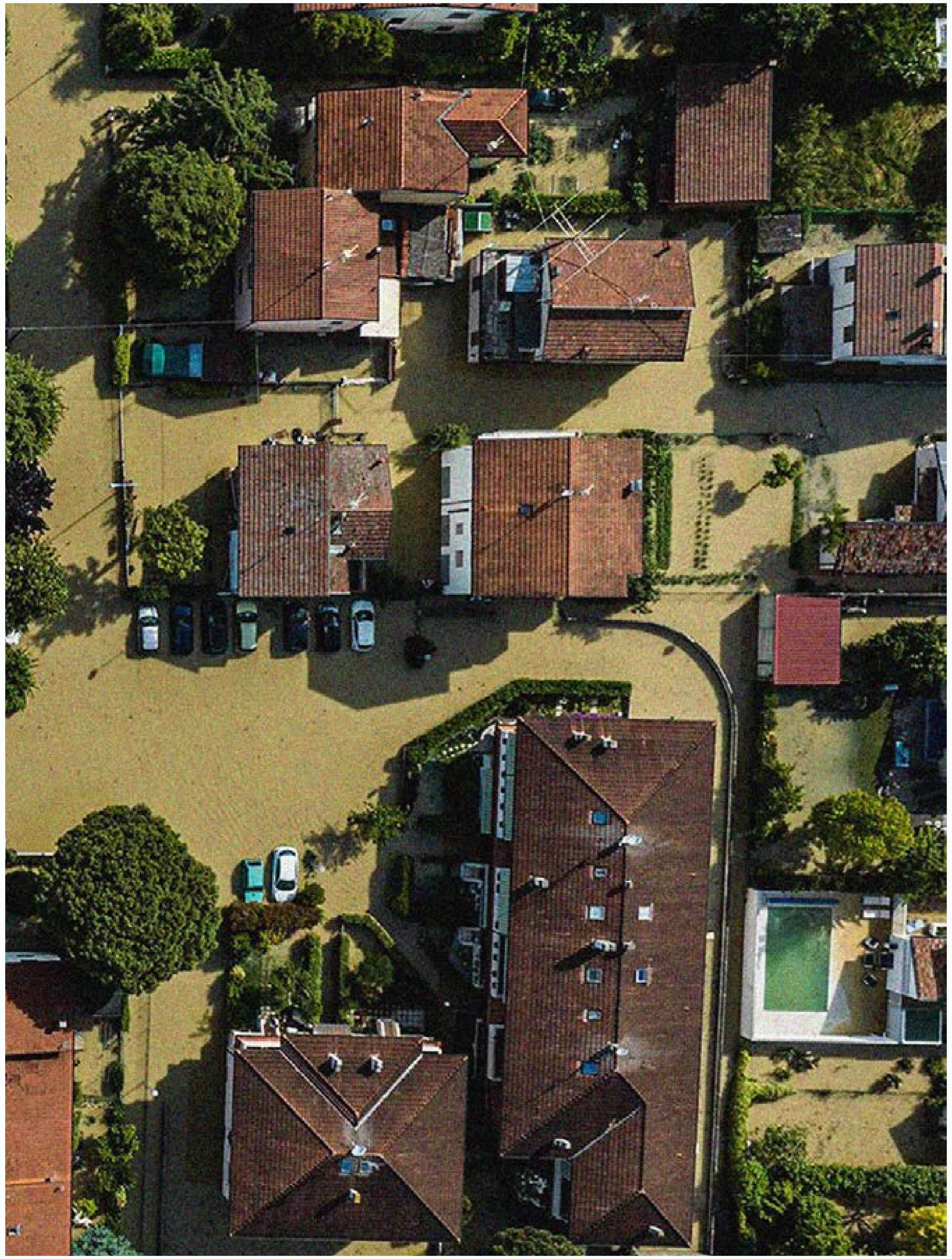
The town of Lugo, 2023, was left under water following floods that left at least 14 people dead.
Cecilia Fasciani/NurPhoto/Getty

1.0

A Continent Under Pressure

Europe is entering a period in which water behaves less predictably more politically. Flooding is becoming more frequent and more damaging, but impacts vary by place. Risk grows where climate pressure meets land use, urban form and the capacity of institutions and infrastructure to manage the situations. Recent events show how quickly engineered systems can exceed their limits, turning rainfall into disruption and making water a direct issue for safety, health, and the everyday economy.

1.0



The town of Lugo, 2023, was left under water following floods that left at least 14 people dead.
Cecilia Fasciani/NurPhoto/Getty

01. Europe and Water Resilience

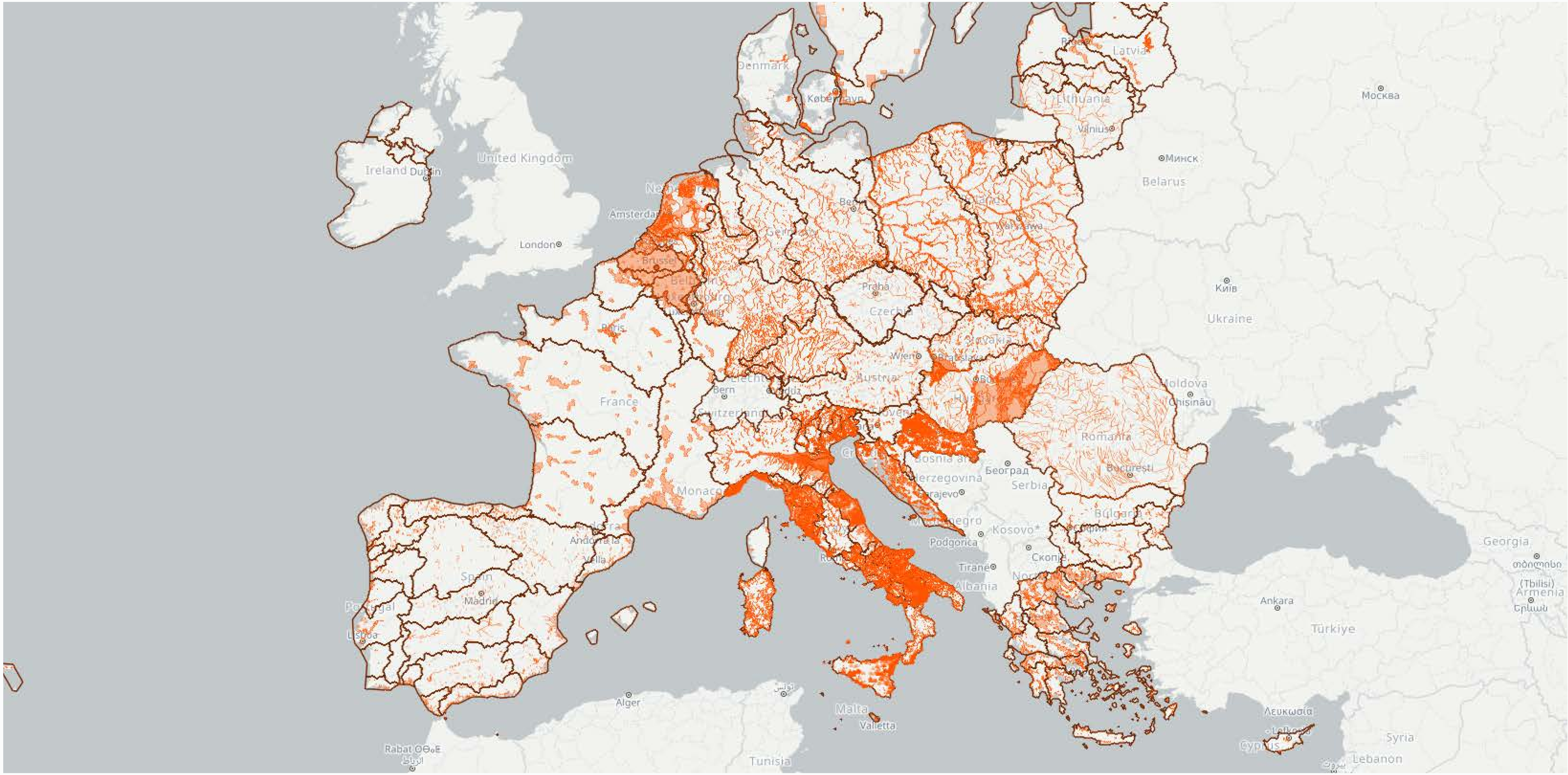
1.1.1 Some areas of Emilia-Romagna recorded at least 500mm during a 36-hour period in 2023.
Emanuele Valeri/EPA

Across Europe, water resilience is often framed through the visible impact of flooding: rivers overtopping their banks, underground networks overflowing into streets, and transport systems that fail under a few hours of intense rainfall. The real condition is broader and more structural.

Across the EU, over 14,000 areas are officially flagged as having potentially significant flood risk.[1] A tenth of Europe's urban population already lives in flood risk zones.[2] Each year, approximately 216,000 people are exposed to river flooding and losses average €5.3 billion.[3] Including the UK, current river flood damages are estimated to be roughly €7.6 billion per year, with more than 160,000 people exposed.[4]

Coastal flooding already costs nearly €1.4 billion per year and exposes around 100,000 people. Without more adaptation, annual EU losses could rise to €210 billion and up to €1.3 trillion by 2100, and population exposure to 1.6 million and up to 3.9 million by 2100.[5] Zooming out, weather related extremes drove €44.5 billion per year in losses during 2020 to 2023, underscoring a sharp upward trend that floods contribute to.[6]

The Commission's European Climate Risk Assessment warns that coastal flood costs alone could exceed €1.6 trillion per year by 2100 without further action.[1] Additionally, city form matters, as hard surfaces and drainage bottlenecks amplify cloudburst flooding a risk now tracked by the EEA for urban planning and early action.[7]



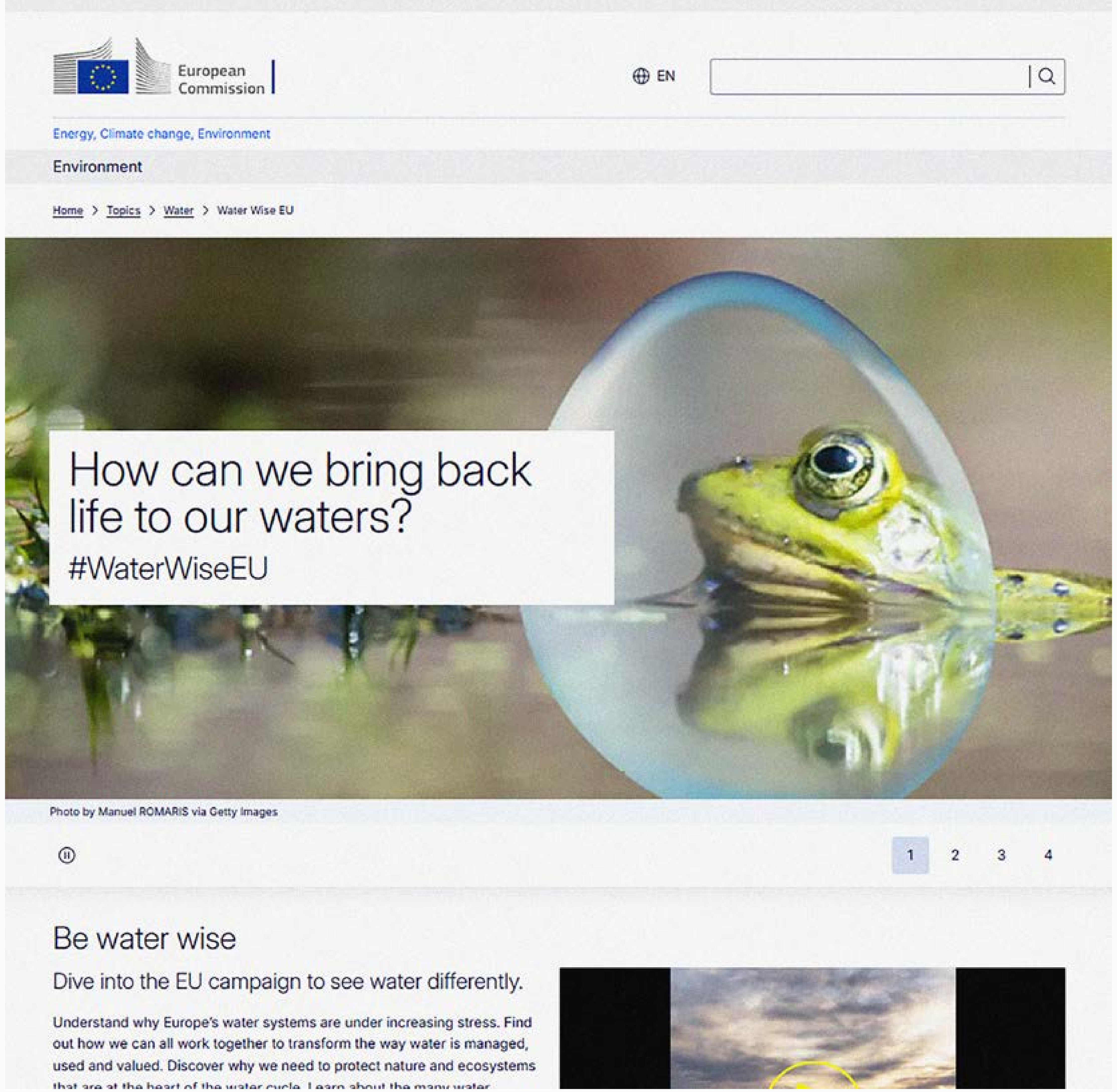
European Commission,
WISE Freshwater, EU Flood Risk Areas
Viewer (DISCOMAP), supported by the
European Environment Agency

1.1.2

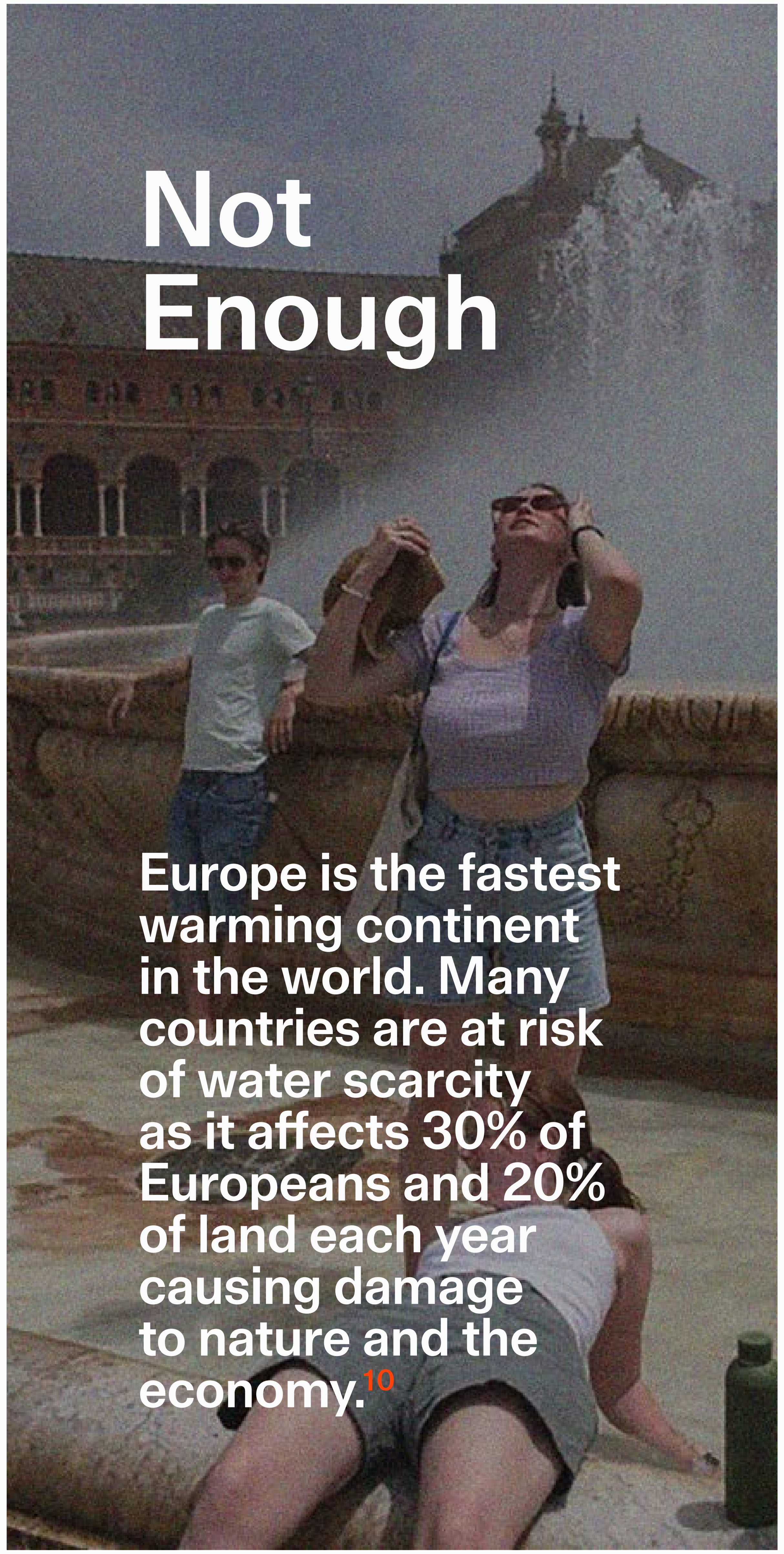
#WaterWiseEU

How we think about water

The European Commission has launched a public campaign that frames water resilience as a shared European project, setting a clear goal of a water-resilient Europe by 2050. Within the Water Wise EU initiative, the “Too much water” brief states that water related disasters represent 90 percent of natural disasters, and their frequency and intensity are expected to increase. It also quantifies what is often treated as episodic disruption. Floods have cost more than 170 billion euros in Europe since 1980, and 12 percent of the European population lives in areas prone to river flooding. Between 1980 and 2022, floods caused 5,582 deaths, and one in nine hospitals in Europe is located in an area prone to flooding.[8] Coastal flooding is presented not as a marginal risk, but as an escalating economic exposure, with potential costs projected to exceed 1.6 trillion euros by 2100.[9] These numbers show how flood risk is a systemic pressure on public safety, public health and public budgets.



#WaterWiseEU: Official Website 1.1.3



Not Enough

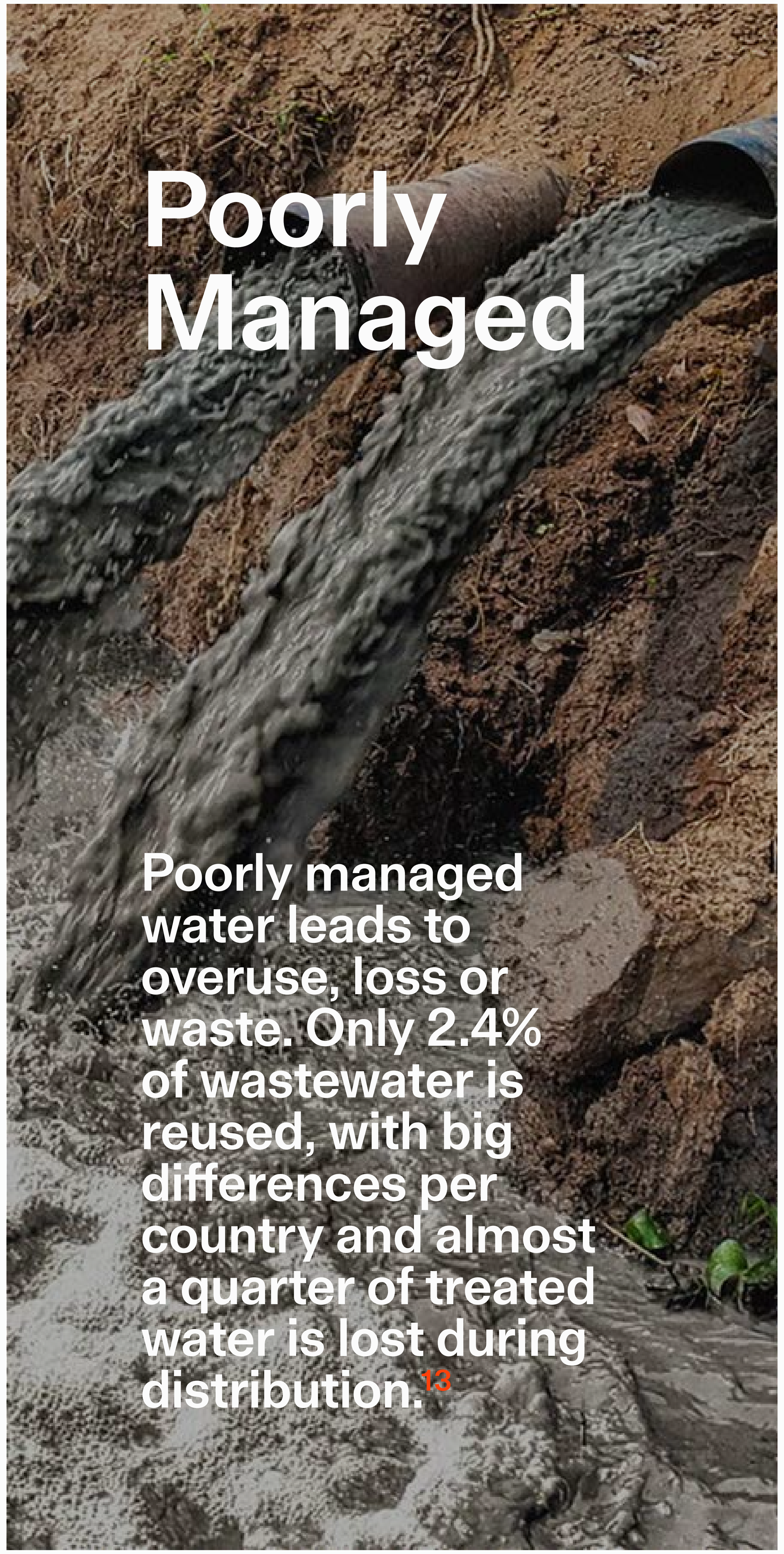
Europe is the fastest warming continent in the world. Many countries are at risk of water scarcity as it affects 30% of Europeans and 20% of land each year causing damage to nature and the economy.[10]

Too Much

Floods are becoming more frequent, dangerous and expensive. River floods are hitting the EU harder than ever, affecting millions and damaging our economies as floods have cost over EUR 170 billion since 1980.[11]

Polluted

Many of our rivers, seas and groundwater are polluted: from chemicals, plastics and agriculture and other sources making only 37% of Europe's surface waters in a healthy ecological state.[12]



Poorly Managed

Poorly managed water leads to overuse, loss or waste. Only 2.4% of wastewater is reused, with big differences per country and almost a quarter of treated water is lost during distribution.[13]

1.1.4 People cool off with a fountain's water during a heat wave in Seville, Spain, 2022. Jorge Guerrero/AFP/Getty Images

1.1.5 Valenica Flood 2024

1.1.6 Autopsies found plastic particles concentrated in the brain, with higher levels in recent cases. Getty Images

1.1.7 More than 370,000 spills using storm overflows were recorded last year in UK. Getty/iStockphoto

Problem Statement

Too Much Water in European Cities

Valenica Flood 2024 1.1.5

Designing Water Resilience
Within #WaterWiseEU

We position this booklet inside the #WaterWiseEU framework because it offers a shared European frame that is both ambitious and practical.

It sets a 2050 horizon while translating the agenda into local entry points through country pages and a partner community that helps move the conversation from policy language to actionable priorities.

Starting from this frame allows us to align design strategies with priorities and metrics that public authorities already recognize, while also asserting a professional position: architects can contribute to flood resilience as a spatial and civic project, at a time when design is still too often kept outside of the conversation.

1.1.8 Catania guarda il mare
Park Associati

1.2.1 A photo taken by a drone shows the flood-affected area at the Paar river following heavy rainfalls in Gotteshofen near Ingolstadt, Germany, June 2, 2024.
Ayhan Uyanik/Reuters

02. Europe's Flooding Since 2000

Across the last 25 years, Europe's most severe floods unfolded as disruptions inside lived environments, where water moves from rivers to streets and into overloaded drainage systems, intersecting with transport, utilities and public services at the precise points where cities are least able to absorb the pressure.

2000 2005 2010 2015 2020 2025 2030

2000

In the autumn of 2000, large parts of the United Kingdom experienced prolonged flooding, with damages often cited at around £3.5 billion.[14] The disruption was caused by extensive amount of water but also duration, logistics, and recovery, as it resulted with closed roads, interrupted services, and persistent knock-on impacts.[15]

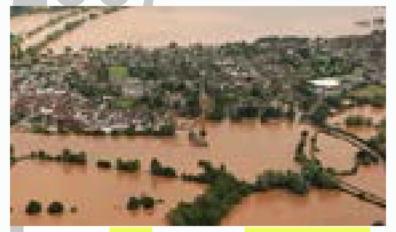
1.2.2 Residents use duckboards to get about in Shrewsbury after floods in December 2000. Homes and businesses that had only just recovered from the earlier floods were once again under water, David Jones/PA

2002

In August 2002, intense rainfall triggered flash floods that escalated into record basin flooding across Central Europe, hitting cities such as Prague and Dresden. Impacts are reported at around 100 deaths and losses of about €9 billion in Germany, €3 billion in Austria, and €2.5 billion in the Czech Republic.[16]

1.2.3 Krizikova, border of the Prague 8 Karlin district 2002

2007



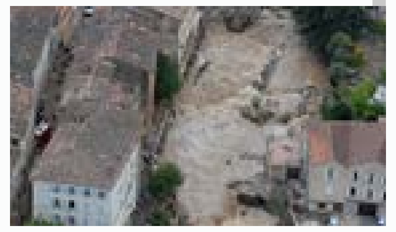
In the UK in the summer of 2007 widespread river and surface-water flooding produced at least 13 deaths and an estimated £4 billion in total costs in England, with impacts extending well beyond household repair into business disruption and public services.[15]

1.2.4 Upton upon Severn, which is about seven miles north of Tewkesbury over the border in Worcestershire, was also badly hit by the floods in 2007, Getty Images

2010

2010 saw major floods across Europe, from Danube and Vistula river flooding to the deadly 15–16 June Var flash floods in France. Poland's floods caused 19 deaths, affected over 100,000 people, cost about €2.5 billion, and exposed gaps in getting central forecasts to local responders.[17,18]

1.2.5 The swollen Nartuby River on 15 June 2010 flowing through the centre of Trans en Provence, Trans en Provence Town Council



2014

In May 2014, Southeastern Europe experienced floods due to saturated ground failures. The Aon report describes heavy rain and flooding across the region, with 57 deaths and total economic losses of about €2.1 billion, including severe national impacts in Serbia and Bosnia and Herzegovina.[19]

1.2.6 People evacuate in boats from Obrenovac, south-west of Belgrade, on Saturday, Marko Djurica/Reuters

2018

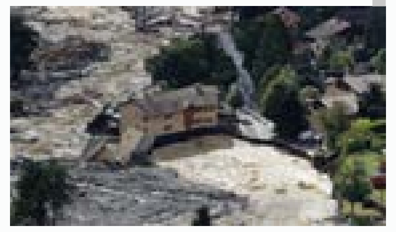
The October 2018 Aude event in southern France is described as a catastrophic flash flood that caused 15 fatalities and substantial national economic losses.[20]

1.2.7 The worst flooding for a century has devastated parts of southwest France in 2018 Sylvain Thomas/AFP

2020

In October 2020, Storm Alex struck the Alpes-Maritimes region and adjacent territories, with the a case study noting extreme precipitation in the region and reporting 20 fatalities and around €2.5 billion in economic losses.[21]

1.2.8 Damage in Roquebilliere after heavy rains and flooding hit the Alpes-Maritimes department in 2020, Valery Hache/AFP



2021

The July 2021 floods in Germany, Belgium and the Netherlands caused more than 200 deaths and around €44 billion damages.[22]

1.2.9 Severe flooding in Erftstadt-Blessem, Google Earth/@BezRegKoeln

2023

In May 2023, Emilia-Romagna faced severe flooding and landslides following unprecedented rainfall episodes with 17 deaths and estimated costs of more than €8.5 billion reported.[23]

1.2.10 Cars are submerged in floodwaters after heavy rains hit Italy's Emilia Romagna region, in Lugo, Italy, May 19, 2023. REUTERS/Claudia Greco

In September 2023, Storm Daniel caused catastrophic flooding in Greece reporting at least 16 deaths and damage estimates above €2 billion.[24]

1.2.11 A bus submerged by floods in Patanias, Greece, Alexandros Avramidis (Reuters)

2024

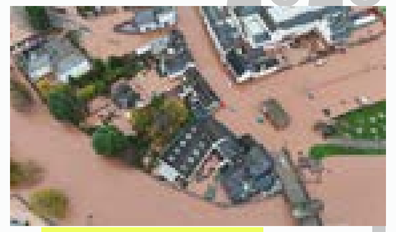
From 29 October to 16 November 2024, a DANA cold-drop storm produced extreme rain across eastern Spain, killing about 237 people and causing roughly €10.7 billion in damage.[25]

1.2.12 Residents look at cars piled up after being swept away by floods in Valencia, Alberto Saiz

In September 2024, Storm Boris produced widespread river flooding across parts of Central and Eastern Europe.[26] In October 2024, floods and landslides in Bosnia and Herzegovina caused at least 22 deaths.[27]

1.2.13 A drone view shows a flooded residential area in Donja Jablanica, Bosnia and Herzegovina, October 4, 2024 REUTERS/Amel Emric

2025



In November 2025, Storm Claudia killed three people in Portugal and produced flooding that extended into other countries.[28]

1.2.14 Claudia storm kills three elderly persons

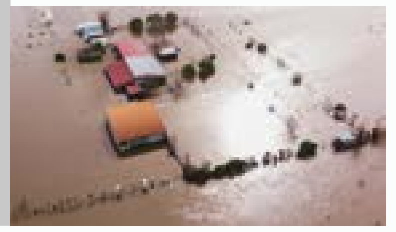
2026

In Southern Italy a declared emergency after storms in multiple southern regions.[30]

1.2.16 Cyclone Harry damage toll climbs over one-billion-euros mark in Sicily alone

In Portugal, flooding in the Mondego and Coimbra area included the failure of infrastructure under flood stress, including transport disruption and evacuation of 3,000 residents.[29]

1.2.15 A flooded area after a dike burst Sao Joao do Campo, Coimbra, Portugal. Miguel A Lopes/EPA



Flood risk in Europe is rising and uneven, driven by shifting hydrology, high exposure, and growing losses. Central and eastern regions may see up to 18 percent higher river discharge in the mid term, while southern Europe may face 10 to 20 percent less. Extreme precipitation that contributes to surface flooding is projected to increase in central and eastern Europe and in north and north eastern Europe.

Around 52 million people, about 12 percent of the EU population, live in floodplains, while more than 300 million, about 70 percent, live in urban areas where soil sealing increases runoff. About 4 percent of floodplains and 40 percent of urban areas are covered by non absorbent surfaces, increasing vulnerability as asphalt and concrete expand. Around 11 percent of hospitals, 10 percent of schools, 15 percent of industrial facilities, and 36 percent of EU urban wastewater treatment plants sit in floodplains.

Between 2008 and 2023, floods displaced more than 320,000 people in Europe. Between 1980 and 2023, floods killed 4,226 people in the EU 27 and 5,688 in the EEA 32. Over the same period, average annual flood losses in the EU were €7.8 billion, with €48.2 billion in 2021 and €25.7 billion in 2023. Without decisive action, coastal flood costs alone could rise from about €1 billion in 2020 to more than €1 trillion per year in the EU by the end of the century.[31]

Has flood risk increased over the last century?

Streets are flooded during heavy rainfall in Catania, Sicily, 2026 1.2.17

The data indicates a worsening condition. The European Commission reports high cumulative impacts since 1980, including major economic losses and thousands of deaths across Europe.[32] The United Kingdom briefing discusses century scale change through sea level rise, noting roughly 12 centimeters of rise along the English Channel coast over the last 100 years. It also anticipates increasing flood risk as rainfall extremes and sea level rise interact.[33] The interaction between climate pressure and urbanization is also highlighted, including a six percent increase in sealed land and growing exposure in flood prone areas since 2000.[34]

The physical drivers that can intensify flooding, including sea level rise and extreme rainfall, have become more visible in recent decades. Exposure and vulnerability have also increased, shaped by land sealing, settlement patterns, and dependence on infrastructure. Whether flooding feels worse in a specific city depends on how these drivers align with local river corridors, drainage capacity, governance, and preparedness. The event record shows that flood catastrophe is rarely only rainfall. It is the point at which water meets a built environment that has not been designed, operated, or governed for the conditions that arrive.

1.3.1 Italian floods in 2023: the clean up in deluged towns, Claudia Greco/Reuters

03. Italy's Flood Risk

In Italy exposure is spread across the entire country and is intensified by the way settlements and infrastructure have been built onto its geography through centuries.[35] The first point is the scale of hydrogeological exposure. Updated national assessments report that 94.5 percent of Italian municipalities are affected by at least one form of hydrogeological risk, including floods, landslides, coastal erosion and avalanches.[36]

Since 1872, HANZE records over 570 damaging flood events in Italy, showing how persistent and widespread flood risk has been nationwide.[37]

Piazza San Marco in Venice, November 4, 1966 1.3.2

Valle d'Aosta
Types: mountain flash floods, debris-laden river floods (Dora Baltea)
Why: narrow valleys, steep catchments, towns/infrastructure along valley floor

Lombardia
Types: urban flash floods (Seveso/Olona), major river floods (Po/Ticino/Adda)
Why: high soil sealing (Italy's highest), hard-paved urban areas in floodplains

Piemonte
Types: large river floods (Po, Tanaro) and flash floods in tributaries
Why: wide settled floodplains, leveed rivers, intense rain events (e.g., 1994)

Liguria
Types: very fast flash floods in short coastal basins
Why: steep hills straight to the sea + dense coastal cities with heavy paving

Toscana
Types: very fast flash floods in short coastal basins
Why: steep hills straight to the sea + dense coastal cities with heavy paving

Umbria
Types: Tiber/Nera floods and tributary flash floods
Why: towns and roads on valley floors; updated maps show expanded hazard zones

Sardegna
Types: flash floods and river floods in granitic basins
Why: steep, fast-responding catchments; urban growth on flood-prone fans and plains

Lazio
Types: Tiber/Aniene river floods; ponding in reclaimed coastal/agro-Pontino plains
Why: Rome's vast urbanization on floodplain corridors; reclaimed lowlands need pumping

Campania
Types: Volturno and Regi Lagni floods; urban flash floods
Why: Highly sealed coastal/plain areas and dense urbanization on lowlands

Sicilia
Types: flash floods, river floods, and "medicane"/coastal storm events (e.g., Apollo 2021)
Why: very steep basins straight to towns/coast; intense rain; rapid runoff over sealed areas

Trentino - Alto Adige / Südtirol
Types: Alpine floods and debris flows (torrents), Adige/Isarco
Why: steep alpine basins, glacier/snowmelt pulses, settlements in valley bottoms

Friuli-Venezia Giulia
Types: river floods (Tagliamento, Isonzo) and alpine flash floods
Why: intense alpine rain, limited natural storage in valleys

Veneto
Types: River floods (Piave, Brenta-Bacchiglione, Adige) and coastal storm-surge flooding
Why: built-up plains and coastal lowlands; fast runoff to rivers/lagoons

Emilia-Romagna
Types: large river floods and levee breaches (May 2023)
Why: very flat, heavily cultivated/urbanized plains with long leveed rivers

Marche
Types: mountain-to-coast flash floods
Why: steep basins to coastal plains + paved valley bottoms and towns on riverbanks

Abruzzo
Types: Aterno-Pescara, Sangro floods; fast rises from Apennine basins
Why: steep catchments feeding densely used valley floors; active re-mapping widens hazard

Molise
Types: Biferno, Trigno river floods
Why: settlements/infrastructure along narrow floodplains

Puglia
Types: Ofanto and Gargano floods; urban flash floods after cloudbursts
Why: paved coastal/plains and karst with poor natural retention

Basilicata
Types: Bradano, Basento, Agri river floods; debris-rich flows from badlands
Why: erodible clay "calanchi" landscapes feeding sediment-heavy floods; valley-floor uses

Calabria
Types: flash floods and debris flows in "fiumare" (ephemeral torrents) and coastal plains
Why: very steep basins straight to towns/coast; intense rain; rapid runoff over sealed areas

Italy's regions and their flood risks 1.3.3

The drivers of flood exposure vary sharply by region.

In steep catchments, flash floods can begin within hours of intense rainfall and leave little time for warning. Development time may range from minutes to several hours, depending on land surface conditions.[38,39]

Prolonged or heavy rainfall combined with steep slopes is also a common trigger for shallow landslides, which can rapidly turn into debris flows.[40]

In large plains, the dominant hazard is fluvial flooding, shaped by how large basin flows move through the river network, especially where river corridors are constrained.[41]

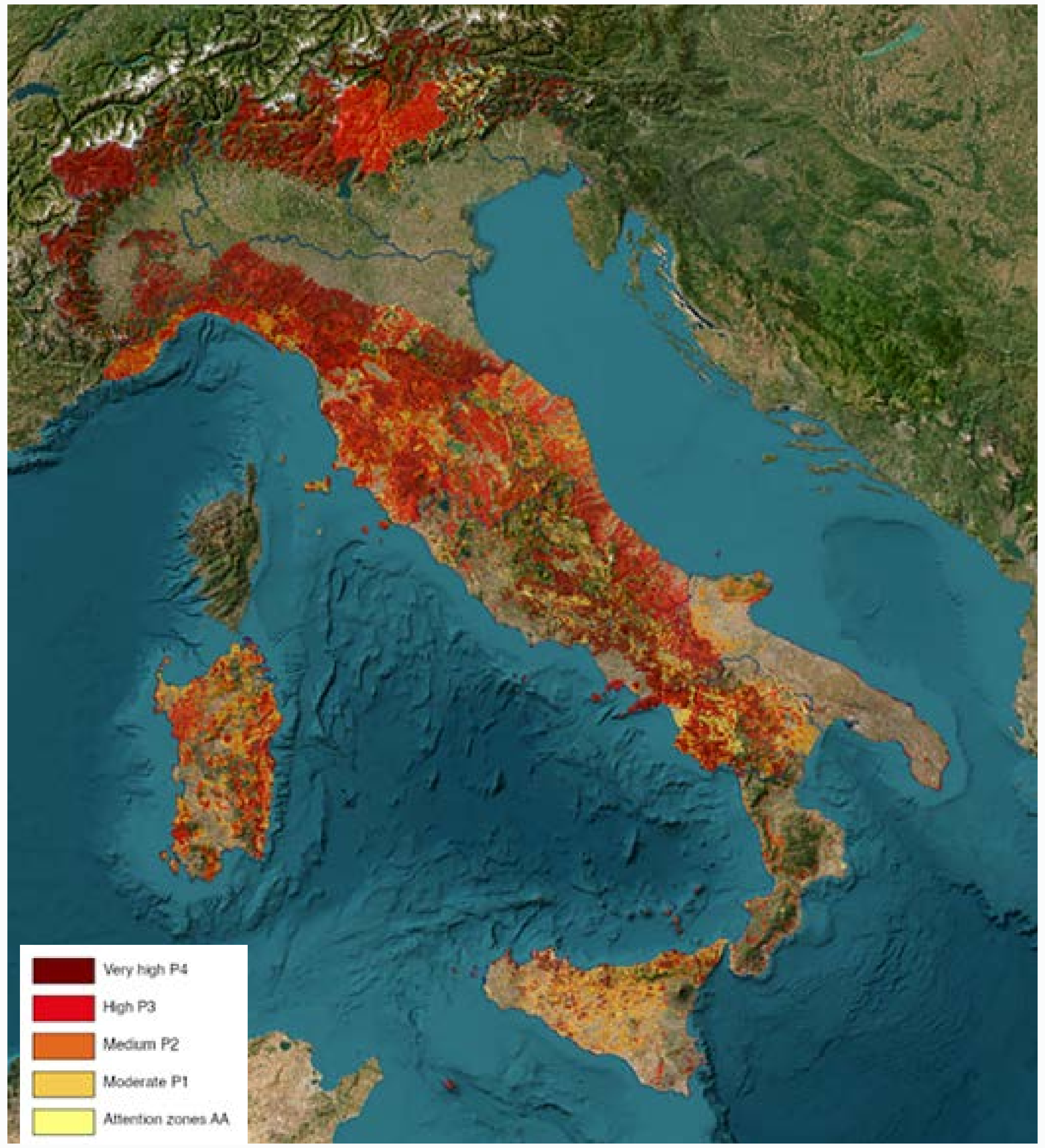
Along coasts and estuaries, storm surge and high winds coinciding with high tides can flood densely settled shorelines. In urbanized coastal zones, especially when heavy rainfall occurs at the same time, these processes can disrupt critical infrastructure and transport systems.[43,44]

Flood and Landslide Exposure

Hazard zones

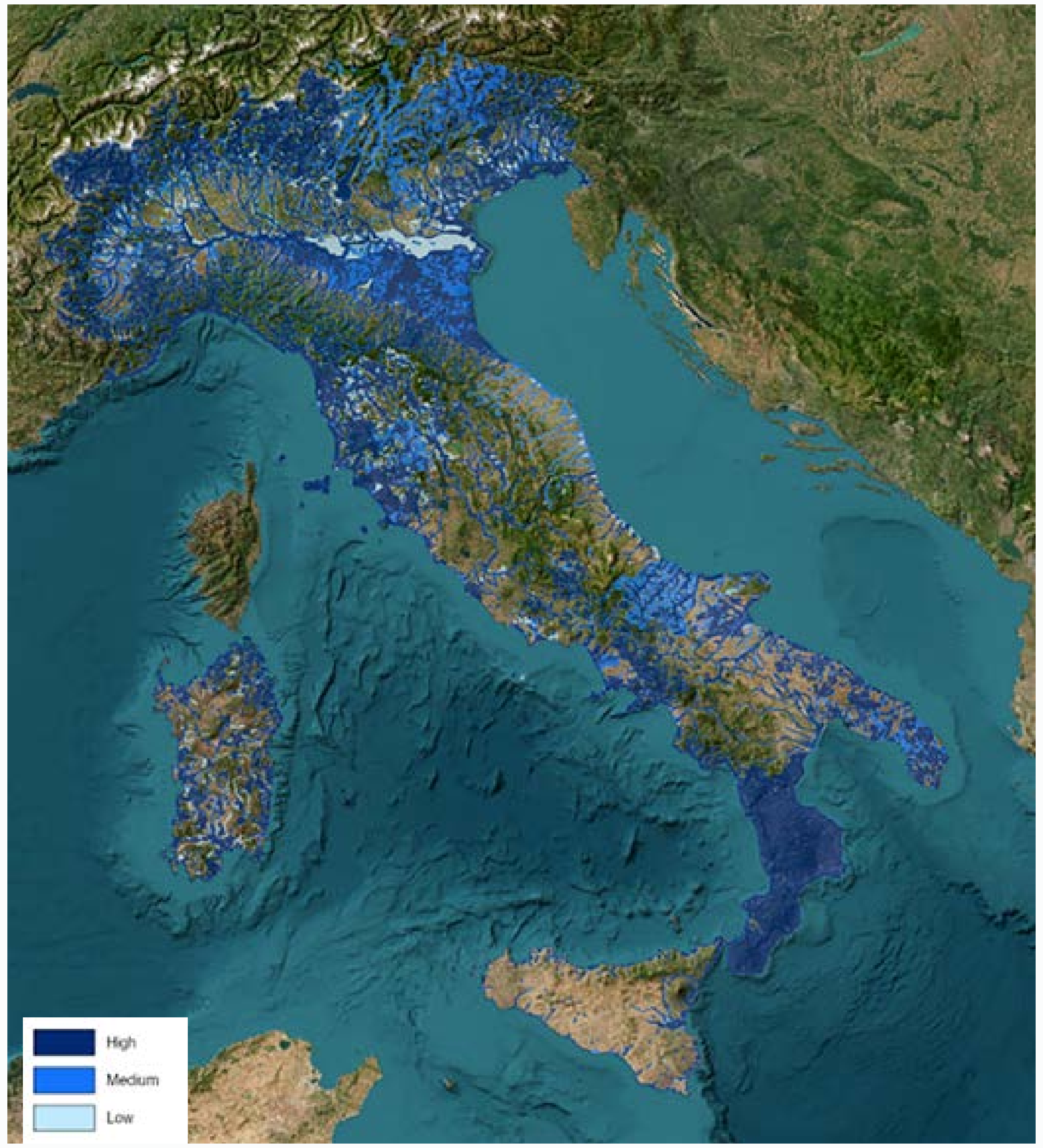
ISPRA's risk indicators show that 6,818,375 people, about 11.5 percent of the population, live in areas classified as medium hydraulic hazard. These areas also include 2,901,616 families and 1,549,759 buildings.[45] This confirms that flood exposure in Italy affects not only homes, but also economic activity and public institutions.[46] Additionally, national reporting also shows widespread landslide exposure, with millions of residents and buildings located in landslide hazard areas as well.[47] These figures indicate that flood and landslide risks are structural conditions that also intersect with housing, logistics, public services and cultural continuity.

Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), IdroGEO web map viewer (PIR view), Landslide Hazard 1.3.4



Population 1,284,960 (2.2%)
Families 582,163 (2.2%)
Buildings 742,192 (4.0%)
Industries and services 74,974 (1.5%)
Cultural heritage 13,966 (6.1%)

Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), IdroGEO web map viewer (PIR view), Flood Hazard 1.3.5



Population 6,818,375 (11.5%)
Families 2,901,616 (11.5%)
Buildings 1,549,759 (10.7%)
Industries and services 642,979 (13.4%)
Cultural heritage 33,887 (16.5%)

Soil Sealing

Artificial land and population density

Region	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Abruzzo	4,9%	4,9%	4,9%	4,9%	4,9%	5,0%	5,0%	5,0%	5,0%	5,1%
Basilicata	3,1%	3,1%	3,1%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%
Calabria	5,0%	5,0%	5,0%	5,0%	5,0%	5,1%	5,1%	5,1%	5,1%	5,1%
Campania	10,3%	10,3%	10,3%	10,4%	10,4%	10,5%	10,5%	10,5%	10,6%	10,6%
Emilia-Romagna	8,7%	8,7%	8,7%	8,8%	8,8%	8,8%	8,8%	8,9%	8,9%	9,0%
Friuli-Venezia Giulia	7,9%	7,9%	7,9%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,1%
Lazio	8,0%	8,0%	8,0%	8,1%	8,1%	8,1%	8,1%	8,2%	8,2%	8,2%
Liguria	7,2%	7,2%	7,3%	7,3%	7,3%	7,3%	7,3%	7,3%	7,3%	7,3%
Lombardia	12,0%	12,0%	12,0%	12,0%	12,0%	12,1%	12,1%	12,2%	12,2%	12,2%
Marche	6,8%	6,8%	6,9%	6,9%	6,9%	6,9%	6,9%	7,0%	7,0%	7,0%
Molise	3,9%	3,9%	3,9%	3,9%	3,9%	3,9%	3,9%	3,9%	3,9%	4,0%
Piemonte	6,6%	6,6%	6,6%	6,6%	6,6%	6,7%	6,7%	6,7%	6,7%	6,7%
Puglia	8,0%	8,0%	8,0%	8,1%	8,1%	8,2%	8,2%	8,2%	8,2%	8,2%
Sardegna	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,3%	3,4%	3,4%
Sicilia	6,4%	6,4%	6,4%	6,4%	6,5%	6,5%	6,5%	6,5%	6,5%	6,6%
Toscana	6,1%	6,1%	6,1%	6,1%	6,1%	6,2%	6,2%	6,2%	6,2%	6,2%
Trentino-Alto Adige	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	3,0%	2,9%
Umbria	5,2%	5,2%	5,2%	5,2%	5,2%	5,2%	5,2%	5,3%	5,3%	5,3%
Valle d'Aosta	2,1%	2,1%	2,1%	2,1%	2,1%	2,1%	2,1%	2,2%	2,2%	2,2%
Veneto	11,5%	11,6%	11,6%	11,7%	11,7%	11,8%	11,8%	11,8%	11,9%	11,9%
total %	**7,0%**	**7,0%**	**7,0%**	**7,0%**	**7,1%**	**7,1%**	**7,1%**	**7,1%**	**7,2%**	**7,2%**

1.3.6

Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), "Impermeabilizzazione e consumo di suolo," Indicatori ambientali

Artificial Land	2009	2012	2015	2018	2022
Belgium	9,9%	10,8%	11,4%	11,7%	12,0%
Bulgaria		1,7%	1,8%	2,3%	2,4%
Czechia	4,3%	4,4%	4,6%	4,4%	4,7%
Denmark	6,4%	6,7%	6,9%	6,9%	6,9%
Germany	6,8%	7,0%	7,4%	7,6%	7,8%
Estonia	1,8%	1,9%	2,0%	1,7%	1,9%
Ireland	3,7%	3,8%	3,8%	4,2%	4,6%
Greece	2,9%	3,3%	3,4%	4,0%	4,0%
Spain	3,2%	3,3%	3,4%	3,7%	3,9%
France	5,1%	5,2%	5,4%	5,6%	5,6%
Croatia			3,7%	3,2%	3,1%
Italy	6,6%	6,8%	6,9%	6,6%	6,5%
Cyprus		5,1%	5,4%	6,2%	8,2%
Latvia	1,5%	1,6%	1,6%	1,7%	1,9%
Lithuania	2,6%	2,6%	2,7%	2,1%	2,2%
Luxembourg	8,9%	9,7%	9,8%	7,4%	9,2%
Hungary	3,6%	3,8%	4,1%	4,0%	4,0%
Malta		23,8%	23,8%	27,5%	25,9%
Netherlands	10,7%	11,3%	12,0%	12,6%	13,0%
Austria	3,9%	4,1%	4,3%	4,2%	4,6%
Poland	3,2%	3,3%	3,4%	3,6%	3,9%
Portugal	5,1%	5,2%	5,3%	6,4%	6,3%
Romania		2,0%	2,1%	2,8%	2,8%
Slovenia	3,0%	3,2%	3,3%	4,3%	3,8%
Slovakia	2,6%	2,8%	3,0%	3,4%	3,1%
Finland	1,5%	1,6%	1,6%	1,7%	2,1%
Sweden	1,5%	1,5%	1,6%	1,8%	1,9%
Average	**3,5%**	**3,8%**	**4,0%**	**4,2%**	**4,4%**

1.3.7 Eurostat, Land cover overview by NUTS 2 region

Population Density	2022
Belgium	383,6
Bulgaria	58,8
Czechia	138,2
Denmark	140,6
Germany	235,4
Estonia	31,3
Ireland	75,9
Greece	80,3
Spain	95,1
France	107,6
Croatia	69,0
Italy	198,1
Cyprus	100,6
Latvia	29,7
Lithuania	45,2
Luxembourg	252,6
Hungary	105,3
Malta	1.696,8
Netherlands	517,8
Austria	109,6
Poland	119,8
Portugal	115,0
Romania	81,3
Slovenia	104,8
Slovakia	111,5
Finland	18,3
Sweden	25,7

1.3.8 Eurostat, Population density

Across all of these contexts, land transformation is a consistent amplifier. Italy's soil consumption reporting records that artificial cover now occupies 7.16 percent of the national territory and that impermeable surfaces continue to expand, with most new land take concentrated in low slope areas and near coasts and water bodies.[48] The interesting thing is that only five EU Member States combine a higher share of artificial land than Italy with a higher population density: Belgium, Germany, Luxembourg, the Netherlands and Malta.[49,50] In other words, Italy's land take is disproportionately high relative to how many people it accommodates. This matters because when ground loses its ability to absorb and delay rainfall, pluvial flooding becomes more frequent, drainage systems fill faster and river peaks become harder to buffer.

Milan works as a lens because it shows how flood risk is produced through terrain, infrastructure and governance decisions that accumulate over time.

Seveso flooding in Niguarda, Milan, 1976

1.3.9

1.3.9 Seveso flooding in Niguarda, Milan, 1976

Milano Condition

Our living lab

Several conditions merge into a single metropolitan condition of Milan, shaped by historic river engineering and by development pressure across the wider river basins.[51] Firstly, Milan grew for centuries as a city structured by canals and managed flows, but most of this water heritage has been buried or diverted into underground networks.[52] At the same time, urban expansion has sealed large areas of ground, so heavy rain becomes rapid surface runoff and adds pressure to sewers.[53] When river corridors are constrained, runoff accelerates across impermeable surfaces and underground networks carry the flow, then flooding becomes a symptom of the city's form as much as of rainfall itself.

1976

1.3.10 3 October 1976: the Seveso floods the Niguarda–Viale Fulvio Testi area.
Fotogramma

1977

1.3.11 3 October 1976: the Seveso floods the Niguarda–Viale Fulvio Testi area.
Fotogramma

1978

1.3.12 26 February 1978: flooding in the Viale Suzzani / Ca' Granda area.
Fotogramma

1979

1.3.13 13–17 October 1979: wooden footbridges in Niguarda.
Fotogramma

1993

1.3.14 January 1993.
Fotogramma

2000

1.3.15 1st of September 2000.
Fotogramma

2002

1.3.16 November 2002.
Shutterstock

2010

1.3.17 October 2010

2014

1.3.18 July 8, 2014.
Federico Ferramola / LaPresse

2023

1.3.19 October 31, 2023.
Matteo Corner/ Shutterstock

2024

1.3.20 "The constant rain in Milan this week saw the River Lambro burst its banks"

2025

1.3.21 "Seveso floods, Lambro alert"

The City as a Hydraulic System

Cities Built Against Water

02

A man walks his dog along a flooded street in Castel Bolognese, Italy, 2023.
Luca Bruno / AP

2.0

The City as a Hydraulic System

Urban flooding in Europe is a systemic problem. Cities seal the ground and tighten river and drainage corridors, so rain turns into fast runoff with little space to infiltrate or be stored. Sewer networks, often combined, must absorb peaks they were not designed for, and they fail first. Under stronger climatic pressure these limits are reached more often. Flooding is therefore a product of urban form, infrastructure capacity, and governance, repeating across cities in different contexts.

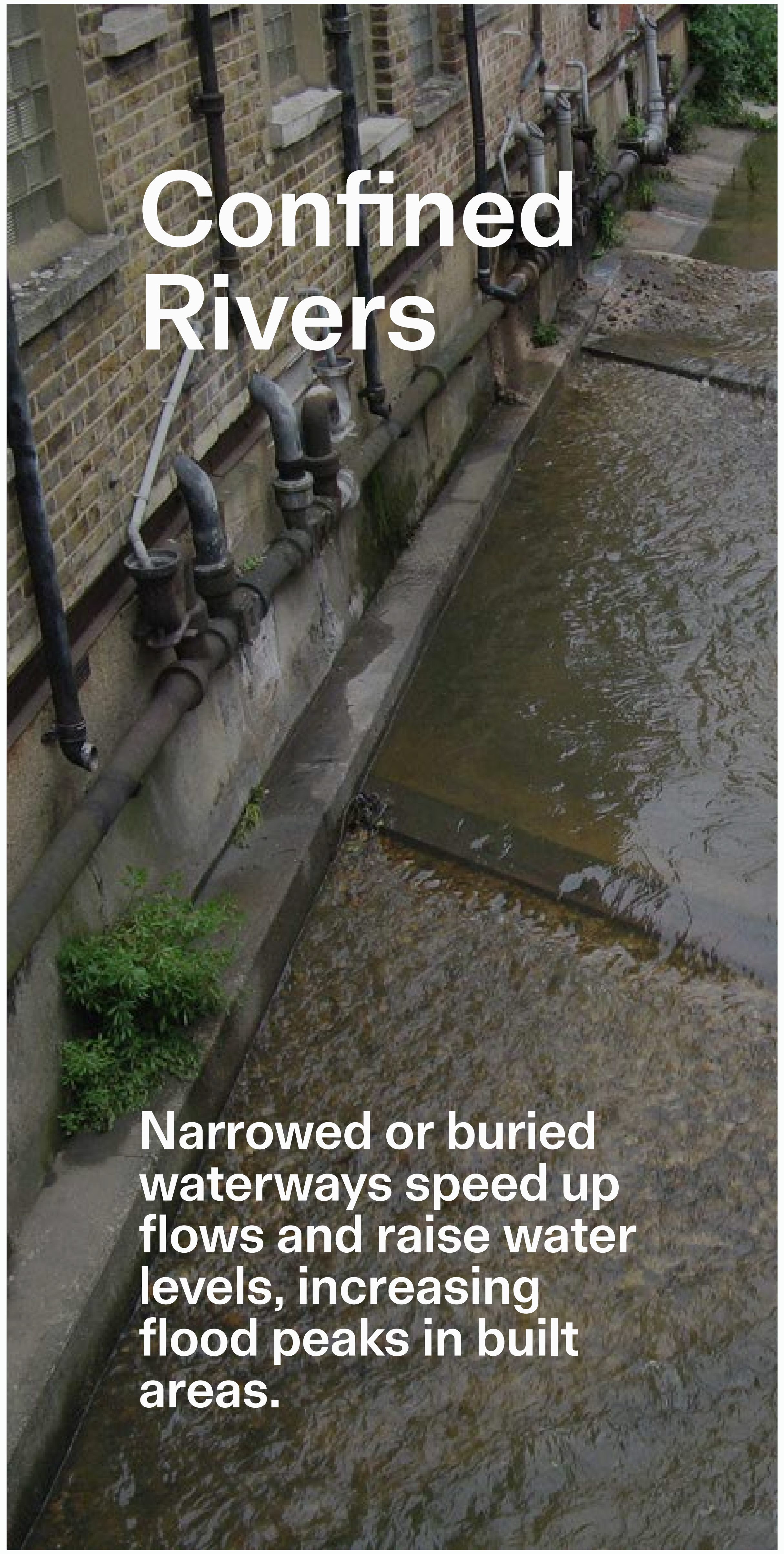
A man walks his dog along a flooded street in Castel Bolognese, Italy, 2023. Luca Bruno / AP

2.0

2.1.1 Summer 2016: northern Germany, northern Italy and northern France most at risk of damage
Francois Mori/AP

01. Why Cities Flood

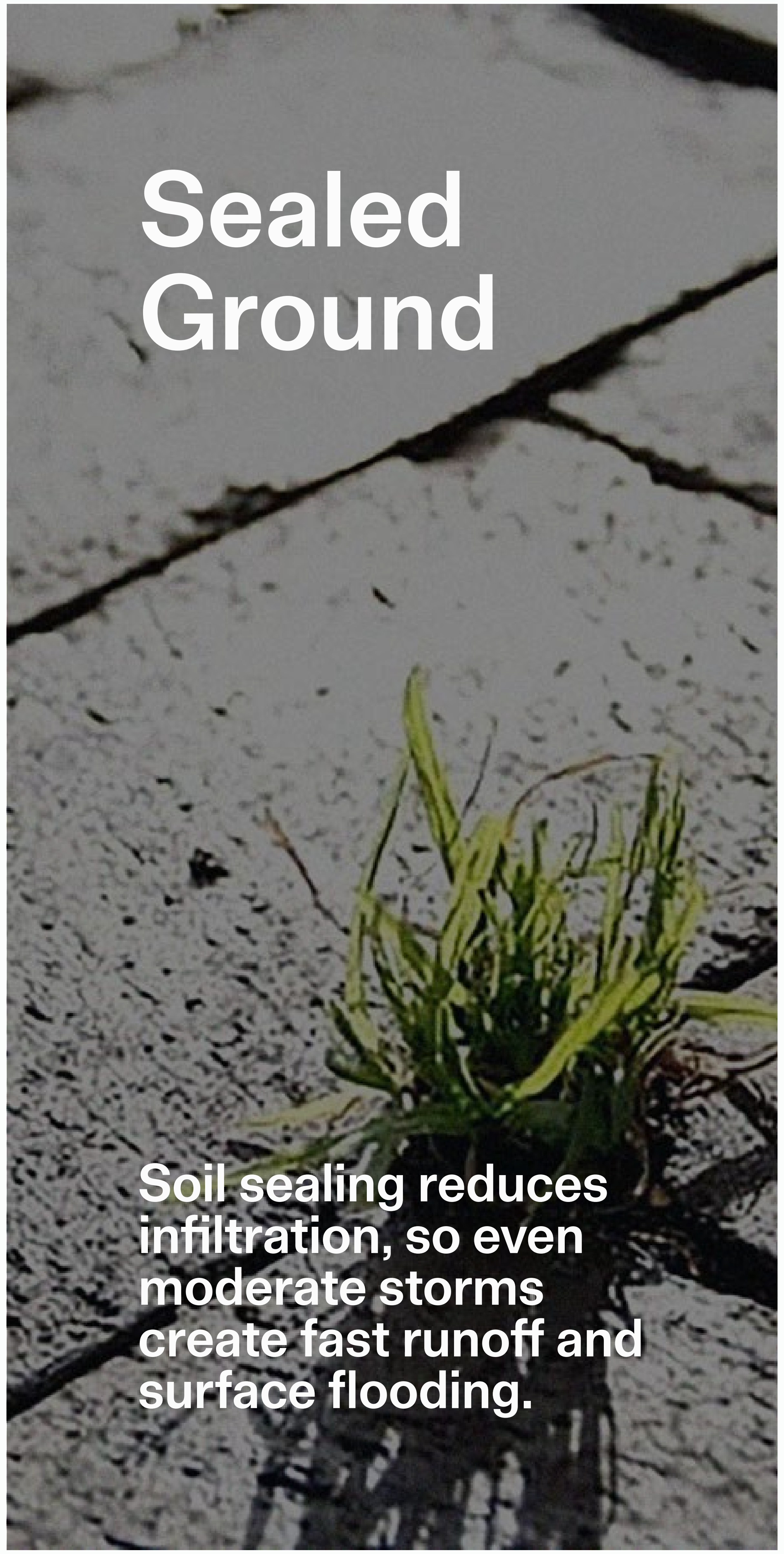
Urbanization makes the water cycle faster and more intense. As land is sealed, rain that once infiltrated is routed over roofs and streets into inlets and pipes, producing quicker peaks and concentrated flows that can exceed street and sewer capacity. In many European cities, long-term growth in population and built-up land has increased exposure and vulnerability to flooding.[54]



Confined Rivers

Narrowed or buried waterways speed up flows and raise water levels, increasing flood peaks in built areas.

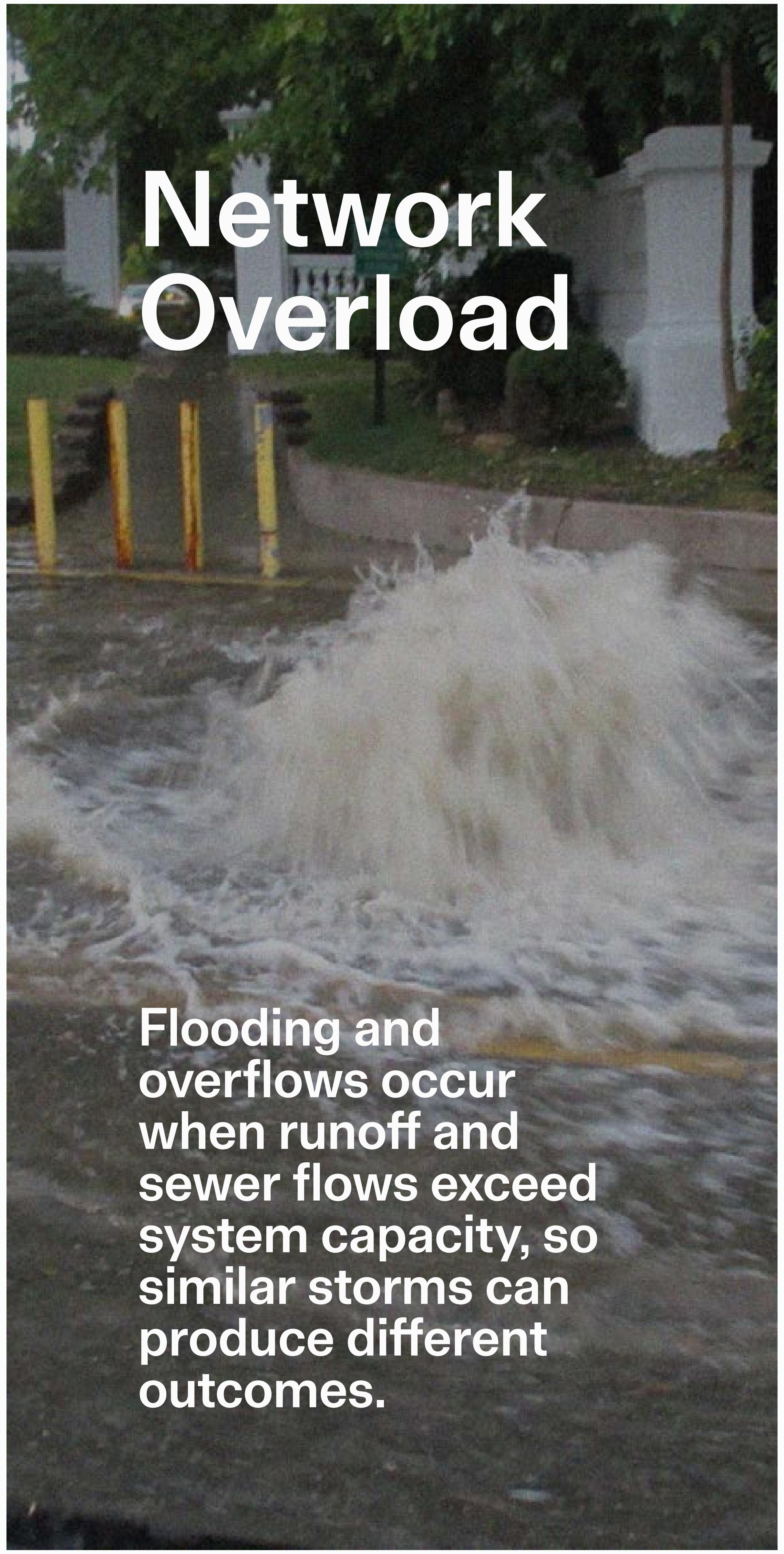
2.1.2 Improve channel geomorphology to create habitat



Sealed Ground

Soil sealing reduces infiltration, so even moderate storms create fast runoff and surface flooding.

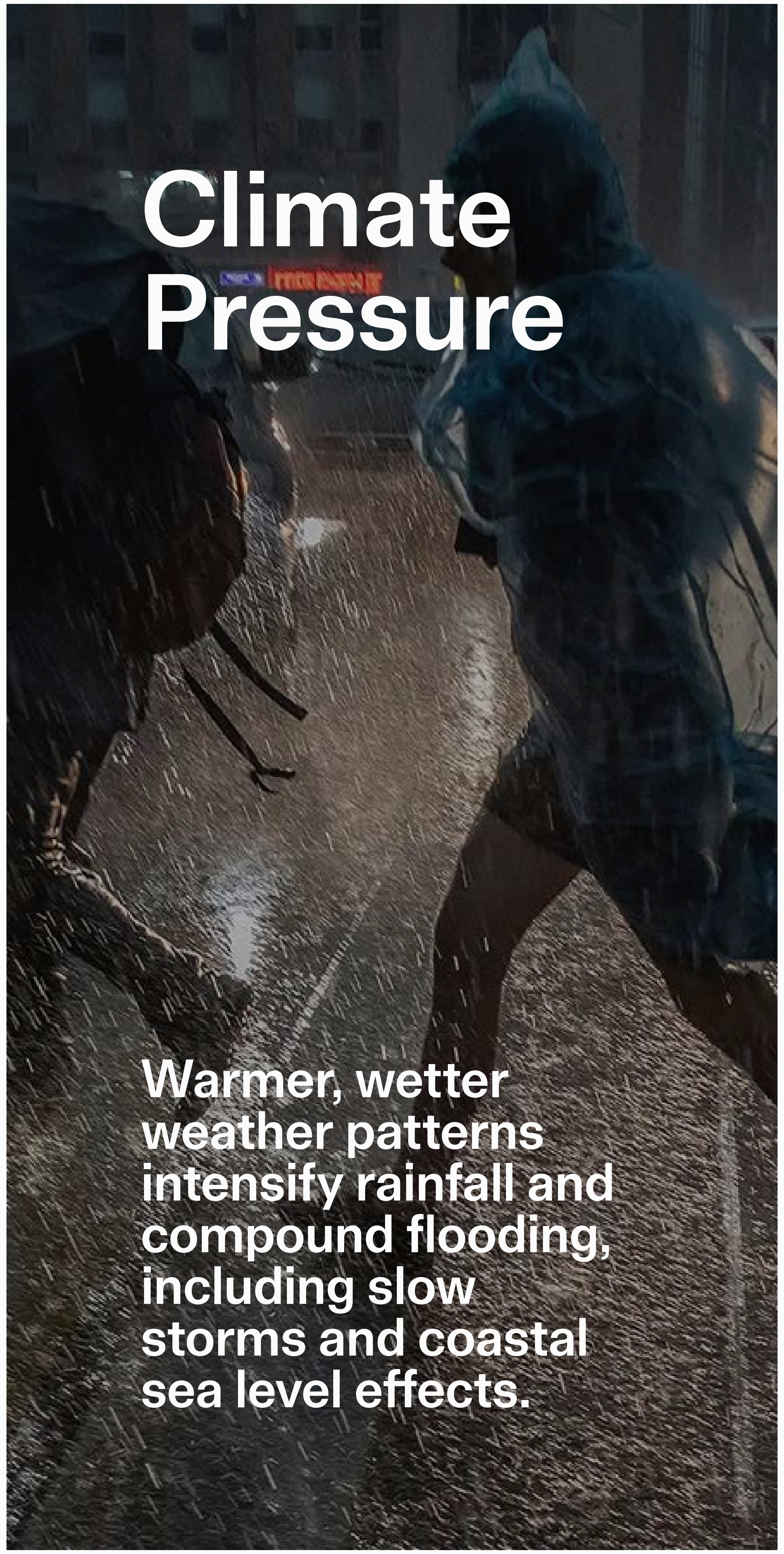
2.1.3 Soil sealing is genuinely alarming



Network Overload

Flooding and overflows occur when runoff and sewer flows exceed system capacity, so similar storms can produce different outcomes.

2.1.4 Malfunction of the city sewer



Climate Pressure

Warmer, wetter weather patterns intensify rainfall and compound flooding, including slow storms and coastal sea level effects.

2.1.5 Why has it been raining so hard? How climate change is causing heavier downpours. Alamy

Confined Rivers
Reduced floodplain space

In many European contexts, river corridors are managed as infrastructure and not as spatial systems. When channels are narrowed or pushed underground, flows speed up and water levels rise more quickly during heavy events.[55] Flooding can therefore become catastrophic when high water volumes meet built terrain and constrained blue infrastructure.[56]

Milan, Italy, 14 July 2014 (Seveso): flooding became severe where the river runs through a long covered reach in the city, so high flows met a constrained corridor and overflowed into dense urban areas. 2.1.6

Sealed Ground

Lost infiltration capacity

When the ground loses permeability, infiltration becomes minimal. Even moderate storms can then produce severe flooding because the city offers fewer places where water can slow down and soak in. Surface water flooding is therefore a spatial outcome of how urban land is built, paved and directed to drainage infrastructure. In European cities, flood risk is often tied to high shares of sealed surfaces and limited capacity for absorption. This means flood hazard increasingly reflects land cover and urban form as much as it reflects rainfall.[57]

2.1.7 Copenhagen, Denmark, 2 July 2011: the cloudburst produced severe surface flooding because most urban surfaces are impermeable, so rainfall became fast runoff that spread across streets and into buildings.

Network Overload

Capacity threshold exceeded

The problems often become visible inside of the drainage network, because flooding and overflows occur when runoff or sewer flows exceed the system's capacity. Even a small increase in rainfall intensity or duration can trigger a much larger rise in overflows and surface flooding.[58] This is why two neighborhoods can experience the same storm and still face very different outcomes. The Malmö cloudburst study shows that sewer system design defines both exposure and recovery, and that combined systems can produce different impacts than separated systems.[59] In this sense, the disaster is also what happens when too much water reaches networks that are not designed to manage it.

2.1.8 Malmö, Sweden, 31 August 2014: a cloudburst caused widespread pluvial flooding and the event record shows much higher damage claims in areas connected to combined sewers than in areas with separated systems, linking outcomes to network design and capacity.

2.1.9 Western Europe, July 2021 (Germany and Belgium): extreme rainfall from a slow moving low pressure system led to catastrophic flooding, and attribution work found that climate change increased the likelihood and intensity of this kind of heavy rainfall event.

Climate Pressure
Heavier recurring storms

Climate pressure worsens these mechanisms. A warmer atmosphere holds more moisture, which increases the potential for heavier rainfall.[60] In parallel, intense storms can become highly destructive when they move slowly or stall over a small area, because extreme volumes can build up in a short time.[61] Additionally in the Mediterranean, this dynamic meets a geography that can intensify risk. Mountain ranges and slow-moving cyclonic systems can trap humid air and extend downpours, and parallelly soil moisture and land use influence how rainfall turns into runoff.[62] Along coasts, rising sea level increases both the frequency and severity of extreme conditions. Flood impacts are often compound, and they become worse when high sea levels occur alongside heavy rainfall and river flooding.[63]

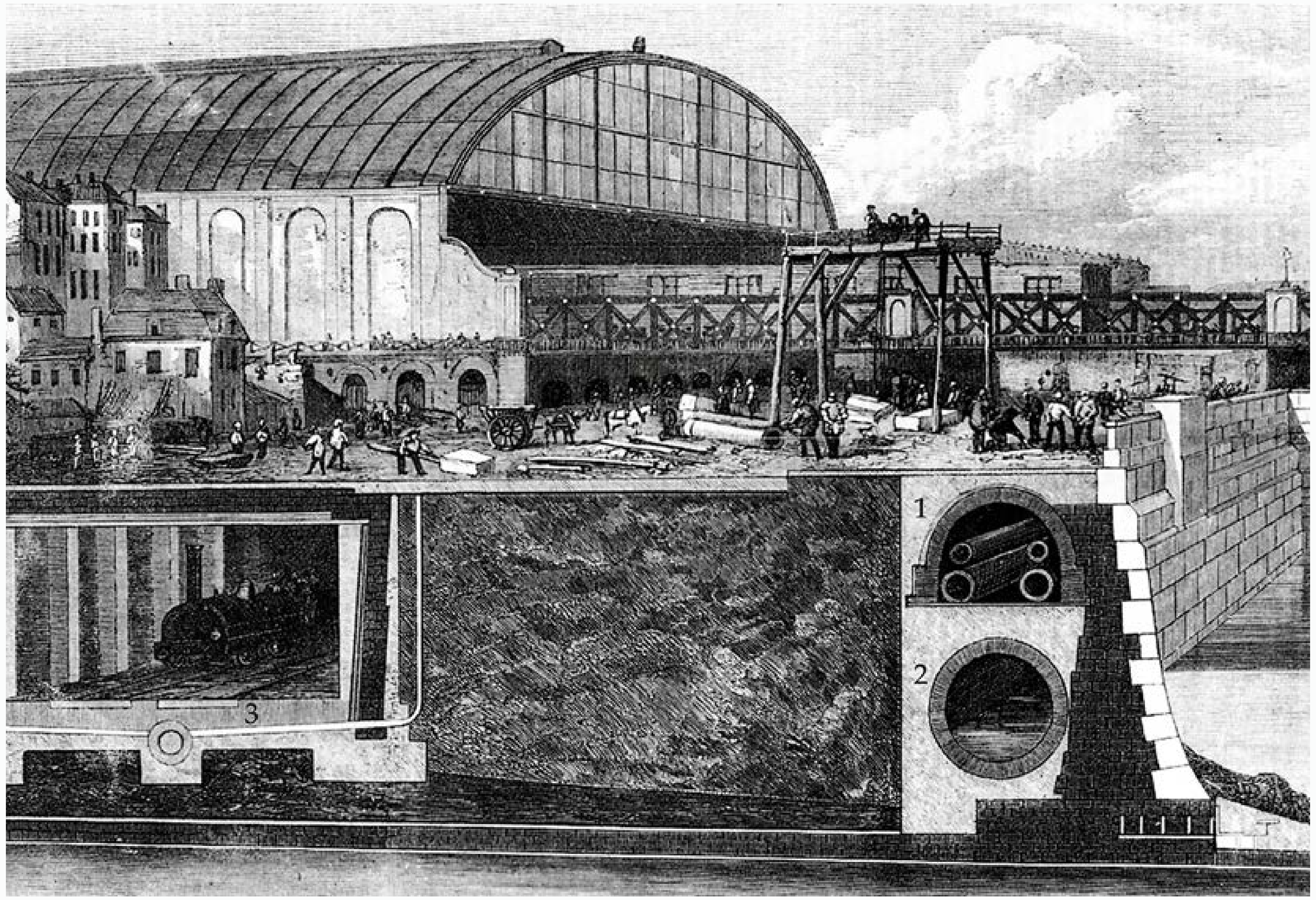
Urban growth speeds up runoff, sealed ground reduces absorption, confined river corridors remove space for water to spread, and drainage networks reach their limits during short, intense downpours. Climate change adds more moisture to the atmosphere and can slow storm movement in some cases, while higher coastal water levels raise the starting point for flooding during storms.

The impacts also go beyond damage that can simply be repaired. A field report on the Emilia Romagna floods shows that response capacity includes evacuation, continuity of care for displaced people, and coordination across different levels of the health system. This makes clear that flooding tests everyday services and public governance.[64] When risk builds up where urban form and institutional capacity do not match, flooding becomes also a driver of inequality.

Urban flooding results from multiple overlapping conditions.

Firefighters on the flooded streets of Lewin Brzeski, Poland, on September 19, 2024.
Omar Marques/Getty Images

2.1.10



2.2.1 Section view of the Thames Embankment depicting London’s underground infrastructure. The tunnel for the Metropolitan District Railway is at left (3); Joseph Bazalgette’s sewer system (2) runs beneath the “subway,” a horizontal shaftway built to house gas and water pipes (1). From the Illustrated London News, 22 June 1867.

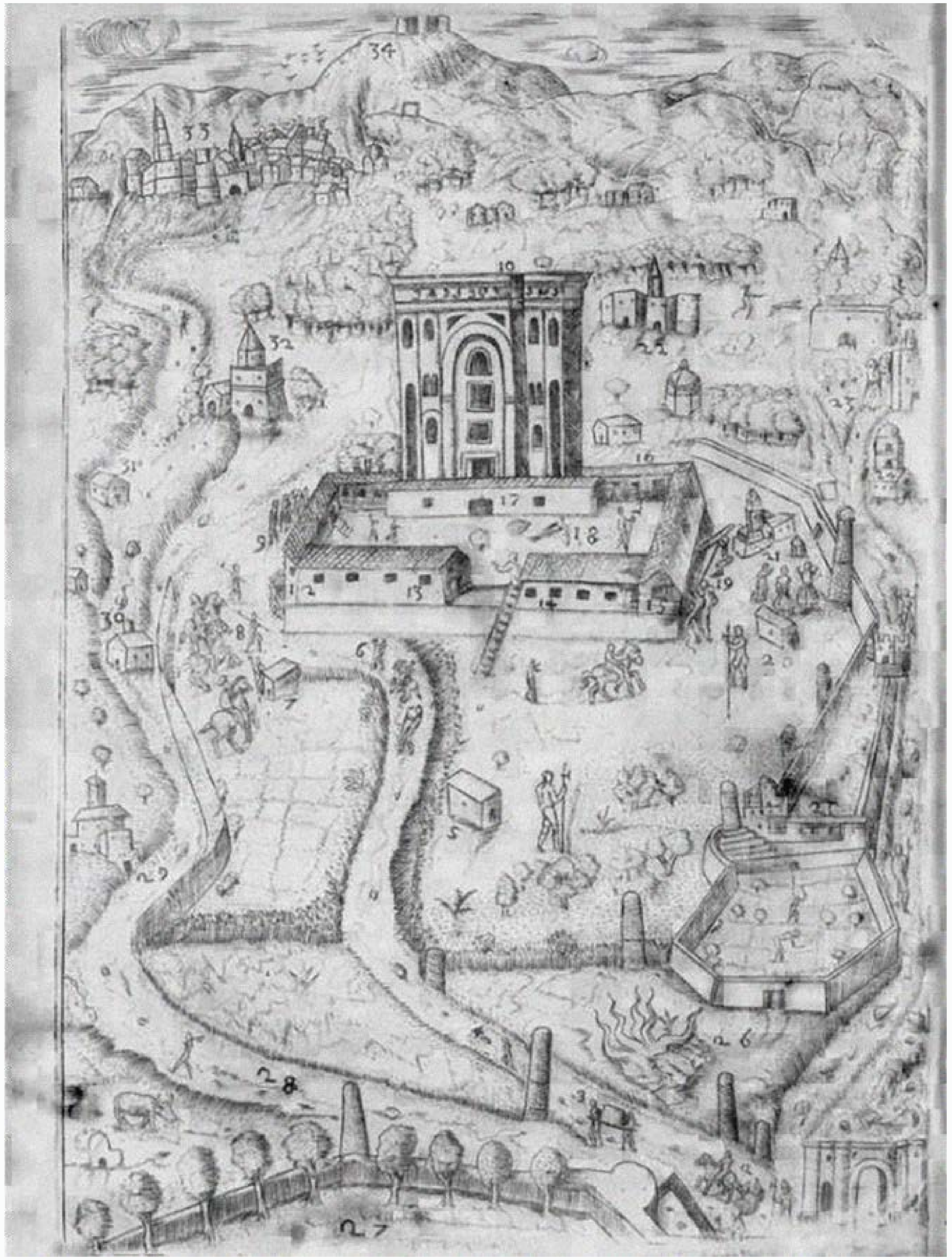
02. History of European Water Systems

European cities have always been built around water, but not always with water in mind. Water was always comfort, trade and public life. It was also a carrier of waste, risk and disease. The city of streets and buildings sits on top of a second city made of pipes, canals and sewers. When that hidden city fails, disease and disruption surface quickly.[65]

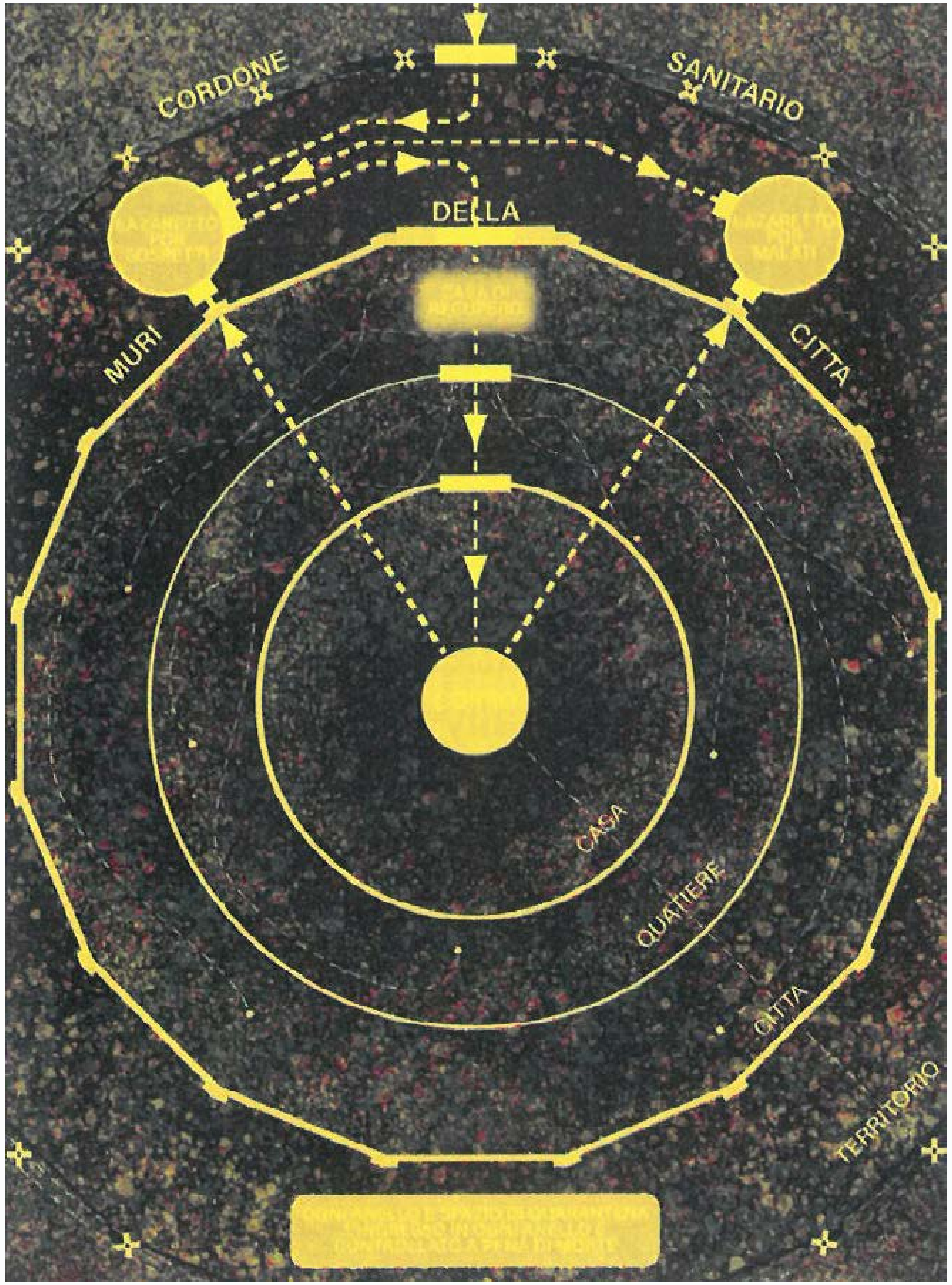
Cities Shaped by Water

A history of sanitary design

Long before the nineteenth century sanitary revolution, epidemics already pushed cities to act through space. During the Black Death and later plague waves, Italian city states developed a layered logic of defense that separated the sick from the healthy, controlled entry, quarantined contacts, and shifted risk outward from the house to the city edge and into the wider territory. Plague hospitals, later called lazarettos, were placed outside the walls as controlled enclosures. Cities were also periodically cleansed, with waste removed and canals and ditches cleared, because decay was widely linked to illness, whether explained through bad air or contagion.[66]



2.2.2 Giovanni Filippo Ingrassia, illustration of an isolated facility for ventilating and disinfecting clothing from city households, located outside Palermo's walls 1576



2.2.3 Diagram of prophylactic plague defense system

Milan as a Sanitary City

Plague control as spatial design

Milan is an example of how epidemic control became an urban and architectural project, with water infrastructure embedded in the strategy.

After 1348, authorities treated contagion as something that could move through people, objects and space, and responded by redesigning thresholds, interiors and movement in buildings and the city.

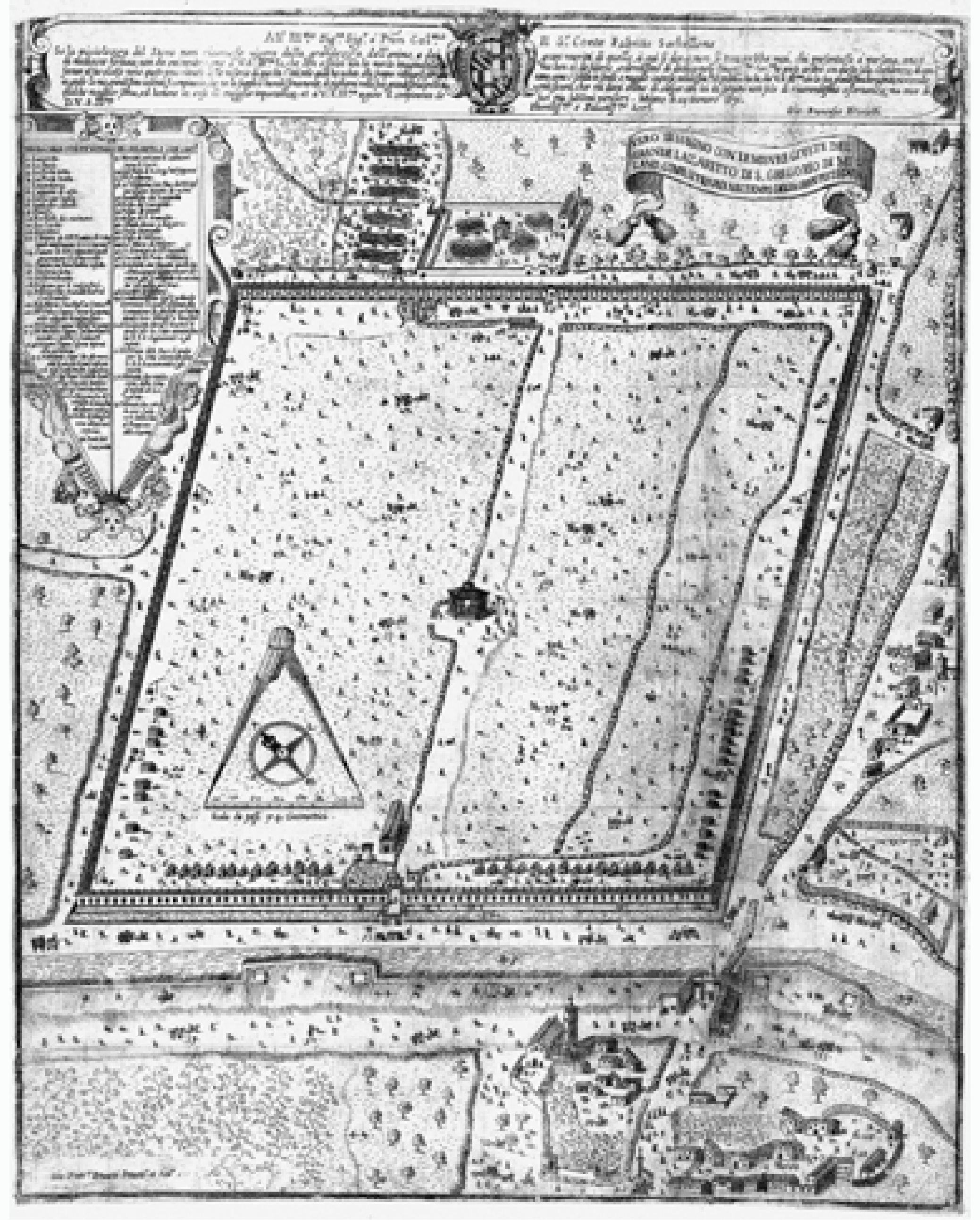
In early 1374, Bernabò Visconti issued regulations to remove infected people from the city, limit contact, impose quarantine on those exposed and block entry from infected places. Under Gian Galeazzo Visconti, this expanded into territorial exclusion, including the use of the Adda River as a *cordon sanitaire* along a major transport corridor. Within the city, officials could mark houses as *domus infecta*, seal them, relocate the sick to designated sites, and hold suspected contacts in temporary camps beyond the walls, treating the home, the neighborhood, and the city as environments that required isolation and cleansing, where measures such as whitewashing also asserted public authority.[67]

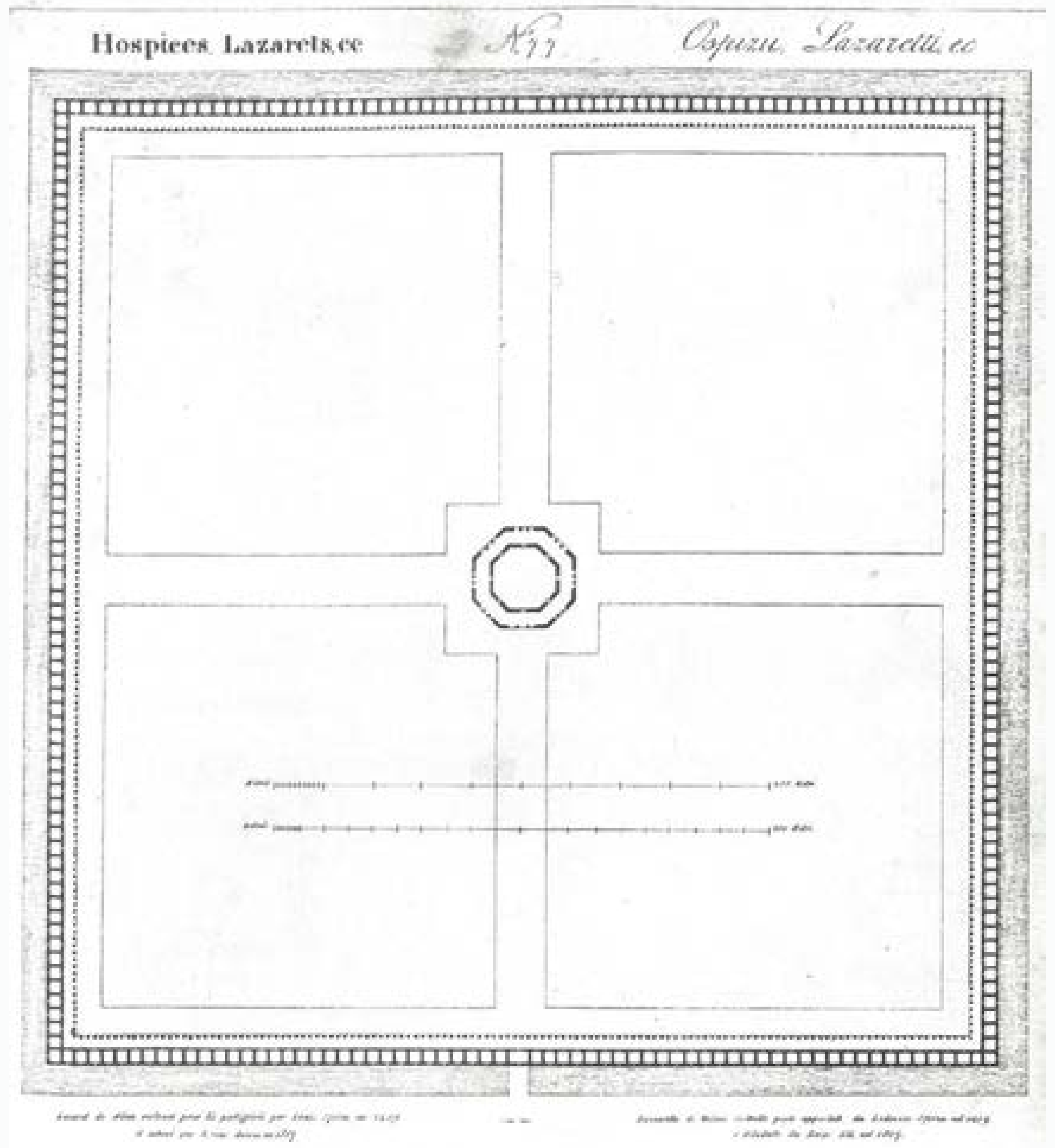
Lazaretto of Milan
Lazzaro Palazzi

The Lazaretto of Milan, designed by Lazzaro Palazzi in the late fifteenth century, was built outside the walls as a vast, enclosed square. Its form came from the idea of both separation and sanitation through its geometry and surrounding water. The moat acted as a spatial boundary, while each room included a built-in latrine that discharged human waste directly into the moat.[68]

2.2.6

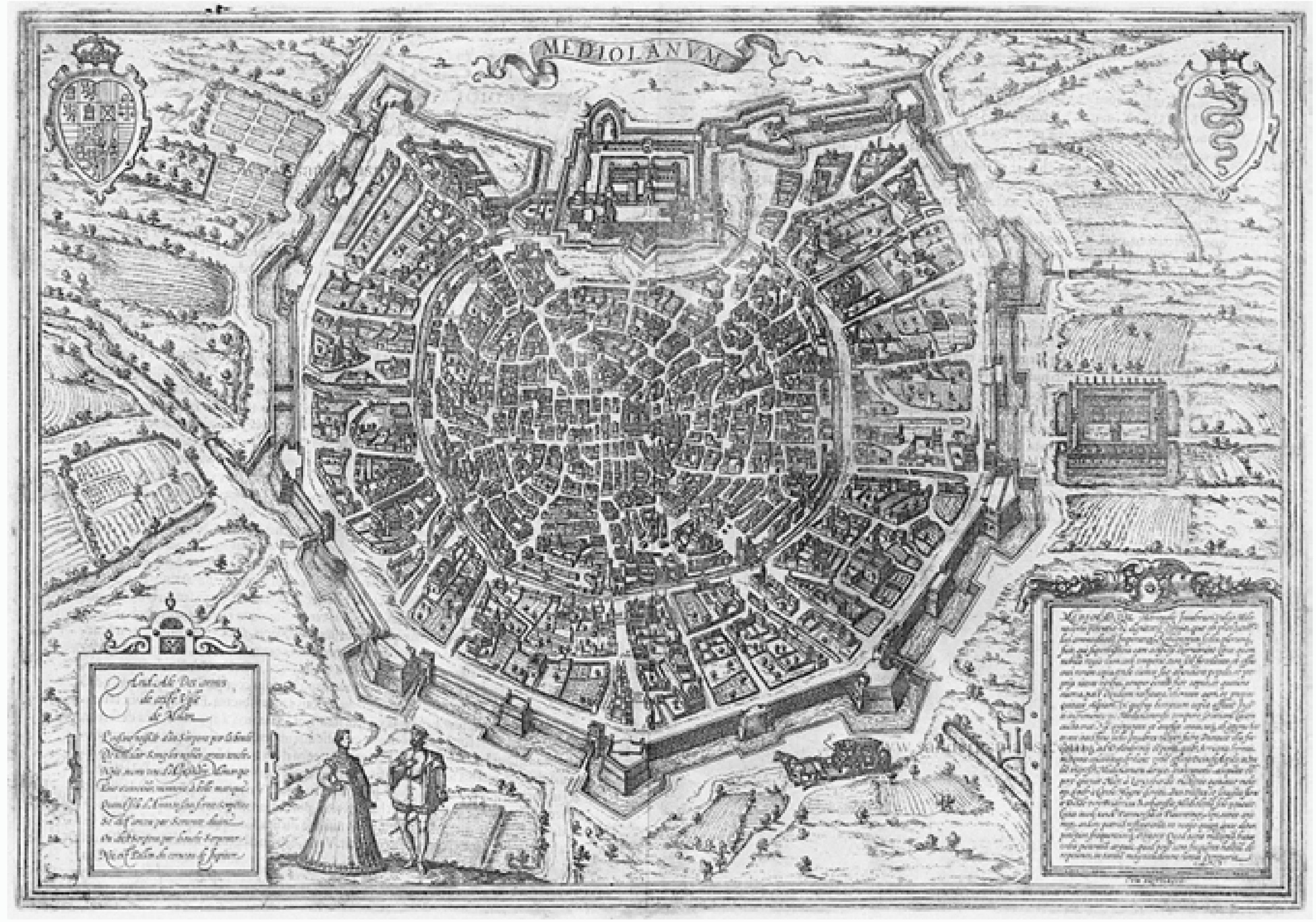
Giovanni Francesco Brunetti, Lazzaretto of Milan during the 1630 plague, etching, January 29,1631; Brunetti survived the plague in the lazaretto





2.2.4

Jean-Nicolas-Louis Durand, 1833 illustration of Lazaretto of MIlan, completed 1488

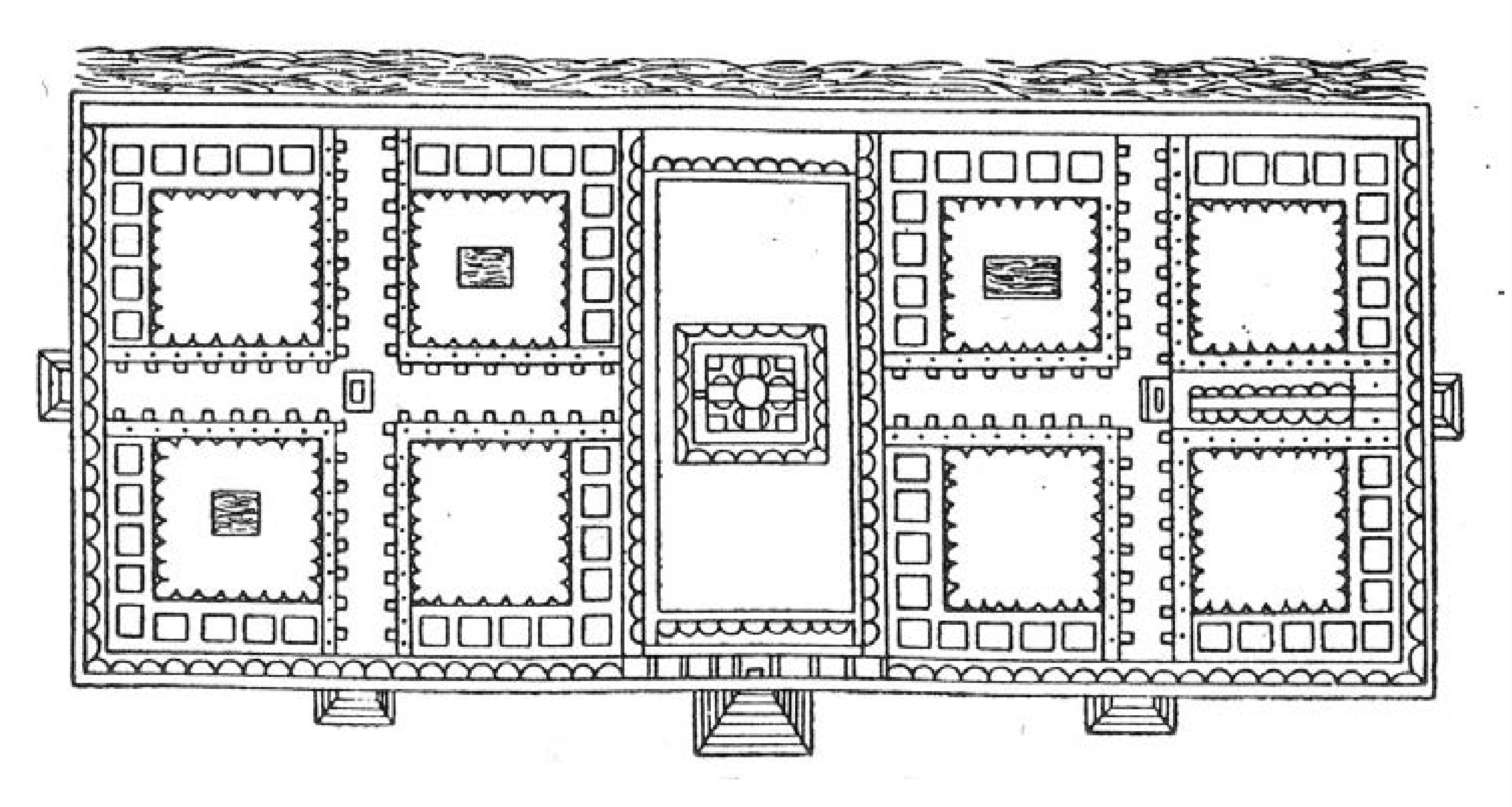


2.2.5

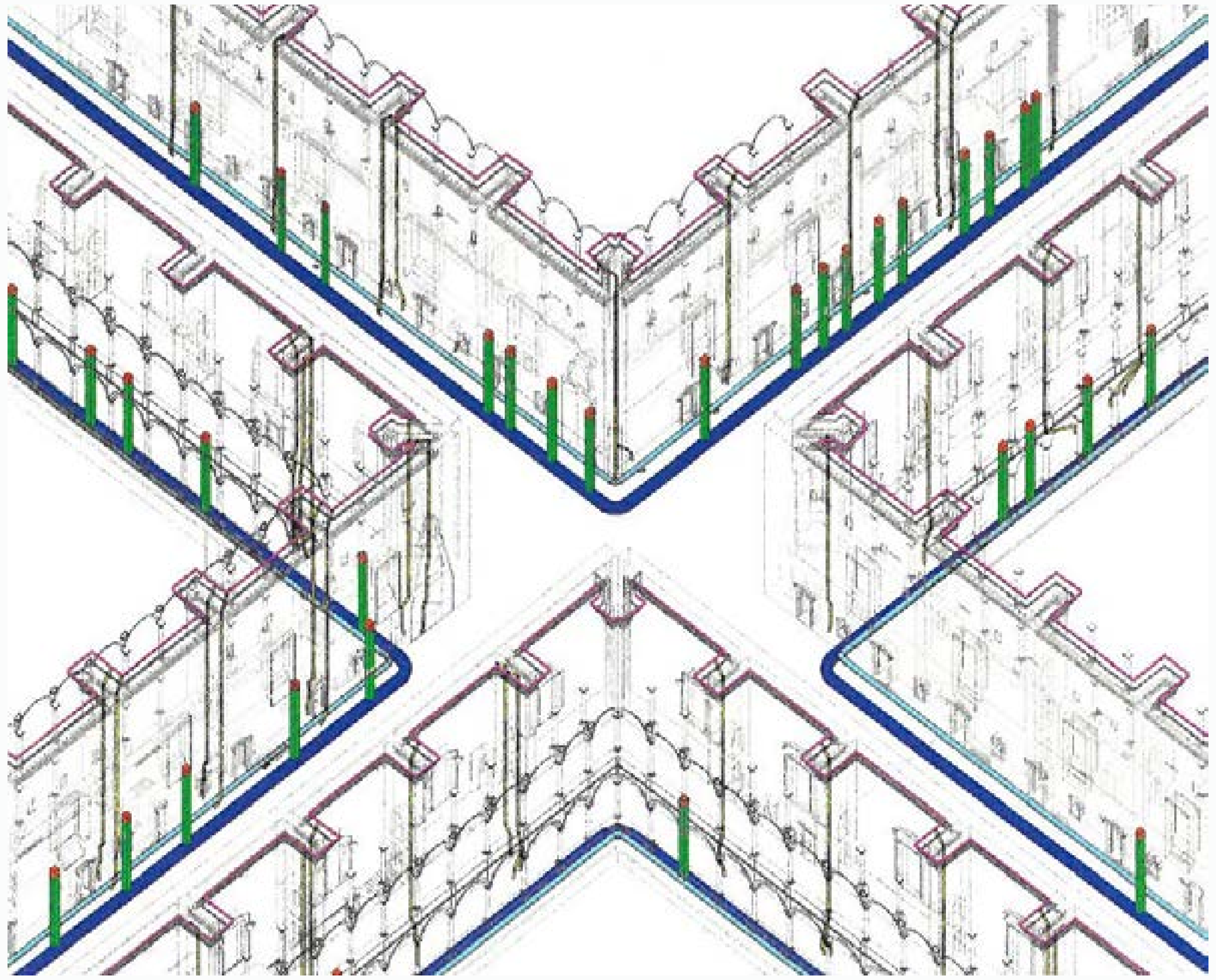
View of Milan showing lazaretto outside city walls, engraving from Georg Braun and Frans Hogenberg, *Civitates orbis terrarium*, 1572

Ca' Granda Hospital
Antonio di Pietro Averlino (Filarete)

The Ca' Granda hospital was built in parallel with the lazaretto and was designed to maximize ventilation and light, while integrating water supply and waste removal into its plan. It included a canal for fresh water supply and built-in washbasins and toilets, as well as a sanitation system embedded within the building fabric.[69]



2.2.7 Plan of the Hospital drawn by Filarete



2.2.8 Computer model of the sanitation system - canals, latrines, and ventilation tubes - embedded into the Ca' Granda hospital wards by Filarete

Water, Governance & Health

Urban form as sanitary infrastructure

Epidemic risk pushed the city to become an engineered environment, where water served multiple roles at once: it was a boundary used to manage access and a flushing and disposal medium designed into architecture, but also a broader urban system that linked sanitation and governance, anticipating the later nineteenth century evolution.[70]

The infrastructure response to disease began with an idea that urban form and urban management are public health tools.[71] That idea later became the base for water supply and sewerage systems. Across Europe, urban water services evolved slowly and unevenly. Romans built aqueducts and fountains that made reliable supply a civic project, but later centuries did not consistently extend that model, and many cities relied on local sources and manual distribution for long periods.[72]

In that context, wastewater disposal remained close to everyday life, accumulating in streets, shallow drains, and household storage. Contemporary accounts of this long arc still frame the premodern city as chronically unhealthy, with stormwater drains and open ditches struggling to keep dense streets inhabitable.[73]

The Cloaca Maxima (Greatest Sewer) served as one of the earliest sewage disposal systems on a grand scale 2.2.9

2.2.10 *Monster Soup*, satirical etching by William Heath on Thames water pollution, 1828

Urban Sanitary Reform

19th century epidemics

When waterborne epidemics spread through crowded nineteenth century cities, they forced cities to rethink infrastructure, housing standards, and the everyday management of cleanliness.[74]

Cholera revealed that many urban water supplies relied on rivers and local sources that also received waste. The disease spreads mainly through water contaminated with human faeces, but this mechanism was not yet understood. Early responses often focused on quarantines and cordons sanitaires, but these measures disrupted trade and food supply and were difficult to enforce in an urban economy.

Under this pressure, many governments began to shift from containment measures toward sanitary reform. Across Europe, the same pressure produced different technical choices, but a shared direction.[75]

London[76]

The Thames contamination

In early 19th century London, the Thames worked as both a water source and a waste route. Many people used water from local pumps and river intakes, while waste from homes and streets entered drains that often led back to the same river. Cholera outbreaks exposed this risk.

In 1854, John Snow mapped deaths in Soho and linked the outbreak to one public pump whose water had been contaminated by human waste. This did not settle the debate immediately, but it showed that disease could follow the logic of urban water supply.

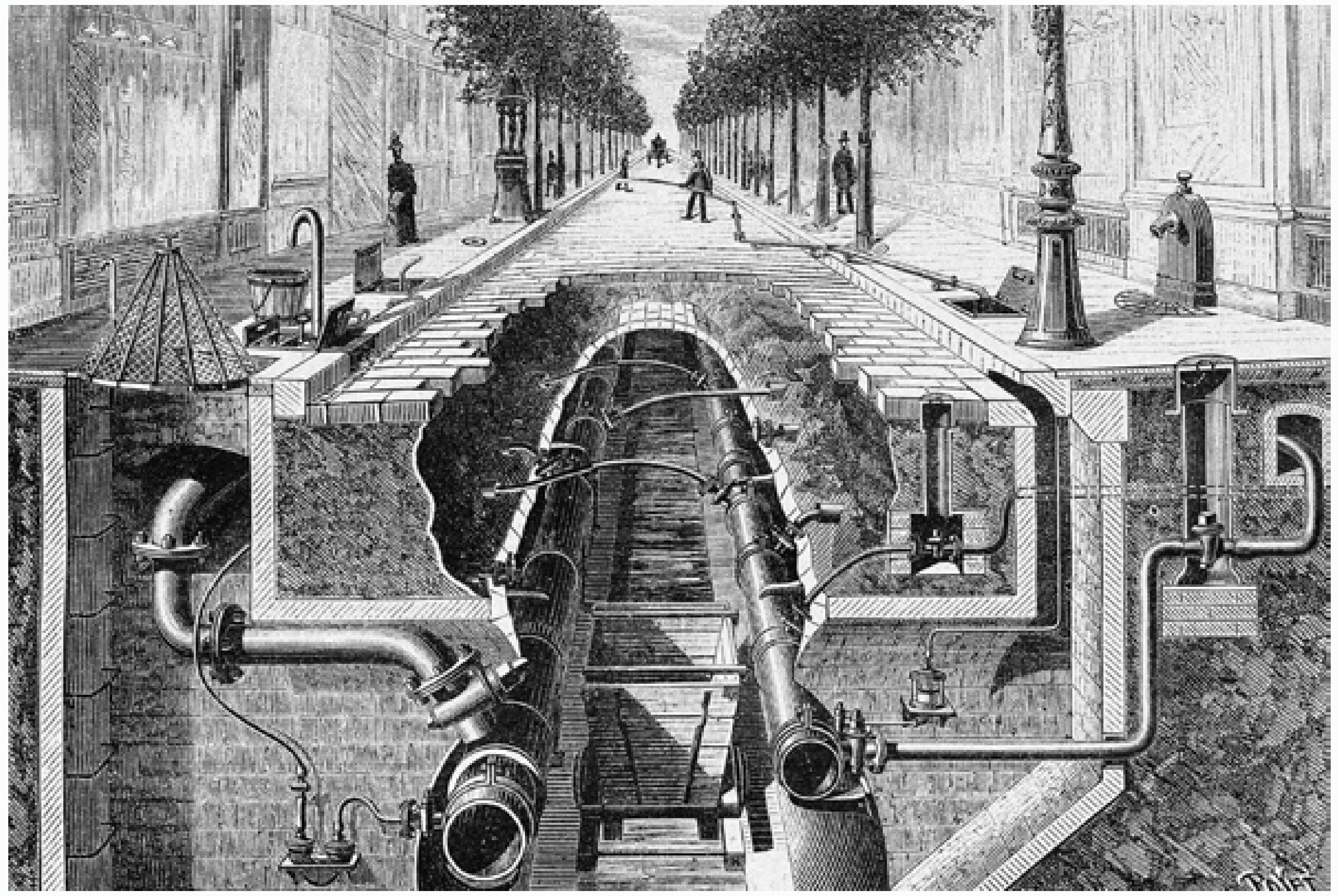
In 1858, the Great Stink made river pollution impossible to ignore. The smell from the Thames became a political crisis and forced investment in major works. The response was the metropolitan sewer project led by Joseph Bazalgette. London built interceptor sewers to collect flows before they reached the central river, moved sewage downstream beyond the dense core, and supported the system with pumping stations and new riverfront embankments. This was also a shift in governance, because it meant treating sanitation as a city network instead of a local problem.

Unfortunately, the Thames remained heavily polluted as the system improved conditions in the city centre, but it shifted the problem along the river, showing that drainage without treatment relocates risk rather than removing it.

Cholera Map of the Metropolis, 1849, Exhibited in the Registration Districts 2.2.11

Joseph Bazalgette (top right) at the northern outfall sewer being built below London's Abbey Mills pumping station 2.2.12
Otto Herschan/Getty

2.2.13 Demolition of Butte des Moulins for Avenue de l'Opéra, 1870.



2.2.14 Water supply system of Paris, engraving from *La Nature*, France, 1886

Paris[77]
Sanitation as city design

In early 19th century Paris, doctors and reformers linked sickness and mortality to poverty and to the conditions of housing and streets. Alexandre Parent Duchatelet argued for public hygiene and studied the Paris sewer system in 1822 presenting the sewers as an urban structure that made the city habitable by removing corrupted water linked to infection, and he treated sanitation as a citywide design problem.

During the cholera epidemics of 1832 and 1849, authorities used police powers to quarantine and cleanse affected houses and streets. But the first law against unsanitary dwellings did not arrive before 1850 when it gave the state the right to investigate and condemn suspect buildings.

After 1853, Haussmann used this framework to reshape Paris at city scale. Commissioned by Napoleon III as Prefect of Police, he normalized the emergency cleansing powers developed during cholera and applied them as a permanent approach to urban change.

Between 1853 and 1870, Paris carried out large demolition of medieval neighborhoods and built wide avenues as part of a broader reconstruction justified through infectious disease risk. Sanitation became modern infrastructure tied to the redesign of streets and the expansion of systems such as sewage, fresh water, ventilation, sunlight and parks.

Many older European districts still rely on combined sewer systems. Storm drainage and wastewater removal were often folded into the same corridors of pipes, then retrofitted repeatedly as regulation and budgets evolved. In some European cities, water pollution control arrived late enough that combined sewers with only basic screening remained in use until around 2000.[78]

Today, the pressure has returned to a new form. The combined system is insufficient again, time due to capacity. Aging sewer infrastructure, climate change and urbanization of cities are increasing the problem of the difference between what networks can handle and how much heavy rain there is. The right approach needs to pair sewer rehabilitation with stormwater retention, low impact development and green infrastructure to reduce runoff entering combined systems in the first place.[79] In other words, the solution is again urban redesign combining underground works with surface decisions about soil, streets, roofs, storage and the right to space for water.

In the nineteenth century, waterborne disease exposed how vulnerable cities were through their water systems. Today, heavier rainfall and overloaded networks expose the same weakness through flooding.[80]

Public health depends on urban form, and water infrastructure is part of this built environment that must be designed and managed.

A pedestrian crosses through deep water on a flooded road in London on July 25, 2021
Justin Tallis/Afp/Getty Images

2.2.15

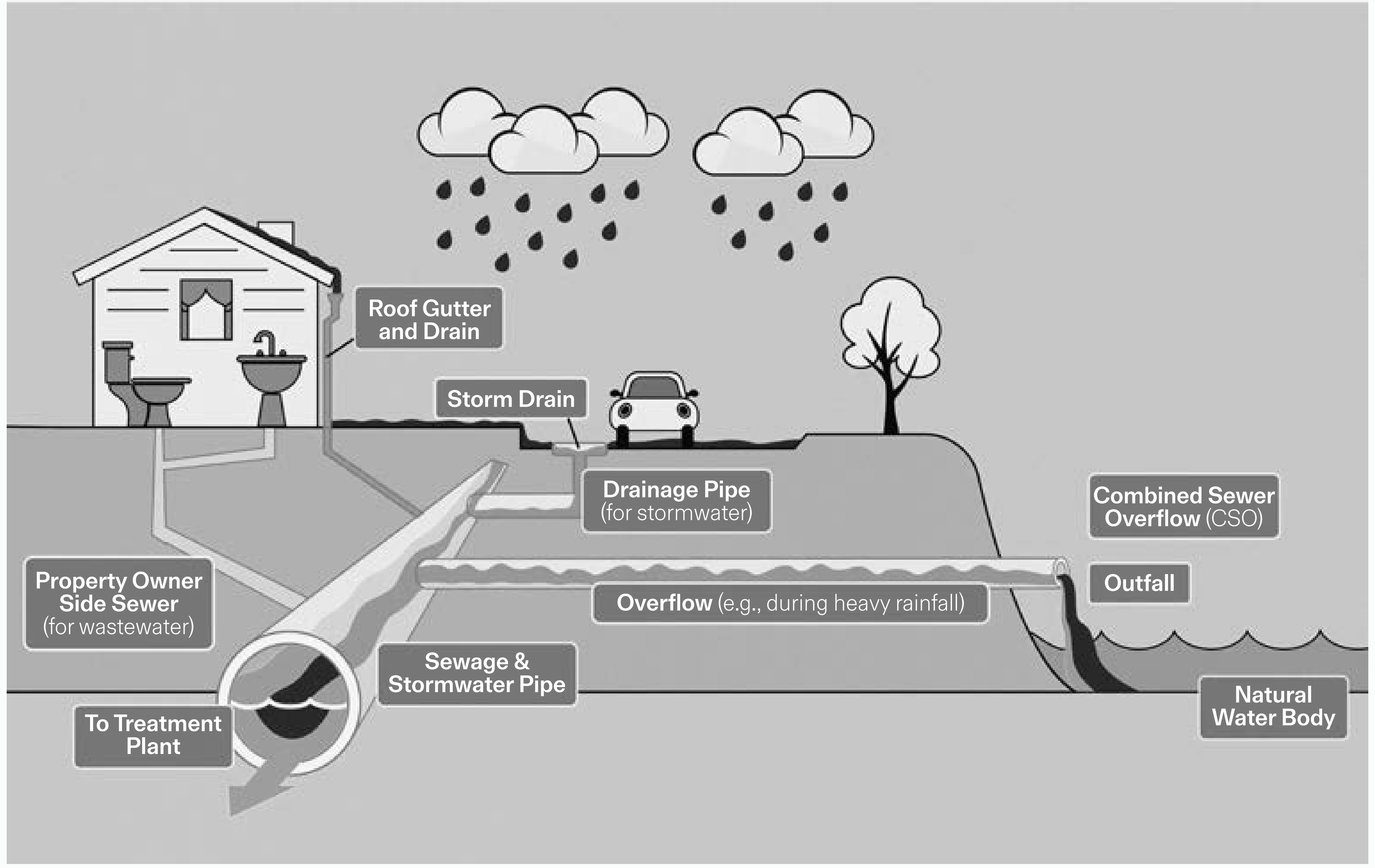
2.3.1 Temporary swimming ban after sewer overflow, Palombina waterfront, Ancona (archive photo, 6 August 2016)

03. The Combined Sewer City

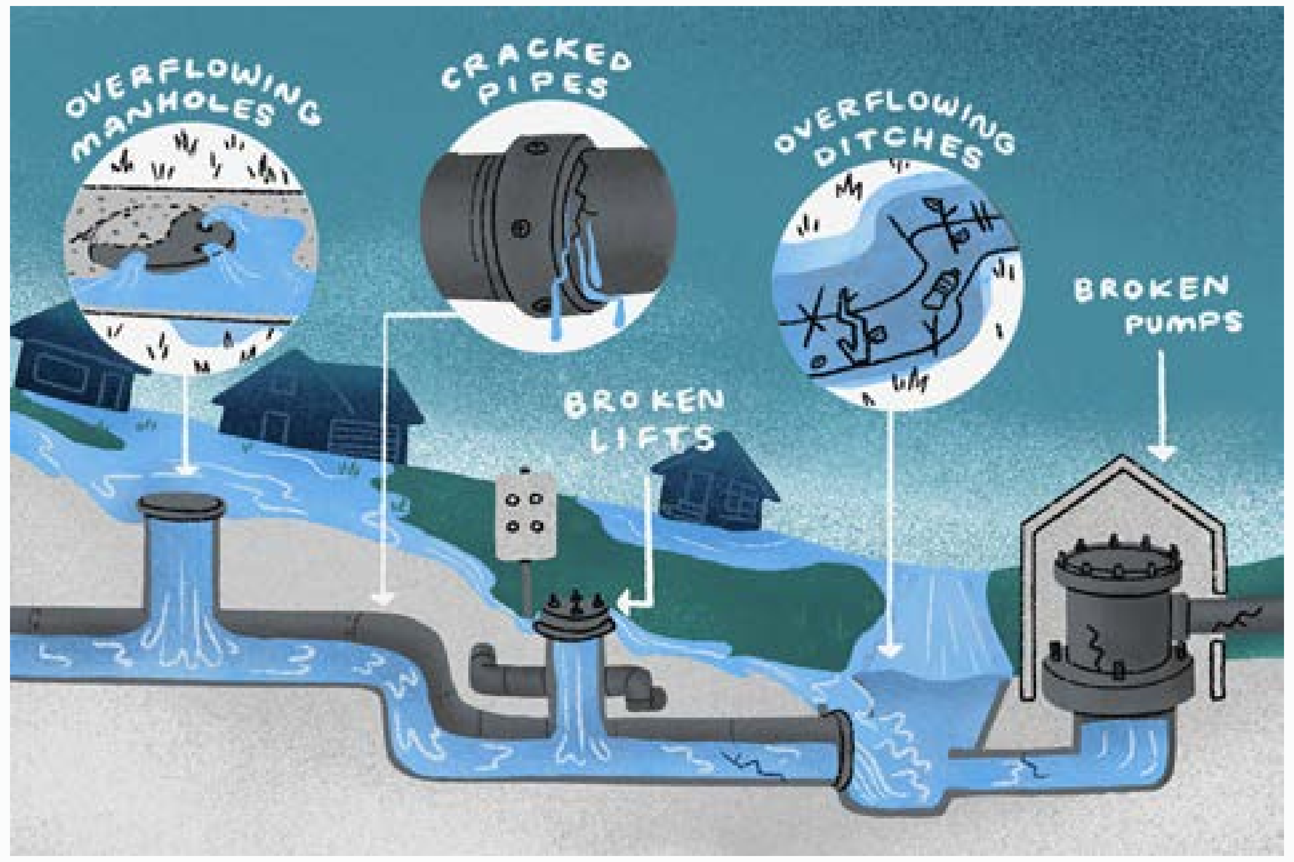
Many European cities still rely on combined sewers, where stormwater runoff and wastewater share the same pipes.[81] Problems arise because the same network must manage both the capacity of daily wastewater that is relatively steady, but also stormwater that arrives in short, intense peaks. To prevent the system from backing up, overflow structures release excess water during heavy rainfall.[82]

Combined Sewer Oveflows
CSOs

Overflows occur when rainfall driven inflows exceed the capacity of sewer pipes or the wastewater treatment plant. The triggers are highly context specific. Key drivers include rainfall variability in frequency, intensity, duration, and seasonality, especially when storms arrive in close succession before storage has recovered. The amount of impervious surface connected to the combined network is also crucial, because runoff quickly increases flow and dilutes wastewater. Risk increases where the share of combined sewers is high, where in-network storage is limited, where design thresholds for dilution are low, and where local conditions such as high groundwater require pumping. Finally, operational failures can also increase the frequency of overflow events.[83]



2.3.2 As rain falls from the sky and into the roof gutter and drain, the runoff travels into a storm drain above ground, reaching a drainage pipe below ground. Below the home, wastewater from toilets and sinks travels through the property owner's side sewer pipe to a combined sewage and stormwater pipe headed for a treatment plant. During heavy rain an overflow pipe takes an untreated mix of combined sewage and stormwater to an outfall pipe, creating a combined sewer overflow into a natural water body like the ocean.



2.3.3

Sewer overflows can occur when sewer system infrastructure or equipment is faulty. Cori Lin/Onibaba Studios / for Illinois Answers Project

2.3.4 A sign warns of a combined sewer overflow, a point where sewage and rainwater discharge into the Olentangy River in Columbus, Ohio.
Diana Kruzman/Grist

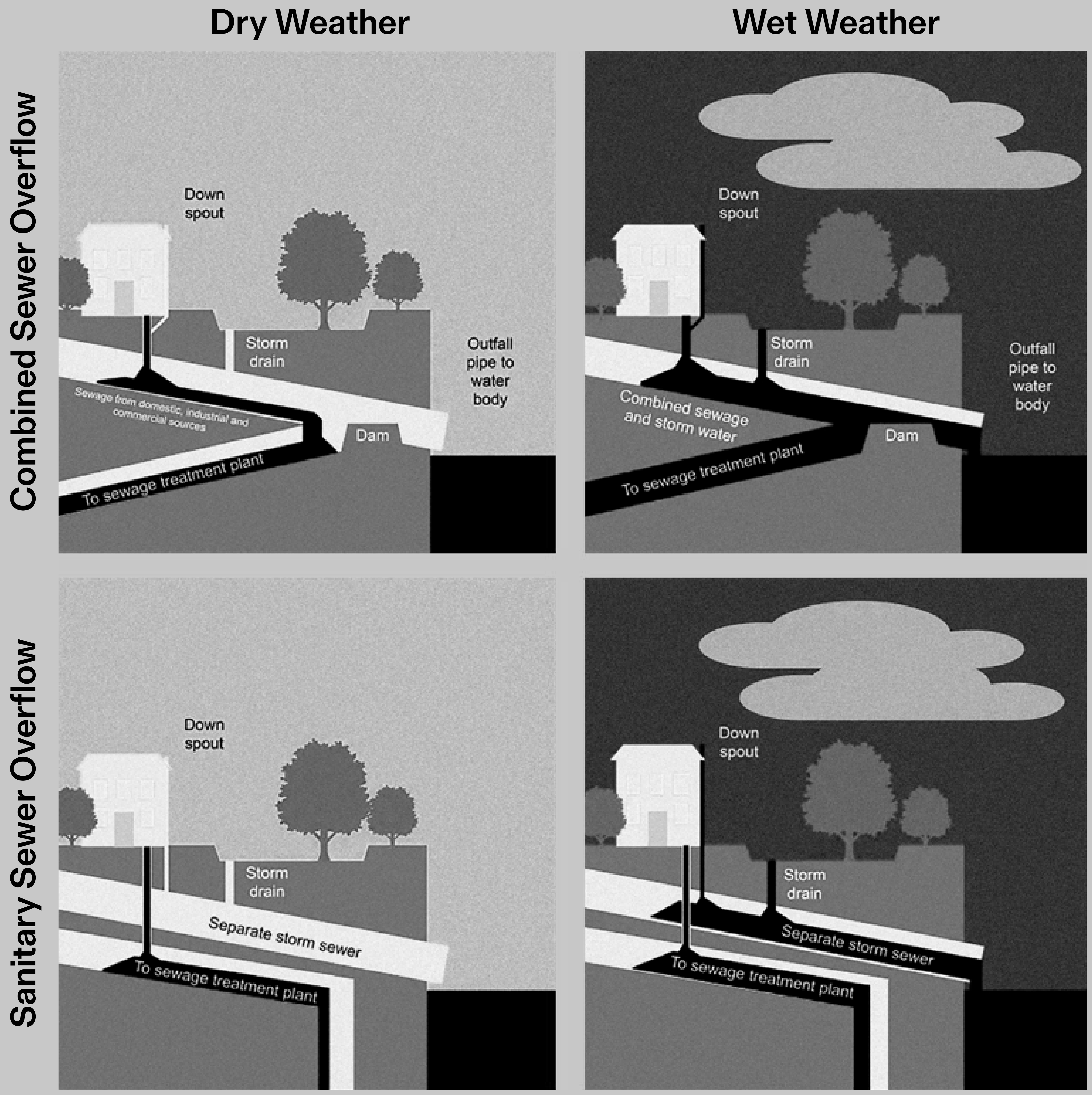
Pollution From Oveflows

Water contamination

During intense rainfall or snowmelt, once capacity limits are reached, combined sewer overflows discharge excess water directly into rivers or coastal waters. They are meant to reduce the risk of treatment works flooding and to prevent wastewater backing up into properties.[1] The main drawback is that overflow discharges contain wastewater pollution loads, pollutants carried from streets and surfaces, and material remobilized from within the sewer itself. Together, these inputs can significantly degrade water quality. The impacts become especially visible where people and ecosystems directly interact with water, including bathing waters and urban shorelines.[84,85] Overflows can also release emerging contaminants during storm events, including pharmaceutical and personal care compounds that would otherwise be reduced through standard treatment. Reviews of the evidence stress that the scale and significance of these releases vary by location, which makes it difficult to apply one management model across different cities.[86]

Limits of sewer upgrades

At the city scale, upgrades face two main limits. The first is knowledge, because it is hard to quantify overflow volumes and pollution loads without detailed sewer network data, which makes prioritization and cost effective planning difficult.[87] The second is leverage, because effective mitigation often depends on reducing how much runoff and wastewater enters the network, supported by targeted storage, treatment, and operational improvements, rather than pipe and plant upgrades alone.[88] Policy responses also show that combined sewer overflows are a governance and finance issue. In the United Kingdom, the Storm Overflows Discharge Reduction Plan focuses on stronger monitoring, long term targets, and large scale investment, treating overflow reduction as a system wide infrastructure challenge.[89]



A combined sewer overflow occurs when stormwater and wastewater flow through combined sewer systems and cause an overflow.
Grace Hauck / Illinois Answers Project

2.3.5

During a CSO, a storm can produce both flooding and pollution, creating ecological and operational stress at the same time.

Flooding in Milano, Marche-Zara-Istria, September 22, 2025. Personal Photographs: Rea Novakovic Matosic — 2.3.6, 2.3.7, 2.3.8, 2.3.9

2.4.1 A man rides on a bicycle through floodwaters after heavy rains hit Italy's Emilia-Romagna region, in Lugo, Italy, May 19, 2023.

04. European Flood Mechanisms

Urban flooding tends to follow three paths. Rivers can overtop their banks and spread into streets and neighborhoods, rainfall can overwhelm drainage and turn roads into channels even far from waterways, and the sea can push inland during storm surge when winds and tides align. In European cities these pathways often overlap, because sealed ground, aging networks, and constrained river corridors mean one storm can trigger several failures at once.[90]

We can group urban flooding into three recurring mechanisms:[91]

Fluvial flooding happens when rivers, lakes, or streams overflow onto neighboring land, often after excessive rain or snowmelt. Risk models consider rainfall intensity and duration, current river levels, soil saturation, and terrain profile, since flat areas can see slow rising water that lingers, while hill or mountain areas can flood fast and carry damaging debris.

Pluvial flooding is driven by extreme rainfall and can occur independently of overflowing rivers or lakes, in cities or rural areas, even where there are no nearby bodies of water. There are two common pluvial forms: surface water floods, when drainage systems are overwhelmed and water pools in streets and buildings, usually shallow and gradual but economically costly, and flash floods, sudden high velocity torrents triggered by intense rain or failures such as a dam breach, dangerous because of speed and debris.

Coastal flooding occurs when seawater inundates land, typically during severe windstorms that generate storm surge or during tsunamis and severity depends on storm strength, tide levels, and coastal topography.

In European cities, these mechanisms are not isolated. Sealed surfaces, aging drainage and constrained waterways mean the same storm can trigger several flood pathways in one metropolitan area. That is a shared condition across urbanized areas as flooding is a recurring stress test of urban form and infrastructure performance.

Major European urban environments: flood drivers and sewer patterns

City		"Flooding issues" recurring or significant events (river, coastal, pluvial) + combined sewer overflows		Main Sewer Pattern (City Scale)	
1	London[92,93,94,95]	surface-water floods + CSOs + tidal risk	• London has multiple risks: surface-water (pluvial) flooding, tidal Thames surges • combined sewer overflows during heavy rain • there were notable flash-flood events in July 2021 with underground stations and roads flooded	Inner city mostly Victorian combined + new storage tunnel	• Grey + black vs rain: much of central and inner London is still on a Victorian combined sewer system, designed by Bazalgette in the 19th century • Heavy rain causes CSOs to the Thames, so the city is building the Thames Tideway Tunnel, a huge storage tunnel that intercepts these combined flows and conveys them to Beckton WWTP • Separate storm sewers exist in some suburbs and newer developments, but the heart of the system is still combined

2	Paris[96,97,98,99]	Seine floods + pluvial/CSO issues	• Paris is exposed to Seine floods and urban pluvial flooding
			• the combined system leads to CSO discharges during storms, which the city is trying to reduce ahead of the 2024–26 sporting events
				Large historic combined network with growing storage volume	• Grey + black + rain:
					  • Paris relies on a historic combined sewer network that collects wastewater and stormwater together; overflows go to the Seine and Marne when intense rain exceeds capacity
					  • The city is building big underground storage basins (e.g. near Austerlitz) to buffer stormwater and reduce these overflows

3	Copenhagen[100,101,102]	famous 2011 cloudburst repeated pluvial events	• the 2011 cloudburst dumped ~90 mm of rain in 2 hours, causing • €1 billion damage and triggering a full Cloudburst Management Plan	Historically combined, now adding separate & surface SUDS	• Grey + black: mostly in combined sewers in older parts of the city • Rainwater: still partly to combined sewers, but the cloudburst plan pushes surface retention, green streets, parks and basins (e.g. Hans Tavsens Park / Gro Nørrebro) so more stormwater stays on the surface or in separate drains rather than entering the pipes
4	Rotterdam[103,104,105]	fluvial/tidal + pluvial but very managed	• exposed to river/tidal risk from the Nieuwe Maas plus heavy-rain flooding • the city uses climate adaptation as a branding tool • Benthemplein water square is the classic reference	Largely combined, plus big storage & water squares	• Grey + black: for most of the central city, wastewater is in combined sewers together with stormwater Rainwater: much still into combined sewers, but the city has large underground storage, pumping and water squares that hold peaks on the surface and empty slowly back to the system or canals
5	Amsterdam[106,107,108,109,110]	heavy rain events, focus on "Rainproof"	• protected against large-scale river/coastal floods by dikes, but vulnerable to heavy-rain / cloudburst events • Amsterdam set up the Amsterdam Rainproof programme specifically because intense showers were flooding streets and cellars	Mix: older combined, newer separate + some pilot "new sanitation"	• Grey + black: normally mixed in sewers and pumped to WWTPs • Rainwater: older neighbourhoods: a lot of combined sewers; many newer areas: separate storm drains or infiltration, plus blue–green roofs • Grey/black separation: Amsterdam is a key example where "new sanitation" pilots exist, this is not citywide, just a few innovation districts"

6	Hamburg[111,112,113]	heavy-rain flooding in streets	• faces storm surges from the Elbe and increasingly heavy-rain flooding
			• Hamburg publishes heavy-rain hazard maps and uses "water sensitive urban design" pilots in parks and streets
				Mix: separate in outskirts, combined in inner city	• Grey + black vs rain:
					  • City has two sewer systems: separate in most outer districts and combined in the inner city
					  • Combined sewers carry household + industrial wastewater and rain
					  • overflows go into rivers during storms and are now being reduced with retention basins and EU-financed upgrades

7	Berlin[114,115,116,117]	pluvial flooding & CSO problems	• increasingly hit by intense convective storms
			• the city's Umweltatlas has detailed maps for pluvial flood hazard and uses those in planning
				~¾ separate system, ~¼ combined (inner city)	• Grey + black vs rain:
					  • Berlin explicitly has both systems - about three-quarters of sewered areas use a separate system where wastewater and stormwater go in different pipes
					  • inner-city districts use a combined system, with CSOs during storms that pollute the Spree and canals; the city is building storage sewers (e.g. Mauerpark tunnel) to buffer these events

8	Barcelona[118,119,120,121]	flash floods CSOs close beaches	• very prone to flash floods / "gota fría"-type events - steep catchments, dense urbanisation, short intense storms
			• the combined system and CSOs cause frequent beach closures due to pollution"
				Mostly combined, many coastal CSO structures + tanks	• Grey + black + rain:
					  • The central network is largely combined, with around 93 coastal CSO structures discharging during storms
					  • Barcelona has built 13+ massive stormwater tanks and tunnels under the city to store excess flows and then pump them to WWTPs after storms

9	Madrid[122,123,124]	intense storms, CSOs to Manzanares	• experiences intense convective storms
			• the combined system can overflow and send polluted water to the Manzanares
			• research on Madrid's watershed focuses a lot on water quality and CSO impacts during wet weather
				Mainly combined + big stormwater detention vaults	• Grey + black + rain:
					  • Studies describe the urban drainage system of Madrid as mainly combined, conveying domestic sewage, industrial wastewater and stormwater in the same pipes
					  • to manage peaks, Madrid uses stormwater detention vaults (e.g. Butarque), which capture runoff and release it slowly to treatment plants

10	Brussles[125,126,127]	very vulnerable to heavy-rain flooding	• repeatedly affected by heavy-rain "water bombs", with some of Europe's worst pluvial-flood vulnerability due to topography and high impervious cover	Combined sewers dominate	• Grey + black + rain:
					  • Brussels has a predominantly combined sewage system where domestic + industrial wastewater and rainwater share the same pipes and overflow structures during storms
					  • This makes Brussels a classic case where SUDS / nature-based solutions + storage are being promoted to reduce pressure on the combined network

11	Zurich[128,129,130]	some flood risk but strongly managed	• less dramatic than some others, but Zurich still has to manage intense rainfall and river/lake levels
			• the strategy is strongly focused on storage and controlled discharges"
				Combined with big underground storage reservoirs	• Grey + black + rain:
					  • according to descriptions of Zurich's sewerage, wastewater and stormwater are typically collected in combined sewers, buffered in large underground reservoirs (≈40,000 m^3) and then sent to the Werdhölzli WWTP
					  • only at the very extremes do emergency overflows discharge to Lake Zurich or the Limmat

12	Milan[131,132,133]	river + heavy-rain (Seveso, Lambro)	• recurrent flooding from Seveso and Lambro rivers and from heavy summer storms • "Esondazioni del Seveso" in northern districts are a known chronic issue	Mostly combined	• Grey + black: discharged together into domestic sewers • Rainwater: in most of the city, road gullies and roof drains go to the same sewers → a mista / combined network, with only limited separate storm drains in some newer zones • Wastewater and stormwater then go to the three WWTPs south of the city (Nosedo, San Rocco, Peschiera Borromeo)

London
Surface water flooding

London combines two main pressures, one being tidal surges on the Thames and the other being short, intense rainstorms that overload streets and drainage. Historic river flooding shaped major infrastructure defense systems, including the Thames Barrier, which began operating in 1983 to reduce tidal flood risk.[134] However, recent storms show how disruptive surface water flooding can still be. In July 2021, heavy rainfall led to flooding inside properties, impacts linked to sewer surcharge, and widespread disruption across the transport system, including many Underground station closures.[135] The City of London's Strategic Flood Risk Assessment records the 25 July 2021 extreme rainfall event and links local flooding patterns to the capacity limits of a connected combined sewer network. Because much of inner London still uses combined sewers, heavy rain can also trigger combined sewer overflows to the Thames.[136] The Thames Tideway Tunnel is designed to intercept and store these combined flows, then transfer them for treatment, reducing polluted spills to the river.[137]

Thunderstorms flooded roads and parts of the Underground rail system in London on Sunday, July 25, 2021. Justin Tallis/AFP/Getty Images 2.4.2

2.4.3 “Paris is still on flood alert even though the rain has stopped.” Julien Mattia/NurPhoto via Getty Images

Paris

Seine flood risk

Paris is under risk of both river flooding from the Seine and urban pluvial flooding that can overload drainage in dense neighborhoods. A major Seine flood remains a regional-scale risk, with potentially wide disruption to services and infrastructure across Île-de-France.[138] In parallel, Paris still relies heavily on a historic combined sewer network, and the city’s own sanitation zoning explains that the system does not have enough capacity to carry stormwater to treatment during many rain events, so storm overflows can release a mixed flow of wastewater and rainwater into the Seine, degrading water quality.[139] To reduce these discharges, Paris has expanded storage, including the Austerlitz basin (about 50,000 m^3), which is designed to retain excess wet-weather flow and cut overflow gate openings from roughly ten to fifteen times per year to about two on average.[140] With recent storms producing heavier downpours on saturated ground, this combination of river risk and network limits becomes harder to manage under climate pressure.[141]

Copenhagen
Cloudburst flooding

Copenhagen's main flood pressure comes from cloudbursts that can overwhelm streets and sewers in a short time. On July 2, 2011, the city was hit by an extreme downpour of over 100 millimetres in a couple of hours, and the Cloudburst Management Plan later cites damages of roughly DKK 5 to 6 billion, which pushed flood risk to the top of the city agenda.[142,143] The plan explains that most of Copenhagen's sewerage system is still a combined network where rainwater and wastewater share the same pipes, and it states directly that capacity is not sufficient for extreme rainfall.[142] Instead of relying on pipe upgrades alone, the city has pursued a combined approach that shifts more stormwater to surface routes and storage through streets, parks, basins and tunnel solutions that can pump excess water to the harbor.[142,144]

In July 2011, Copenhagen was hit by a "cloudburst" — an extreme rain event. The storm dumped more than 5 inches of rain on the city in a few hours. Martin Lehmann/Polfoto via AP

2.4.4

2.4.5 Flooding in December 2013 of the quays of Noordereiland, an island in the river.
Municipality of Rotterdam

Rotterdam
Multi-source flooding

Rotterdam sits in a low delta where river water and the sea meet, so flood risk arrives from several directions at once. High river levels and storm surge can push water up the estuary, while intense rainfall can overwhelm drainage and put water onto streets.[145] The city relies on major flood defenses, including the Maeslant storm surge barrier, which has reduced flood exposure in Rotterdam's unembanked areas, even as sea level rise keeps pressure on long term risk.[146] Inside the city, a large share of the network is still a combined sewer system that carries both wastewater and rainfall. During heavy rain it can surcharge and spill through overflow structures. Rotterdam's sewer strategy therefore shifts toward holding more rainwater outside the network and releasing it more slowly, alongside selective separation where it is feasible.[147]

Amsterdam
Intense downpours

Amsterdam is well protected from large scale river and coastal flooding by dikes and regional water management, yet it remains vulnerable to short, intense downpours that can flood streets and basements.[148] The city created the Amsterdam Rainproof program because heavy showers were repeatedly putting water onto the public realm and into buildings, and the climate adaptation policy frames this as a priority for day to day resilience.[149] Recent heavy rains have again exposed the limits of drainage capacity in some neighborhoods, with streets flooding during intense events.[150] At city scale, the sewer pattern is mixed. Many older areas still use combined sewers that can lead to overflows during storms.[151] Newer districts more often use separated systems or local infiltration, and the city also tests new approaches in selected pilots rather than across the whole network.[148] Evidence from water quality studies also links sewer system performance to the condition of canals and urban waters, which makes storm management both a flooding and a pollution question.[152]

Amsterdam July 15, 2021. Piroschka Van De Wouw 2.4.6

2.4.7 Dramatic flooding hits Hamburg's historical fish market in August 2016.
Caro/Hechtenberg/Newscom

Hamburg
Storm surge risk

Hamburg faces two flood pressures, one from the Elbe and the other from intense rainfall. Storm surges can push North Sea water up the river, a risk made stark by the 16 February 1962 surge, when about one sixth of the city was under water and around 315 people died in Hamburg alone.[153] Heavy rain adds a different kind of disruption when runoff exceeds local drainage capacity. To support planning and preparedness, the city publishes flood area information and hazard and risk maps, and it also provides dedicated heavy rain hazard maps.[154] The sewer pattern is split. Outer districts mostly use separate systems, while the inner city is connected to a combined network. When downpours hit, that combined system can reach its limits, so Hamburg Wasser uses retention and combined water storage basins to hold peaks and reduce overflows to receiving waters.[155]

Berlin
Pluvial flooding

Berlin is increasingly challenged by short, intense cloudbursts that produce pluvial flooding on streets and in low points of the urban fabric. A recent climate and hydrodynamic study for Berlin shows that extreme rainfall is expected to intensify under warming, which raises surface flood risk in already flood prone districts.[156] To support planning, the Berlin Environmental Atlas publishes heavy rainfall hazard maps that show expected flood extent, depth, and flow velocity for rare to extreme scenarios.[157] At city scale, the sewer pattern is split. About three quarters of sewered areas use a separate system, while roughly one quarter, mainly within the S Bahn ring, is drained by a combined system.[158] During heavy rain, this combined network can overflow and degrade receiving waters. Berliner Wasserbetriebe notes that the Mauerpark storage sewer was built to prevent overflows to the Panke during storms, as part of broader upgrades to reduce pollution impacts.[159]

Flooding on Trautenaustraße Berlin in June 2023. Leonhard Lenz 2.4.8

2.4.9 Barcelona airport and highways hit by flooding in 2024

Barcelona
Mediterranean cloudbursts

Barcelona's flood risk is driven by Mediterranean cloudbursts interacting with steep urban topography. Intense downpours can concentrate a large share of annual rainfall into only a few days, while upper slopes funnel runoff rapidly toward the coast and paved surfaces absorb very little.[160] Much of the drainage network is combined, so it can trigger combined sewer overflows that affect coastal water quality. A Barcelona and Badalona assessment identifies 93 CSO structures across the system and notes that seawater quality can fail bathing standards for days after spill events, with repeated impacts during the bathing season.[161] To reduce street flooding and polluted discharges, the city is investing in sewer upgrades and expanding retention storage, with 15 rainwater retention tanks already in place and further tanks planned.[162] Forecast based bathing water management is also used to predict pollution spread after heavy rainfall and support targeted beach warnings or temporary closures.[163]

Madrid
Drainage overload

Madrid is increasingly disrupted by intense rainstorms that can overwhelm drainage in a short time. In September 2023, heavy rainfall led to flooding and forced the closure of roads, metro lines, and rail connections in and around Madrid.[164] At city scale, Madrid's sewer network is described by the municipality as entirely combined.[165] During heavy rain, this raises the risk of polluted spill events to receiving waters, including the Manzanares basin. To manage these peaks, Canal de Isabel II operates a network of storm tanks that retain the first and most polluting runoff, then release it gradually to treatment plants. Canal reports 65 storm tanks with total storage of 1.46 hm^3, including Arroyofresno and Butarque, each up to 400,000 m^3, designed to protect rivers like the Manzanares and reduce flooding.[166]

A woman walks through water on a flooded sidewalk after a downpour in central Madrid, Spain, August 28, 2017. REUTERS/Paul Hanna

2.4.10

2.4.11 Heavy rainfall in front of the Belgian Royal Palace, in Brussels. Belga / Nicolas Maeterlinck

Brussles

Combined sewer flooding

Brussels is highly exposed to pluvial flooding, because heavy downpours run off sealed ground into low valleys and quickly saturate the sewer network. Streets can turn into streams, and water can back up through the subsoil into basements and lower floors.[167] This vulnerability is closely tied to its predominantly combined system. During intense rain, that single network can overflow and discharge polluted mixed flows into the Senne and the canal.[168] Monitoring around key overflow points shows that these spill events can occur on many rainy days each year, which makes flooding and water quality part of the same urban problem.[169]

Zurich
Underground exposure

Zurich's flood risk is less dramatic than some other capitals, but it is still shaped by intense rainfall and by high water levels in the Sihl and the Limmat. For them flooding can occur on roughly a one hundred year scale, with high potential damages because a lot of structures sit underground.[170] On the wastewater side, it largely operates a combined system.[171] To avoid frequent emergency discharges, the system relies on large underground storage reservoirs, reported at about 40,000 cubic meters total capacity, which buffer peak inflows and are pumped to treatment once the storm passes. Only in really rare extremes, when storage is full, would untreated overflow reach the river.[172]

2.4.12

Cars drive on a flooded street following thunderstorms and torrential rain in Zurich, Switzerland July 13, 2021.
REUTERS/Arnd Wiegmann

2.4.13 Two women at a flooded intersection in Milan after a violent storm hit the city on October 31, 2023. Vasile Mihai-Antonio/ Getty Images

Milan
Seveso flooding

Milan's flood risk comes from the overlap of river hydraulics and intense rainfall in a dense urban basin. Along the Seveso, chronic overflow has been a long running condition as the city records 120 Seveso floods between 1976 and 2023, so detention infrastructures have become a priority for protecting northern districts.[173] At the same time, much of the city drains through a mixed sewer network of more than 1,600 kilometres that conveys water toward the southern edge of the city.[174] There, the main treatment plants at San Rocco and Nosedo handle most of Milan's wastewater.[175]

Cities were **built against water**, but water has its own **intelligence**. When storms arrive, it returns to the paths we buried and the ground we sealed.

Volunteers wade through a flooded street after Storm Leonardo passed by Alcacer do Sal, Portugal, February 5, 2026. REUTERS/Pedro Nunes

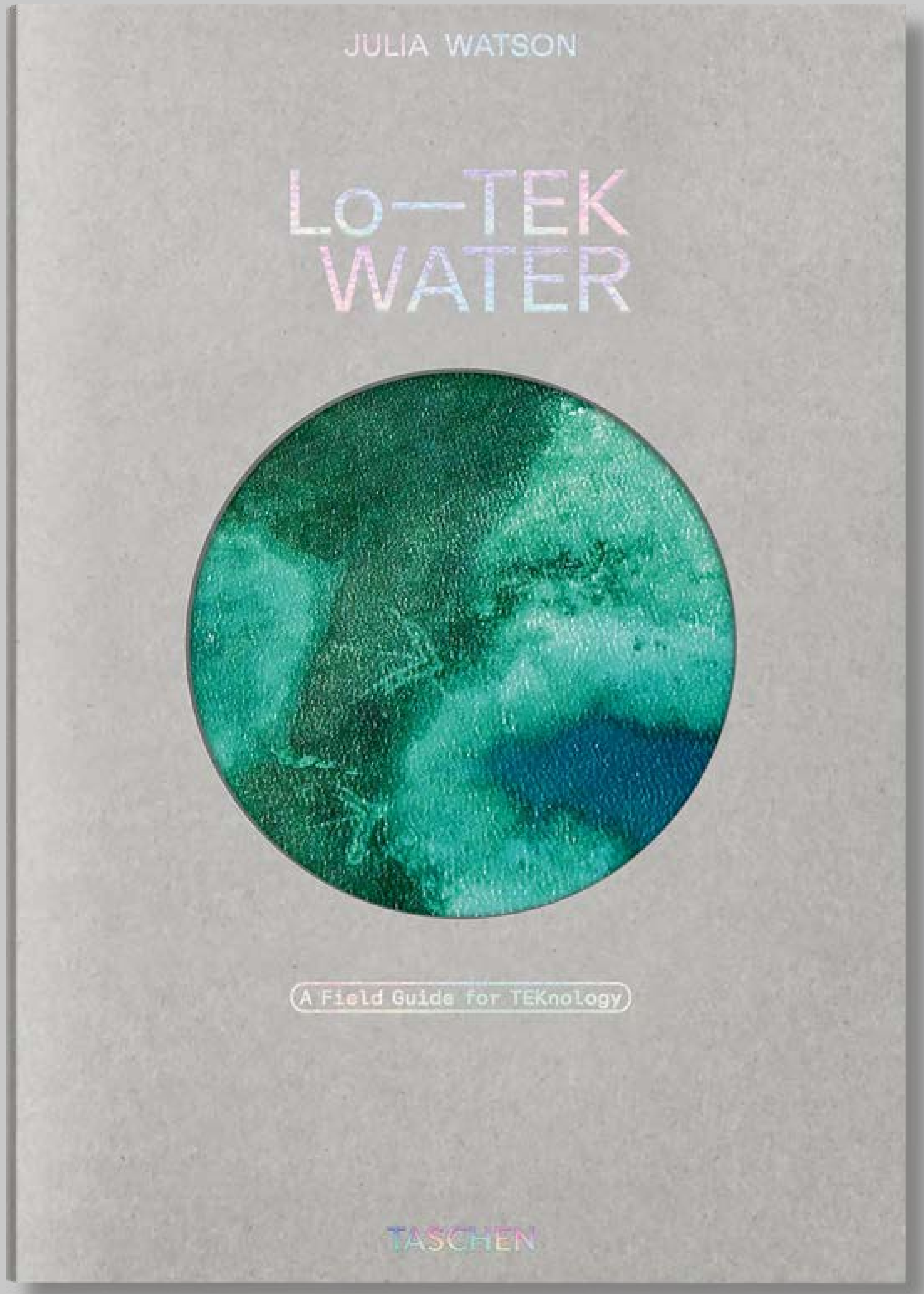
2.4.14

Why is this happenning?[176]

It is because we paved over wetlands, buried streams, and sealed soil under concrete and asphalt. Cities that once absorbed rain through the ground became hard and impermeable. Water that once filtered through soil, recharged aquifers, and supported vegetation now runs across roads and rooftops with limited space to slow down or infiltrate.

We also straightened rivers, confined them to channels, and pushed them underground, treating control as progress. By blocking natural flow paths, we disrupted water cycles. Floodplains became development sites and marshes became parking lots.

Now, when storms arrive, water follows the routes it once knew. The flooding we call disaster is often just a response: an overflow of systems we constrained, compressed, and forgot to respect.



Julia Watson. Lo—TEK. Water. A Field Guide for TEKnology, cover 2.5.1

[Water] does not die alone; when it is poisoned, obstructed, or exploited, it takes entire ecosystems and communities with it. The question is whether humanity will listen in time to restore its balance.[176]

Julia Watson

Milan as a Layered System
The Hidden Water Risk

03

3.0 Emergency workers carry a woman after a storm caused the Seveso river to overflow in Milan, Italy, on October 31, 2023. Matteo Corner/ Shutterstock

Milan as a Layered System

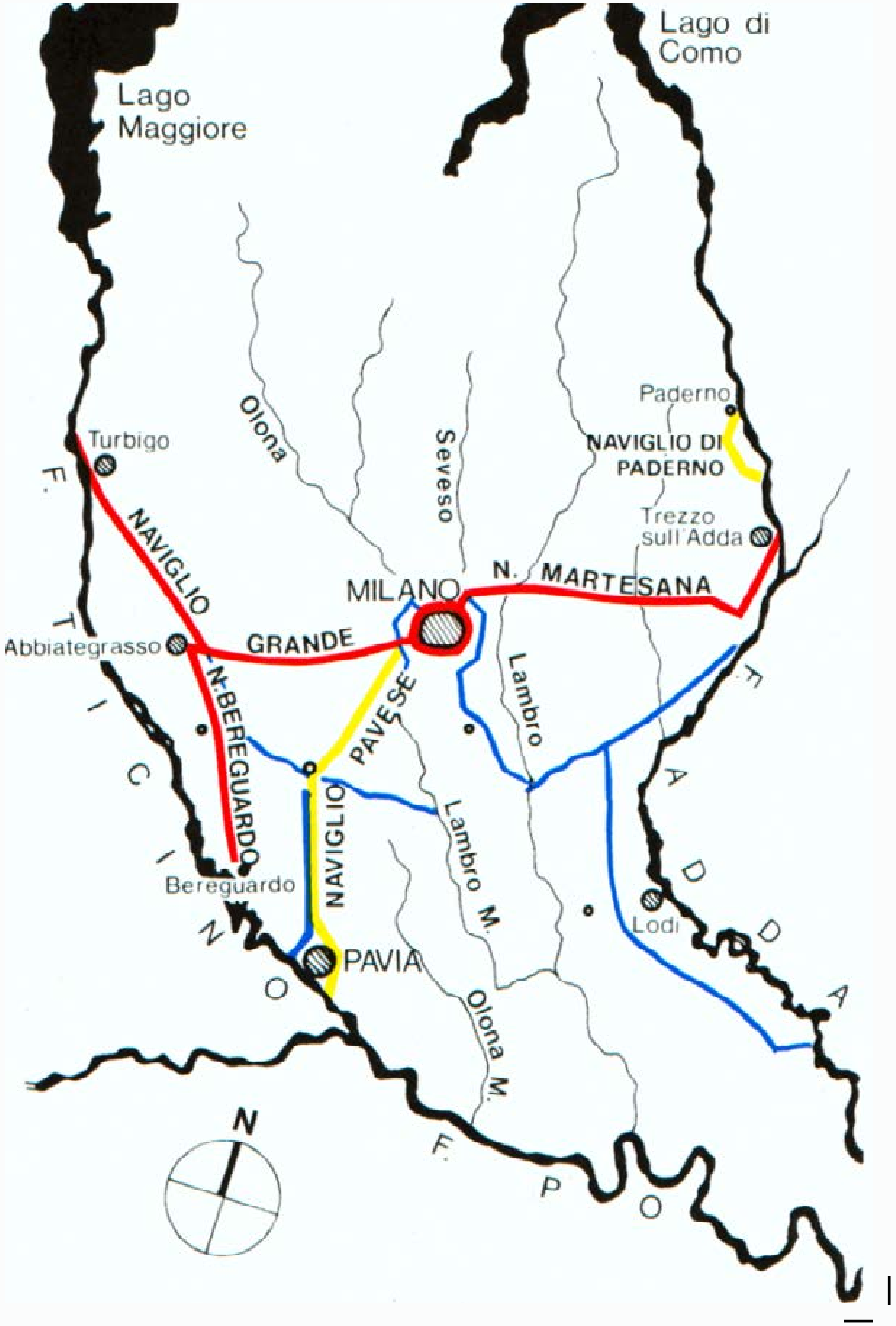
Milano is not just exposed to water. It has been built through water, against water and over water, through a long sequence of spatial and technical decisions. It is a complex urban waterscape shaped by buried courses, sealed surfaces, groundwater conditions and networks operating on the limits of their thresholds. Due to this, flood risk is an intersected condition, produced by the interaction of ground, infrastructure, and the limited room left for water to move and settle.

3.0

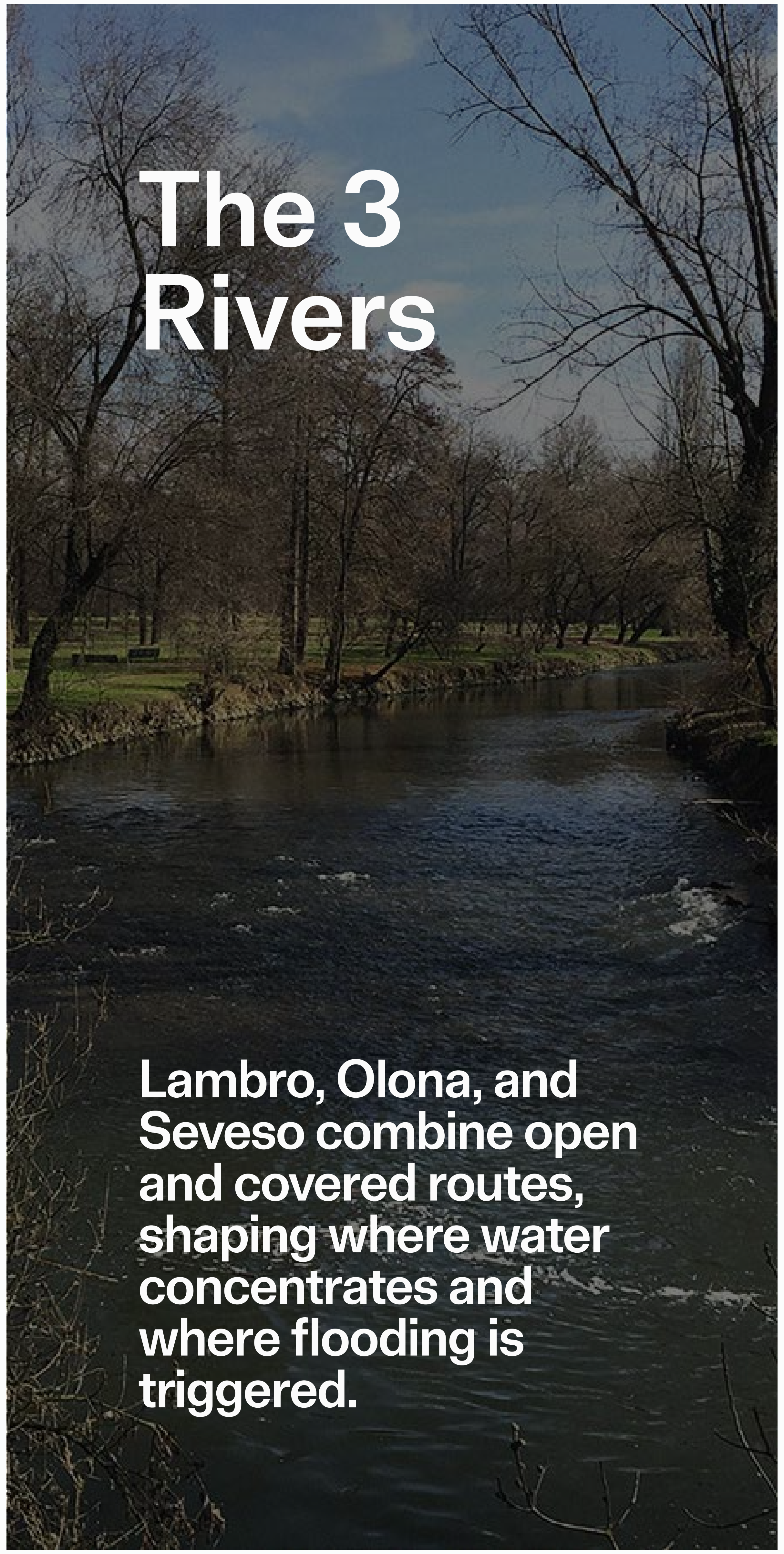
Emergency workers carry a woman after a storm caused the Seveso river to overflow in Milan, Italy, on October 31, 2023. Matteo Corner/ Shutterstock

01. A City Shaped by Water

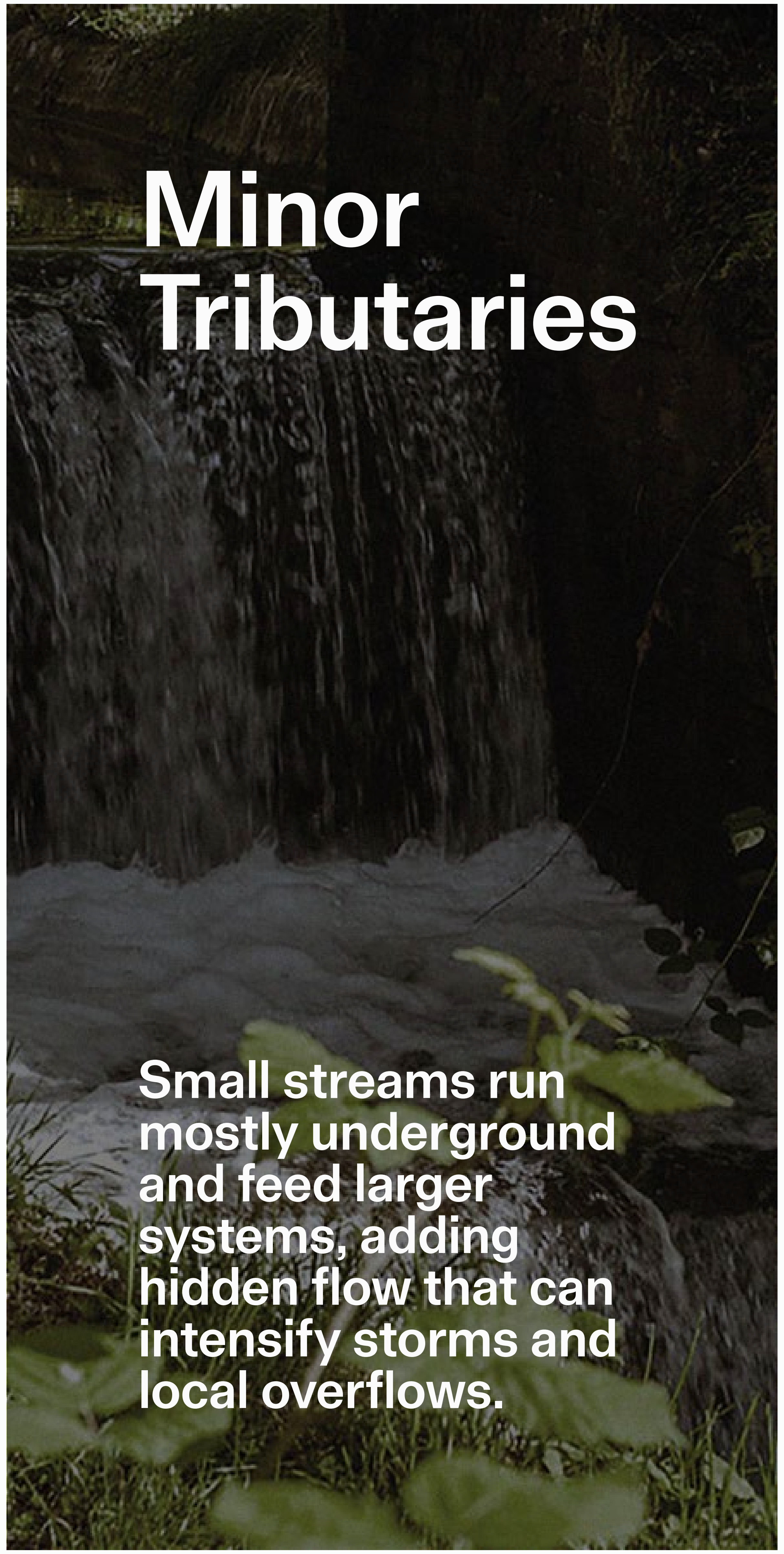
Milan's hydrography is defined by a dense network of natural rivers, artificial canals, and buried conduits that together shape how water moves through the metropolitan area. The city is crossed by three main rivers whose courses have been altered over centuries through major hydraulic works.[177,178]



3.1.1 Map of artificial cannels system (Navigli) in Milan and Pavia province at the end of XX century.

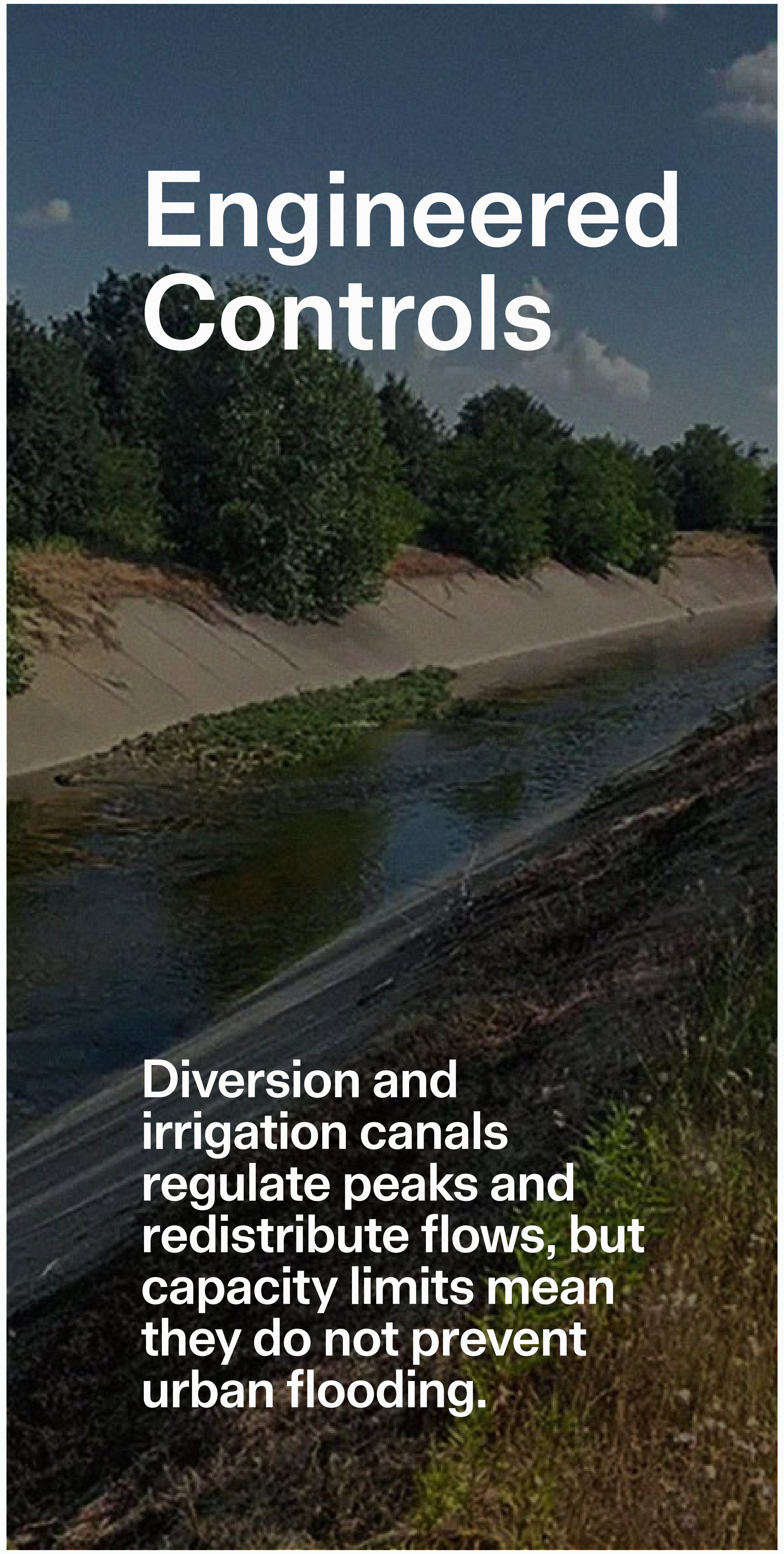


3.1.2 The Lambro river



3.1.3 Pudiga

3.1.4 Il Naviglio Martesana



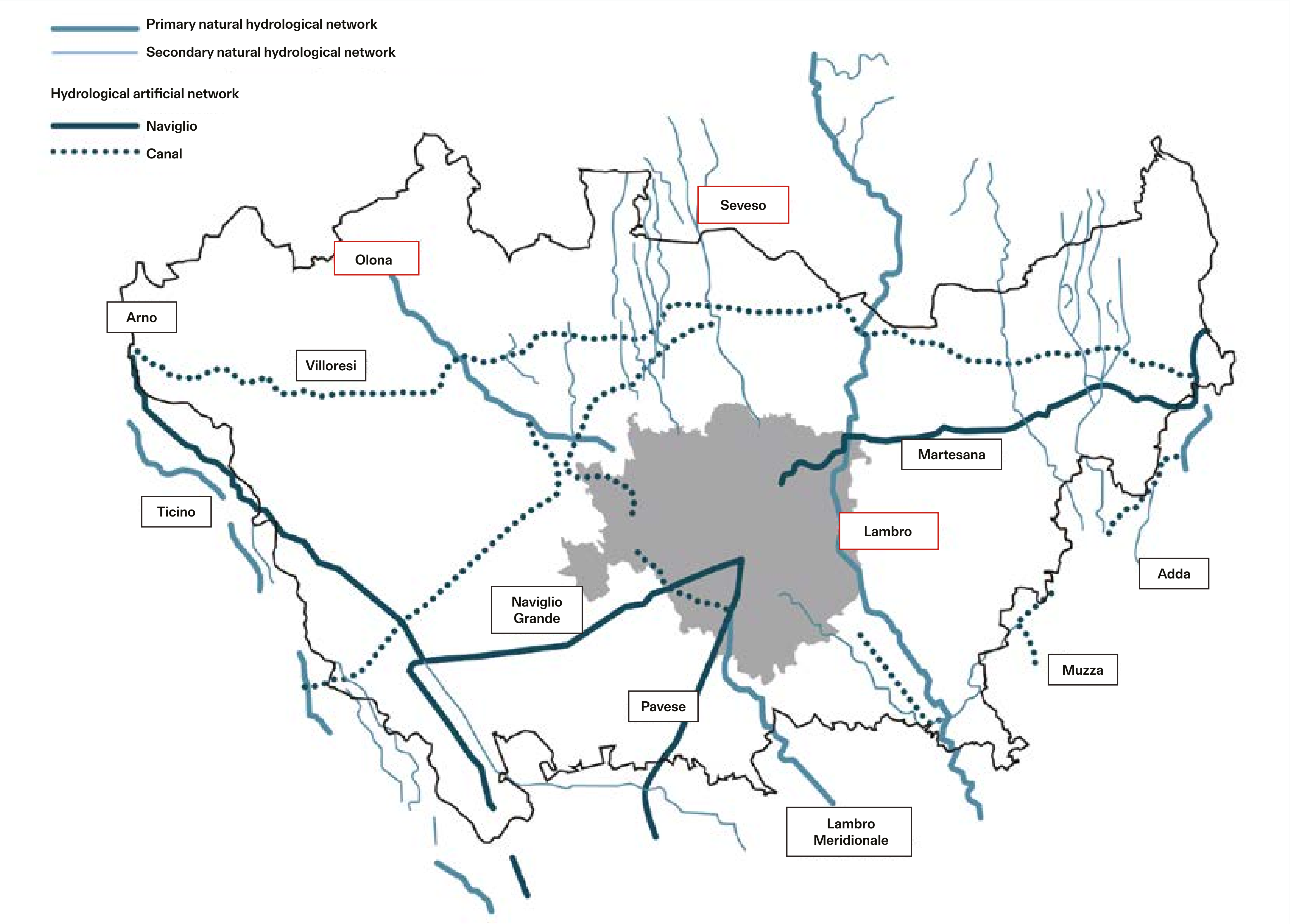
3.1.5 Canale scolmatore dell'Olona

The 3 Rivers
Lambro, Seveso & Olona

The Lambro runs largely in the open and crosses the eastern side of Milan.

The Olona reaches the city near the Gallaratese area and today runs underground beneath the western ring roads as far as San Cristoforo; it no longer flows directly into the Darsena, but passes beneath the Naviglio Grande and feeds the Southern Lambro Collector, the Colatore Lambro Meridionale.

The Seveso enters Milan from the north and runs covered through the city, reaching its confluence with the Naviglio della Martesana beneath the roadway of Via Melchiorre Gioia, then diverting near Ponte delle Gabelle into the artificial Cavo Redefossi, which ultimately discharges into the Lambro.[177,178]



Map of surface hydrography (Source: Aprea et al., 2018, adapted from image by Legambiente). 3.1.6

3.1.7 Pudiga: "Bollate diventa Venezia," Piazza San Francesco. Giordano Minora

Minor Watercourses
Hidden tributaries

Within the municipal territory, additional watercourses contribute to this hybrid system of open and culverted flows. In the San Siro area, two streams feed the Olona, the Fugone (also known as the Merlata) and, further downstream, the Mussa, both cross parts of the contemporary city underground. Other streams are also present, including the Pudiga and the Garbogera, alongside various smaller artificial channels.[177,178]

Canal Network
The Navigli system

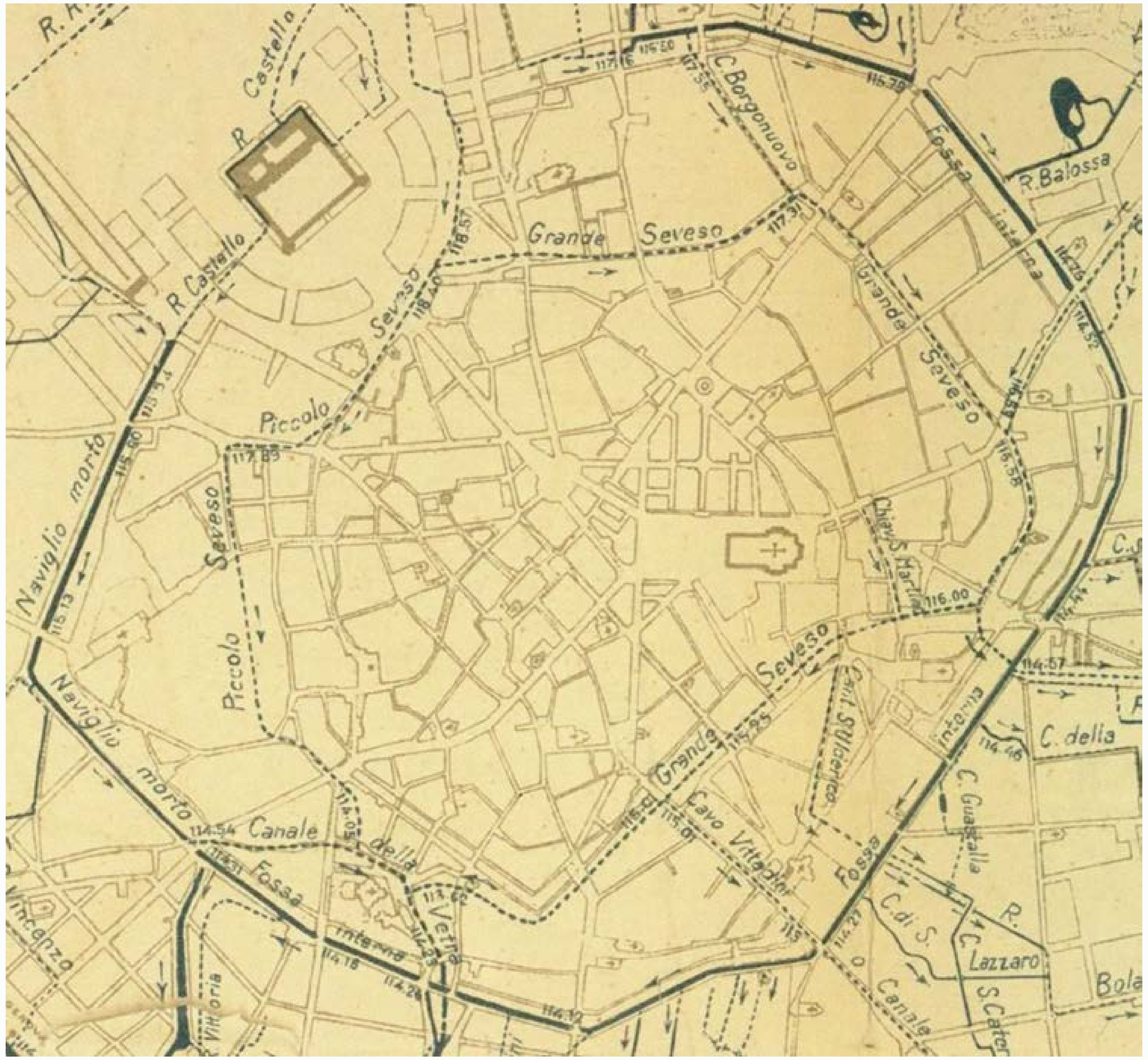
Milan's canal system remains a defining component of the current hydrographic structure.

The Naviglio Grande runs from the Ticino to the Darsena at Porta Ticinese and historically functioned as a major navigable and hydraulic spine.

The Naviglio Pavese draws water from the Darsena and returns it toward the Ticino near Pavia, linking the city to a broader regional water geography.

The Naviglio della Martesana, which reaches the city from the Adda, remains central to the minor hydrographic network and connects to the Seveso and the system that generates the Cavo Redefossi.

The Cavo Redefossi today runs as an engineered drainage corridor, largely underground, crossing the eastern side of the city and ultimately joining the Lambro.[177,178]



Hydrographic map of Milan (1870), showing the watercourses (both natural and artificial) that crossed the city.

3.1.8

3.1.9 Canale Scolmatore di Nord Ovest

Engineered Controls
Flood relief

Several major engineered infrastructures govern flood management and irrigation at the metropolitan scale.

To address frequent flooding of the Seveso and the Olona, the North West diversion canal, the Scolmatore di Nord Ovest, operates as a relief channel, although it has often proven insufficient to prevent urban flooding, particularly in the Niguarda area.

North of the city, the Villoresi Canal crosses the plain and connects the Ticino to the Adda, supplying irrigation water to areas that are naturally less water rich than the zones north of Milan.[179]

The **Olona** reaches Milan near the Gallaratese area and today runs largely underground beneath the western ring roads, then passes under the Naviglio Grande and feeds the Colatore Lambro Meridionale.[177,178]

The **Olona** diversion is an engineered branch that reroutes part of the flow within the western system to manage levels and reduce pressure on the main corridor through the city.[177]

The **Merlata** is a tributary of the Olona system and in the contemporary city it is largely managed through culverted sections where it crosses dense urban fabric.[177,178]

The **Pudiga** is part of Milan's minor hydrographic network and is largely handled through culverted stretches where urbanization constrains the channel.[178]

The **Garbogera** is a northern watercourse within the municipal network and includes significant culverted sections where it intersects the built city.[178]

The **Seveso** enters Milan from the north and today runs covered through the city until it connects to the Martesana system, after which flows are routed into the Cavo Redefossi corridor.[177,178]

The **Martesana** is the eastern canal that receives the Seveso connection in the urban area and remains a key backbone of Milan's minor hydrographic network.[177,178]

Ponte delle Gabelle marks the urban hinge where the system gives rise to the Cavo Redefossi, linking inner-city canals to the engineered drainage route.[177,178]

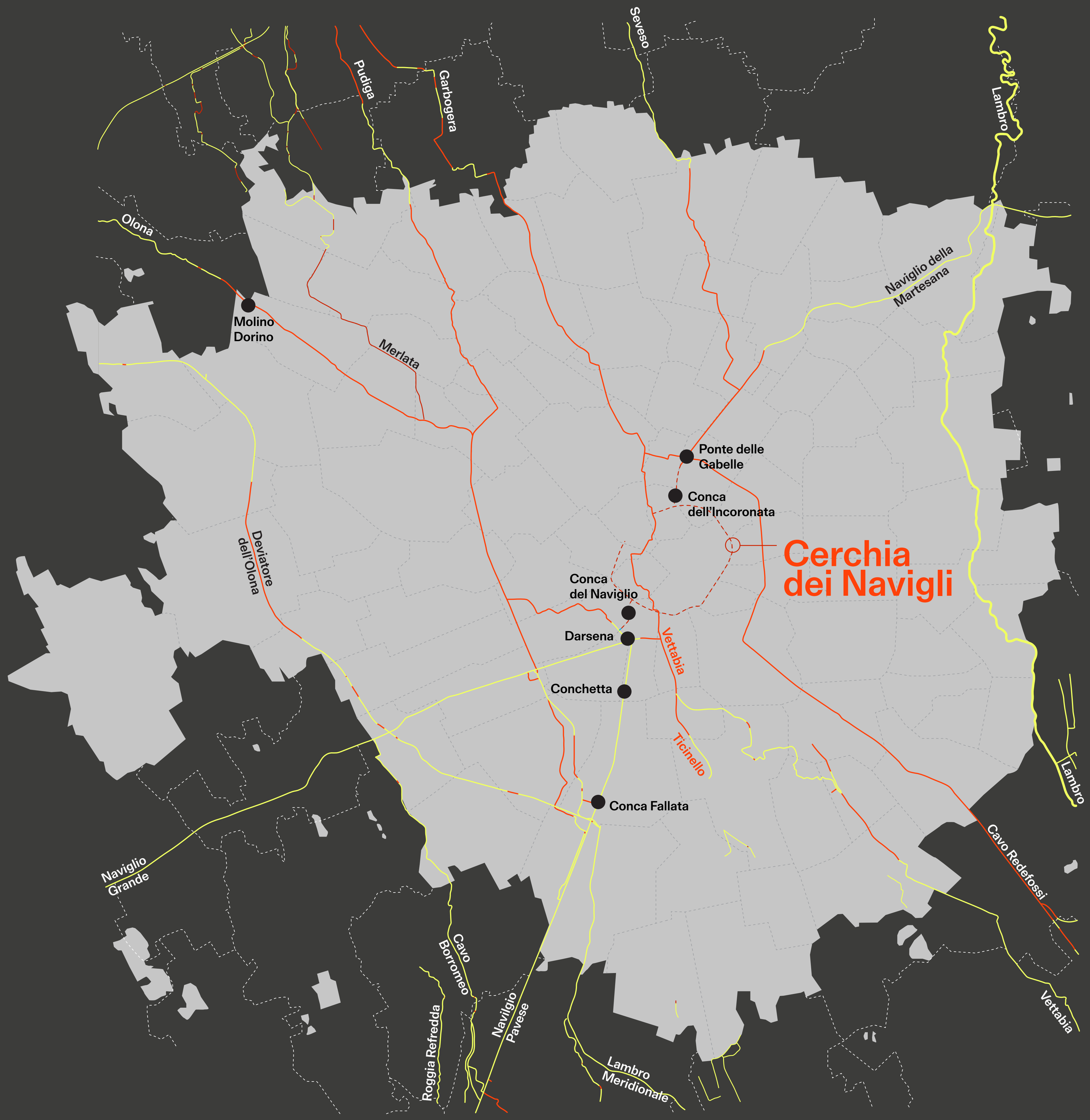
Conca dell'Incoronata (in disuse)is a historic canal interface that today is shown as out of use, but it still indicates how Martesana waters once entered the inner canal ring.[177]

Cerchia dei Navigli (no longer existing as a canal) is the former inner ring canal, now eliminated as an open water ring and replaced by buried infrastructure and surface streets.[177,178]

Conca del Naviglio (in disuse) is shown as out of use and represents a former controlled transition point within the inner canal system near the Darsena area.[177]

The **Darsena** is the central basin where Milan's canal system concentrates flows and operations, acting as the main node between the Naviglio Grande and the Naviglio Pavese.[177,178]

The **Naviglio Grande** runs from the Ticino to the Darsena at Porta Ticinese and remains a defining hydraulic axis in Milan's canal network.[178]



culverted sections
open-air sections

Milano water system network,
Adapted from The Passenger (Iperborea), "Milano."

3.1.10

The **Naviglio Pavese** draws water from the Darsena and carries it south toward Pavia, maintaining Milan's canal connection to the wider regional system.[177,178]

The **Cavo Redefossi** is a major engineered drainage corridor generated near Ponte delle Gabelle that today conveys diverted urban flows across the east and southeast before discharging into the Lambro.[177,178]

The **Vettabbia** is a receiving stream in the southern system that carries waters conveyed into its corridor through Milan's canals and buried conduits.[177]

The **Cavo Vettabbia** is an engineered channel that structures and conveys flows within the Vettabbia system across the southern and southeastern areas of the municipality.[177]

Mulino Vettabbia is a hydraulic node on the Vettabbia corridor that signals the working infrastructure associated with the managed watercourse system.[177]

The **Ticinello** is a minor southern watercourse within the municipal network that functions as part of the local drainage and irrigation fabric.[177]

The **Lambro Meridionale** functions as a managed collector channel that receives the routed waters of the Olona and also operates as an overflow pathway connected to the Naviglio Grande system.[177,178]

Conchetto (in use) operates as an active control point within the southern canal and collector network near the Darsena corridor.[177]

Conca Fallata (in use) is an active lock and regulation point along the southern canal system.[177]

The **Cavo Borromeo** is a minor engineered channel in the southwest that contributes to the fine-grained network of managed surface water lines.[177]

Roggia Refreddo is a minor open-air channel in the southwest that supports the local network of irrigation and drainage watercourses.[178]

The **Lambro** runs largely in the open across eastern Milan and acts as the main receiving river for several engineered channels and collectors, including the Cavo Redefossi and the Vettabbia system.[177,178]

Molin Dorino is a western node on the Olona corridor that marks a strategic interface between the river system and the metropolitan hydraulic network.[178]

How did Milan's water system evolve over time?

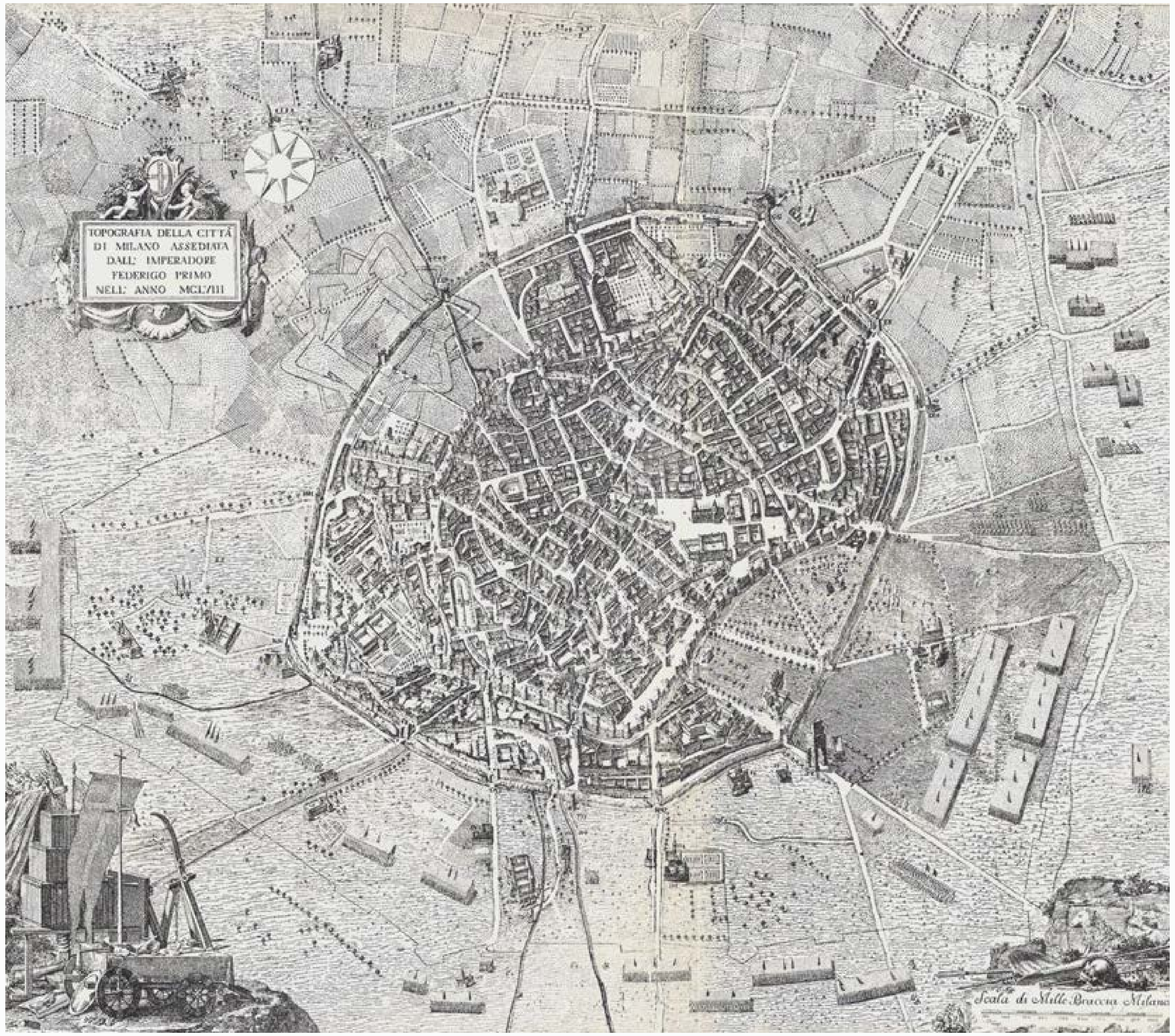
Milan - The Old Canals 3.1.11a

Ancient Wetlands
Marshes, springs & early irrigation

Milan's hydrography has been deeply reshaped since antiquity, with settlement, defense, sanitation, navigation, and flood control repeatedly redefining the relationship between the city and its waters.

According to some reconstructions, the historic center, first settled in Celtic times and later in the Roman era, lay between the riverbeds of the Nirone and the Seveso. The area was likely rich in water and included marshy zones fed by resurgence springs. In later periods, these waters were increasingly captured and managed through spring fed irrigation channels known as *fontanili*, turning diffuse wet landscapes into governed productive systems.[179]

Hypothetical map of Milan in its early beginnings (6th–3rd century BC) 3.1.11b



3.1.12 Milano Topography, 1158

Roman Moat

Fortified city water belt

The first major structural transformation occurred in Roman times, when a defensive ditch was created to encircle the fortified city. It was originally fed by the Nirone and the Seveso.

Along the line of this ancient ditch, two conduits still exist today, now buried, known as the Piccolo Sevese and the Grande Sevese, with the latter still part of the minor hydrographic network.

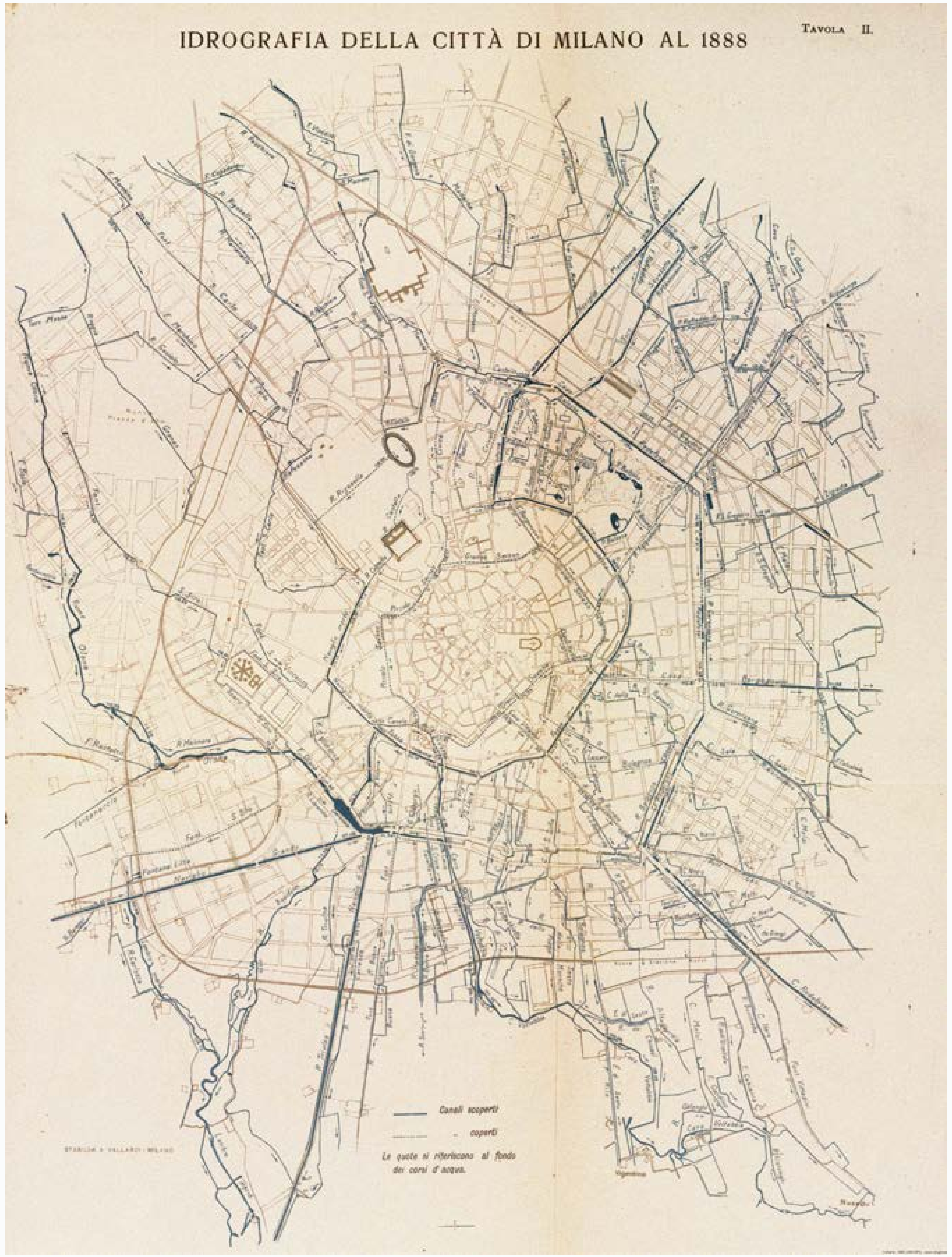
Through the Vetra canal, the waters of this system flowed into the Vettabbia stream, and part of this connection remains in operation in modified form.[179]

Medieval Canals
Construction → Closure

In 1155 a second, wider ditch was created, corresponding to what later became known as the Cerchia dei Navigli. This inner ring remained intact until relatively recent times, when public health concerns began to drive its covering.

It was progressively covered through several interventions between the late nineteenth century and the 1930s, and later definitively filled between 1968 and 1969 due to structural problems in the coverings themselves.

More broadly, the systematic culverting and burying of waterways in Milan became a defining twentieth century trajectory, beginning in the 1930s and concentrating most heavily between the 1950s and the 1970s, when many channels were driven underground as part of a wider urban modernization agenda.[179]



Hydrography of the City of Milan, 1888. 3.1.13

3.1.14 Where the Martesana dies and the Redefossi is born, on Via Melchiorre Gioia (1940–45)

Redefossi
Engineered flood bypass

The Cavo Redefossi itself was reinforced as a flood control response at a precise moment in the city's history.

The stretch from Piazza Medaglie d'Oro to the Lambro was excavated between 1783 and 1786 to address frequent floods affecting Porta Vittoria, Porta Romana, and Porta Ludovica.

Over time, the Redefossi corridor became increasingly integrated into the urban fabric and today runs largely underground beneath the boulevards of the eastern ring of the Bastions, turning a surface waterway into concealed infrastructure.[179]

Naviglio Pavese
Route to Po and Adriatic

Between the first half of the seventeenth century and the early nineteenth century, through several phases and difficulties, the Naviglio Pavese was excavated. This canal extended the city's navigable network by connecting central Milan to Pavia and, from there, to the Po and the Adriatic, linking Milan's internal water system to continental trade geographies and the wider basin.[177,178]

Il Naviglio Pavese 3.1.15

3.1.16 Map of Milan's historic water system, Astronomi di Brera, 1814.

Modern Redirecting of Rivers
The buried network

In parallel, natural rivers were progressively redirected, constrained, or buried as urbanization intensified.

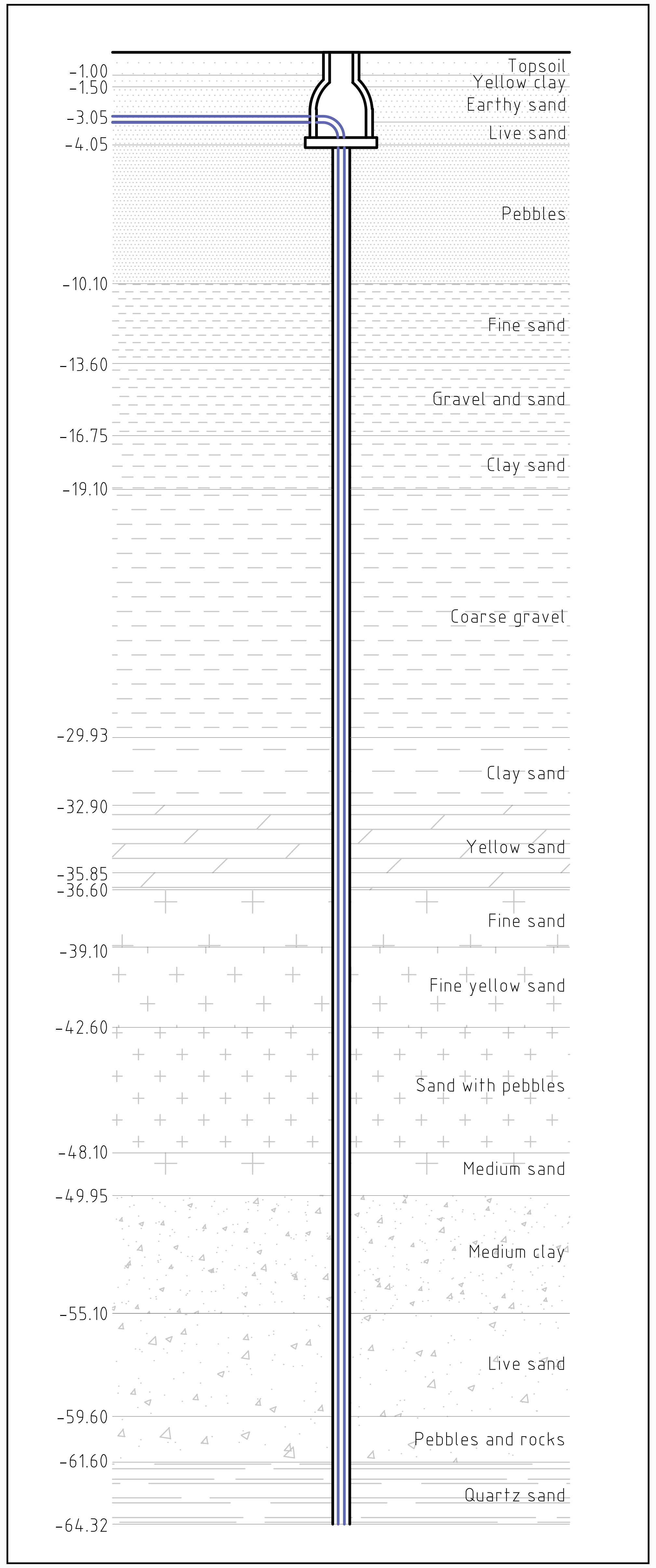
The Olona, rising in the Varese pre Alps, reaches Milan near the current Gallaratese area and now runs underground beneath the western ring roads as far as San Cristoforo. In the past it flowed directly into the Darsena, but today it passes beneath the Naviglio Grande and feeds the Southern Lambro Collector.

The Seveso, similarly, has been brought underground for long sections, before being routed into the artificial Redefossi system.

The Lambro has remained more consistently open as it crosses the eastern city and collects the waters of the Redefossi and the Vettabbia near Melegnano.[177,178]

These changes marked a shift from an open hydrographic landscape to a **controlled, buried and engineered network** operating as one system.

La copertura, 1930 - Conca di Viarenna 3.1.17



3.2.1 Schematic section of well Comasina, Milano.
Drawing: Jurica Pajic

02. Groundwater Conditions

Milan's water system starts from groundwater because the city sits on fluvioglacial deposits that store large volumes of water in permeable aquifers at multiple depths, separated by less permeable layers.[180]

Groundwater Base
Fluvioglacial aquifers

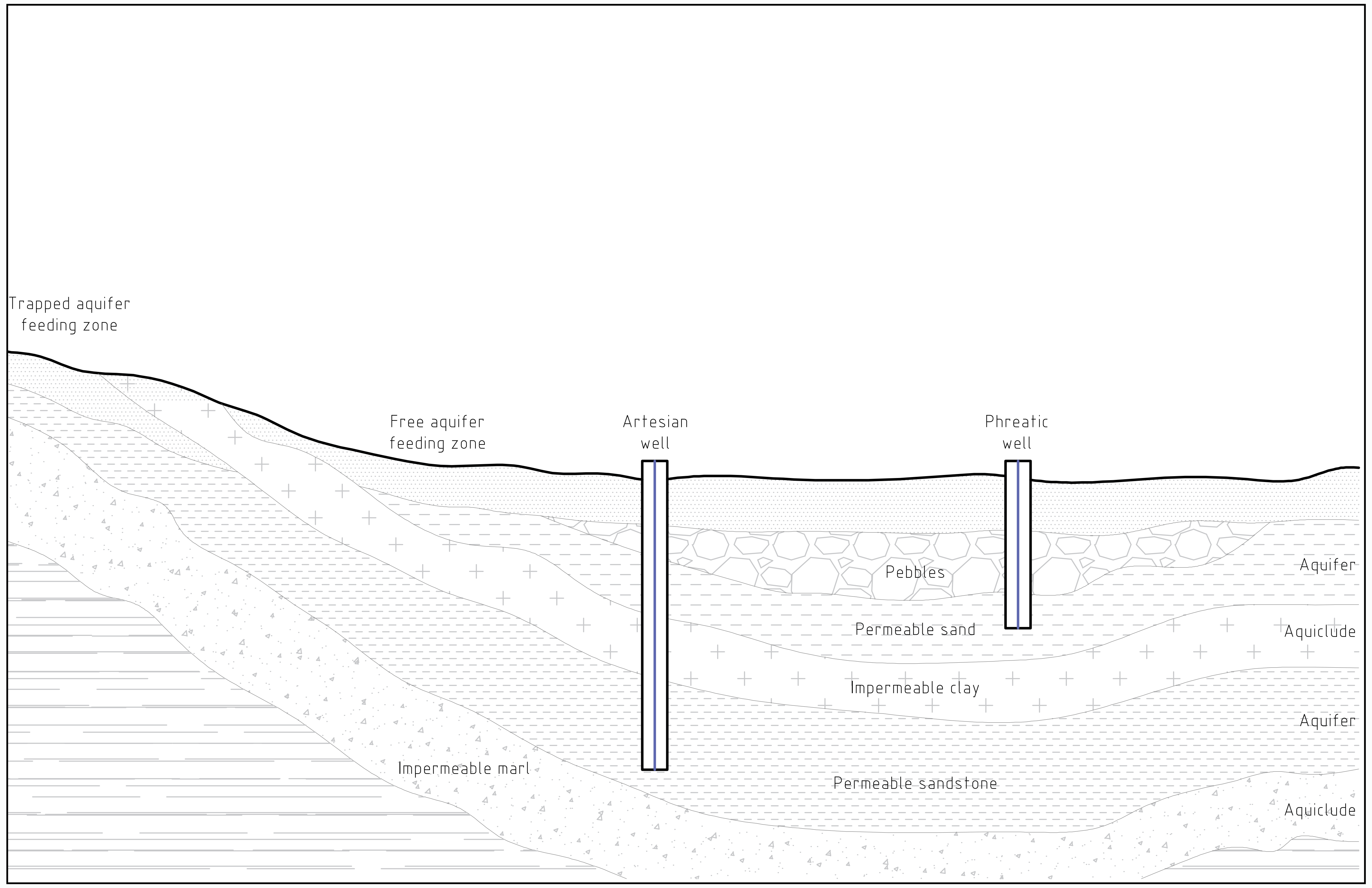
Milan's subsoil is structured as alternating permeable layers that function as aquifers and impermeable layers that act as aquicludes, formed by sediments transported and deposited by rivers and glaciers. Near the surface, soils are predominantly gravelly and sandy, which allows water to infiltrate and move easily, while at greater depth grain size becomes finer with increasing silt and clay, reducing permeability and separating the layers more distinctly. A typical vertical sequence includes 0 to 2 or 4 metres of agricultural soil, followed by siliceous sands interbedded with gravel, pebbles, and clayey layers, and then mixed alluvial deposits down to about 40 to 50 metres where coarse material decreases and clay banks increase, enabling groundwater storage at several depths.[180]

Vertical subdivision of soil layers			
Hydrostragraphic layers		Hydrogeological layers	Geological epoch
Wurm glaciation	1st Aquifer	Gravely sand	Late Pleistocene
Mindel-Riss glaciation	2nd Aquifer	Gravely, sandy silt	Middle Pleistocene
Ceppo glaciation		Conglomerates and basal sandstone	Early Pleistocene
Villafranchian glaciation	3rd Aquifer	Sandy clay	
		Clay	Calabriano

Vertical subdivisions of soil layers. 3.2.2
Table: Jurica Pajic

ACQUIFER	DEPTH	CONDUCTIVITY HYDRAULIC (M2/S)	QUALITATIVE CHARACTERISTICS
I aquifer	from 0 to 30 - 40m	10-3 / 10-4	very vulnerable, it can be subject to microbiological and chemical contamination
II aquifer	from 40 to 100m	10-4 / 10-5	there may be plumes of chemical contaminants, especially in the areas of intercommunication with the aquifer above
III aquifer	from 100 to 200 m and beyond	10-4 / 10-6	possible presence of H_2S and at depths greater than 200 m, even brackish water

Types of aquifers. 3.2.3
Table: Jurica Pajic



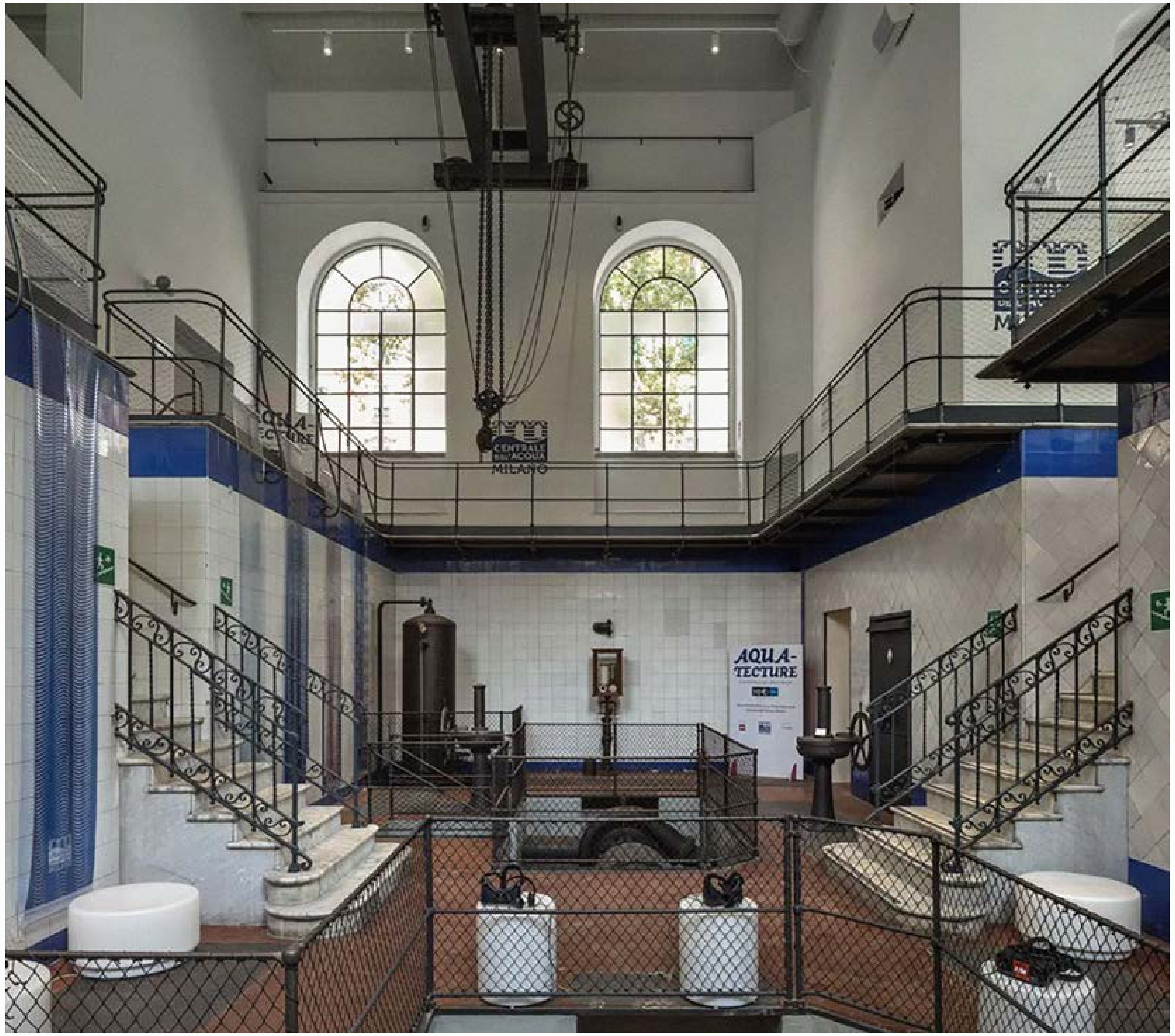
3.2.4 Geological section scheme.
Drawing: Jurica Pajic

Aquifer Types
Free vs artesian

A free aquifer occurs when the groundwater level does not reach the impermeable layer above, while an artesian or semi-confined aquifer occurs when groundwater reaches the impermeable layer above and remains under pressure because it is confined between impermeable strata. Because of this cap, the water cannot reach its natural piezometric level, and when a well intercepts an artesian aquifer the water can rise above the top of the aquifer and may rise within the well without pumping, making these aquifers the starting point of Milan's distribution system.[180]

Industry and Groundwater
Pumping and rebound

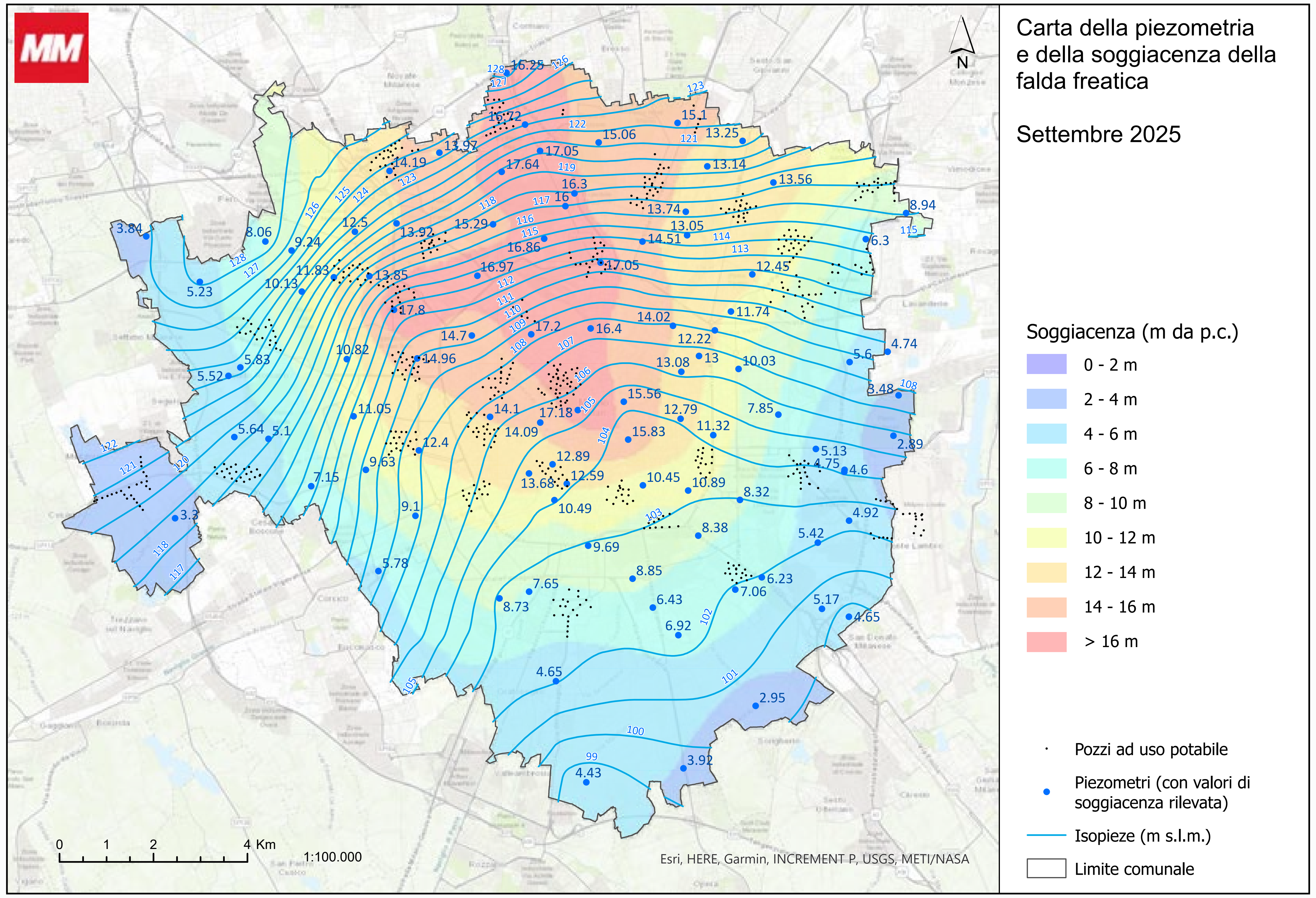
Across the twentieth century, groundwater levels in Milan shifted with the city's economy, remaining close to the surface until the 1950s, dropping between 1955 and 1970 with maximum declines of about 15 metres, then rising again from 1970 to 1990 and further from the 1990s as industrial pumping declined and urban demand reduced.[181] Intensive pumping for factories and construction produced long term drawdown, while deindustrialization in the early 1990s triggered a rebound that brought groundwater back toward earlier levels, with direct consequences for tunnels, stations, and other buried assets.[182] When the piezometric level rises, it can damage buildings and underground infrastructure, which is why the concept of a sustainable piezometric level has been proposed as a planning target in industrial and urban areas.[183]



The historic Via Cenisio pumping station 3.2.5

Soggiacenza

The depth from the ground



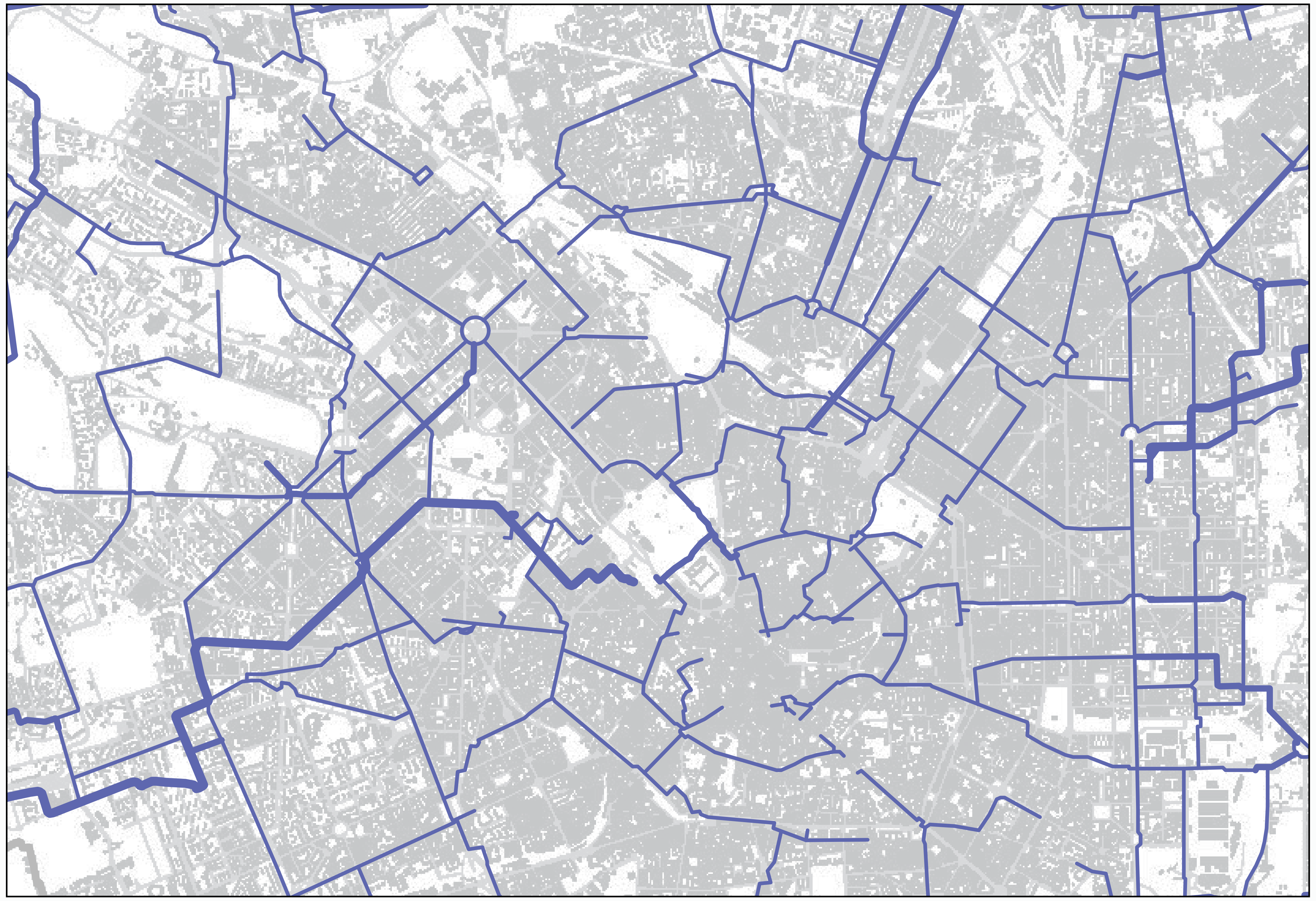
3.2.6 **Piezometric map and depth to the groundwater table September 2025**

Today, the key design metric is *soggiacenza*, the depth from ground surface to the water table, because it indicates how much room exists for infiltration and how much hydrostatic pressure acts on underground spaces.

MM S.p.A. piezometric mapping from September 2025 shows that Milan is not uniform, since groundwater is deep in some areas and much closer to the surface in others, which affects basements, foundations and metro infrastructure and changes recharge behaviour, including the role of canal infiltration alongside rainfall recharge.[184,185]

Groundwater conditions vary across Milan, so solutions must be designed district by district rather than applied uniformly.

Piezometric map of the province of Milano 3.2.7
a) 1958
b) September 2011



3.3.1 Structure of water distribution network. Drawing: Jurica Pajic

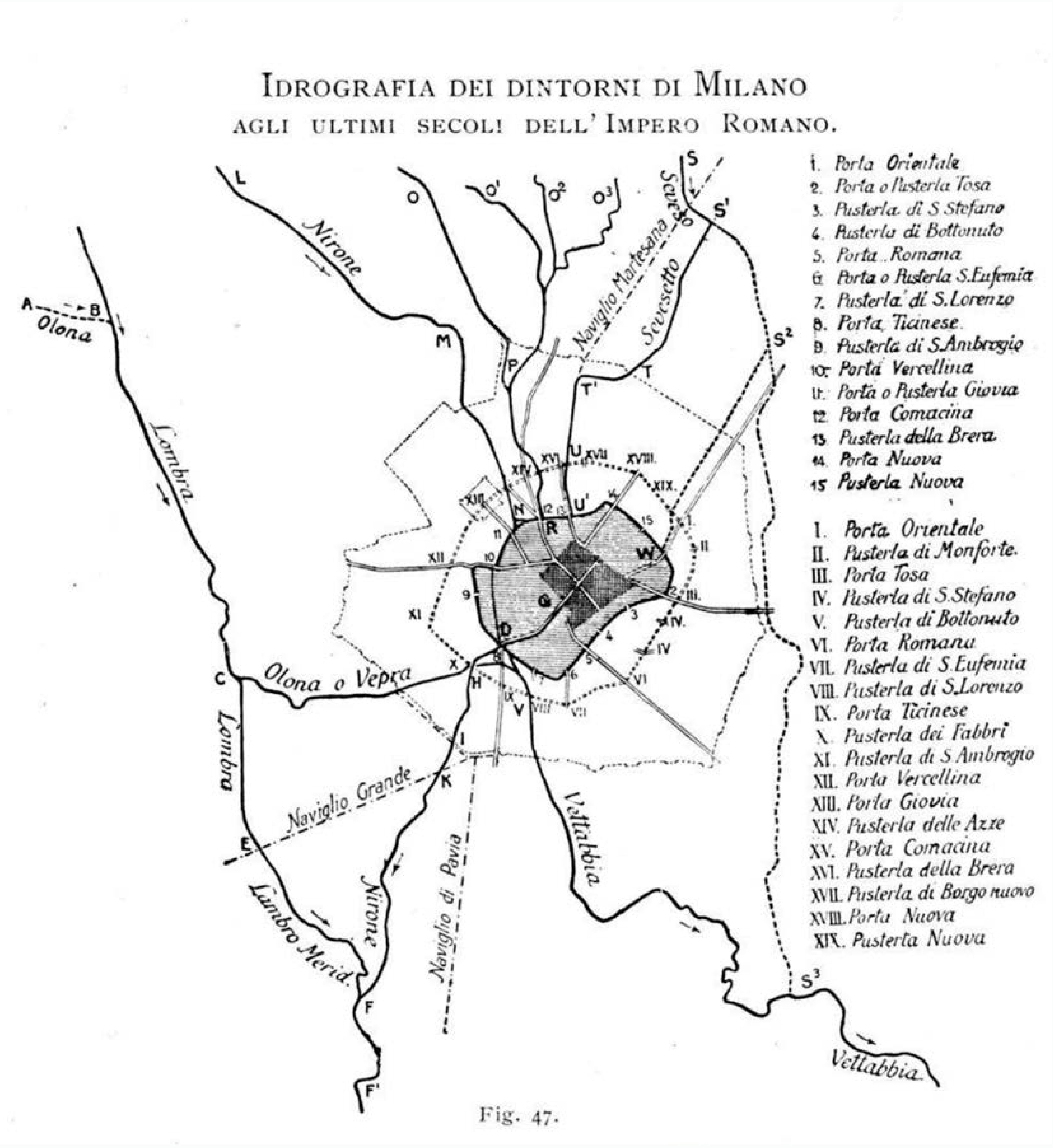
03. The Integrated Water Network

In Milan, potable water systems and sewers evolved together because the city had to bring clean water into dense neighborhoods and move used water and rainwater out, despite low natural slope and a dense historic network of canals and buried watercourses.[186]

Roman to Premoder System

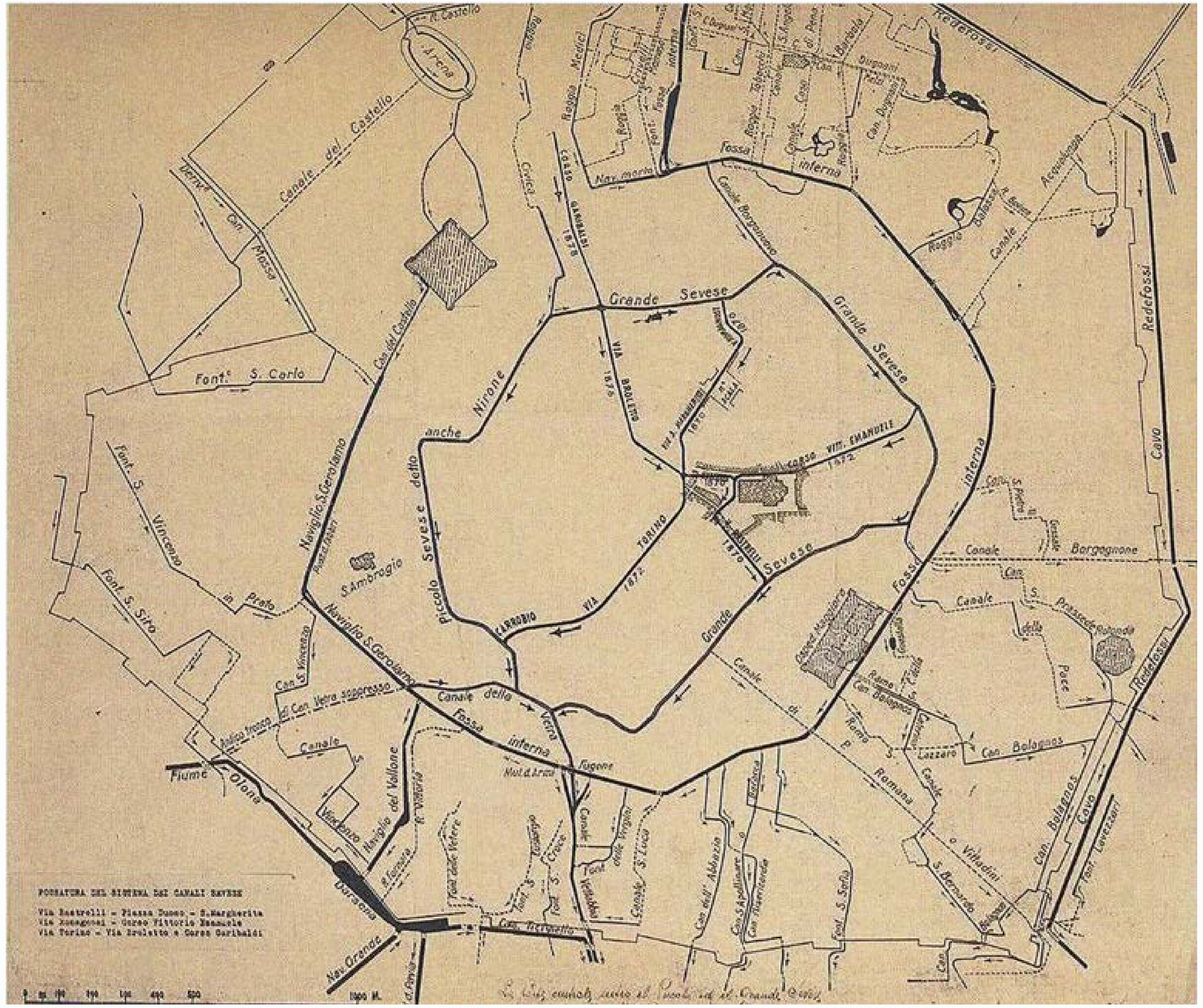
From planned drains to patchwork

Urban sewers are among the oldest city technologies. In Rome they already existed in the 6th century BCE, built to drain marshy land, feeding smaller street conduits into the Cloaca Maxima and then the Tiber. Milan followed the Roman model after the conquest and archaeological finds support the presence of Roman era sewer conduits. Sewers were converged toward an emissary channel aligned with today's Via Torino toward the Carrobbio and then continued beyond the defensive ditch toward the Lambro Meridionale. After the fall of the Roman Empire, hydraulic works deteriorated. From late medieval and early Renaissance periods, new sewer channels returned, but without a general plan. They were often built street by street, and runoff was directed into older defensive water corridors, including the Seveso and the internal canal ring. In this phase, the conduits were meant mainly for natural and rain waters, while human waste was typically managed through cesspits emptied and hauled outside the city. Sanitary statutes and ordinances regulated this system and the night work of the *navazzari* who collected waste.[187]



Hydrography of the Milan area in the final centuries of the Roman Empire

3.3.2



3.3.3 Milan's hydrography showing waterways (both natural and man-made) crossing the city.

Nineteenth-Century Reform

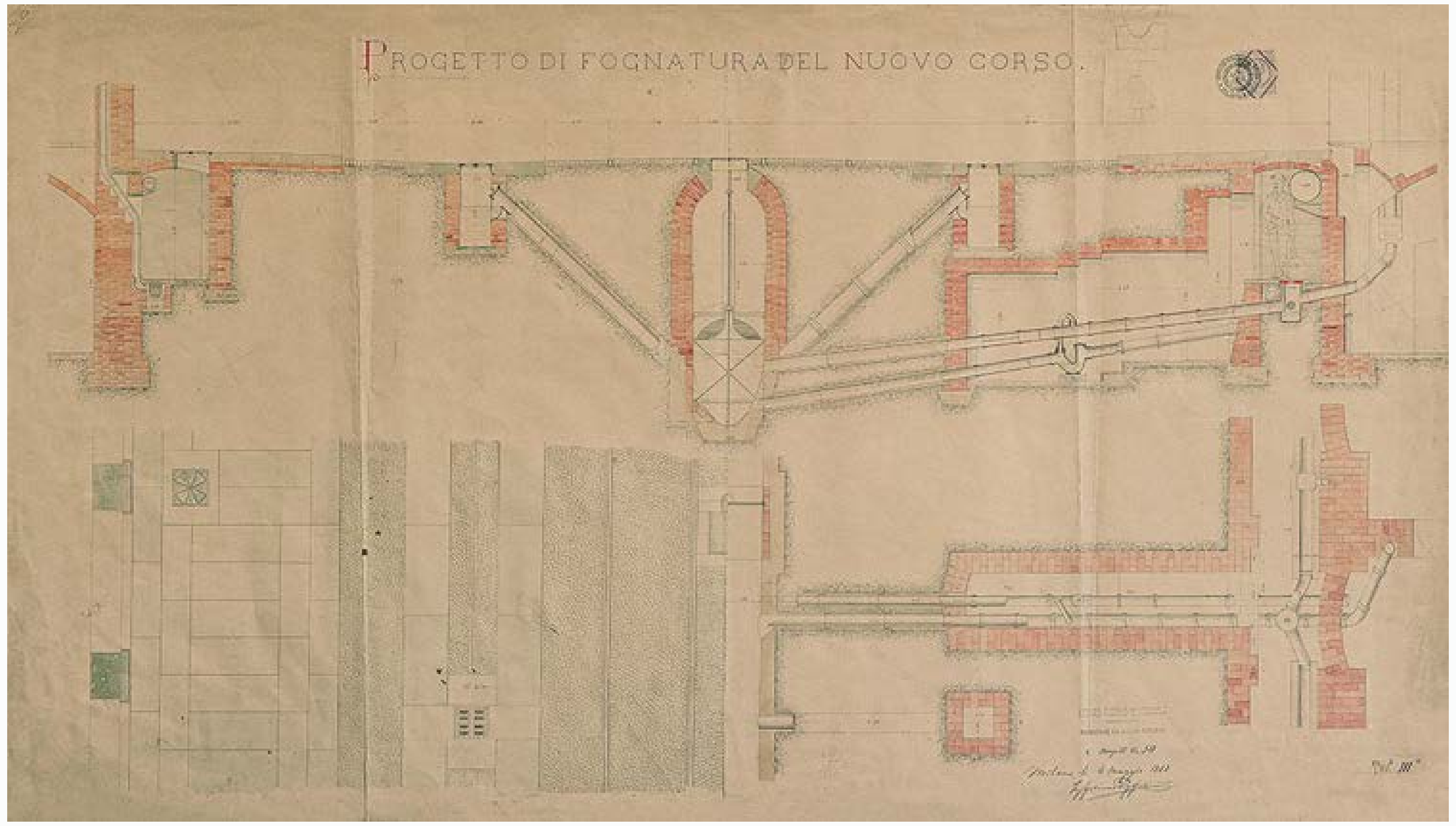
An integrated sewer plan

In 1807, road reforms introduced new buried street drains under concave road profiles. These early nineteenth century drains are described as shallow, not inspectable and prone to clogging, with flooding as a frequent result. A decisive shift began after Italian unification with 1866 as a turning point, when engineer Emilio Bignami published a technical memorandum arguing for an organic sewer network. In 1868, municipal engineers Bignami and Cesa Bianchi presented a modern sewer proposal for the central area between the Grande Sevese and Piccolo Sevese. The plan presented a combined approach, one conduit collecting both wastewater and rainwater, with sections designed to keep flow velocities higher even in low flow periods and to limit sedimentation.[188] Basically, due to the earlier system being inefficient and causing frequent flooding and serious sanitary problems, a structured network was needed.[189]

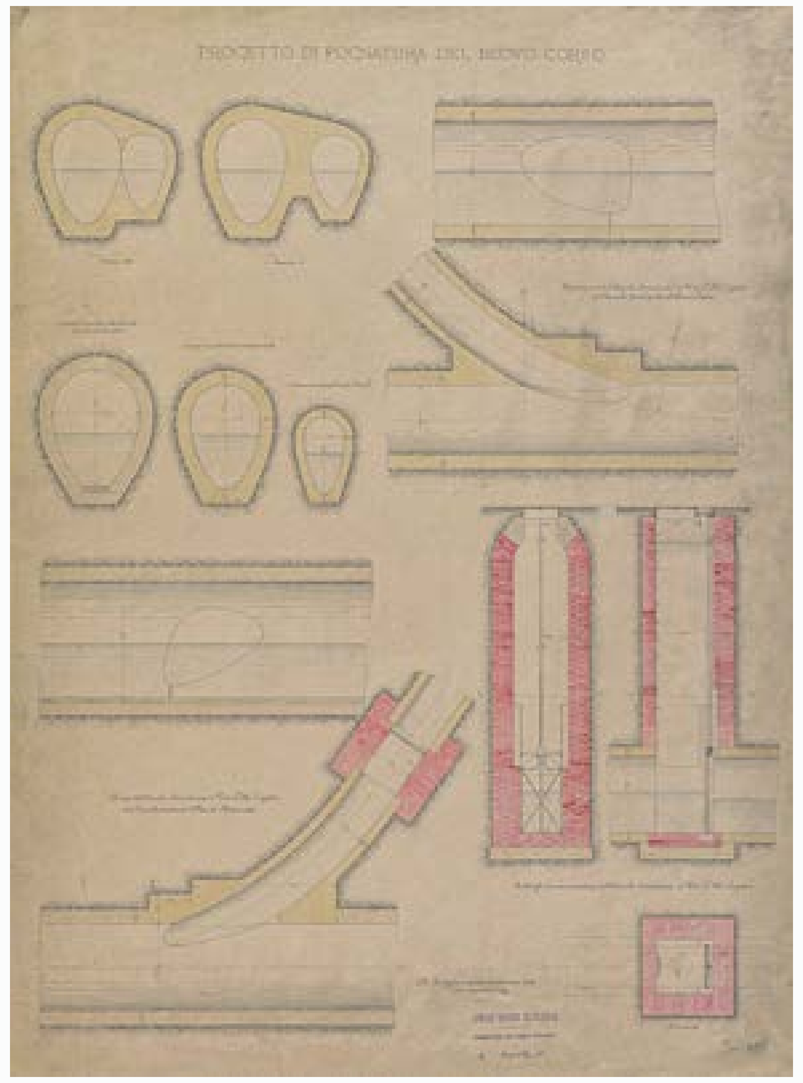
Poggi Combined System
Citywide network

From the 1880s, the sewer question was linked directly to Milan's first public planning efforts and to the aqueduct as a response to rapid urban and industrial growth due to a population increase from 192,000 in 1861 to 490,000 in 1901. Milan's physical conditions shaped design choices: a dense web of canals, shallow groundwater, minimal slope and no adequate outfall for large storm flows. In this context the city an approach with collecting used water and rainwater in the same system, largely by gravity.

The key milestone was Felice Poggi's "*Progetto per la fognatura generale della città*," completed in 1890. The project area was 2,560 hectares within the ring of the current circonvallazione roads, conceived as a network independent from the preexisting surface waterways.[190] During the same period there was a move toward a general plan that could connect old and new districts and regulate private building connections to the public network.[191]



Sewer plan for the Nuovo Corso (1888, Via Dante): Plan and section of the street showing the position of the main sewer collector, building connections, rainwater catchpits/manholes, and service voids along the facades intended to house utilities (gas, drinking water, electrical and telephone cables) 3.3.4



Construction details of conduits and junction structures: From the Nuovo Corso sewer project (1888, Via Dante) 3.3.5

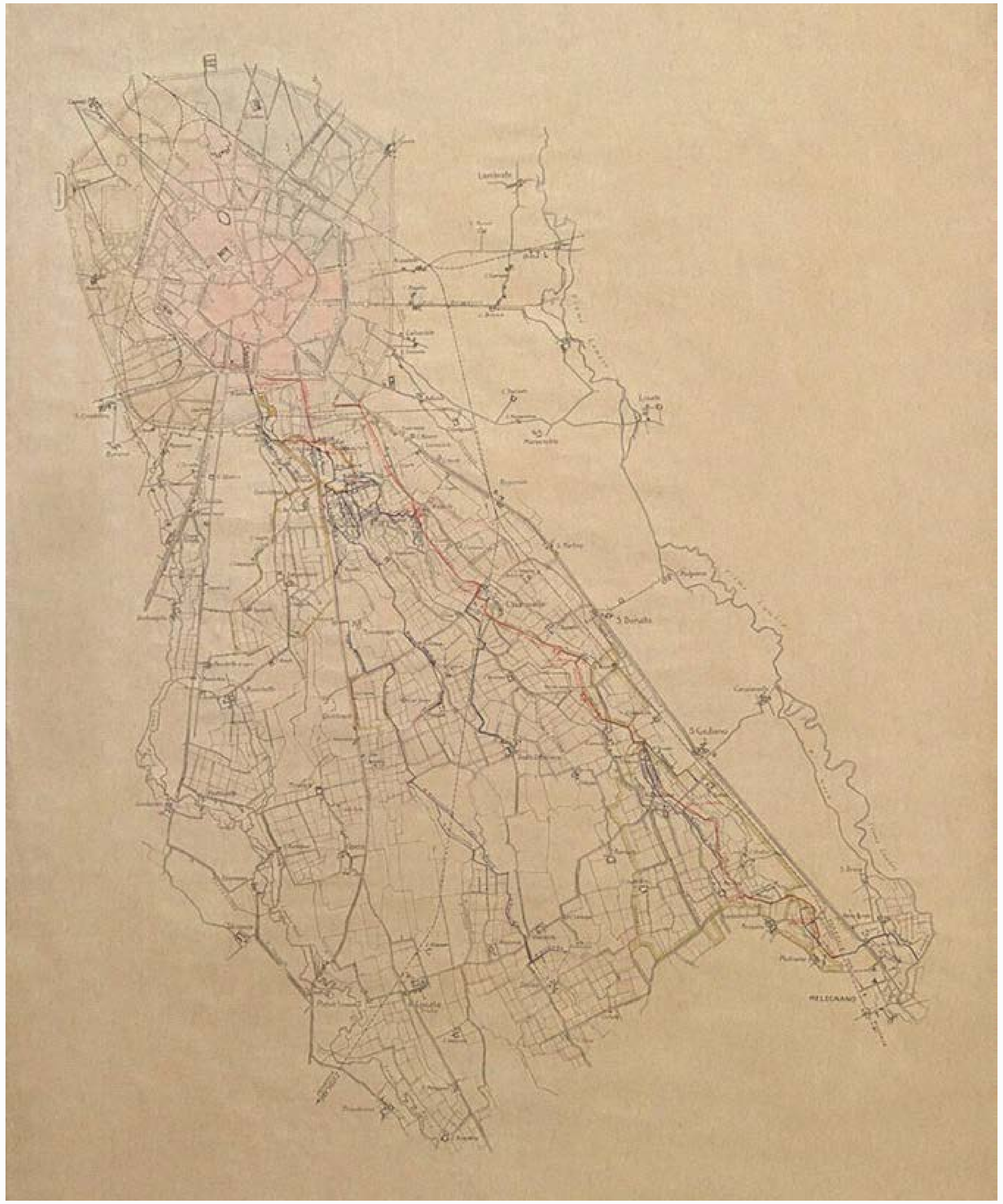
1911 Expansion Plan
Citywide network

In 1911, the plan is updated and expanded, establishing the long-term design rules of the system: sewers kept independent from natural rivers and streams, gravity-driven flow using ground slope, continued reliance on a combined network, stormwater carried in large-section pipes, and a grid-like local network that also provides storage capacity. Wastewater is discharged toward the Vettabbia and reused on irrigated meadows under formal agreements.[192]

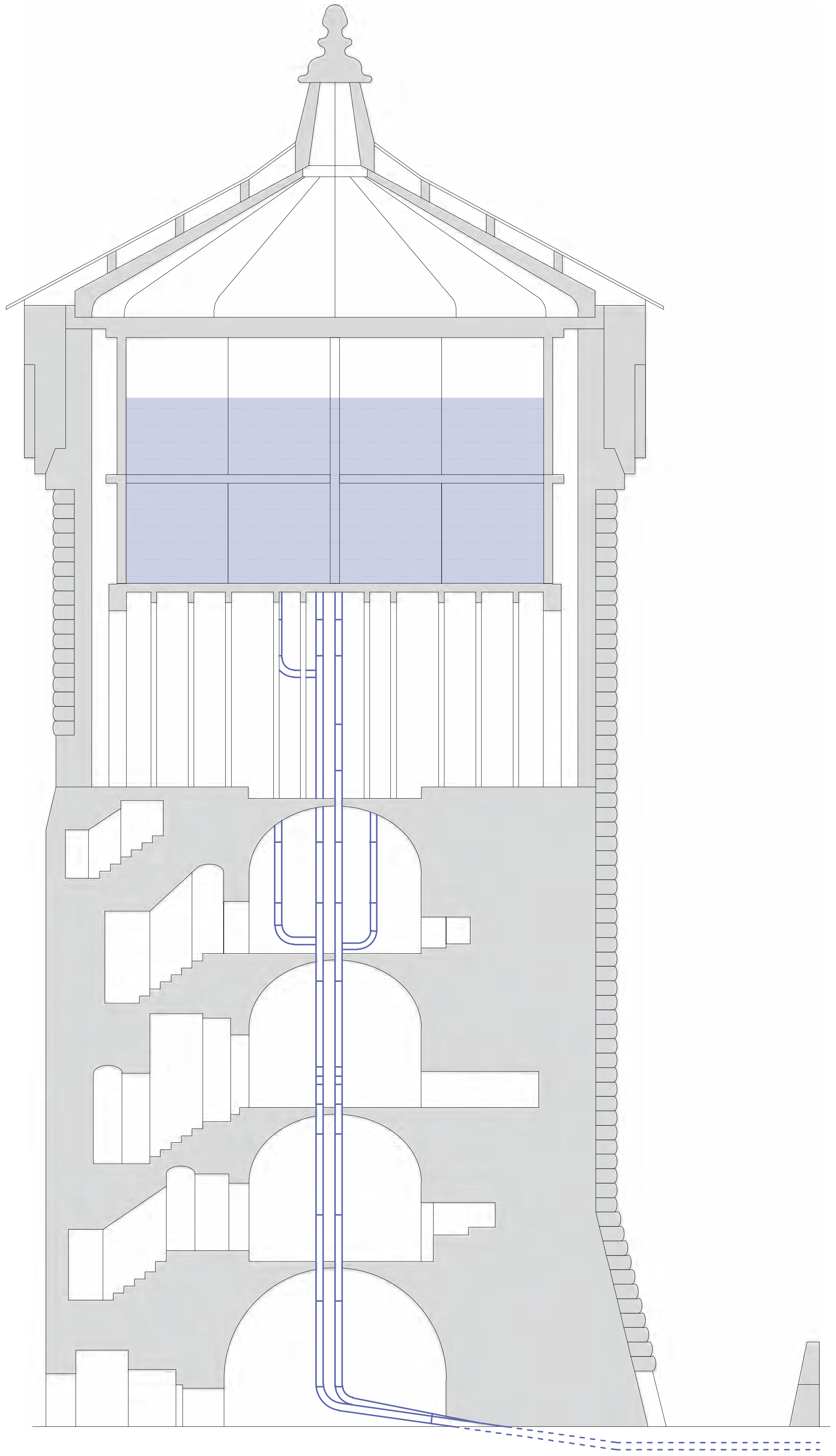
Domestic sewer study (1888, Via Dante): Section through the building facing Nuovo Corso (still standing at the corner with Largo Cairoli) highlighting the internal drainage pipes 3.3.6

Roggia Vettabia
Reuse system

For centuries, wastewater was directed toward the Roggia Vettabbia and used on the southern marcite fields, where slow flow across irrigated meadows enabled biological self-purification. Municipal commissions monitored the effectiveness and hygienic safety of this natural treatment method across later decades. This southern irrigation landscape as a large system was already shaped before 1200 through Cistercian agricultural works.[193]



A map linking Milan's 1890 sewer plan to the expansion of the Vettabbia irrigation district, highlighting the drainage areas by collector and the Nosedo emissary channel carrying urban wastewater south toward the Lambro for agricultural reuse. 3.3.7



3.3.8 Section of the south Castello tower at the end of 19th century.
Drawing: Jurica Pajic

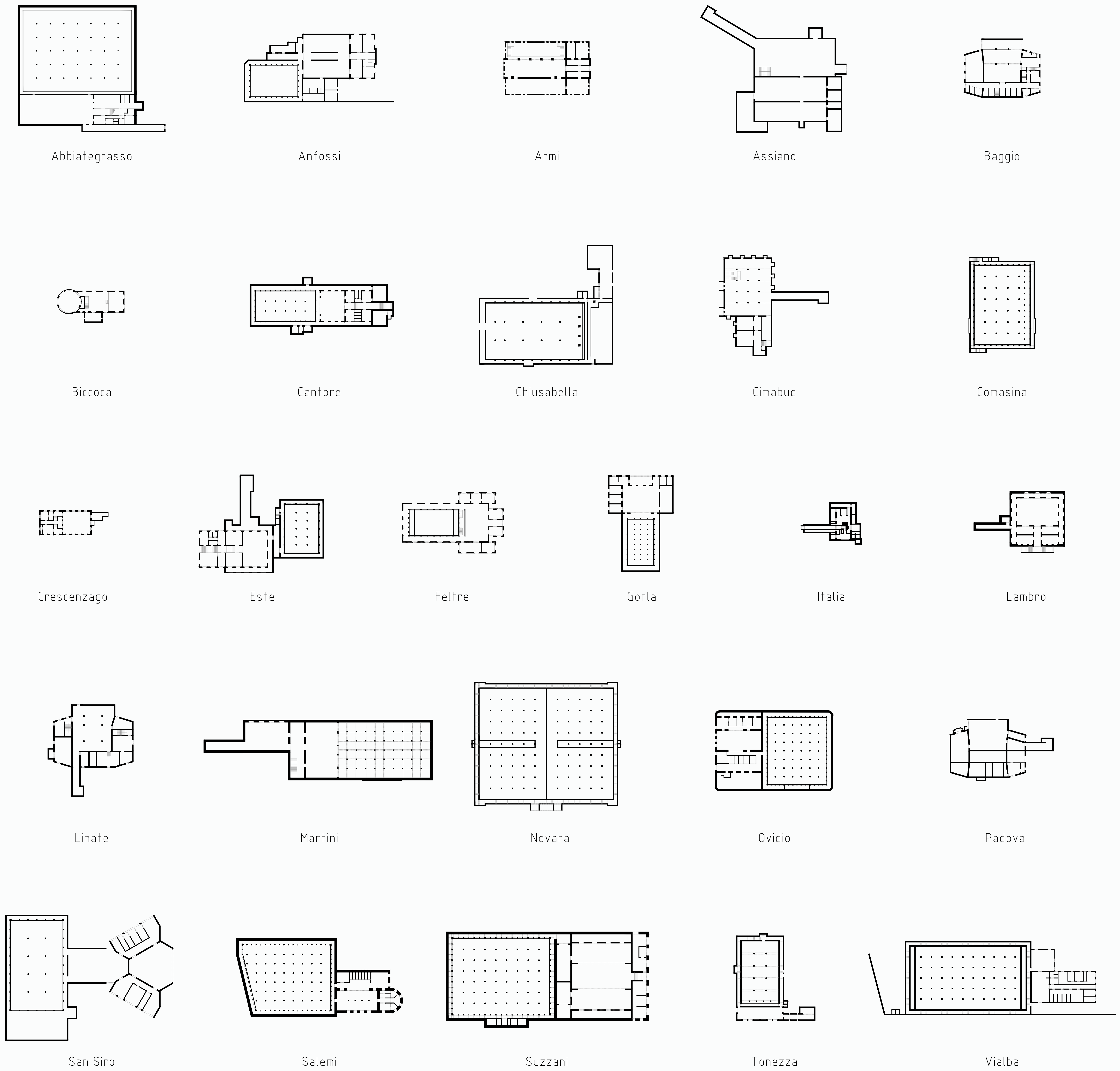
Public Water Supply
Aqueduct expansion

Milan built its first public aqueduct relatively late compared to other European cities. The city relied on canals for many uses and on abundant shallow groundwater accessed through private wells, but growing population and hygiene expectations pushed the municipality toward a public system.

In 1888 the city tested deeper wells near the Arena, finding cleaner water protected by clay layers. In 1889 the first pumping plant entered service, and storage tanks were installed high in the Castello Sforzesco towers in 1893 and again in 1904 to stabilize pressure. From there the system expanded through new pumping plants and a growing distribution network. The aqueduct became a public, citywide service tied to modern living standards and to sewer performance, since domestic water use also helped keep sewers flushed.[194]

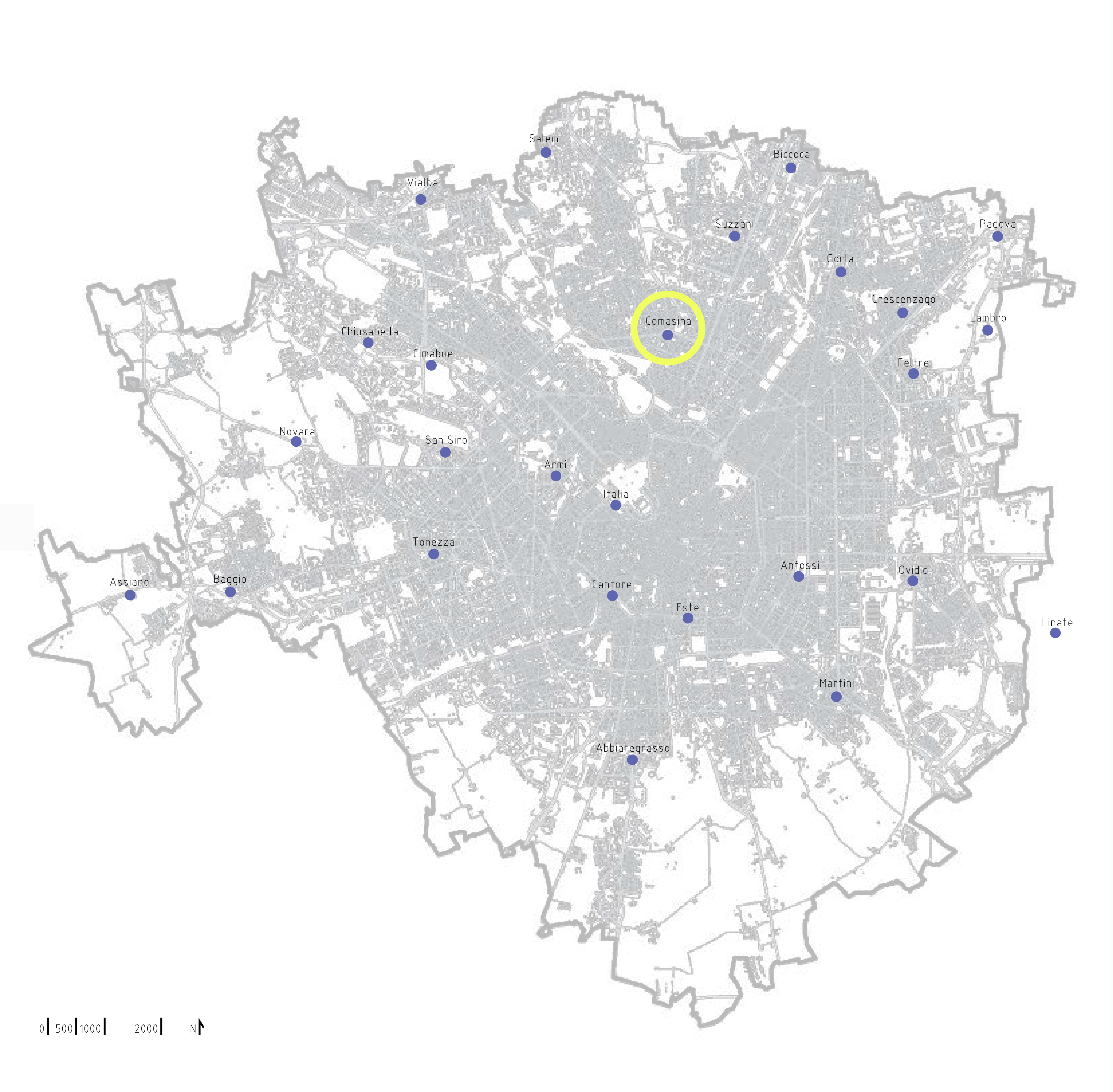
Contemporary System
Pumping stations and wells

The contemporary system is organized around 584 wells (about 400 active) connected to 32 pumping stations (28 active), each acting as a local node where groundwater is lifted, treated, and then pushed into the mains. From there, the network distributes water across roughly 2,209 km of pipes, supplying homes, fountains, and public facilities citywide.[195] Each pumping station uses a double lift system with a collection tank to settle fine material such as sand and silt. The production scale is about 220 million cubic meters of drinking water per year, with treatment steps that include aeration, activated carbon filtration, and reverse osmosis where needed, plus disinfection when required. It also describes intensive water quality monitoring, with 190,000 analyses per year on 18,000 samples taken across the system, including at pumping stations and fountains.[196]



Plans of Milan's Pumping stations.
Drawing: Jurica Pajic

3.3.9



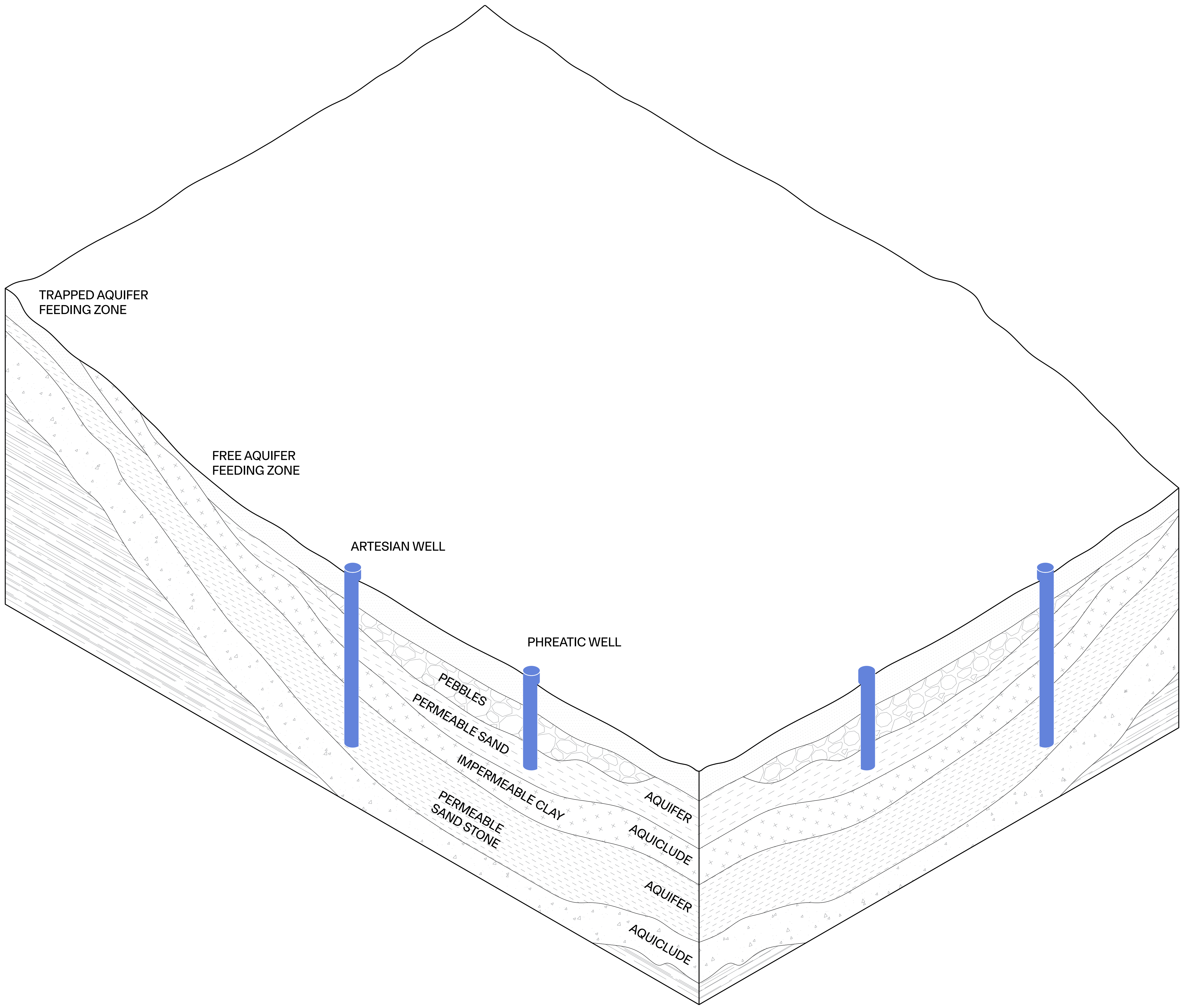
3.3.10 Locations of Milan's Pumping stations.
Drawing: Jurica Pajic

Pumping Stations[197]

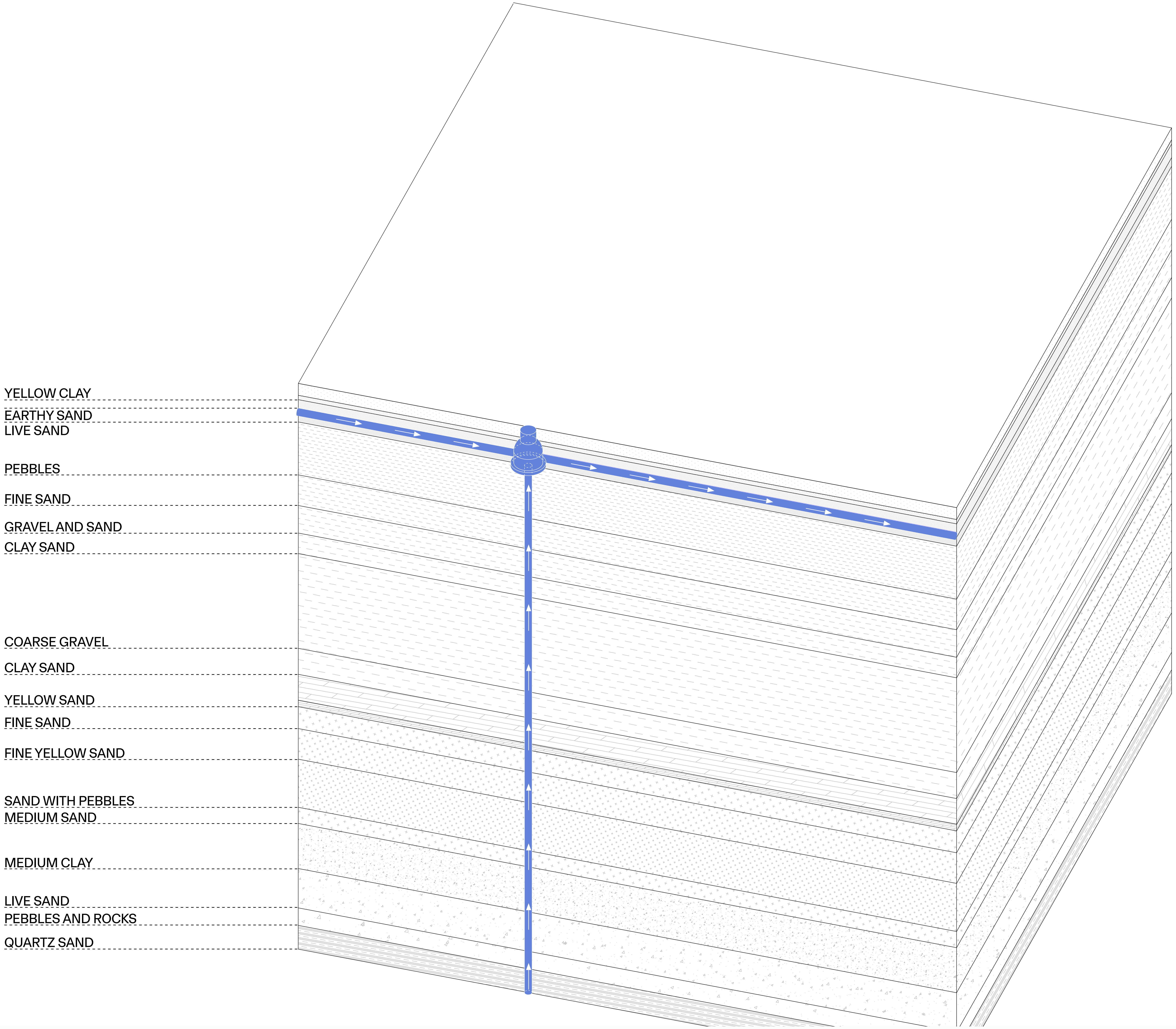
How do they work

aquifers (groundwater)
↓
wells
↓
pumping stations
↓
water treatment (aeration / carbon / osmosis / disinfection)
↓
storage tanks
↓
water distribution network
↓
buildings/users
↓
sewers
↓
main collectors
↓
wastewater treatment plants
↓
rivers/environment

Milan's pumping stations draw from two groundwater conditions: free aquifers, where the water table remains below the overlying impermeable layer, and artesian or semi-confined aquifers, where water is confined between impermeable strata and remains under pressure. In artesian conditions, once a well penetrates the aquifer, water can rise above the top of the layer and may even lift within the well without pumping, providing a reliable source for the city's supply system.[197]

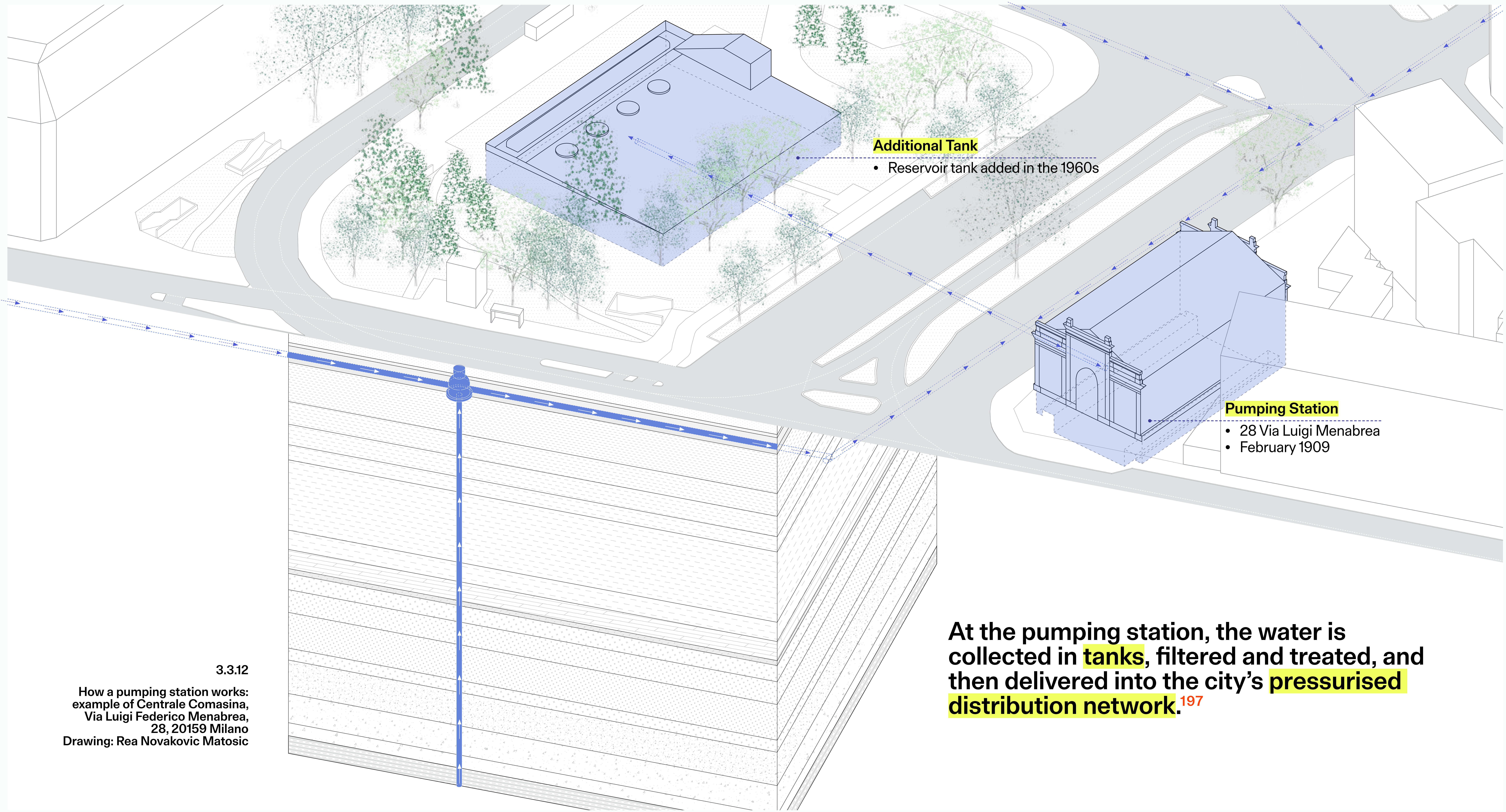


Subsoil, Stratigraphy & Aquifers 3.3.11
Drawing: Rea Novakovic Matosic



Rain infiltrates the ground over many years and fills underground layers of sand and gravel known as aquifers. The city drills wells as vertical shafts 40 to 100 metres deep to reach these aquifers. Pumps installed in the wells lift the groundwater to the surface. Short buried pipes, around three metres below ground, convey the water from each well field to a nearby pumping and treatment station.[197]

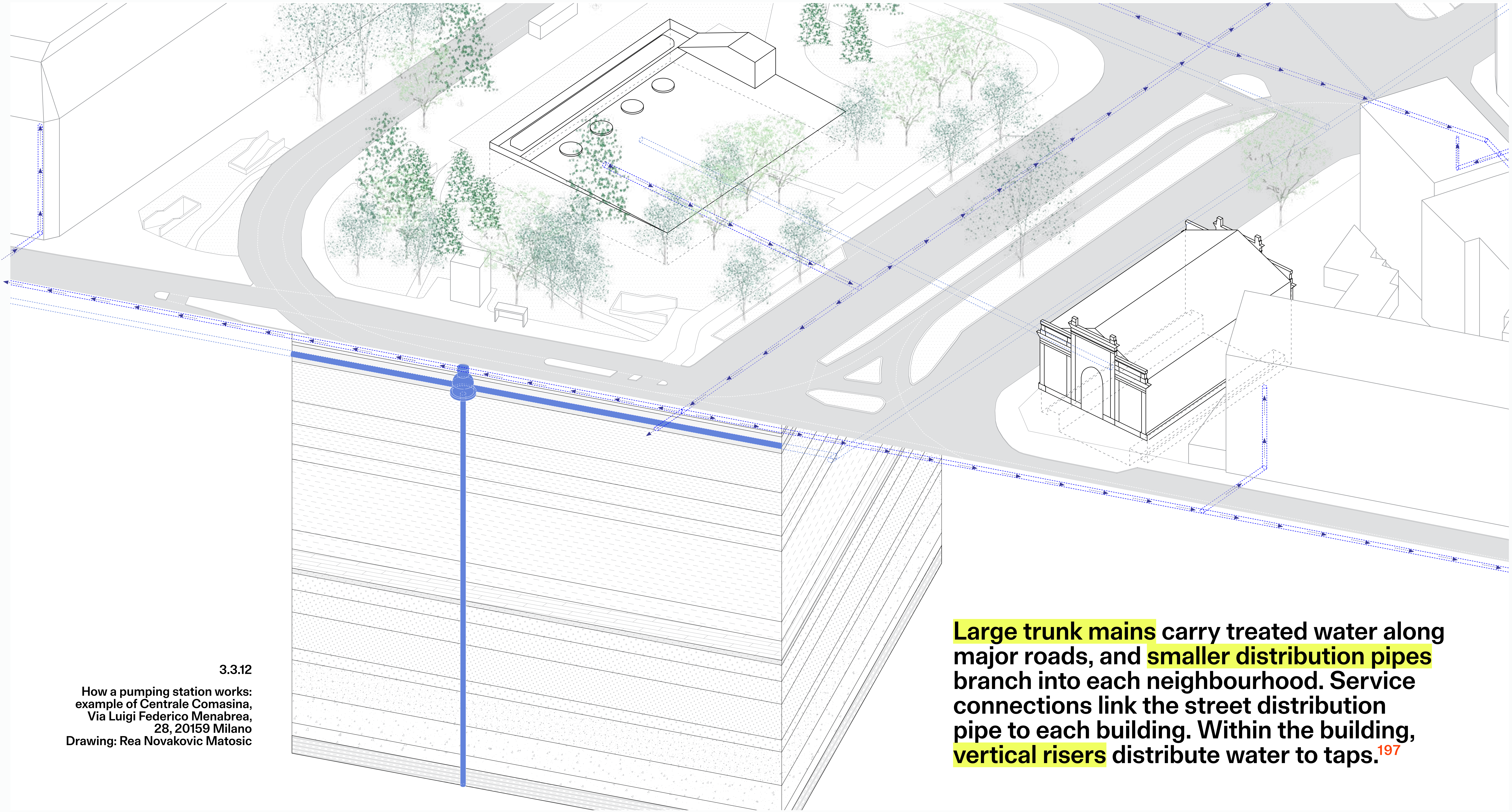
3.3.12 How a pumping station works: example of Centrale Comasina, Via Luigi Federico Menabrea, 28, 20159 Milano
Drawing: Rea Novakovic Matosic



3.3.12

How a pumping station works: example of Centrale Comasina, Via Luigi Federico Menabrea, 28, 20159 Milano
Drawing: Rea Novakovic Matosic

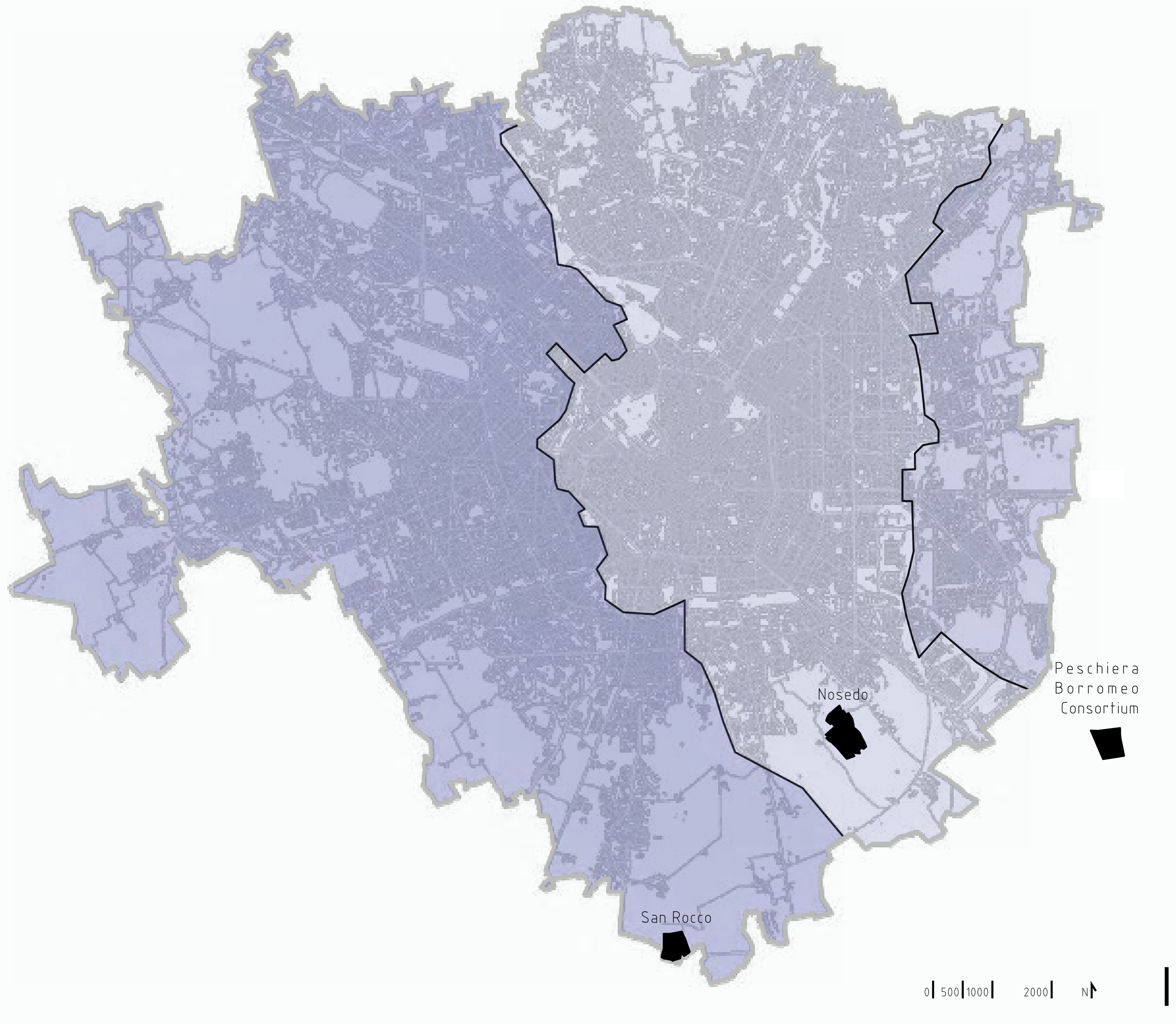
At the pumping station, the water is collected in tanks, filtered and treated, and then delivered into the city's pressurised distribution network.[197]



3.3.12

How a pumping station works: example of Centrale Comasina, Via Luigi Federico Menabrea, 28, 20159 Milano
Drawing: Rea Novakovic Matosic

Large trunk mains carry treated water along major roads, and smaller distribution pipes branch into each neighbourhood. Service connections link the street distribution pipe to each building. Within the building, vertical risers distribute water to taps.[197]



3.3.13 Locations of purifier plants and their operating areas.
Drawing: Jurica Pajic

Contemporary System

Combined sewers and treatment plants

Milan's municipal sewer network is a gravity-based combined system developed from the second half of the nineteenth century, designed independently from the surface watercourse network. It extends about 1,450 km of conduits, has an average age of 60+ years, and serves roughly 12,000 ha of urbanized area. It is structured around major collectors serving concentric zones around the historic center; stormwater is managed through large conduits plus a closed-mesh minor network that increases in-network storage capacity. The system includes 28 pumping stations, 8 network control devices, and 17 hydropluviometric monitoring stations.[198]

Downstream, wastewater treatment serves about 2,536,000 equivalent inhabitants across three plants: the Milano Peschiera Borromeo Consortium, Milano Nosedo, and Milano San Rocco facilities. The main line includes coarse screening (>30 mm) and fine screening (>3 mm), followed by grit and oil removal, activated-sludge biological treatment, sedimentation, sand filtration, and final peracetic acid disinfection.[199] Since 2003, the sewer network has been integrated with advanced treatment to enable agricultural reuse: about 90% of treated effluent from Nosedo and San Rocco is reused for irrigation downstream of the city.[200]

Sewer system network in Milano 3.3.14

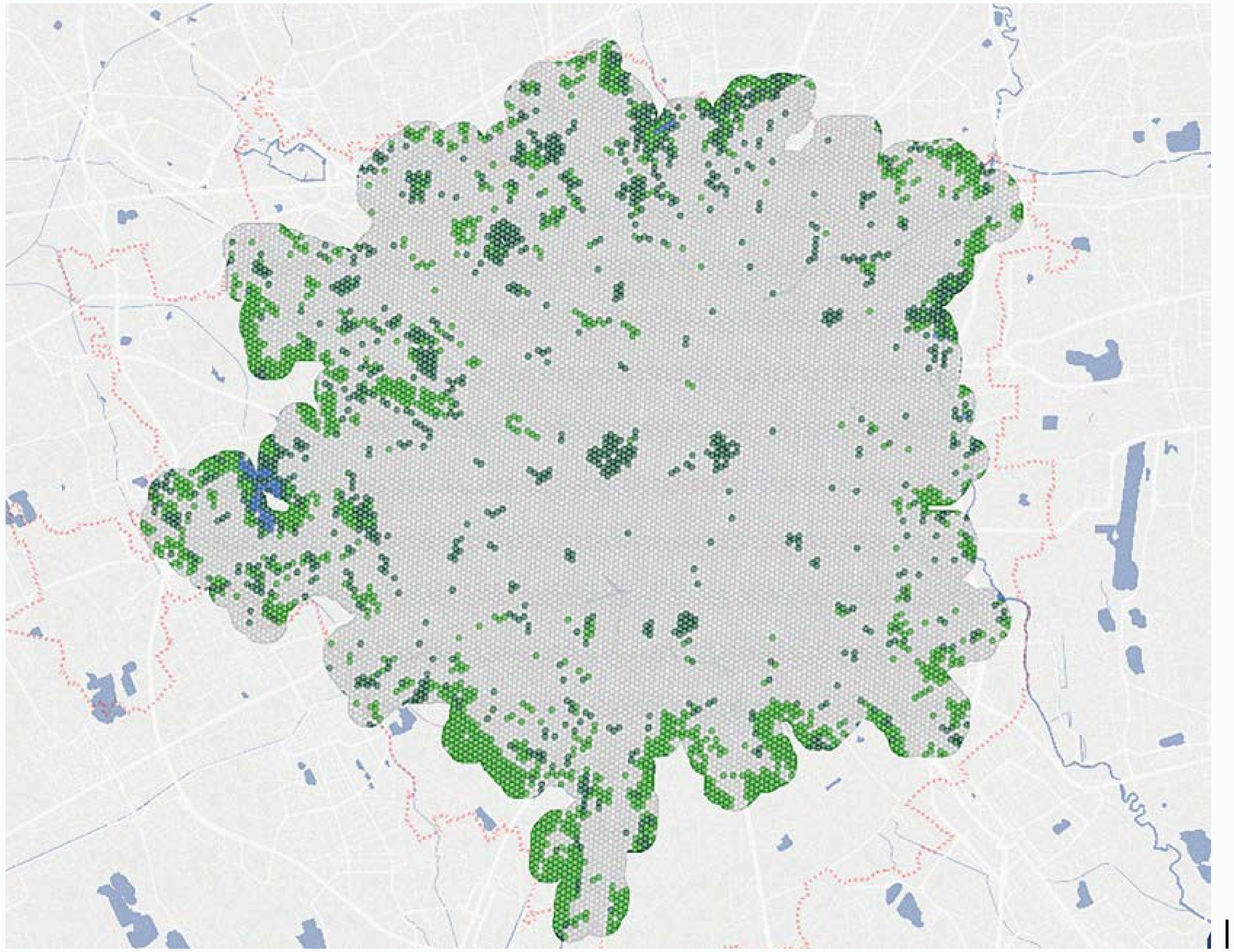
Firstly, large parts of the city operate with a combined sewer configuration, where rainwater and wastewater share the same hydraulic capacity. The network logic was shaped by Milan's low ground slope, shallow groundwater, and the absence of a strong downstream outfall for storm flows. Large conduits and distributed in-network storage were used to limit and delay discharges into watercourses, reducing the likelihood of overflow during peaks.[201] The stormwater strategy relies on the interaction between major collectors and a minor mesh network that provides additional distributed storage capacity.[202]

Second, the infrastructure is old at the city scale. MM Spa reports an average sewer age above 60 years, which means maintenance, upgrading and operational control as a permanent challenge.[202]

Third, Milan's floods often occur where river and channel overflows interact with the drainage network. Recurring overflow issues have involved both the Seveso and the Redefossi, and several mitigation works have reduced but not eliminated the problem. These include a Redefossi overflow channel built in 1976 and the Nord Ovest diversion system, which diverts waters from the Olona, the Naviglio system, and the Seveso toward the Ticino. Before the Seveso enters its covered urban route, a decantation and screening structure on Via Ornato improves conditions at the point where the river becomes an underground conduit.[203]

Floods and sewers are inseparable because storms overload a single interconnected network where runoff, wastewater and river flows converge.

Sewer system in Milano 3.3.15



3.4.1 Milan Urban Green Space Map (HUGSI, 2024)

04. Soil Permeability

Much of Milan's ground is sealed by urbanization and intensive land use. About 95 percent of the territory is impermeable, and only about 5 percent is neither urbanized nor agricultural. Over the last century, the number of rainy days per year in the metropolitan area drops from about 95 to about 79 while the total amount of water falling is broadly similar. Fewer rainy days, similar volumes, and limited infiltration capacity concentrate rainfall into more intense runoff and make flooding more frequent.[204]

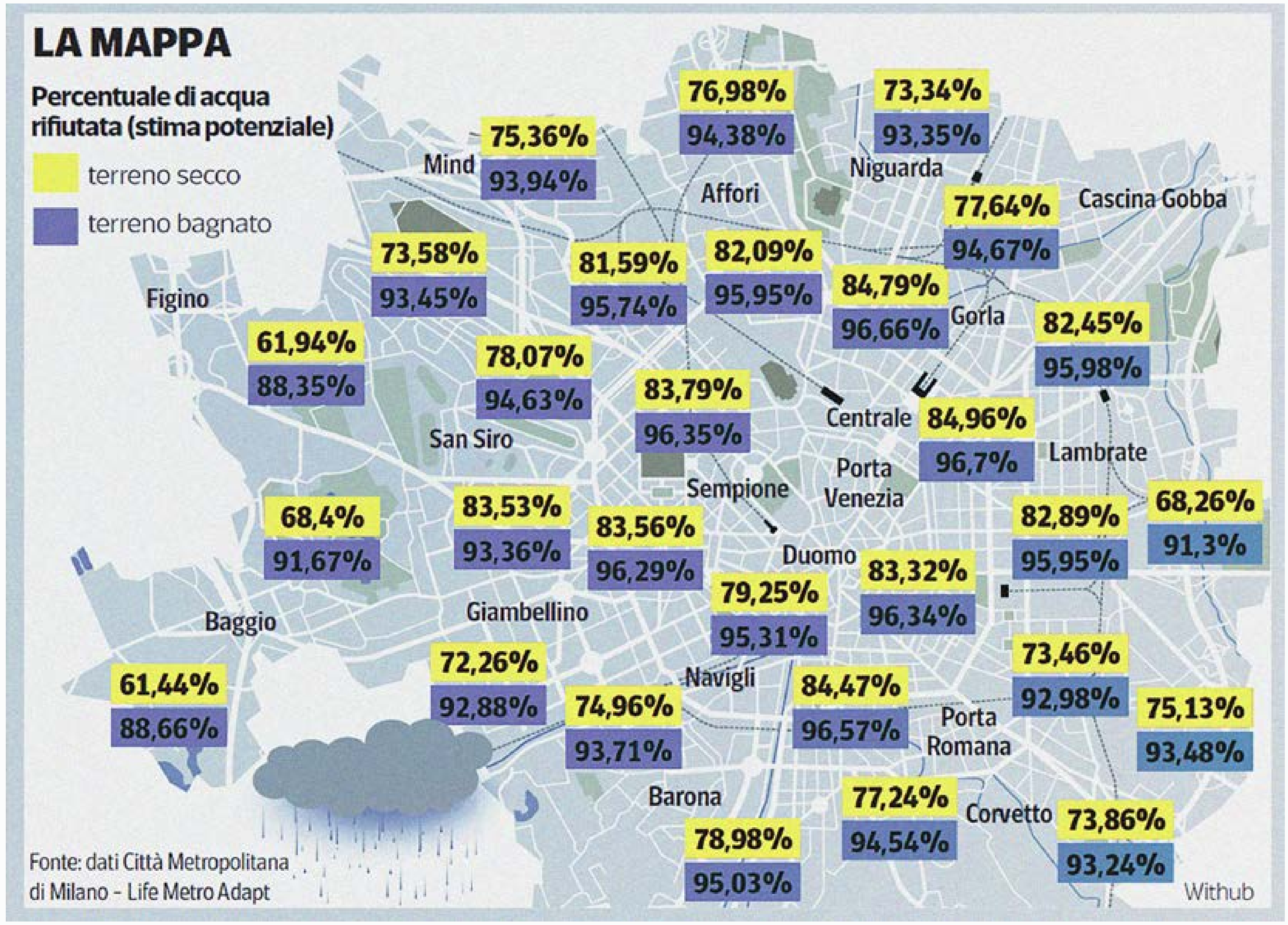
Runoff

Dry vs wet

Even in the best case, well over half of rainfall in Milan cannot infiltrate, and during back to back storms most rain becomes runoff, which overwhelms sewers and increases flood risk.[205] At the metropolitan scale, about 71 percent of rainfall becomes runoff under dry soil conditions, rising to about 92 percent when the ground is already wet, and to about 94 percent within Milan.[206] In dense central districts, roughly 83 to 85 percent of rainfall becomes runoff even on a dry day, increasing to around 96 percent under wet conditions.[205] This excess water is routed across streets and into the drainage network, increasing hydraulic stress and the operational burden on sewers.[206] The map indicates where unsealing, tree pits and bioretention, permeable paving, and detention or storage would deliver the largest runoff reductions, especially where values are highest or where runoff rises sharply from dry to wet conditions.[205]

yellow = share of rain the ground rejects when it is dry

blue = share of rain the ground rejects after rain



Map of rainwater runoff percentage (potential estimate) 3.4.2

3.4.3 The Seveso entering its covered urban section in northern Milan

Covered Seveso
Limited capacity

Low permeability turns rainfall into rapid surface runoff, which sharpens peak flows in a system with limited spare capacity. In Milan, this effect is amplified because the Seveso runs through a fully covered urban section, with no open corridor to absorb, spread, or slow water. Downstream of the CSNO intake, the added runoff generated by sealed surfaces can quickly push the channel and culvert system toward its conveyance limit, even during relatively frequent events. Once that capacity is reached, excess water has little room to dissipate and flooding becomes recurrent across the metropolitan area, including within Milan.[207]

Increasing permeability where possible, and pairing it with storage and controlled discharge where it is not, is therefore central to reducing flooding.

Milan Heat and Soil Sealing (2017–2022 / 2022); KoozArch, SOIL > cement (commissioned by the Urban Center of the Municipality of Milan), using ISPRA soil consumption data (2022) and temperature mapping (summer daytime mean 2017–2022). 3.4.4

3.5.1 “Seveso, 60 anni di esondazioni”

05. Where the System Breaks

Milan’s flooding problem is chronic. Seveso overflows have been recorded for decades, and they recur several times a year. Between 1976 and 2014, 104 Seveso overflow events were recorded in Milan, about 2.6 per year, with peaks of eight events in 2010 and eight events in 2014.[208] Additionally, peak flows in the Milan area can reach or exceed 40 cubic meters per second.[209]

1970 · 1980 · 1990 · 2000 · 2010 · 2020 · 2030

1976

Flooding had been happening since the 1950s, but this was the year when three occurred in the single month of October on the 3rd, 13th, and 30th. It was also the year of the Seveso disaster, the dioxin cloud that spread over the lower Brianza. Therefore, 1976 earns the title of "annus horribilis" in the history of the Seveso.[210,211]

3.5.2-3
3 October 1976: the Seveso floods the Niguarda–Viale Fulvio Testi area.
Fotogramma

1977

Jul 30, 1977 - city flooding
Aug 29 & Oct 9, 1977
Seveso (Niguarda)[210]

1978

Feb 26, May 23 & Jun 17, 1978 flooding episodes (incl. Niguarda)[210]

3.5.4 26 February 1978: flooding in the Viale Suzzani / Ca' Granda area.
Fotogramma

1979

Aug 18, Sep 22, Oct 13 & Dec 22, 1979 - widespread flooding (Viale Zara & other areas)[210]

3.5.5 13–17 October 1979: wooden footbridges in Niguarda. Fotogramma

1980

Oct 1980
Seveso (Niguarda)[210]

1981

Sep 24, 1981
city flooding[210]

1984

May 4 & May 27, 1984
multiple locations[211]

1988

Jun 5, 1988
city flooding
Oct 30, 1988
Seveso (Niguarda)[210]

1992

Jul 11, 1992
Lambro/Parco Lambro–Rogoredo area flood[210]

1993

Aug 27, Sep 23 & Sep 25, 1993 city flooding[210]

3.5.6 31 January 1993. Fotogramma

1994

Jul 28, 1994
Seveso (Niguarda)
Nov 6, 1994
Lambro (Parco Lambro)[210]

1996

Jun 22 & Jul 2, 1996 Seveso
Lambro events
Oct 16 & Nov 14, 1996
multiple city sites (Lambrate, Ponte Lambro, Via Mecenate)[210]

1997

Aug 6, 1997
Via Valfurva flooding[210]

1998

Jul 3, 1998
Seveso (Niguarda)
Oct 8, 1998
Via Feltre flood[210]

1999

Nov 6, 1999
Via Marotta flooding[210]

2000

Nov 6, 2000
Vettabbia valley flood[212]

3.5.7 1st of September 2000.
Fotogramma

2002

Nov 26, 2002 Major flood: Seveso & Lambro overflow severe damage across N. Milan (Zara/Istria areas)[213]

3.5.8-9 26 November 2002.
Shutterstock

2010

Sep 19 & Oct 18–19, 2010
Severe flooding
Metro closures
~€70 m damages[214]

3.5.10 October 2010

2014

Jun 24, 2014 Flooding begins ahead of July events

Jul 8, 2014 Major Seveso overflow (Niguarda/Isola; power cuts, streets under water)

Jul 26, 2014 Seveso overflows again (Fulvio Testi/zone nord)[215,216]

There were six–nine Seveso overflows between July–Nov 2014, making 2014 the peak year

3.5.11 July 8, 2014.
Federico Ferramola / LaPresse

2023

Oct 31, 2023 Seveso overflow (≈6 hours) Niguarda/Isola & Fulvio Testi hit[217]

3.5.12 October 31, 2023. Matteo Corner/ Shutterstock

2024

May 15–16, 2024 Lambro & Seveso overflows after 24h of heavy rain; widespread flooding across Milan & Lombardy[218]

3.5.13 "The constant rain in Milan this week saw the River Lambro burst its banks"

2025

Sep 22, 2025 Seveso overflow (≈9 hours): Niguarda & Isola flooded[219]

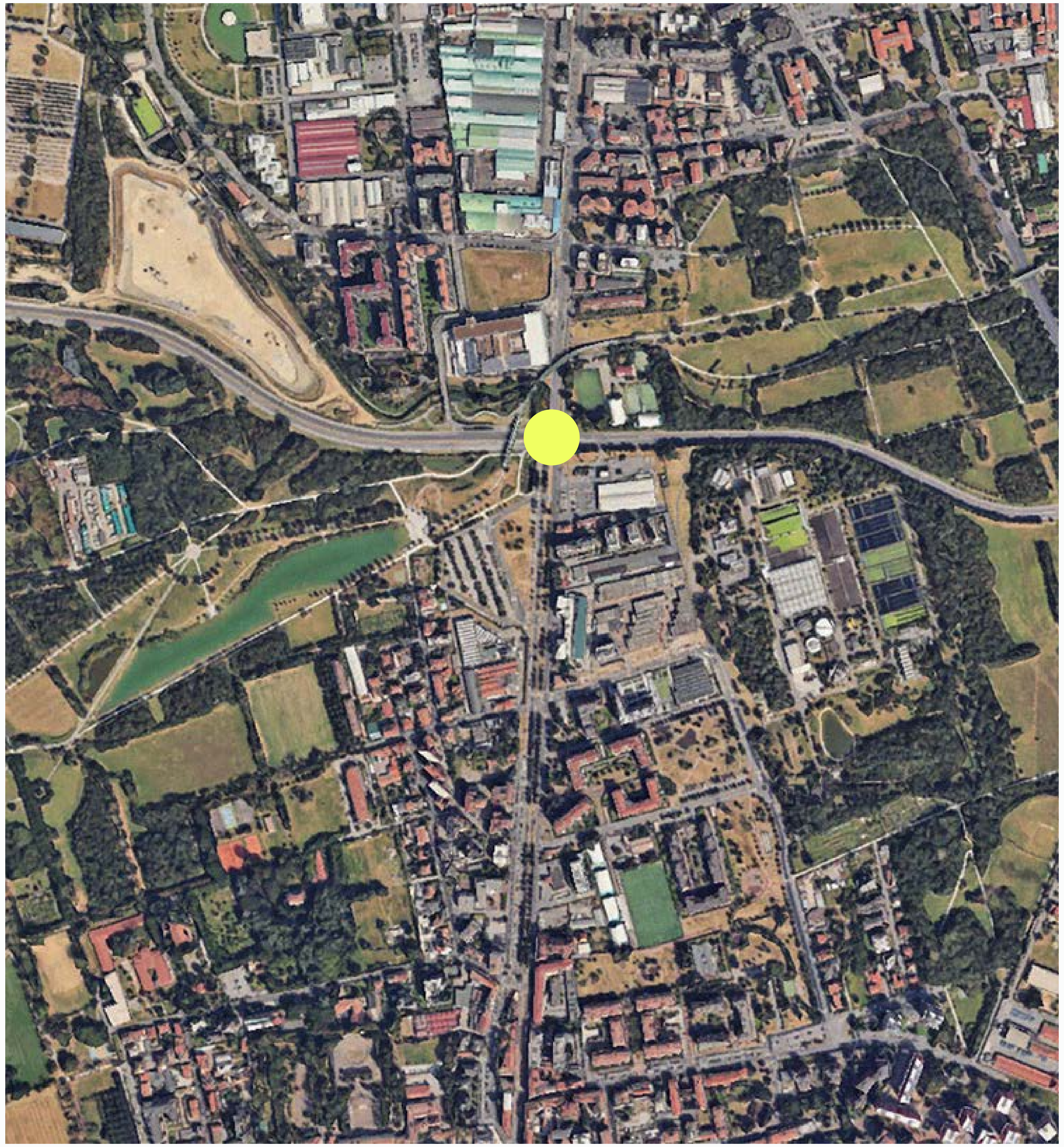
3.5.14 "Seveso floods, Lambro alert"

Flood Impacts
Disruption and high losses

When flooding hits, the impact can scale fast from local disruption to network level damage. In October 2010, Seveso flooding was reported to have disrupted the metro and produced an estimated 70 million euros in damage.[220] The 14 July 2014 event damage assessment describes more than 60 millimeters of rain in five hours, a flooded area of about 3 square kilometers in North Milan, and the officially reported losses of 27.2 million euros, mostly private owners suffering. But total building losses are estimated to be even higher when modelling the event at building scale.[221]

Flooding in Milano, July , 2014.
Federico Ferramola / LaPresse

3.5.15



3.5.16 The Seveso entering its covered urban section in northern Milan: Via Luigi Ornato × Via Aldo Moro, Google Maps

System Bottleneck
Culvert capacity

Several reasons explain why the Seveso remains such a big problem. The downstream conveyance in Milan was shaped by late nineteenth century decisions to cover and channel the river underground, and this culverted system is now insufficient and cannot realistically be upgraded, with a maximum discharge capacity of about 40 cubic meters per second for the Seveso-Redefossi system. Once peak flows exceed that ceiling, the risk of surface flooding rises significantly.[222] The critical threshold is where the open corridor becomes underground near the Parco Nord edge (Via Luigi Ornato × Via Aldo Moro): this transition works as a funnel and bottleneck, so pressure builds upstream and seeks escape routes across North Milan's streets.

Milan can flood even when there is no rainfall in the city because storms upstream in the Seveso basin can push high flows into the covered reach, which has limited capacity and little space to dissipate peaks. Under critical conditions, water runs under pressure inside the culvert and can surface through manholes, producing street flooding driven by upstream inflow rather than local rain.[223,224]

Runoff Control / Discharge Limits

Invarianza idraulica e idrologica

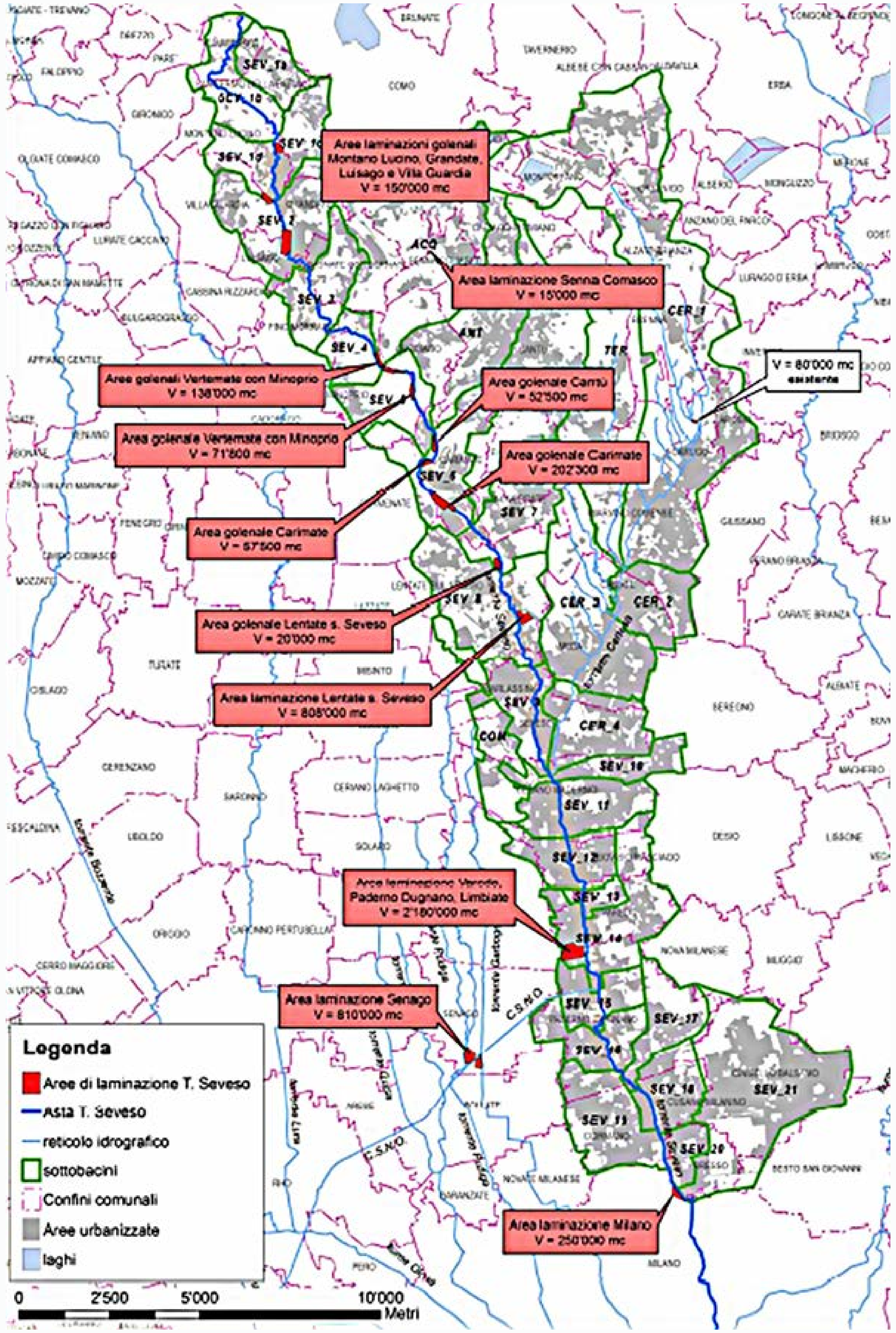
This is also why the Lombardy framework for *invarianza idraulica e idrologica* targets runoff at the source. When you build, renovate, or pave over land, you are expected not to worsen stormwater runoff for the neighborhood and downstream watercourses, because impermeable surfaces reduce infiltration and push more water faster into drains and rivers. The basic rule is that if an intervention increases sealed surface area, it must add measures so that the amount and speed of water leaving the site remains similar to before, typically through on-site reuse, infiltration, or temporary storage with slow release, and only when necessary, discharge to sewers or water courses under defined limits.[225]

The same regulation sets maximum allowable discharge rates based on hydraulic criticality. In high criticality areas, the limit is 10 liters per second per hectare. In medium and low critical areas, the limit is 20 liters per second per hectare. Stricter limits may apply if required by the manager of the receiving network.[226] The guidance also defines reference minimum detention volumes per hectare of impervious drained surface. The values are about 800 cubic meters per hectare in high criticality areas, 500 in medium criticality areas, and 400 in low criticality areas. In high critical areas, an additional reduction coefficient is applied.[227] For small interventions, the same annex allows simplified compliance procedures for projects under 300 square meters.[226]

The allowed discharge depends on how critical the area is:

- high (Area A): max 10 liters/second per hectare
- medium (Area B): max 20 liters/second per hectare
- low (Area C): max 20 liters/second per hectare

Invarianza idraulica e idrologica - website 3.5.17



3.5.18 Proposed project layout for the Seveso stream

Detention Storage

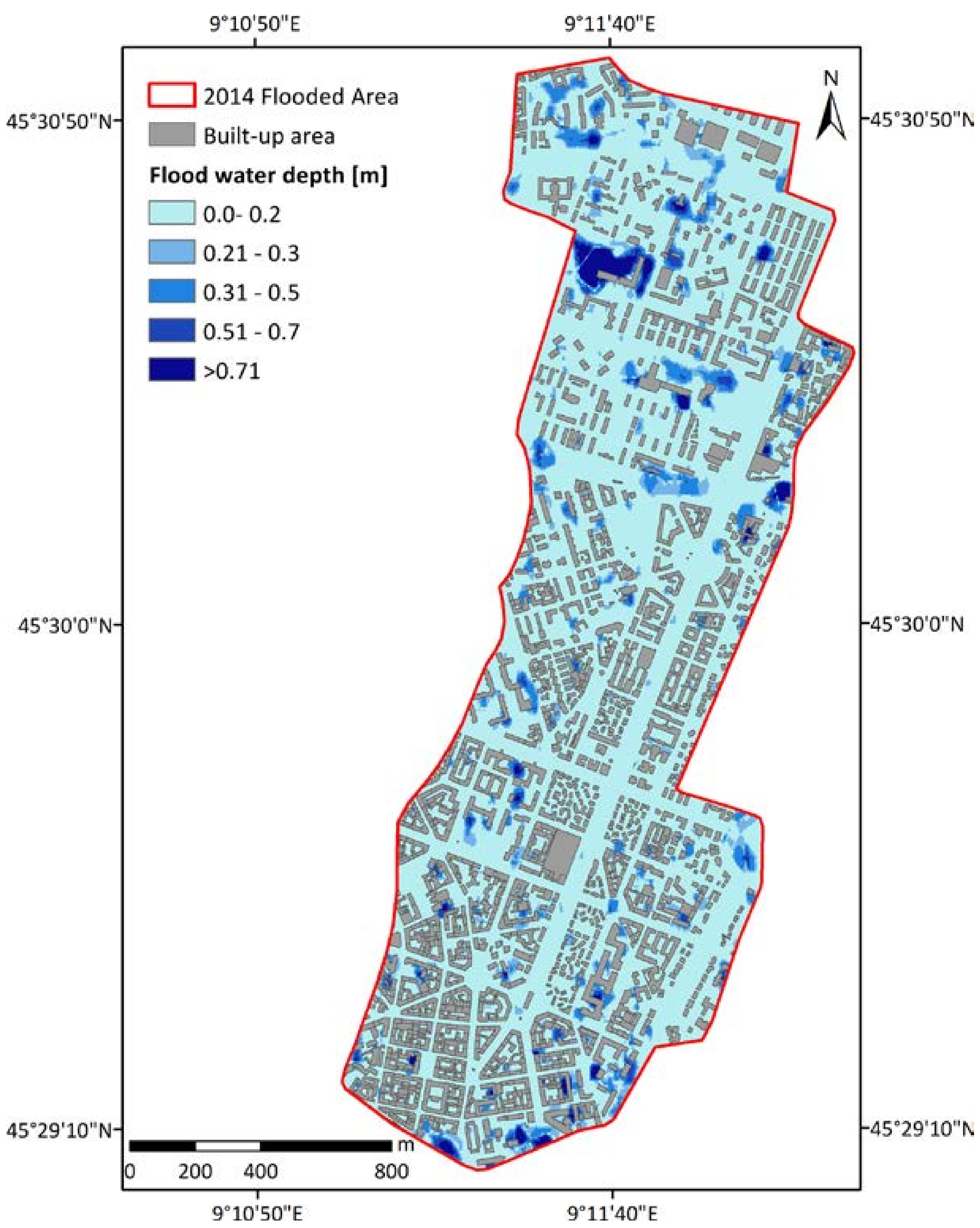
Le vasche di laminazione

Nevertheless, downstream discharge capacity remains limited, so detention storage along the river is a main lever for reducing flood peaks. Avoiding overflows requires about 4.8 million cubic meters of total detention capacity distributed along the Seveso. Detention can be in line, within the river system, or offline. Offline basins sit beside the river, fill only when water levels exceed a set threshold, and then release water later through a dedicated outlet, lowering the peak discharge downstream. The main planned storage volumes and locations include about 150,000 cubic meters in the upper basin, about 522,000 cubic meters in floodplain style areas around Vertemate con Minoprio, Carimate, and Cantù, about 828,000 cubic meters at Lentate sul Seveso, about 2,200,000 cubic meters across Paderno Dugnano, Varedo, and Limbiate, about 810,000 cubic meters at Senago, and about 250,000 cubic meters at the Milan basin.[228]

At Lentate sul Seveso, the detention basin is at executive design stage, and the works have been tendered. The total capacity is 828,000 cubic meters, made up of 20,000 cubic meters of floodplain storage and 808,000 cubic meters in an excavated basin. The basin is emptied through a combination of gravity discharge and pumping, with a total emptying time of roughly 60 hours.[229] In Milan, the Parco Nord Bruzzano basin is a 250,000 cubic meter retention area designed to store Seveso floodwater. It was built between 2015 and 2023, has a stated value of 30 million euros.[230]

Damage Pattern
Even shallow floods still cost

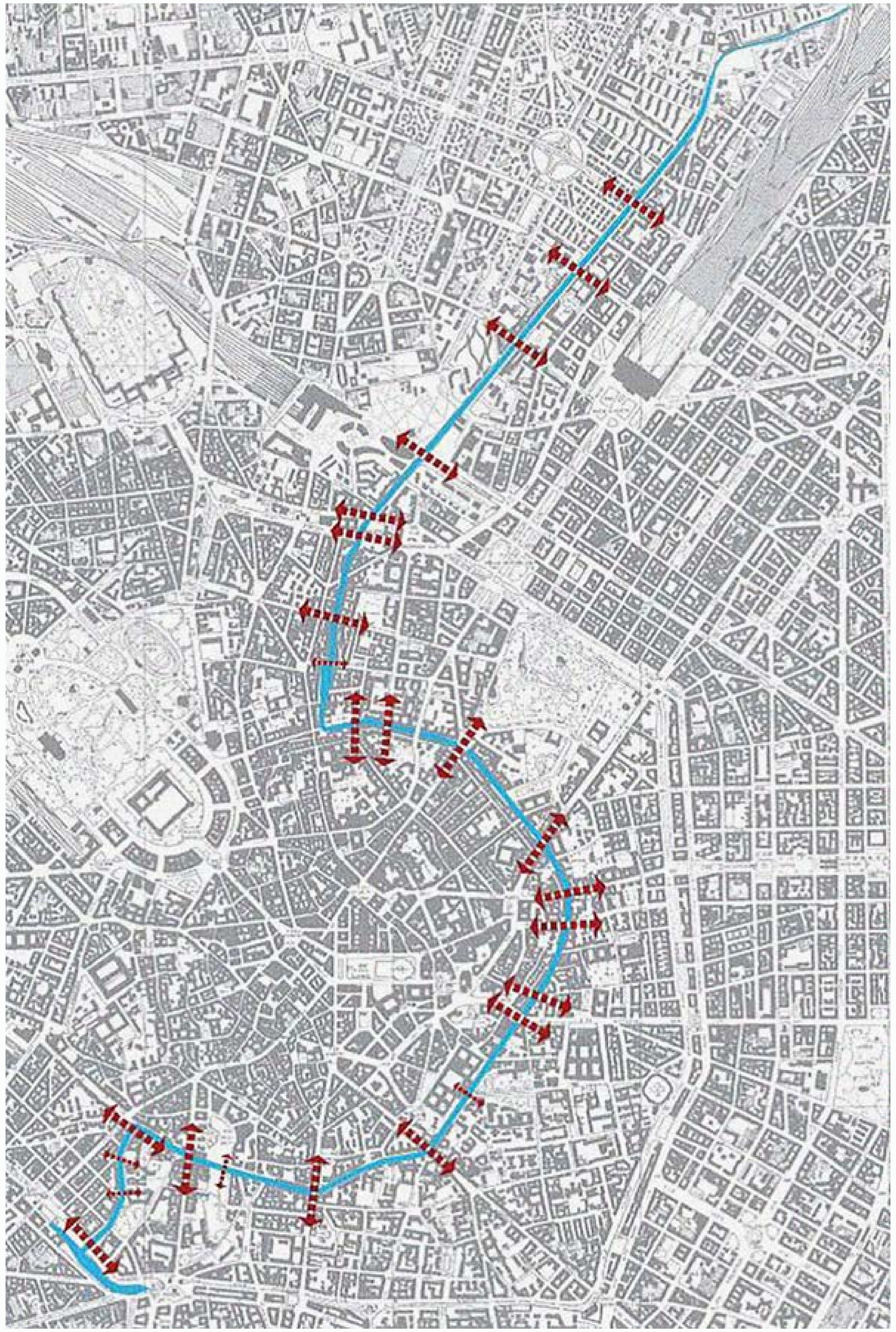
A 2014 damage study shows why even shallow flooding can cause major losses in dense neighborhoods. It reconstructs flood depths from the mapped 2014 flood extent using a 5-meter by 5-meter terrain model. After correcting for building footprints and terrain artefacts, it estimates a mean flood depth of about 19 centimeters and a 90th percentile depth of about 42 centimeters. It finds that 81 percent of flooded residential buildings are inside/near mapped topographic sinks. The study assesses 1,540 residential buildings using a framework that combines hazard intensity, urban flow pathways, and building vulnerability, including whether basements are present. To conclude, flood damage concentrates where micro topography, sealed ground, and vulnerable building types exist together. This is why runoff control rules and distributed storage infrastructure both matter.[231]



3.5.19 Estimated flood depths for the flooded polygon in Milan. Built-up-area shapefile from OpenStreetMap contributors 2022. Distributed under the Open Data Commons Open Database License (ODbL) v1.0. Base map is from © Regione Lombardia 2022.

Flood risk management in Milan requires two coordinated measures: source control to prevent runoff and detention basins along the Seveso.

La vasca di laminazione, Parco Nord, Google Maps 3.5.20



3.6.1 The route of the reopened Navigli canals with the 25 bridges

06. Should We Reopen the Navigli?

Reopening Milan's inner Navigli has been framed as a gradual and potentially partial return of the historic water trace, starting from the still open Martesana and reconnecting it through the former inner ring to the Darsena, then toward the larger canal system.[232,233]

Referendum
Beginning and timeline

The idea about the reopening of Milan's inner canal ring (Cerchia interna) was triggered by the 2011 consultative referendum and later incorporated into the city planning framework, which treats the canal trace as a high landscape sensitivity corridor and calls for a feasibility-led approach that prioritises public space, cycling, and urban green while managing impacts on traffic and public transport. In this context, the Politecnico feasibility study (2014) frames the project as a technical and urban infrastructure intervention, requiring the canal to operate simultaneously as a water system, a public-space structure, a mobility corridor, and, where feasible, a navigable route.[232,233]

I nuovi Navigli Milanesi. Storia per il futuro. Book cover 3.6.2

2011

12–13 June 2011
Milan's consultative referendum approves (with a strong "Yes") the goal of restoring the Darsena and gradually reactivating the Navigli system through a feasibility-driven pathway.[234,235]

3.6.3 Referendum.
Niccolò Caranti

2012

22 May 2012
The PGT (Piano di Governo del Territorio) is approved by City Council, framing major strategic transformations that later include the Navigli reopening agenda.[236]

3.6.4 PGT 2012 - website

2013

13 June 2013
A formal convention between Comune di Milano and Politecnico di Milano (DAStU) starts the feasibility-study workstream.[234]

2014

Dec 2013 – Jan 2014
The study's first phase closes and early results are consolidated into an initial report package.[237]

2014

14 April 2014
A second convention is launched, strengthening the technical framework and collaboration around the feasibility work.[234]

2015

26 April 2015
The Darsena reopens after redevelopment, becoming the most tangible "water-system" milestone connected to the broader Navigli narrative.[238]

3.6.5 "Riaperta la Darsena"

2015

10 June 2015
The feasibility study conclusions are presented publicly at Palazzo Reale (Comune + Politecnico), making the findings widely accessible.[239]

June 2015
Media highlight the feasibility package with headline figures on costs/benefits, keeping the project in the political-public arena.[240]

2017

Nov 2017
MM S.p.A. drafts a PFTE (technical–economic feasibility) for hydraulic reconnection + reopening of selected inner stretches (Phase I).[241]

2018

26 Mar – 17 Apr 2018
City governance acts (Council agenda item + Giunta decision) formally trigger a public-debate process around the PFTE.[241]

3.6.6 Facilitated table discussion during the 2018 Milan Public Debate on the Navigli reopening

2018

11 June 2018
The Dibattito Pubblico opens with the Mayor's presentation and publication of the project dossier online.[241]

3.6.7 Cover of Dibattito Pubblico Riapertura dei Navigli Milanesi: Relazione finale (final report)

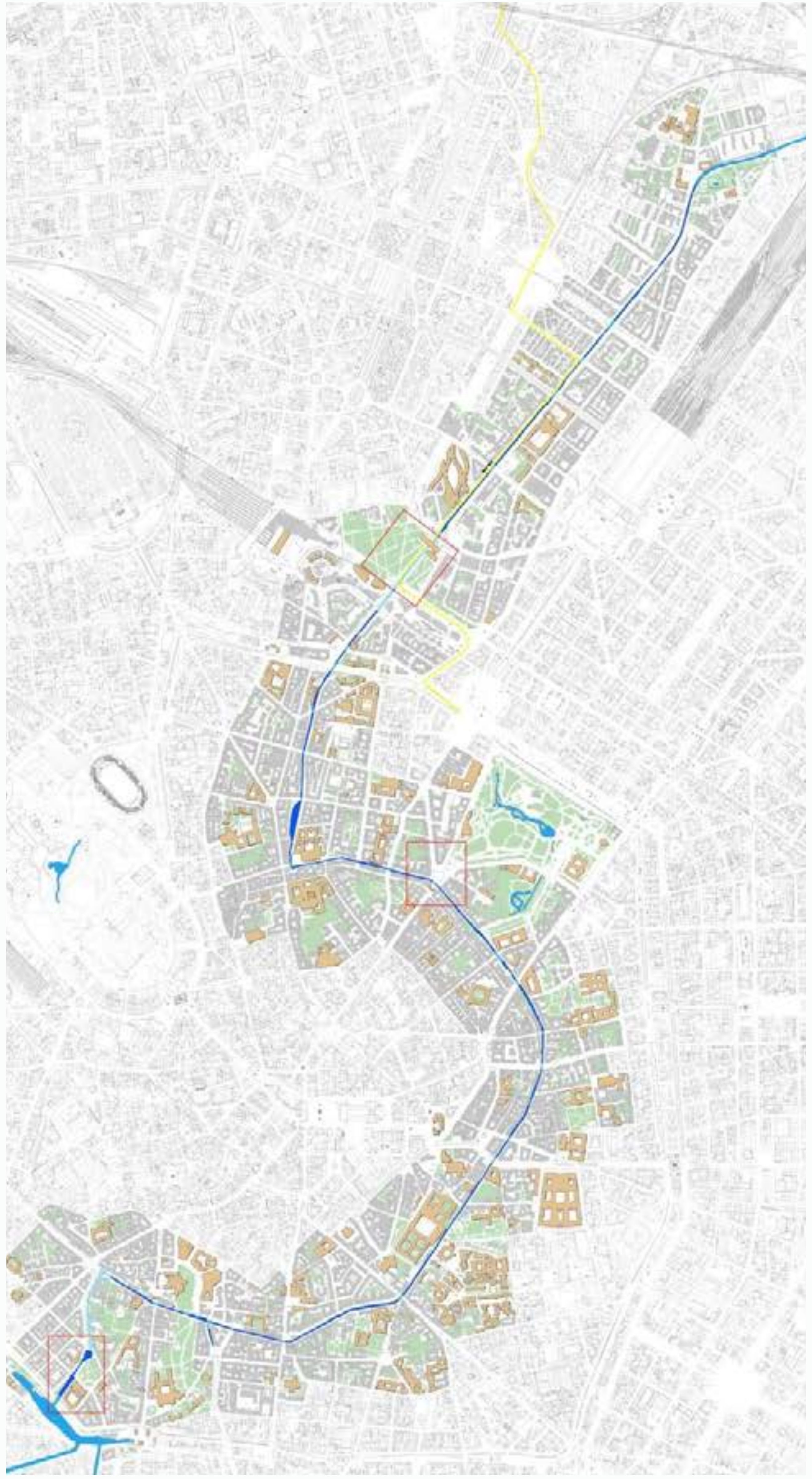
2018

24 Sept 2018
The debate closes with the Relazione conclusiva presented to the city, summarizing positions, issues, and requests for revisions.[241,242]

Oct 2018
The final report is revised to integrate requested notes.[241,242]

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

the conversation goes quiet due to other political priorities and the COVID-19 epidemic



3.6.8 Cassina de' Pomm–Darsena Navigli Route

Canal Reconstruction
Hydraulic model

In technical terms, the corridor is treated as infrastructure as much as public realm. A hydraulic model was developed for about 8.1 kilometres from Cassina de' Pomm to the Darsena, with goals that include securing flows for hygiene and usability, setting water levels for tourist navigation, locating locks, estimating travel times, and testing a hydraulic disconnection between the Seveso and the Martesana. The historic inner ring was covered in 1929 for hygiene reasons, so the intervention is not a simple uncovering of an intact canal. It is a reconstruction that requires choices about sections, crossings, and how the canal sits within today's streets and underground systems.[232,233]

Flooding Limits
Upstream peaks

It is also important to be clear about flooding. This corridor begins inside the city and includes the point where the Seveso meets the canal system near via Melchiorre Gioia, so it can only influence how water is routed and managed once flows are already in Milan. Flood peaks that drive Milan's most disruptive events form upstream of this threshold, so reopening the inner Navigli cannot solve Milan's flooding on its own. It can still support risk reduction at the margin through routing choices and coordinated upgrades inside the same corridor, but the core problem starts long before via Melchiorre Gioia.[232,233]

Location of the Martesana–Seveso junction in Milan. Google Maps. 3.6.9

Reopening the inner Navigli can improve water management in the city, but flood risk depends on managing upstream peaks.

Navigli, Milan 3.6.10

Milan flood risk is a layered system problem. Flooding occurs when fluvial peaks from the rivers meet a city that has limited hydraulic room because key corridors are culverted, surfaces are sealed and pipes are shared between stormwater and wastewater.

The worst events happen when these mechanisms coincide. High river levels reduce the ability of sewers and collectors to discharge, while intense rainfall fills the sewer network and keeps water on streets. In that condition, flooding becomes both surface driven and pressure driven, with disruptions scaling quickly from local inundation to network failure across transport, utilities and buildings. Groundwater adds a further constraint by shaping where infiltration is viable and increasing sensitivity for tunnels, basements, and buried infrastructure.

This complexity leads to a conclusion: Milan needs coordinated action across four layers at once. Upstream river detention and smarter diversion for fluvial peaks, source control and added buffers for pluvial runoff, street and public space redesign to manage surface pathways and protect weak points, and groundwater aware design.

Water resilience in Milan depends on coordinated action across rivers, canals, collectors, sewers, streets and groundwater.

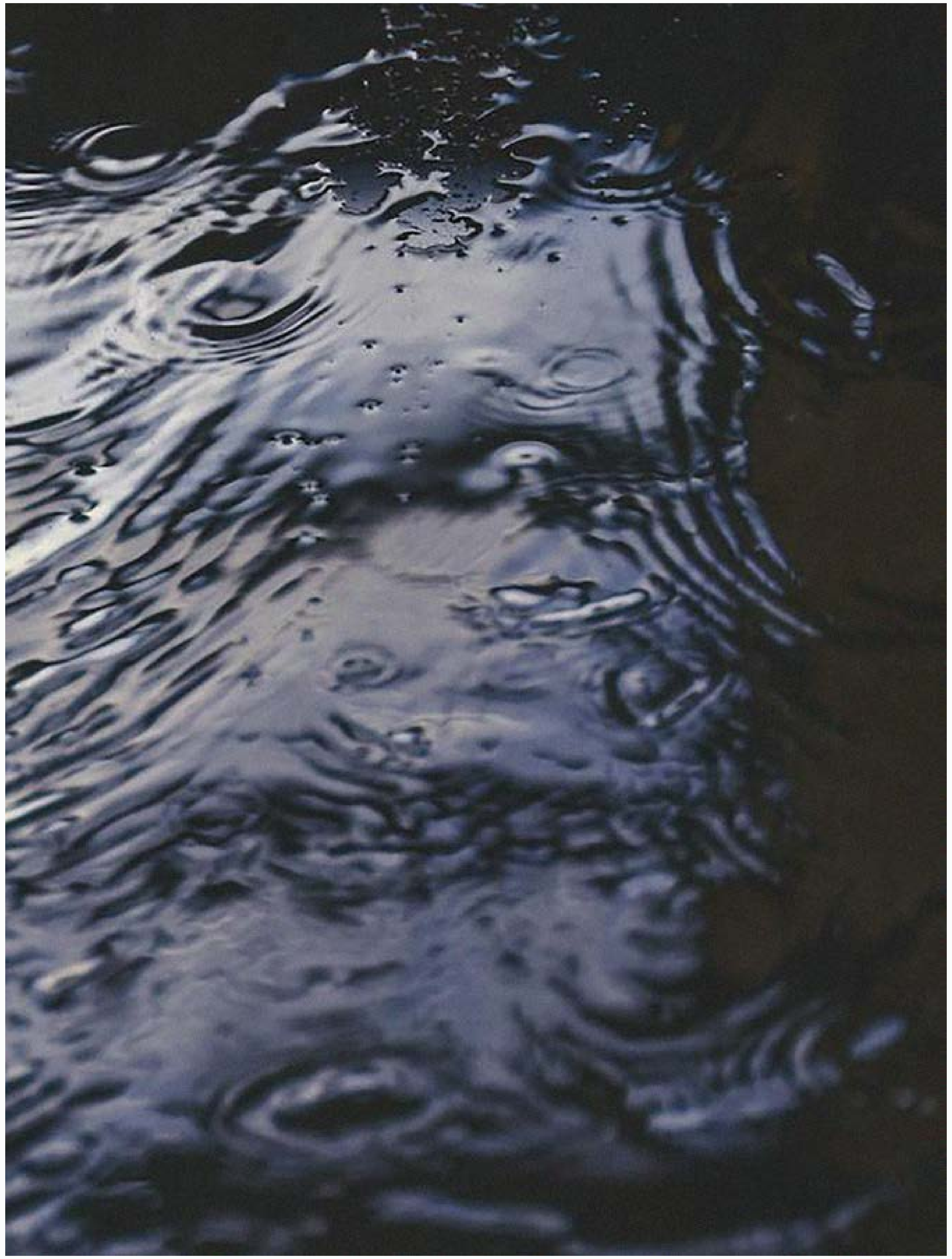
Designing a Response
Conclusion

”How to File a Claim After a Flood“ 4.0

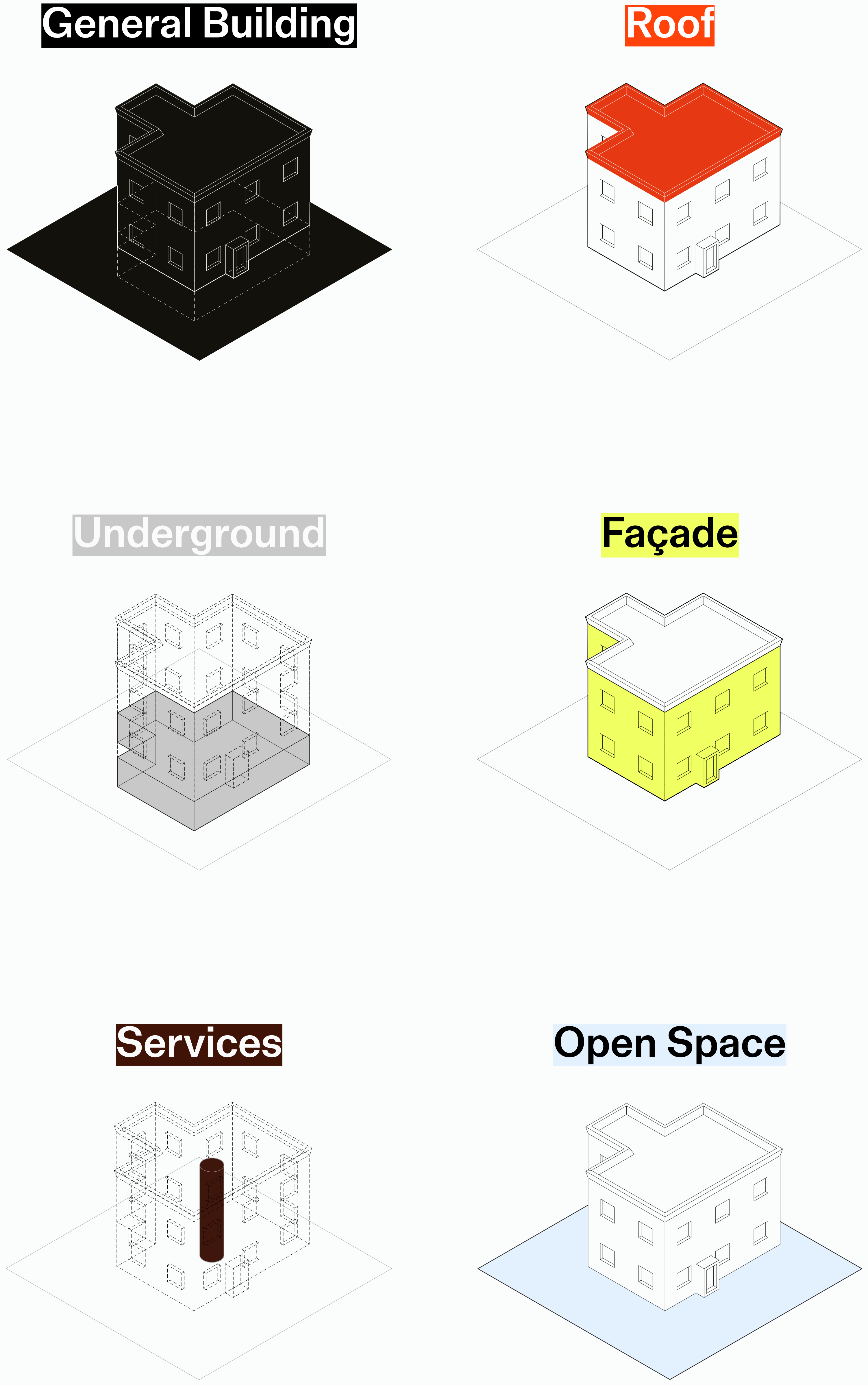
Designing a Response

No single intervention can resolve urban flood risk because the problem is produced across multiple layers at once. Rainfall intensity, ground permeability, waterways, drainage networks, public space and governance decisions all interact to create conditions where disruption happens.

Resilience is therefore a multi-scale design task. This is why solutions must connect scales, and why this research focuses on what architects can implement in everyday practice through repeatable micro strategies while also defining a direction for longer-term change.



"How to File a Claim After a Flood" 4.0



4.1 Elements of a building. Drawing: Rea Novakovic Matosic

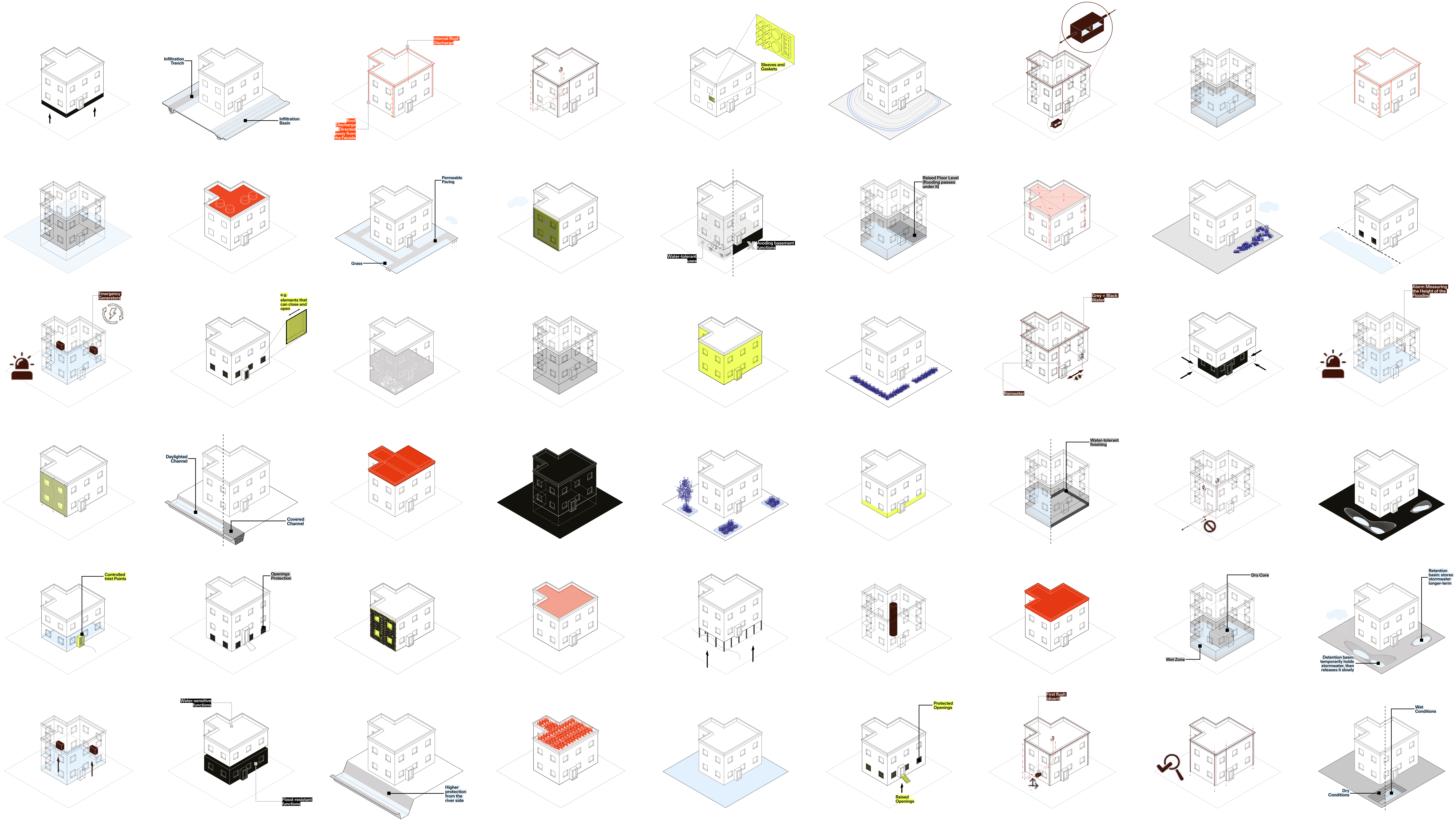
Design Strategies for Daily Practice

Flood risk management is often discussed at the scale of rivers and major infrastructure, but a large share of impact is determined at the scale of buildings and streets. This section shifts the focus to the micro scale, where exposure, damage, and practical adaptation measures can be assessed and implemented through everyday design and renovation decisions.

Flood risk is not uniform across the city. It changes with the location and features of individual buildings, so assessment needs to work at micro scale and account for the uneven distribution of the building stock. Micro scale methods can estimate damage across multiple flood events and test different levels of property level protection, producing inputs that support practical decisions and cost benefit analysis for risk reduction.[243]

Flood adaptation in the built environment also depends on decentralized measures, including flood proofing at the building scale. A decentralized approach reduces reliance on a small number of large public works by shifting part of the response to local measures. It also reduces uncertainty by using flexible solutions designed for local conditions, and it spreads risk reduction across many actions rather than one single line of defense. In the Seveso flood prone areas of Milan, new construction and renovation trigger a hydraulic feasibility check. This links flood risk reduction to ordinary project cycles and to building scale interventions. When these checks and measures stay isolated within individual projects, the benefits remain fragmented. The same applies to sustainable drainage and similar strategies. Their impact is hard to see when the city builds them as disconnected pieces, even if the technical logic is correct.[244,245]

This is where architects can make a difference on a day-to-day basis. Building scale decisions shape runoff, thresholds, and failure points. Small moves that sometimes feel basic, such as where water can enter, where it can be stored, how it can drain, and how vulnerable spaces are protected, are not minor. When one building becomes three buildings, then a street, then a neighborhood, and then a city, these repeated decisions accumulate into systemic change. This is when flood risk reduction stops being an exception and starts becoming a normal condition of how the city is built and renewed.



Infiltration Trench
Infiltration Basin
Internal Roof Discharge
Roof Discharge Directed away from the Facade
Sleeves and Gaskets
Permeable Paving
Grass
Water-tolerant uses
Avoiding basement functions
Raised Floor Level (flooding passes under it)
Emergency Generators
e.g. elements that can close and open
Grey + Black Water
Rainwater
Alarm Measuring the Height of the Flooding
Daylighted Channel
Covered Channel
Water-tolerant finishing
Controlled Inlet Points
Openings Protection
Dry Core
Wet Zone
Retention basin: stores stormwater longer-term
Detention basin: temporarily holds stormwater, then releases it slowly
Water-sensitive functions
Flood-resistant functions
Higher protection from the river side
Protected Openings
Raised Openings
First flush (divert)
Wet Conditions
Dry Conditions

Manifesto

Europe’s water challenge is no longer a standalone issue. It is a multi-layered reality shaped by intense flooding and drought, widespread water pollution, and fragile infrastructure, all intensifying under accelerating climate change.[1] As the fastest-warming continent, Europe already faces stark realities:[2] 30% of Europeans experience water scarcity each year, affecting 20% of the land,[3] while floods have racked up over EUR 170 billion in damages since 1980.[4] Meanwhile, only 37% of surface waters meet healthy ecological standards,[5] a quarter of treated water leaks from aging distribution systems, and wastewater reuse sits at just 2.4%.[6]

Flood risks alone show how far this crisis extends. Over 14,000 areas across the EU are flagged as high-risk, with one in ten urban residents already living in flood-prone zones. Annual damages run into the billions, and without serious adaptation measures, both economic losses and population exposure are projected to escalate sharply by 2100.[7]

The scale of the problem demands a response that is equally systemic. What is needed is a shift in how we understand water risk and how we act on it. The following principles establish that shift as a framework for coordinated action across the built environment.

[1] European Commission, Directorate-General for Environment, “See Water Differently,” Water Wise EU, accessed January 7, 2026, https://environment.ec.europa.eu/topics/water/water-wise-eu_en; [2] European Commission, “See Water Differently.”; [3] European Commission, Directorate-General for Environment, “Too Much Water,” Water Wise EU, accessed January 7, 2026, https://environment.ec.europa.eu/topics/water/water-wise-eu/too-much-water_en; [4] European Commission, Directorate-General for Environment, “Not Enough Water,” Water Wise EU, accessed January 7, 2026, https://environment.ec.europa.eu/topics/water/water-wise-eu/not-enough-water_en; [5] European Commission, Directorate-General for Environment, “Polluted Water,” Water Wise EU, accessed January 7, 2026, https://environment.ec.europa.eu/topics/water/water-wise-eu/polluted-water_en; [6] European Commission, Directorate-General for Environment, “Poorly Managed Water,” Water Wise EU, accessed January 7, 2026, https://environment.ec.europa.eu/topics/water/water-wise-eu/poorly-managed-water_en; [7] European Commission, “Too Much Water.”

1. Water at the center of design and planning

Time is accelerating the problem. Rainwater arrives suddenly, overloads networks, and turns small design oversights into systemic failures. Cities are reaching their breaking point faster than anticipated, while large-scale infrastructure takes too long to plan, fund and build. Architecture offers a different path: solutions that can be implemented quickly, at smaller scales, and repeated across multiple sites. Change does not require decades of planning. It requires repeatable actions applied consistently across buildings and public spaces, starting now.
When coordinated over time, these project-scale interventions produce city-scale effects faster than any single infrastructure project ever could.

2. A need for a trans-scalar approach

Water resilience requires a shift in how the problem is framed. Water risk is systemic and inter-connected, so impacts cannot be contained within the scope of a single site or a single discipline. Water travels across catchments, streets, plots, and infrastructures, linking public and private space into one continuous cycle. For that reason, isolated solutions tend to displace risk rather than reduce it. A trans-scalar approach is not a design choice, but a basic requirement.

3. Flooding as the consequence of design

Flooding, in particular, is often described as an external event to defend against, but in many cities it is also the consequence of design decisions repeated over time: ground made impermeable, waterways constrained, thresholds lowered, and networks continuously pushed beyond their intended capacities. In this sense, flooding is not only a hazard, but also an outcome of how the built environment has been shaped through countless individual decisions.

4. We refuse the promise of absolute protection

The language of “defence” suggests a clean separation and the tendency to keep water outside of cities. That strategy is increasingly unrealistic and, when taken literally, can concentrate investment in isolated infrastructure solutions while relocating vulnerability elsewhere. What we can do instead is design for a world where flooding is a condition to be handled, not a problem to be erased so it becomes a managed risk shaped by space, time, and accountability. The goal is not absolute protection, but reduced exposure, reduced disruption, and a city that effectively responds to changing conditions.

5. Water resilience depends on awareness

Water systems can be technically effective yet culturally invisible, and that invisibility weakens shared understanding of the system's constraints and our responsibilities. What we can do is bring water back into the visible landscape by showing where it goes, where it gathers, and why certain design decisions follow. When risk knowledge is translated into spaces people can see, use, and support, resilience becomes a public culture: something practiced daily, shared by communities, and maintained across time.

This work sets out a clear position: water risk is already here, already systemic, and already exceeding the capacity of conventional responses. What we need is a fundamental shift from reactive defense to proactive design, from isolated interventions to connected strategies, from invisibility to accountability. That work begins with how we frame the problem and it continues with every decision we make.

The path forward is not one large solution but **many coordinated actions**, repeated over time, across sites, and embedded into **how we build**.

Appendix

Lexicon / Selected Terminology

Aquiclude
A low-permeability layer that limits groundwater movement and separates aquifers, shaping pressure conditions and water table behavior.

Aquifer
A permeable underground layer that stores and transmits groundwater, forming a key part of a city's water supply system.

Artesian aquifer
A confined aquifer under pressure, where water can rise in a well above the top of the aquifer without pumping.

Buried watercourses
Former open waterways that have been covered or diverted into underground corridors, becoming less visible while still shaping urban flood dynamics.

Cascading effects
A chain of knock-on disruptions triggered by flooding, where failure in one system amplifies failures in others.

Catchment
The wider territory that drains rainfall toward a river system, where upstream land use and topography influence urban flood peaks.

Coastal flooding
Seawater inundation of land, often caused by storm surge and high tides, sometimes compounded by heavy rainfall and river peaks.

Combined sewer overflow (CSO)
A relief discharge point where mixed stormwater and wastewater is released to a river or sea to prevent the sewer system or treatment works from backing up.

Combined sewer system
A sewer network in which stormwater runoff and wastewater share the same pipes, creating vulnerability to overload during intense rainfall.

Compound flooding
Flooding produced by overlapping drivers such as heavy rainfall, elevated sea level, and high river discharge occurring at the same time.

Constrained river corridor
A river space that has been narrowed, straightened, buried, or hardened, reducing the room available for water to spread during peak flows.

Continuity of care
The ability of health and social services to keep operating during and after floods, including evacuation capacity, data sharing, and coordinated response.

Critical assets
Infrastructure and services whose failure multiplies flood impacts, including hospitals, transport, utilities, and emergency systems.

Culverting
The practice of routing a stream or river underground through a covered channel or pipe, often increasing flow speed and shifting risk downstream.

Decentralized measures
Distributed actions across many sites that reduce reliance on single major works by spreading risk reduction through buildings, streets, and districts.

Detention basin
A storage basin designed to temporarily hold floodwater and release it later, lowering peak discharge and reducing downstream flooding.

Detention volume
A required storage capacity associated with impervious area, used to temporarily hold stormwater and release it slowly to reduce peaks.

Discharge limit
A maximum permitted outflow rate from a site, typically expressed per hectare, used to prevent new development from overloading networks and waterways.

Diversion canal
An engineered channel that redirects flood flows from one watercourse to another, used to reduce pressure on vulnerable urban corridors.

Exposure
The people, buildings, infrastructure, and services located in areas that can be flooded.

Flash flooding
Rapid-onset flooding that can develop within minutes to hours, often high-velocity and debris-laden, especially in steep catchments.

Flood hazard
The physical characteristics of a flood event, including extent, depth, velocity, and probability, considered independently from what is affected.

Flood risk
The likelihood of flooding and the severity of its consequences, shaped by hazard, exposure, and vulnerability.

Flood risk management plan
A plan that translates flood risk mapping into coordinated actions across prevention, protection, preparedness, response, and recovery.

Floods directive
The European Union framework that requires assessment of significant flood risk areas, flood hazard and risk mapping, and flood risk management planning.

Fluvial flooding
Riverine flooding that occurs when rivers, streams, or lakes exceed their channel capacity and inundate surrounding land.

Fluvioglacial deposits
Sands and gravels deposited by rivers and glaciers, often highly permeable and capable of storing large volumes of groundwater.

Fontanili
Spring-fed irrigation channels typical of the Lombard plain, historically used to capture resurgence waters and manage agricultural landscapes.

Groundwater rebound
The rise of groundwater levels after industrial pumping declines, increasing hydrostatic pressure on underground infrastructure.

Groundwater table
The depth at which soil becomes saturated, shaping the feasibility of infiltration strategies and the risk to basements and underground infrastructure.

Hydraulic and hydrologic invariance
A regulatory principle requiring that development does not increase the quantity and speed of runoff leaving a site compared to pre-project conditions.

Hydraulic feasibility check
A project-level assessment required in flood-prone areas to verify that new construction or renovation does not worsen runoff and downstream risk.

Lexicon / Selected Terminology

Hydraulic threshold
A limit condition at which a network, channel, or system shifts from normal operation to failure, overflow, or flooding.

Hydropluviometric monitoring
A system of sensors that measures rainfall and water levels to track storms, forecast thresholds, and support operational control.

Impervious surfaces
Surfaces that do not absorb water, such as roofs and paved streets, which accelerate runoff and concentrate flow into inlets and pipes.

In-network storage
The use of sewer volume, large conduits, or network layouts to temporarily hold water and delay peak discharges.

Infiltration
The process by which water enters the ground instead of flowing across the surface toward drains and waterways.

Nature-based solutions
Interventions that use soils, vegetation, and landscape systems to manage water while also delivering co-benefits such as cooling, biodiversity, and amenity.

Offline detention basin
A basin located beside a river that fills only when river levels exceed a threshold and empties later, reducing peak flows without continuously storing water.

Overflow channel
A bypass route that diverts excess flow away from constrained urban sections toward safer conveyance paths.

Permeability
The capacity of soil and ground layers to absorb and transmit water, influenced by soil type, compaction, contamination, and the extent of sealing.

Piezometric level
The level to which groundwater rises in a well due to pressure, used to map confined aquifers and assess risk to underground assets.

Pluvial flooding
Flooding driven by intense rainfall that overwhelms urban surfaces and drainage systems, even when rivers do not overflow.

Population equivalent
A standard unit for wastewater system sizing that expresses pollution load as the equivalent output of one person.

Property-level measures
Building and plot protections that reduce direct flood damage, including thresholds, barriers, valves, and protection of vulnerable rooms and systems.

River basin
A governance and hydrological unit defined by the full drainage area of a river and its tributaries, linking upstream and downstream flood conditions.

River basin management
A governance approach that manages water quantity, water quality, and flood risk across an entire basin rather than within isolated jurisdictions.

Runoff
Rainwater that flows over surfaces toward low points, inlets, rivers, and sewers, increasing rapidly where ground is sealed.

Lexicon / Selected Terminology

Separate sewer system
A sewer configuration where wastewater and stormwater are carried in different pipes, reducing overflow pollution while not eliminating flood risk.

Sewer capacity
The maximum flow a sewer network can convey before surcharge, overflow, or surface flooding occurs.

Sewer surcharge
A condition in which sewers become pressurized and water backs up toward streets and buildings, often causing interior flooding.

Soil sealing
The replacement of absorbent ground with roofs, asphalt, and concrete, turning rainfall into faster runoff and increasing pressure on drainage networks.

Soggiacenza
The depth from the ground surface down to the groundwater table, used as a practical design metric to understand infiltration potential and hydrostatic pressure.

Storm surge
An abnormal rise in sea level driven by wind and low atmospheric pressure during storms, increasing coastal flood risk.

Storm tank
A large storage facility that holds wet-weather flows and releases them later to treatment, reducing both flooding and pollution spikes.

Stormwater peak
The short, high-intensity surge of runoff that reaches sewers during heavy rainfall, often more decisive than total rainfall volume.

Sustainable drainage
Site and public-space strategies that capture, slow, store, and sometimes treat rainwater before it reaches sewers, reducing peak loads.

Surface water flooding
A form of pluvial flooding where water accumulates and moves across streets and enters buildings because drainage capacity is exceeded.

Systemic risk
Risk that spreads across interconnected systems such as mobility, energy, health, and housing, producing cascading failures and high uncertainty.

Vulnerability
The degree to which exposed assets and communities are susceptible to damage and disruption, influenced by building types, thresholds, basements, and the robustness of services.

Wastewater treatment plant
Infrastructure that treats sewage before discharge or reuse, and that can become a bottleneck when storm inflows exceed operational capacity.

Water resilience
The ability of a territory to keep functioning under water stress, whether that stress appears as excess, scarcity, pollution, or disruption of basic services.

Waterscapes
The visible and hidden water landscape of a city, including rivers, canals, culverts, sewers, groundwater, and the spaces that shape how water moves.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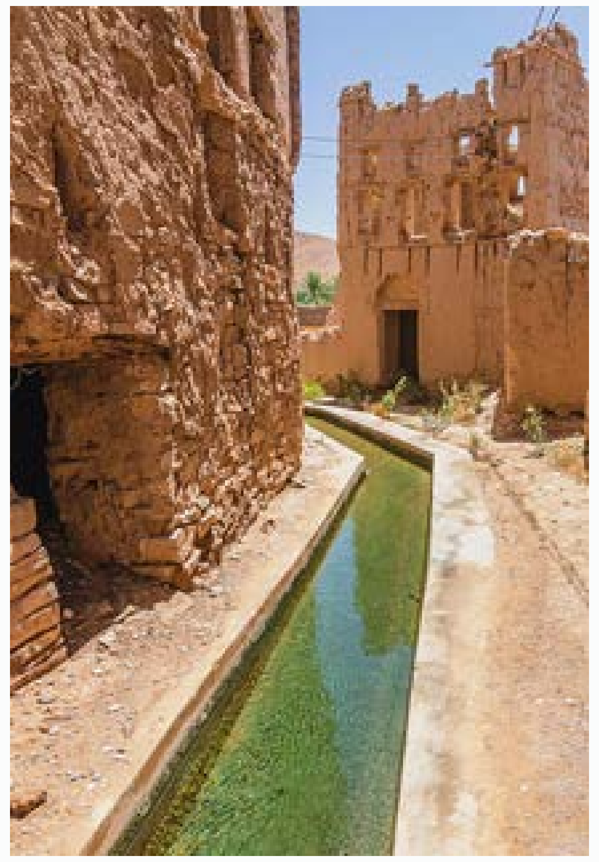
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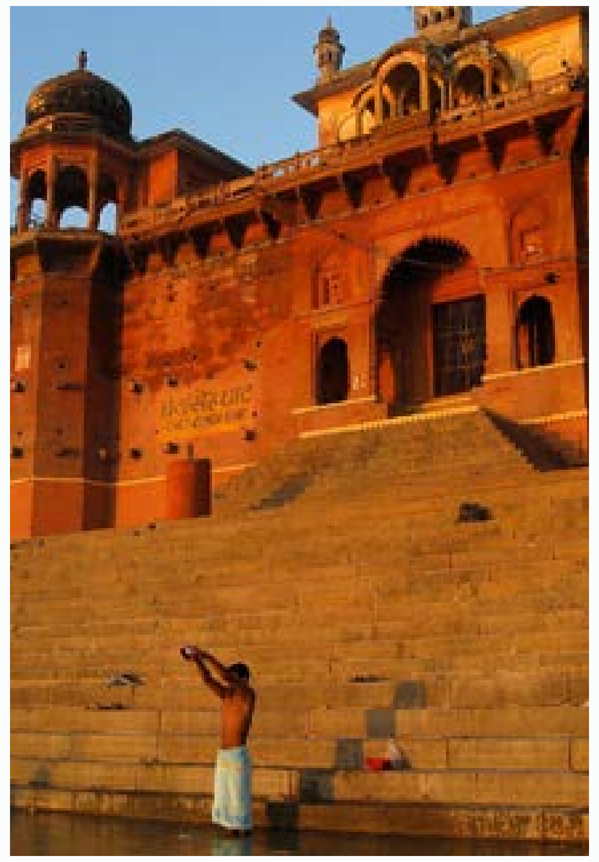
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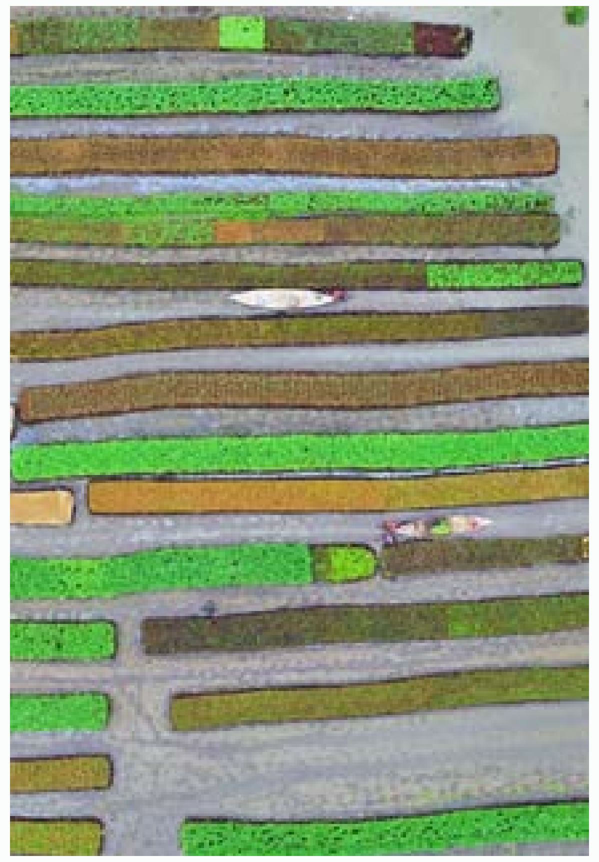
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01 Matera, Italy
02 Lijiang, China:
03 Oman, Aflaj
04 Xochimilco, Mexico

05 Rajasthan, India
06 Varanasi, India
07 Madeira, Portugal
08 Freiburg, Germany

09 Venice, Italy
10 Gujo Hachiman, Japan
11 Provence, France
12 Yazd, Iran

13 Seoul, South Korea
14 Bangladesh, Baira
15 Valais, Switzerland
16 Ifugao, Philippines


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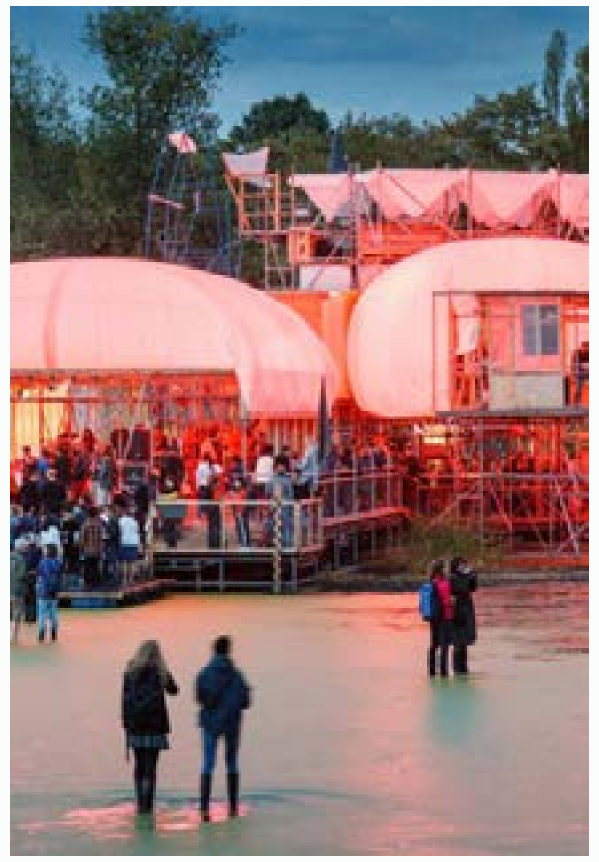
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01 De Urbanisten: Waterplein Benthemplein
02 MARS: Waterbench
03 Copenhagen Municipality + LYTT: Tåsinge Plads
04 City of Malmö + MKB Fastighets AB: Ekostaden Augustenborg

05 Via Pacini (SUDS)
06 Transsolar: Cologne riverfront (Deutzer Hafen)
07 Room for the River (Rijkswaterstaat)
08 Turenscape, Sponge City

09 Schønherr: Karens Minde Aksen
10 SLA: Sankt Kjeld's Square & Bryggervangen
11 Rainaway Tiles
12 SMAT: Idropolitana project

13 Powerhouse Company: Floating Office Rotterdam
14 raumlabor: Floating University
15 Desvigne, Parco Sei
16 Waterweg


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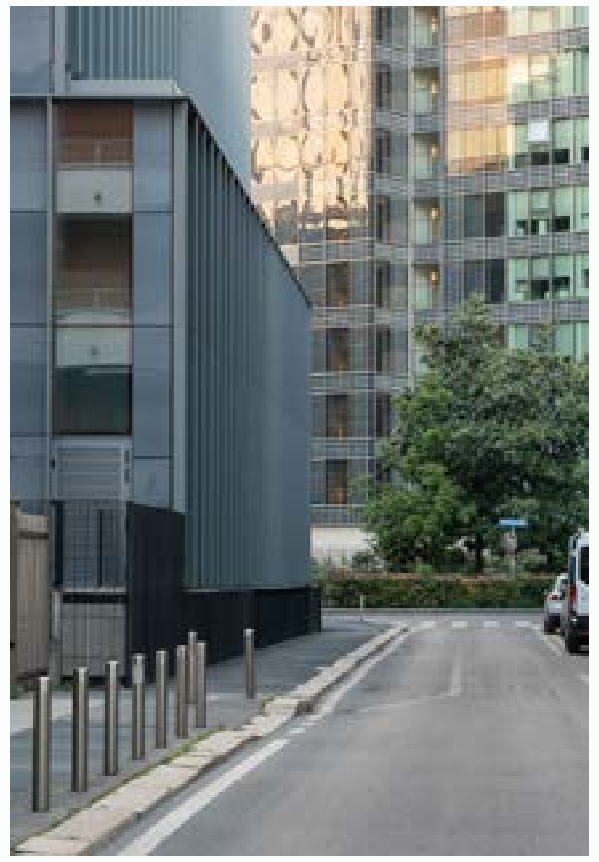
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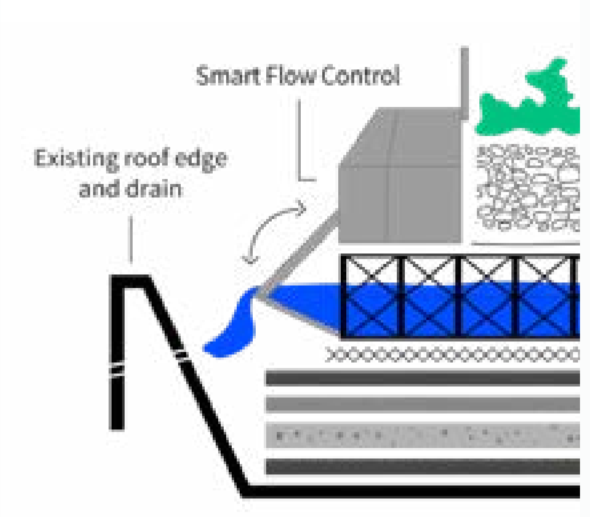

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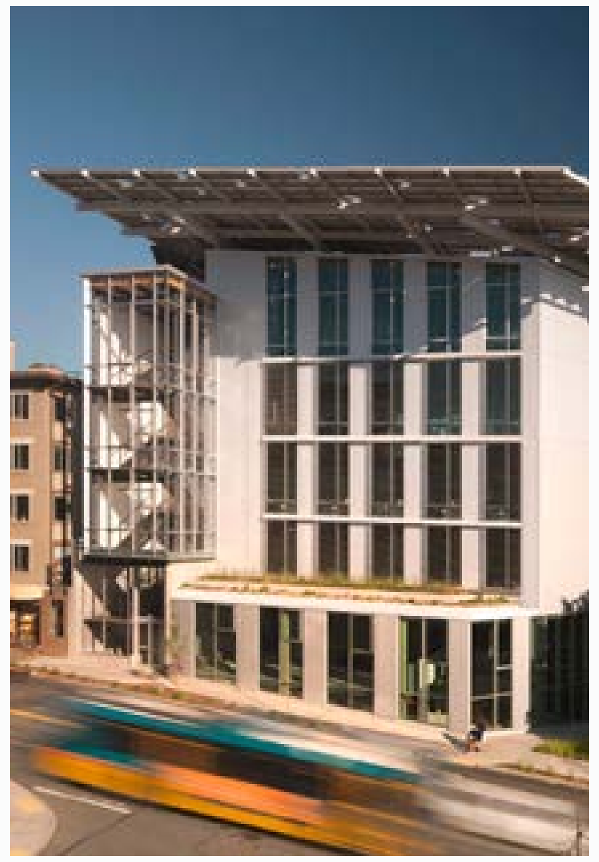
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01 Park Associati: Palazzo Sistema
02 Renzo Piano Building Workshop: The Whitney Museum of American Art at Gansevoort
03 Shigeru Ban: Make It Right House
04 John Pardey Architects: Narula House

05 Curious Practice: Vikki's Place
06 Herzog & de Meuron: 306 Pérez Art Museum Miami
07 Taillandier Architectes Associés: Residence Terre Sud
08 Bob Gysin + Partner AG (BGP Architekten): Hafencity, Elbarkaden BF 44-45

09 Am Sandtorkai / Dalmannkai waterfront blocks
10 Park Associati: Lybra: Removable Flood-Barrier Detail
11 Carlo Scarpa: Fondazione Querini Stampalia
12 Third Nature Architects: Enghaveparken

13 Atelier Dreiseitl: Potsdamer Platz
14 Municipality of Amsterdam (RESILIO lead): Tropenmuseum depot roof (Amsterdam)
15 Park Associati: Luxottica Digital Factory
16 Miller Hull Partnership: The Bullitt Center


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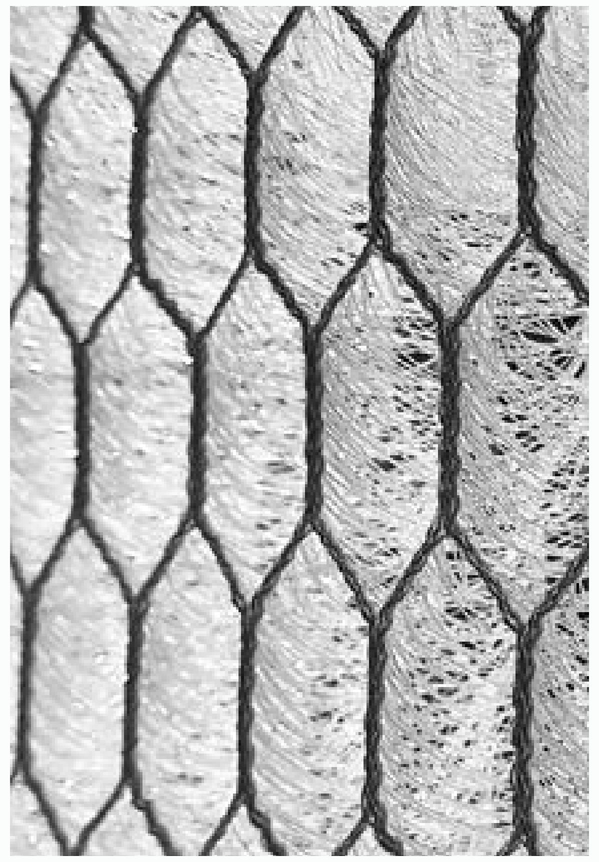
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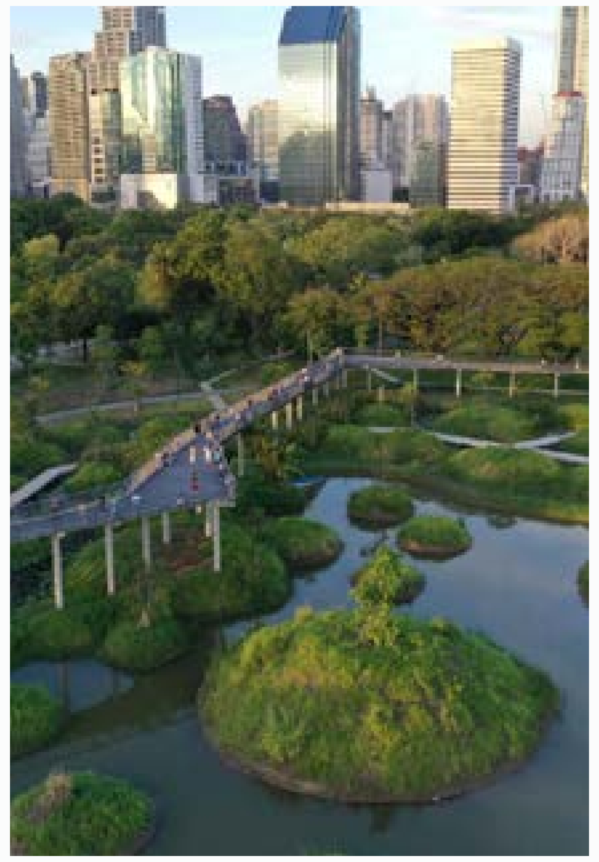
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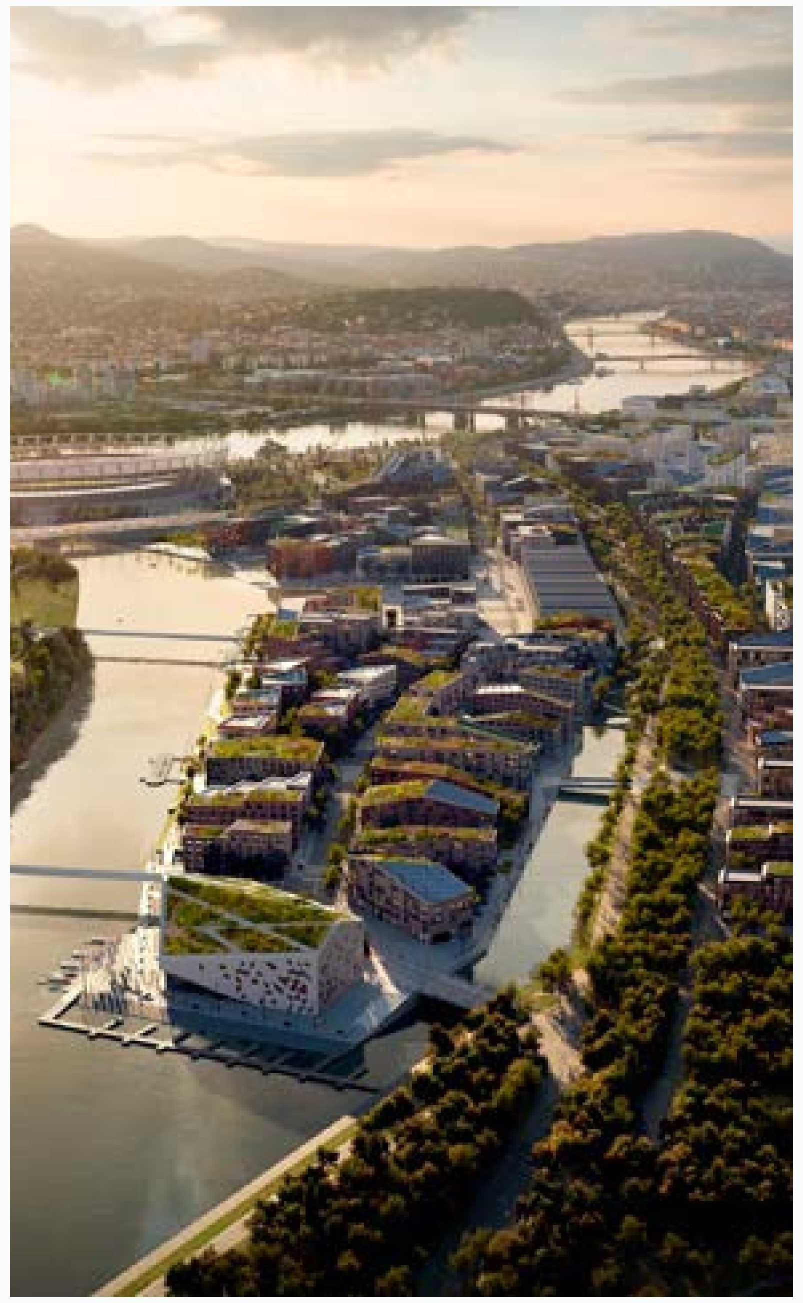
01 ZEDfactory (Bill Dunster) + Arup: BedZED
02 Associated Architects: Michael Baker Boathouse
03 BACA architects: The UK's First Amphibious House
04 Factor Architecten: Floating homes Maasbommel

05 TAKA Architects: Merrion Cricket Club
06 BACA Architects: Cottles Quay - Amphibious 2.0
07 HydroSKIN
08 Paul de Ruiter Architects: Museumpark parking garage

09 Henning Larsen Architects: DER SPIEGEL Headquarters (Ericusspitze)
10 City of Copenhagen + HOFOR: Klimakvarter Østerbro cloudburst roads
11 City of Copenhagen: The Courtyard of the Future at Straussvej
12 Third Nature Architects: Enghaveparken

13 Third Nature Architects: Climate Tile
14 MIAS Architects: Banyoles Old Town Refurbishment
15 “Navigli” di Bologna in via Riva Reno
16 Arsomslip/ Turrenscape: Benjakitti Forest Park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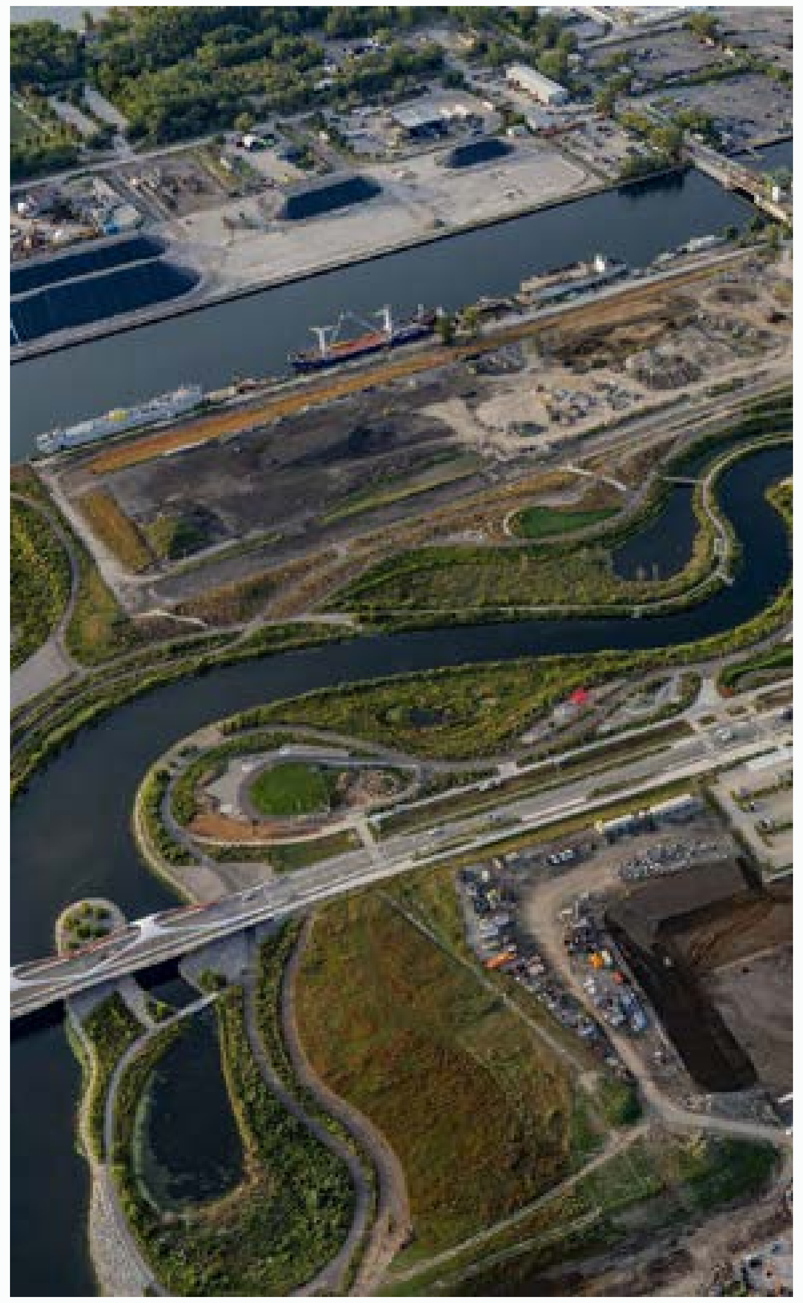
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01 Snøhetta: Budapest South Gate Masterplan
02 OLIN: ResilienCity Park
03 Bosch Slabbers: Reconstruction Molenwaterpark

04 LAND: Sulbiate–Aicurzio Water Park
05 Henning Larsen: Bishan Park
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Figures

Introduction

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1.3.3 Italy’s regions and their flood risks

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Part 3

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3.1.17 La copertura, 1930 - Conca di Viarenna
Source: https://navigliroloading.eu/la-copertura-della-fossa-interna/

3.2.1 Schematic section of well Comasina, Milano. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.2.2 Vertical subdivisions of soil layers. Table: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.2.3 Types of aquifers. Table: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.2.4 Geological section scheme. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), https://www.politesi.polimi.it/handle/10589/231087

3.2.5 The historic Via Cenisio pumping station
Source: https://www.domusweb.it/it/notizie/2018/10/04/a-milano-nasce-un-museo-dellacqua-pubblica-la-centrale-dellacqua.htm

3.2.6 Piezometric map and depth to the groundwater table, September 2025
Source: Metropolitana Milanese S.p.A., Carta della Piezometria e della Soggiacenza della Falda Freatica: Settembre 2025 (PDF), accessed February 18, 2026, https://www.latuaacqua.it/wps/wcm/connect/milanoblu/2cb24abd-c10f-4975-8330-2cfdcc3191e4/Piezometria_Settembre_2025.pdf

3.2.7 Piezometric map of the province of Milano in a) 1958 and in b) September 2011
source: https://www.researchgate.net/publication/269706020_The_groundwater_flow_velocity_distribution_in_the_urban_areas_A_case_study

3.3.1 Structure of water distribution network. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.2 Hydrography of the Milan area in the final centuries of the Roman Empire
Source: Marco Prusicki, 9 giugno 2010 - Lavori in corso (IReR / INU Quaderni), p. 8, fig. 47, "Idrografia dei dintorni di Milano agli ultimi secoli dell'Impero Romano."

3.3.3 Milan's hydrography showing waterways (both natural and man-made) crossing the city.
Source: https://www.ilcielosumilano.it/2020/10/14/milano-citta-dacqua-non-lo-e-piu-da-mezzo-secolo/

3.3.4 Sewer plan for the Nuovo Corso (1888, Via Dante): Plan and section of the street showing the position of the main sewer collector, building connections, rainwater catchpits/manholes, and service voids along the facades intended to house utilities (gas, drinking water, electrical and telephone cables)
Source: https://www.centraleacquamilano.it/una-rivoluzione-sotterranea/

3.3.5 Construction details of conduits and junction structures: From the Nuovo Corso sewer project (1888, Via Dante)
Source: https://www.centraleacquamilano.it/una-rivoluzione-sotterranea/

3.3.6 Domestic sewer study (1888, Via Dante): Section through the building facing Nuovo Corso (still standing at the corner with Largo Cairoli) highlighting the internal drainage pipes
Source: https://www.centraleacquamilano.it/una-rivoluzione-sotterranea/

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3.3.7 A map linking Milan's 1890 sewer plan to the expansion of the Vettabbia irrigation district, highlighting the drainage areas by collector and the Nosedo emissary channel carrying urban wastewater south toward the Lambro for agricultural reuse.
Source: https://www.centraleacquamilano.it/una-rivoluzione-sotterranea/

3.3.8 Section of the south Castello tower at the end of 19th century. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.9 Plans of Milan's Pumping stations. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.10 Locations of Milan's Pumping stations. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.11 Geological section scheme (axonometric drawing). Drawing: Rea Novakovic Matosic
Source: Adapted from Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.12 How a pumping station works: example of Centrale Comasina, Via Luigi Federico Menabrea, 28, 20159 Milano. Drawing: Rea Novakovic Matosic
Source: Adapted from - Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.13 Locations of purifier plants and their operating areas. Drawing: Jurica Pajic
Source: Jurica Pajic, Fluid Encounters: Public Water System of Milano Metropolitan Area (master's thesis, Politecnico di Milano, academic year 2023/2024), accessed February 18, 2026, https://www.politesi.polimi.it/handle/10589/231087

3.3.14 Sewer system network in Milano
Source: Metropolitana Milanese S.p.A. Le fognature nel sistema idrico integrato. PDF. Accessed February 18, 2026. https://www.fast.mi.it/wp-content/uploads/2020/04/MM-Le-fognature-nel-sistema-idrico-integeato.pdf

3.3.15 Sewer system in Milano
Source: https://www.spurgo-italia.it/2019/04/04/rete-fognaria-milano/

3.4.1 Milan Urban Green Space Map (HUGSI, 2024)
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3.4.2 Map of rainwater runoff percentage (potential estimate)
Source: https://milano.corriere.it/cronaca/25_luglio_08/piogge-violente-quanto-e-impermeabile-il-suolo-di-milano-i-dati-zona-per-zona.shtml

3.4.3 The Seveso entering its covered urban section in northern Milan
Source: https://milano.repubblica.it/cronaca/2023/11/02/news/fiume_seveso_racconto-419356007/

3.4.4 Milan Heat and Soil Sealing (2017–2022 / 2022); KoozArch, SOIL > cement (commissioned by the Urban Center of the Municipality of Milan), using ISPRA soil consumption data (2022) and temperature mapping (summer daytime mean 2017–2022).
Source: https://koozarch.com/projects/publication-soil-over-cement

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Source: https://milano.corriere.it/foto-gallery/cronaca/14_giugno_26/seveso-60-anni-esondazioni-eefab190-fd2d-11e3-ab47-248f75b22665.shtml

3.5.2 October 1976: the Seveso floods the Niguarda–Viale Fulvio Testi area. Fotogramma
Source: https://milano.repubblica.it/cronaca/2014/07/08/foto/milano_quarant_anni_di_esondazioni_del_fiume_seveso-90985709/1/

3.5.3 3 October 1976: the Seveso floods the Niguarda–Viale Fulvio Testi area. Fotogramma
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Source: https://milano.repubblica.it/cronaca/2014/07/08/foto/milano_quarant_anni_di_esondazioni_del_fiume_seveso-90985709/1/

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3.5.16 The Seveso entering its covered urban section in northern Milan: Via Luigi Ornato × Via Aldo Moro
Source: Google Maps

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3.5.18 Proposed project layout for the Seveso stream.
Source: Agenzia Interregionale per il Fiume Po (AIPo), Dossier area laminazione: Seveso plan and the Paderno Dugnano–Varedo–Limbiate basin, PDF, https://www.agenziapo.it/sites/default/files/Dossier%20area%20laminazione%20MOD_0.pdf

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3.5.20 La vasca di laminazione, Parco Nord
Source: Google Maps

3.6.1 The route of the reopened Navigli canals with the 25 bridges
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3.6.5 "Riaperta la Darsena"
Source: https://x.com/comunemi/status/592314447764561920

3.6.6 Facilitated table discussion during the 2018 Milan Public Debate on the Navigli reopening
Source: https://ascoltoattivo.net/progetti/facilitazione/dibattito-pubblico-progetto-navigli/

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3.6.9 Location of the Martesana–Seveso junction in Milan.
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Thank you!

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