

ecology

Landscape-based strategies for the restoration
of the water cycle in the riverscapes of Cuenca

Graduation report

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Infrastructuring ecology: Landscape-based strategies
for the restoration of the water cycle in the riverscapes of Cuenca

Master thesis report

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Urbanism track
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Landscape-based strategies for the restoration
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Abstract

For at least seven centuries, the inhabitants of the Tomebamba Valley have found opportunities to prosper by making the most of a bountiful natural water infrastructure, comprising an extensive network of rivers, numerous lakes and vast expanses of páramo ecosystems and rainforests. This natural system has played a decisive role in the history of this region and has ultimately enabled the emergence of a city that remains, to this day, intimately linked to the rivers that flow through it.

However, from the 20th century onwards, the arrival in the region of the wave of modernism that was spreading across the world triggered a series of increasingly profound transformations to this system, in response to the adoption of modern lifestyles by its inhabitants and the consequent need to integrate the rivers even further into the city's metabolism. The interplay of these landscape transformations and infrastructural developments established a model of extraction in the form of a unidirectional system, in which the assurance of a constant flow of resources and benefits drawn from this natural system for the normal course of daily life in the city comes at the expense of its ecological integrity.

Within this context, this project examines the impact of practices that appear to be inherent to the current conception of an Andean riverscape in this region and, taking the restoration of the global water cycle as its starting point, explores how the intersection of engineering and ecology can shape the landscape to enable a model in which there is room for both the harnessing of this natural system and its future integrity.

Keywords: *Riverscapes, water infrastructure, urban metabolism, water cycle restoration*

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Desde las montañas llegan los ríos.
From the mountains come the rivers.

Se precipitan por las estribaciones, ágiles y sonoros, ensayando las primeras sílabas de la espuma, insinu
They rush down the foothills, nimble and resounding, rehearsing the first syllables of foam, barely visible

Conforme reciben el caudal de los afluentes, ensanchan el caudal, adquieren mayor
As they receive the flow of their tributaries, they widen their course, gaining greater

a manera de un transparente reptil, hasta llegar a la vaguada, en cuyo c
like a transparent reptile, until they reach the valley floor, at the centre of

A manera de las líneas de la mano, los ríos surcan el verde ate
Like the lines on a hand, the rivers cut through the velvety gree

Ríos, signos de la vida, señales del ser, símbolos del designio de este par
Rivers, signs of life, signs of being, symbols of the destiny of this landsca

Tomebamba, línea enérgica y dilatada de la v
Tomebamba, an energetic and expansive line

Tarqui, corriente sosegada del pensa
Tarqui, a tranquil stream of thought;

Yanuncay, nervioso y vehemente, como el curso de la afectividad;
Yanuncay, nervous and impassioned, like the course of emotion;

Machángara, precipitado e imprevisible co
Machángara, hasty and unpredictable like

Igual que las líneas de la palma de la mano, los ríos de Cu
Just like the lines on the palm of the hand, the rivers of Cu

Somos un antiguo pueblo de labrado
We are an ancient people of farmers,

En el flujo de nuestros ríos lavamos la ropa de la s
In the flow of our rivers we wash the week's laund

Junto a sus már
Along their ban

apacentamos ovejas y
we graze sheep and ox

labramos
we skilfully

El susurro de las venas fluviales nos
The murmur of the rivers greets and

uándose apenas como un cordel de lirios.
as a string of lilies.

ímpetu, abriéndose paso entre las rocas, arrastrándose sigilosos,
mpetus, cutting their way through the rocks, creeping stealthily,

entro se asienta la ciudad, ingrávida y pequeña como una paloma.
which sits the city, weightless and small as a dove.

rciopelado de la llanura.
en of the plain.

aje.
pe.

ida;
of life;

miento;

omo el destino.
fate.

enca marcan con su sonora urdimbre la singularidad de nuestro ser y quehacer.
enca mark, with their resonant weave, the uniqueness of our being and our endeavours.

res, pastores y artesanos.
shepherds and craftsmen.

emana.
ry.

genes sembramos el maíz, el trigo, las legumbres y hortalizas;
ks we sow maize, wheat, pulses and vegetables;

bueyes;
ken;

con primor la arcilla, la piedra, la madera y los metales.
y work clay, stone, wood and metals.

saluda y arrulla cuando nacemos y nos aduerme y despide cuando nos extinguimos.
dulls us when we are born, and puts us to sleep and bids us farewell when we cease to exist.

Morir implica para nosotros un doble silencio: el del murmullo del agua y de la sangre.
For us, death implies a double silence: that of the murmur of water and of blood.

Excerpt from the essay '*The landscape of Cuenca: A dialogue between man and nature*', by Efraín Jara Idrovo (1998).

Motivation

The 5th river of Cuenca and the future of Cuenca's riverscapes

On 16 September 2025, Cuenca, the city of four rivers, witnessed how a fifth river formed in its streets. In response to the state government's intention to authorise the start of mining activities for gold and other minerals in the natural area of Quimsacocha (or Kimsakocha, in Quechua), thousands of citizens mobilised to raise their voices for the protection of this area, vital for the water supply of the cities thanks to the Páramo ecosystem that make it up.

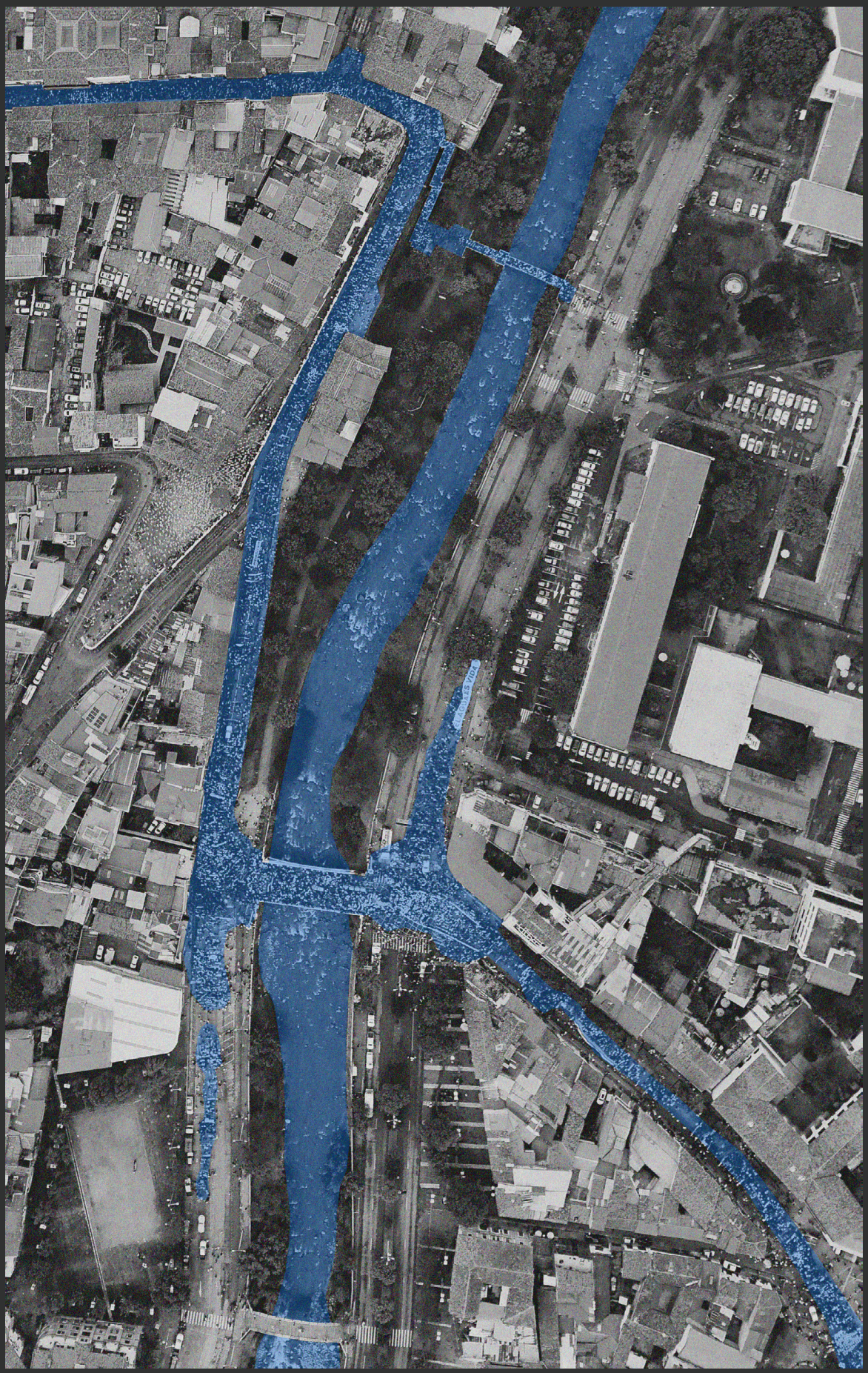
This high mountain ecosystem, unique to specific regions of Central and South America, can be found in no more than six countries in the world and plays a crucial role in the water cycle by acting as an intermediary between the atmosphere and the Andean rivers. Páramo ecosystems feature an ubiquity of water and can be described as acqueous landscapes, as they function as large, natural water storage infrastructures that absorb and retain precipitation in several forms, to later release it little by little in the form of small streams that flow and come together to form the rivers in this region, including the four rivers that cross Cuenca and on which it depends.

With a highly diverse flow, Cuenca's fifth river was made up of approximately 100,000 urban and rural inhabitants of the region, in what was the most attended social and environmental demonstration in the city's history. Union members, farmers, environmental activists, social leaders, students, academics and people from every social sector sector joined forces to raise their voices in the streets of Cuenca in defence of what can arguably be considered as the greatest collective good enjoyed by the city and the region. The fifth river demonstration brought together thousands of people from very different contexts and with different lives united by a common cause, not only demonstrating water's capacity to act as a factor of social unification, but also reminding us of its vital importance for all forms of life.

The threat posed by extractive interests, however, is merely the most visible and symbolic tip of the iceberg representing the unsustainable exploitation to which the region's river landscape has long been subjected, as a result of a model that has treated rivers as inexhaustible resources, through widely spread practices that are deeply embeded in the urban daily life of Cuenca and because of which they have become almost 'invisible'. The potential for long-term negative impact that the widespread replication of these practices prompted me to take a step further and choose this topic for my graduation project to ask myself what would my hometown region look like if we were to think holistically about its riverscapes and their future, for its future is our own.



↑ Quimsacocha, an aqueous landscape
Source: Fausto Cardoso



↑ 16th of September 2025 at the banks of the Tomebamba River
Source: Omar Hidalgo



↑ 'We are the Fifth River'
Source: Fausto Cardoso



Foggy afternoon in the Cajas Mounrain Massif



1. Contextualisation

1.1 The first human-driven climate change

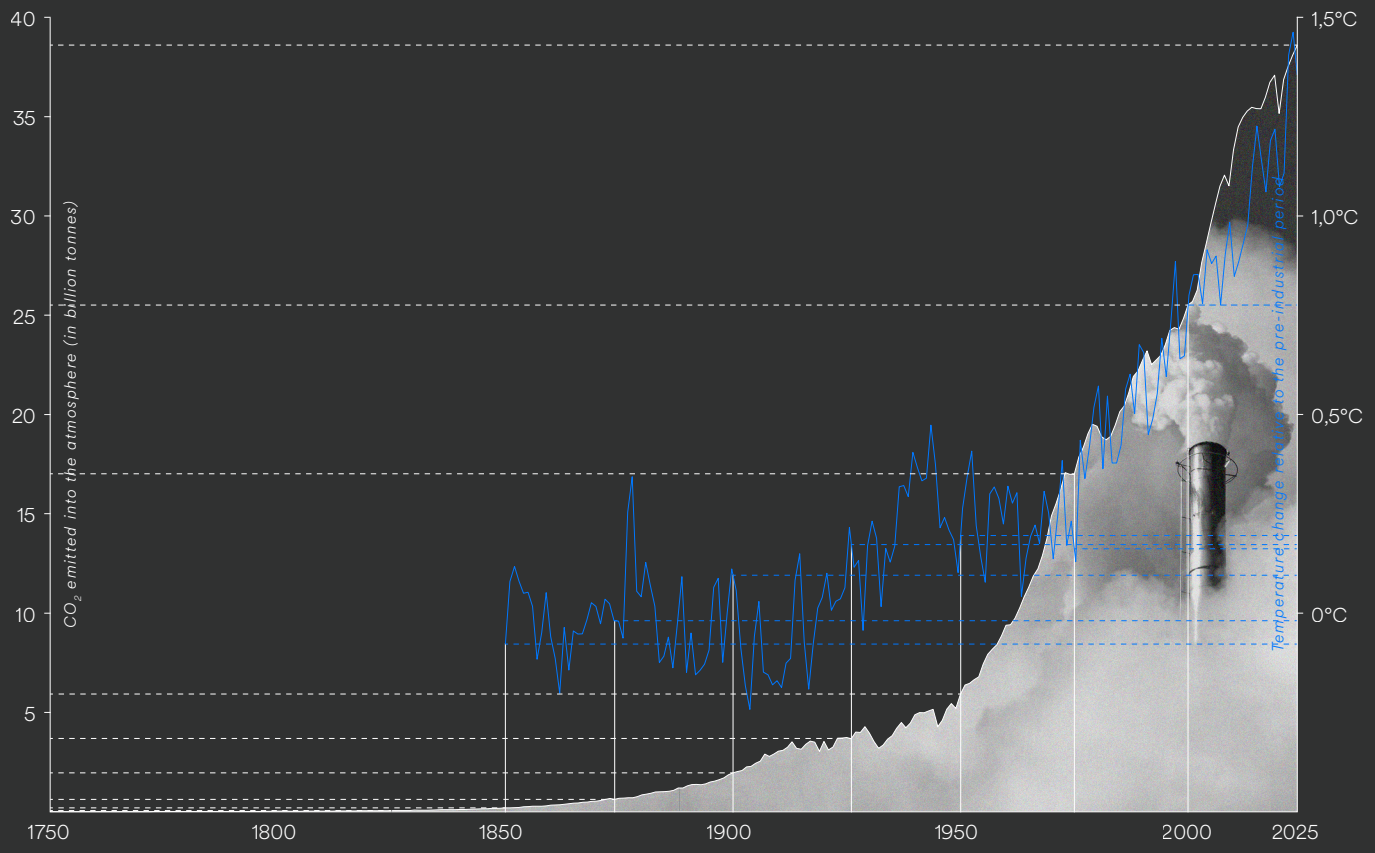
Just as the amount of water on the planet is part of a closed circuit, the amount of carbon on Earth has remained constant throughout history. During the 4,5 billion years of our planet's existence, as a result of the processes inherent in the carbon cycle, carbon dioxide (CO_2) levels have fluctuated in a constant exchange between the soil and the atmosphere. These fluctuations have caused variations in atmospheric temperature, which in turn triggered various climate change processes in the past.

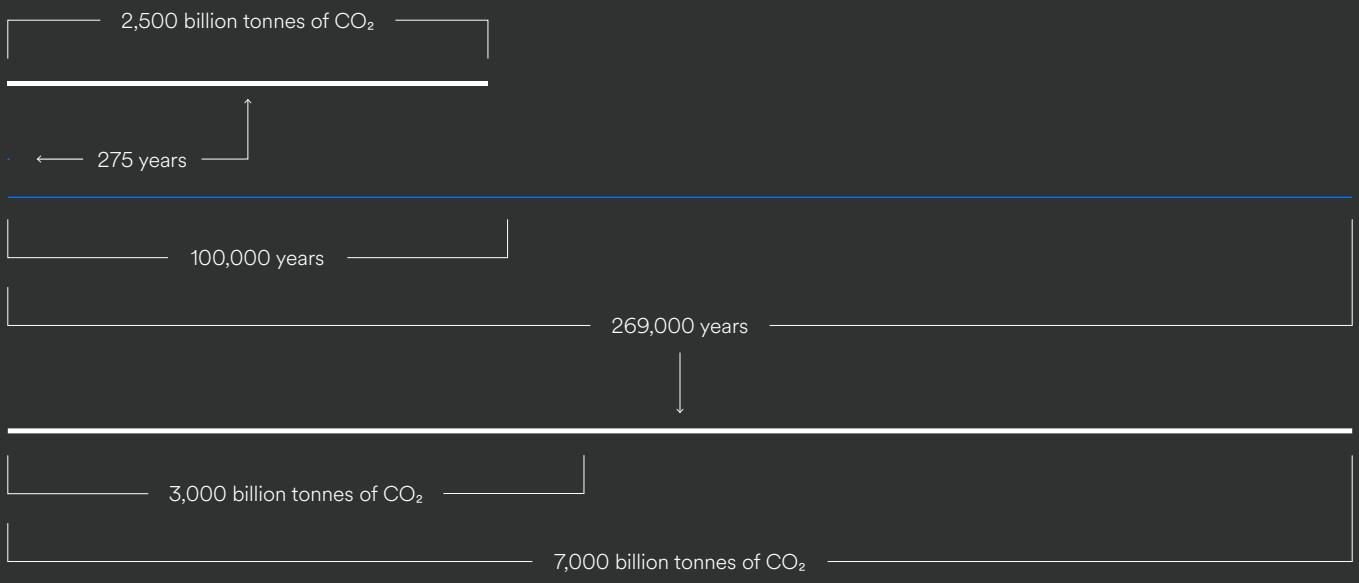
One of the largest events of this type experienced by the planet occurred approximately 56 million years ago and is known as the Paleocene-Eocene Thermal Maximum. It is estimated that during this event, extreme volcanic activity released between 3,000 and 7,000 billion tonnes of carbon into the atmosphere, causing the average temperature of the planet to rise by between 5°C and 8°C, leading to a process of mass extinction of marine and terrestrial species (Jabr, 2024).

Today, our planet is once again undergoing a process of climate change as a result of a new massive release of CO_2 into the atmosphere. The polar ice caps are melting, the ocean is warming and expanding, raising its level, and the behaviour of the climate is becoming increasingly unpredictable and extreme. This time, however, the causes of this global phenomenon have a completely different origin. The burning of what Dirk Sijmons described as 'solidified sunshine' that formed over hundreds of millions of years underground, to transform the energy they contain for our needs, is the main factor that has consolidated humanity as the Earth's main metabolic force, driving a new massive flow of carbon from the Earth's crust into the atmosphere, resulting in widespread global warming.

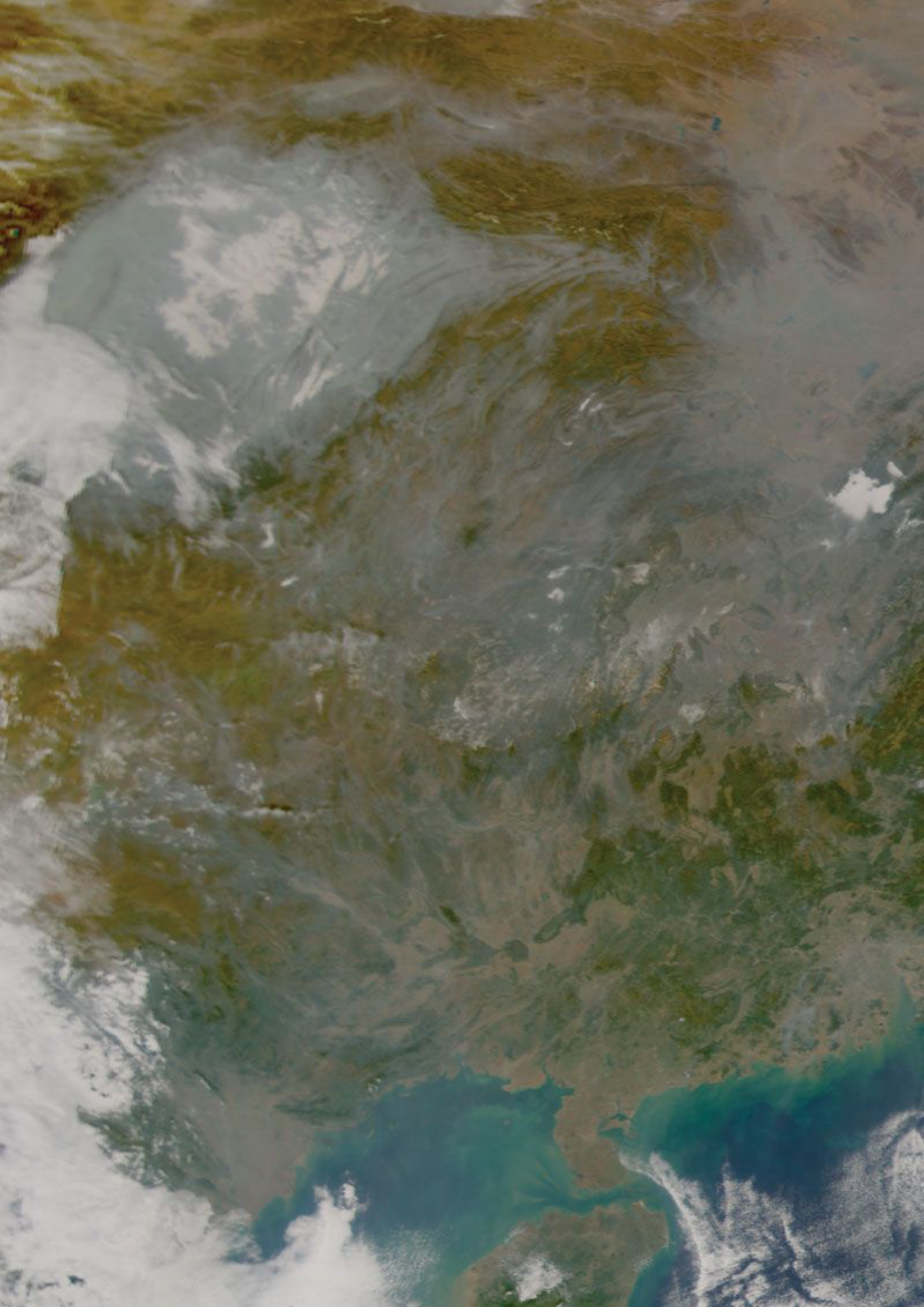
Unlike the Paleocene-Eocene Thermal Maximum, whose estimated duration has been calculated at between 100,000 and 269,000 years (Piedrahita et al., 2025), human dependence on fossil fuels has led to the release of a comparable amount of CO_2 in a way shorter period of time: in just about 275 years (since 1750), over 2,500 billion tonnes of CO_2 have been emitted to the atmosphere (Jabr, 2024). Scientific estimates suggest that never in the history of Earth has such an amount of carbon been released into the atmosphere in such a short period of time, and climate models show that even if current emissions of CO_2 and other greenhouse gases into the atmosphere were to stop completely, the planet's temperature would continue to rise for a couple of decades (MacDougall et al., 2020), confirming that even if radical measures were taken now, climate change is a phenomenon that will continue to develop in the coming years.

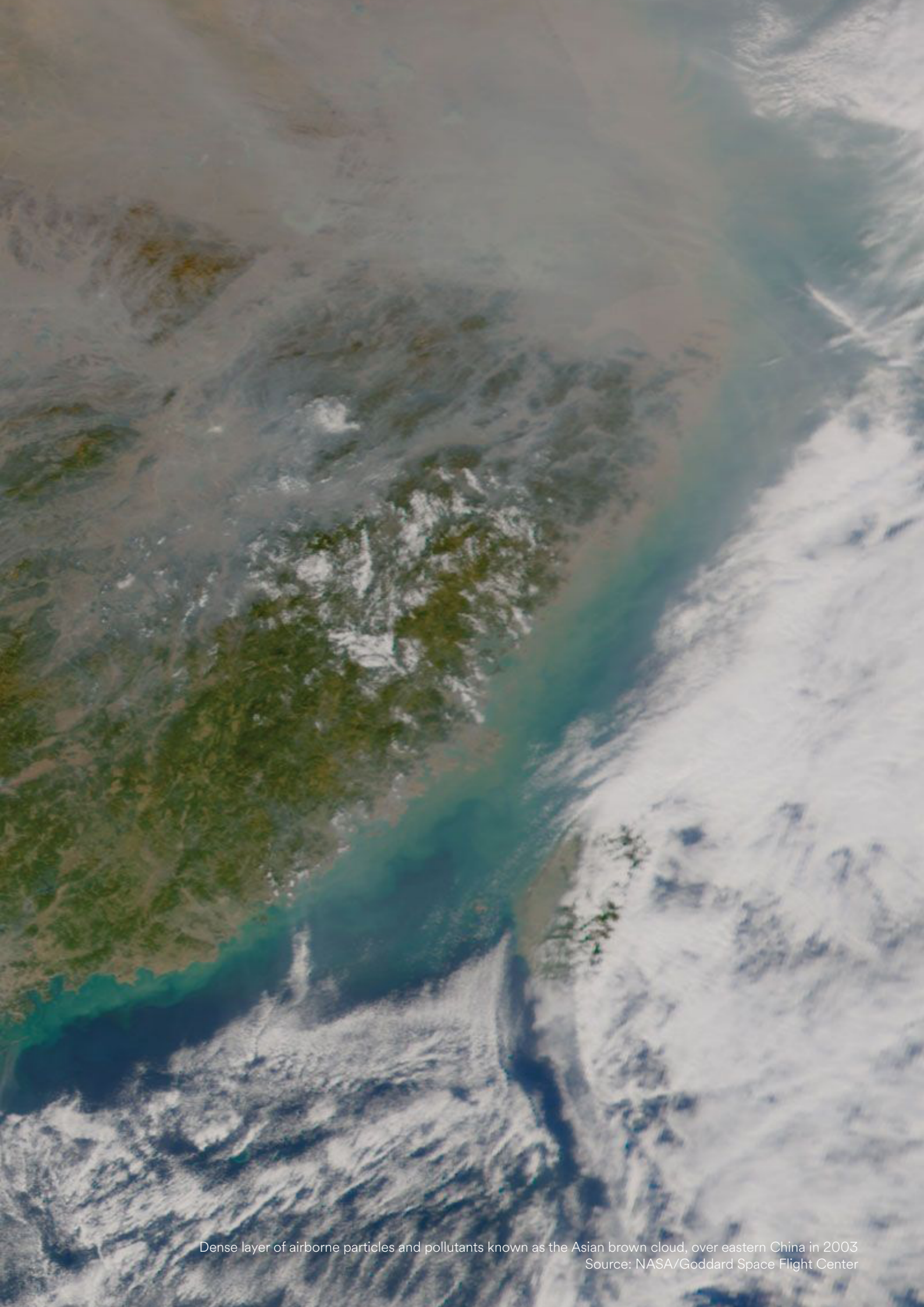
As this is a global phenomenon, everything we value as a necessity is susceptible to its impacts: water, food, health, biodiversity, economy, energy, and transport (Mos-Shogbamimu, 2021). In essence, climate change threatens to collapse both the ecosystems and infrastructure that sustain humanity's quality of life. The magnitude of this risk increases as the atmosphere warms and the climate becomes more extreme. The inevitability of this phenomenon must compel us to question the way in which we, as a species, relate to the planet on all scales, and to foster a process of critical reflection on the models extraction, production and consumption that humankind has created.





↑ Comparison of CO_2 emitted during the past 275 years vs. CO_2 emitted during the Paleocene-Eocene Thermal Maximum
Sources: Our World in Data | Jabr | Piedrahita et al.





Dense layer of airborne particles and pollutants known as the Asian brown cloud, over eastern China in 2003
Source: NASA/Goddard Space Flight Center

1.2 On the approach to water as a resource

Water has been one of the main shapers of human history. Historically, access to water has consolidated as a defining factor in the locations where humans chose to settle and cities began to grow. Increasingly complex and interdependent urban water infrastructures have enabled the provision of several commodities such as drinking water, health, food, energy, flood protection, and well-being for people (Wan Rosely & Voulvoulis, 2023).

The process of global urbanisation that began with the Agricultural Revolution brought several changes not only in the way of life of the humans, but also in the way we interact with the environment. This historic milestone was the turning point at which the human species cast off its intimate symbiosis with nature, in which it had lived for over 2,5 million years (Harari, 2015). This separation of people from nature has deeply transformed also the way humans relate to water.

The emergence of the first cities in history marked the beginning of the commodification of water, which established itself as a fundamental resource for urban dwellers to achieve abundance and prosperity. Over the past centuries, the development of urban daily life and people's routines has become increasingly reliant on the extraction, processing, storage, and distribution of water, making it an ubiquitous, yet largely invisible, resource in our day-to-day activities. This ever-increasing exploitation of water has been made possible through the construction of a series of human-made artefacts attached to natural water systems, such as dams, intake and outtake canals, purification plants, distribution pipes, treatment plants and sewers.

Questions about the ecological impact of human actions did not begin to take a relevant role in discussions until the last decades of the 20th century, when environmental degradation became increasingly evident and, ultimately, gave rise to the environmental movement. Despite the ecological awakening, much of a de-naturalised modelling and building of the networked infrastructure that supported large-scale urbanisation had already been carried out in previous decades. Nature was deprived from consideration in the urban modelling processes (Swyngedouw & Kaika, 2014), which included the development of water infrastructure.

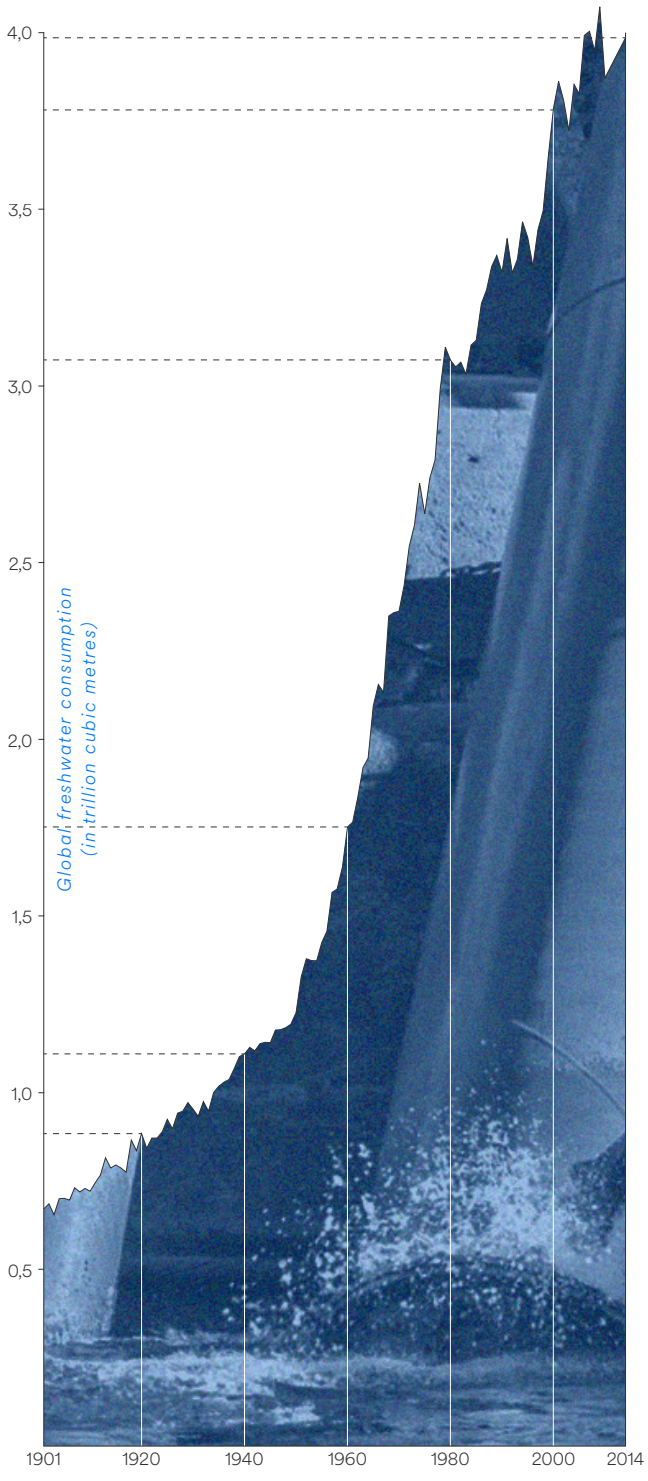
Therefore, the combined operation of these artefacts has enabled a destructive linear process that contrasts with the natural water cycle (Wan Rosely & Voulvoulis, 2023). By gathering large numbers of humans in relatively small areas, cities disrupt this cycle, creating an imbalance that human water infrastructure attempts to fill (McDonald et al., 2014). This mechanisation of hydrological systems and the landscape in general has been based on vast expertise in engineering and technology, which have served as means to either maximise the benefits obtained from natural systems or reduce the 'nuisances' caused by them as needed, in processes that have systematically disregarded the fluctuations inherent in nature's cycles. In consequence, current urban water management paradigms often focus solely on water supply, wastewater treatment, and drainage systems, overlooking the connections between urban areas and their supplying regions, the broader performance of the hydrological systems to which they are attached or the potential of water in urban lanscapes (Wong et al., 2020).

'The infrastructure that made possible the last half millennium of urbanization was conceived as a one-way system providing a predictable flow of resources in lieu of nature's volatile processes'.

William Sherman, 2005.

Contemporary built environments are the product of natural and human-made relationships (Iuorio, 2023), although the former have been extensively disregarded during the urbanisation process of the past two centuries. This has resulted in an underperformance of modern urban water management models, which is reflected in the incapacity of urban water systems to operate under extreme weather conditions, or the severe disruption of the water cycle that urban areas cause. Neglecting the integrity and care of the natural infrastructure and the ecologies that sustain water supplies around the world has created vulnerable and unresilient water systems.

Climate change has exacerbated these vulnerabilities; they are becoming increasingly evident and hard to ignore, which highlights not only an urgent need for climate adaptation measures in order to sustain accesibility to a basic resource like water, but also a deeper transformation of the current understanding of the water management paradigm and of the way we approach the hydrological systems that largely sustain our daily lives. This change must start from both the consideration of the fundamental premise that water is a finite resource, and an acknowledgment and understanding of the natural and artificial processes that happen beyond our eyes can see, that ultimately allow us to benefit from this resource.



↑ Evolution of global freshwater consumption
Source: Our World in Data


1960
2000



Disappearance of the Aral Sea as a result of large-scale river diversion projects for cotton production from the 1960s onwards
Source: NASA Earth Obsevatory



Public water tap in the outskirts of Cuenca (1970)
Author: Galo Ordóñez



2. Introduction & problematisation

2.1 The Paute Basin

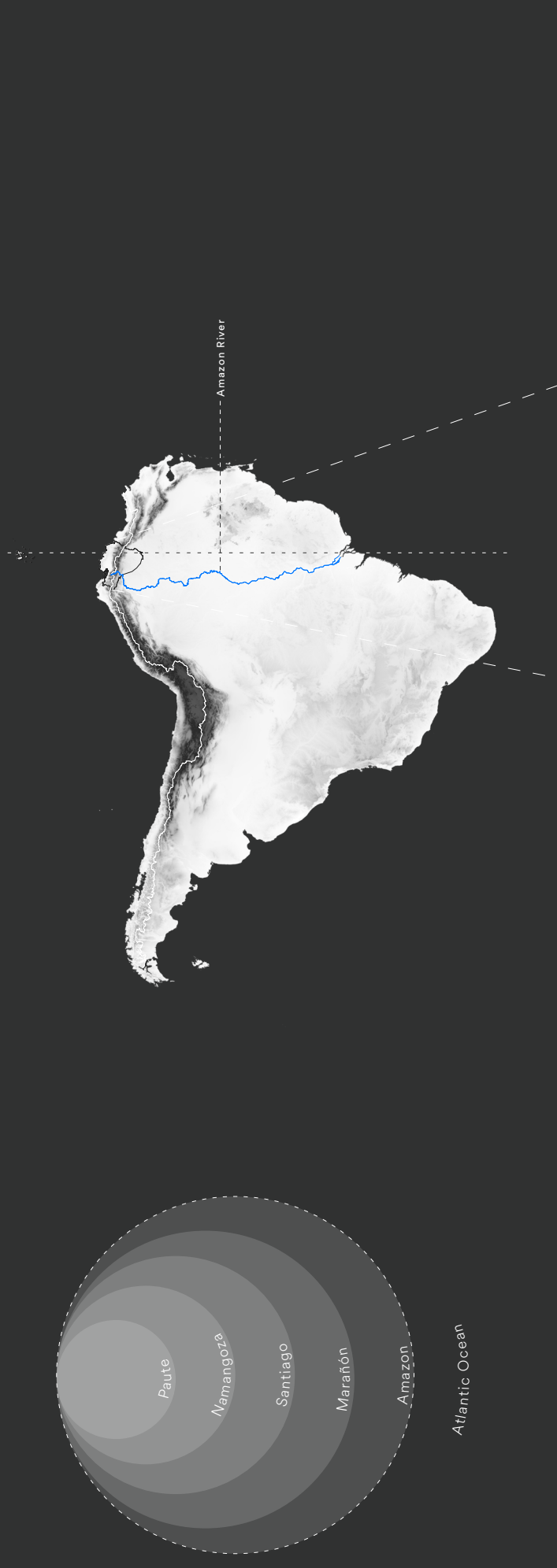
In the south of the Ecuadorian Andes, covering an area of 6,431 km^2 lies the hydrographic basin of the Paute River. As a a sub-basin of Ecuador's Atlantic macro-basin, the Paute Basin is located on the eastern side of the Andean *Divortium aquarum*, the division line that runs from north to south and splits the country in two major watersheds.

This means that the water that falls as precipitation in this basin must complete a very long journey before reaching the sea. Through streams and rivers that eventually feed into the Paute River, the water flows, leaving behind the Andes Mountains and descending towards the Amazon region of Ecuador. Here, the Paute River joins the Upano to form the Namangoza River, which in turn is a tributary of the Santiago, which feeds the Marañón, which, when it joins the Ucayali River in the Peruvian rainforest, gives rise to the Amazon.

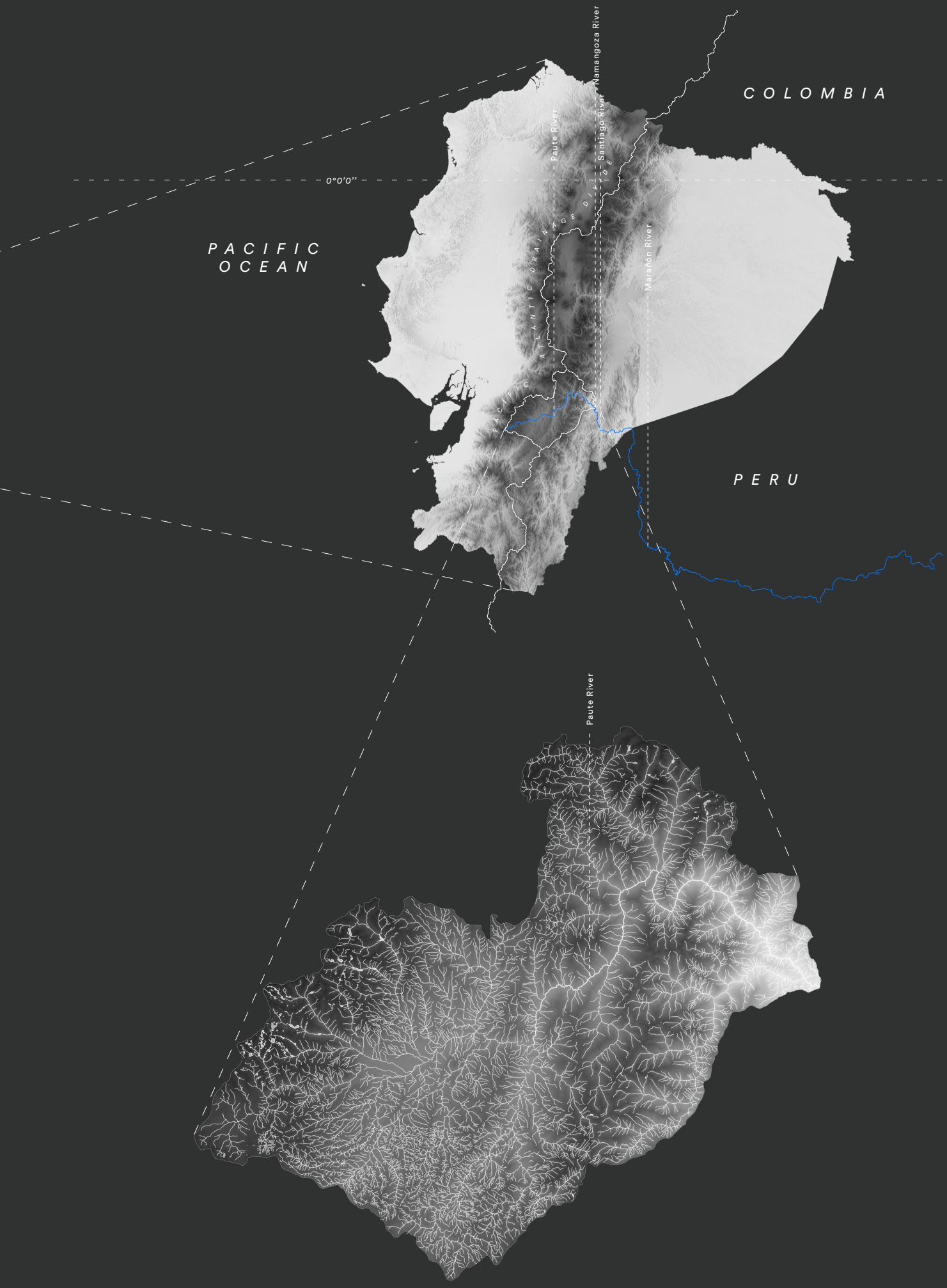
The main stream of this river basin is not called the Paute River until the point where the Cuenca River joins the Santa Bárbara River. German geologist, botanist and explorer Theodor Wolf described this fluvial system as 'a broad-crowned tree, which makes it difficult to determine which of the branches is the main one and the direct continuation of the trunk' (1892). However, between the wetland areas where the first small streams that feed the Paute River originate and the mouth of the Amazon River in the Atlantic Ocean, there are approximately 3,300 kilometres.

'No other river in South America that flows into the Atlantic Ocean originates in such close proximity to the Pacific Ocean as the Paute River'.

Theodor Wolf, 1892.



↑ Amazon Basin composition



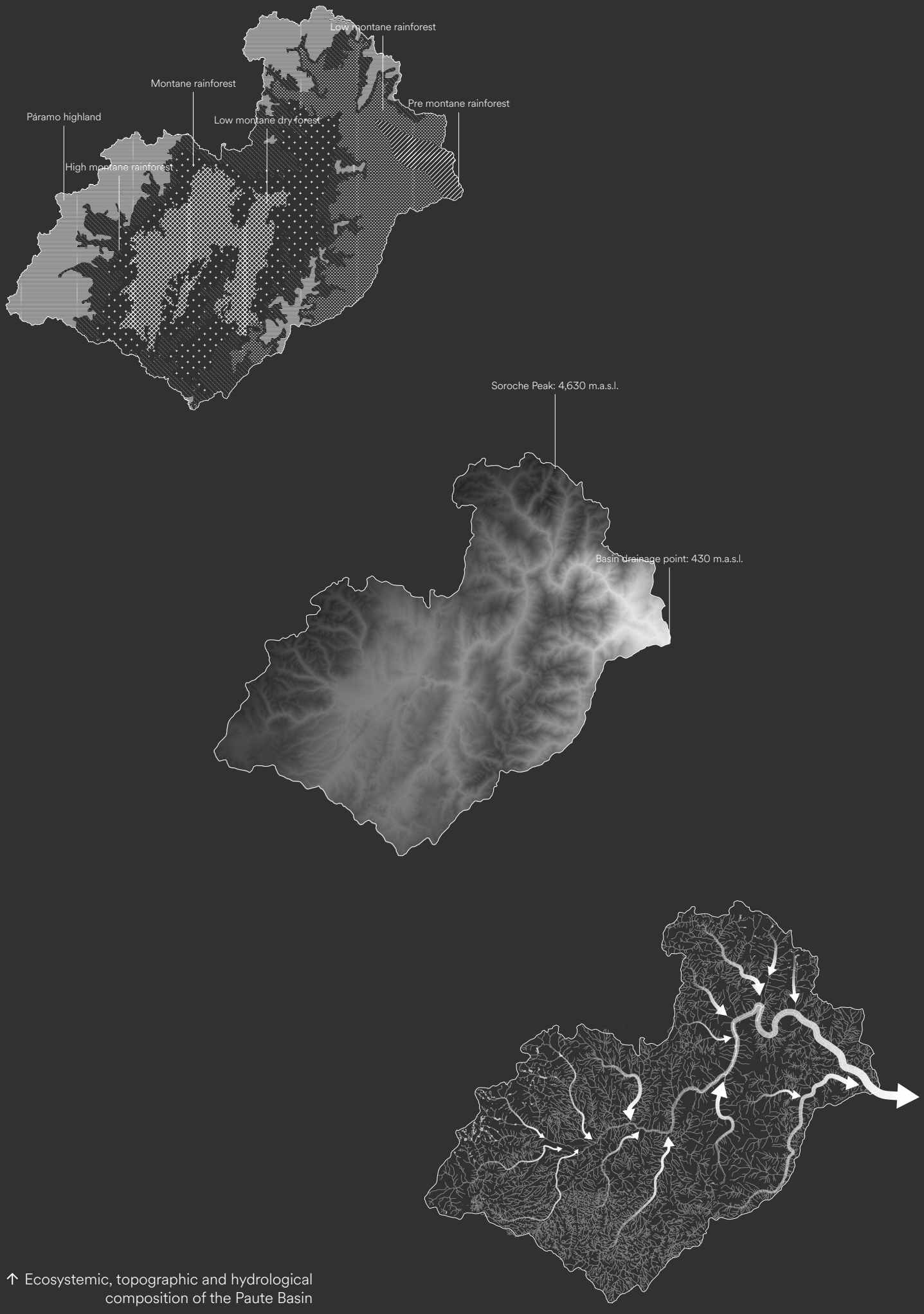
↑ Location and hydrography of the Paute Basin

Located just between 2°15′ and 3°15′ south of latitude 0 (i.e., around 300 kilometres), the Paute Basin features a climate typical of equatorial regions; its temperatures remain relatively stable throughout the year, with slight seasonal variations. The combination of its geographical location in relation to the equator and the varied topography characteristic of the Andes Mountains endows the region with a wide range of natural characteristics typical of Ecuador's Andean areas, reflected mainly in a rich variety of ecosystems made up from the extensive diversity of flora and fauna species that inhabit the region.

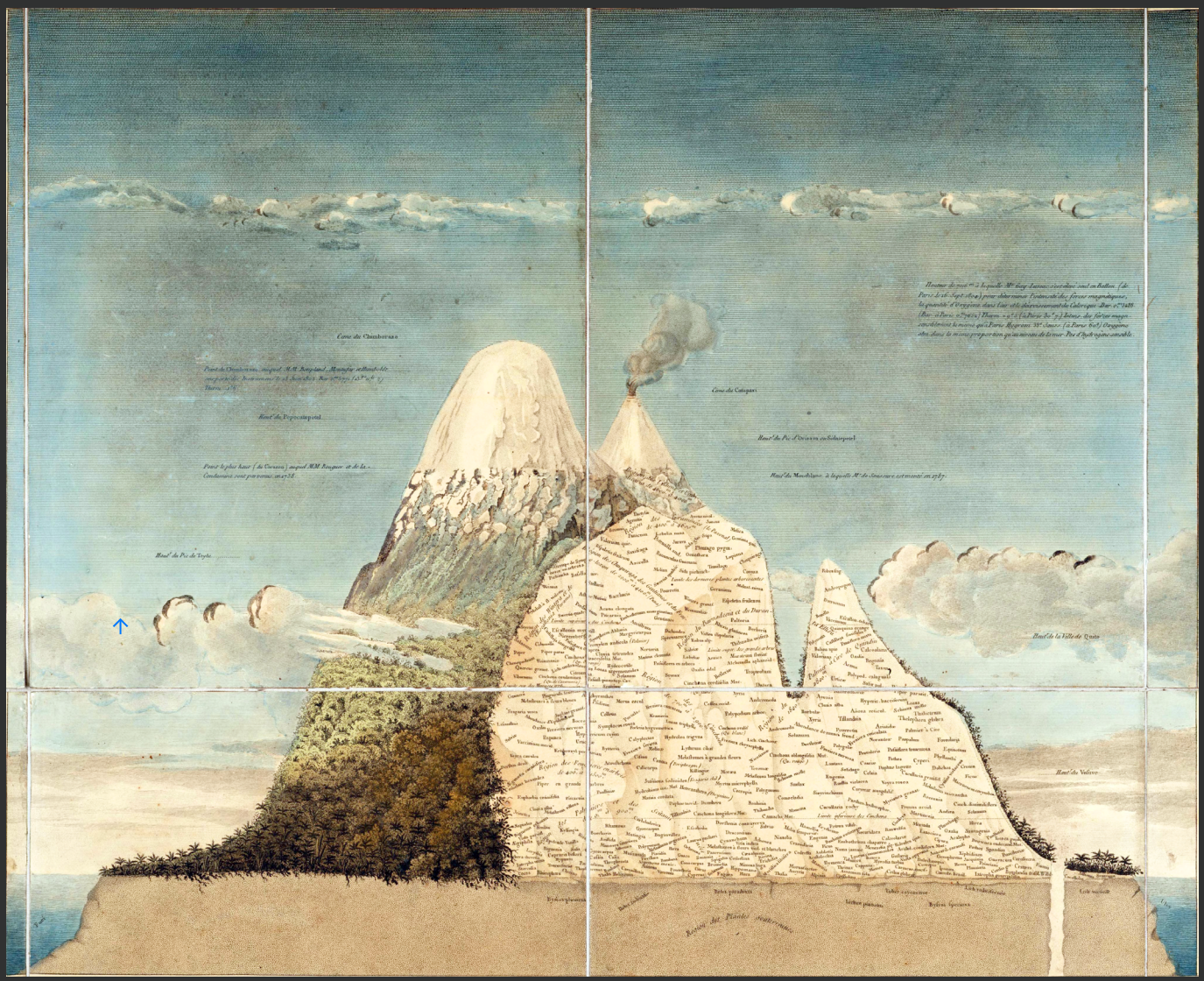
With a markedly rugged topography, altitudes in the Paute Basin vary widely; its highest peaks, located in the western sub-mountain range, are about 4,650 metres above sea level, while at its lowest point, where the Paute River leaves its basin and joins the Amazonian Upano River to form the Namangoza, the terrain is only about 430 metres above sea level. Between these two extremes, the Paute Basin has large areas of land at altitudes between 2,000 and 3,000 metres, between the two ridges of the mountain range in areas known as inter-Andean valleys, which in some cases feature relatively less rugged terrains.

This difference in altitude within the Paute Basin results in a wide range of climatic zones that are home to very diverse ecosystems. These range from the cold high mountain *Páramo* landscapes, through the temperate dry inter-Andean valleys, to the humid cloud forests of the lower areas. Thus, within the boundaries of the same basin, it is possible to find sites with average annual temperatures of 5°C as well as those with an average temperature of 22°C, located just a few dozen kilometres apart from one another.

This great diversity of ecosystems is also possible thanks to the basin's abundant water resources. Moist air masses rising from the lower lands bordering the mountain range, both from the Amazon region to the east and from the Pacific Ocean to the west, irrigate the highlands of the basin throughout the year with precipitation that takes the form of rain, drizzle and fog, particularly during the wet season between January and May, giving rise to the countless watercourses that cross and bathe the region before joining their waters in the Paute River, which drains its waters through the north-eastern end of the basin.



↑ Ecosystemic, topographic and hydrological composition of the Paute Basin



↑ Alexander von Humboldt's *Tableau Physique* (1807), depicting the vegetation diversity of Ecuadorian Andean regions
Source: avhumboldt.de

'On the map, the Paute River system resembles a tree with a broad canopy, and at first glance it is difficult to tell which of the branches is the main one and the direct continuation of the trunk'.

Theodor Wolf, 1892



↑ Fluvial structure of the upper Paute River basin

2.2 A land of opportunities

The bountiful ecological and environmental conditions of the Paute Basin certainly did not go unnoticed by the first human groups to inhabit this territory. Their arrival, around 8,000 BC (Salazar et al., 2004), marked the beginning of the harnessing and transformation of the natural systems that make up this region.

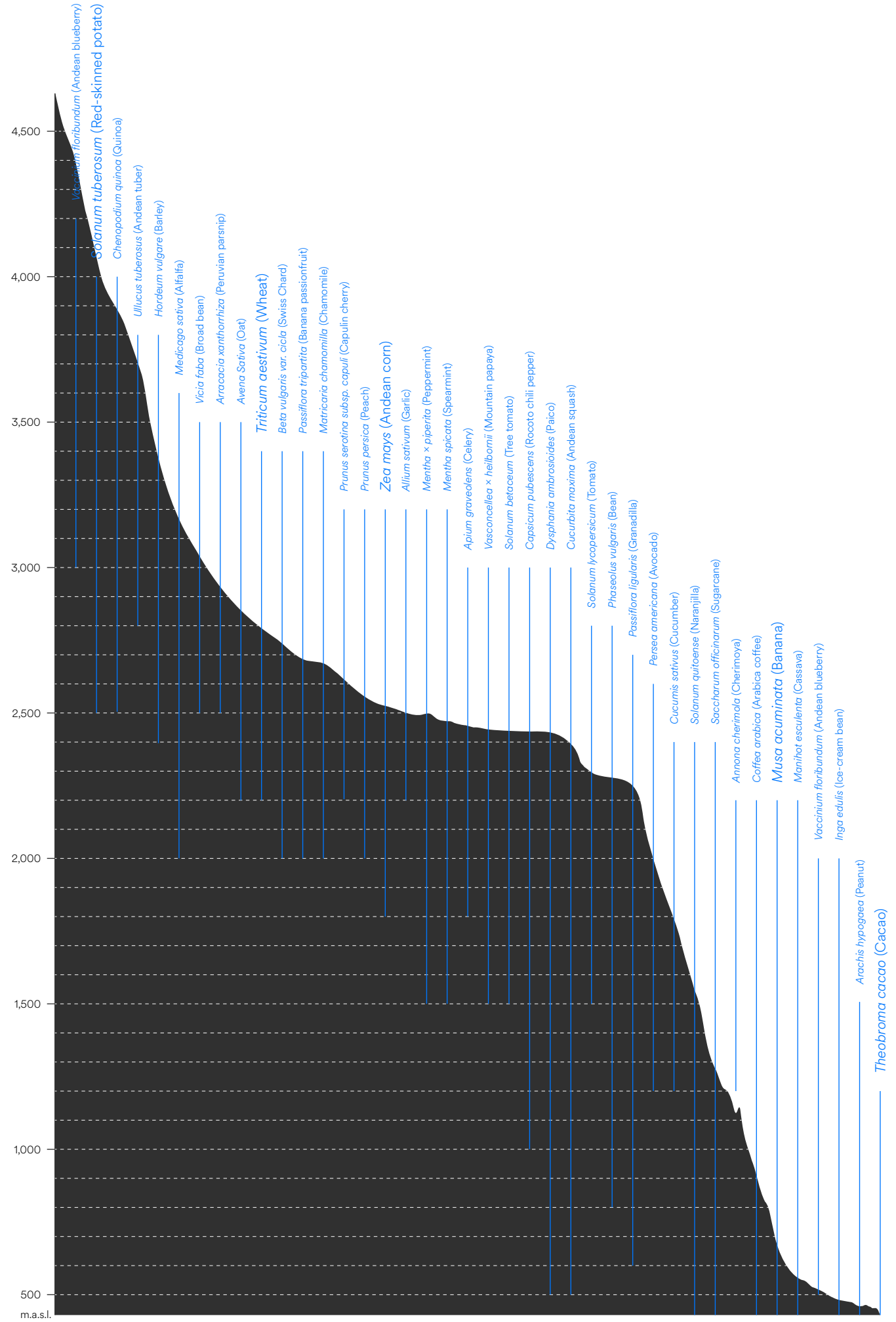
Thus, for just over ten millennia, the wealth of resources embedded in the diverse natural landscapes of the Paute Basin has become the means by which its inhabitants have achieved prosperity and stability. This has been reflected in the settlement and development of the various cultures that have inhabited the region.

This prosperity took many forms: that of clean water for drinking, irrigating crops or nourishing spirituality. The earth, stone and straw used to build homes and temples, and the wood burned to keep warm and cook maize and potatoes. The temperate plains used to raise livestock and the energy contained in its mighty, turbulent rivers, harnessed first to grind grain and later to light their towns.

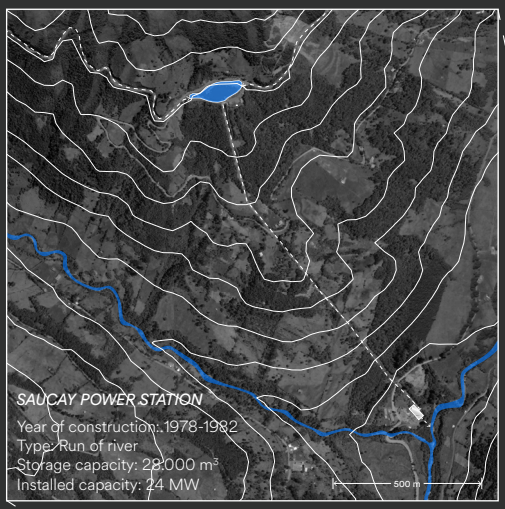
This abundance of resources, which hold the potential to facilitate human development, combined with the certainty provided by a stable climate throughout the year and a wide variety of climatic zones, has established itself over time as the ideal conditions for human habitation in this region. Access to the opportunities offered by this combination is one of the most decisive factors in shaping settlement patterns in the Paute Basin, where towns have sprung up where natural resources are readily available, the climate is mild and the topography is suitable.

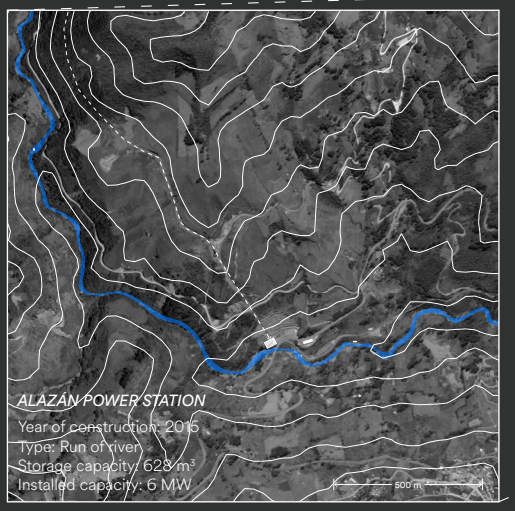
Nowadays, the harnessing of the resources available in this region plays a crucial role in the quality of life of millions of Ecuadorians, and its benefits extend beyond the geographical boundaries of the basin. Not only does the supply of drinking water for more than 800,000 people (INEC, 2022) and the economic livelihood of the region's rural population depend on the use of water from its streams, rivers and lakes through production on its extensive agricultural and livestock lands; the Paute Basin has also established itself over recent decades as the energy heart of Ecuador.

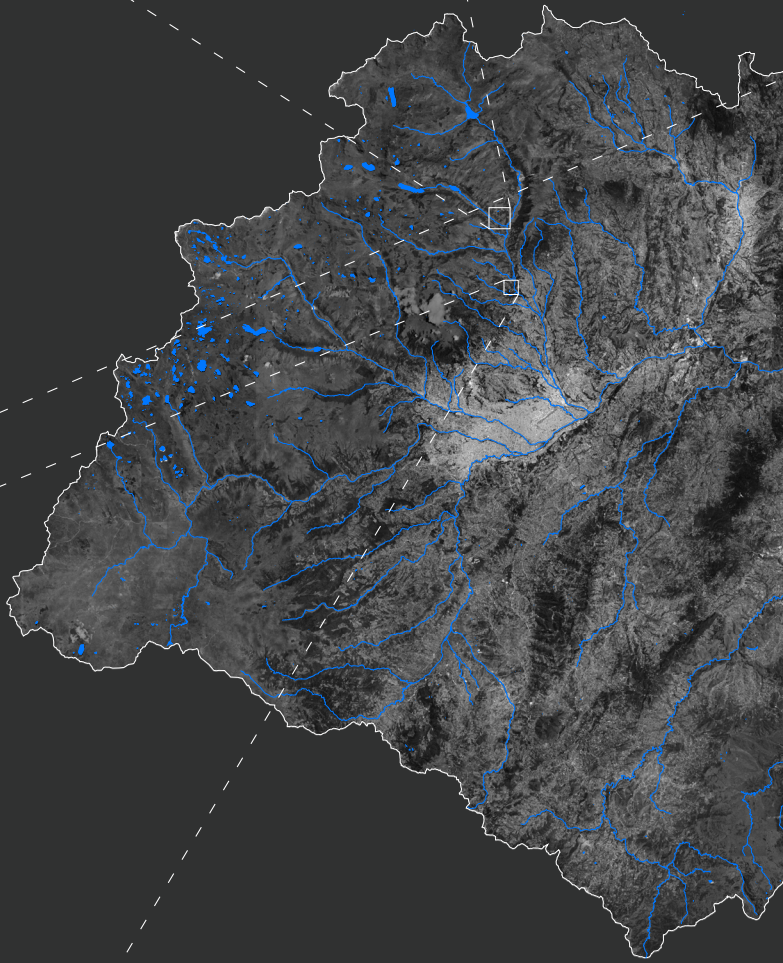
Since the second half of the 20th century, a number of hydroelectric power projects of varying scales, together with their associated infrastructure, have been integrated into the region's river system. The Paute Integral Hydroelectric Complex, comprising the Mazar and Daniel Palacios dams and the Sopladora hydroelectric plant – which reuses the water from the turbines of the former two – has established itself as Ecuador's most important energy production infrastructure complex. The 1,756 megawatts that this corridor of hydroelectric facilities delivers when operating at full capacity, combined with the 46 megawatts supplied by the other three small-scale hydroelectric projects in the basin, result in a total capacity of 1,803 megawatts. This represents just over 38% of Ecuador's national electricity demand (Tapia, 2024), a country whose electricity consumption can, at times, depend on hydroelectric generation for up to 90%.



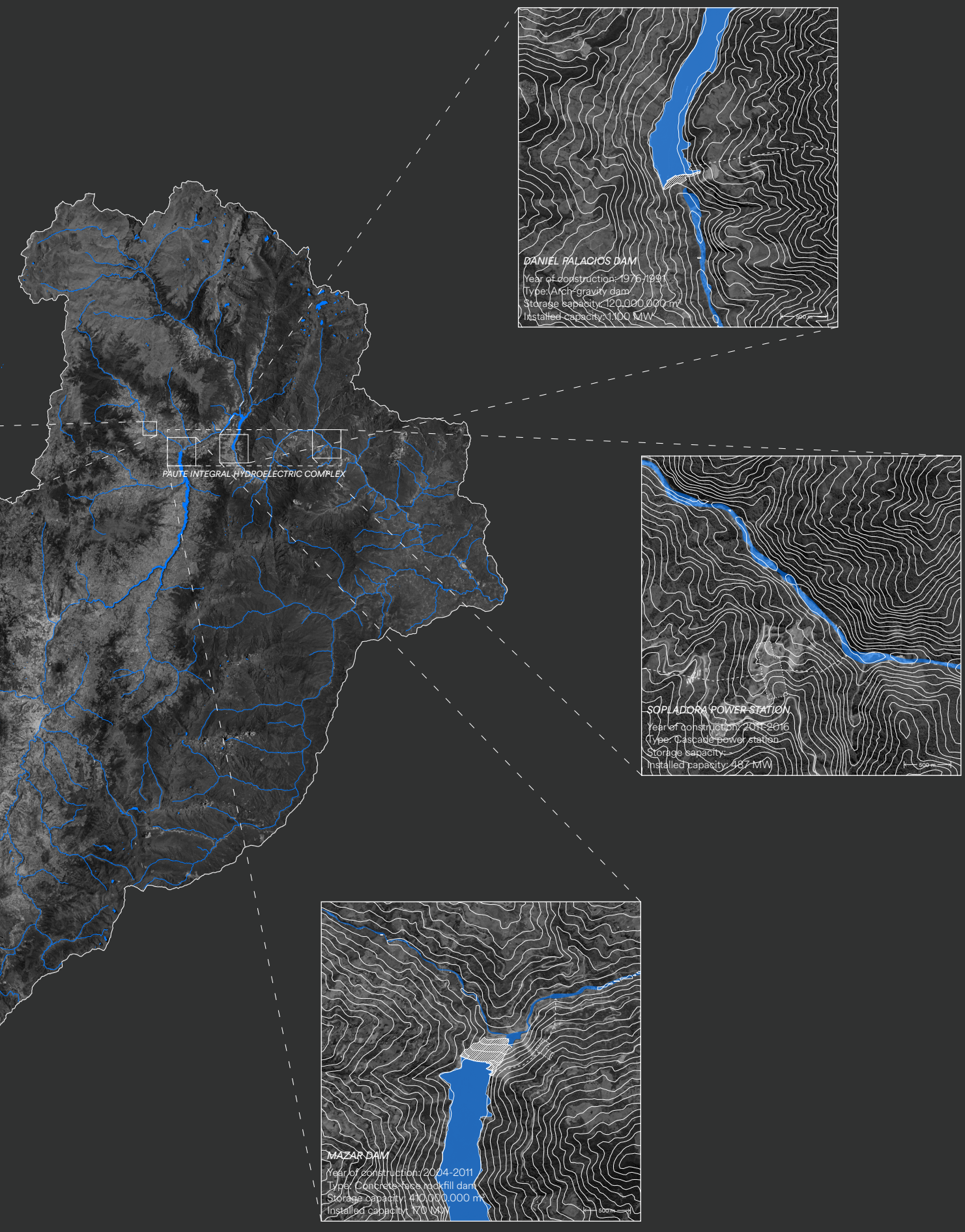
↑ Variety of products which can be grown in the altitude ranges of the Paute Basin


SAUCAY POWER STATION
Year of construction: 1978-1982
Type: Run of river
Storage capacity: 28.000 m³
Installed capacity: 24 MW
500 m


ALAZÁN POWER STATION
Year of construction: 2015
Type: Run of river
Storage capacity: 628 m³
Installed capacity: 6 MW
500 m




SAYMIRÍN POWER STATION
Year of construction: 1956-1963
Type: Run of river
Storage capacity: N/A
Installed capacity: 16 MW
500 m



↑ Hydropower generation in the Paute Basin

2.3 The Tomebamba Valley

Nestled between the Eastern and Western mountain ranges of the Los Andes range that make up the Paute Basin lies the wide Tomebamba Valley. With a relatively flat topography—an exception within its rugged surroundings—the altitudes of this inter-Andean valley range from 2,450 to 2,700 metres above sea level. Its morphology follows that of the larger river basin in which it lies, with a gentle slope descending from west to east. In addition to numerous streams and small watercourses, four of the main tributaries that contribute to the formation of the River Paute converge here: the Machángara, Tomebamba, Yanuncay and Tarqui rivers.

Its gentle topography, combined with the mild average annual temperature of 16°C (INAMHI, 2013), the fertility of its soils and the abundance of water supplied by its rivers, are among the main factors that made this valley a historic settlement site for people from diverse cultures. Through successive processes of conquest and subjugation, these cultures have succeeded one another over time, resulting in a stratified historical landscape in this territory, in which it is possible to discern various forms of interaction between humans and the natural environment.

The Cañaris, the Incas, Spanish conquistadors and citizens of the Republic have inhabited this valley since the beginning of its urbanisation process, which took place approximately 1,600 years ago (Salazar et al., 2004). First *Guapondélig*, then *Tomebamba*, and since 1557, the year of the Spanish founding, *Santa Ana de los Ríos de Cuenca* (Saint Anne of the Rivers of Cuenca); these are the names given to the settlement that emerged from this habitation throughout its history. The



'The Matadero (nowadays Tomebamba) *River valley continu*
respect until it reaches Sayausí. Then, just before this town, th
plain of Cuenca spreads out before the traveler's eyes. As if by
highlands to one of the most inhabited and best-cultivated reg
road, the contrast has a surprising effect. No inland city occu
of a wide valley, full of fruit trees and fertilised by so many riv



↑ 1878 plan of the city of Cuenca, by Salvador Mora
Source: IERSE

es eastward. It is narrow and extremely monotonous in every
e valley suddenly opens up, and the beautiful, well-cultivated
y magic, one is transported in an instant from the desert of the
gions of the republic, and when seen for the first time from this
pies such an advantageous location as Cuenca, in the center
vers'.

Theodor Wolf, 1875.

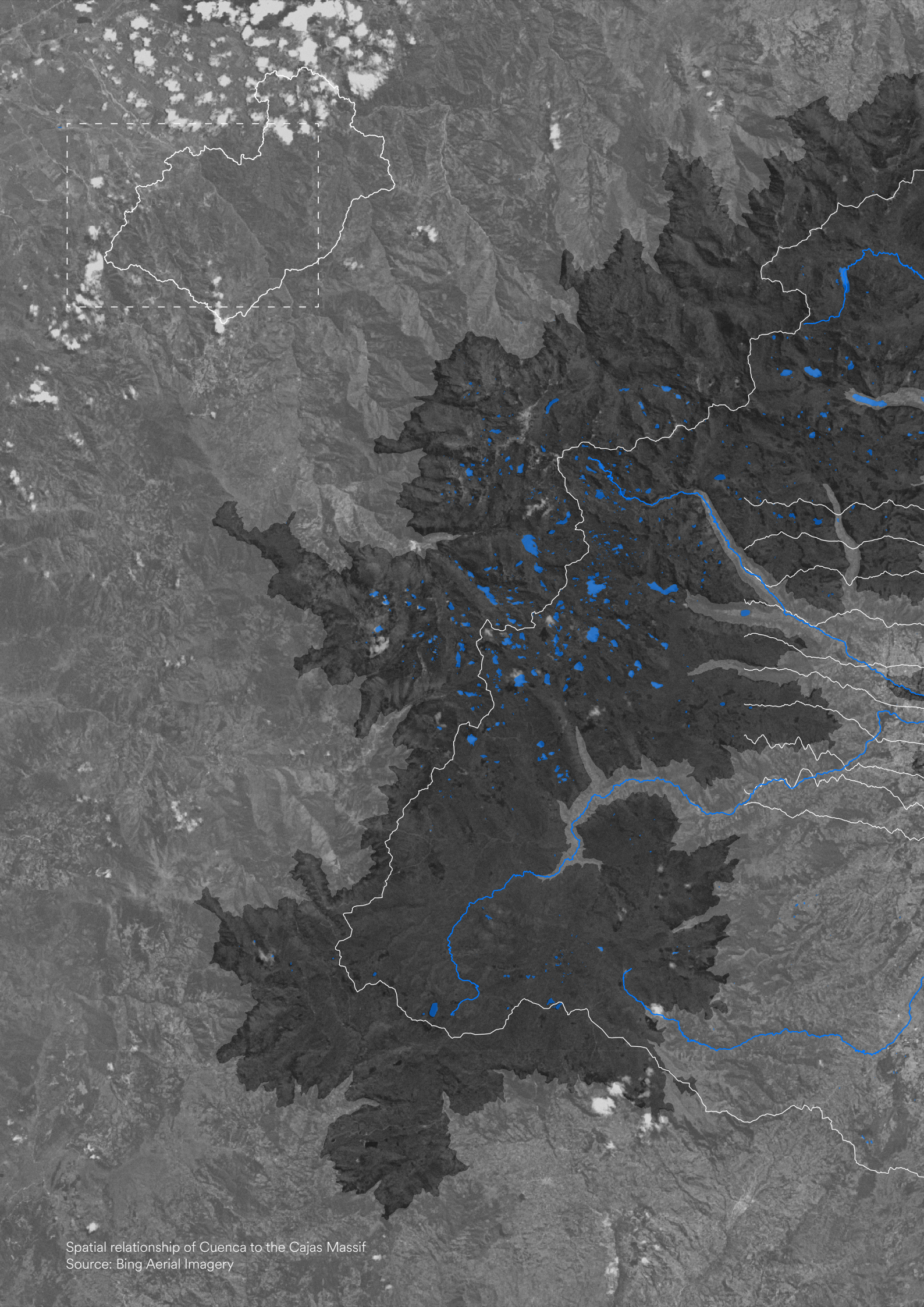
reference to the rivers in the name given to the city at the time of its Spanish founding is a clear reflection of the decisive role they played in the choice of this valley as a settlement site, not only by the Spanish, but also by the Cañaris and Incas, who, prior to the colonial period, had already developed mechanisms to harness their benefits, mainly in the form of diversion channels for the irrigation of agricultural plots and for ceremonial-religious purposes (Salazar et al., 2004).

'The aforementioned town may be founded, provided that it has a permanent water supply, wood for fuel, land to distribute, and the means to build water mills alongside it'.

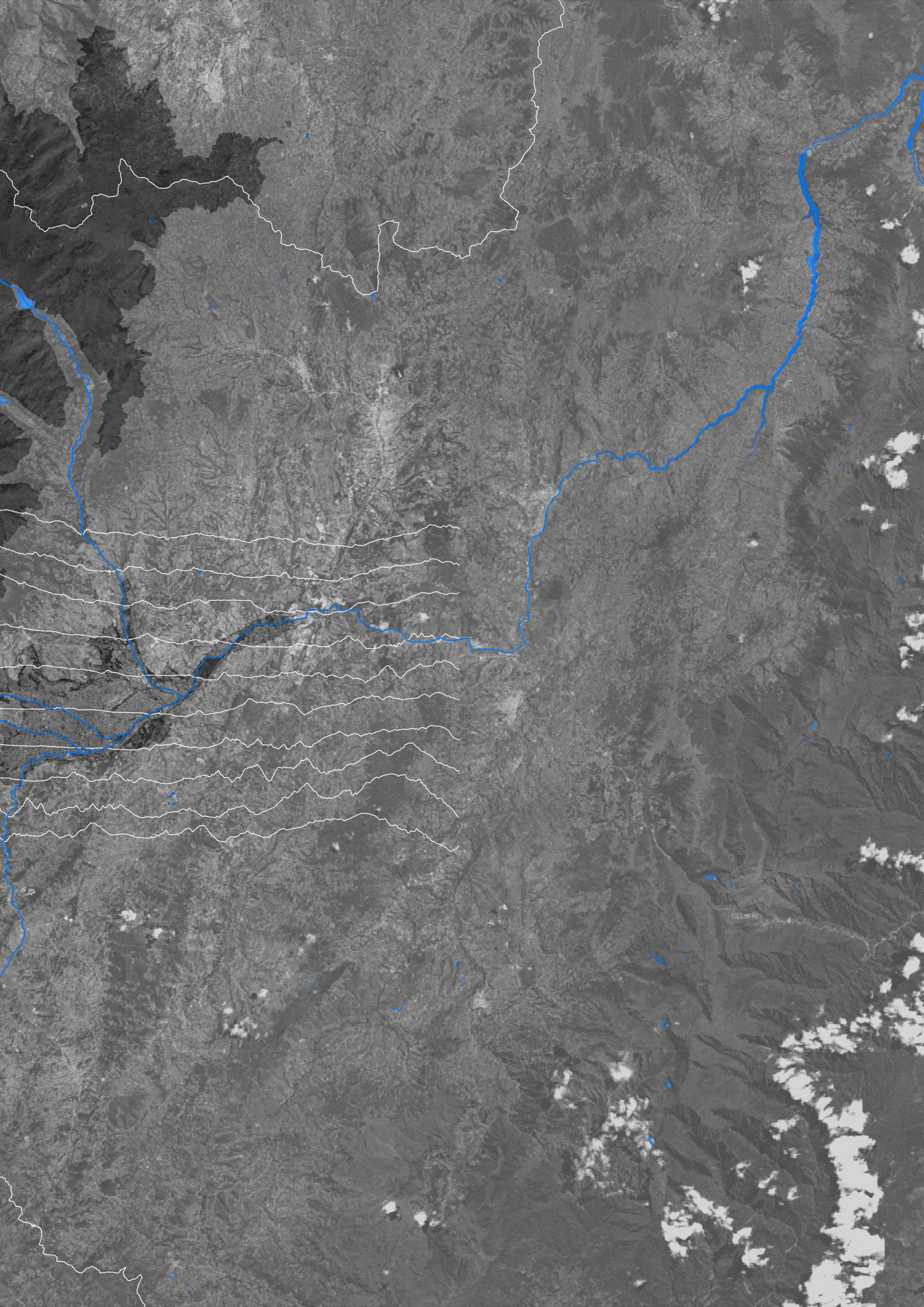
Founding charter of the city of Cuenca, 1557.

This historic and virtually uninterrupted supply of water in the Tomebamba Valley, upon which the prosperity of the cultures that have inhabited it has been built, is largely due to its location near El Cajas, the extense mountain massif which borders and embraces the valley from the north and west. It is in the vast wetlands and numerous lakes of this massif, which rises over 4,500 metres above the sea level, that the four rivers crossing it have their source, sometimes bearing different names from those they acquire in their better-known stretches, yet forming part of the same watercourse.

Thus, the settlement that occupies this valley—now known simply as Cuenca—has grown since its inception in close connection with and dependence on the valley's river system, which has played a decisive role in the evolution of its landscape and the lives of its inhabitants.



Spatial relationship of Cuenca to the Cajas Massif
Source: Bing Aerial Imagery







Upper headwaters of the Tomebamba River, in the Cajas Massif

2.4 The city of four rivers

The passing of the centuries has not only reaffirmed the vital role that the rivers running through this valley have historically played for its inhabitants, but has also highlighted their growing importance today. As the population has grown rapidly over recent decades, so too has the region's dependence on its river system.

With a population of around 361,000 within the urban boundary and 235,000 in peri-urban and rural areas, Cuenca is currently Ecuador's third-largest city (INEC, 2022). The supply of drinking water to the urban area and the rural areas closest to the city depends exclusively on surface water sources, namely the four rivers that flow through it and converge there, bringing the number of people whose access to this service depends on this system to 496,000 (ETAPA EP, 2025). In addition, the water drawn from the rivers feeds the irrigation systems of the agricultural and livestock areas near the city, which in turn supply it with food and raw materials.

'No generation of people in Cuenca has been able to do without the influence of its rivers'.

Margarita Vega de Córdova, 1997.

Rivers, besides being suppliers of this essential resource, appear on the urban map like veins running through a city which, taking advantage of the flat topography of the valley where their waters converge, has grown up around them. As they flow through the urban area, the rivers provide the city with generous linear green spaces, corridors that contribute significantly to the quality of life of its inhabitants and act as natural boundaries between urban zones. Furthermore, the stability of its flow (combined with that of several other rivers originating in the region) is a key factor in hydroelectric power generation on various scales and, consequently, in Ecuador's energy security, highlighting its importance as a natural source of multiple ecosystem benefits for the region and the country.



Beyond, however, the material benefits or practical services that rivers provide, or the productive activities that the use of their waters and associated landscapes has enabled in the past and continues to enable today (drinking water, electricity, agricultural and livestock production, sanitation), their vital role in the succession of historical events that have shaped the landscape and ways of life in this valley gives them a leading role in the historical interpretation of Cuenca's urban landscape. This importance is reflected in the accounts that describe the consolidation of both everyday activities and popular traditions that took shape around them. In this way, the rivers of Cuenca can be interpreted as urban corridors of memory, along which it is possible to trace the ways in which the valley's inhabitants related to them at different times.

The reflection of the cultural history of a built environment that owes much of its existence to the rivers that flow through it, combined with the unique richness of the natural setting in which it is embedded, has led to recognition both as a World Heritage Site, granted to Cuenca by UNESCO in 1999, as well as the inclusion of the Cajas Massif on the List of Ramsar Sites in 2002, which recognises unique wetland ecosystems of high ecological, biological and hydrological value and rich biodiversity around the world. In this sense, the regional riverscape has been and remains one of the main historical sources of identity for its inhabitants, to the extent that the city cannot be imagined without the presence of its four rivers and the mountain range from which they originate.

'A holistic understanding of Cuenca includes also the Cajas Massif, with its forests, mountains and lakes. These two heritage sites are of interest to humanity and should also be understood as a single entity'.

Fausto Cardoso, 2024.



The Tomebamba Valley as seen from the edge of the Cajas Massif
Source: Diego Luzuriaga



↑ Popular tradition of catching fish in the Yanuncay River (1920)
Source: Manuel Jesús Serrano | INPC



↑ Popular festivity at a pond formed by water diverted from the Tomebamba River (1922)
Source: Manuel Jesús Serrano | INPC



↑ The Tomebamba River as a public laundry, with the Cajas Massif in the back (1943)
Source: Unknown author | INPC



↑ Cuenca's first hydroelectric power station, fed by the waters of the Yanuncay River (1930)
Source: Manuel Jesús Serrano | INPC

2.5 The modernisation of water

'Cities become more dense and simultaneously more diffuse, they grow and expand like a carpet over large parts of the earth's surface. They merge into complex networks which overrun and transform the landscape. They form an urbanised landscape that is subject to constant transformation'.

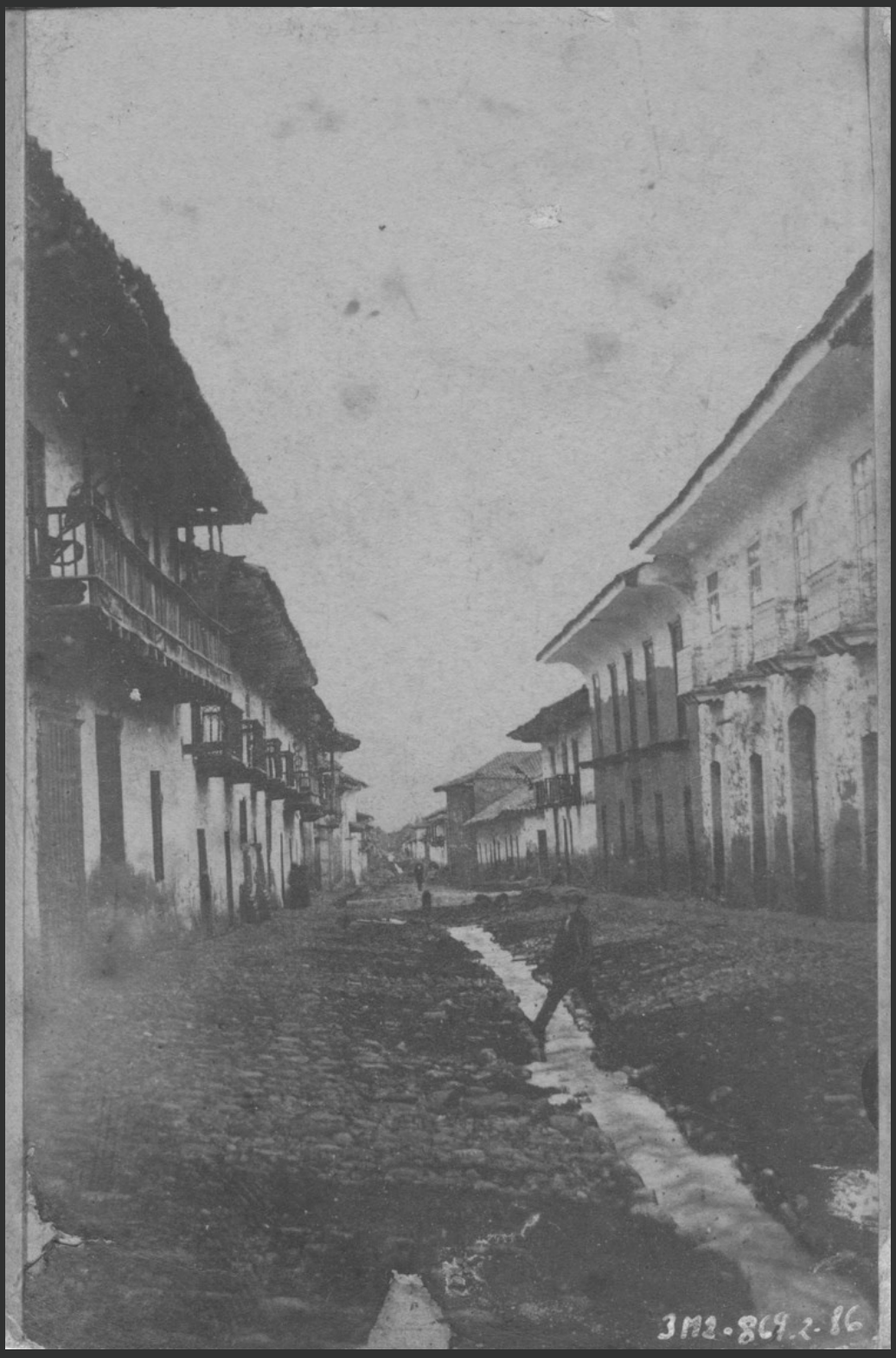
Frits Palmboom, 2012.

A holistic understanding of Cuenca and its surrounding landscape as a single entity is also applicable when thinking about resources, and especially water. Over the last few decades, particularly from the start of the second half of the 20th century, and in tandem with the modernising revolution that was spreading across the world, human activity began to have a significant impact on the region's previously relatively untouched natural landscape. These interventions meant that the relationship of interdependence between the city and the surrounding landscape intensified, and led to the convertion of specific areas into supporting regions from which different resources are extracted and/or produced for consumption in the urban area.

Just after the start of the second half of the century, as a result of improvements in the quality of life brought about by infrastructure modernisation and a wave of rural-to-urban migration, Cuenca began to experience an unprecedented process of population growth and urban expansion – the most intense in its history – which took place between 1950 and 1975. In just 25 years, the city grew from a population of 40,000 and an area of approximately 200 hectares to 105,000 inhabitants and an area of around 700 hectares (Salazar et al., 2004). The rapid population growth, combined with the change of era represented by the modernisation boom, resulted in an urgent demand for the expansion and upgrading of urban infrastructure. A telephone network, paved and lit streets, a sewerage system, and domestic electricity and water supplies became standard basic necessities.

The urgent need to provide a constant supply of high-quality drinking water to a rapidly growing population led to the construction of the first pieces of modern engineering infrastructure for the abstraction, conveyance, purification and distribution of water drawn from the Culebrillas River. Although numerous open channels had already been built during the pre-colonial period to divert water from the Tomebamba River to the settlement originally inhabited by the Cañari and later by the Incas of Tomebamba, the urbanisation process and lifestyle transformations resulting from the Spanish founding of the city completely transformed its primary function. It ceased to be a means of transporting and supplying clean water, and became a conduit for receiving and carrying away domestic waste. Thus, with the arrival of modern drinking water infrastructure, the uncomfortable habits of fetching water daily in buckets or jugs from the rivers, or walking to them on sunny days to clean oneself—habits repeated for centuries—were left behind. The expansion of distribution networks made it possible to supply water on a widespread basis, chemically treated and delivered directly to homes, which made the process of obtaining water extraordinarily simple and convenient for the consumer. Water, as a resource, became much more accessible.

This novel ubiquity of water – embodied in the



↑ Cuenca in the 1880s: the street canals as arteries of urban sanitation
Source: INPC



↑ Former water purification process at El Cebollar, the first purification facility of Cuenca (1968)
Source: Galo Ordóñez



↑ Construction of the El Labrado storage dam in the high course of the Chulco River (1969)
Source: Avance Magazine

simple act of turning on the tap in the bathroom or kitchen at home and letting the water flow – led to a significant transformation in the water consumption habits of the people of Cuenca and in their overall relationship with water. The introduction of modern hygiene habits into daily routines led to a considerable increase in urban domestic water consumption: there is no longer any need to fetch water from the rivers; now the water comes to us. The rise in consumption, driven by both population growth and new individual consumption habits, meant that the city's sole water treatment plant came under immense pressure. As a result, it required two expansions—in 1958 and 1976—to increase its production capacity. Within this period, new water intake structures had to be built on the Tomebamba River in 1970 to increase the flow entering the drinking water production system.

Between these two expansion projects, in 1969, the region's first dam was built. The El Labrado dam was constructed as one of the first projects aimed at increasing water storage capacity, thereby reinforcing the fragile drinking water security of Cuenca. Storage limitations, however, were not the only challenge facing the water system at the time, and in response to the growing pressure on the infrastructure during the 1960s in terms of supply and sanitation, the municipal authorities devised the first Drinking Water and Sewerage Master Plan, issued in 1970. Population growth, however, showed no sign of slowing down, and within a few years the measures proposed by this first plan proved insufficient, requiring the development of a new Master Plan for Drinking Water and Sewerage, published in 1983. Among the key points of these two plans, and as a measure to reduce the pressure on the city's sole water treatment plant at the time, was the proposal to construct a new water treatment plant in the Machángara River basin, a facility that would not be completed until 1996. In turn, population growth meant that more water would need to be extracted and secured throughout the year in the coming decades, which is why the construction of two new water storage reservoirs in the Machángara and Yanuncay river basins was also proposed.

The rise in water consumption from the 1950s onwards not only meant that more water was being extracted from rivers, but also that the volume of water to be disposed of after consumption increased significantly. The complete lack of any sense of awareness regarding the environmental impact of processes linked to urban growth, characteristic of the period, meant that, for several decades, the urban sewerage system discharged the city's wastewater directly into rivers, without any form of treatment. Thus, just as upstream the implementation of modern water collection works gave the rivers the role of suppliers of this essential resource for the city, the construction of the sewerage works that discharge the city's wastewater into them turns them, downstream, into metabolic cleansers; responsible for carrying waste away from the urban area, and maintaining public hygiene. During this period, in the technical jargon used by the municipal authorities, rivers were referred to as 'receiving bodies' (Ordóñez, 2008). Thus, thanks to the incorporation of modern infrastructure into the river landscape, rivers acquired a variable urban function that changes depending on the area of the city surrounding them.

It was not until the late 1960s that a growing concern about the state of the rivers began to emerge, initially from the then recently established (in 1968) municipal water supply company, ETAPA EP. The deplorable condition of the rivers, which had become authentic public dumping grounds receiving not only sewage but practically any type of waste that urban residents wished to dispose of, became the main motivation for the launch of systematic water quality monitoring studies. This event would become the historic milestone marking the start of a sustained but very slow process of raising awareness regarding the importance of the ecological integrity of the rivers.

By 1984, discussions had begun at the municipal level regarding the need for a wastewater treatment plant in Cuenca to safeguard the health of downstream residents and the ecological integrity of the river. The discussion, however, progressed very slowly, and it was not until ten years after it began, in 1994, that the first sewage interceptors came into operation, preventing sewage from being discharged into rivers within the urban area. This improved the condition of the rivers within the city but did not truly resolve the underlying problem. It was not until 1999 that the Ucubamba sewage treatment plant was opened, and untreated wastewater finally ceased to be discharged directly into the rivers.

In a process that unfolded almost in parallel with population growth—and as a reflection of the changes taking place on the other side of the urban-rural boundary—the area of land devoted to agriculture and livestock farming in the region also experienced significant growth during the second half of the 20th century, in response to the city's rising demand for food during this period. The small agricultural plots on which the produce that fed the Cuenca region between the 16th and 19th centuries was grown, and which were located in the immediate surrounding area,

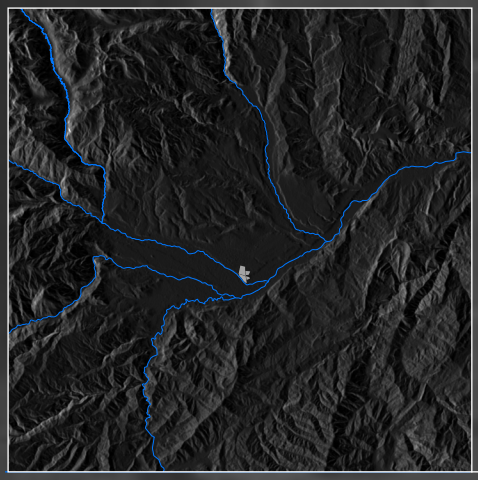


ceased to exist as such as the city grew and the use of this land changed. This gradually pushed agricultural and livestock production further and further away from the urban centre, and created a demand for new land for this purpose. The expansion of the agricultural and livestock frontier in the Cuenca region during the 20th century took place, in many cases, at the expense of large extensions of native forest, moorland and wetlands—ecosystems that play a vital role in the ecological regulation cycle of rivers—which were cleared to convert these territories into production landscapes. At the same time, water concessions began to be formally granted to farmers and livestock breeders, enabling the creation of irrigation systems that rely on the extraction of surface water from rivers and streams.

The late 1990s and the first decade of the 21st century were a period marked by an intensification of water infrastructure works in Cuenca, in order to keep pace with the needs of a population that had been growing sharply since the 1950s. Consequently, the works focused primarily on increasing drinking water production through the construction of two new treatment plants, as well as on expanding the urban sewerage network.

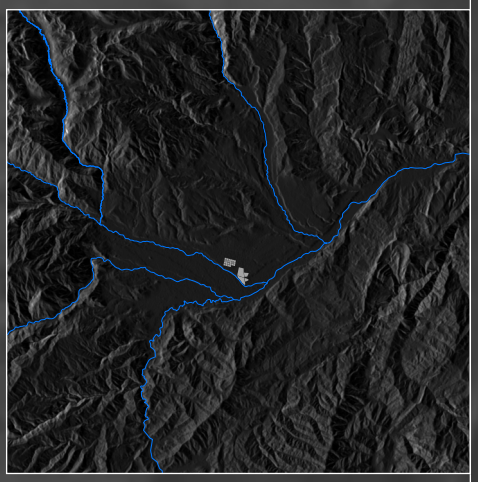


Expansion of the agricultural and cattle frontier at the expense of montane rainforest
Source: Bing Aerial Imagery



1500

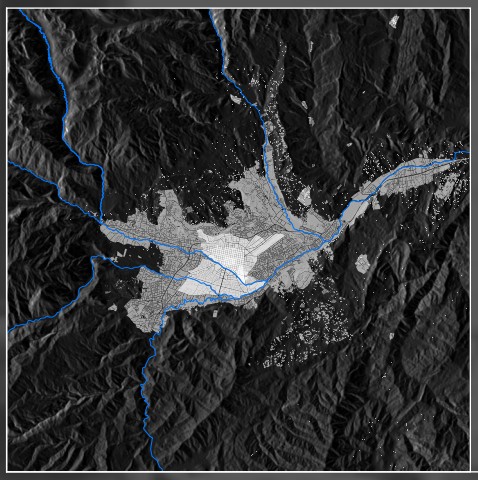
The first sedentary inhabitants of the Tomebamba Valley, The Cañaris, settled at the banks of the Tomebamba River. They lived here until the 1460s, when they were subjugated by the Incas, who were expanding their empire from the south. The Cañari settlement of Guapondélig was renamed Tumipampa (Tomebamba) and became the capital of Chinchaysuyu, the northern province of the Inca Empire.



1570

The Inca rule didn't last long. In 1557, after the arrival of Spanish conquistadors and the establishment of the colony, the Spanish re-foundation of the city took place northwest from Guapondélig/Tomebamba. By 1570, Santa Ana de los Ríos de Cuenca (Saint Anne of the Rivers of Cuenca) was a small village with just a few hundred inhabitants.

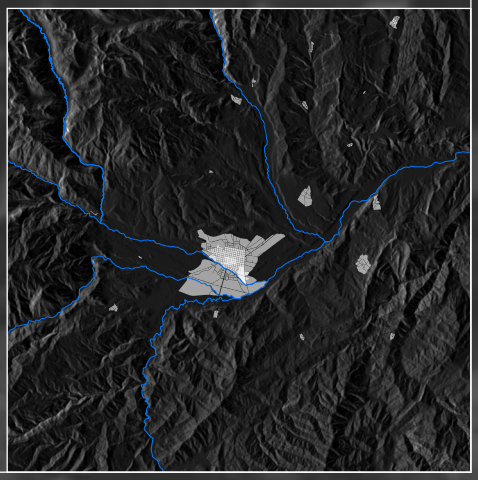
Urban and demographic growth in the Tomebamba Valley
Image source: Galo Ordóñez



2025

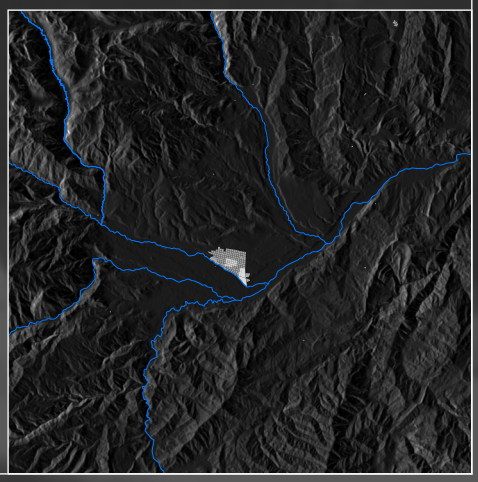
Over the last half-century, the growth trend has persisted. By 2025, nearly 600,000 people live in Cuenca and its surroundings, and the urban area now covers the entire Tomebamba Valley. The city has begun to climb up the surrounding mountains.

In just 25 years, Cuenca's population more than doubled, going from 40,000 to 105,000. During this period, the urban area expanded by a factor of 3.5, increasing from 200 to 700 hectares. Small settlements in the surrounding rural landscape of the city began to expand too.



1975

1950



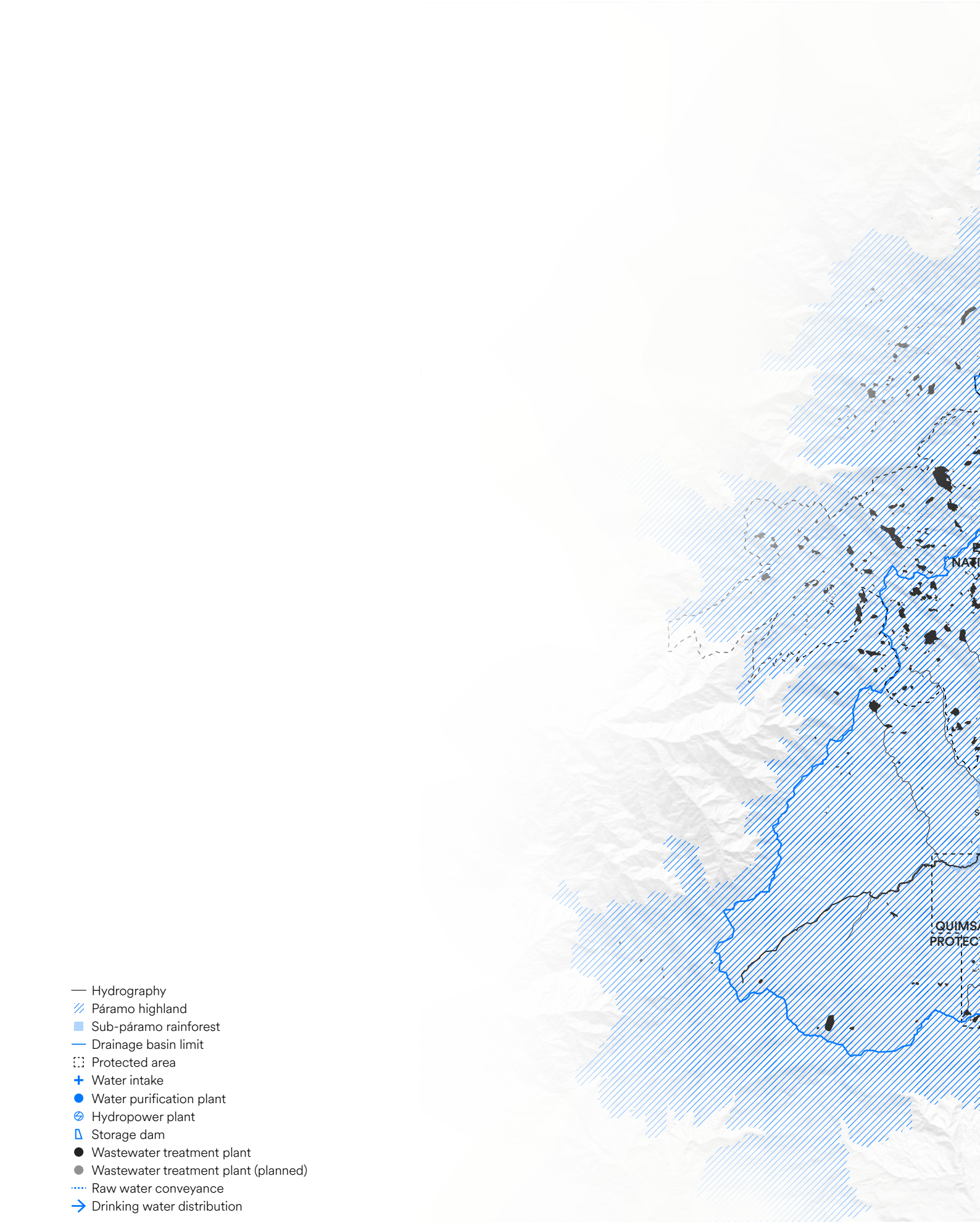
Over the span of almost 400 years, both the urban area and population of Cuenca grew at a very slow pace, until the modernisation wave arrived in Ecuador during the 1950s. Infrastructural improvements which esentially resulted in the sanitation and electrification of the city delivered enhanced living conditions, which in turn marked the beginning of a demographic boom and intense urban expansion period.

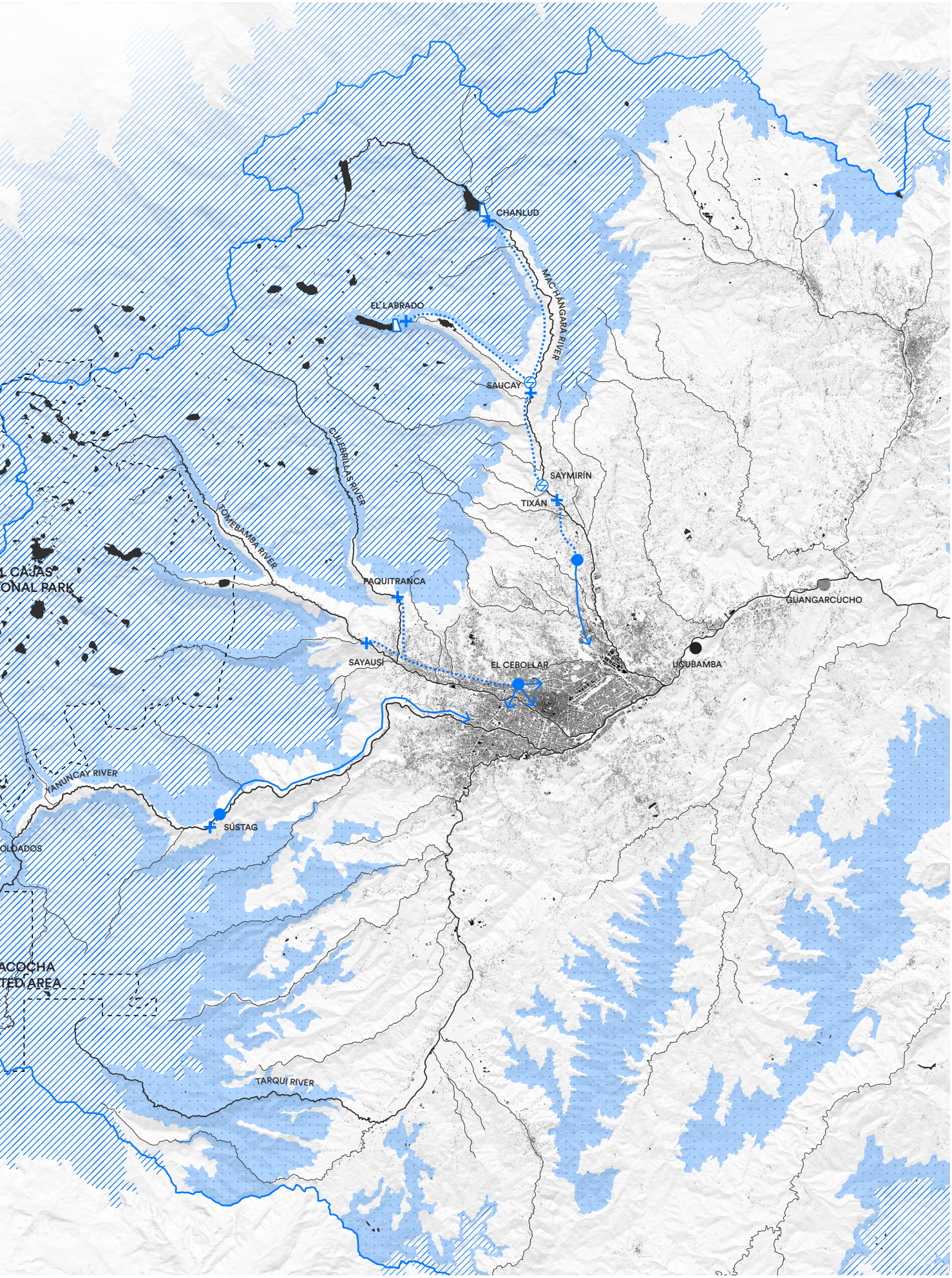

Begins the construction of the city's second wastewa
Spanning 160 days, the most severe drought in over 50 years is recorded in the region. F
The Cuenca region exp
The Tarqui River flow jumps from its average rate of 3,2 cubic metres
The amount of wastewater produced by the city surpasses the operating capacity of th
River water quality starts to be monitore
Continuous population growth pushes municipal authorities to draw up a plan to increase drinking wa
The city's first water treatment plant, Ucubamba, begins operations. Nearly 100%
A large-scale s
Water from the Machángara River begins to be extracted for drin
The Chanlud Dam (17 million cubic metres storage capacity) is built in the headw
The first combined sewage interceptors are built, runn
ETAPA EP acquires 11,000 hectares of land in th
Several campaigns to study the quality of river water are carried out, revealing serious deterioration in water quality at th
The Water Master Plan for Cuenca (
It is estimated that of the approximately 6,200
Downstream from the Saucay project, the Saymirín run-of-ri
An area
The El Cebollar water purification plant is exp
As a result of population growth, the agricultural and livestock frontie
Industrial development leads to the gradual dismantling
Intake works are built in Sayau
Due to rapid population growth, the city's drinking water and sewerage systems are unc
The Labrado Dam (6,2 million cubic metres storage capacity) is built in the headwaters of the Machángara
The current drinking water production and waste water treatment municipal company,
Expansion works are carried out at the El Cebollar Plant in order to increase drinking water production. All of the c
In order to meet the growing energy demand of the city, the Saucay run-of-river hydropower
Water from the Culebrillas River begins to be extracted and conveyed from Paquitranca
The first pipes for the household w
The largest overflow ever recorded in the history of the Tomebamba River sweeps away five of the
The Department of Drinking Water is founded, and the first studies for water intake works are drawn up. The construction of the first water
Public taps are the main sou
Sewerage works in Cuenca begin: The first canals that cross the city carrying water from the Tomebamb
30.000 people
The city has no drinking water or piped water supply, no bathrooms, and no sanitation facilities. The Tomebamba River is used as a source o
Cuenca gets electrified: The construction of the Yanuncay River hydropower plant allows to gradually replace kerosene and candles for elect
Large areas of riparian forest in the middle basin of the Tomebamba River are burned, due to the mistaken belief that smoke attracts rain (1
One of the worst droughts ever recorded hits the region. Rivers dry up, leaving the population unable to grow food or practice hygiene (19
25.000 people live in Cuenca (1892)
'The streets are the latrines of the masses; the ditches that receive the waste from the houses do not flow freely'. V. Solano (1849)
Foundation of the Republic of Ecuador (1830)
Ecuador's First Shout of Independence: liberation from the Spanish colony (1809)
'All streets running east to west have abundant water channels that facilitate cleaning'. F.J. de Caldas (1804)
14.000 people live in Cuenca (1787)
Water of the Tomebamba River is extracted and carried to the city through a system of open channels (1765)
Wood is extracted from the forests along the Tomebamba River (1600)
The Tomebamba River carries away the newly built main bridge (1596)
Several grain mills operate along the Tomebamba River (1579)
The Spanish foundation of the city takes place (1557)
Spanish conquerors arrive in Tomebamba (1534)
Columbus disembarks at Guanahani (1492)
Inca conquest (1480)
Cañari occupation of the region
1300
1400
1500
1600
1700
1800
1900



↑ Modern socio-hydrological history of Cuenca

Sources: Ordóñez | Wolf | Salazar et al.| Municipality of Cuenca | ETAPA EP | INEC | INPC


Hydrography
Páramo highland
Sub-páramo rainforest
Drainage basin limit
Protected area
Water intake
Water purification plant
Hydropower plant
Storage dam
Wastewater treatment plant
Wastewater treatment plant (planned)
Raw water conveyance
Drinking water distribution
5 km



↑ Cuenca's natural and man-made water infrastructure

2.6 Rivers under pressure

The population growth experienced by Cuenca over recent decades, combined with the adoption of modern lifestyles by its inhabitants—which involve ever-increasing water consumption—has led to a sharp rise in the population's dependence on the river landscape of the Tomebamba Valley. For decades, the attitude towards the region's river system has been to regard it as a resource to be freely exploited and extracted for human use, without the environmental impact of these actions on the integrity of the system being a factor to be considered.

Although recent decades have seen a growing awareness of the importance of ecological integrity and the well-being of the rivers in the Cuenca basin (Ordóñez, 2008), the lingering effects of a positivist and extractivist approach to nature adopted during the 20th century still largely shape the relationship between humans and the region's riverine landscape. Thus, the system—understood not only as the network of rivers and streams that comprise it, but also as the rainforests, wetlands and lakes that form part of their headwaters and from which these watercourses originate—is subject to the effects of a series of anthropogenic factors that exert pressure upon it and have led to profound alterations to its natural state and, on a broader level, to disruptions in the water cycle.

The case of the Andean climbing catfish (*Astroblepus ubidiai*) is probably one of the clearest examples illustrating one of the main aspects of the degradation of the rivers in the Cuenca region in recent years. Locally known as *Preñadilla* or *Challua*, the Andean climbing catfish is a species native to the torrential rivers that flow down the Ecuadorian Andes. Its suction-cup mouth allows it to cling to rocks so as not to be swept away by strong currents. Its survival depends largely on the high levels of water purity and oxygenation in the rivers it inhabits, which are generally shaded streams that flow through the dense vegetation of Andean forests (Arbeláez & Vega, 2008).

However, rising pollution levels in the rivers of the Cuenca basin have severely affected populations of this species in recent years. The discharge of sewage in areas of the city that do not yet have a sewerage system, or from combined sewer systems during extreme rainfall events, together with the conversion of riverbanks in the middle and upper reaches for agricultural, livestock and urban expansion purposes, are some of the main sources of water quality degradation in Cuenca's rivers, and therefore, the main causes of a drastic reduction on the populations of this species. Consequently, the Andean climbing catfish, which until less than a century ago was still abundant in the region's rivers and streams and even formed part of the local diet (Ordóñez, 2008), has entered during the past decades in the 'Critically Endangered' category on the International Union for Conservation of Nature Red List of Threatened Species.



1582

*'There is hardly a river or stream in this region that does not have the "*Challua*" in its waters'.*

- Inca Garcilaso de la Vega, Peruvian-Spanish writer and historian





'Due to pollution, the Andean climbing catfish has virtually disappeared from our rivers'.

- Galo Ordóñez, ETAPA EP engineer

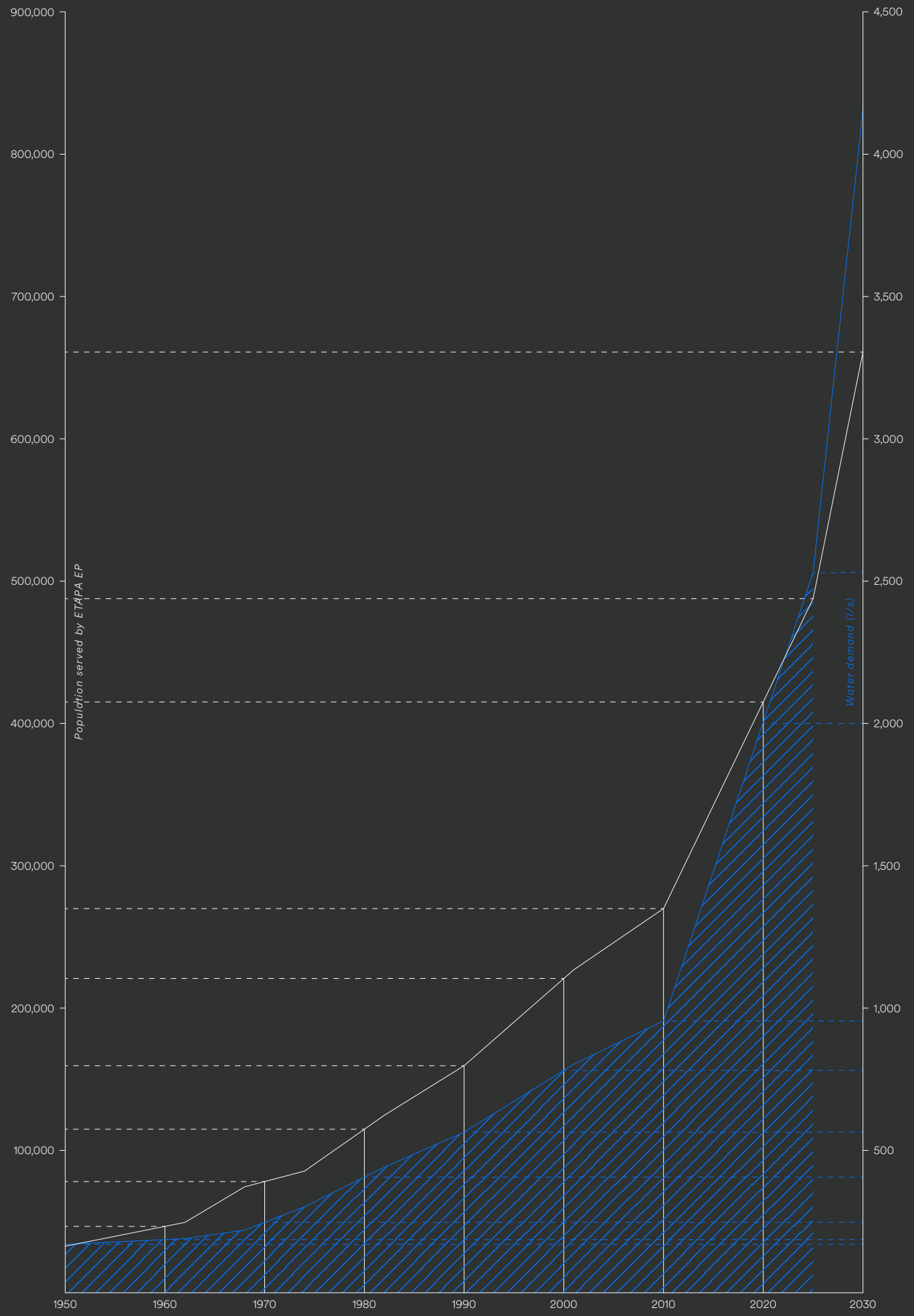
2008

↑ *Astroblepus ubidiai*, native to rushing Andean rivers
Source: Finding Species

Water abstraction for drinking water production is another disruptive action that alters the ecological integrity of rivers. As the population of the city continues to grow, and with it the demand for water, the need to maintain a stable supply throughout the year grows too. Currently, the municipal drinking water company, ETAPA EP, serves around 500,000 residents, which translates to an extraction from river courses of over 2,500 litres of water per second. Estimates by the company itself, which take into account current population growth trends and a planned expansion of the service area over the coming years, predict that the population to be supplied by 2030 will rise to 661,000. This implies that the amount of water that will need to be extracted from the rivers to supply that population will reach 4,160 litres per second (ETAPA EP, 2025).

This figure alone exceeds the average flow rate of 3,200 litres per second of the River Tarqui (Zambrano, 2024), meaning that by 2030 the volume of water that will need to enter the drinking water treatment system every second to meet the Cuenca's demand will be greater than the total flow of one of its four rivers. The increase in demand over the past years, combined with scenarios of extreme drought such as those experienced by the region in 2023 and 2024, has led to ocasional conflicts between the demand for human consumption and the minimum ecological flow of rivers downstream of the abstraction works. A reduction in this flow can have serious consequences for riparian flora and fauna, and alter soil conditions in the riverbed (Alomía Herrera & Carrera Burneo, 2017). With reduced water regulation capacity due to changes in land use in the middle and upper reaches (Buytaert et al., 2005), and rising demand for drinking water, rivers are approaching a critical point.

The current state of the Cuenca river system mirrors that of most natural systems and ecosystems around the world from which our species has developed ways to derive practical benefits. What Erik Swyngedouw and María Kaika defined as the 'urbanisation of nature' (2014) (that is, its transformation for human benefit) could be described in this case as the urbanisation of riverscapes. This process has caused profound changes to the natural systems that enable the water cycle to function and, ultimately, to the rivers themselves. The current conditions of the riverscapes does not only compromise the rivers, but also the livelihood of the population that benefits from them.



↑ Registered and projected population growth and drinking water consumption in Cuenca
Source: Hermida, Hermida, Cabrera & Calle | Ordóñez | INEC | ETAPA EP

3. Methods





Antique tradition of catching fish using baskets on the Yanuncay River (1930)
Author: Manuel Jesús Serrano

3.1 Problem statement

The last 75 years have seen explosive population growth and urban expansion in Cuenca, a phenomenon that has driven a remarkable development of the city's drinking water and sanitation infrastructure. On a broader scale, this has meant profound changes to the region's natural landscape in response to the need to provide a constant supply of resources to meet urban consumption patterns.

Harnessing the opportunities offered by the region's river system has undoubtedly led to a substantial improvement in the living conditions of Cuenca's population in recent years, resulting in an uninterrupted supply of basic commodities in the urban area—such as drinking water, food and electricity—and, more widely, the attainment of a modern standard of living.

However, the region's growing dependence on its riverscape to sustain the livelihoods of a growing population has sharply increased the pressure on this natural system; a pressure that stems primarily from changes to the landscape that interfere and disrupt the natural water cycle. The current model for exploiting its benefits is based on an unbalanced relationship, which has established as one of the 'one-way systems' described by William Sherman (2005), in which a stable flow of benefits and consumable resources is provided at the expense of the inherent volatility of natural processes.

The effects of this imbalance are not merely ecological; they also have a profound social and economic dimension, particularly when looking to the future. As long as the harnessing of the benefits of this system continues at the expense of its ecological integrity, the opportunities for future generations in this region to continue enjoying the ecosystem services that underpin their quality of life are decreasing. The current situation calls for a rethinking of the conception of the model for the use of the riverscape and the natural environment in general, leading to healthier ways of interacting with them that are sustainable over time and and geared towards supporting the water cycle.



↑ Problem framework: Urbanisation of water as the main disruptoing agent of the water cycle

3.2 Research question

How can the **landscape and water infrastructure** of Cuenca be transformed to incorporate the **restoration of the water cycle** as a **guiding principle**, and how will this alter the benefits provided by riverscapes?

- What are the ecosystems critical to the natural production process of the water that Cuenca benefits from, and how do they perform?
- What are the main anthropogenic transformations that the riverscapes have undergone in modern history, and how have these enabled the urbanisation process of Cuenca?
- In which ways are the riverscapes currently being exploited, and how do these actions affect their ecological integrity and disrupt the water cycle?
- What spatial strategies could contribute to the restoration of the water cycle in Cuenca and to what extent would these transform the current ways of benefiting from the riverscapes?



Upper reaches of the Machángara River

3.3 Theoretical framework

Urban Political Ecology

Under an approach to the urban process as a socio-ecological phenomenon, Urban Political Ecology stands as a critical framework for analysing how cities, nature, and society are deeply intertwined through political, economic, and social processes. At its core, it starts from the idea that the urbanisation process is not separate from nature, but actively transforms and 'produces' it. Rather than seeing nature as something external to the city, it argues on the 'urbanisation of nature': the process through which natural elements like water, energy, land or biomass are conceptualised as resources through their extraction, mobilisation, commodification, and physical transformation in order to sustain urban life and urbanisation (Swyngedouw & Kaika, 2014).

From this perspective, cities are not just built environments but socio-ecological systems, where human and non-human elements (infrastructure, resources, ecosystems) are constantly interacting through metabolic flows. Circulation of materials, energy, and waste connect urban areas to distant ecosystems and supporgin regions, enabling life to develop 'normally' within them.

It points to the positivist perspective on urban science and engineering that emerged during the modernist boom of the 20th century as one of the causes of the increasingly problematic socio-ecological conditions and the environmental crisis humanity faces. It calls for a shift in the way urban and environmental issues are understood and acted upon, moving away from technocratic solutions toward a critical engagement with urban socio-ecological processes.

Landscape as infrastructure

Challenging the traditional conceptualisation of infrastructure which focuses only on technical, technological and functional aspects, and in the face of 'the underperformance of master planning' and the excessive reliance on engineered technology to sustain urban life, Bélanger (2017) argues for a new understanding of what infrastructure is in order to address the challenges urban regions are currently faced with.

As 'ecology becomes the new engineering', Bélanger proposes a contemporary alignment of the disciplines of landscape architecture, civil engineering and urban planning as a way out of the current crisis these professional design disciplines face when challenged to address the predominant issues of the urban age, and from which new practices are being increasingly demanded.

'Landscape as infrastructure' argues for the strategic design of infrastructural ecologies for the achievement of synthetic landscapes of living, biophysical systems that operate as urban infrastructures, and projects them as the way forward into the 21st century to shape and direct the future of urban lives, economies and cultures.

'The engineering of basic elements such as topography, hydrology, and biomass as a system can be instrumental in the amplification of invisible yet fundamental processes that support urban development'.

Pierre Bélanger, 2017.

Urban metabolism

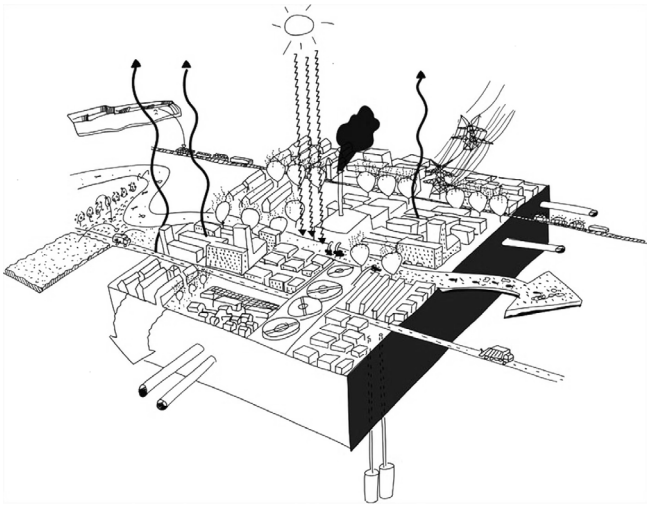
Metabolism is a biological concept that refers to the chemical conversion and breakdown of organic matter to provide living organisms with energy, which enables them to develop vital processes and the synthesis of new organic matter (Sánchez & Raja, 2022).

Through an analogy that takes cities as living bodies, the concept of urban metabolism studies the extraction, conveyance, transformation and disposal of resources to, in and from urban areas. It has its theoretical roots in 19th century's works from Karl Marx and Friedrich Engels who studied the exchange of resources and waste between nature and industrial society (Swyngedouw & Kaika, 2014).

Later formalised as a concept by hydraulic engineer Abel Wolman in 1965, urban metabolism begins from the understanding of the earth as a closed ecological circuit, and enables a more fluid, material, and chemical understanding of urban processes, paying specific attention to flows of elements such as water, energy, food or waste.

'The metabolic requirements of a city can be defined as all the materials and commodities needed to sustain the city's inhabitants at home, at work and at play. Over a period of time these requirements include even the construction materials needed to build and rebuild the city itself. The metabolic cycle is not completed until the wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard'.

Abel Wolman, 1965



↑ Urban metabolism model
Source: Jutta Raith

Sponge City

First proposed in 2000 but further developed over the past years by Kongjian Yu, the Sponge City concept was developed in response to the increasingly severe and repeated water crises that Chinese cities suffered from. Based on a re-examination of the relationship between humans and water, it provides a framework to address water problems through different scales (Macro, Meso, Micro) and drawing on three core characteristics: natural storage, natural infiltration and natural purification.

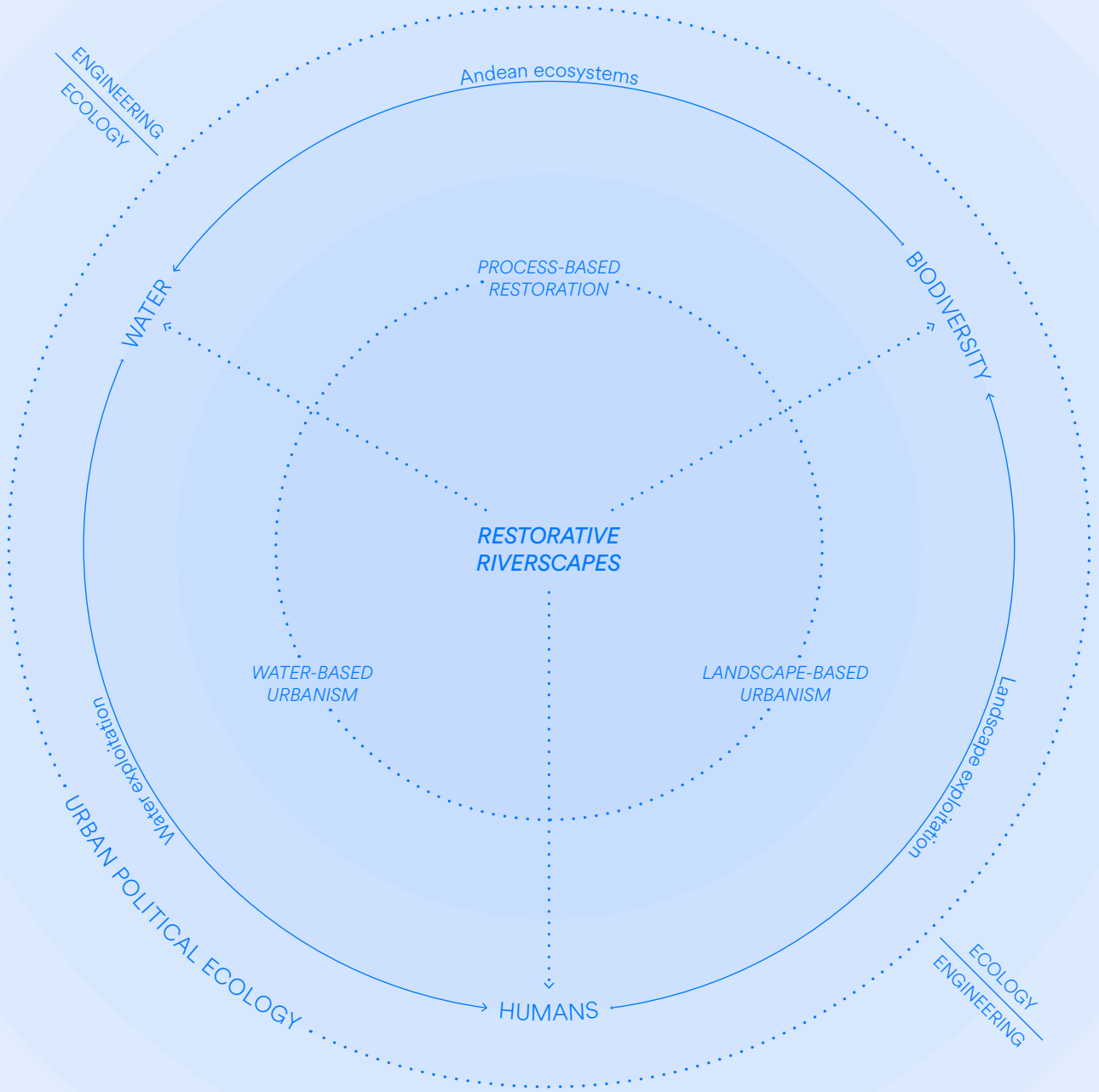
The application of these principles across scales leads to 'water-adaptive landscapes', in which instead of water adapting to people, it is people who adapts to water, placing water at the center of urban design. Rather than a water management model, it is meant to function as an integrated ecological strategy for urban and territorial development (Yu, 2013).

3.6 Conceptual framework

Through a broad, all-encompassing lens provided by the theories of Urban Political Ecology, the project focuses on researching and understanding the urbanisation of water in Cuenca: how natural elements like water and its related landscapes are 'produced': extracted, mobilised, commodified, physically and chemically transformed, disposed. Conceptualised as a resource in order to sustain urban livelihood and daily activities.

Moving beyond the Engineering-Ecology dichotomy that emerged during the post-war boom in positivist urban thinking, the model adopts new, more fluid interpretations of these disciplines, such as those set out in 'Landscape as infrastructure'. The landscape itself is interpreted as the primary piece of infrastructure to be taken into account when making decisions: the biome as a canvas and as an element to be re-engineered and reshaped in order to restore its own natural processes.

Therefore, the maintenance, care and restoration of its inherent mechanisms and processes are observed as opportunities to achieving ways of utilising the river system shaped by their own limits and that do not compromise its future integrity.

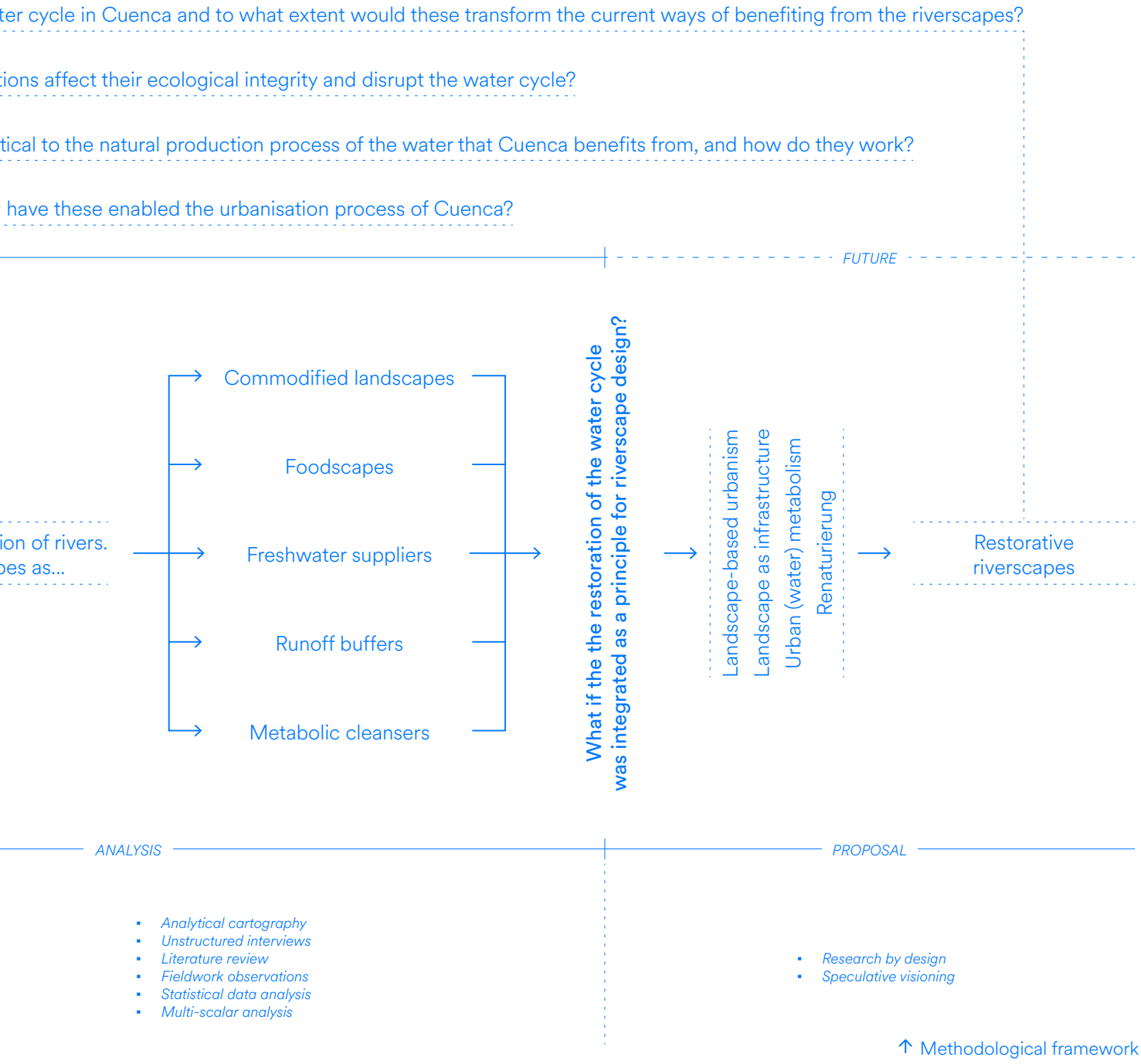

ENGINEERING
ECOLOGY
Andean ecosystems
WATER
BIODIVERSITY
PROCESS-BASED
RESTORATION
RESTORATIVE
RIVERSCAPES
WATER-BASED
URBANISM
LANDSCAPE-BASED
URBANISM
Water exploitation
Landscape exploitation
URBAN POLITICAL ECOLOGY
HUMANS
ECOLOGY
ENGINEERING

3.4 Methodological framework

Building on a historical review of the key changes that this river system has undergone, the project aims to paint a p
is the understanding of how the water cycle functions in this region, in order to establish the ways in which curren
five distinct ways in which the riverscape of Cuenca and its region is exploited, and identifies the effects that each
developed that seek to create new forms of use that reduce human impact over the riverscapes.



picture of its current state, shaped by these events which form the roots of its present reality. Central to this research nt anthropogenic models of use and benefiting from the system are altering it. In this regard, this research defines of these forms of exploitation has on the integrity of the rivers. Building on these five cases, design alternatives are



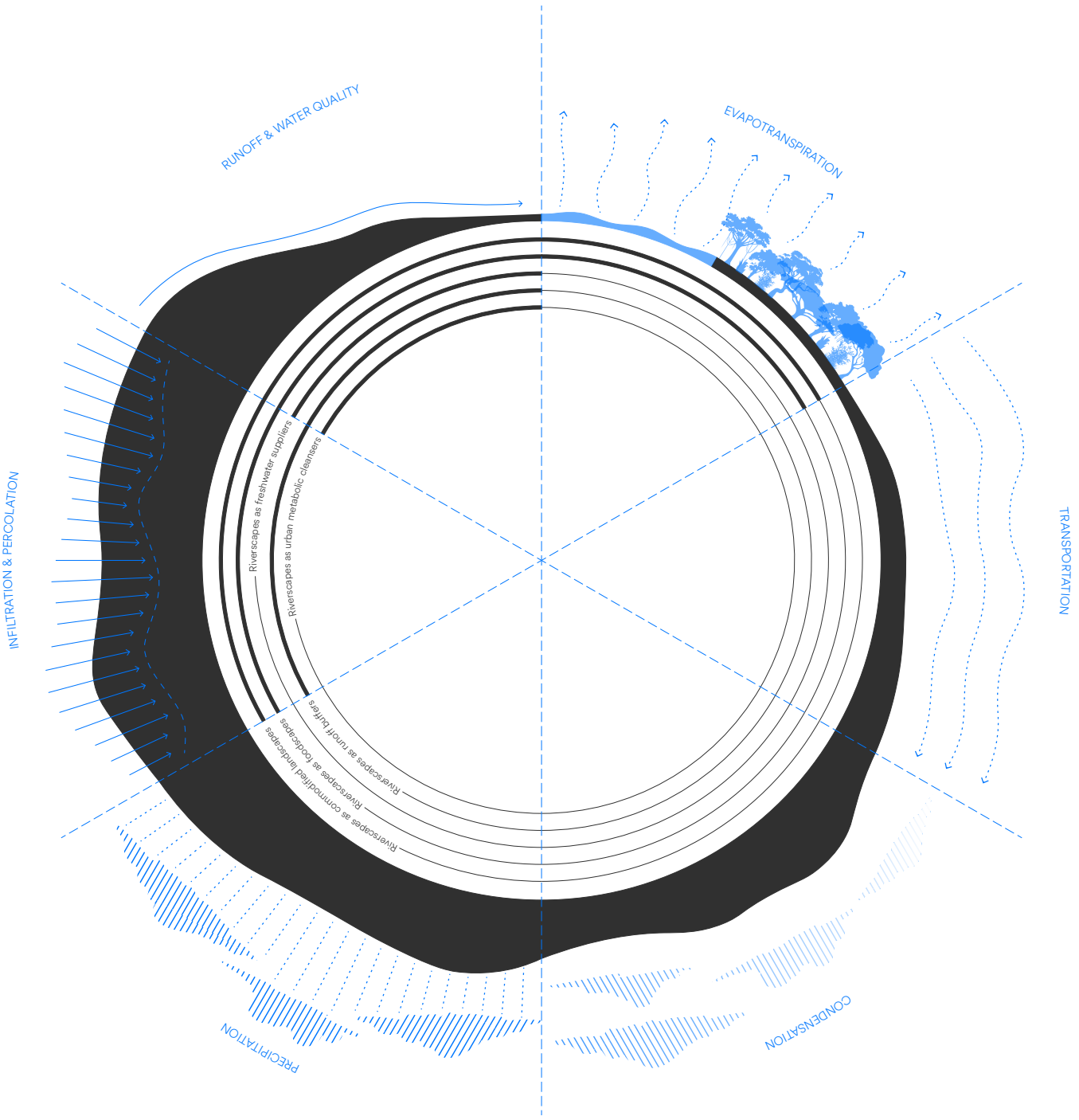
↑ Methodological framework

3.5 Analytical framework: A disrupted cycle

Whilst the alteration of a single stage in a cycle may in itself disrupt the cycle as such, the analytical framework focuses on the specific ways in which the various forms of river landscape use in Cuenca fit into a broader pattern of disruption to the global water cycle. In this sense, the tool situates the challenge posed by this global phenomenon within the local and regional context under study in terms of alterations to the river landscape, by comparing the five forms of exploitation of the river landscape in Cuenca defined in this study with the stages that make up the water cycle.

In this way, the analytical framework serves as the starting point for breaking down a complex (in this case, global) problem into smaller parts; understanding these parts makes it possible to outline their specific causes by initially identifying the stages of the cycle that are most affected by the various forms of exploitation of the local and regional river landscape. Thus, this framework serves as the analytical starting point upon which the spatial interventions proposed in this study will take shape.

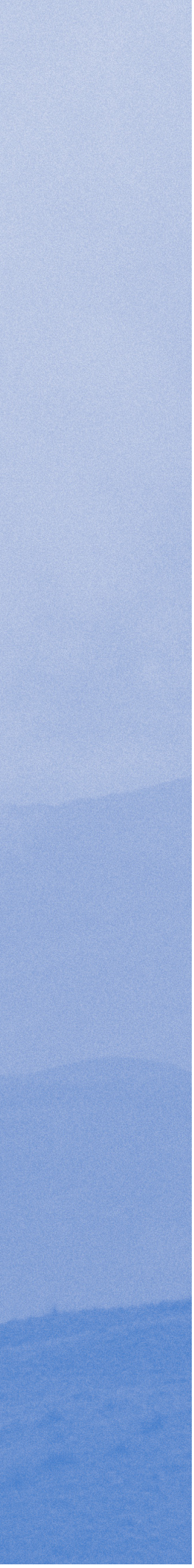
Although water quality does not constitute a stage of the water cycle as such, its inclusion as a subject of analysis within the scope of this research stems from the direct interdependence between the ecosystems that sustain this process and the quality of the water flowing through them; good water quality is essential for the maintenance of the ecosystems that support this natural cycle.



↑ Analytical framework: Forms of riverscape exploitation and disruptions to the water cycle



Ascent of clouds towards the Andes mountain range



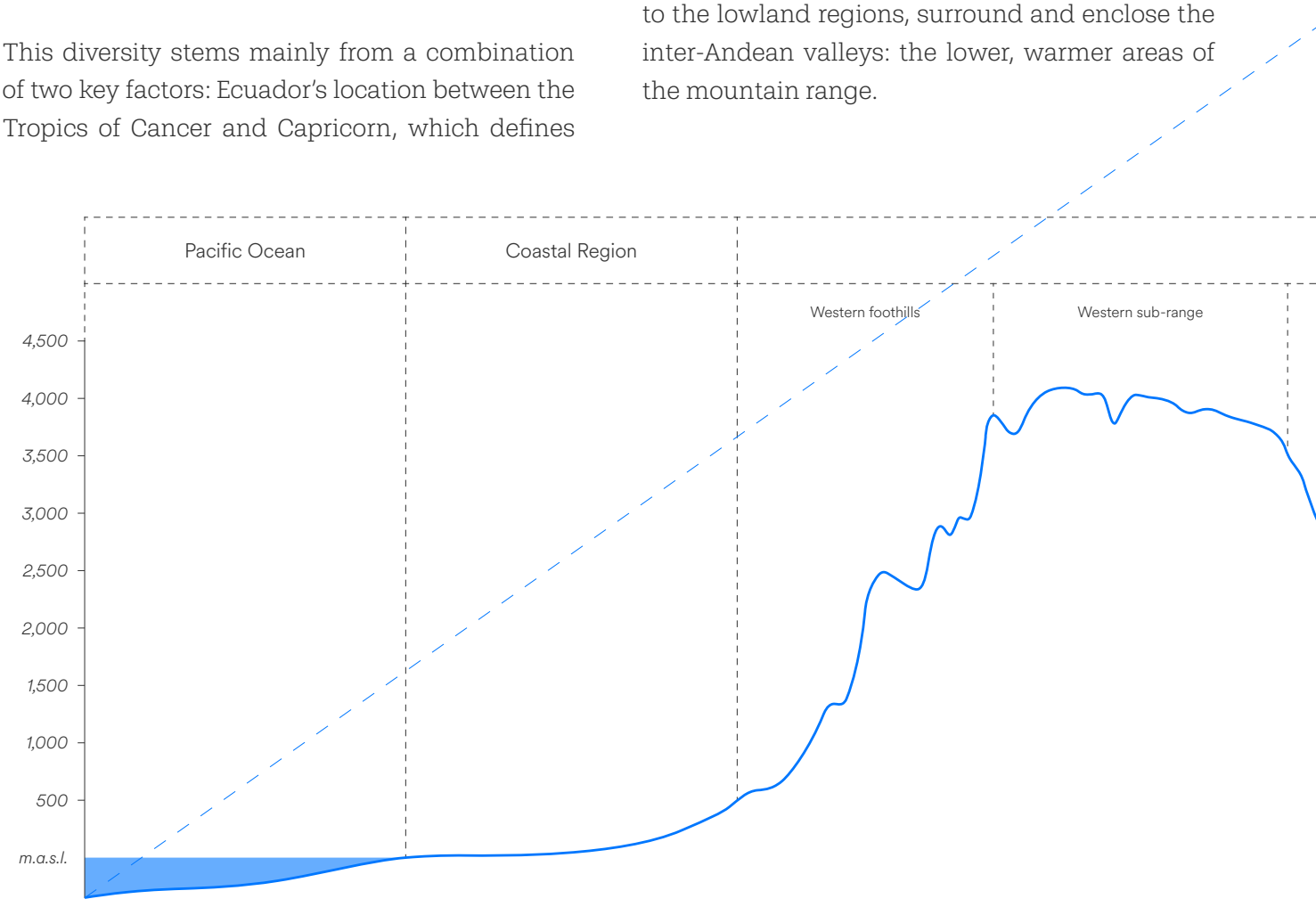
4. The journey of water

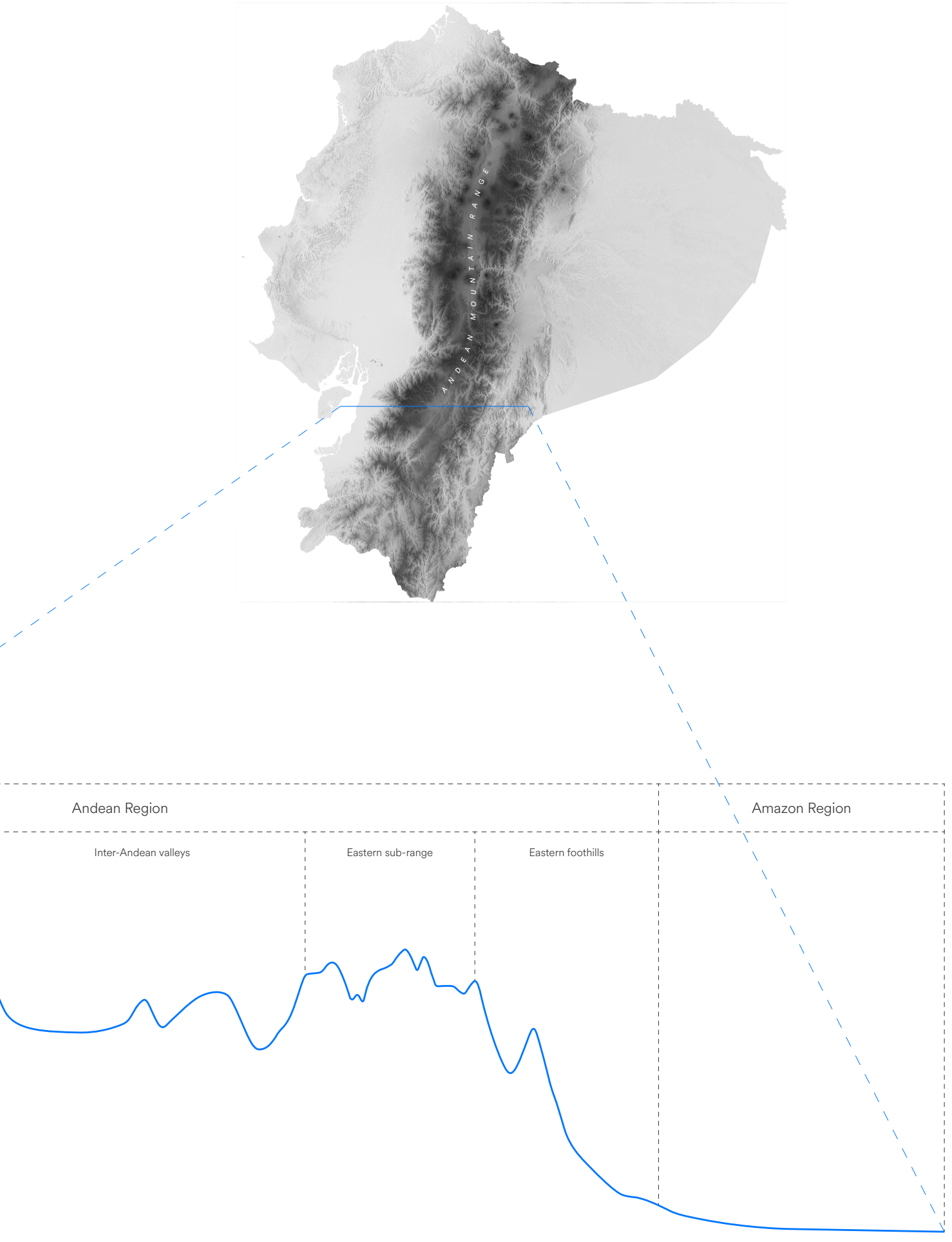
4.1 From droplet to river

Whilst the fundamental processes that make up the water cycle are universal, they unfold at different rates and intensities, and these characteristics vary according to the climatic, geographical and ecosystemic conditions of each region of the planet. Consequently, understanding how this cycle unfolds within the ecosystems that sustain it provides the starting point for understanding how anthropogenic changes to these environments alter this natural process. The water cycle in the Andean region of Ecuador is particularly complex, mainly due to the diversity of ecosystems that play a role in this process.

This diversity stems mainly from a combination of two key factors: Ecuador's location between the Tropics of Cancer and Capricorn, which defines it as a tropical country with a relatively stable climate throughout the year, and the significant variations in altitude inherent to the Andean Mountain Range.

In addition to the island region, comprising the Galápagos Islands, the country consists of another three regions: mainland Ecuador is divided into the Coastal, Andean and Amazonian regions. In most of the section of the Andes that runs through Ecuador, the mountain range is divided into two sub-ranges which, as well as marking the eastern and western boundaries of the range in relation to the lowland regions, surround and enclose the inter-Andean valleys: the lower, warmer areas of the mountain range.



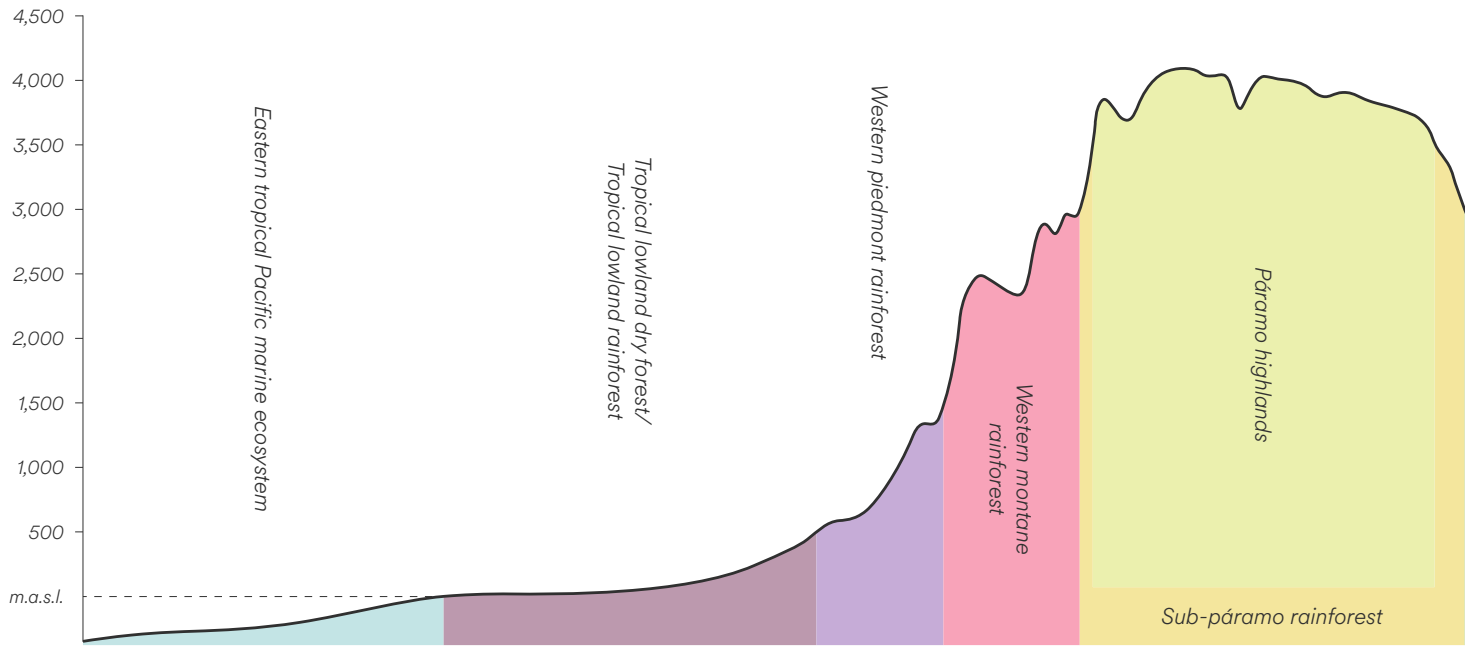


↑ Geographical composition of the Ecuadorian Andes

The great diversity of ecosystems is found mainly in the Andean region, where the rugged topography results in a wide range of altitudes that provide ideal conditions for different species of flora and fauna. Consequently, the range of ecosystems forms a gradient that begins at the lower reaches of the mountain range, as soon as the altitude begins to vary and, with it, other factors such as temperature and humidity levels.

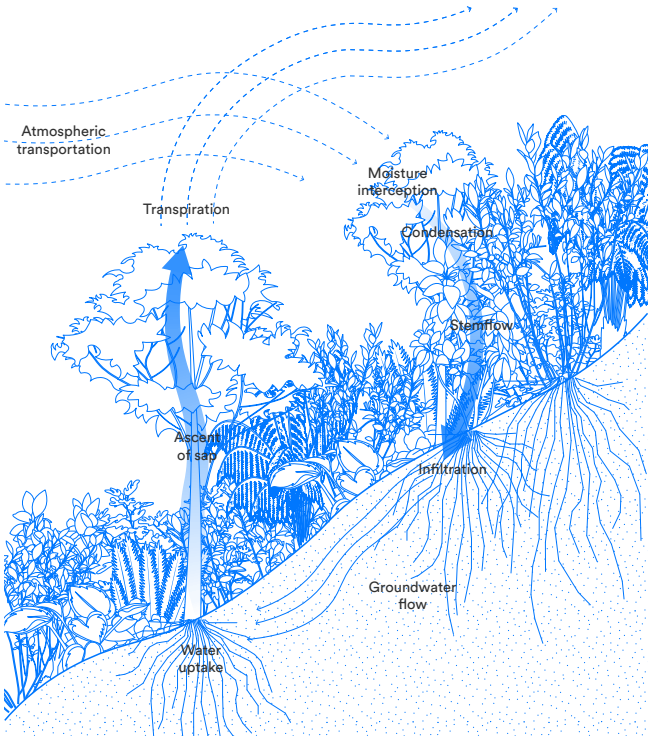
Whilst each ecosystem is specific to the altitude range in which it is found and therefore has its own particular ecological community, a common feature runs through the ecosystems located in the transition zones between the low-lying coastal and Amazonian areas and the high mountain regions. These are characterised by being forested and humid ecosystems, a result of the passage of large air currents laden with moisture from the Pacific Ocean and the Amazon rainforest—also known as 'flying rivers'—which climb up the mountain range. These large masses of humid air form on both sides of the mountain range as a result of the evaporation of seawater and plant transpiration triggered by solar energy. Carried by the wind, when these masses of moisture hit the mountain range they have no option but to ascend, influencing the areas over which they flow and turning them into permanently foggy and humid atmospheres.

At the same time, these ecosystems have their own micro-cycles that contribute to the global water cycle, one of the most important being the recycling of moisture. Through this process, the lush vegetation of the transition rainforests captures and condenses atmospheric moisture on its leaves, subsequently infiltrating it into the

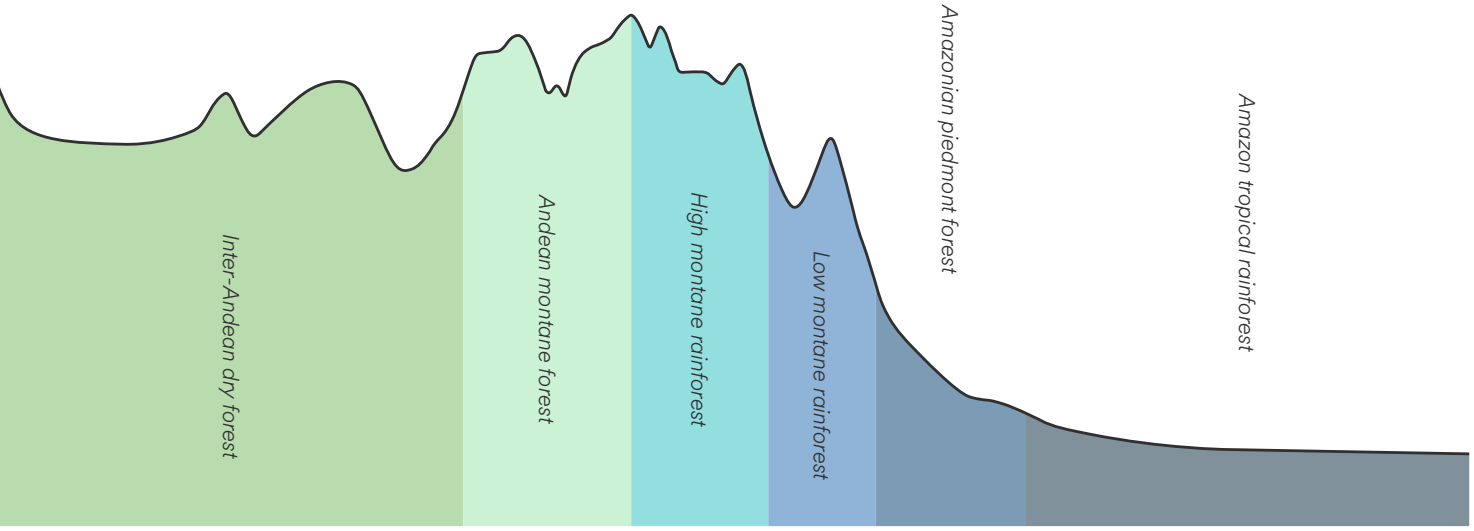


soil via stemflow, reabsorbing it and pumping it through its vascular system from its roots to its canopy, and finally transpiring it through its leaves to return it to the atmosphere, where it continues its journey up the mountain. Therefore, in addition to providing robust protection against erosion, the vegetation cover of rainforests is responsible for high levels of soil moisture throughout the year (Poulenard et al., 2001).

Through the repetition of this cycle, water flows up to the most elevated regions of the Andes in southern Ecuador to reach the high-mountain ecosystem that is most critical to the formation of the rivers flowing down from this part of the mountain range: the Andean páramo. Characterised by the high water retention capacity of its soils, this ecosystem forms the upper limit of the rainforests that make up the foothills of

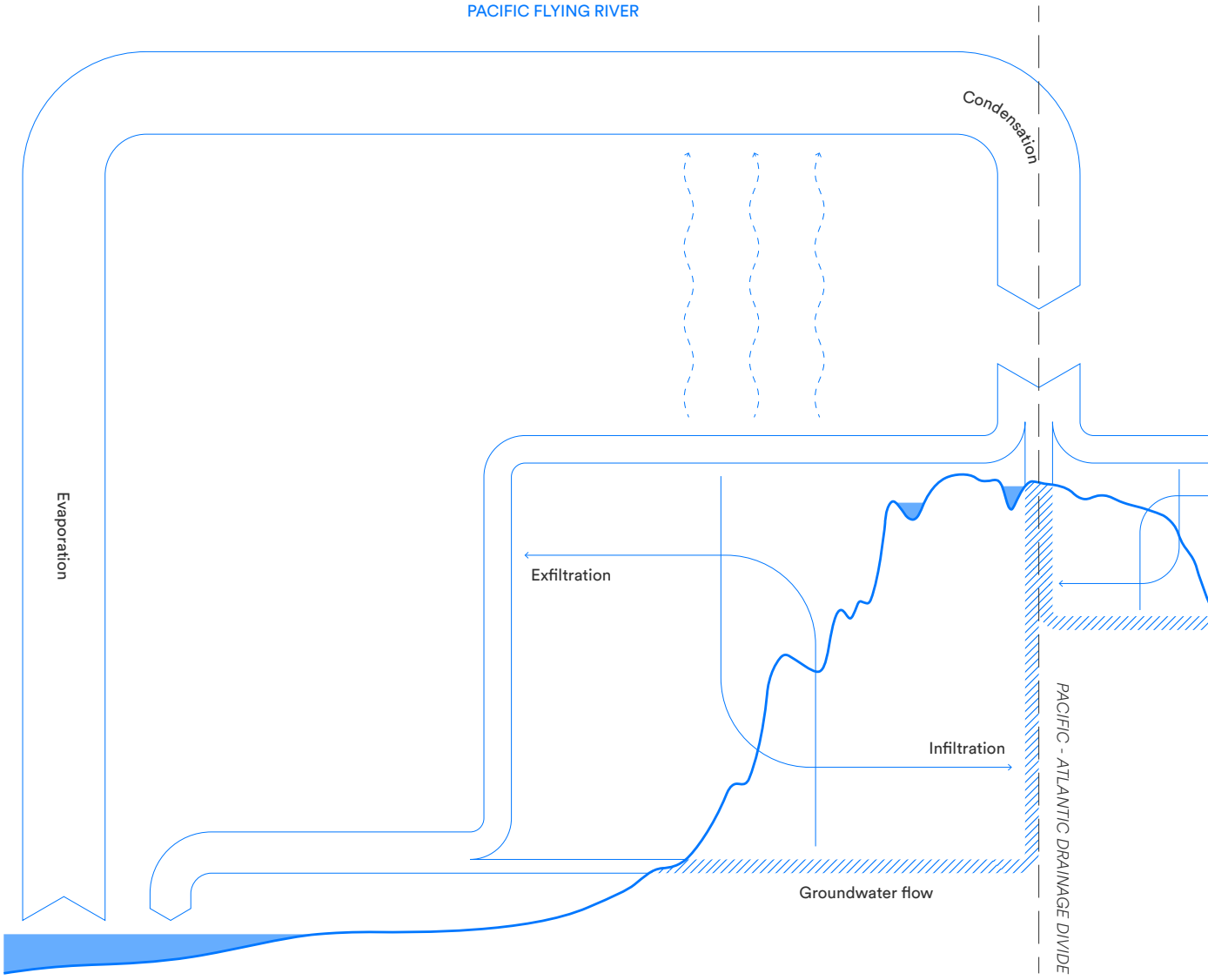


↑ Moisture recycling process



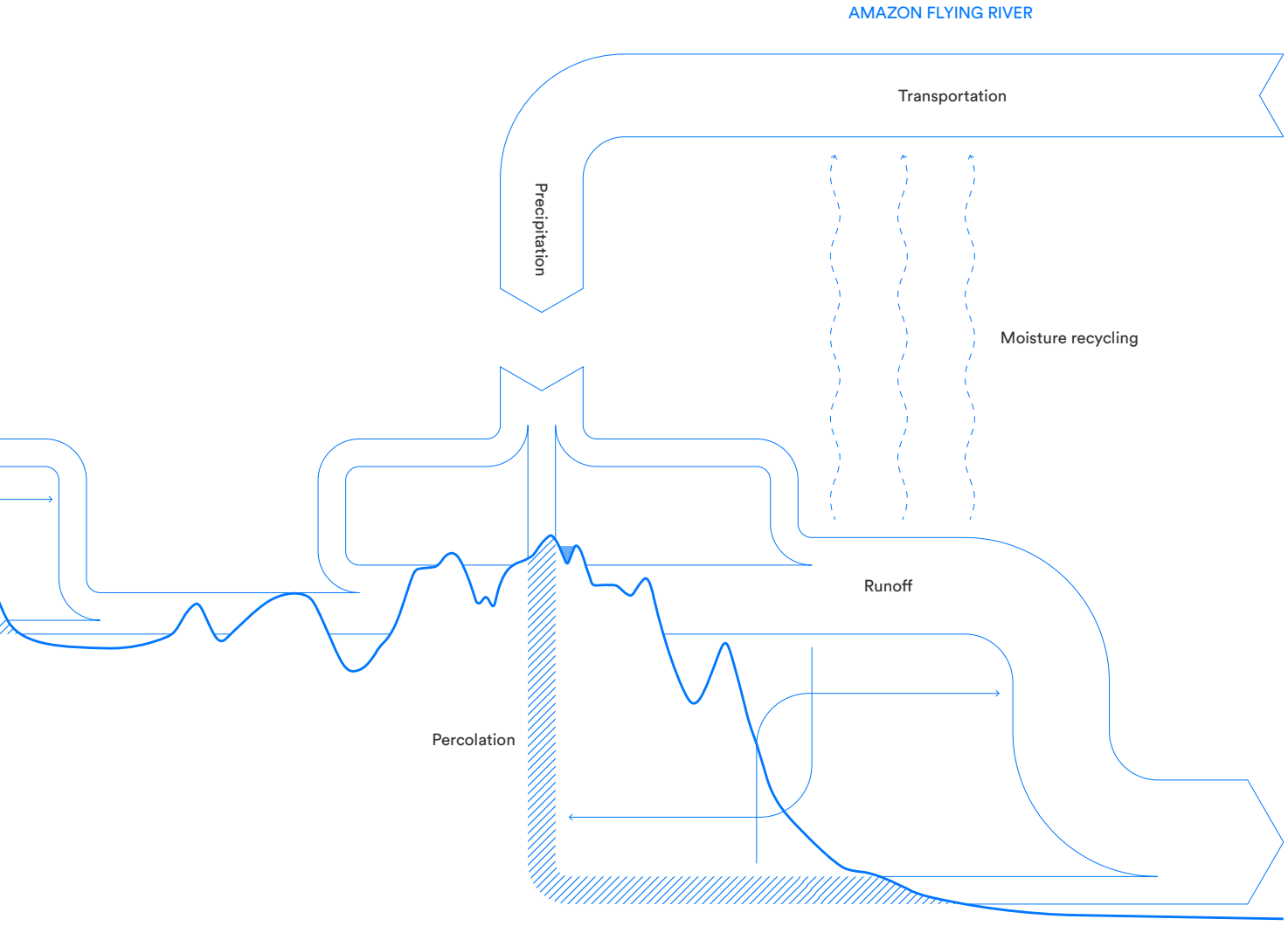
↑ Ecosystemic configuration of the Andean region and adjacent lowlands

the Andes mountain range, and can be found at altitudes above 3,500 metres above sea level. There are two main types of units that make up this ecosystem. Most of the páramo ecosystem is made up by tussock grasslands: areas covered mainly by different species of tussock grasses and whose soil consists of a layer of peat overlying a clayey-rocky substrate. The high precipitation capture capacity and low evapotranspiration rate of tussock species make them key factors in the process of water transfer from the atmosphere to the soil. On the other hand, a smaller portion of this ecosystem is composed by the páramo wetlands. The soils of this ecological unit consist of organic matter which, due to the low temperatures typical of these altitudes, is undergoing an extremely slow decomposition process, and which are therefore can be highly porous, which gives them



the capacity to retain large volumes of water.

Therefore, páramos can be refered to as the Andean natural infrastructures of water production and storage: whether it be the moisture delivered by a cloud that condenses upon contact with the ground and covers the vegetation with tiny droplets of water, or the water that falls in a torrential downpour, the spongy páramo soil acts like a natural buffer that retains and stores this water to later release it gradually, thus ensuring a steady flow in the rivers that form and descend from the high mountain areas. Small but numerous watercourses converge to form increasingly larger streams, which, as they descend from the heights, are fed by surface and underground flows, giving rise to the countless rivers that have their source in this ecosystem.



↑ The water cycle in the Andean Mountain Range



↑ Páramo highlands



↑ Sub-páramo rainforest



↑ Ecosystemic transition: from sub-páramo rainforest to páramo highlands



↑ Ascent of atmospheric water to the páramo highlands



↑ From the atmosphere to the soil: water delivery in the form of fog



↑ Páramo wetlands







↑ Exfiltration process at different scales



↑ Páramo soil composition in a tussock grass area



↑ Páramo wetland and tussock grassland



↑ Groundwater flow in a wetland area



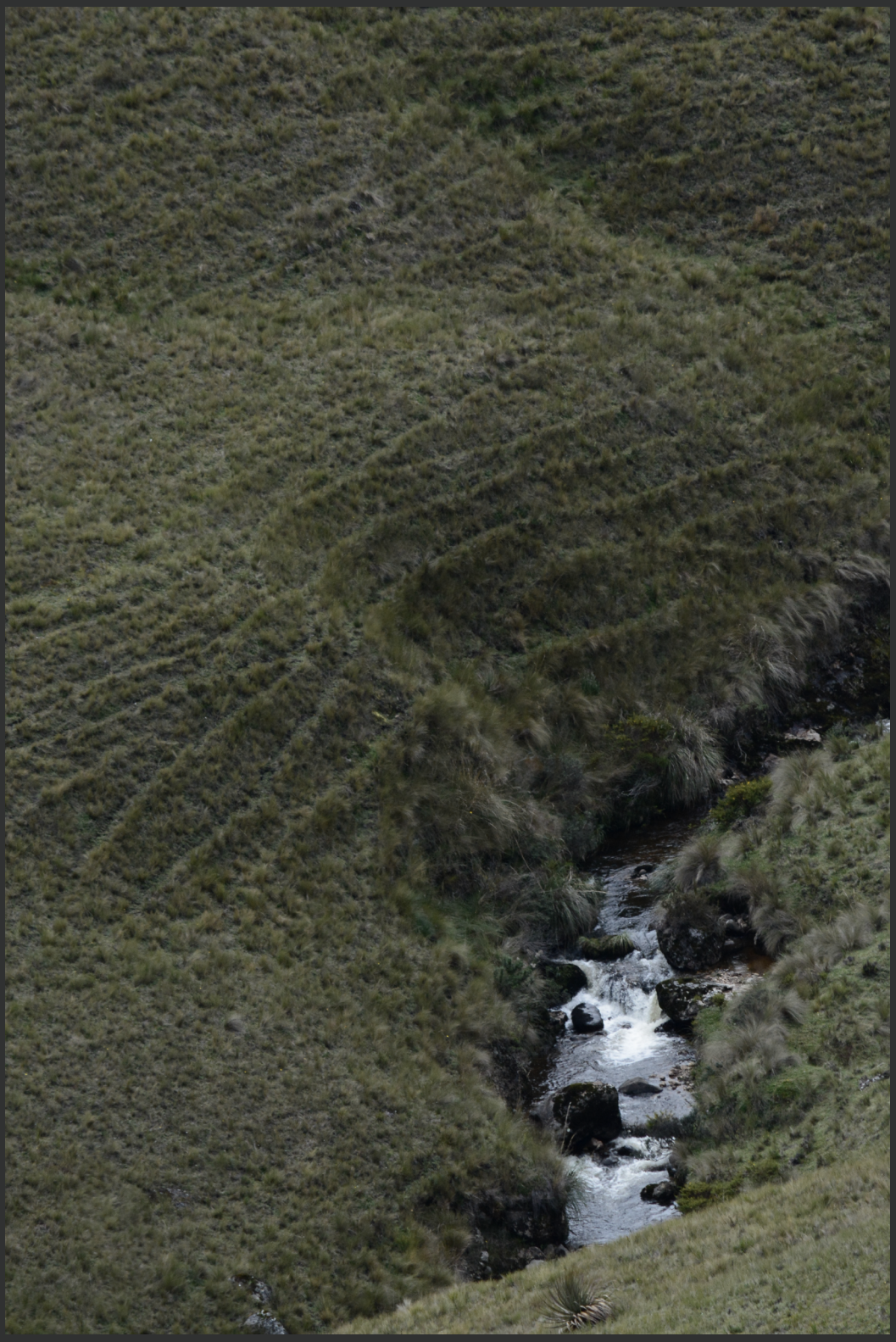
↑ Wetland vegetation



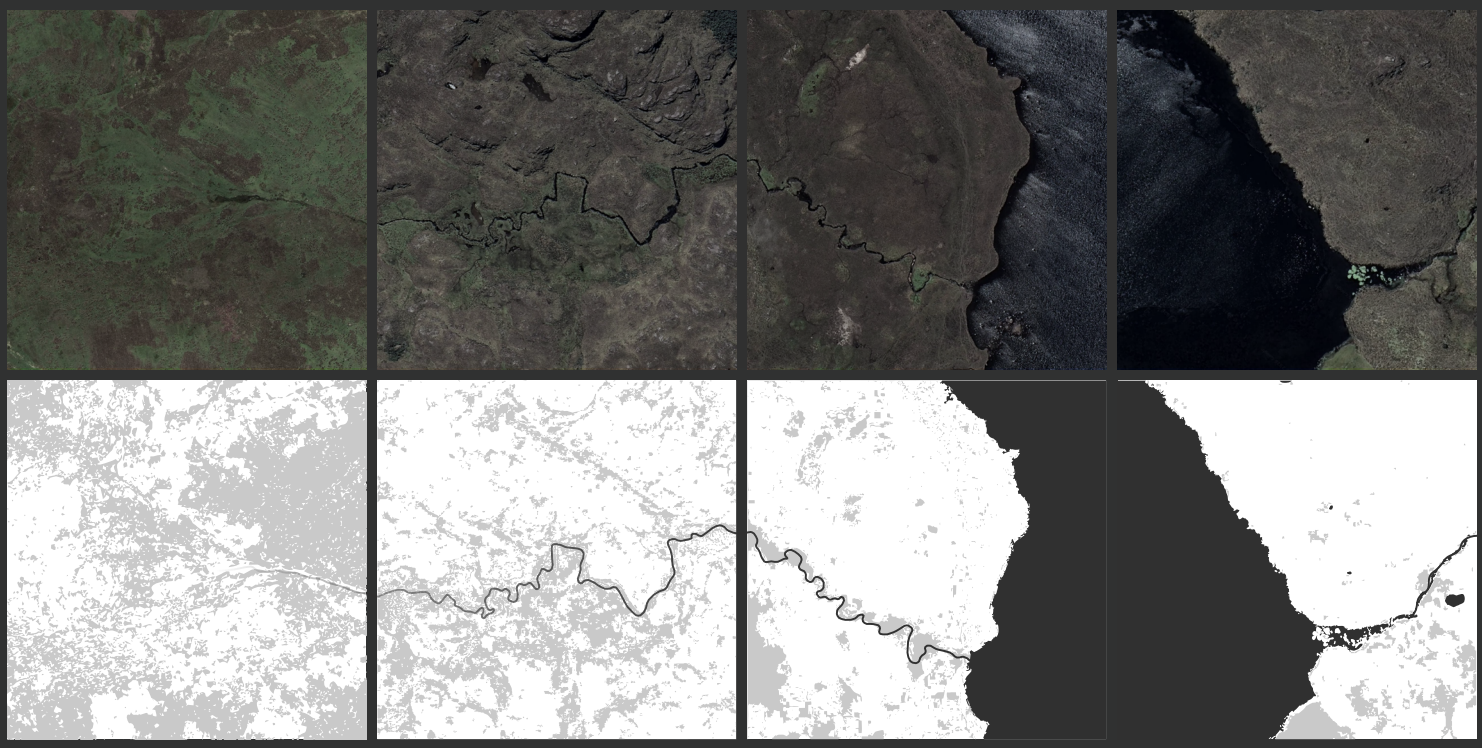
↑ Surface water storage: páramo lake



↑ Area of formation of a stream



↑ Páramo stream running through a tussock grassland



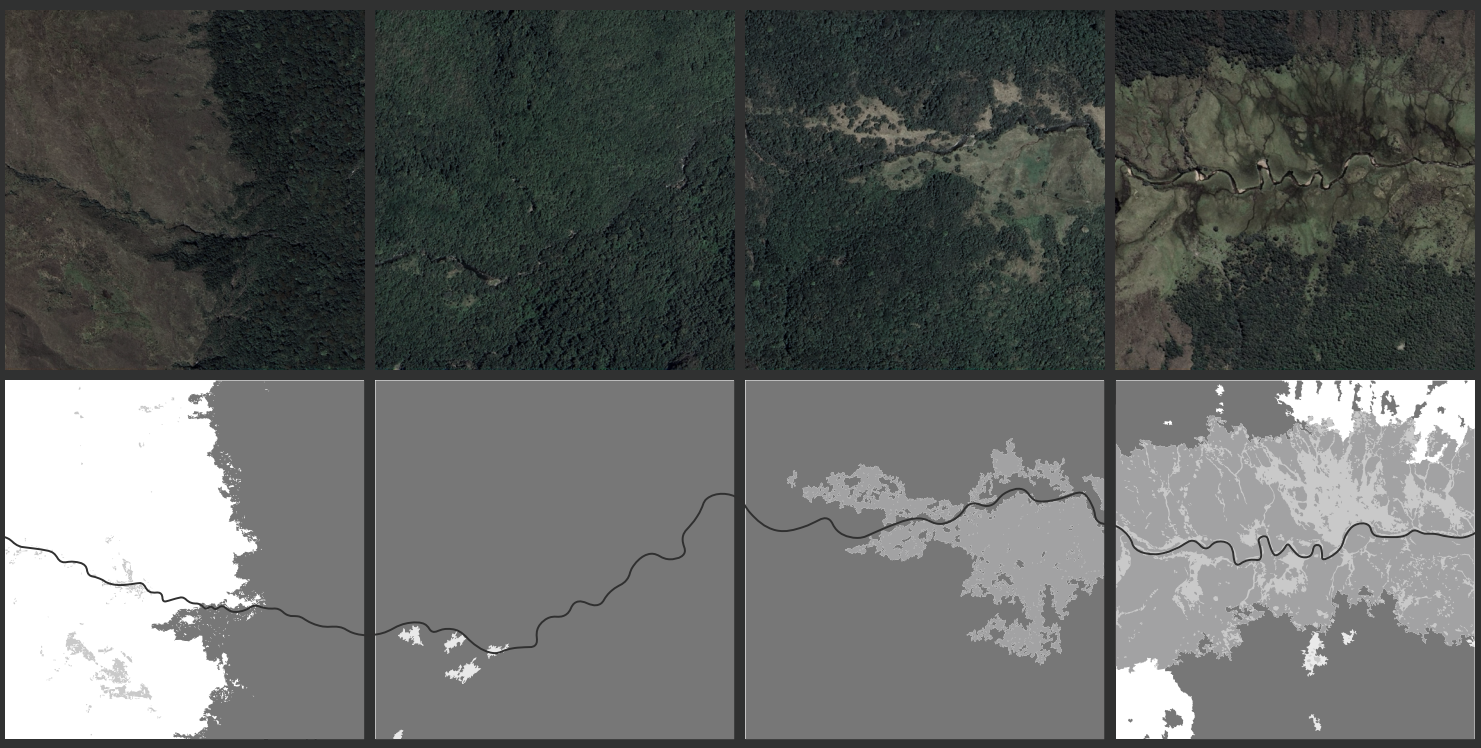
1. Precipitation falls onto the vast páramo grasslands and wetlands. While the peat soil of tussock grasslands has a considerable capacity to retain water, most of it is stored in the highly porous wetland soils.

2. Once the soil becomes saturated, the water finds its way to drain away, following the orography of the terrain and forming small streams.

3. Eventually, the streams find large low-lying areas, which leads to the formation of the main natural infrastructures of surface water storage of the páramo: the lakes.

4. When full, lakes drain the excess water through the lower lying point of their banks, continuing the flow of the streams that feed it and, in many cases, with an increased discharge volume, due to the contribution of other streams that converge in the lake.

- Páramo grassland
- Páramo wetland
- Inter-Andean marsh
- Sub-páramo rainforest



5. On its way down, at an altitude of about 3,500 meters above sea level, water meets the first of multiple ecosystemic gradients it will cross on its journey to the sea. It enters the dense, lush sub-páramo rainforests.

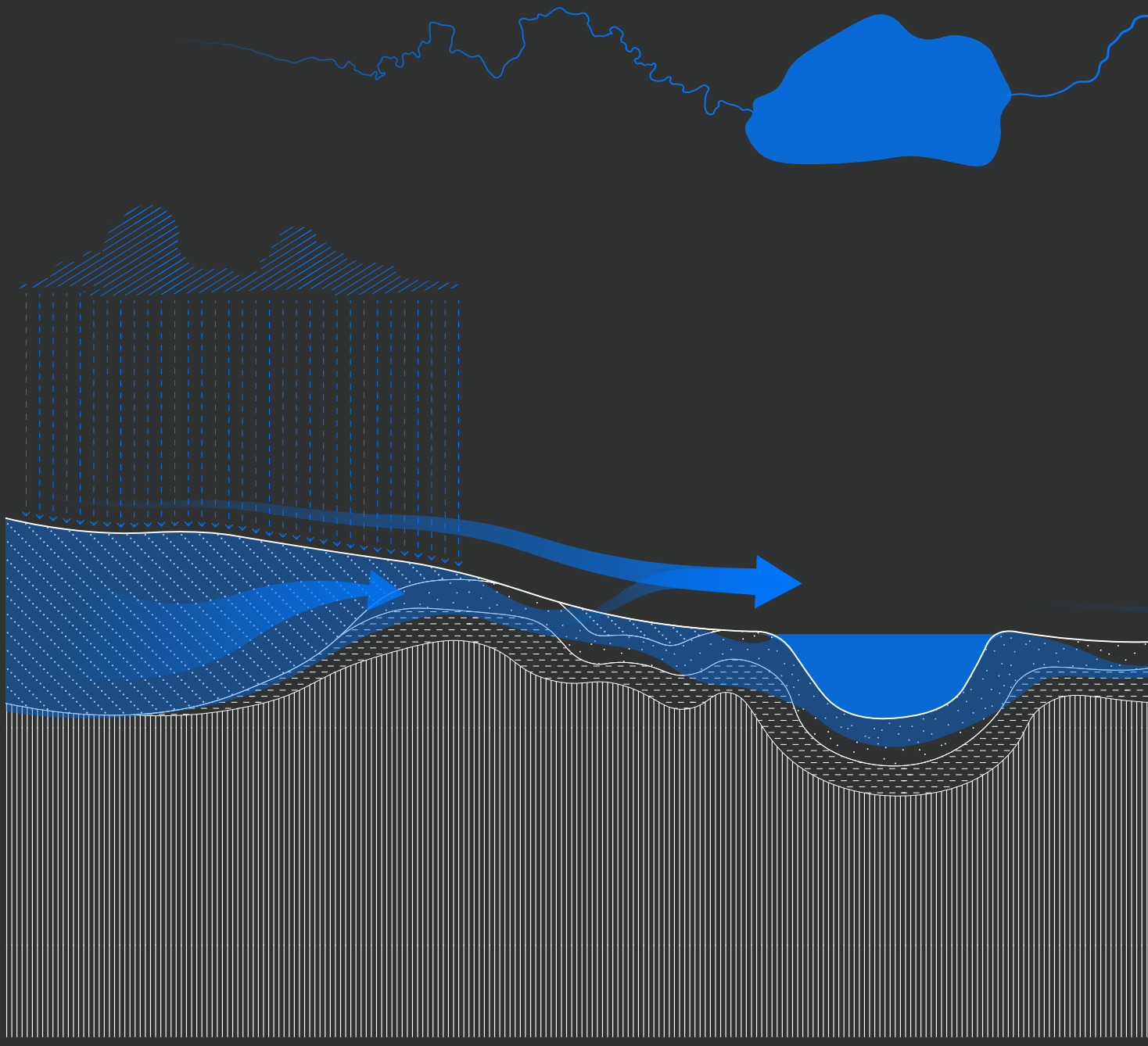
6. As they flow through this ecosystem, the streams continue to swell in volume thanks to the rainforest vegetation, whose leaves intercept, condense and allow atmospheric moisture to seep into the ground. Part of this water is reabsorbed by the vegetation itself, but the rest will eventually end up in the water course.

7. At around 3,000 metres, the sub-páramo rainforests reach their lower limit; on the inner slopes of the Andean sub-ranges, this gives way to the dry forest ecosystem of the inter-Andean valleys.

8. The marshy areas along the banks of the upper reaches of the stream — which, at this point, can already be considered a river — store the excess water flowing down from the lower reaches of the sub-páramo rainforest and the páramo grasslands, before gradually releasing it into it.



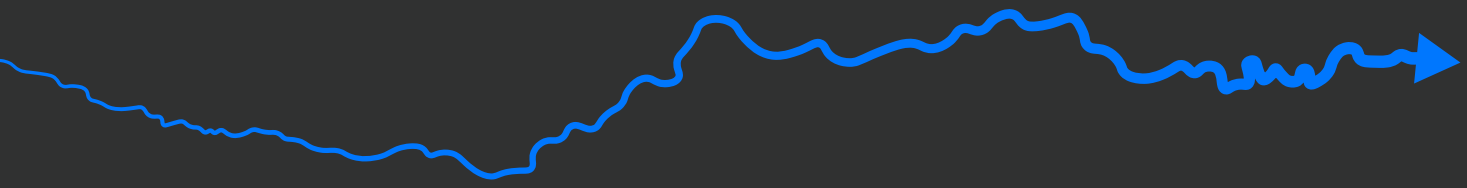
Páramo highland
4,500 - 3,500 m.a.s.l.

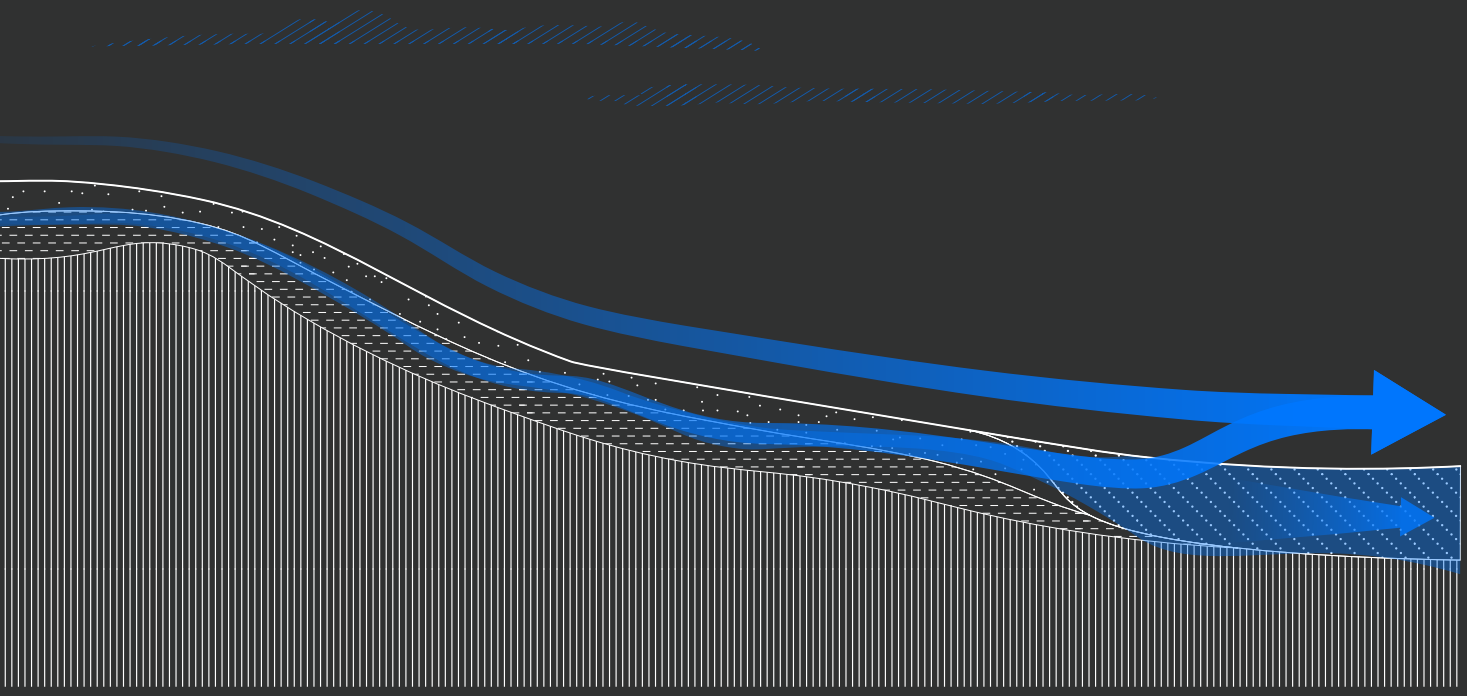




Sub-páramo rainforest
3,500 - 3,000 m.a.s.l.

Inter-Andean valley
<3,000 m.a.s.l.

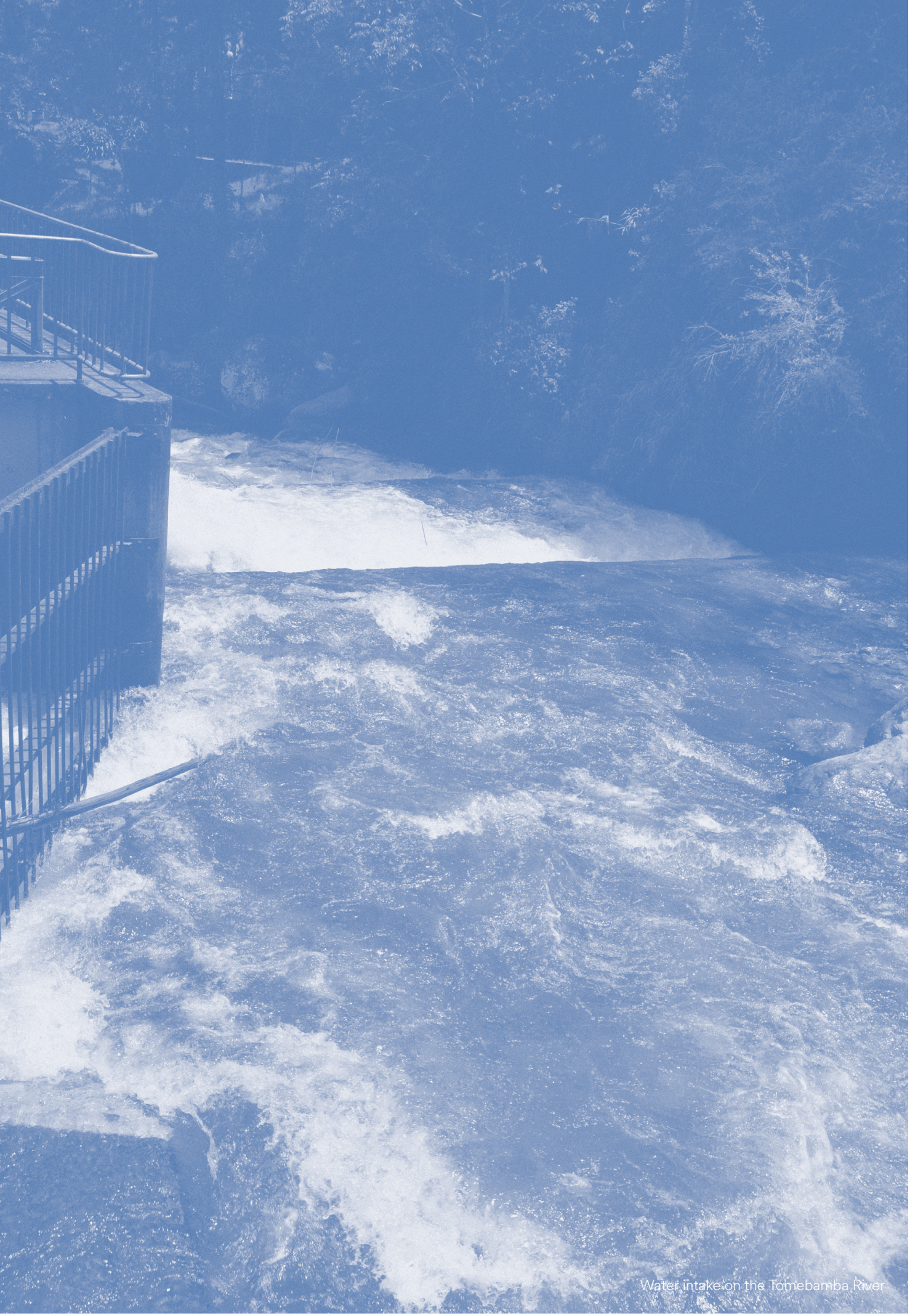




↑ Páramo highlands and sub-páramo rainforests performance in the formation of Andean rivers



5. The urbanisation of water



Water intake on the Tomebamba River

5.1 Riverscape exploitation

Field observations, photographic records, interviews and archival research carried out during the site visit served to reaffirm the extent of the river system's influence and the significance of the role it has played in the historical development of the human settlements that have inhabited the Tomebamba Valley, from its earliest sedentary inhabitants to the contemporary residents of an increasingly urbanised Cuenca.

Similarly, the site visit was also essential in understanding how historical phenomena that extend to the present day—such as population growth and changes in the inhabitants' lifestyles in response to shifting times—have led to an ever-increasing dependence on this river system. This growing dependence, in turn, has led to greater and more profound transformations of the system aimed at maximising the ecosystem and economic benefits derived from it, which have come at the expense of a decline in certain natural qualities.

In order to concrete the analysis, an exercise was carried out to systematise the range of practices involving the use of rivers and their surroundings, as documented in the aforementioned material, enabling them to be grouped according to common uses. This resulted in the identification of five distinct forms of river landscape use that alter the natural conditions of river environments to the extent of affecting factors such as water regulation capacity, water quality and ecological flow, amongst others. It is worth noting that, in developing this categorisation, the analysis went beyond the observation of anthropogenic activities in the rivers and their immediate surroundings; rather, the rivers were taken as the most visible (and resulting from the functioning of) elements of a structural and interconnected system that forms part of the natural landscape, comprising the grasslands and wetlands of the páramo, the sub-páramo rainforests, and the marshes of the inter-Andean valleys, each with its own soil types and biodiversity.

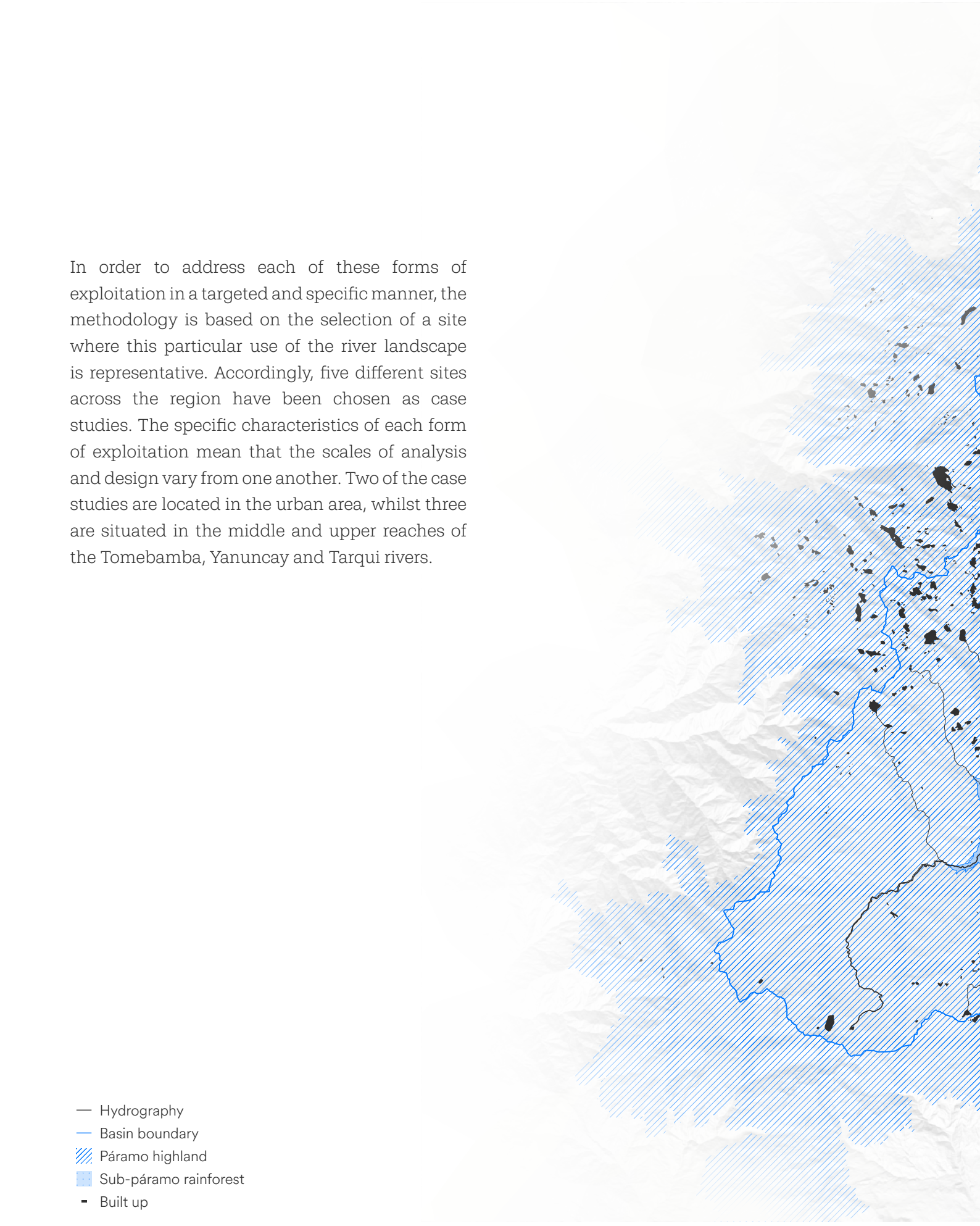
The unsustainability of these practices over time is the main reason why they can be regarded as forms of exploitation: practices which, in the medium and long term, have the potential to profoundly alter the natural characteristics of this natural system and the water cycle, thereby jeopardising the future viability of the rivers. These practices adapt the riverscape to human needs and interests, and as a result, riverscapes become different kinds of landscapes: anthropogenic, urbanised landscapes, functional to specific activities. These are:

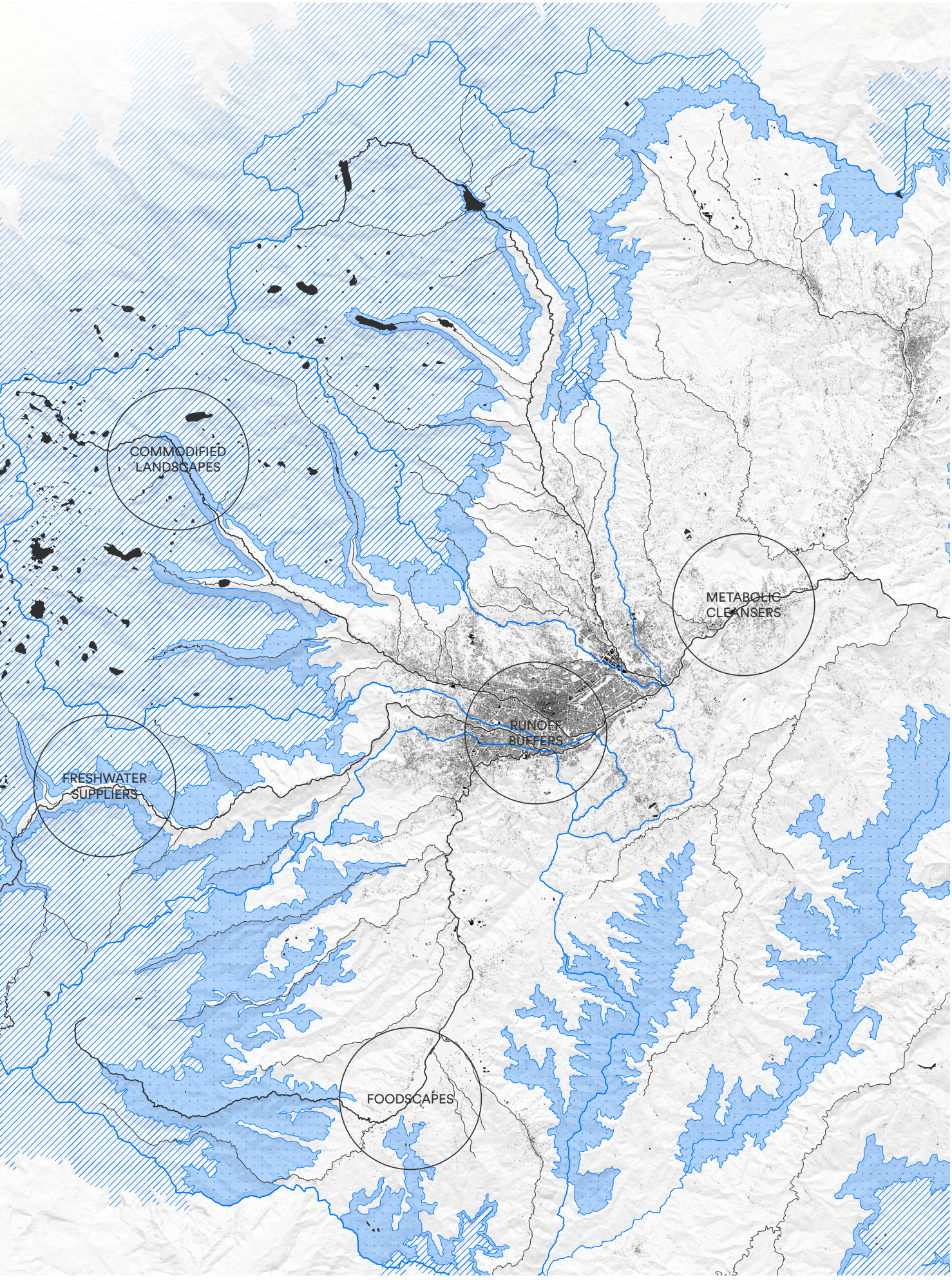
- Riverscapes as commodified landscapes
- Riverscapes as foodscapes
- Riverscapes as freshwater suppliers
- Riverscapes as runoff buffers
- Riverscapes as urban metabolic cleansers

This categorisation aims to systematically identify the specific impacts that each of these forms of exploitation has on the ecological integrity of the system and, based on these findings, to develop alternatives that, as far as possible, maintain the benefits derived from them whilst reducing their negative impacts. To this end, the starting point is the question: What needs to change with regard to each of these forms of use of the system in order to achieve healthy rivers, and what opportunities for use do these changes bring?

↑ Transforming roles of the riverscapes

In order to address each of these forms of exploitation in a targeted and specific manner, the methodology is based on the selection of a site where this particular use of the river landscape is representative. Accordingly, five different sites across the region have been chosen as case studies. The specific characteristics of each form of exploitation mean that the scales of analysis and design vary from one another. Two of the case studies are located in the urban area, whilst three are situated in the middle and upper reaches of the Tomebamba, Yanuncay and Tarqui rivers.





↑ Case study locations

5.2 Riverscapes as commodified landscapes

Throughout its history, Cuenca was a city that was relatively isolated from the rest of the country, mainly due to the complex topography of the region. It was not until 1969 that the first dirt road (nowadays the E-582) was opened through the Cajas Massif to connect Cuenca with the port city of Guayaquil, the country's most populous city. As is generally the case with road infrastructure development in mountainous areas, the route of this road makes use of the terrain's natural contours in order to simplify the route as much as possible.

In this case, the road makes use of the gentle slope of the Quinoas Valley to climb up into the mountain range; the Tomebamba River flows down through this valley towards the city, and the road was built along its banks. Starting at an altitude of 2,500 metres in Cuenca, the road climbs to over 4,100 metres before beginning its descent towards the coastal region, offering a wide variety of landscapes as it passes through numerous high-mountain and transitional ecosystems, including the páramo landscape as it crosses the protected area of the Cajas National Park.

The construction of this road and its subsequent widening led to a surge in traffic volumes, which over the following decades triggered a process of increasingly profound changes in the Quinoas Valley area. In recent years, particularly following its latest expansion in 2012, the sides of this road along the stretch between the urban area and the protected area of the national park have seen the emergence of numerous tourist establishments, which have found an economic opportunity in the growing number of travellers. Today, the landscape along this road reflects the intense tourist character that has taken hold in the valley; the experience of driving along it is somewhat akin to walking down a high street in a city centre, with signs on either side inviting travellers to consume, with one key difference: in this case, the natural landscape itself becomes yet another consumer product.



↑ Urbanisation of the Quinoas Valley



↑ The road through the Cajas Massif: a consumption corridor

The construction of this road transformed the páramo landscapes from an inhospitable and remote place into a destination that is easily accessible and enjoyable. A good example to help imagine what the Quinoas Valley must have looked like a few years ago is the Culebrillas Valley, through which the river of the same name flows and which, a few kilometres downstream, joins the Tomebamba River. The absence of significant human activity along the banks of this river has been the main reason for the survival of the marshes on its banks, which are vital for the river's water regulation.

In the case of the Quinoas Valley, the natural beauty of the páramo ecosystem is now established as the main asset driving economic growth for the businesses operating throughout the valley. Hotels, glamping sites, cafés, restaurants and sport fishing venues make the most of the surrounding landscape, and their marketing promotes a romantic idea of a close connection with nature, where the visitor's enjoyment revolves around a connection with the local landscape and living in harmony with it.

However, the ever-increasing diversity of experiences offered as part of the range of consumer options along this tourist corridor means that more extensive and complex infrastructure must be put in place to enable the development of activities that are promoted and perceived by the consumer as 'natural within the natural environment', but which in practice are entirely alien to it and are, in fact, harmful. Thus, the predominant tourism model is based on a paradox in which the enjoyment of the landscape comes at the expense of the landscape itself.

In this regard, the commodification of the river landscape of the Quinoas Valley and the Tomebamba River is driven by profound transformations and alterations to the very characteristics that define this natural landscape and give it its appeal, which places a big question mark over the legitimacy of the romantic idea of coexisting in harmony with nature on which the current tourism model is based, and the concept of 'natural' within it.

'The Cajas National Park at its fullest'

'Warmth of home in the middle of the páramo'

'Surrounded by lakes and the diverse vegetation of the páramo'

'Switch off and enjoy'

'A magical experience by nature'

'A place nestled amongst mountains and nature'

'A café surrounded by nature'

'Fully integrated into the landscape'

'A space that blends harmoniously with its surroundings'

'An intimate experience amidst mountains, lakes and starry skies'

'Exquisit flavours with a view'

'Belonging to the Andes'

'Nature outside, comfort inside'

'Nature, uninterrupted'

'Spaces that breathe with the mountain'

'Scenery that blends seamlessly with nature'

'All the comforts of a first-class hotel so you feel at home whilst enjoying the natural beauty of Cajas'

'Quietly part of nature'

'Comfort shaped by the wilderness'

'Switch off and enjoy'

'Nestled in the heart of the wilderness'

'The páramo at your doorstep'

'Rooted in the highlands'

'Where nature sets the rhythm'

'An Andean corner filled with surprises and the majesty of nature'

↑ Nature as the main asset in the Quinoas Valley's tourism offering
Source: Booking | Google Maps

The case of the Quinoas Valley clearly illustrates how the development of a single infrastructure project, combined with a lack of planning and land-use control, can act as a tipping point for the ecological integrity of a region and its constituent natural systems. In this case, the accessibility provided by the opening and subsequent extension of this road became the gateway to a process of urbanisation and the conversion of this environment into a tourist hub which, whilst acting as a driving force for the local economy, operates at the expense of the river landscape of the Quinoas Valley.

The most pressing and widespread issue is the threat to the city's drinking water supply. Urban development in this area over recent years has proceeded at a faster pace than the planning authorities have been able to regulate, resulting in a process that has become unrestrained, unplanned and spontaneous. The valley's predominantly natural character until a few years ago meant, for example, that it never had a sewerage system. Against this backdrop, the construction of new tourist establishments in recent years has begun to pose an increasingly serious problem for the supply of drinking water to Cuenca, given their location a few kilometres downstream from the Sayausí water intake works, one of the four such facilities in Cuenca.

This facility, built in 1970 (at that time, far from the city limits and at the foot of a valley that was still largely unspoilt), is where the water that supplies more than 200,000 inhabitants of Cuenca enters the system for treatment (ETAPA EP, 2021). Upstream activity begins to cause problems at certain times of the year: reports by ETAPA EP (2026) show how, during periods of drought, when the flow rate of the Tomebamba River is lower but wastewater discharges continue, the concentration of pollutants in the water rises dramatically. The only factor preventing the water in this river from losing its quality to the point where it is no longer suitable for treatment is the presence of the Llaviuco and Mazán rivers, which flow down from relatively intact areas and whose contributions downstream of the tourist activity zone and just before the water intake works help to dilute pollution levels and improve water quality.

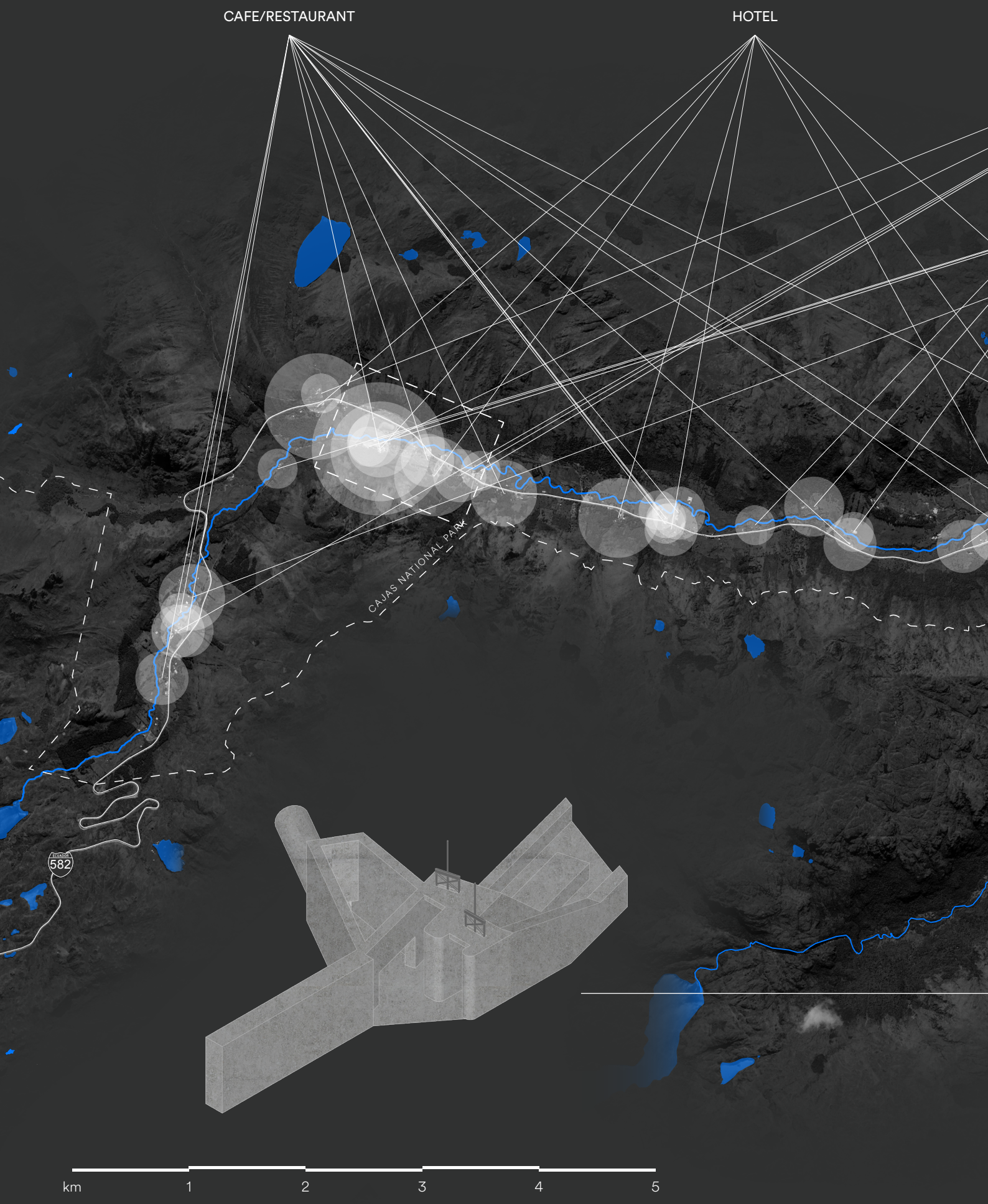




↑ Quinoas (up) and Culebrillas (down): two valleys with different stories



↑ Contribution of the Mazán River (left), which helps to keep the water from the Tomebamba River (right) suitable for treatment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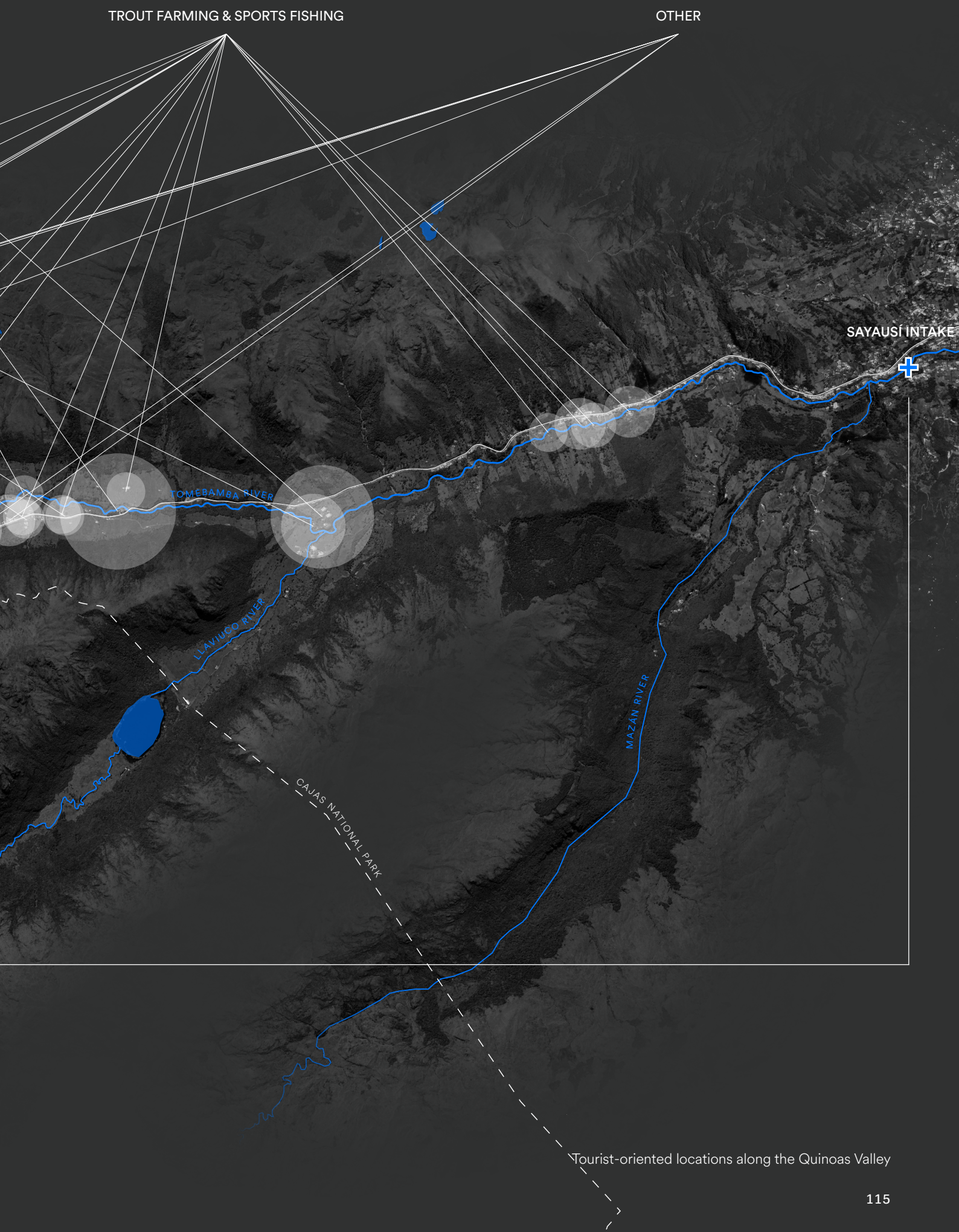
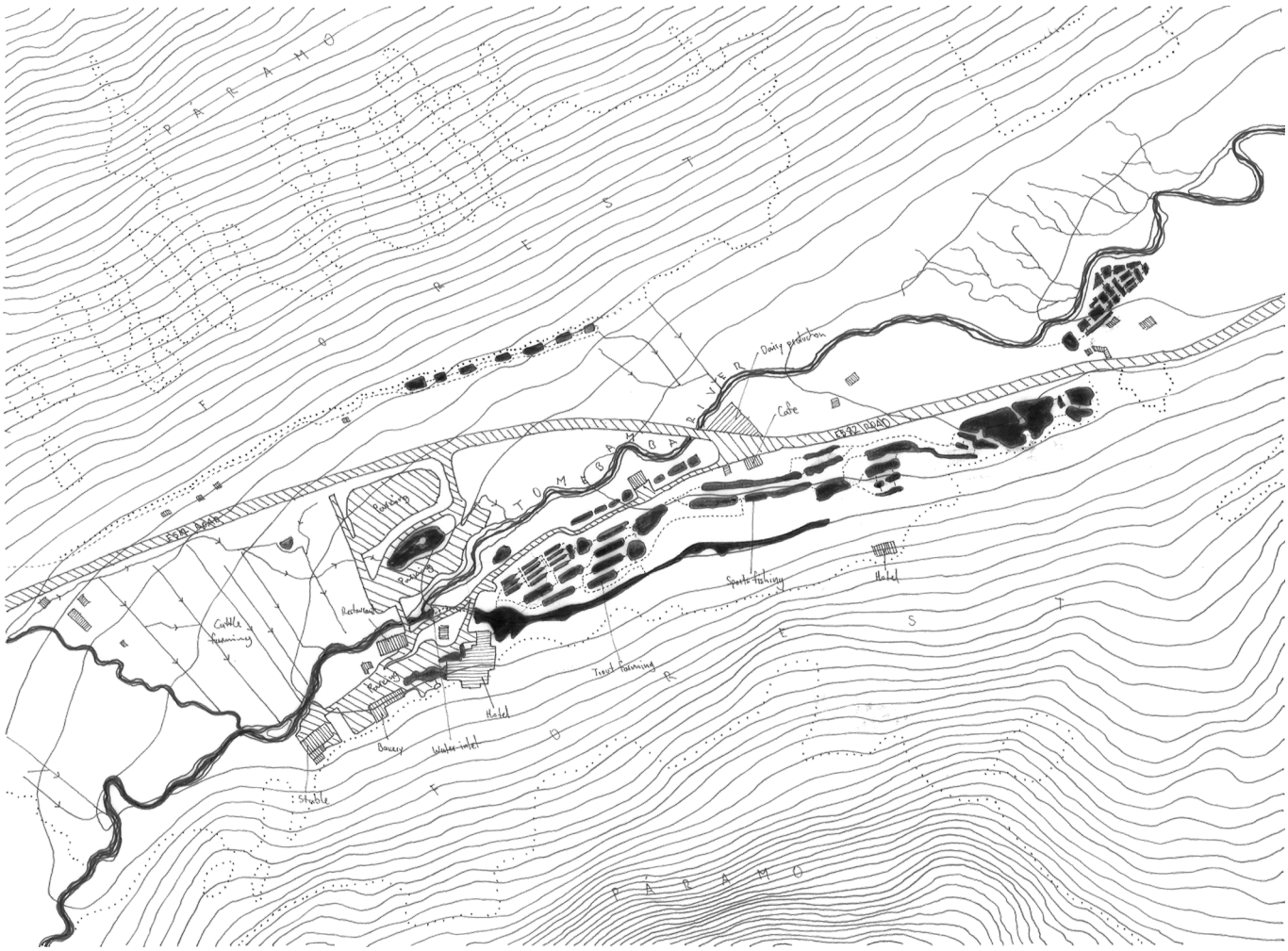


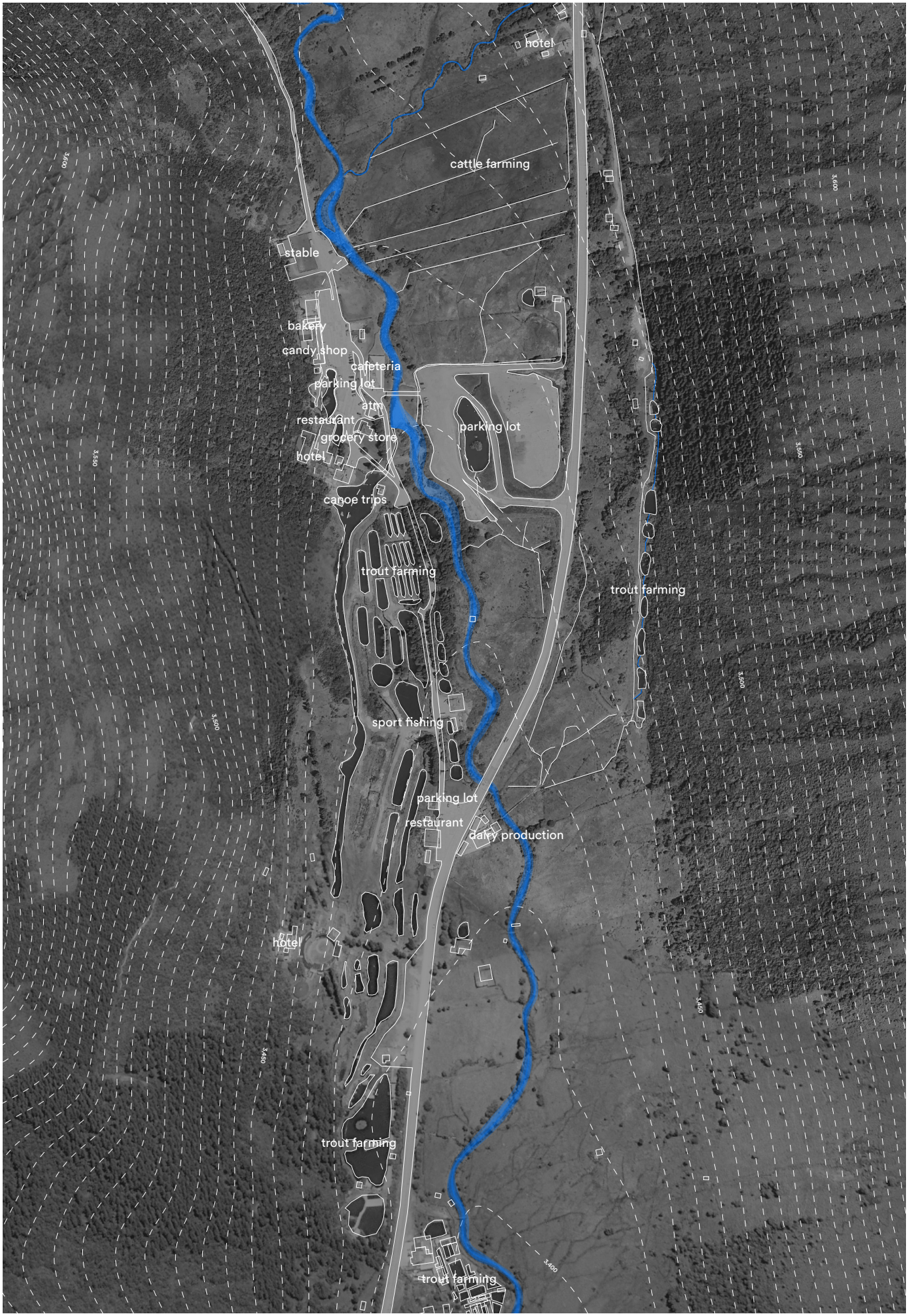
Tourist-oriented locations along the Quinoas Valley

However, water pollution caused by sewage discharge is just one of several impacts resulting from the current tourism model in the Quinoas Valley. Analysis of one of the most established tourist areas in the valley reveals varying degrees of impact on the river landscape caused by the intensification of tourism in recent years.

At this site, located just outside the protected area, one can find, amongst others, the three main services that form the economic pillars of tourism in the Cajas Massif: accommodation, catering and sport fishing. Perhaps harder to discern behind the picturesque image offered by a fish farm in the middle of the mountains, sport fishing is an industry that requires the mechanisation of the riverscape and the conversion of marshy areas in the banks of the river, essential for water storage in the soil, into ponds, as well as the abstraction of significant volumes of clean water to ensure a constant flow through the system of ponds that make them up. Although the water ultimately returns to the river, studies by Varol & Balcı (2020) show that, just like effluents from agriculture and



↑ Land use and services analysis sketch



↑ Tourist-oriented land use and services along the Tomebamba River

livestock farming, wastewater from trout farms increases phosphorus and nitrogen levels in their receiving waters, resulting in less dissolved oxygen in the water available for riparian biodiversity downstream.

Furthermore, alongside water pollution, the species farmed and consumed here, the rainbow trout (*Oncorhynchus mykiss*), is the main cause of the critical situation currently facing the Andean climbing catfish (*Astroblepus ubidiai*), a species native to the region whose population numbers have fallen to historic lows over the last few decades (Ordóñez, 2008) due to predation by the introduced species. Despite its non-native origin to Andean ecosystems, the rainbow trout, introduced to the Ecuadorian Andes from North America during the 1930s and now included on the IUCN's list of the world's 100 most harmful invasive alien species (2004), thrives in the Andean rushing rivers and has firmly established itself on the menu of typical dishes in the Ecuadorian Andes, to the extent to be commonly and mistakenly believed to be a native species.



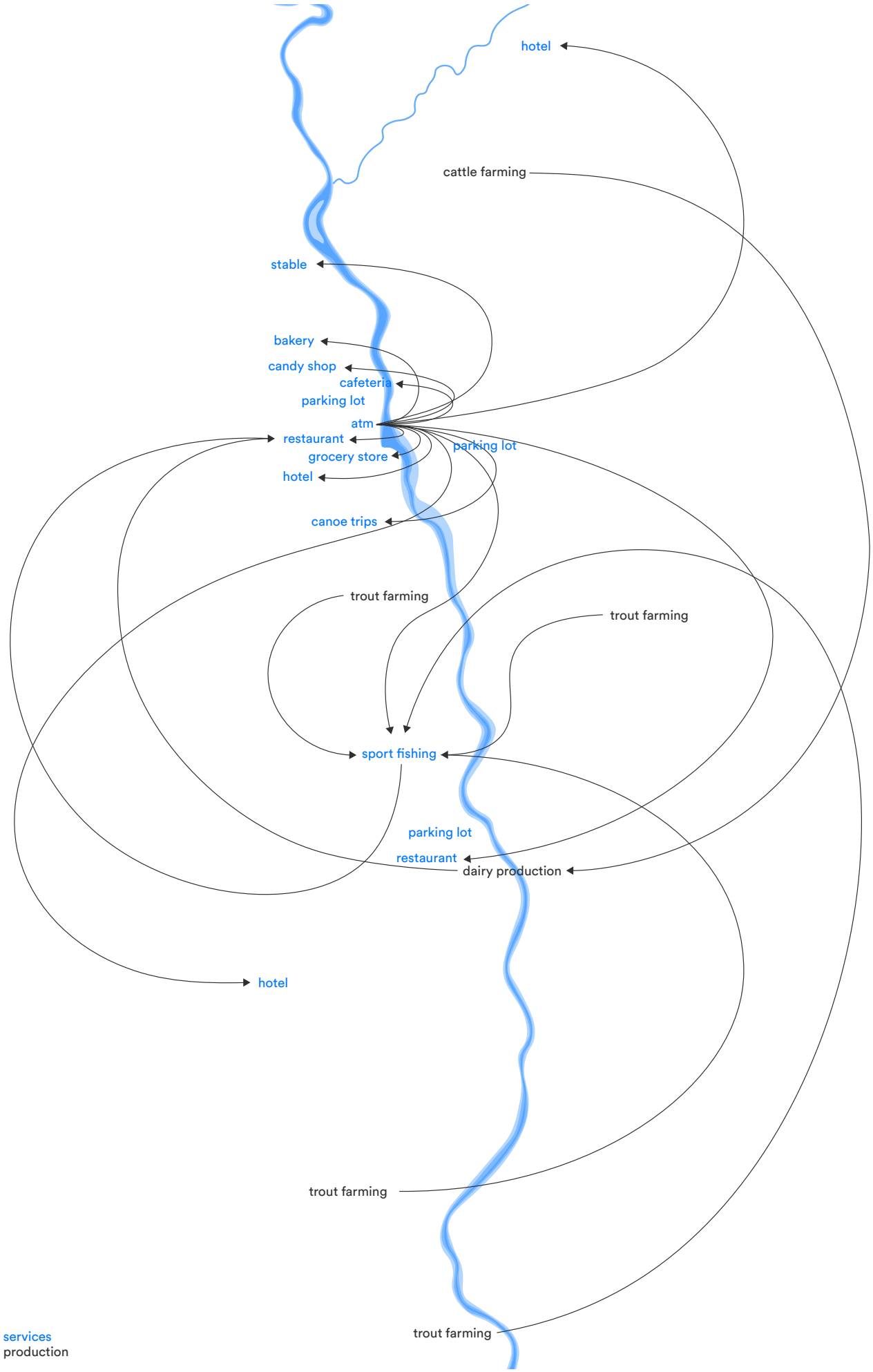
↑ Sign advertising a sport fishing location along the E-582



↑ Trout farm along the banks of the Tomebamba River



↑ Rainbow trout (*Oncorhynchus mykiss*), main invasive predator of the Andean climbing catfish (*Astroblepus ubidiai*)
Source: Kentucky Department of Fish & Wildlife | Finding Species



↑ Economic and material flows within tourism areas along the Tomebamba River

The expansion of services in the area, beyond sport fishing, has taken the form of themed shops, restaurants and various types of accommodation, all of which have created a need for car parks and even the installation of cash machines just a few metres from the river, in a rural high-mountain landscape at 3,450 metres above sea level. Few things can so clearly reflect the starkly profit-driven nature that has fuelled the urbanisation of this environment.

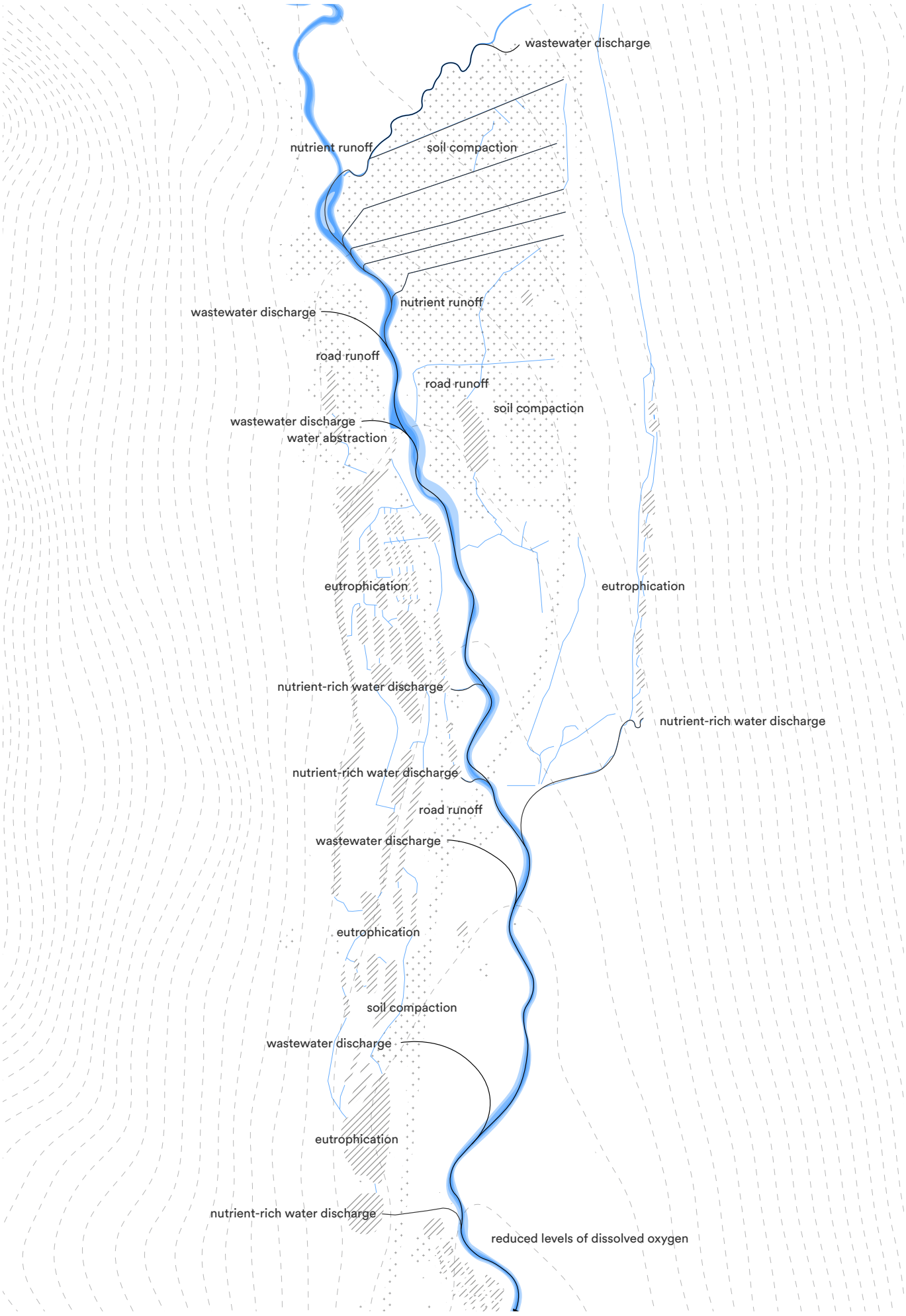
It is here that the hidden flip-side of this growth in tourism provision becomes evident, alongside the degradation of water quality: the loss of the soil's water retention capacity. The infrastructure housing these services is erected without any particular consideration for the characteristics of the soil on which it is situated, being built directly on top of it, paved over and thus sealed and compacted, which destroys its capacity to retain and gradually release rainwater into the river. The conversion of nearby areas for cattle farming further exacerbates this degradation.



↑ Parking areas along the banks of the Tomebamba River



↑ Mountain-fashioned ATM



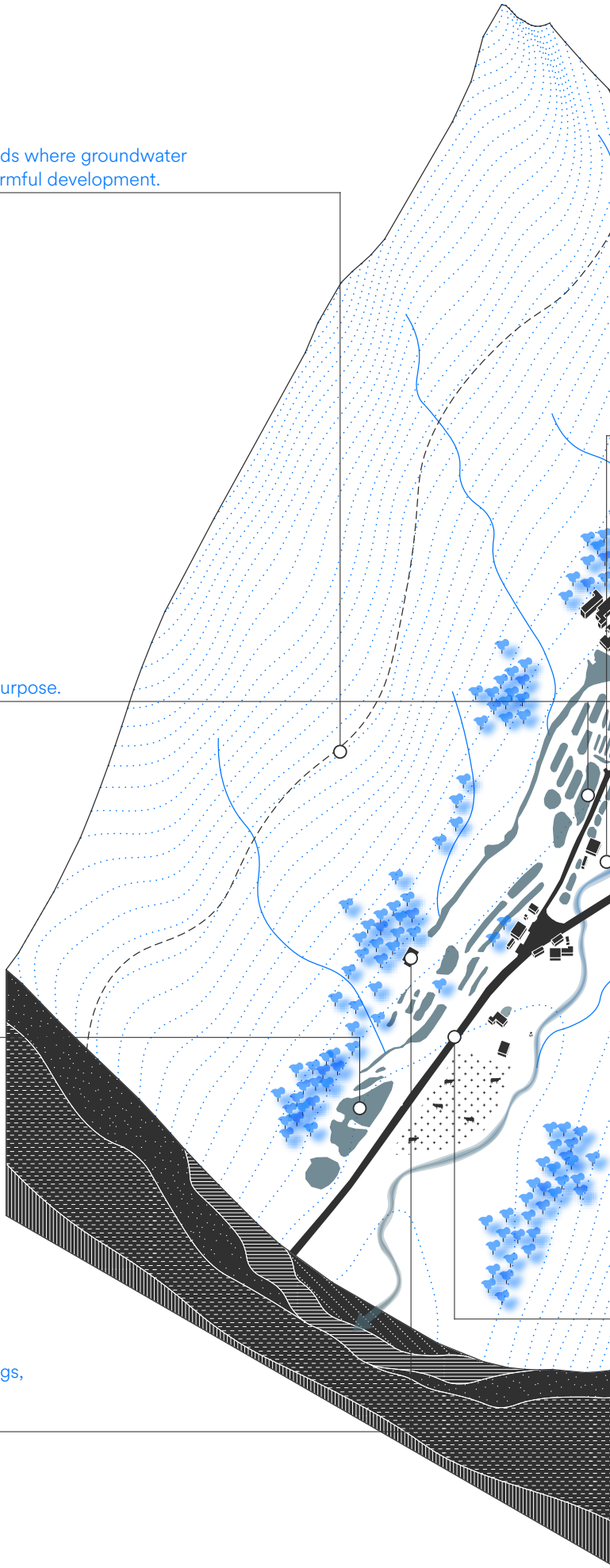
↑ Hidden costs of the growing range of services on offer in the Quinoas Valley

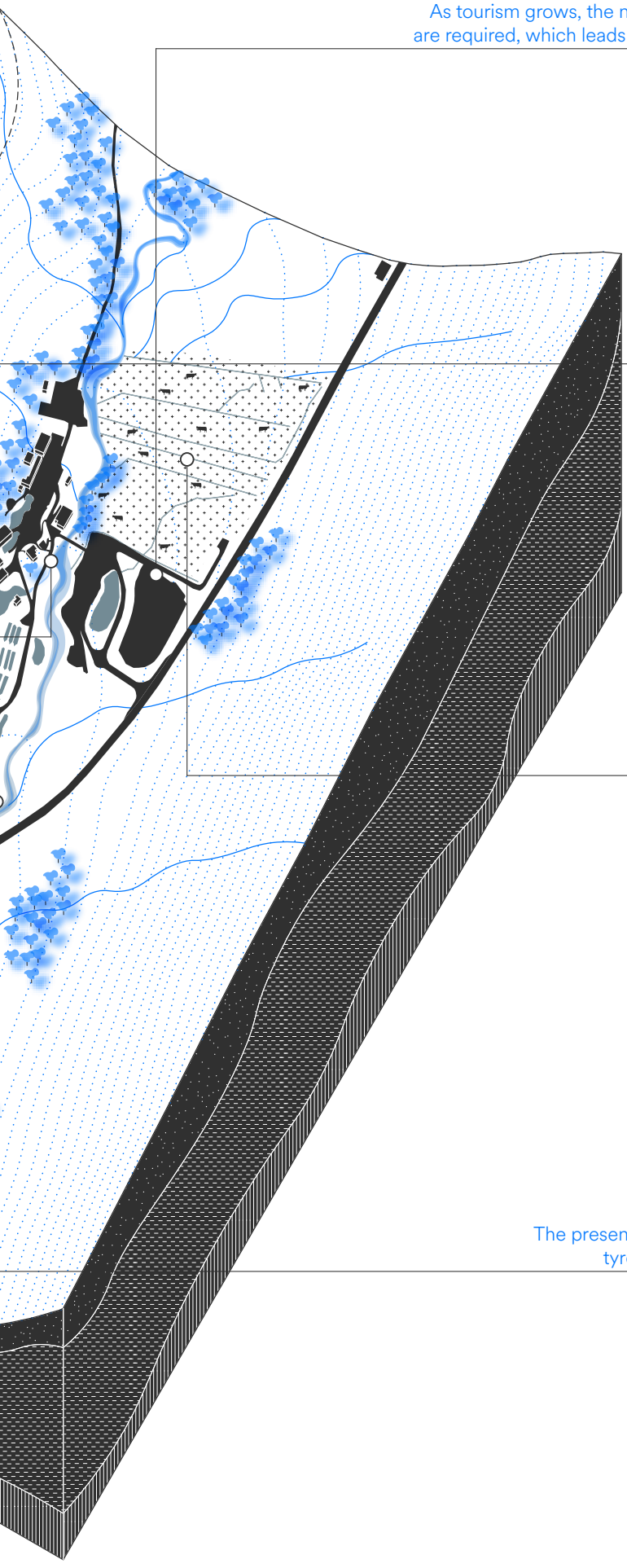
The current boundaries of the national park mean that fragile wetlands where groundwater is replenished and rivers feed are not under legal protection from harmful development.

Trout farming for sport fishing requires a constant supply of clean, oxygenated water; a steady volume is drawn from the river for this purpose.

Effluent water from the fisheries contains high levels of nitrogen and phosphorus, and is discharged directly into the river without any treatment, thereby altering water composition downstream.

Areas of sub-páramo forest are cleared to make way for new buildings, reducing the amount of atmospheric moisture that is captured and transferred to bodies of water.





As tourism grows, the number of visitors increases and, consequently, more parking spaces are required, which leads to large swathes of marshy ground along the river to be paved over.

The lack of a sewerage system results in wastewater discharge into the river, at best after minimal treatment, if it is not discharged directly.

Dairy production in the riverbanks is linked to the loss of wetlands through soil compaction, as well as contributing to water pollution by nutrient enrichment.

The presence of cars in the river surroundings means that heavy metals, oil and tyre wear particles (among other pollutants) end up directly in the river.

The vulnerability caused by a lack of land-use planning and control in a vulnerable and unprotected ecosystem such as the Quinoas Valley has created the perfect conditions for the intensification of a predominantly profit-driven approach, which has fuelled its excessive urbanisation and over-tourism in recent years, with little regard for the environmental costs that this process has entailed.

The transformation of the valley clearly illustrates how private economic interests can take precedence over the preservation of natural systems that are vital for the provision of basic ecosystem services that benefit the community as a whole when there is lack of planning and control. The provision of services whose infrastructural, spatial and consumption requirements are completely disconnected from the ecological functioning of the environment reveals the sheer superficiality of the argument of harmony and connection with nature so frequently repeated by the tourist establishments throughout the valley; conversely, it highlights their evident disconnect from the delicate environment in which they are situated.

This contradiction reveals an approach to the natural landscape that is fundamentally extractive in character, in which the natural landscape is viewed as a consumable resource and becomes a foundation upon which other services are provided. This model of exploitation is based on the adaptation of the landscape to imposed uses, forcibly established on the site, the essence of which is predominantly urban, resulting in numerous instances of environmental degradation.

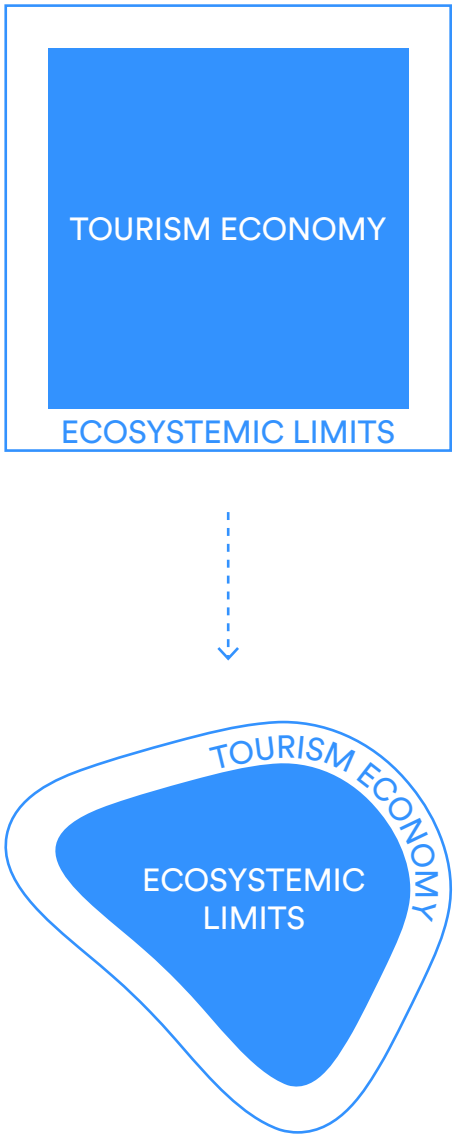
At the same time, it is important to recognise the role of tourism as an economic driver and a source of employment for the province of Azuay and for Cuenca in particular. However, if the tourism model comes at the expense of its main attraction, it is clear that the model needs to be rethought. Rather than moulding the environment to suit imposed services, it is the analysis of the environment and the establishment of its own limits and capacities that must be established as the starting point for defining the tourism model that can be developed in the area.

To reach this point, two parallel approaches could be taken to encourage the gradual transformation of the tourism model. Beyond urgently highlighting the hidden costs of the current tourism model to justify and legitimise the introduction of land-use regulation policies, a strategic approach should be based from the outset on cooperation with the key stakeholders in this equation; that is, the owners of tourist establishments. Sharing scientific evidence on the collective importance of these ecosystems—key factors for their businesses—and their gradual degradation under current trends could serve as a first step towards securing their support. Alongside this awareness-raising process, a strategy of economic incentives through tax relief/exemption could be implemented, with the proceeds directed towards the infrastructure replacement necessary to enable the new model.

Furthermore, a practice already in place and currently being implemented by the Municipality of Cuenca could be strengthened: the acquisition of private plots in areas of ecological importance for their designation as areas of public interest. In recent years, more than 1,200 hectares of land in

páramo areas have been acquired by the municipal authority through the municipal drinking water company, ETAPA EP. These acquisitions could be reinforced (or carried out directly) by the Ministry of the Environment, and the acquired areas could be incorporated into the protected area of Cajas National Park.

Finally, the most difficult challenge to tackle is that of readjusting the expectations and tourism consumption habits of those who sustain the current model. The model exists because it has customers, and the customers are customers because the service appeals to them, which makes transformation a complex task. However, the model also works because there is no awareness among the general public of the hidden costs (so called precisely for that reason) of its operation. Yet nobody wants to experience water or power cuts in their homes because rivers maintain their flow for increasingly shorter periods once the rainy season ends. Widespread awareness of the potential widespread consequences in the medium and long term if we continue down the same path could serve as the main motivation and driving force for shifting the tourism model towards a new paradigm; one based on the restoration of ecosystems and the natural functions of the riverscape, in which being part of this restoration process and caring for the environment in general are the main attractions.

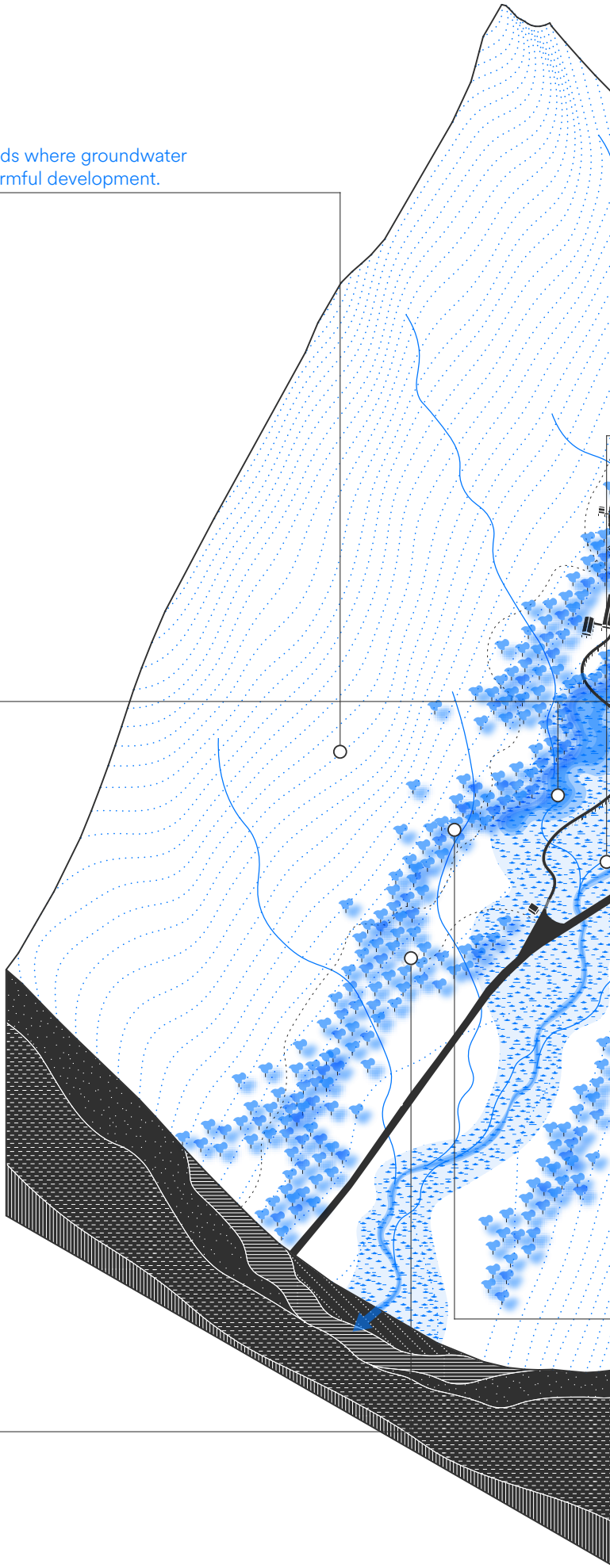


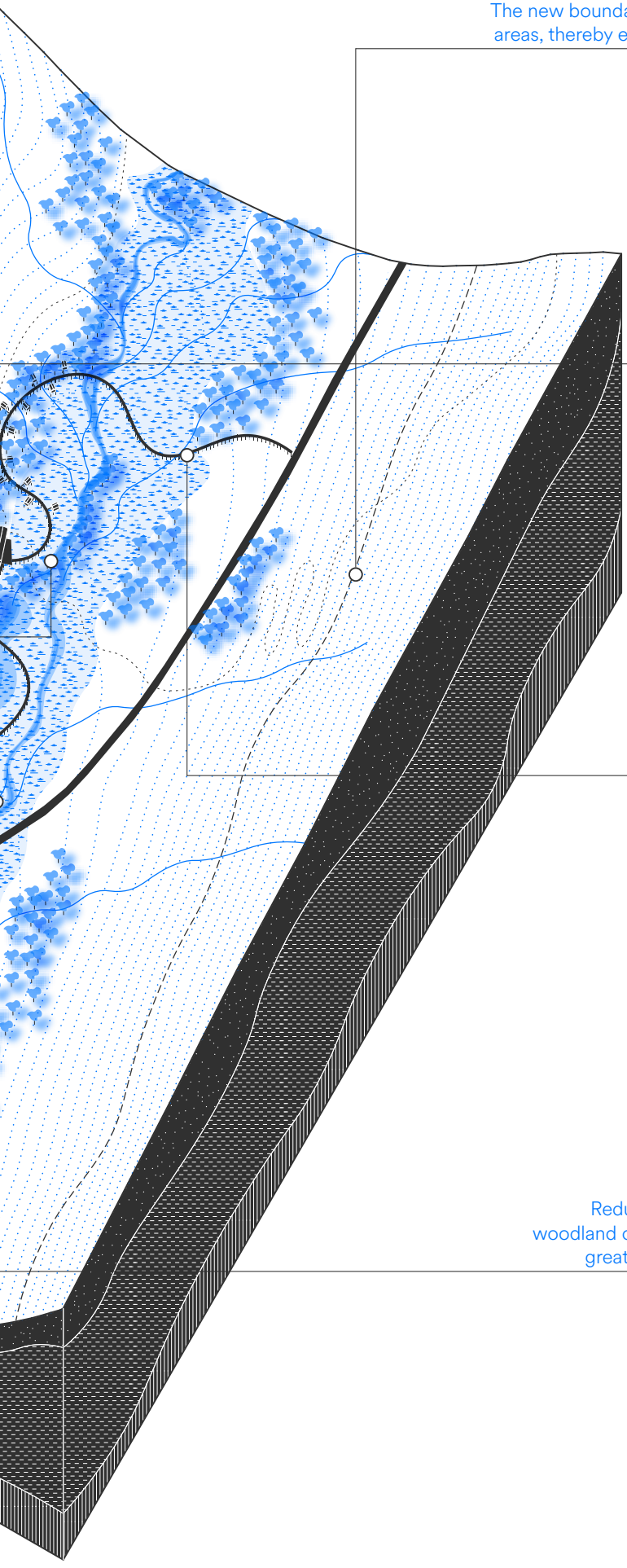
↑ Reversing the current model:
Shaping tourism economy around ecosystem limits

The current boundaries of the national park mean that fragile wetlands where groundwater is replenished and rivers feed are not under legal protection from harmful development.

Trout farms are replaced by projects aimed at the gradual recovery of the Andean climbing catfish population, offering an alternative to an economy based on trout farming. Once the population is sufficiently stable, this species has the potential to be reintroduced into the region's diet, as it was in centuries past.

The restored river environment creates new opportunities of enjoyment of nature: narrow hiking trails are created through the sub-páramo forests and páramo highlands, as a means of enjoying the landscape in a less impactful way.



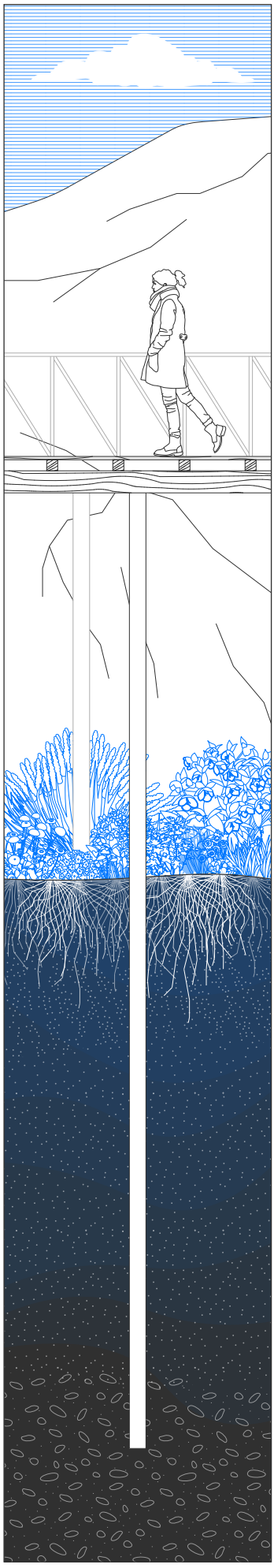


The new boundaries of the national park designate tourist areas as part of protected areas, thereby enabling greater control over land use along rivers and watercourses.

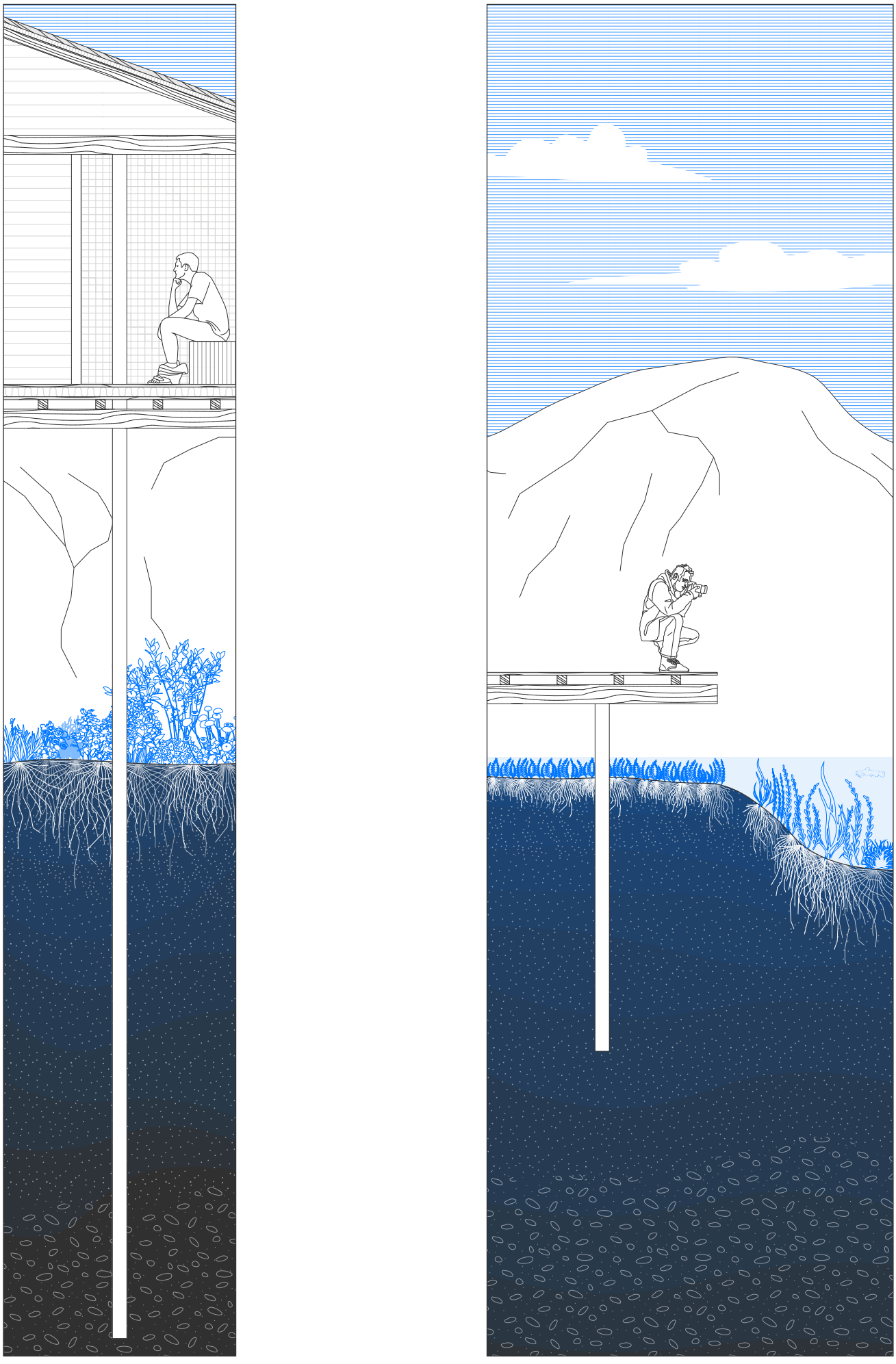
The remotion of dairy production and parking areas from the riverbanks allows for a gradual restoration of riparian marshlands.

The new tourism infrastructure is designed to fit in with the local environment, therefore causing minimal disruption to the soil and water conditions.

Reducing the number of buildings allows for the reforestation of areas of woodland cleared for construction, thereby connecting isolated forest patches: greater vegetation cover increases moisture capture and water retention.







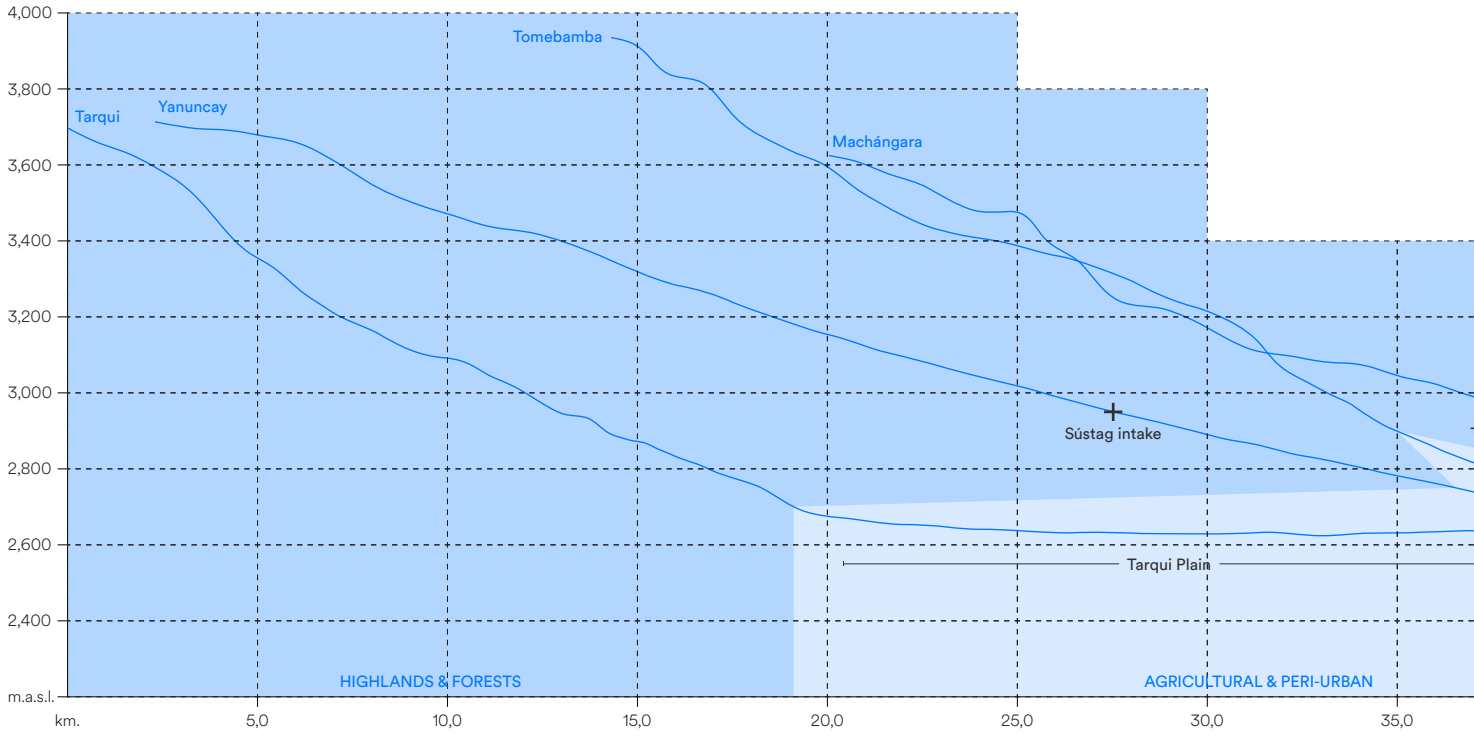
↑ Impressions of a new model of tourism in fragile high-Andean ecosystems

5.3 Riverscapes as foodscapes

Once the rivers leave behind the high-mountain areas comprised by páramo and sub-páramo ecosystems, their courses enter areas where the nearby presence of a city starts to become readable in the landscape. The intense population growth and consequent urban expansion process that the city has undergone over the past decades has transformed the rural character of its surrounding productive areas that supply it with resources like food and raw materials to a new landscape typology. Areas that historically have had a predominantly agricultural land use are currently under transformation as an effect of the little controlled—and therefore, scattered—expansion of the city, which is delivering a hybrid model of mixed-use peri urban areas where housing and agricultural production coexist.

While the elevation profile of three of the four rivers that cross Cuenca remains generally stable and reflects their status as rushing mountain streams along their entire length, one of them shows a slightly different condition in a stretch, which has become a key factor to the historical land use patterns along its banks. Unlike the other three rivers, the Tarqui River's elevation profile shows a marked change from the steep gradient of its upper course to an almost flat gradient as it flows through the vast Tarqui Plain, just a few kilometers downstream from its source.

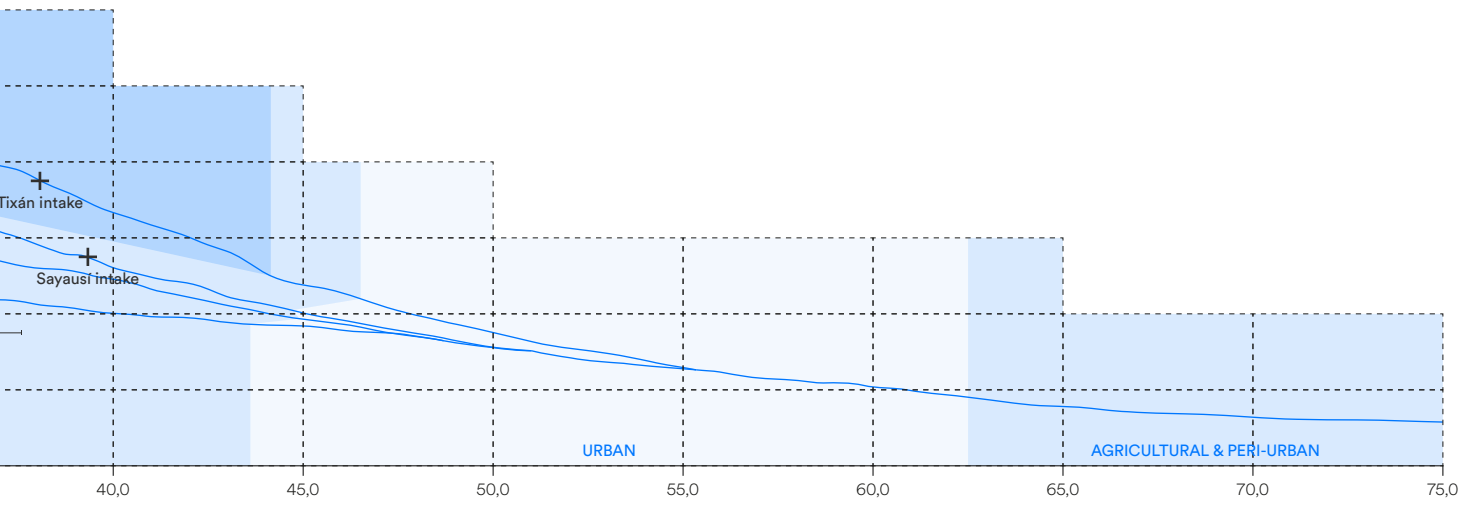
Unlike the areas that make up the catchment basins of the other three rivers that flow through Cuenca, large swathes of the Tarqui River catchment basin lie below an altitude of 3,000



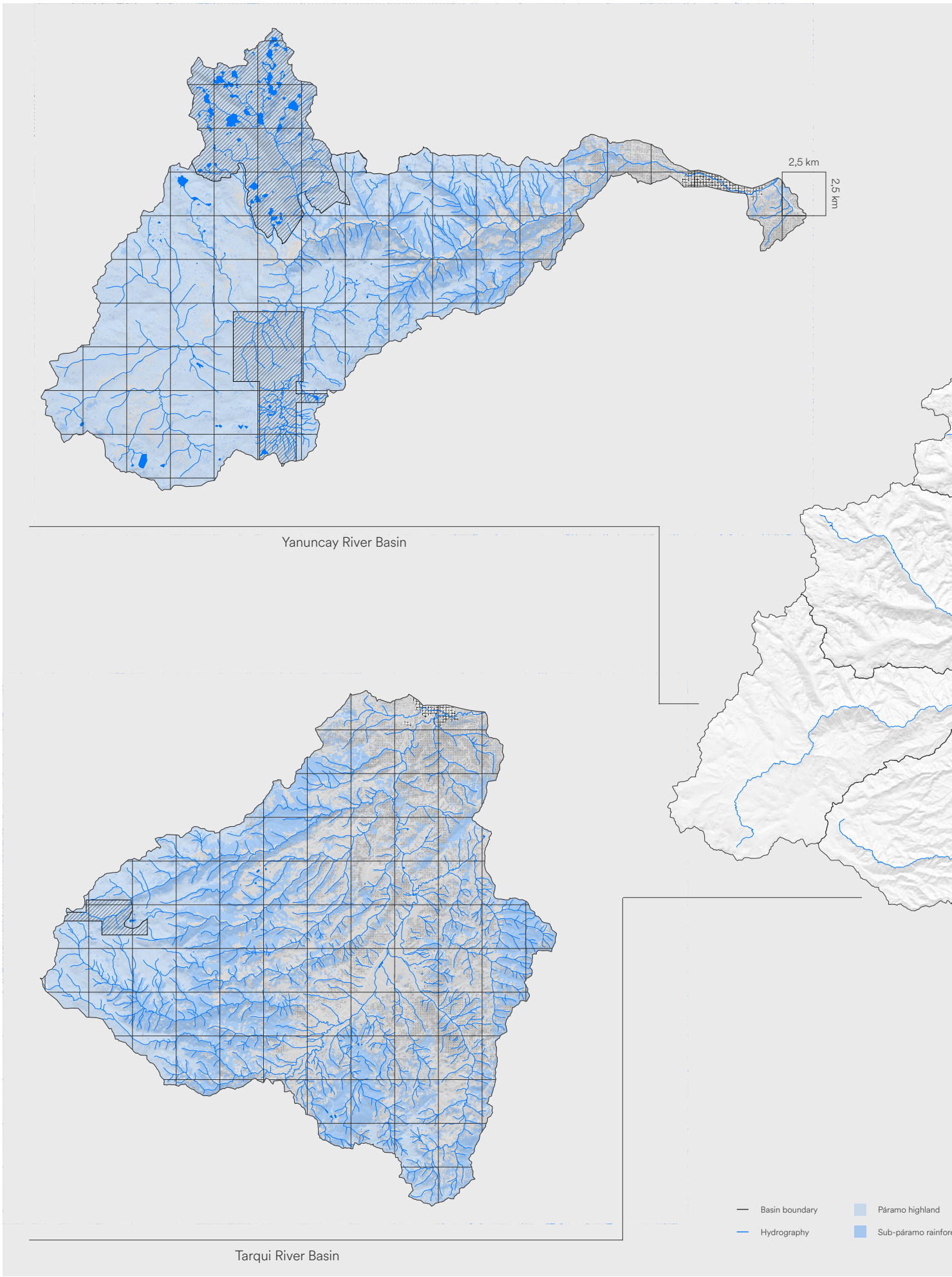
metres, meaning that the proportion of páramo and sub-páramo area relative to the total area of the basin is smaller compared to the other basins. At the same time, this lower altitude means that a larger area of its territory experiences relatively milder temperatures throughout the year.

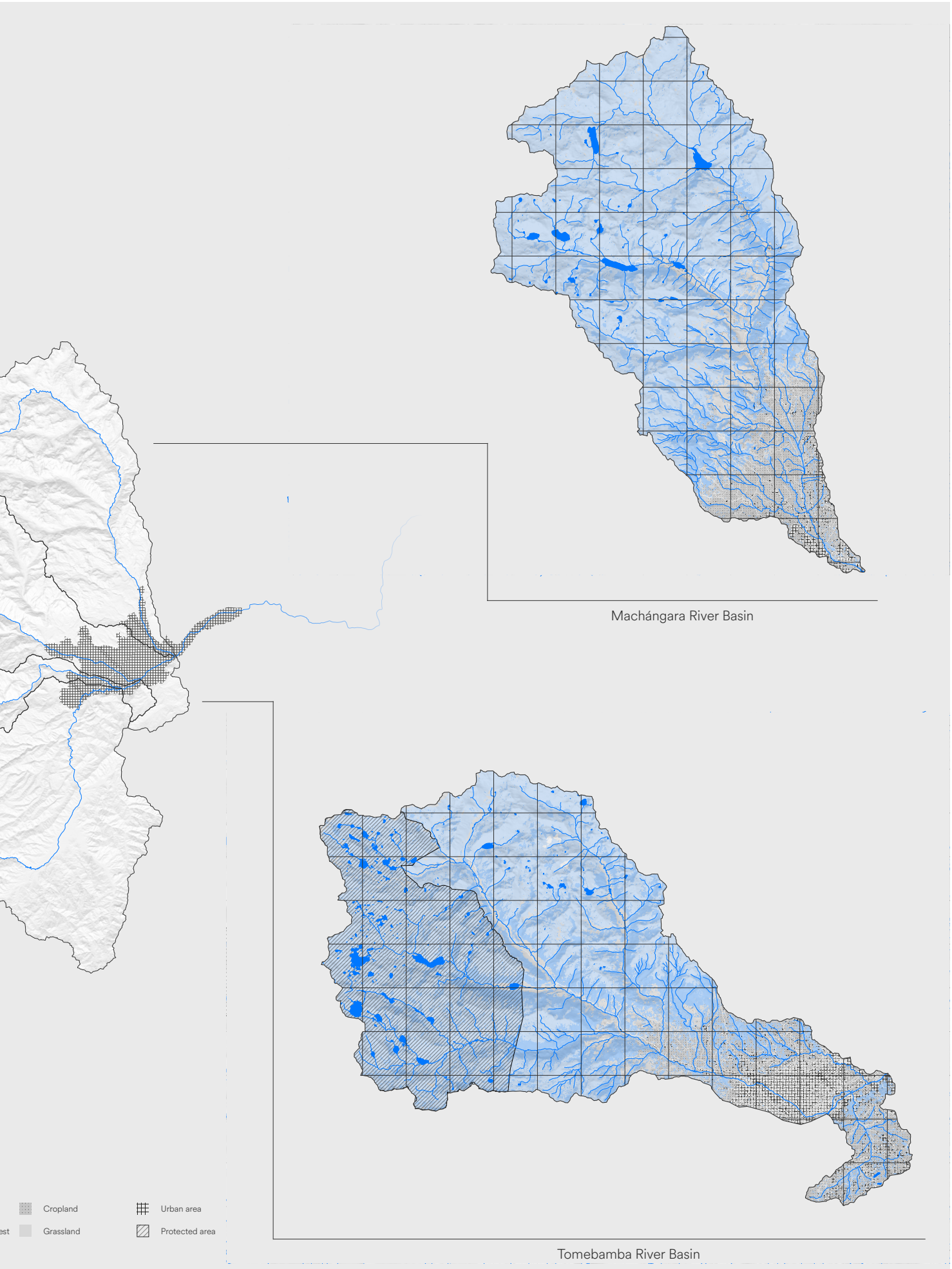
This combination of geomorphological and environmental conditions, together with the constant availability of water that the presence of the river represents and a milder weather than that of the highlands, have historically enabled human settlement and the convertion of this river basin to a productive landscape, a land use pattern which has intensified particularly in the Tarqui Plain to turn this area into the main livestock hub of the Cuenca region.

Therefore, over the last few decades, as a result of the intense expansion of the agricultural and livestock frontier, various modifications to the landscape have been made with the aim of adapting and exploiting the natural conditions of this plain for livestock production, in a process of progressive mechanisation of the landscape. This in turn has resulted in a greater degree of land use alteration and human footprint in the Tarqui River basin in comparison to the catchment areas of the three other river that flow through Cuenca.



↑ Elevation profiles of the rivers of Cuenca and main territorial functions along their courses


2,5 km
2,5 km
Yanuncay River Basin
Tarqui River Basin
Basin boundary
Hydrography
Páramo highland



↑ Land-use patterns in the river basins of the Cuenca region

Besides a gradual but steady land use transformation in the Tarqui Plain, one of the punctual actions that transformed the most the morphology of this river basin involved a deep alteration of the river's meandering course across the plain. Characterised by bends and sharp curves, as is typical of watercourses in flat areas, the river course was straightened during the 1990s with the aim of reducing the risk of flooding inherent to extense river floodplains like this one.

The measures taken certainly contributed to a further consolidation of this area as a cattle farming and dairy production cluster, serving as the main source of livelihood for many families living on the plain. However, as has become evident in the years following the intervention, flood risk did not decrease, but became more frequent given the reduced freedom for water to flow that a straight course implies, as well as the increased speed that the lack of curves and bends provokes in straightened watercourses.

The steady growth of dairy production related activities and the resulting urbanisation in the Tarqui Plain and surrounding slopes brought in a new problem: the Tarqui River began to suffer from increasingly high levels of water pollution. This situation stems from two main factors; on the one hand, the lack of control and planning that has characterised Cuenca's urban growth – and which has also been evident in this area in recent years – has meant that areas that were previously predominantly rural have begun to be developed at a faster rate than the basic sewerage infrastructure can be put in place, making watercourses the main outlets for the problem posed by wastewater management.



On the other hand, the uncontrolled intensification of livestock farming, as well as a lack of any kind of measures for an integrated management of this activity in relation to the river, has resulted in the Tarqui River becoming the main recipient of nutrient pollution from the effluents of this productive activity, which causes a severe degradation of its water quality from the earliest stretches of its course.



↑ Agricultural landscape of the Tarqui Plain

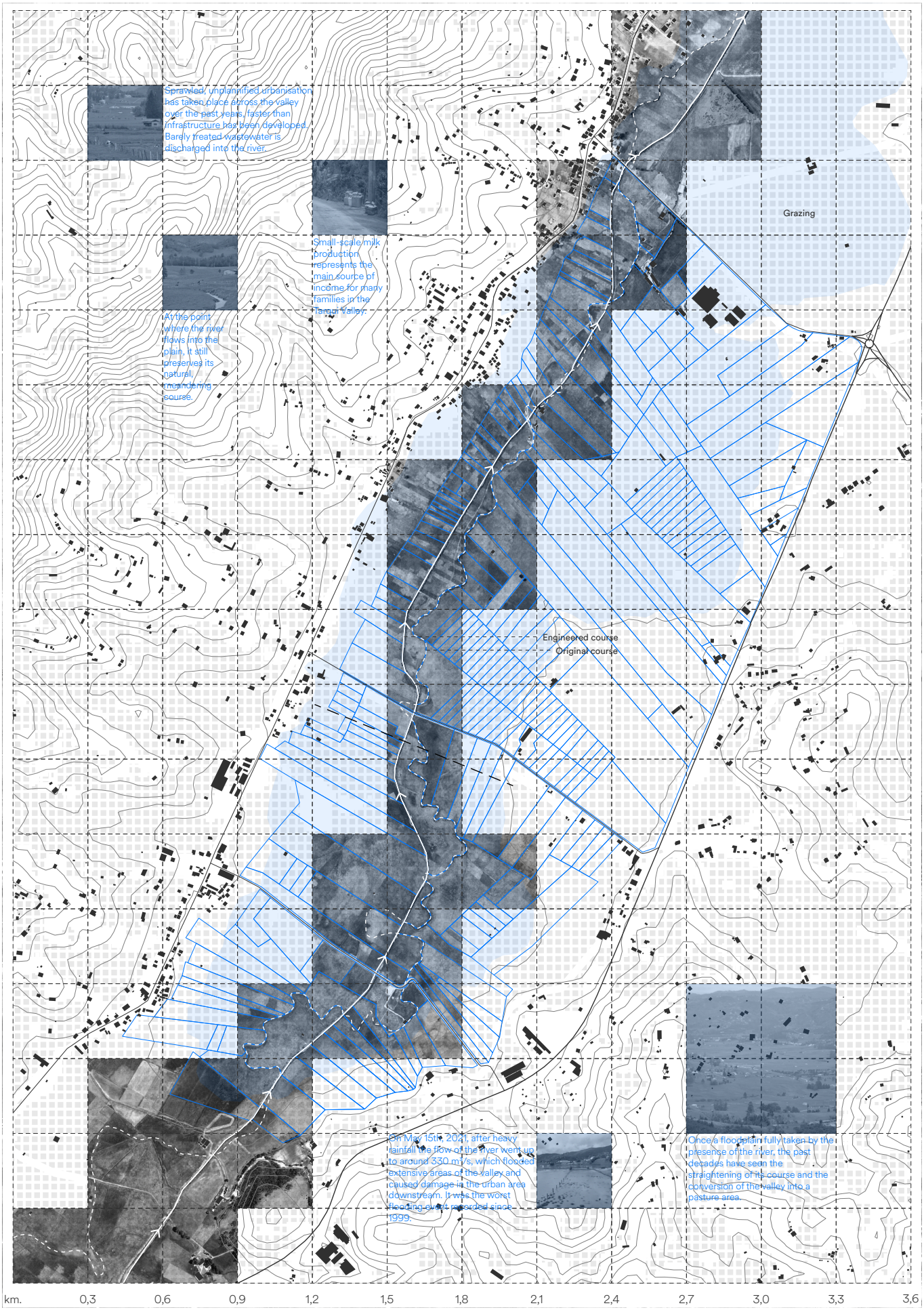
Consequently, throughout Cuenca's modern history, the Tarqui River has earned the reputation of being the most polluted of the four rivers that flow through the city, a fact which also explains why from all four of the rivers that flow throug Cuenca, the Tarqui is the only one from which water is not abstracted for the production of drinking water. The concentration of pollution is further exacerbated due to the river's relatively low flow rate (about 3.2 m^3/s, according to ETAPA EP) in comparison to the other three rivers of Cuenca.

As it is not carried out on an industrial scale, livestock farming in Tarqui is mainly sustained and run by local families who own the land,which is reflected in the high degree of land fragmentation in the valley. Geometric, orthogonal lines are drawn across the landscape to demarcate properties and also rotational grazing areas. From time to time, particularly near the channelised river, the trace of the river's former meandering course still can be seen and even serves as a boundary between properties near the old river course that was erased and redrawn through engineering, creating a visible landscape palimpsest.

Restoring the ecological functions that have been altered in the river involves, in principle, returning its original capacity to flow with a certain degree of freedom through a flexible, hybrid landscape characterised by gradients—a feature typical of river plains such as this one—which contrasts with the straight lines imposed by modern engineering at the end of the last century. A reconfigured cross-section allows for greater variation in the river's flow without causing flooding every time there is heavy rainfall upstream.

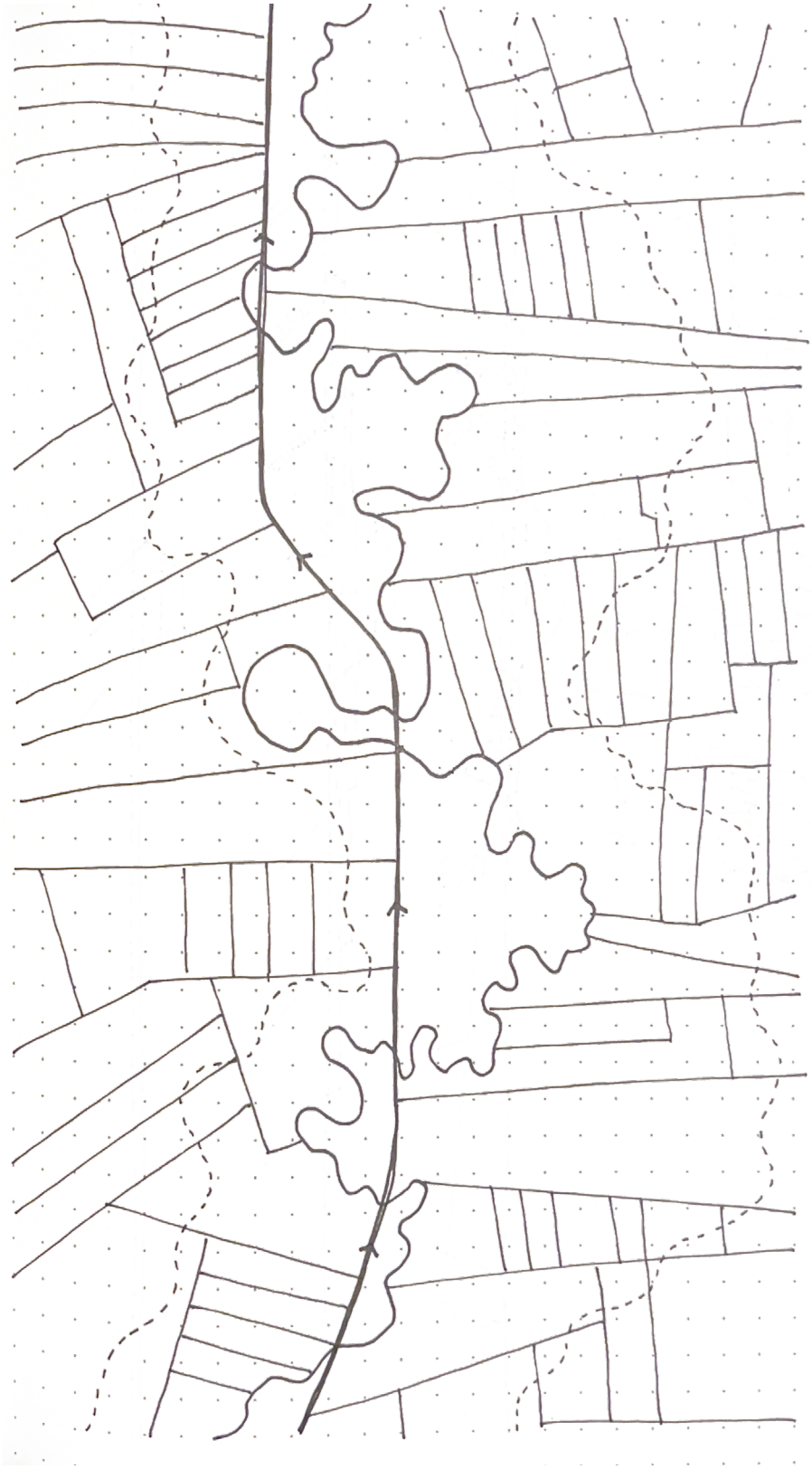
To balance this flexibility required by the water with current land uses along the riverbanks, a system of double dykes serves as the main strategy to protect against potential increases in flow, creating intermediate mixed-use areas populated by riparian vegetation and used for silvopastoralism, designed to flood occasionally. A new cross section allows water to flow freely up to a calculated flow volume corresponding to a once-in-five-years event. The design of the rest of the landscape is not, however, disconnected from its reality and location on a naturally flood-

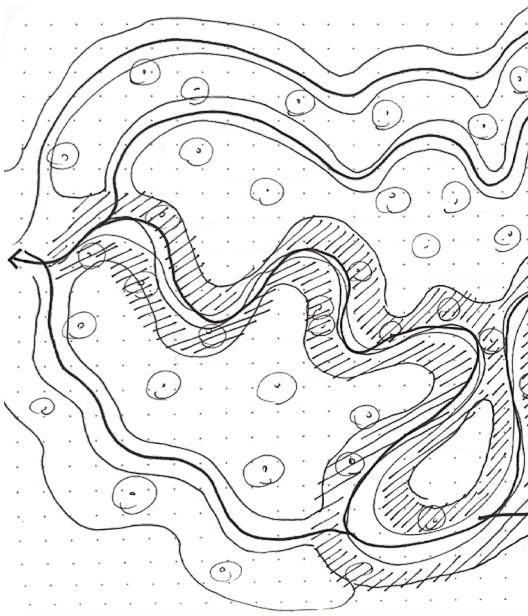


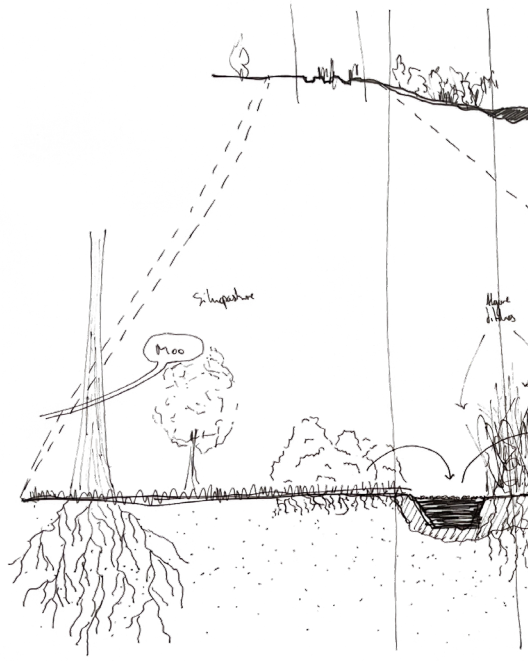


← Landscape palimpsest of the Tarqui Plain

↑ Current spatial configuration and land use in the Tarqui Plain



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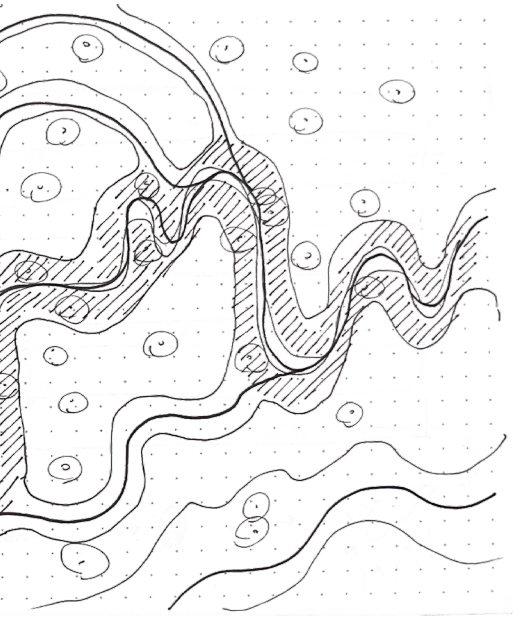
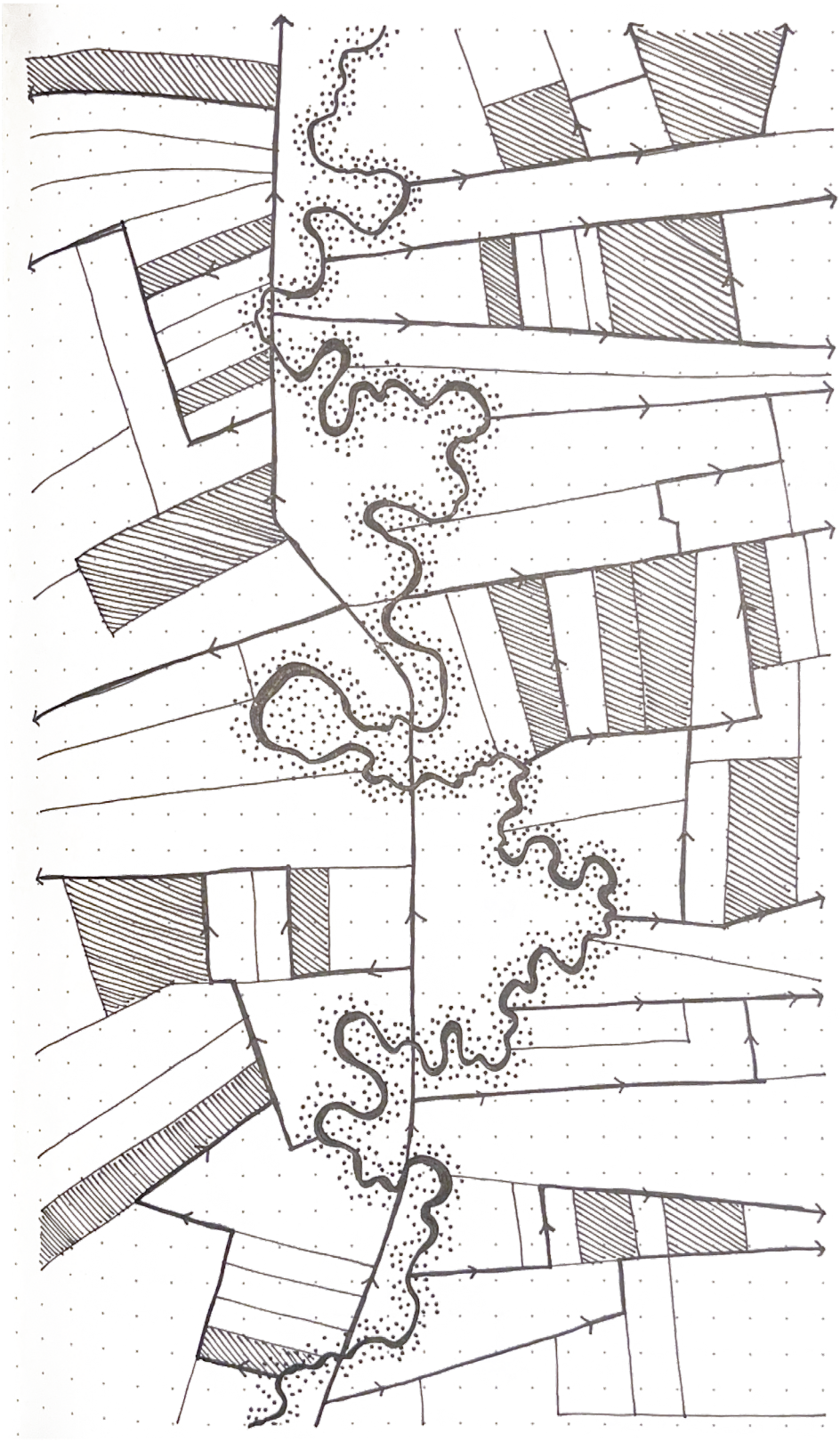






↑ Concept sketches: Flood mitigation and nutrient pollution prevention

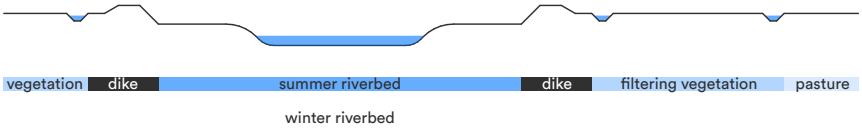
prone plain and its proximity to a watercourse of a certain volume.

Land fragmentation is transformed into a design feature, and water channels are laid out between the plots to provide irrigation under normal conditions; however, during events where the river overflows the embankment, these channels become the next space for accomodating water. In addition, the surface area of certain plots that, under this strategy, become community property is lowered, and these are connected to the channels to increase water storage capacity during flooding or heavy rainfall events. The construction of the dykes is not only intended to mitigate flooding, but also serves as a strategy to protect the river's water quality by preventing surface runoff and reducing the underground flow of effluent from grazing areas into the river. In conjunction with this infrastructure, smaller-scale strategies are deployed to manage nutrient-rich water. In addition to the riparian vegetation growing within the dykes, an additional strip is laid out on the outside, alongside which runs a channel responsible for transporting and partially filtering the water from the upstream areas. To complete the filtration process, a series of constructed wetlands is arranged along the plain, ensuring that the water is purified as much as possible before continuing its journey to the next group of plots.

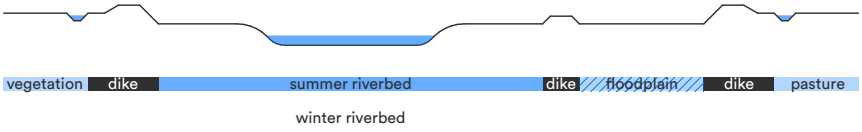
Current section



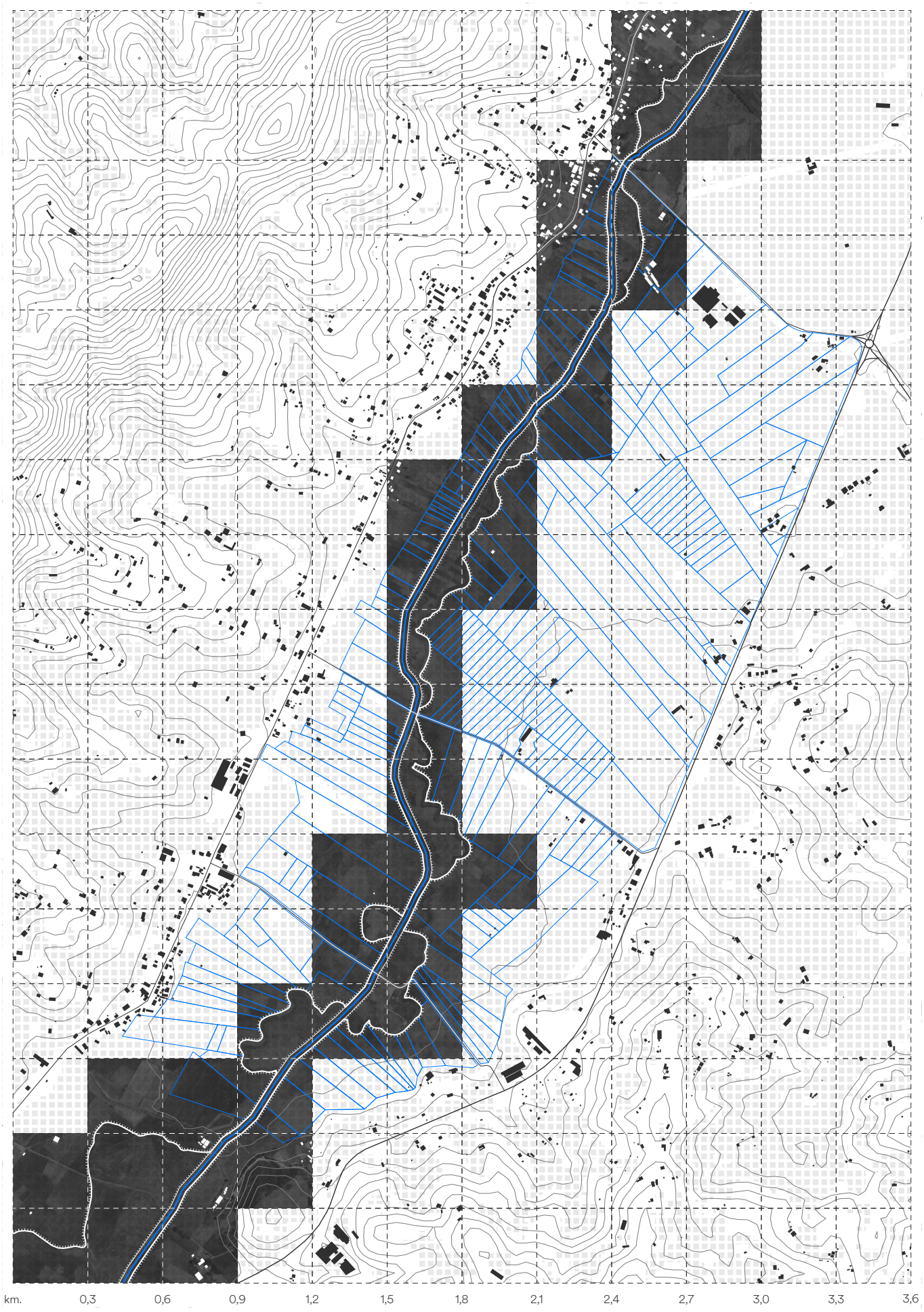
Section typology A: Single course



Section typology B: Double dike



↑ Section typologies



↑ Double dyke system applied in the Tarqui Plain


pasture field
original cou
pasture field



↑ Current Tarqui Plain: Basic composition





↑ Proposed Tarqui Plain: Landscape layer


irrigation ditch
scav
filtering vegetation strip
low dike
riparian vegetation
high di
floodable plot



↑ Proposed Tarqui Plain: Infrastructure layer

AVERAGE FLOW



HIGH FLOW



1-IN-1 YEAR RETURN PERIOD





1-IN-5 YEAR RETURN PERIOD



1-IN-10 YEAR RETURN PERIOD



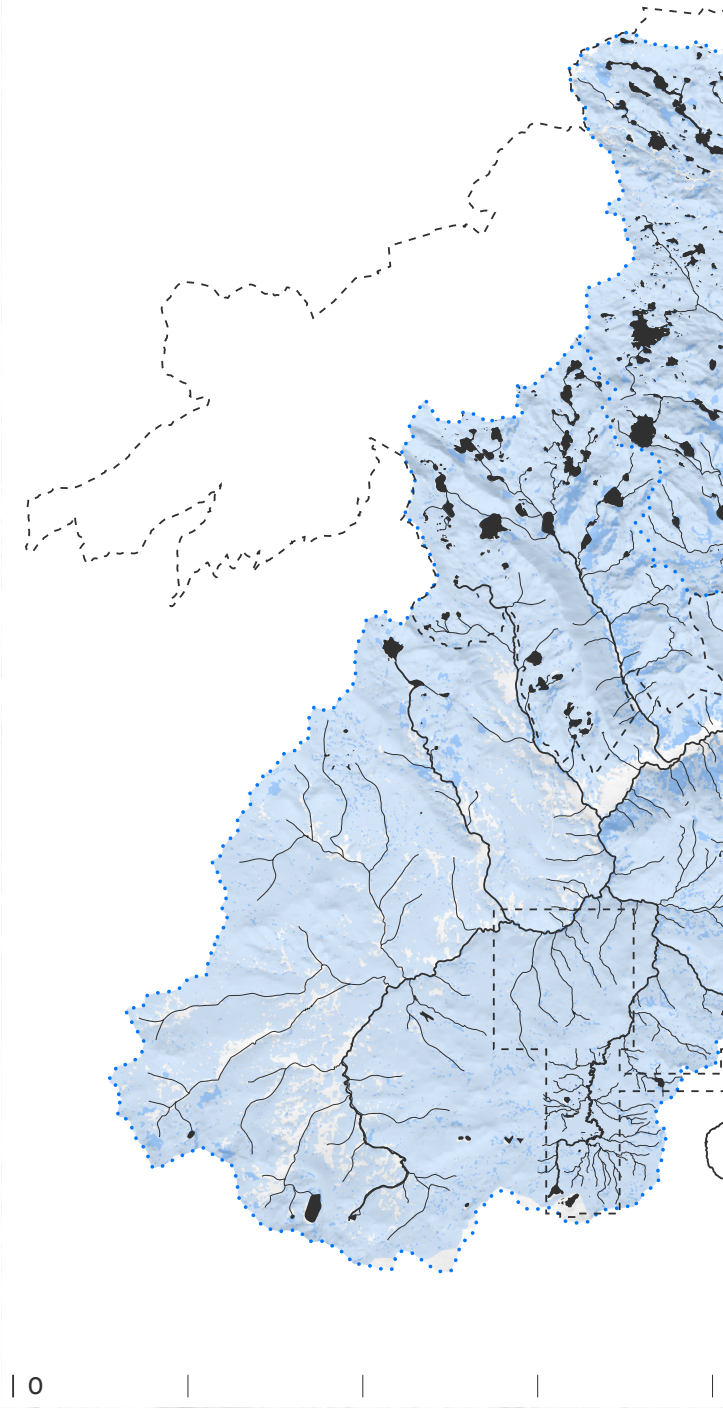
1-IN-50 YEAR RETURN PERIOD

↑ Performance of the double dyke system in the Tarqui Plain under different flow scenarios

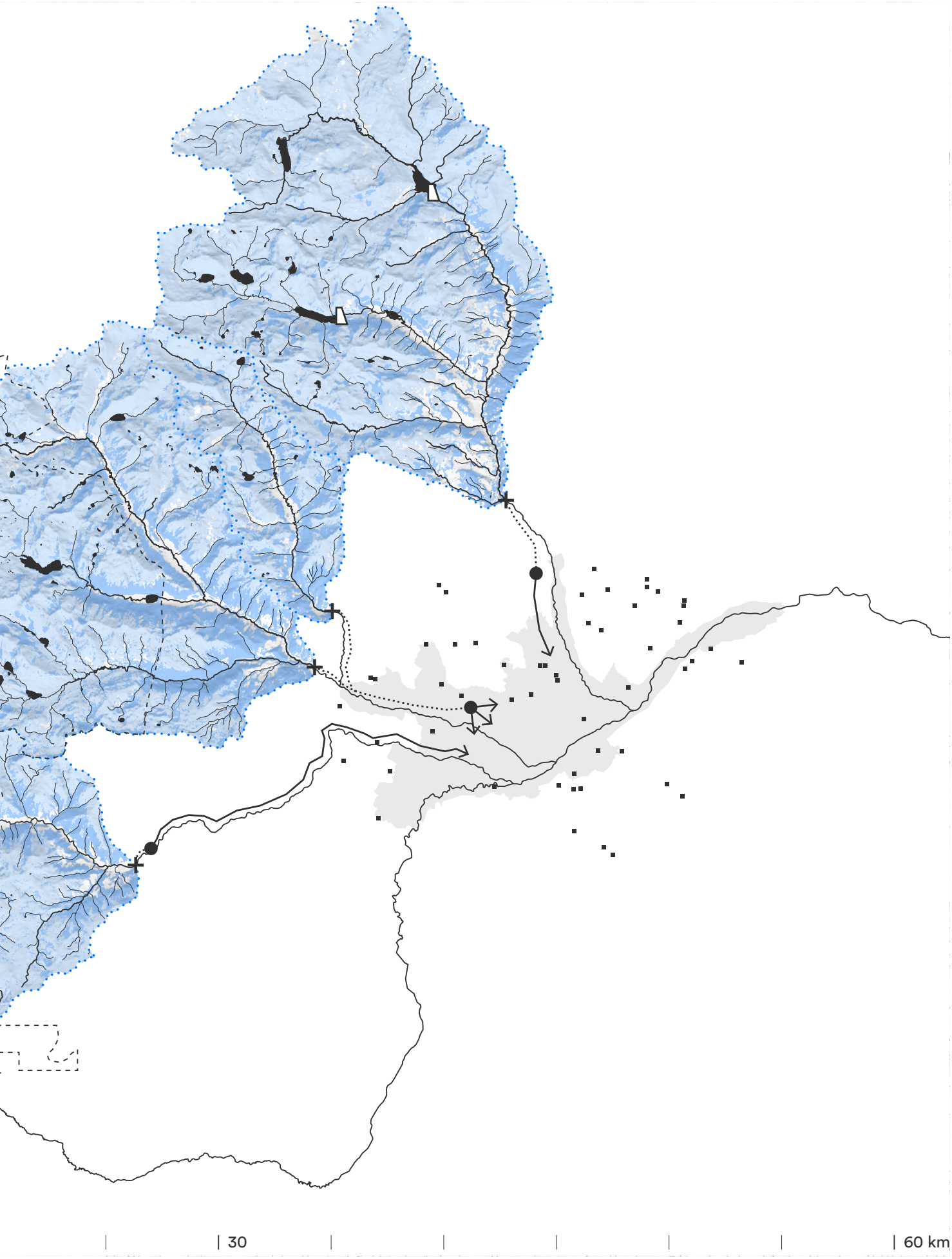
5.4 Riverscapes as freshwater suppliers

Throughout its history, Cuenca has relied solely on surface water sources for its water supply; that is to say, on its rivers. The Yanuncay, Tomebamba (with its tributary, the Culebrillas) and Machángara basisns are the water recharge areas for the rivers from which water is drawn to meet the demand of the urban area.

The journey of water through the drinking water infrastructure, from the abstraction infrastructure in rivers to taps in the city, begins when it enters the system via one of the four river intake structures, where it is diverted from its natural course and transported, after passing through a grit chamber, to the water treatment plants. This is where the water transformation process begins; the water undergoes conventional treatment, in which, through the use of aluminium sulphate and other chemical compounds, the coagulation-flocculation-sedimentation cycle agglomerates and settles unwanted particles, transforming raw water into drinking water. Once treated, water is once more transported to the numerous storage tanks distributed throughout the city and its surroundings, whose combined capacity is of 120,000 m^3 (Roldán, 2016), where it is stored prior to consumption.

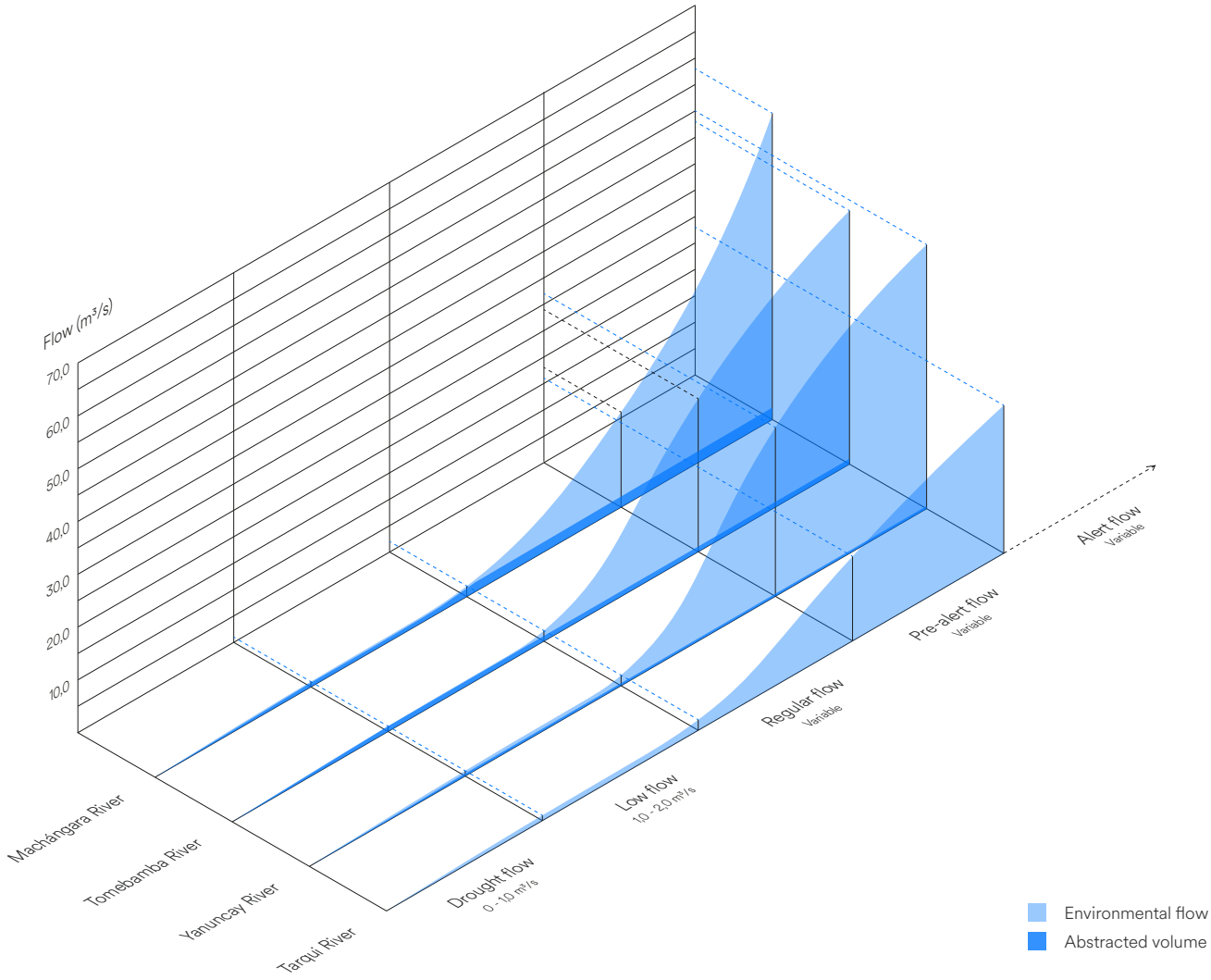


— Hydrography
+ Water intake
● Drinking water purification plant
Water storage dam
▪ Water storage tank
····· Raw water conveyance
→ Drinking water distribution
Intake recharge area
Protected area
Páramo highland
Sub-páramo rainforest
Urban area



↑ Cuenca's drinking water system

As Cuenca's rivers still have low flow rates and are close to their headwaters when they pass through the city—and are therefore independent of major tributaries—their flow rates can vary significantly depending on rainfall upstream. The municipal water company constantly monitors the rivers to track fluctuations in flow rates during periods of rain and drought. To maintain a systematic record, a classification of flow conditions has been developed, covering low water (0–1 m^3/s), low (1–2 m^3/s), normal, pre-alert and alert. As all four rivers have slightly different average flow capacities, the maximum amount of water they can accommodate in their channels varies. Therefore, beyond the low-flow and low-water categories, each river has a different range of cubic metres per second that it can accommodate within the normal flow, pre-alert and alert categories.

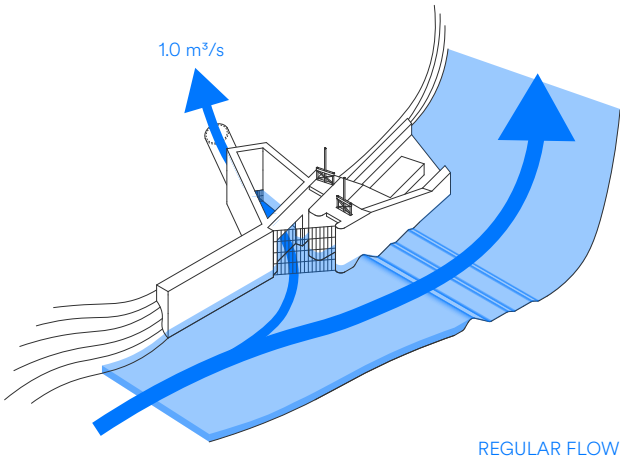


↑ River flow rates and abstraction volumes

Due to the city's constant daily demand, the amount of water abstracted from river flows generally remains constant as well, and is regulated at the intake structures by means of sluice gates. A fixed volume of water is treated to make it safe for drinking, whilst the remainder continues down as part of the river's environmental flow.

During 2023 and 2024, the southern region of Ecuador experienced two extreme periods of hydrological drought, lasting 118 and 160 days respectively without significant rainfall (Tapia 2024). The dependence of the rivers of Cuenca on rainfall at their headwaters became evident, as a drastic drop in their flow rates was recorded during these periods. Although during such events the water company runs public campaigns asking citizens to reduce their consumption and thus minimise the chances of water cuts, the minimum flow entering the El Cebollar treatment plant does not fall below 0.7 m^3/s (it is 1.0 m^3/s under normal conditions). This figure may seem a negligible amount compared to the river's average flow of 6.0 m^3/s (Roldán, 2016), but during drought periods, such an amount can represent its total flow.

In such cases, a conflict emerges as there is not enough water to maintain a constant flow for treatment whilst also ensuring the river's minimal environmental flow. The water company tries to avoid water rationing for the public as much as possible, which means that most of the river's flow is diverted from the riverbed. Several studies show that a reduction in a river's minimal flow can lead to a loss of riparian biodiversity, increased concentrations of pollutants in the water, and imbalances in the river's sediment dynamics (Poff & Zimmerman, 2010).



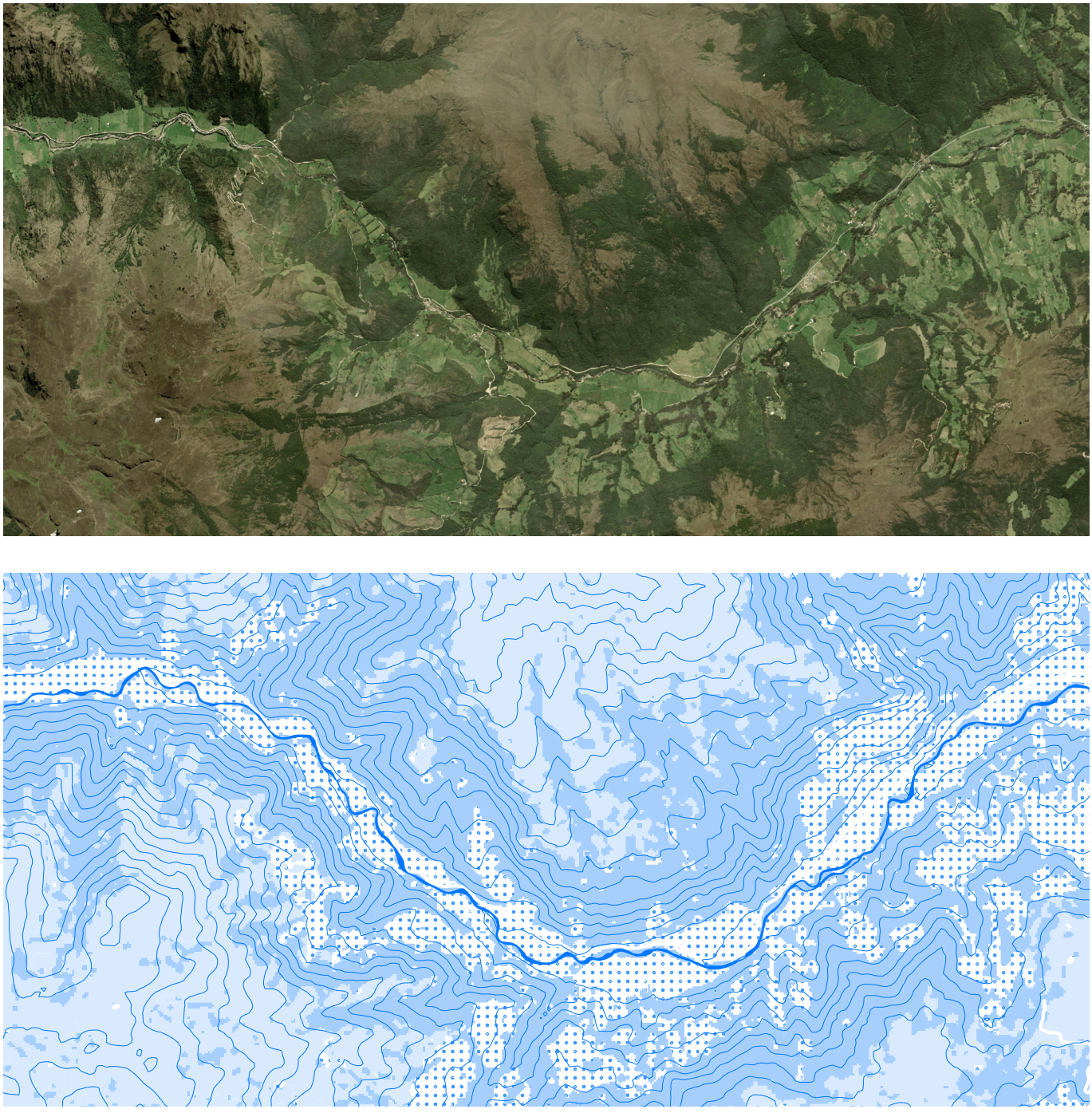
↑ Water abstraction under different flow scenarios

It can be argued that the conflict over competition for water use between human consumption and the maintenance of ecological flow stems from two main factors. The first of these is a behavioural factor, relating to the water consumption habits of Cuenca's urban residents. Records from the municipal water company have determined that the average daily per capita water consumption in Cuenca is around 200 litres per day (Herrera-Andrade, 2025).

To put this figure into perspective, it needs to be viewed in context: the average daily water consumption per person in the Netherlands in 2021 was 129 litres (Central Bureau of Statistics, 2023), considerably lower than that in Cuenca but still above the 100 litres per day set by the World Health Organisation as the maximum recommended limit, which is doubled by the inhabitants of Cuenca. The high figures for drinking water consumption in Cuenca stem from inefficient consumption habits arising from a mistaken perception of the abundance of this resource, sustained by the presence of the region's numerous rivers and the four rivers that flow through the city, which has reinforced the idea of unlimited availability (Herrera-Andrade, 2025). With such high levels of consumption, the constant abstraction of large volumes of water from the rivers remains a necessity even during periods of drought.

Furthermore, the rivers in the Cuenca basin have seen an average decline in their flow rates throughout the modern history of the basin due to changes in land use in the upper catchments and water recharge areas, which consist of páramo and sub-páramo ecosystems. Studies show that the replacement of páramo highlands and sub-páramo rainforests by activities such as agriculture or livestock farming results in a decrease in the soil's water retention capacity (Célleri & Feyen, 2009), which ultimately leads to a reduction in the rivers' ability to maintain their flow between rainfall events in their upper catchments. Given their immediate position between the inter-Andean valleys and the cold high-Andean páramos, the sub-páramo rainforests are the water-critical ecosystem that has suffered most from the advance of the agricultural frontier over recent decades. The morphology of the high valleys through which the rivers flow has caused the agricultural and livestock area to expand mainly along the riverbanks and then climb up the hillsides, clearing large swathes of forest in its path to make way for grazing and crops.

The conversion of sub-páramo rainforests into productive landscapes not only leads to a reduction in the water-regulating capacity of the soil due to compaction and the removal of vegetation cover that retains moisture: it also causes soil and water pollution through nutrient runoff, as well as an increased risk of erosion and landslides on the steep slopes of the valleys, as these are left without the root structure that keeps the soil consolidated. Furthermore, the fact that the soils no longer have the same capacity to infiltrate and retain rainfall means that during heavy downpours, the water will not only fail to keep the soil moist but will also flow all at once into the river, increasing the risk of flooding downstream.

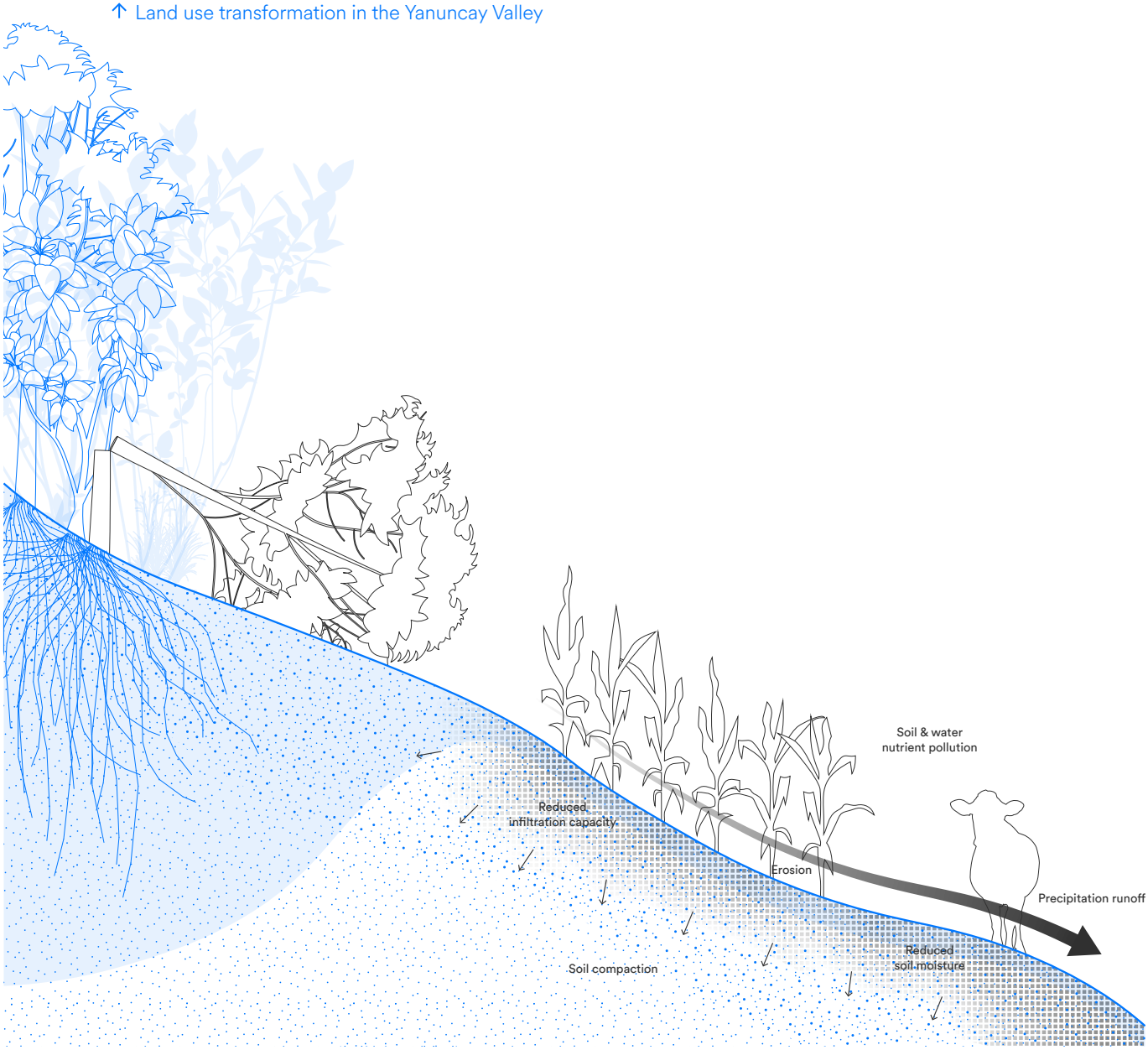


↑ Agricultural and livestock footprint along the Yanuncay River, in the Barabón Valley





↑ Land use transformation in the Yanuncay Valley



↑ Effects of clearing sub-páramo rainforests to create agricultural plots and grazing areas

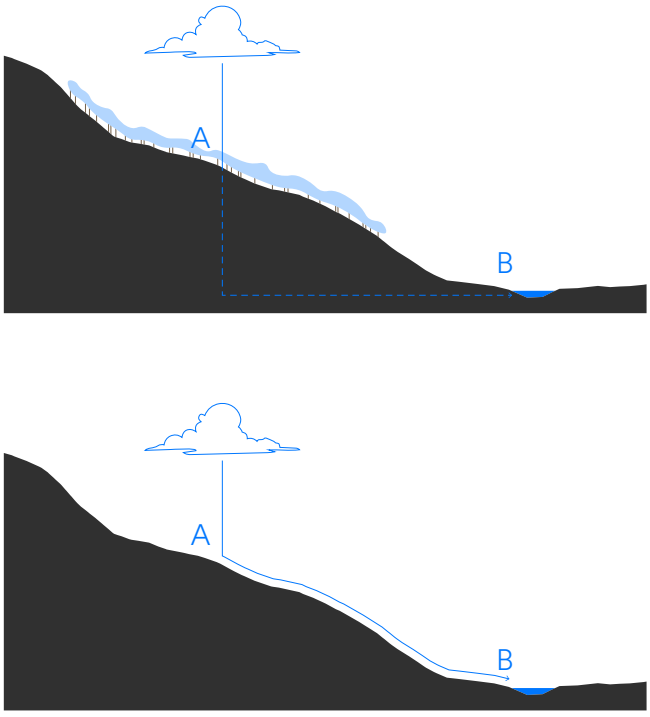


↑ March 12 2026: the Yanuncay River's flow exceeded 100 m³/s after a prolonged period of rain
Source: El Nuevo Tiempo Cuenca

As explained in a previous section, there is a direct link between the behaviour of rivers originating in this region and land use in the uplands. More specifically, their behaviour depends on the water-retention capacity of the páramo and subpáramo soils; a function that is altered by agricultural and livestock farming practices.

Identifying the effects of this land-use transformation is becoming the foundation for developing a landscape strategy to rebalance the current model of agricultural and livestock production. Whilst all agricultural and livestock activities involve a certain degree of alteration to the environment in which they take place, the implementation of specific landscape-based strategies can help to find a balance where production does not come at the expense of rivers' water regulation capacity.

In this regard, the main issue to be addressed is the reduction in the soil's water infiltration and retention capacity resulting from the felling of sub-páramo rainforests and their subsequent conversion into agricultural and grazing land. As a result of this action, rainfall that under original conditions would have infiltrated the upper part of the slope thanks to the rainforest – and would possibly have taken weeks to flow underground before reaching the river – is now drained away immediately. In other words, instead of taking a few weeks to travel from A to B, it now takes a fraction of the time.



↑ Infiltration scenarios with and without vegetation cover

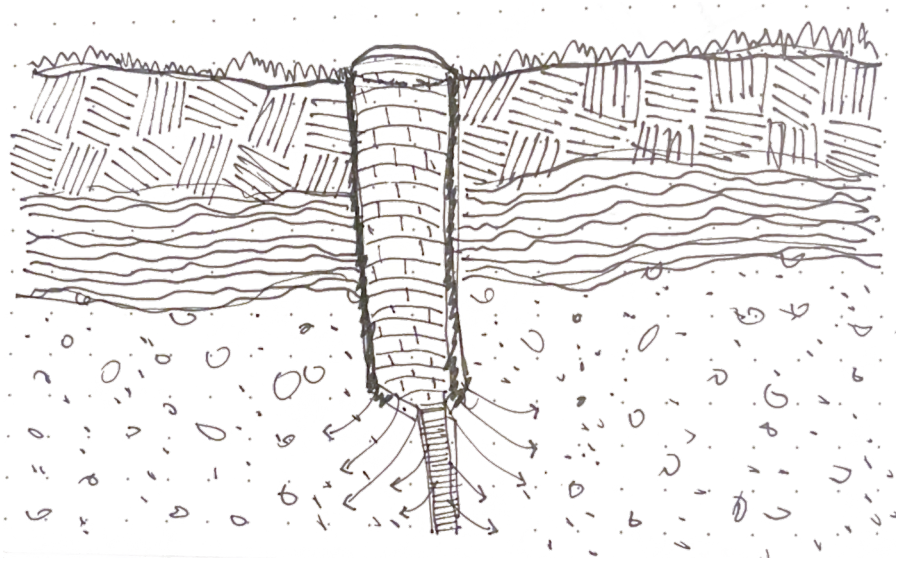
In restoring this vital soil function in agricultural production areas, the complex Andean topography could become one of our main allies. The backbone of the strategy is based on the need to slow down the flow of water from point A to point B. To this end, the creation of a network of contour channels is proposed, through which a variable volume of river water can be abstracted depending on the season and the river's flow, and channelled parallel to the river, but gaining elevation above it thanks to a route with a minimal gradient. Once the channels have gained a certain height above the river, a series of wells are responsible for storing and/or infiltrating the water into the ground along the slope.

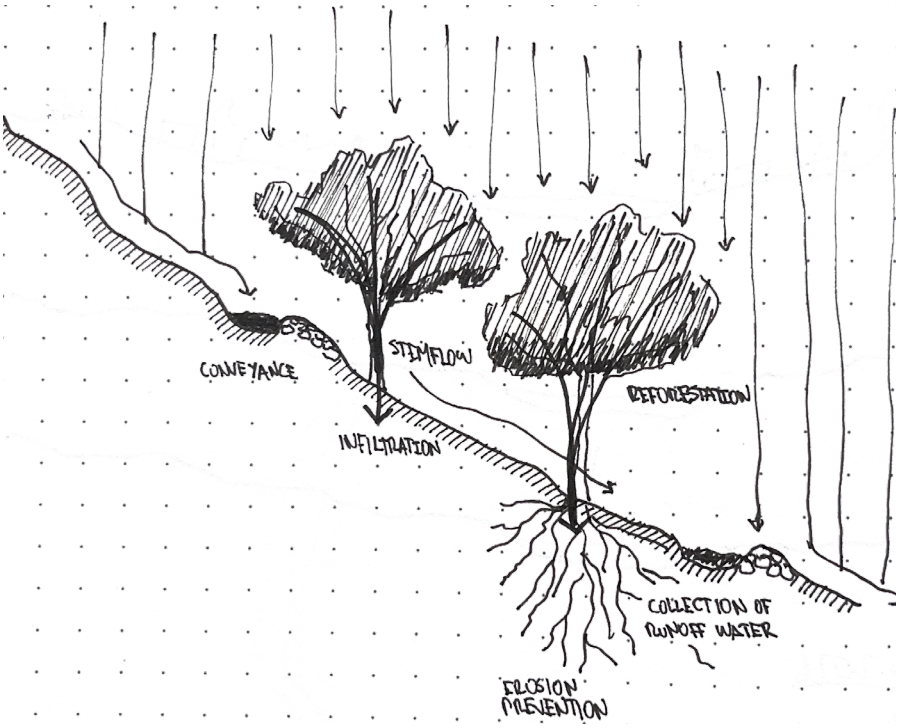
Eventually, the water will reach the water table and, due to the force of gravity, will flow downhill until it reaches the watercourse from which it was originally abstracted. In other words, it will reach point B, but after a longer period of time than if it had flowed over the surface. The volume of water entering the network can be regulated by a system of sluice gates, making this a highly versatile system whose operating intensity can be adjusted according to weather conditions, soil saturation and river flow. Depending on weather conditions, the system can help reduce the amount of rainwater flowing through areas where, due to changes in land use, it can no longer infiltrate. The parallel arrangement of the channels allows rainwater falling on a specific strip of slope to be collected and channelled to a well for infiltration or storage, thereby preventing large volumes of runoff from joining the river flow directly, which would cause a sudden increase in its flow rate and, with it, the risk of flooding downstream.





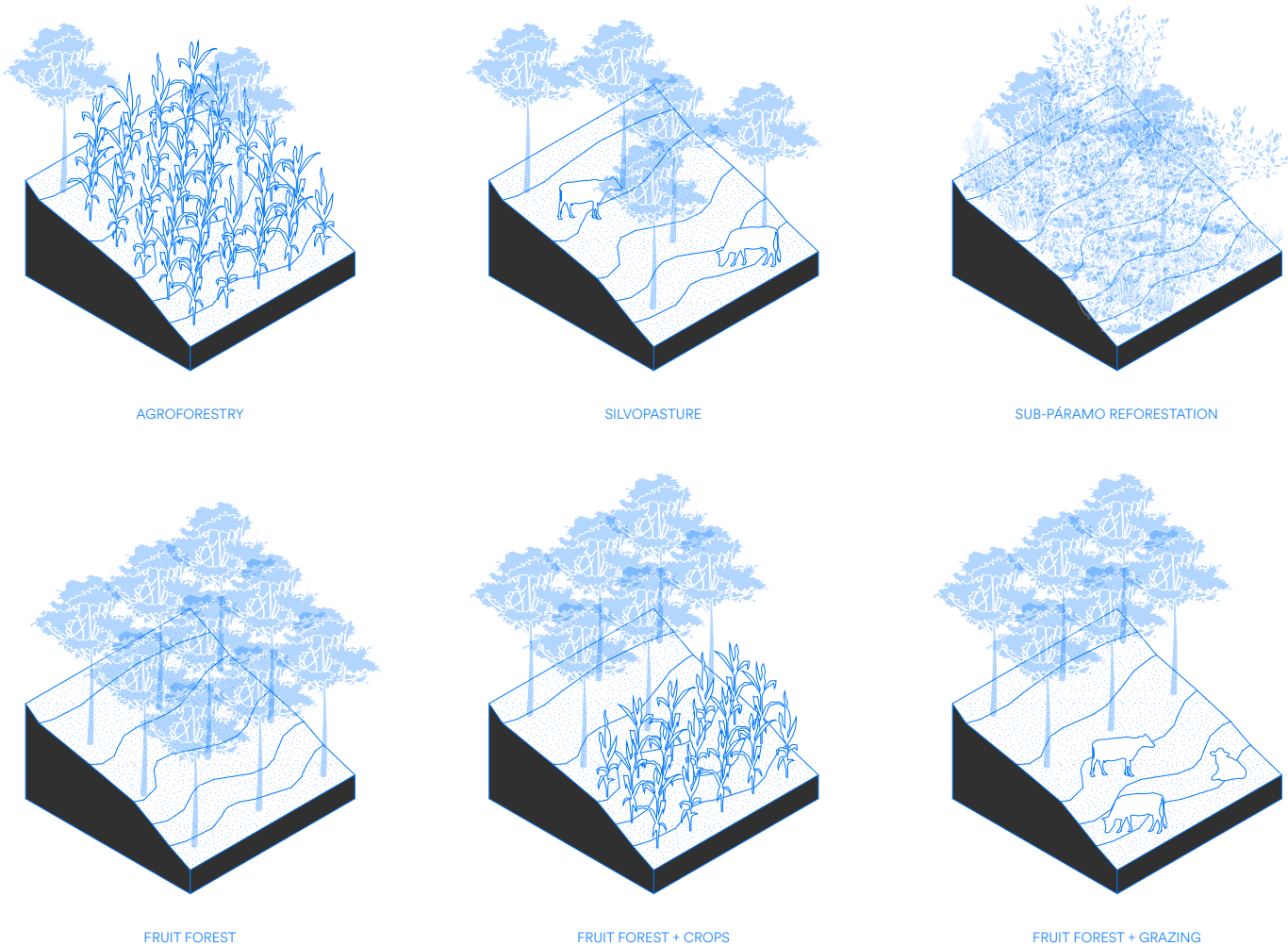




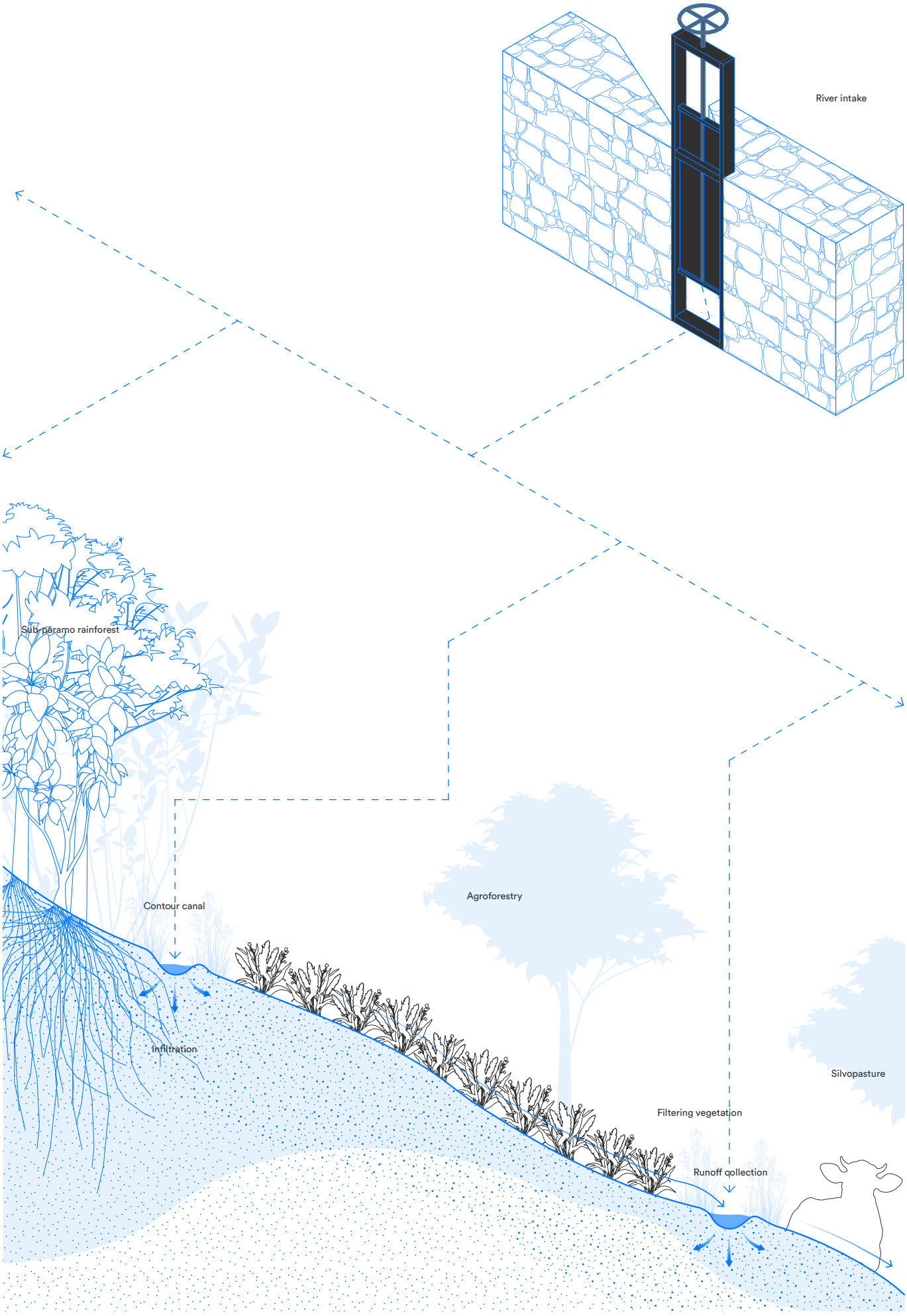


↑ Concept sketches: Water seeding system

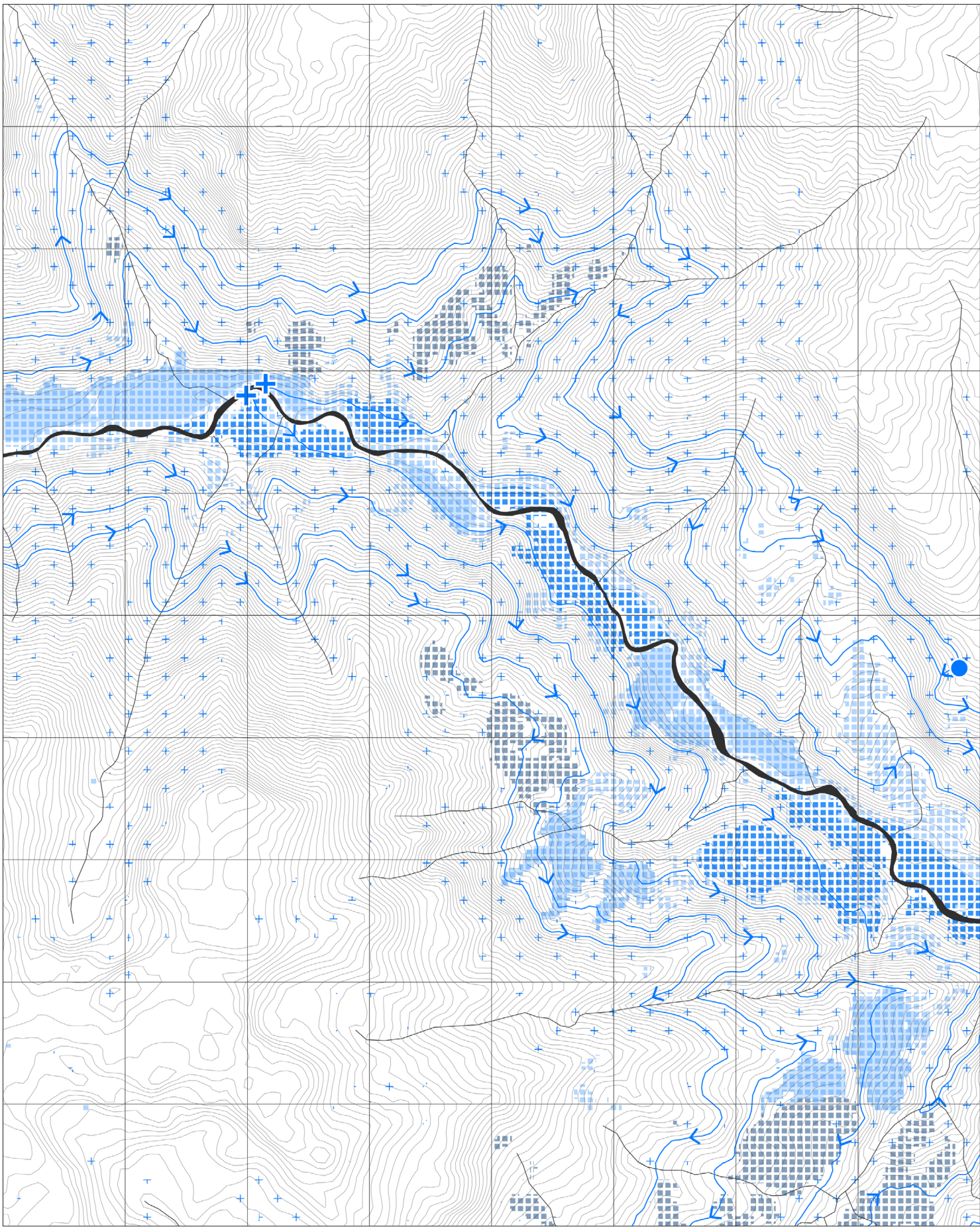
In conjunction with this strategy, adaptation measures are being implemented in the agricultural and livestock areas on the slopes and riverbanks to ensure their integration and functioning as part of the system. To this end, various land-use types based on combinations of agricultural uses and ecological functions are being designed. The principles of silvopasture and agroforestry are implemented to achieve a partial recovery of vegetation cover on the slopes and, consequently, a reduction in erosion risks. In specific areas, the species planted are the same as those found in sub-páramo forests, whilst in others, their role is geared towards replacing the agricultural production that must be relinquished due to the demand for space generated by the strategy; consequently, fruit tree species compatible with the environment are planted, with the produce going to the farmers.



↑ Spatial typologies combining reforestation of native species, agroforestry, silvopasture, and fruit production



↑ Water seeding system in combined agricultural, livestock and forestry lands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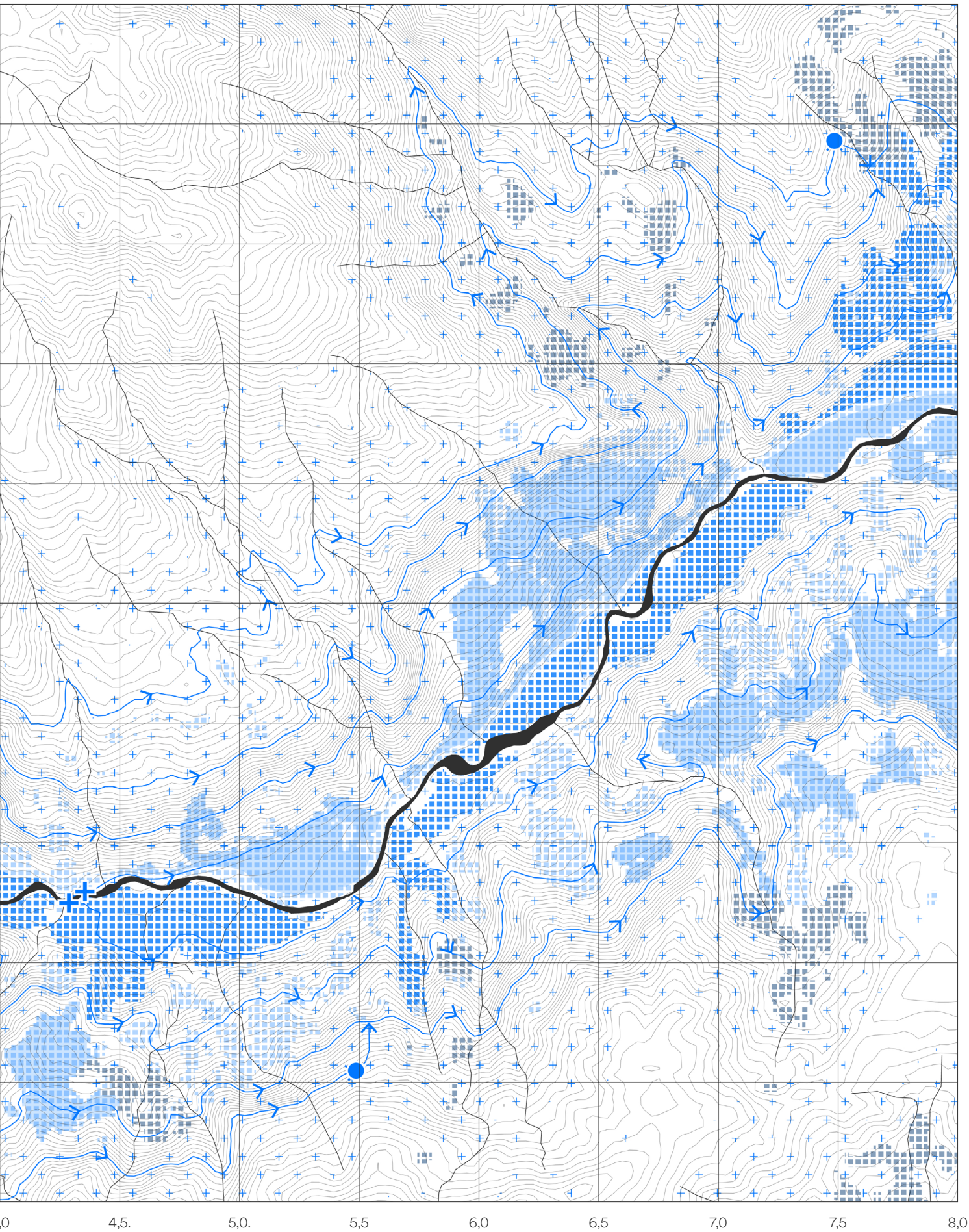
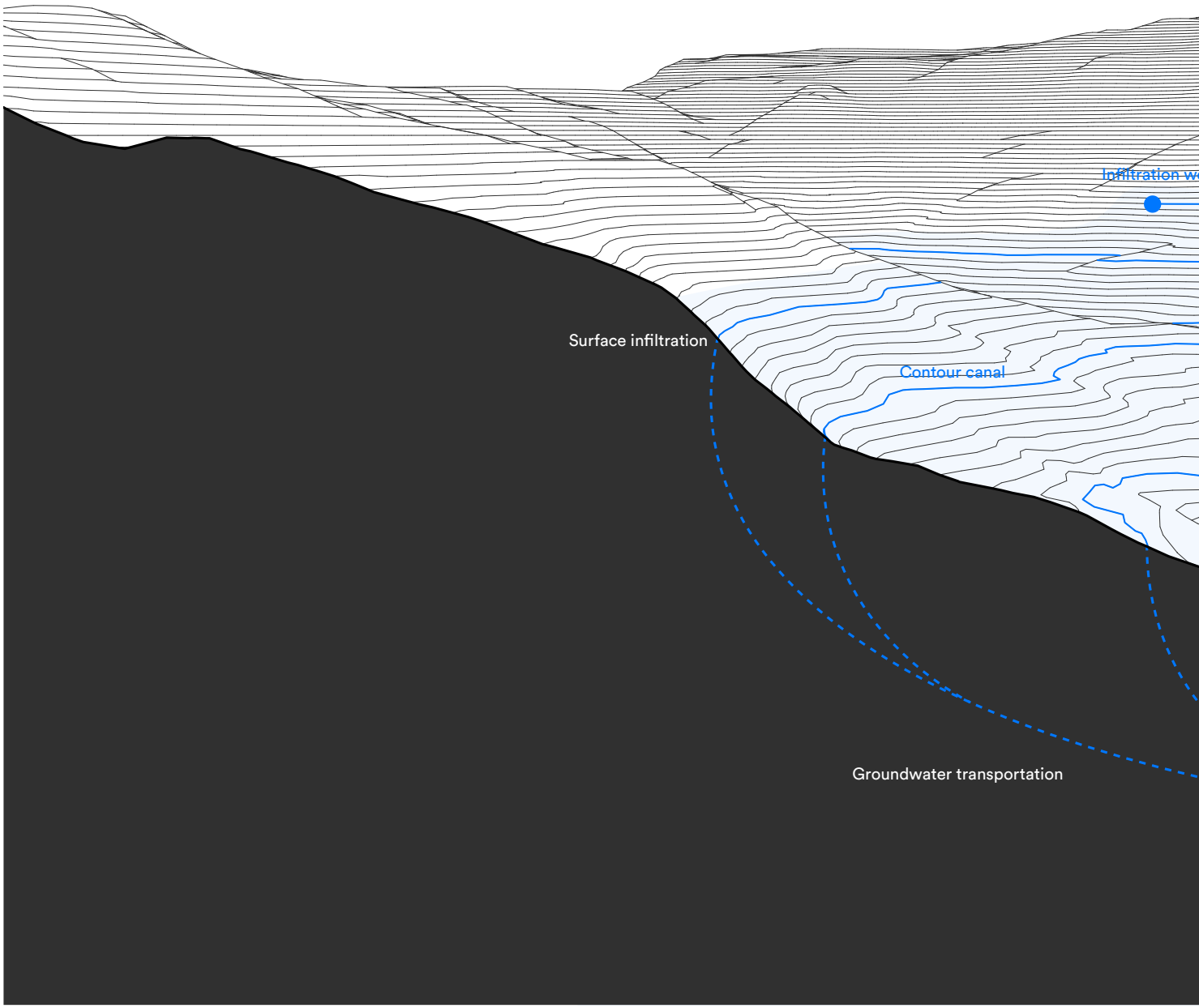
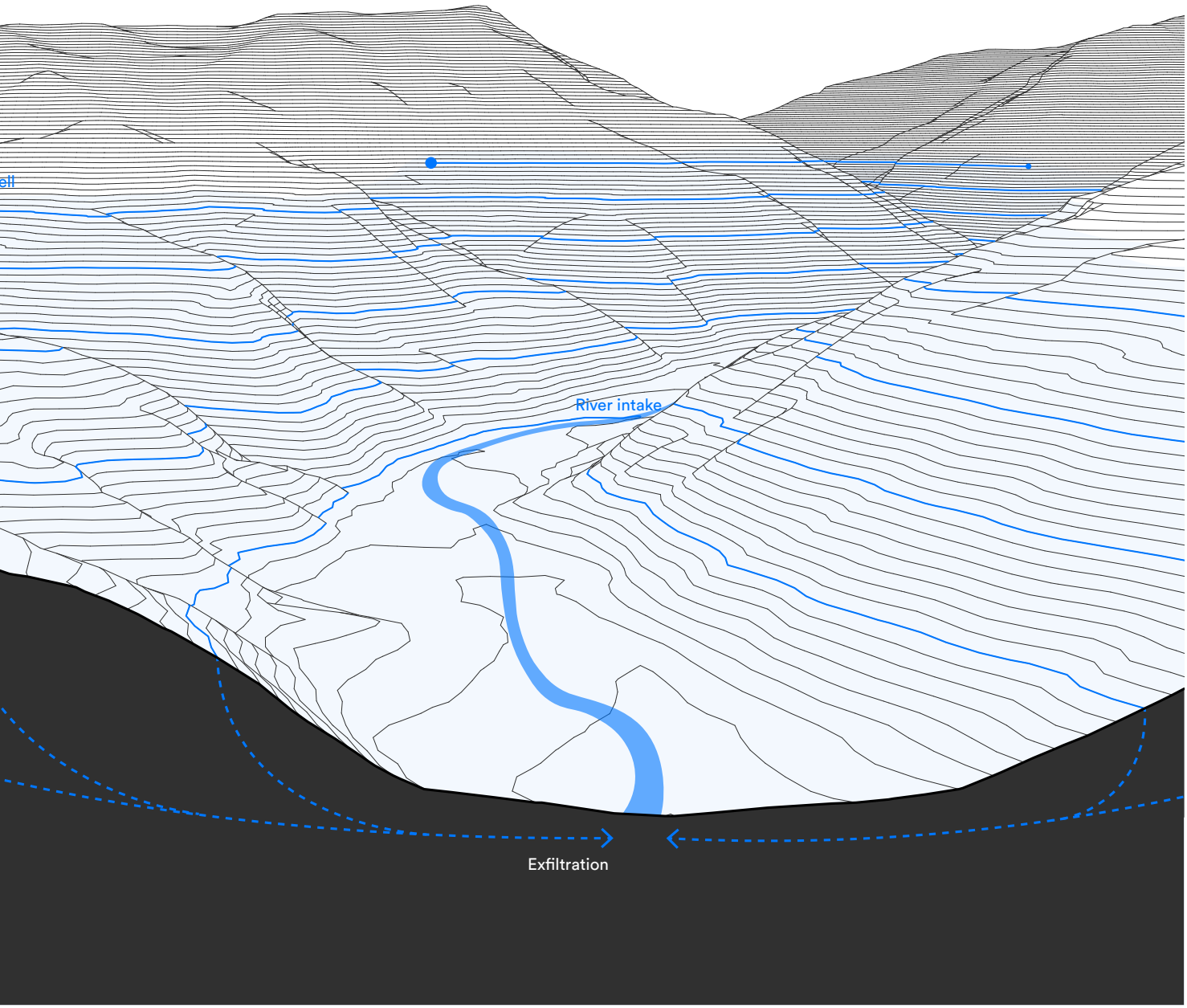
Páramo highland
Sub-páramo rainforest
Reforestation
Agroforestry
Fruit forest
Silvopasture



↑ Water seeding system and land use diversification in the Yanuncay Valley


Surface infiltration
Contour canal
Groundwater transportation



↑ Water seeding system detail





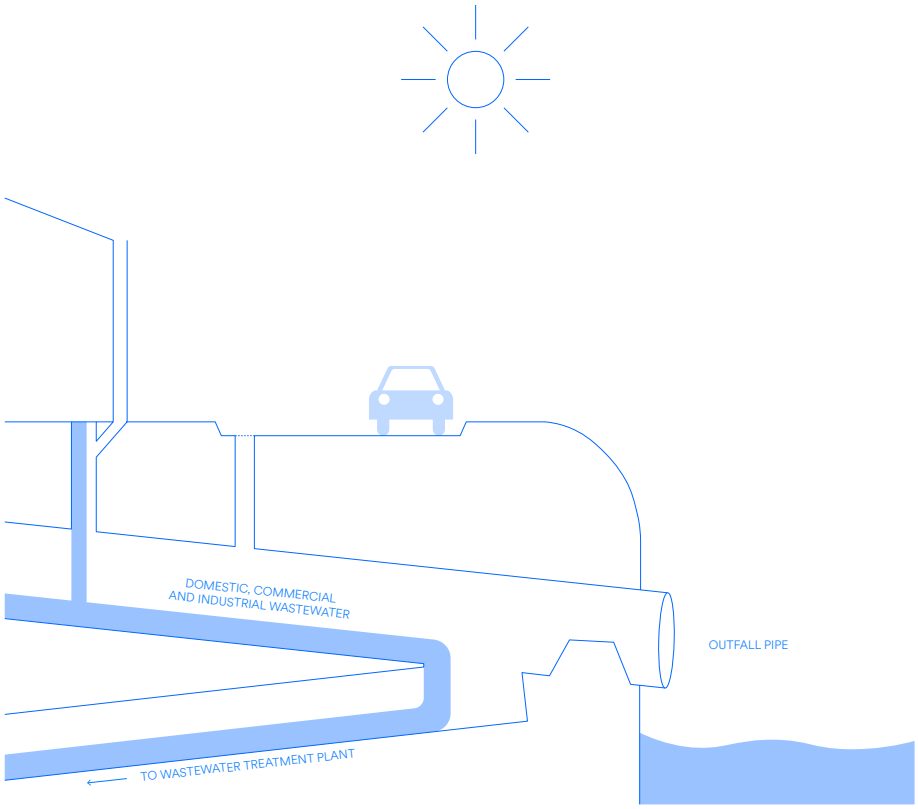
↑ Impression of land use diversification and water seeding system in the upper reaches of the Yanuncay River

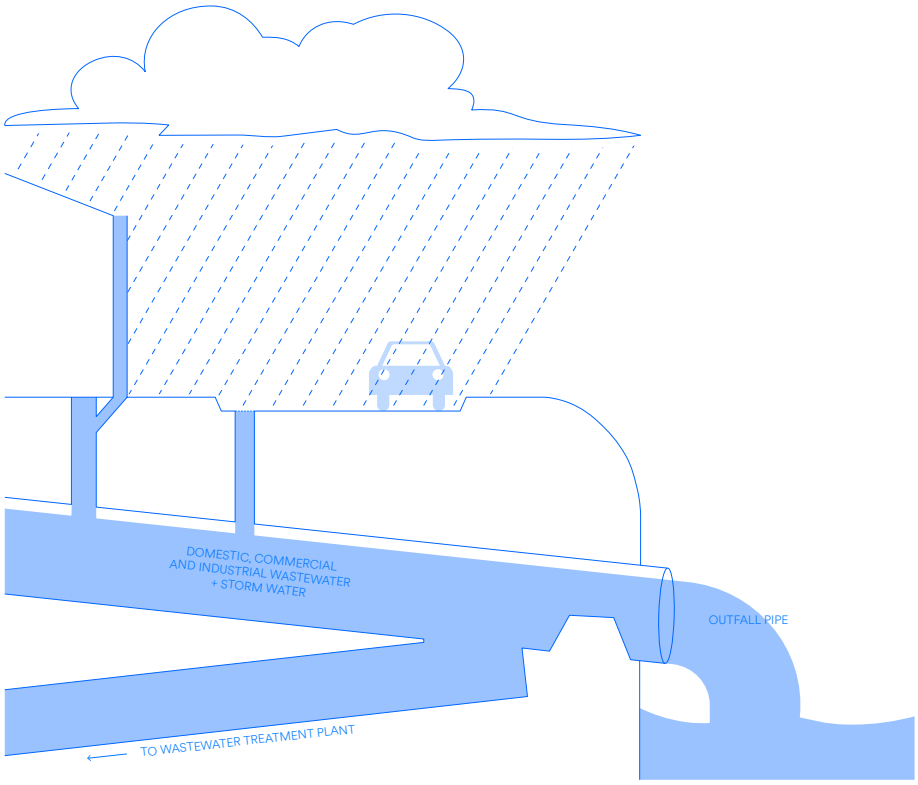
5.5 Riverscapes as runoff buffers

The concentration of large numbers of people in confined spaces, as found in cities, means that major infrastructure must be developed to meet basic urban needs and functions such as housing, transport and services, the construction of which results in the sealing of large areas of soil. From a soil and water perspective, cities are among the main disruptors of the water cycle, acting as places where, in addition to water becoming contaminated, it is unable to infiltrate the soil and recharge underground aquifers. Estimates show that infiltration rates drop about 70 to 99 per cent in built environments comapred to natural environments (Gregory et al., 2006). As for the water that does not infiltrate, there has historically been a view in modern cities that it is an undesirable element that must be disposed of as quickly as possible to avoid nuisances such as water accumulation and flood risk.

From the conventional perspective of urban water management, this challenge has been addressed through the development of combined sewer systems, which have been widely adopted by the vast majority of cities around the world. The model takes its name from the fact that rainwater is collected and fed into a single sewer system through which the city's wastewater is also transported. However, as the system has a limited capacity, its proper functioning depends on the use of urban water bodies as relief valves, which, via overflow outlets from the sewerage network, receive the excess contaminated water that the system is unable to manage during episodes of extreme rainfall. During these events, levels of pollution in urban water bodies that receive the excess residual water can drastically increase in a matter of just a few minutes.

In addition to compromising the water quality of urban water bodies during extreme weather events, the operation of combined sewer systems represents an increased volume of water that must be treated at wastewater treatment plants, thereby reducing the lifespan of the treatment infrastructure and increasing operating costs. Furthermore, this model results in the wastage of large volumes of rainwater, which is lost when it is mixed with sewage in the sewers. In contexts such as that of Cuenca, which has suffered droughts lasting several months in recent years, rainwater harvesting has great potential to alleviate demand for certain uses during these periods, thereby reducing water abstraction from rivers.





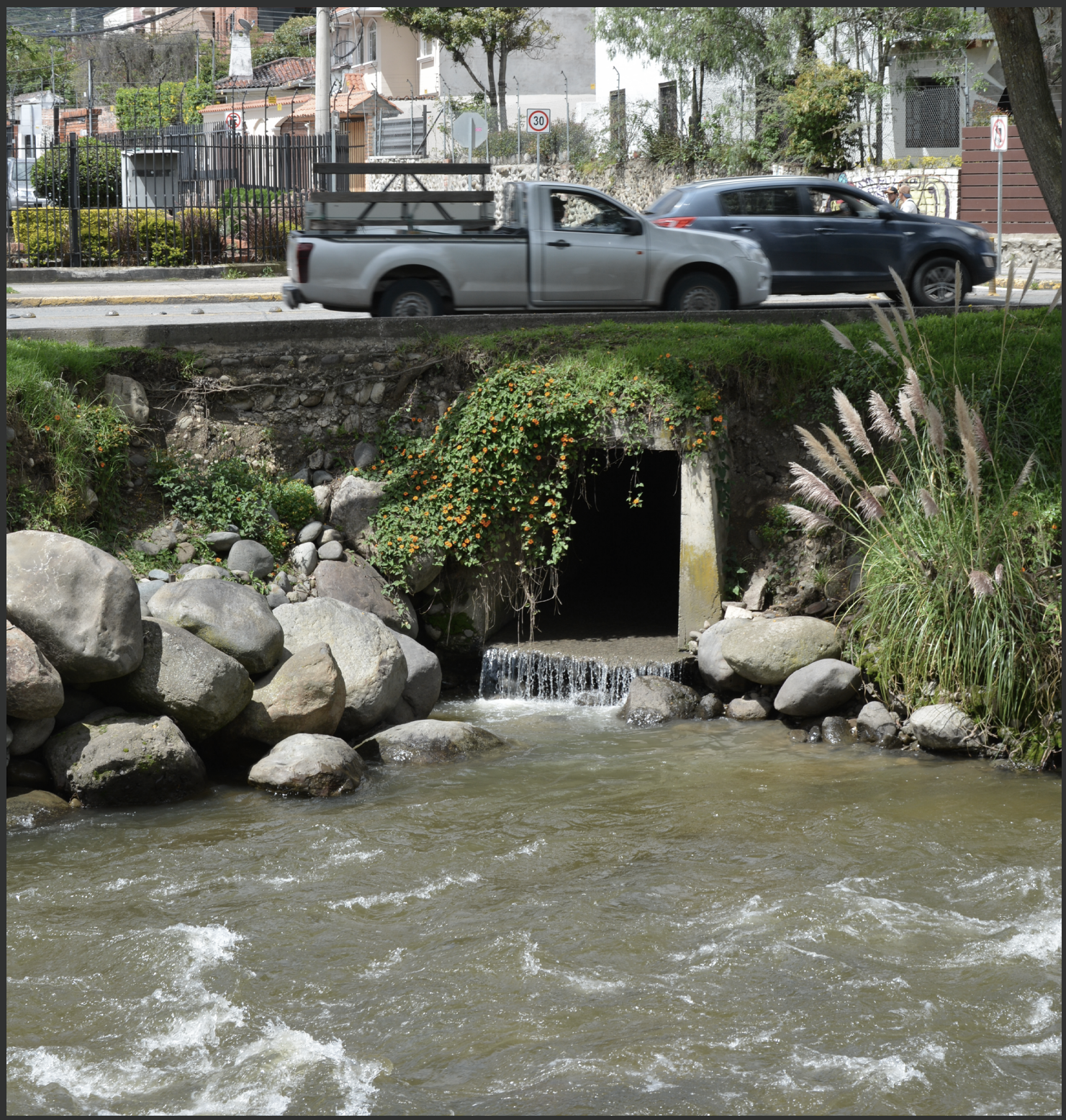
↑ Combined sewer system operation
Source: Adapted from Environmental Protection Agency













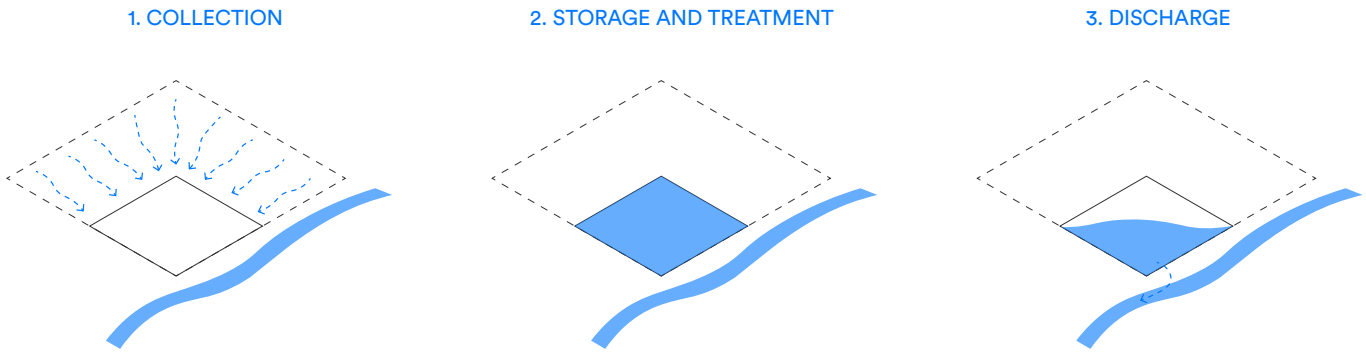
↑ Overflow outlets along the rivers of Cuenca

Extreme weather events, which are occurring with greater frequency and intensity, are increasingly highlighting the costs associated with the 'normal' operation of such systems, as well as the need to incorporate models that take into account river water quality and the overall restoration of the water cycle.

One way to approach urban wastewater management based on restoring the hydrological cycle and river water quality begins with dividing the urban sewerage system into two subsystems, through which wastewater and rainwater are transported and treated separately. Having a network dedicated solely to the conveyance of wastewater means that the volume of water transported within it can be easily estimated, and completely eliminates the risks of overflow and the climatic volatility that characterises combined sewer systems.

However, whilst the separation of systems is likely the first and most important step in tackling pollution in urban water bodies, this measure alone does not solve the problem. Studies by Cojoc et al. (2024) show that urban runoff usually contain a wide variety of pollutants such as heavy metals, oils, microplastics and organic compounds that mix with the water after it flows through infrastructure and surfaces such as highways, green spaces or industrial areas. Caring for urban water bodies involves addressing the presence of these seemingly invisible pollutants in the water before returning it to the hydrological cycle. This approach has the potential to deliver multiple benefits.

To address this challenge, the strategy involves dividing the city into urban micro-basins: areas of the city defined by the topography and the urban fabric, each with a closed sewerage network. All rainwater falling on these defined areas that does not infiltrate is channelled to a multi-purpose area that floods only during episodes of extreme rainfall, where it can be stored and purified. This infrastructure is always located at the lowest point of the micro-basin and alongside rivers, thereby facilitating the flow of water and its discharge following treatment.



URBAN FABRIC



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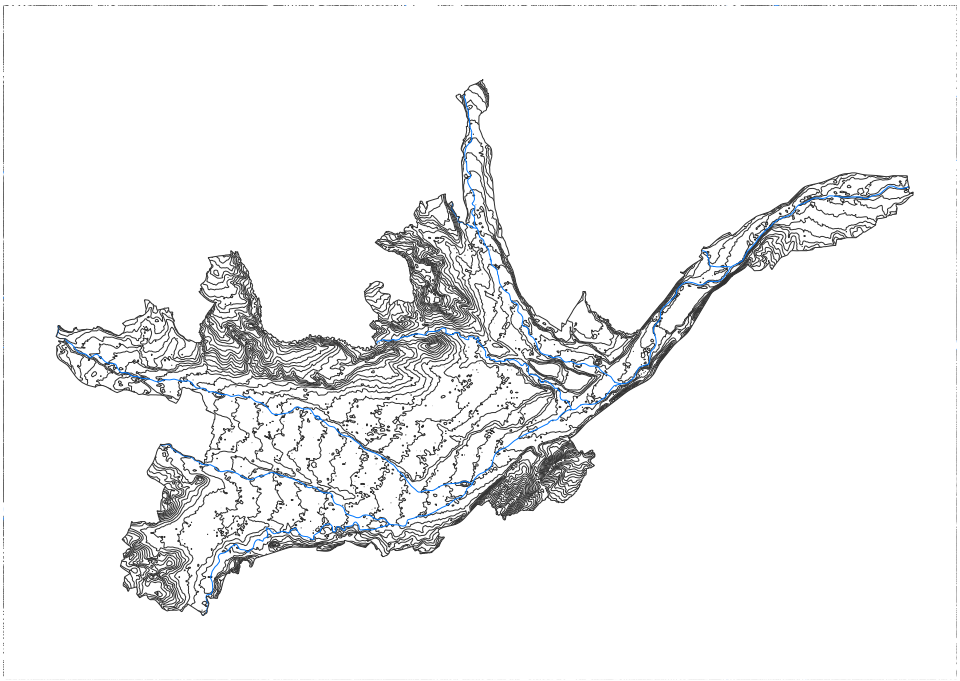
TERRAIN TOPOGRAPHY



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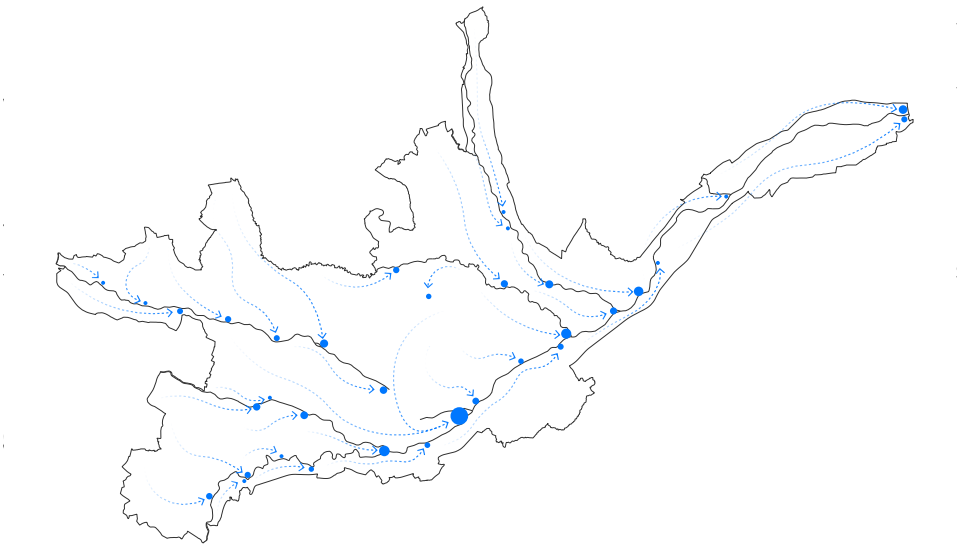
URBAN MICRO-BASINS



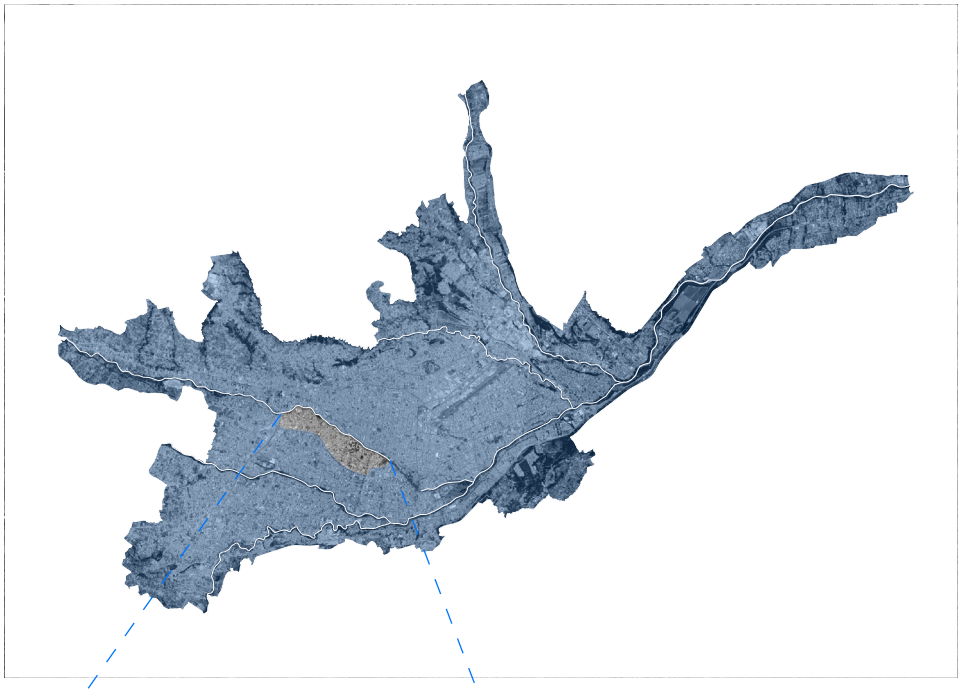
The site chosen to tackle this challenge is a central area of the city, comprising two zones with very different urban fabrics. On the east side lies the El Ejido neighborhood, an outcome of the 1949 urban expansion masterplan, which introduced a completely new urban fabric model, based on the then-popular and ground breaking principles of the Garden City. The avenues and streets are wide, lined with flower beds and trees, and there are many villa-style buildings, set back from the road on their own plots and surrounded by extensive green spaces.

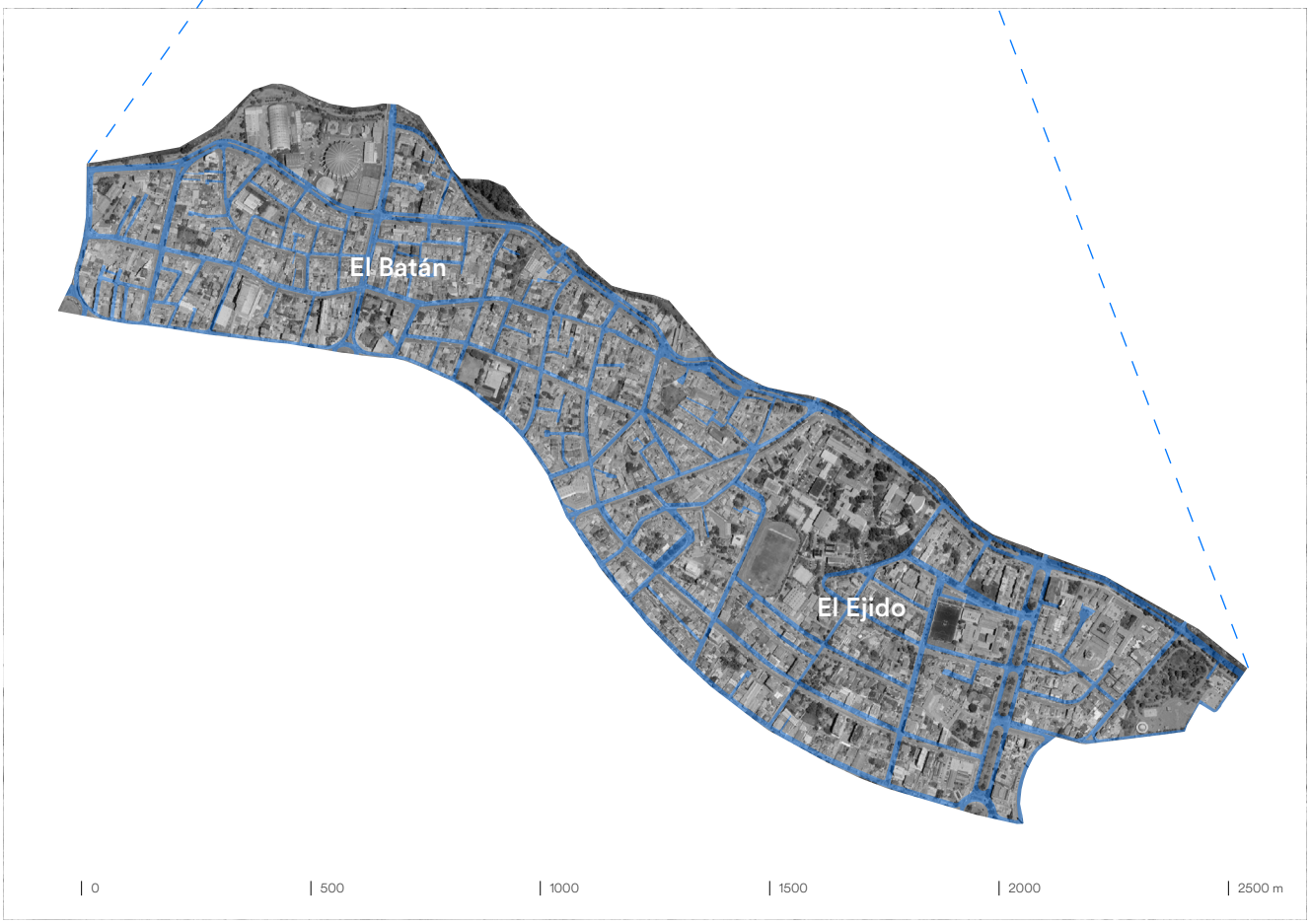
On the west side lies El Batán: a more recently developed area which was not included back then as a part of this masterplan, and which therefore features a less structured urban fabric. Its tracing responds to a more spontaneous planning of the city that came on the later stages of the 20th century, which makes the urban fabric here more organic.

Each urban fabric offers opportunities to manage stormwater runoff in ways that integrate water into the urban landscape as it is transported, purified, infiltrated or stored. The design concepts are based on the premise that a dual sewerage system is constructed, channelling only sewage to the treatment plant. At this point, stormwater no longer disappears into the combined sewer system, but must now be managed through various surface-level measures.

The integration of street-level strategies forms the basis of a neighbourhood-level strategy: the creation of urban micro-watersheds. The aim is to divide the city into defined urban runoff zones, each connected to a river. Interventions at street level function as the components of a superstructure that ensures collected rainwater is transported (via sites where it can infiltrate and be purified through the use of vegetation) to a location near the riverbank where it can be stored, purified and returned. This, in turn, creates new opportunities for urban development.

To estimate the capacity of the runoff storage area, an extreme rainfall scenario is used as a reference figure: 50 mm/h. The total areas of the micro-basin's surfaces are calculated, multiplied by their runoff coefficient and by the amount of rainfall per hour, resulting in the volume of water that will flow from each surface during a rainfall event of that magnitude. Finally, the values for each type of surface are added together, yielding the total runoff volume.




El Batán
El Ejido
0
500
1000
1500
2000
2500 m


ORGANIC URBAN FABRIC
Tomebamba River
GARDEN CITY URBAN FABRIC



Stormwater by surface type

Streets and sidewalks

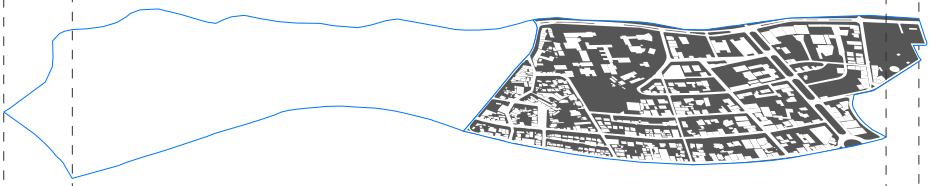
A=342,500 m² x C=0,95 x P=50 mm/h = V=16,269 m³



+

Roofs

A=397,000 m² x C=1,0 x P=50 mm/h = V=19,850 m³



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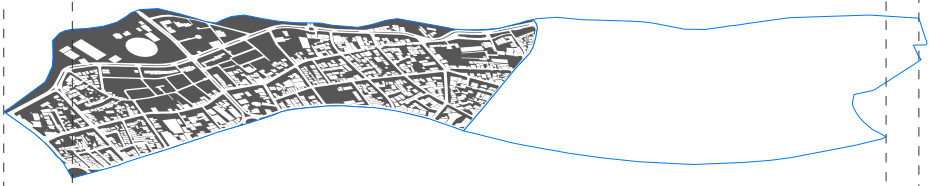
Garden City urban fabric (private space)

A_p=113,900 m² x C=0,95
A_g=211,600 m² x C=0,35 x P=50 mm/h = V=9,113 m³



+

Organic urban fabric (private space)

A_p=203,500 m² x C=0,95
A_g=109,500 m² x C=0,35 x P=50 mm/h = V=11,582 m³

=

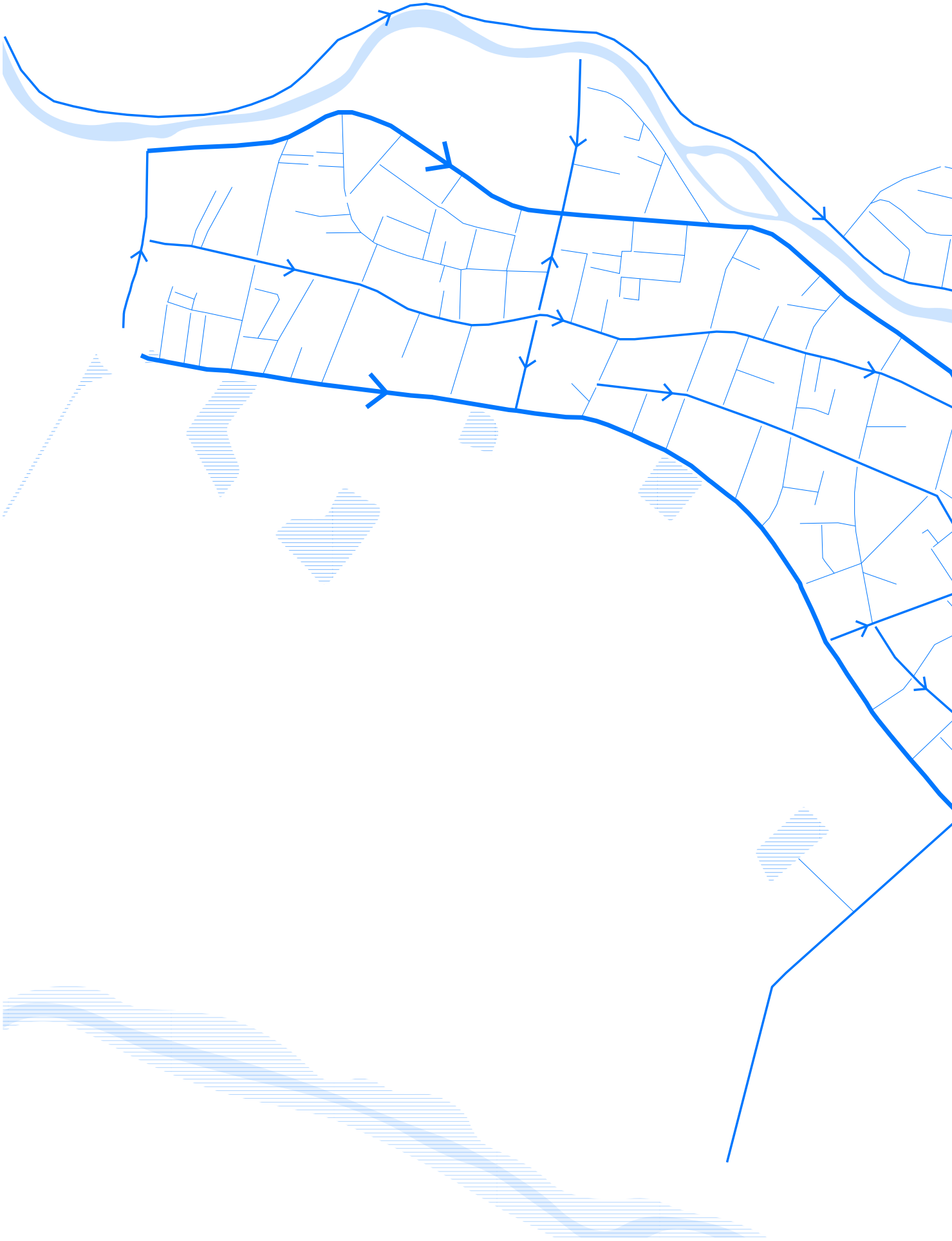


Micro-basin

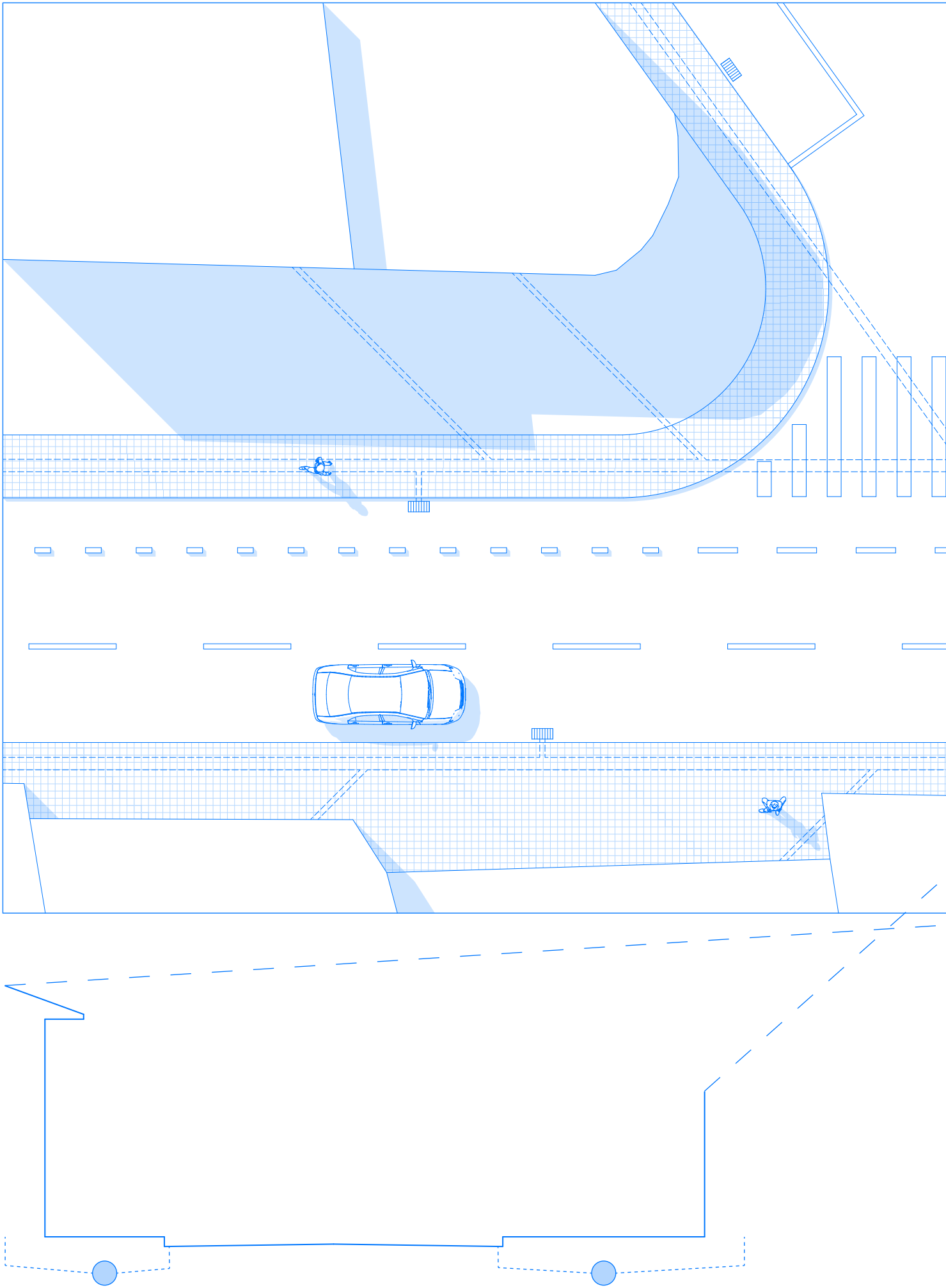
A=1,378,000 m²

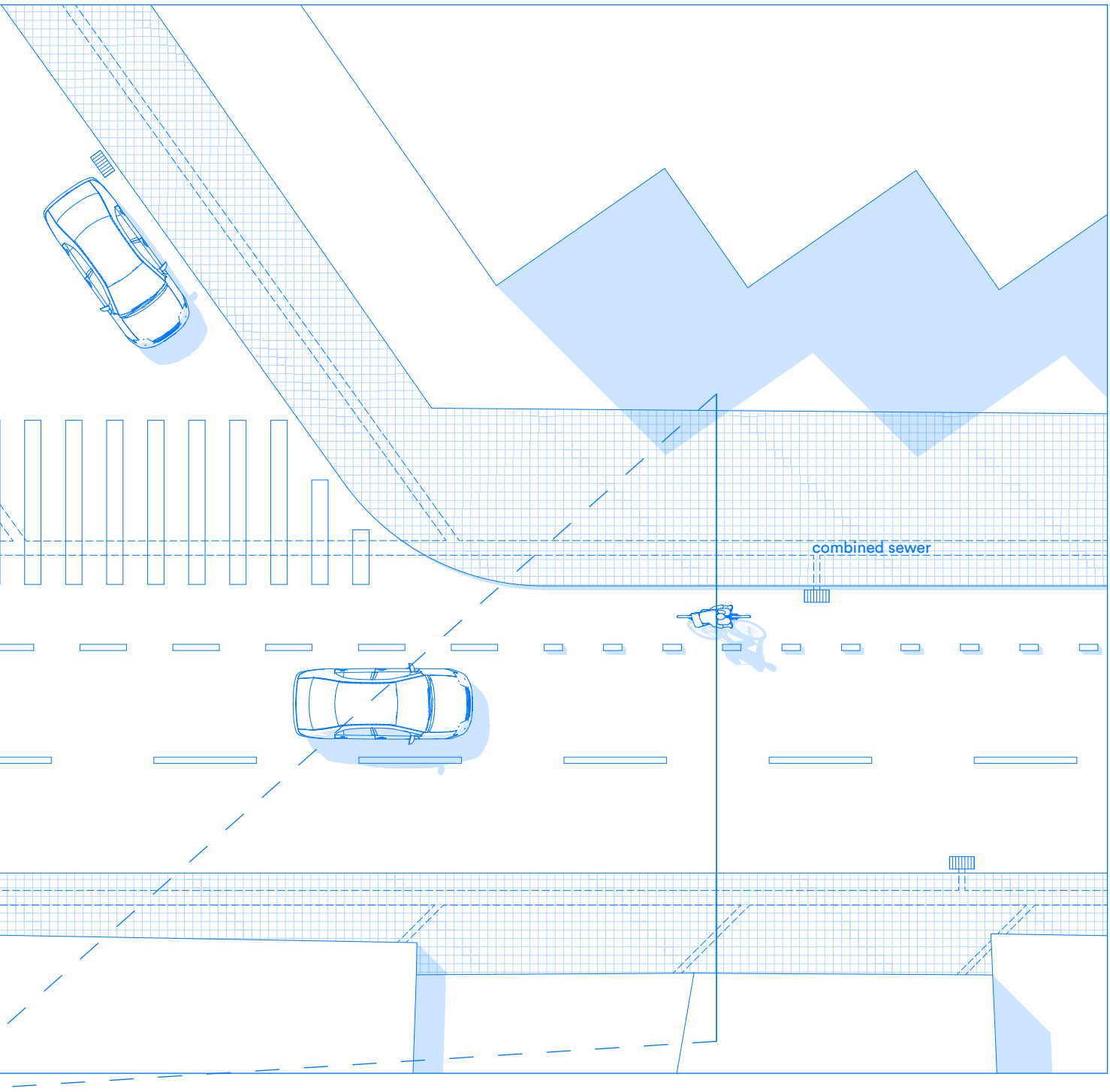
Total volume	V_t=56,814 m³
÷	
Storage area	A_s=16,300 m²
=	
Depth	d=3,49 m

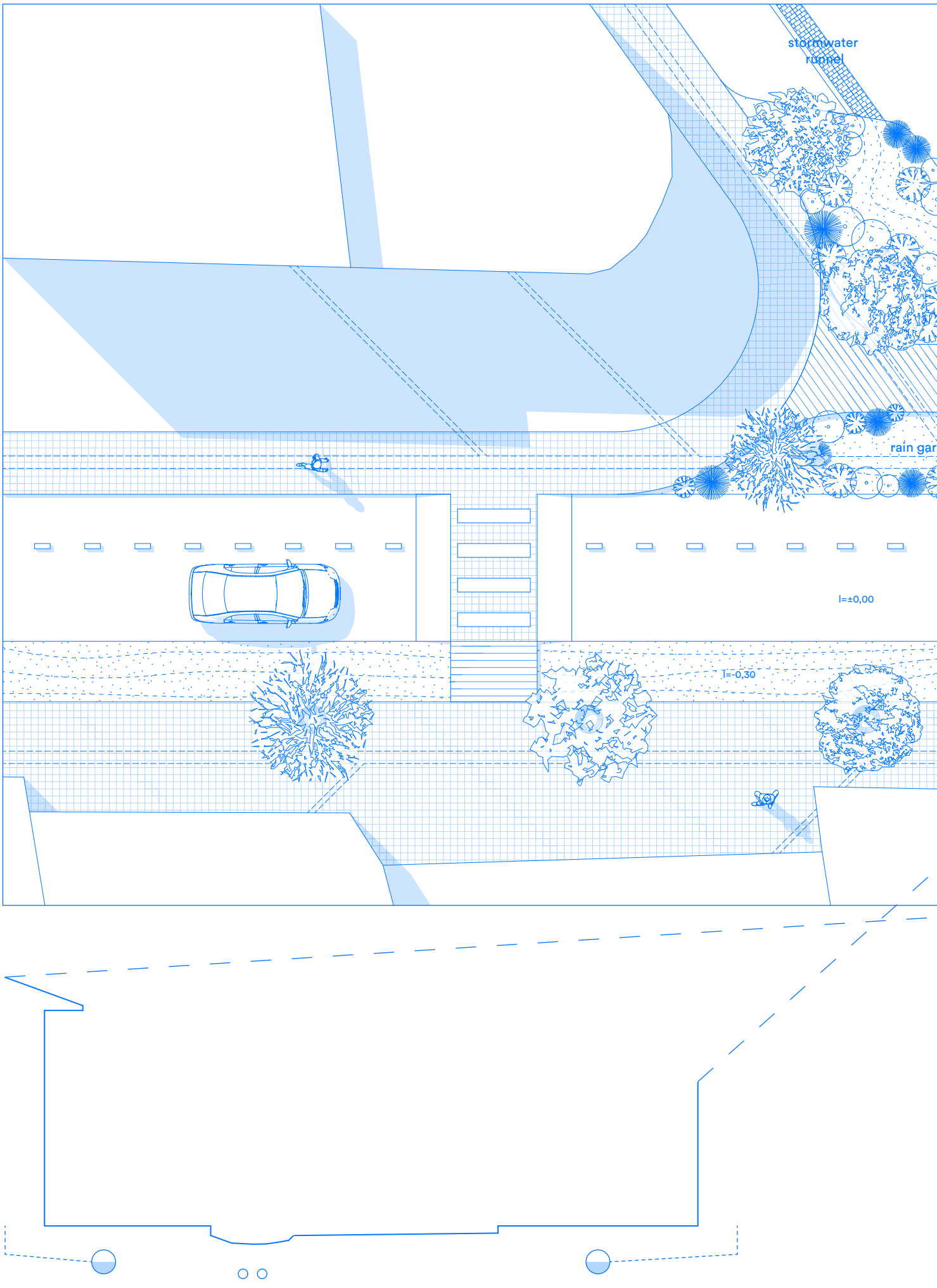
A_g = Green area
A_p = Paved area

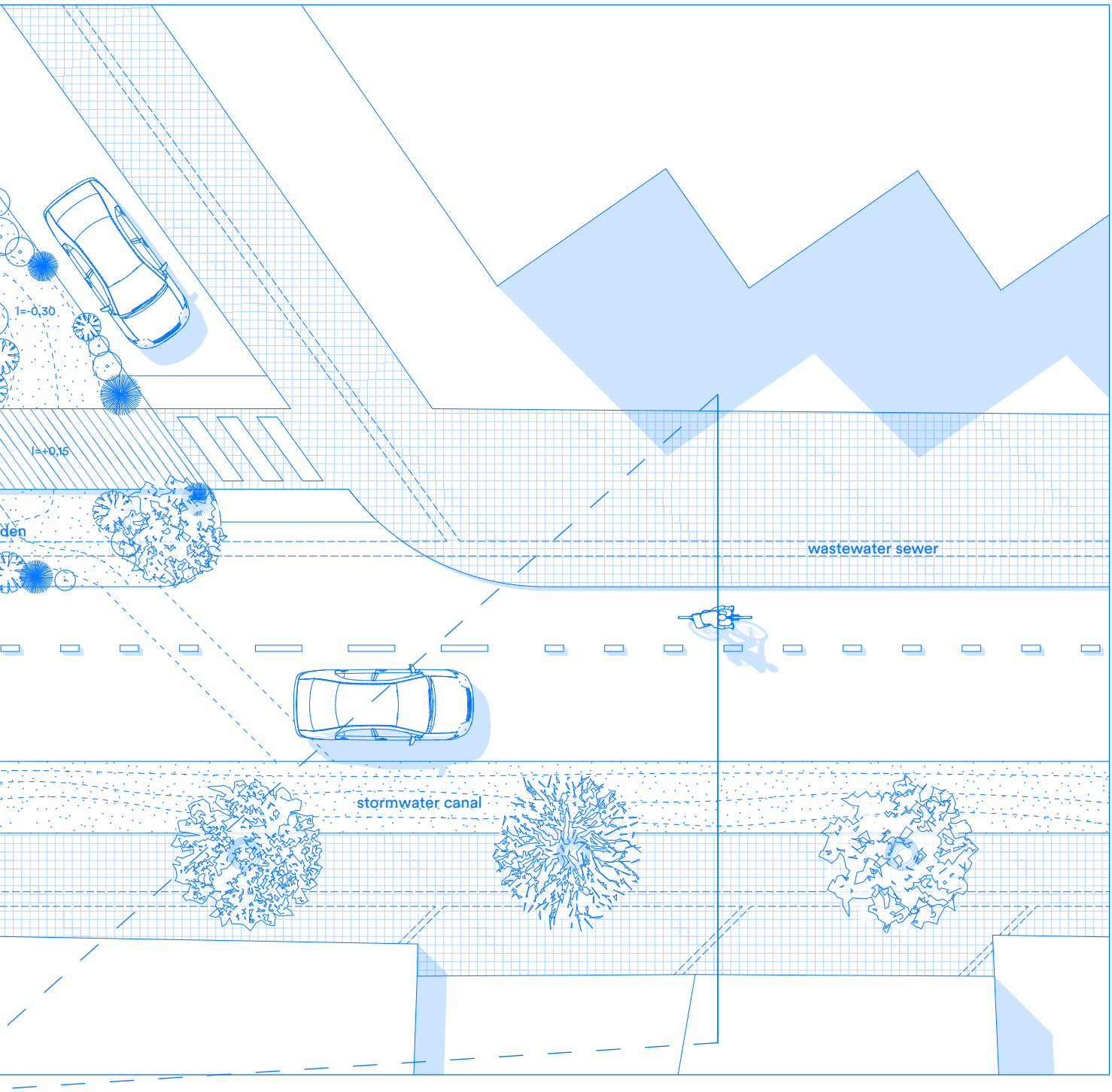







combined sewer


stormwater
runnel
rain gar
l=±0,00
l=-0,30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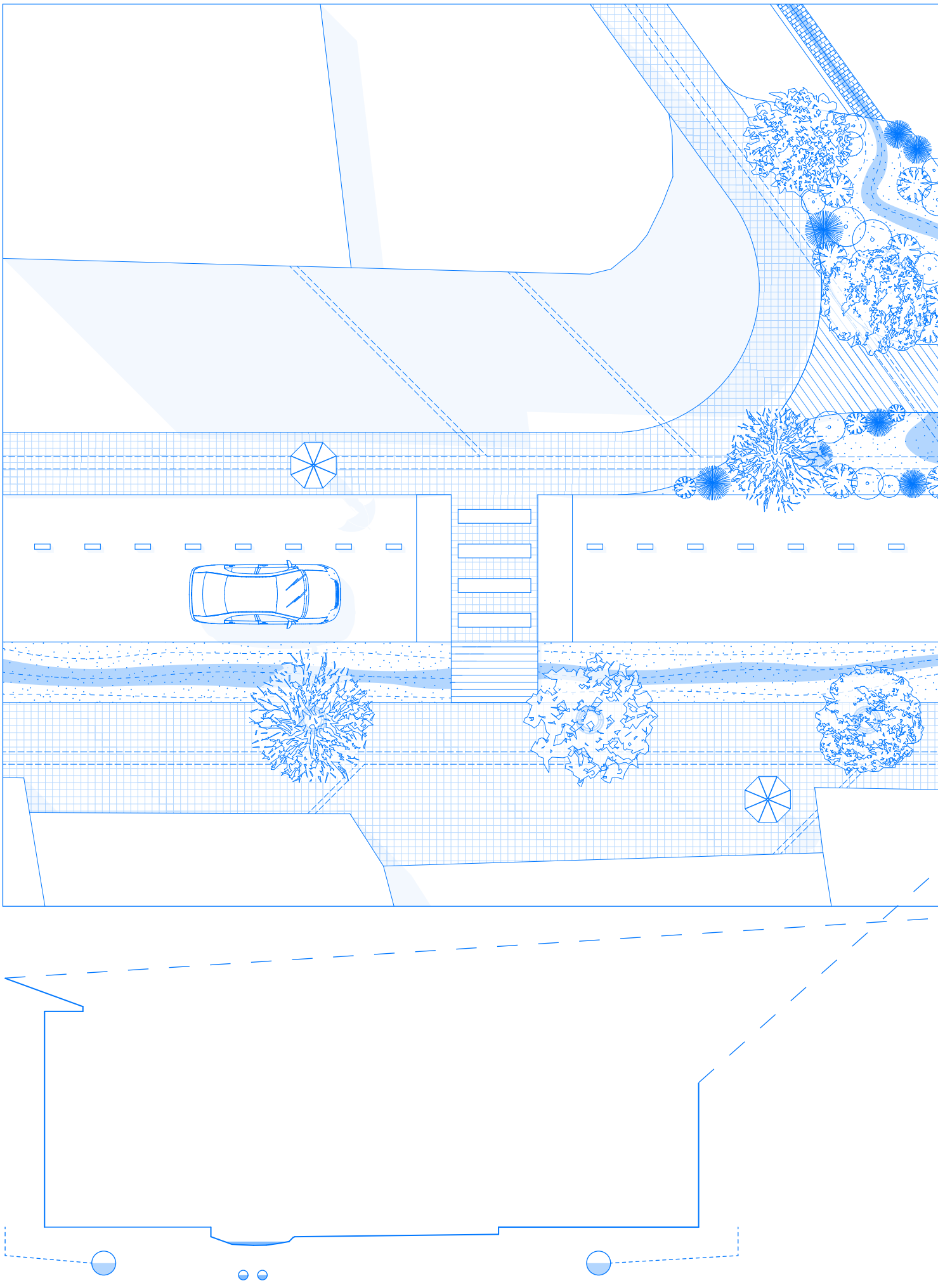
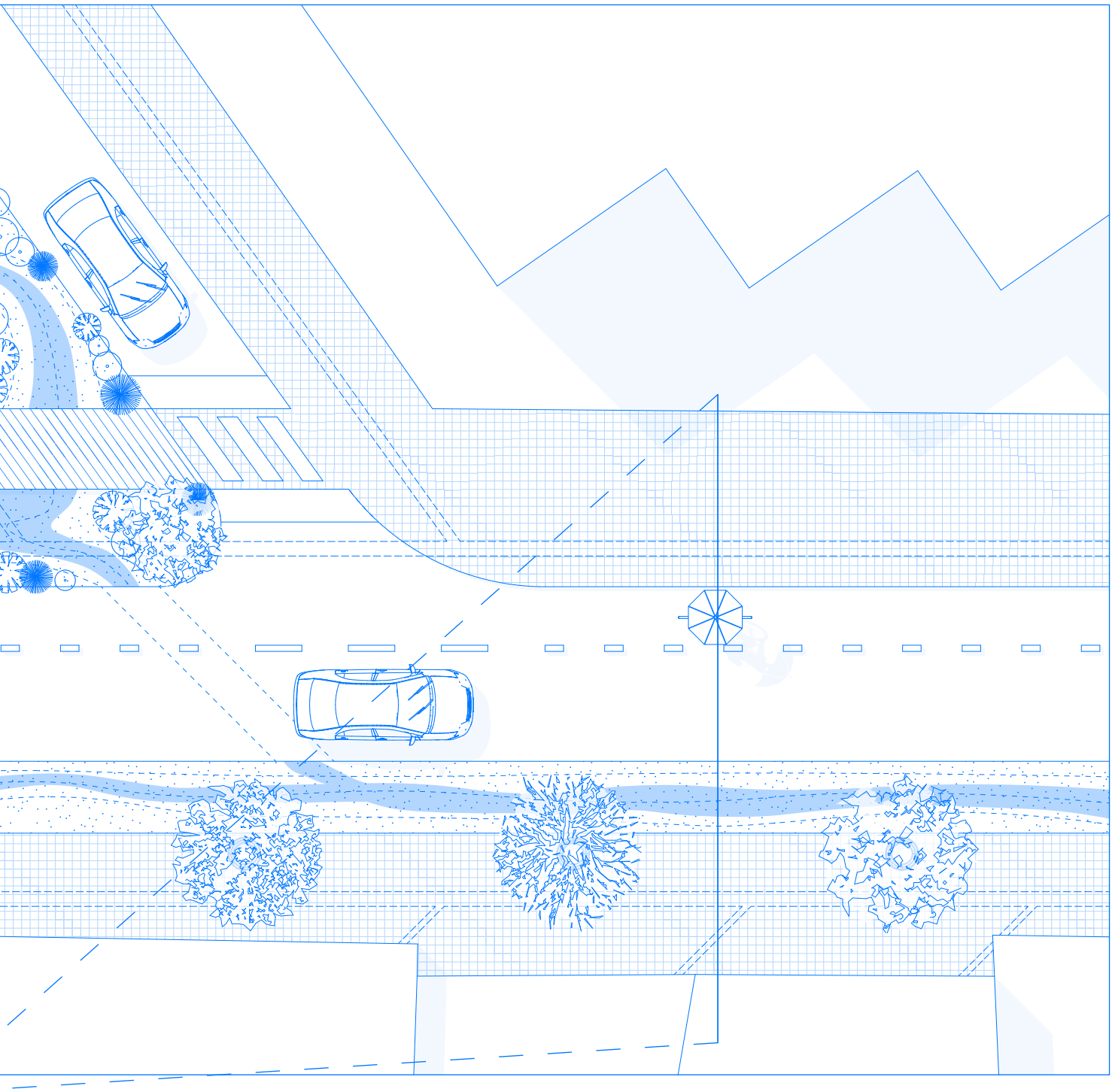
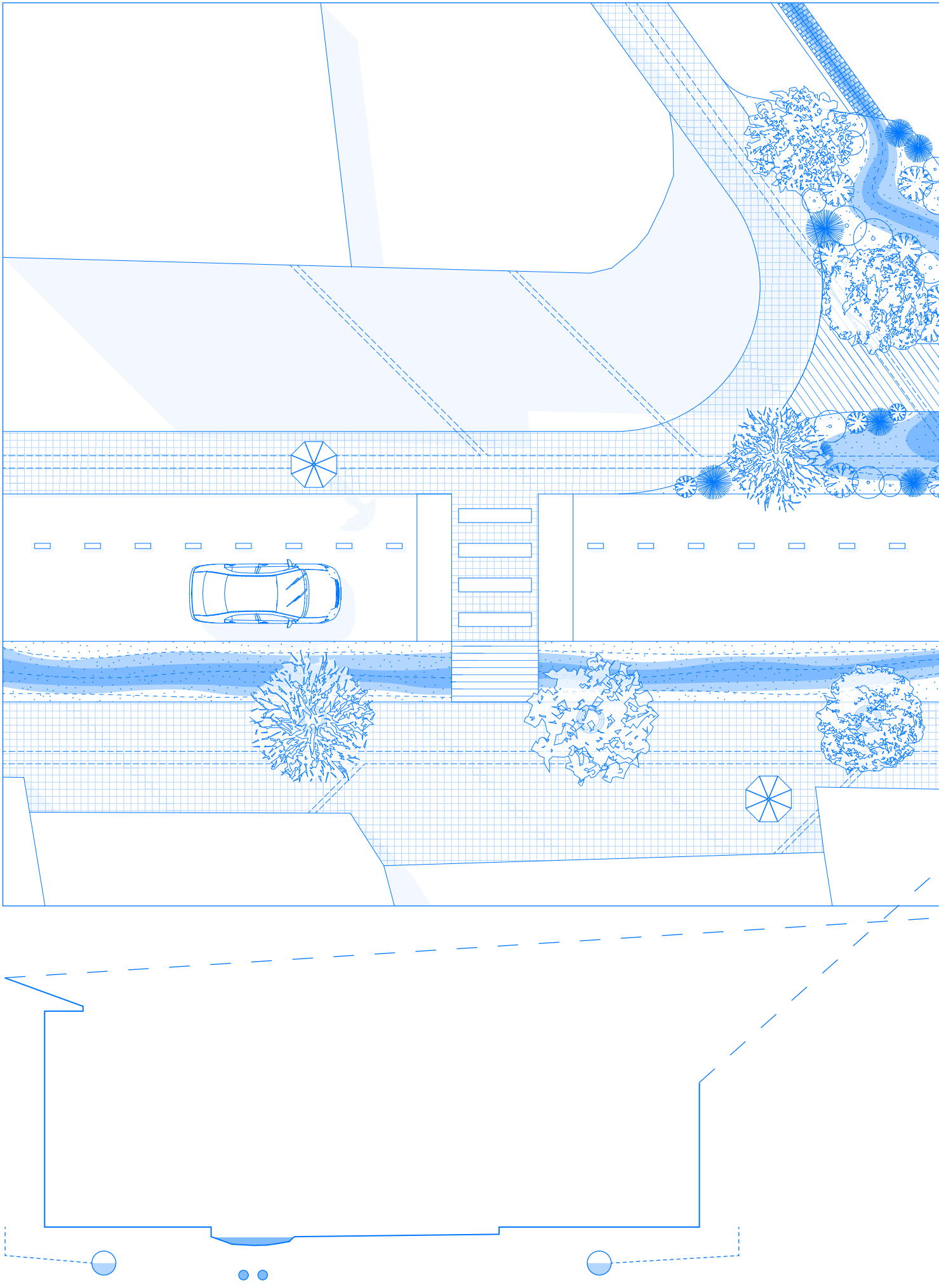
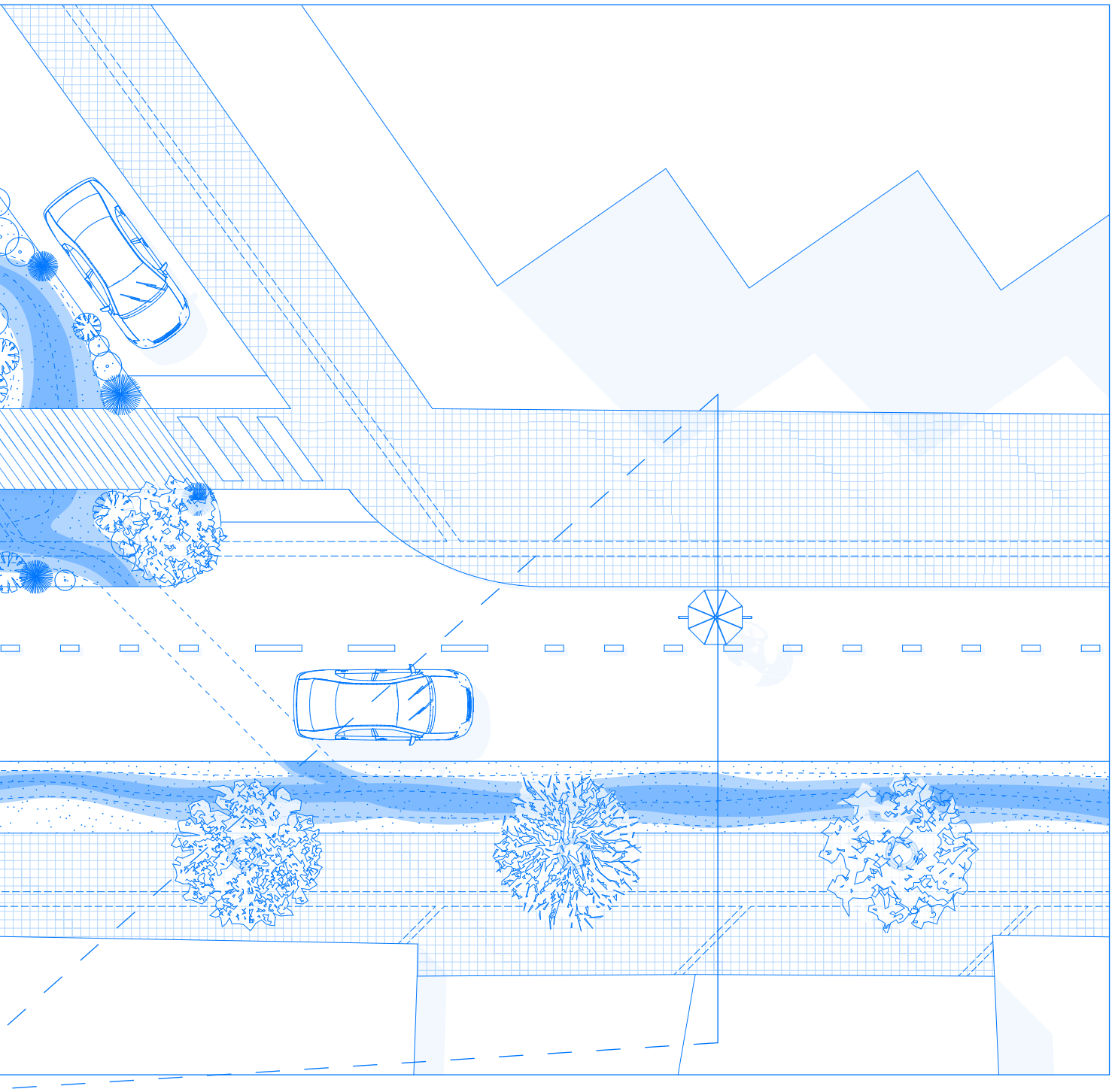
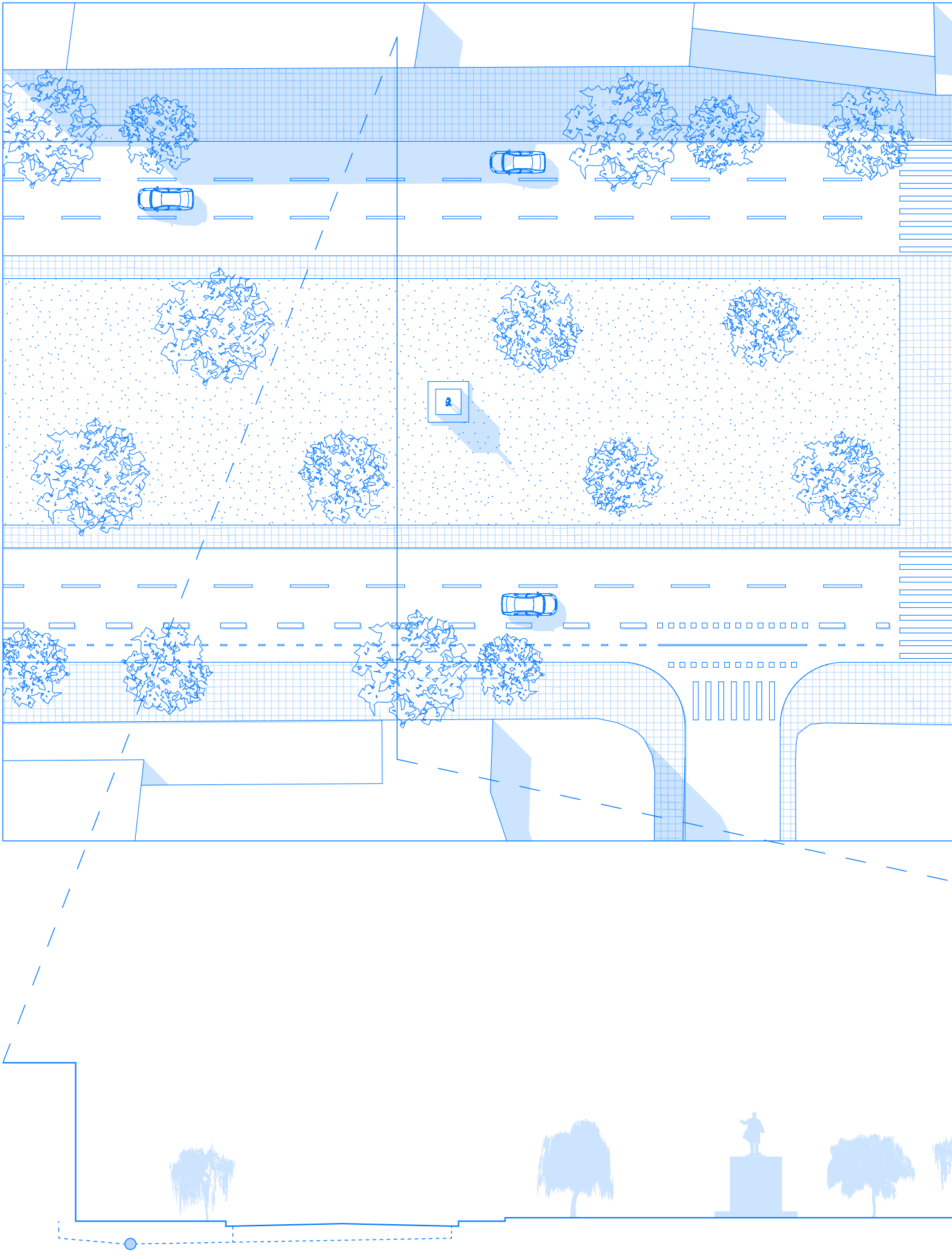
l=+0,15
den
wastewater sewer
stormwater canal

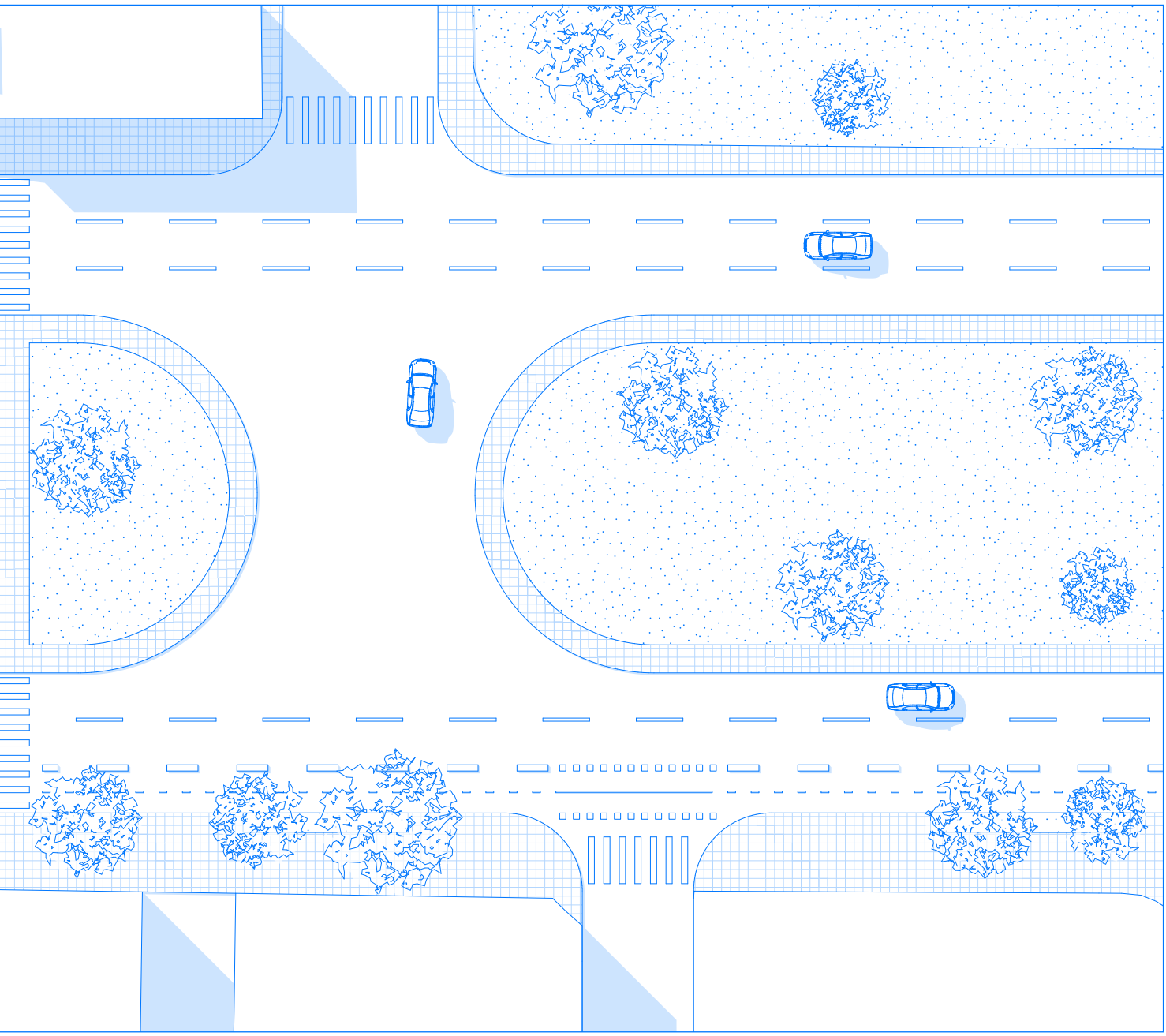


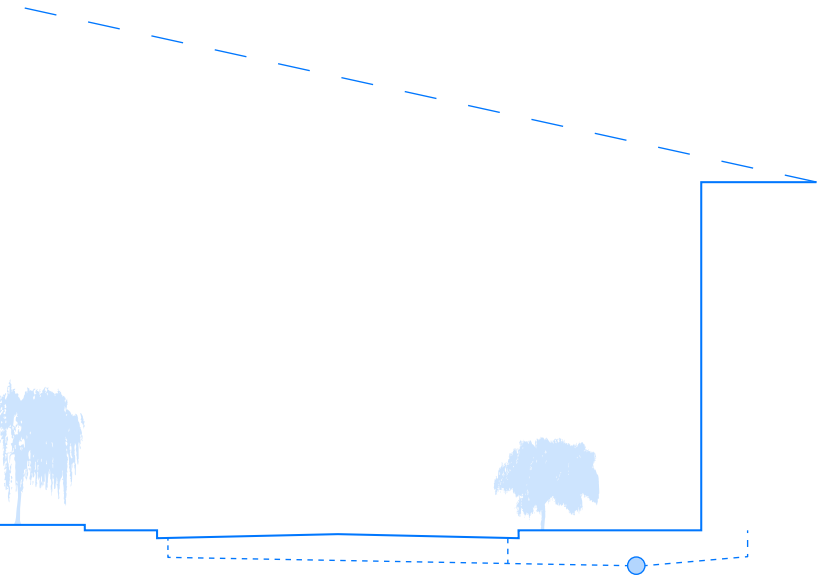


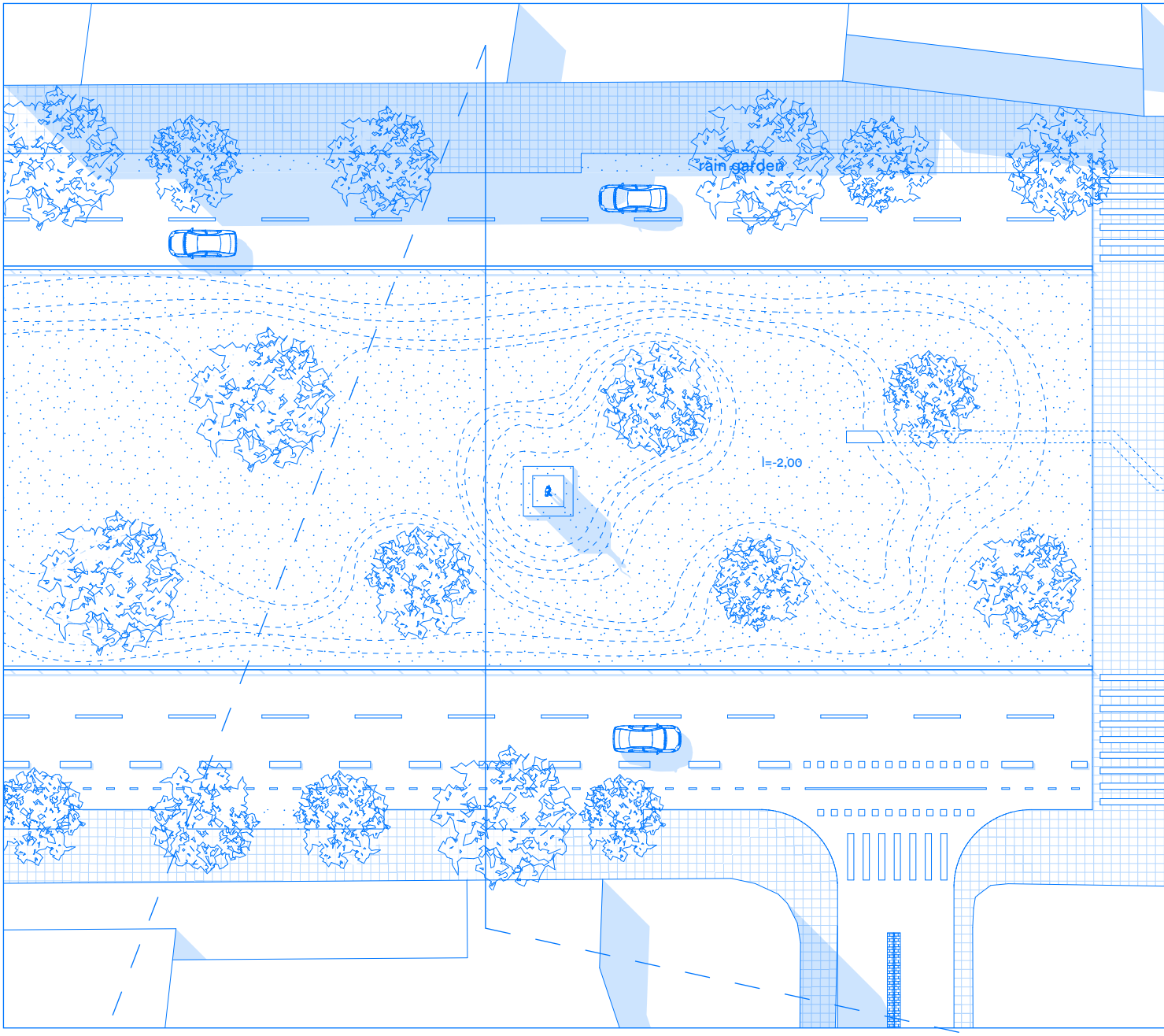








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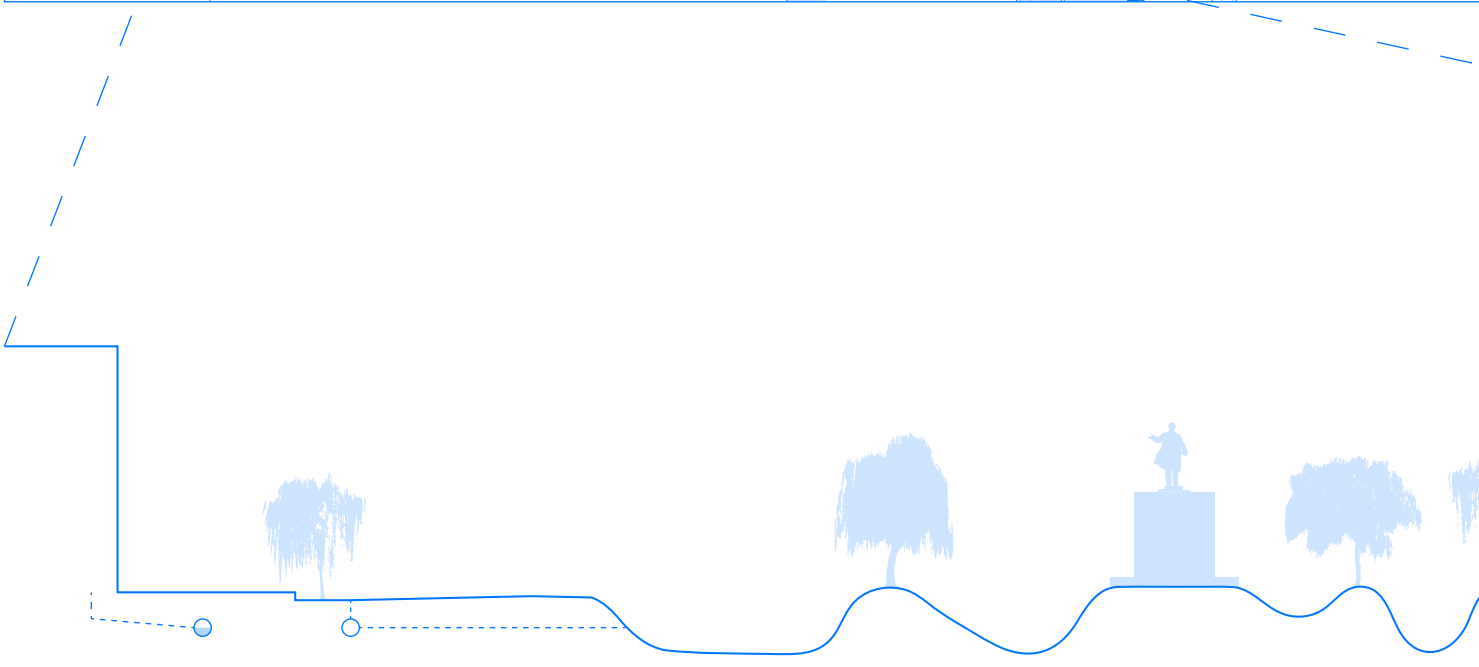

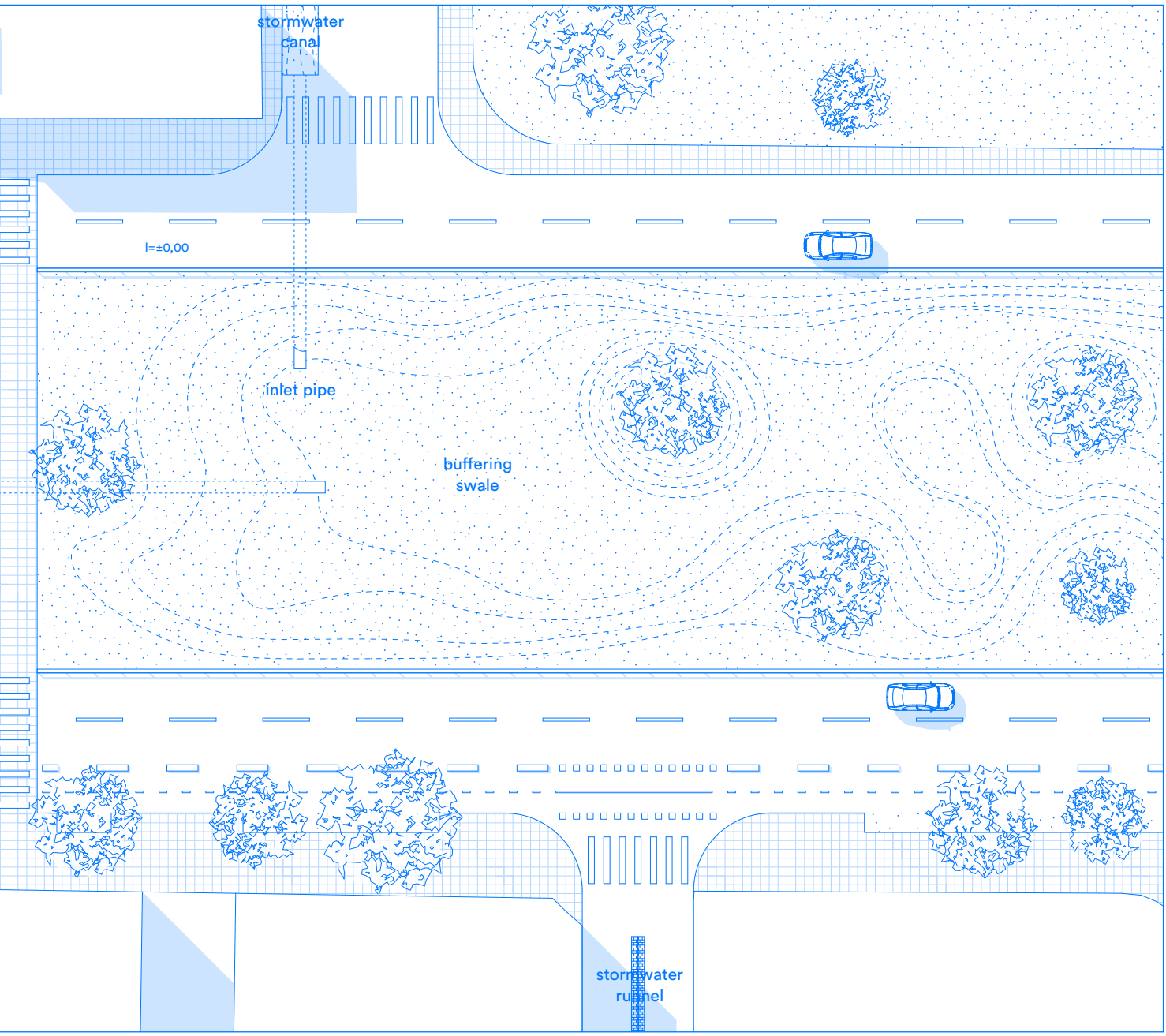
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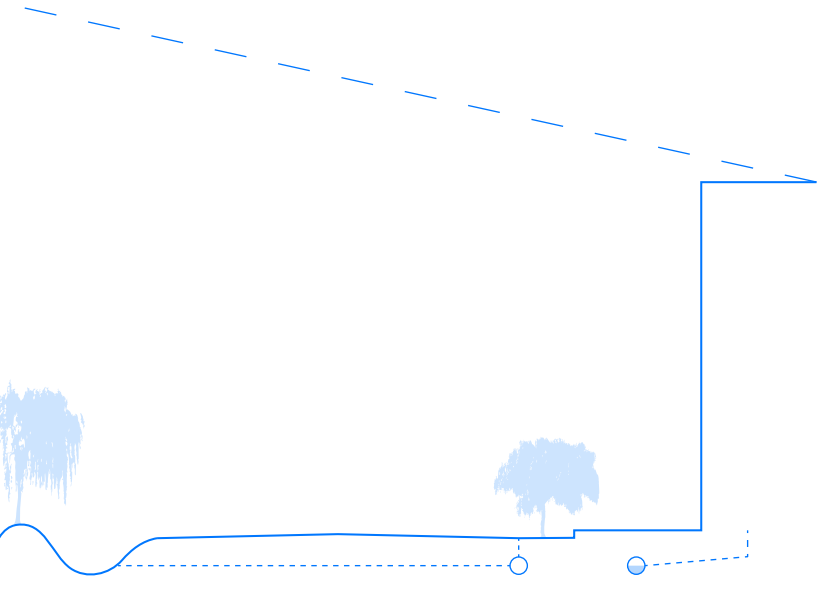

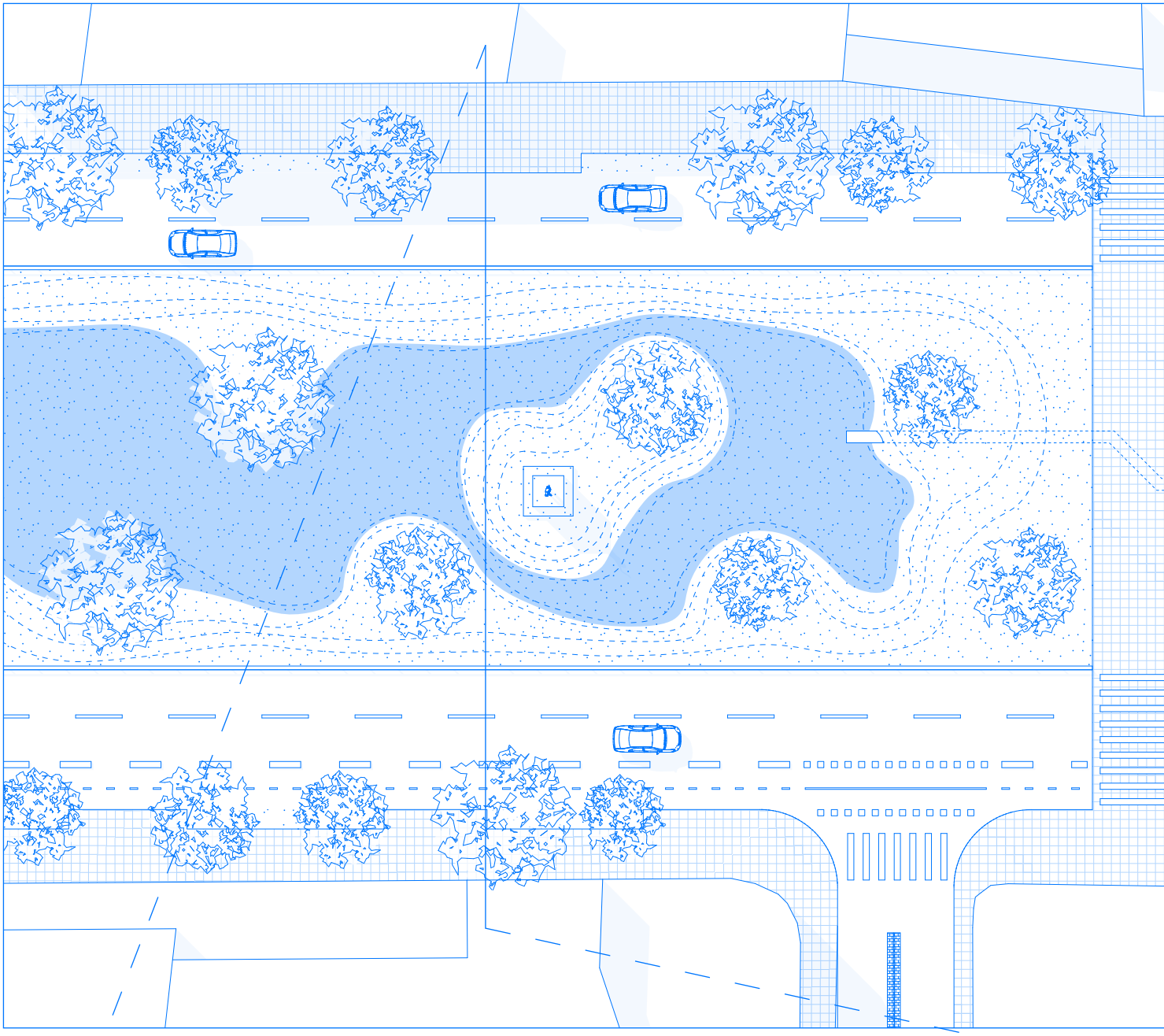

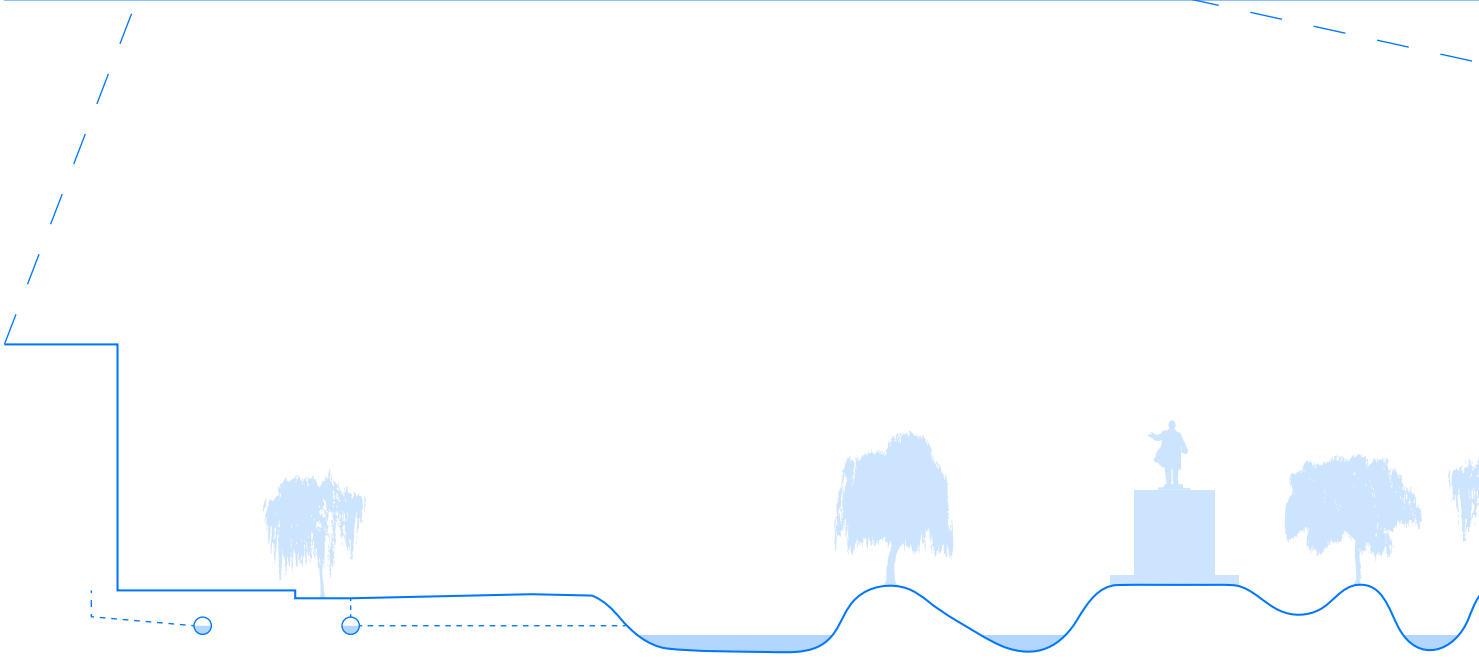

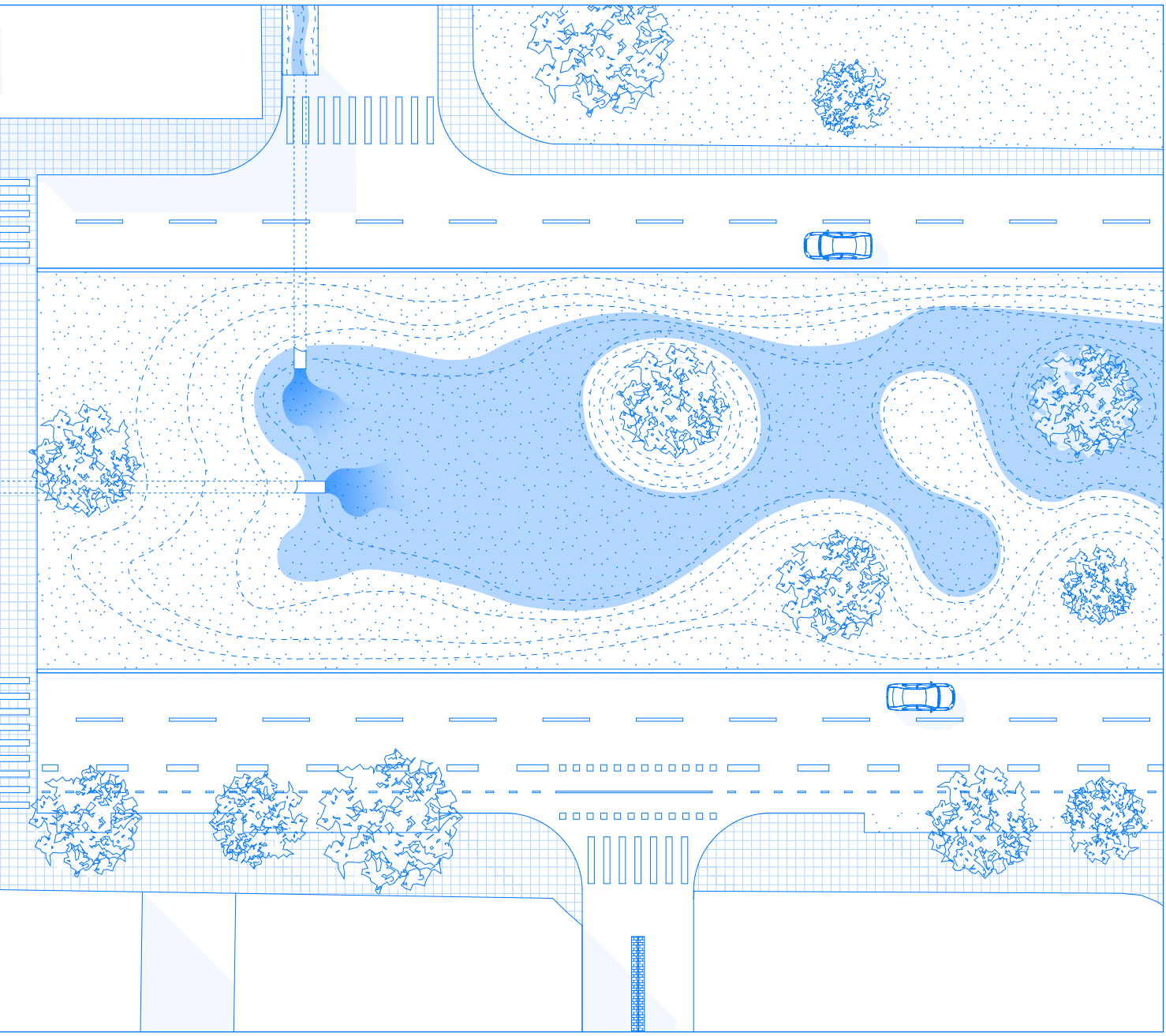

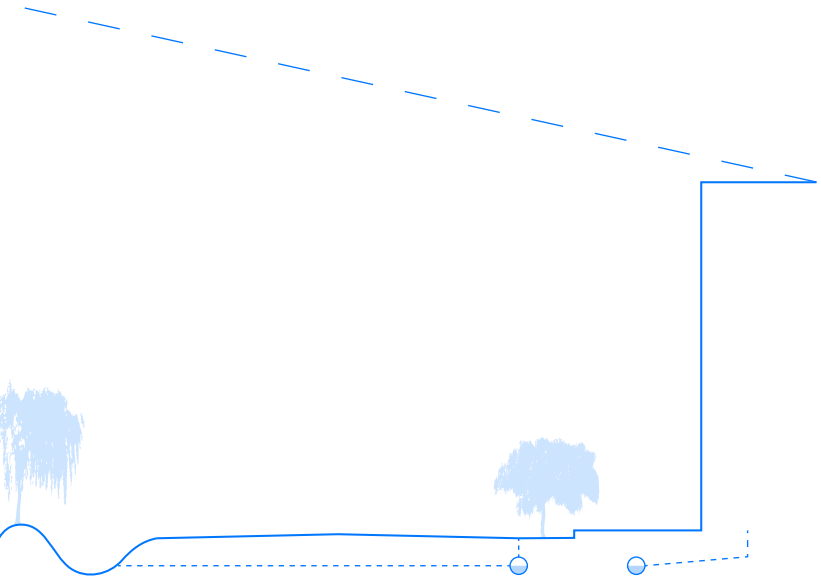

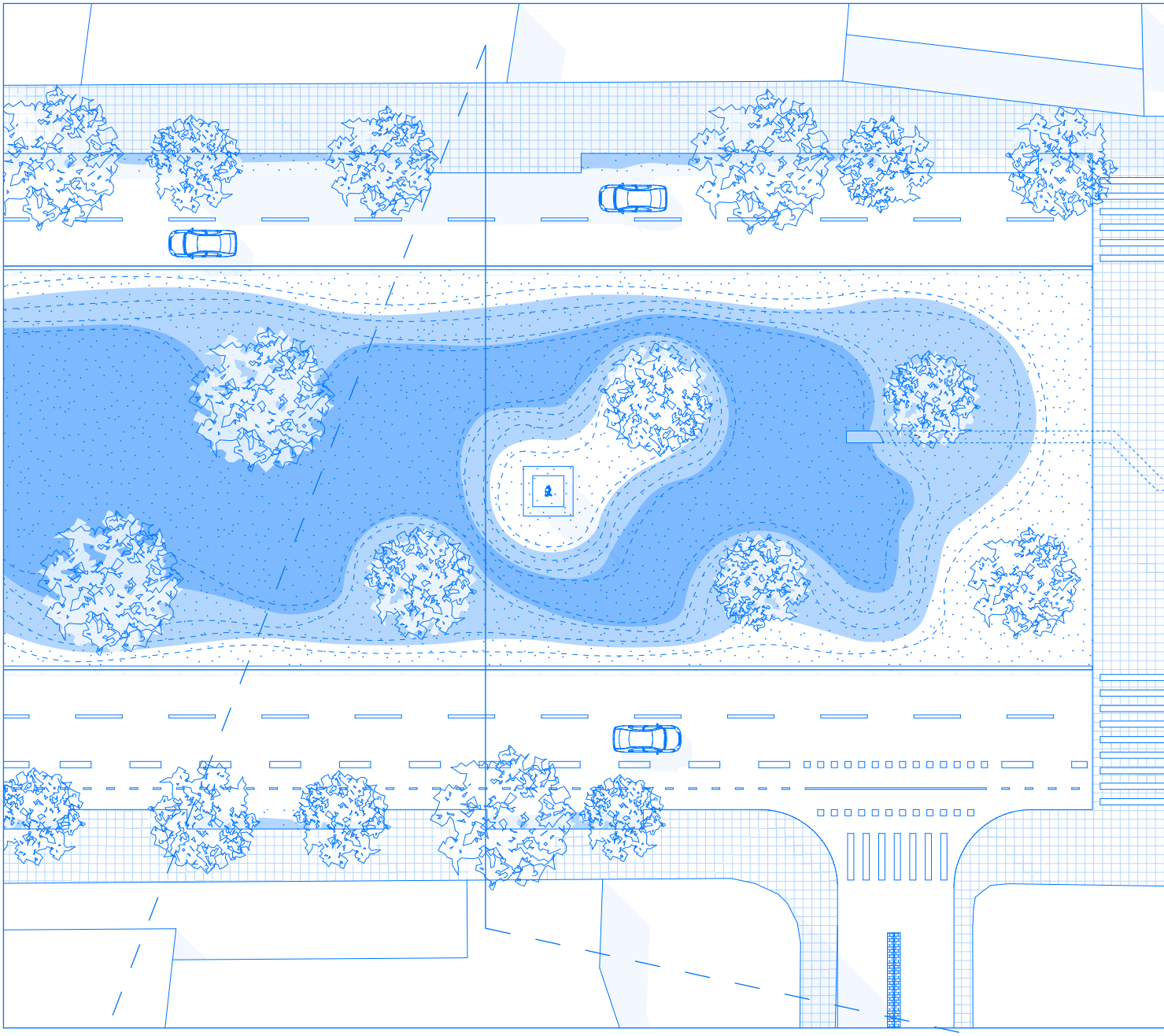

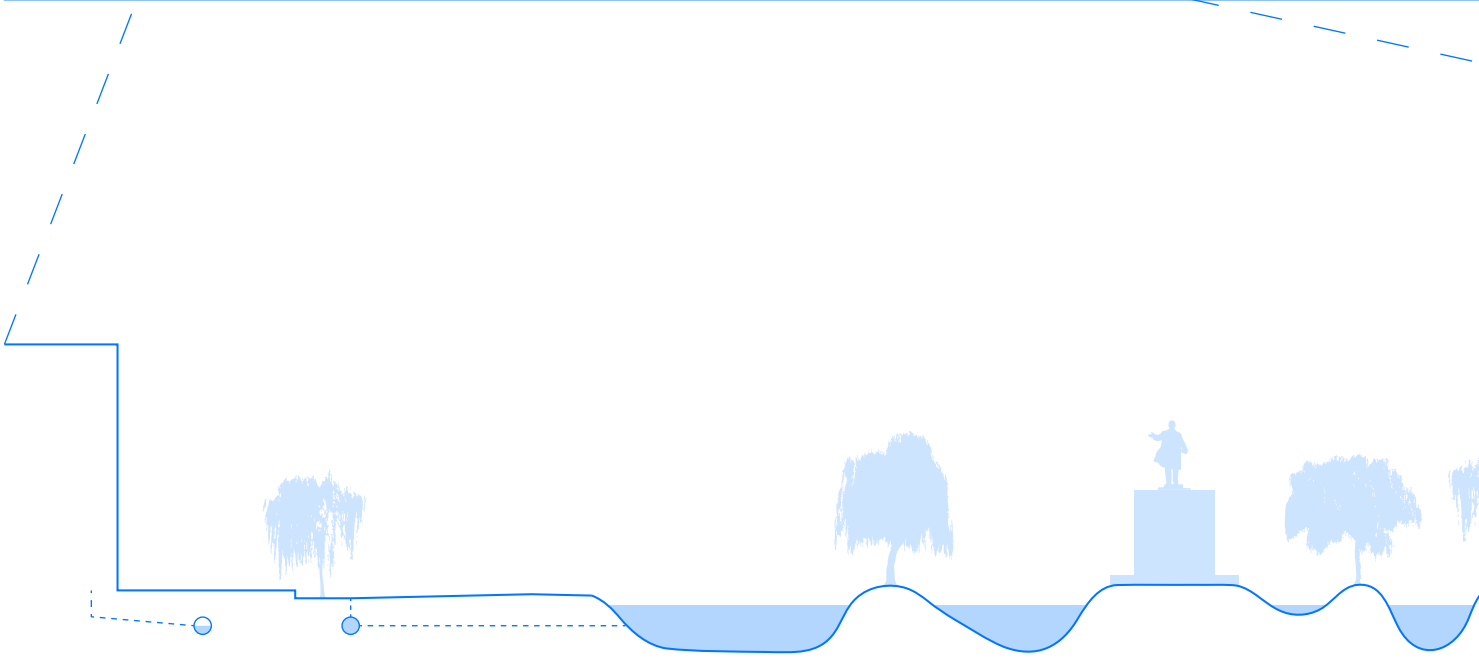

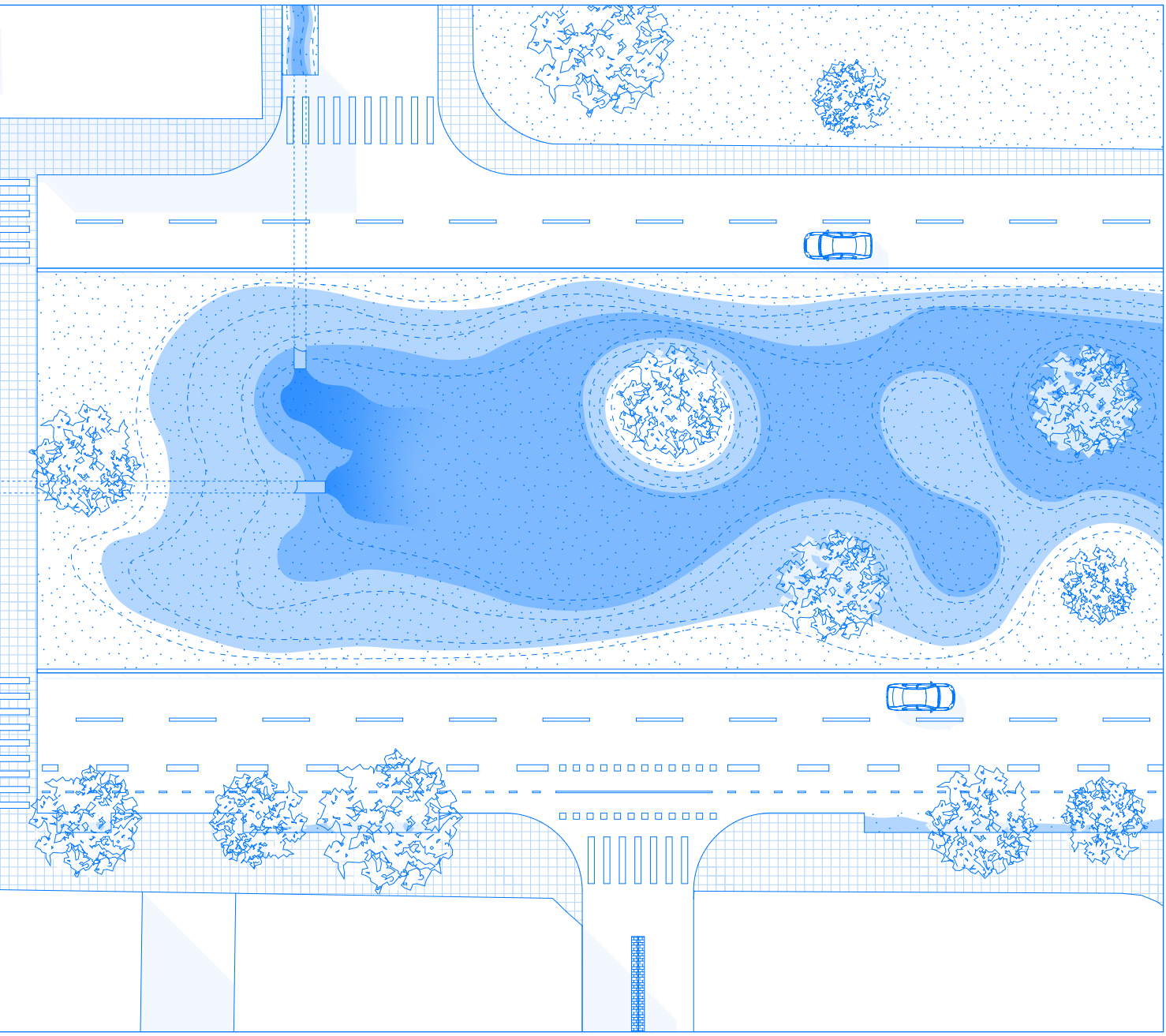

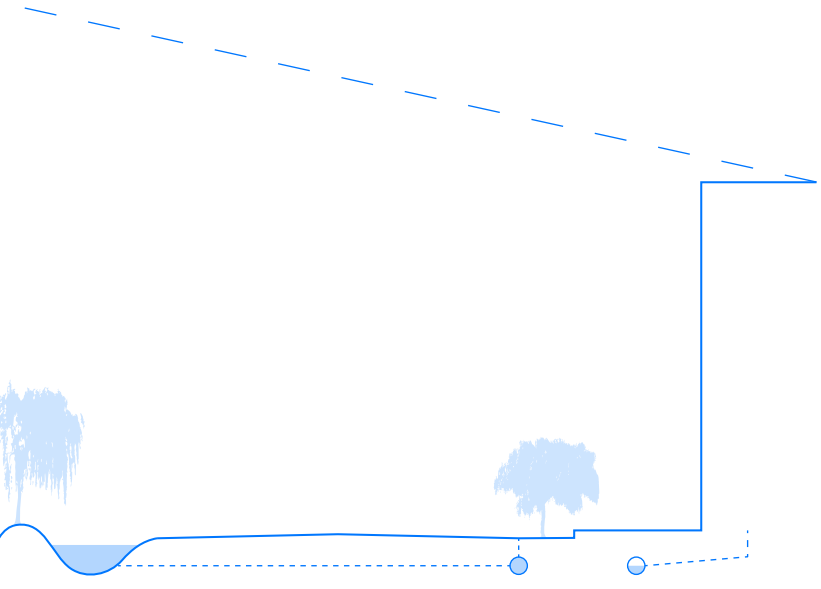

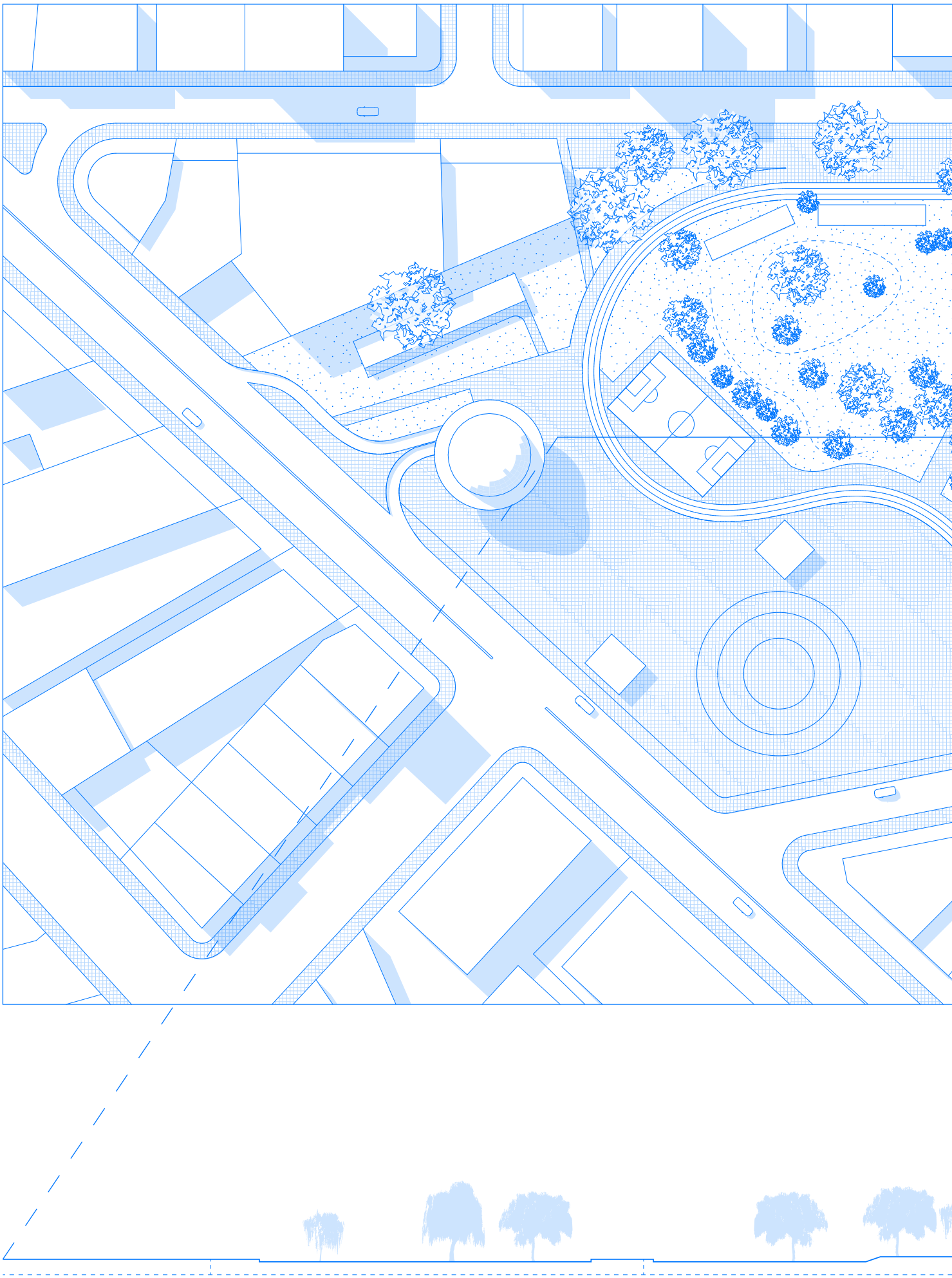

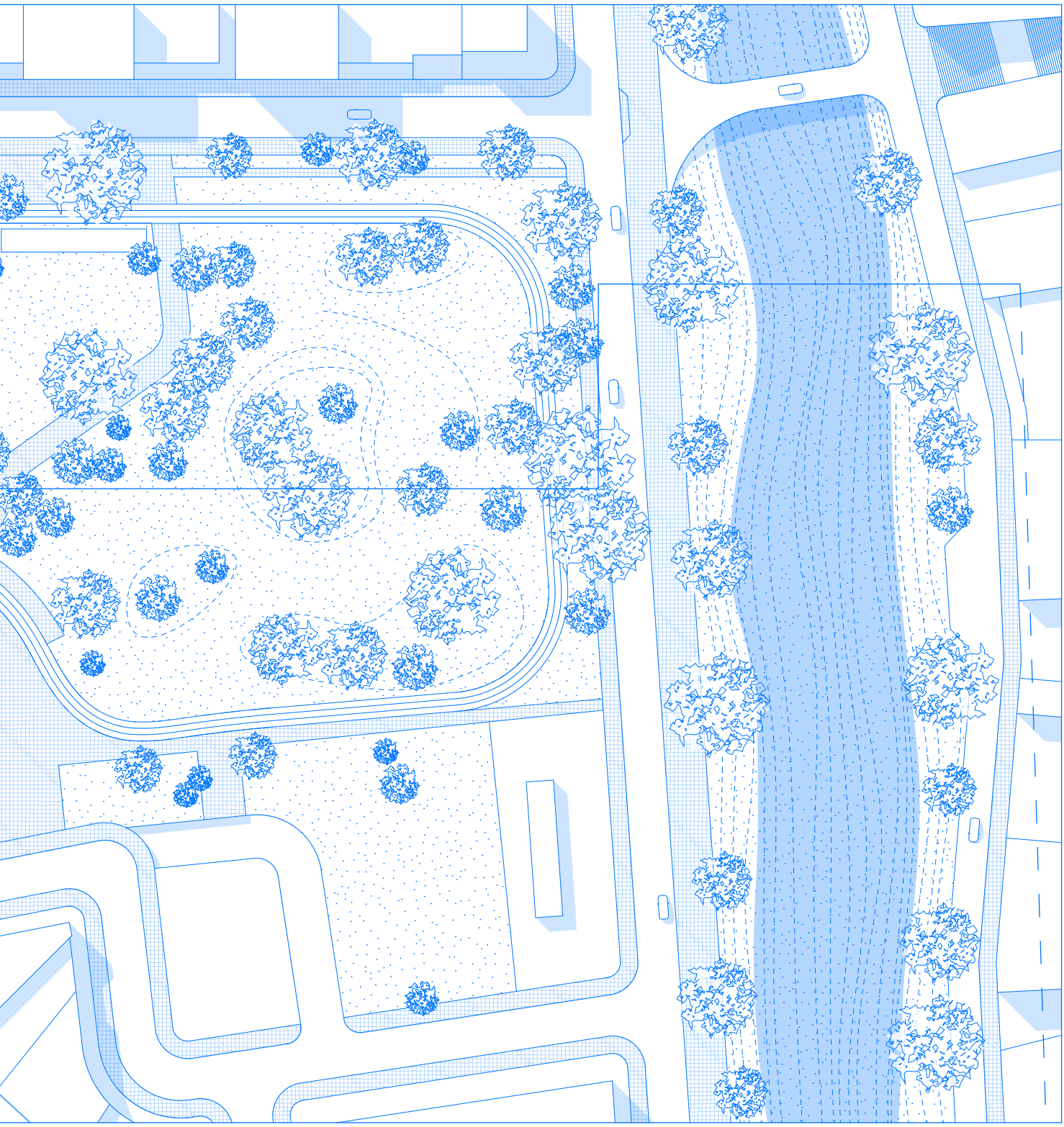

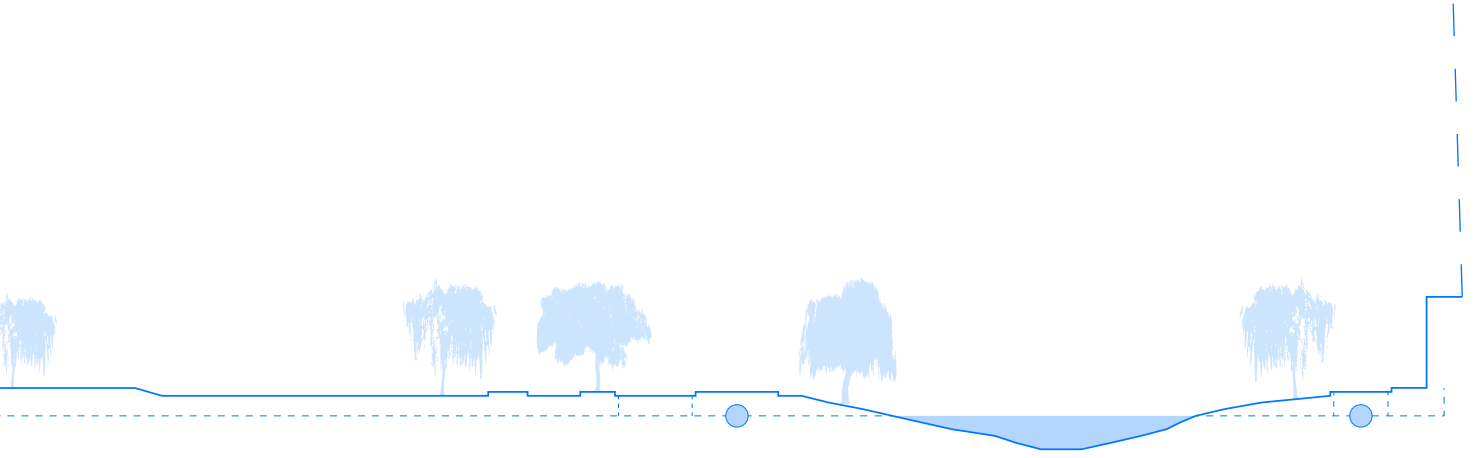

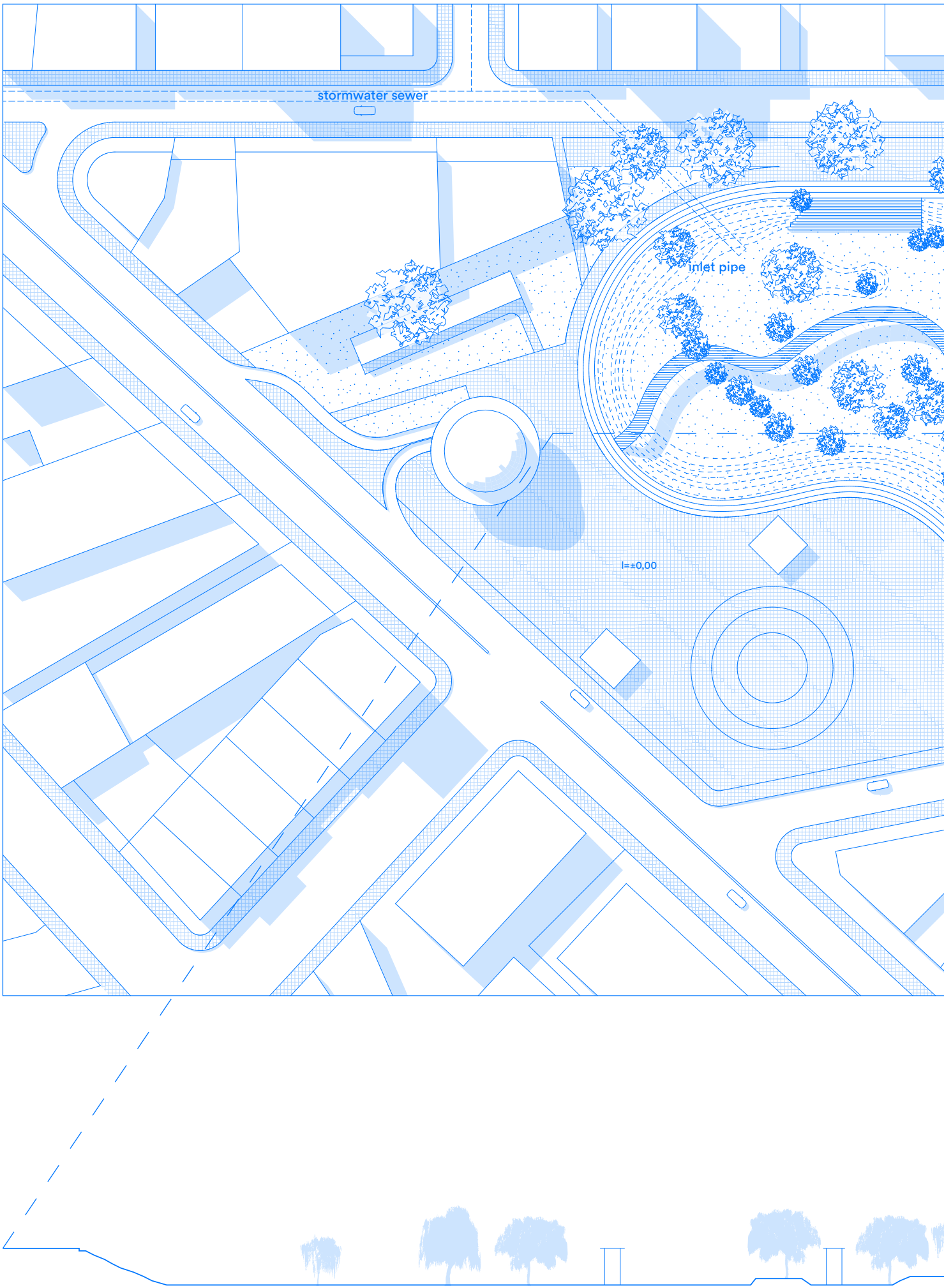
stormwater sewer
inlet pipe
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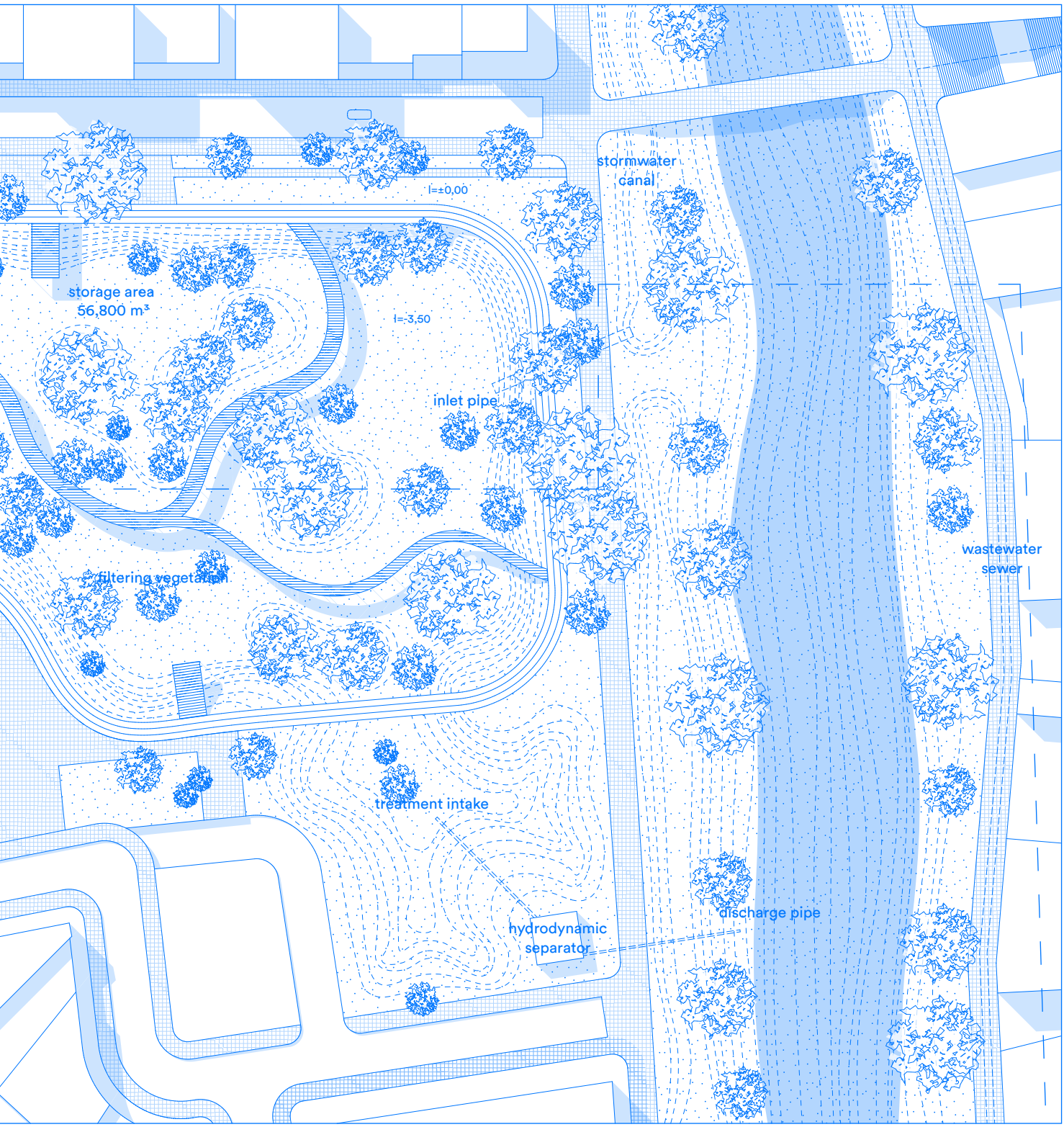
stormwater
canal
l=±0,00
storage area
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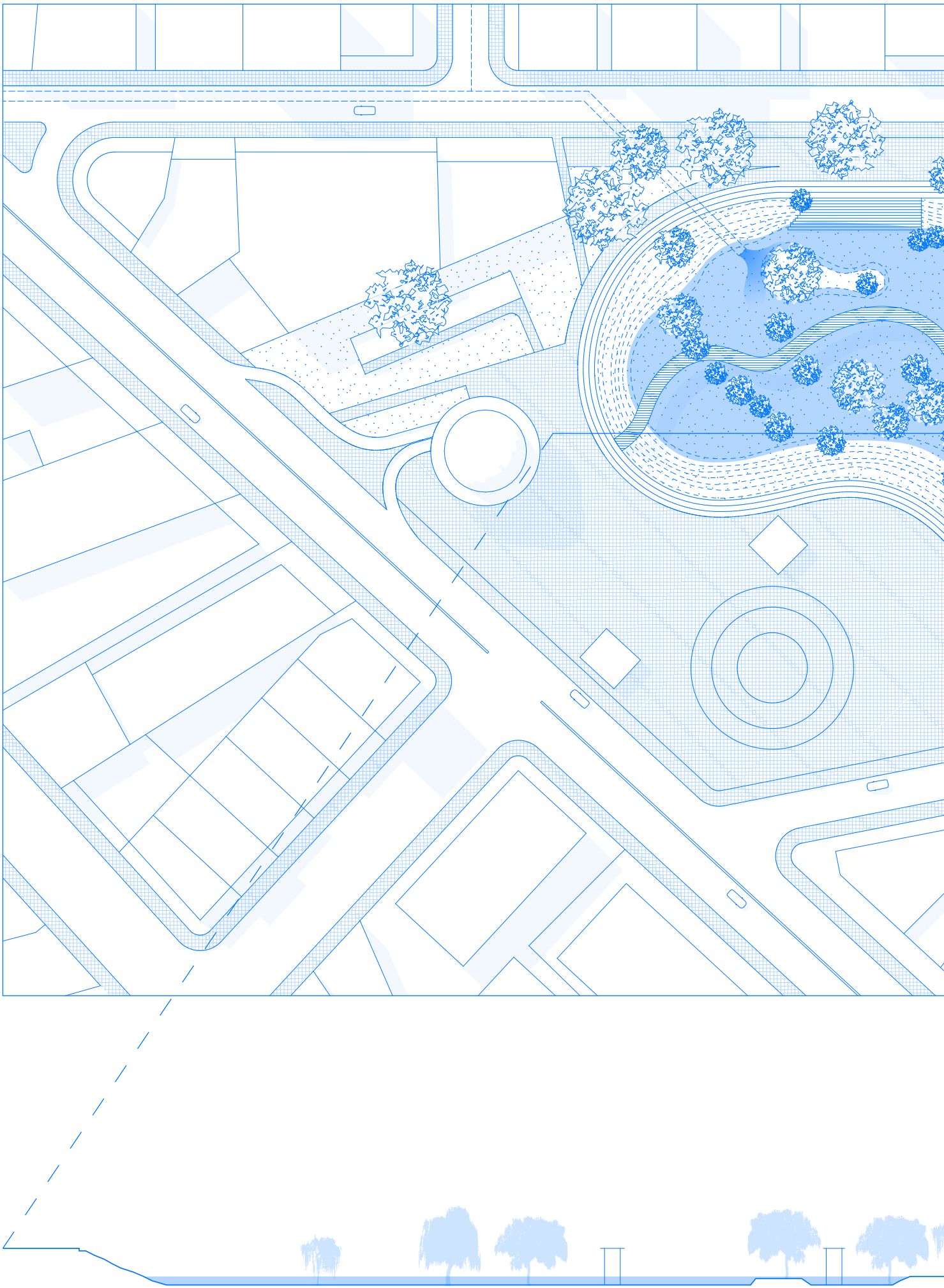
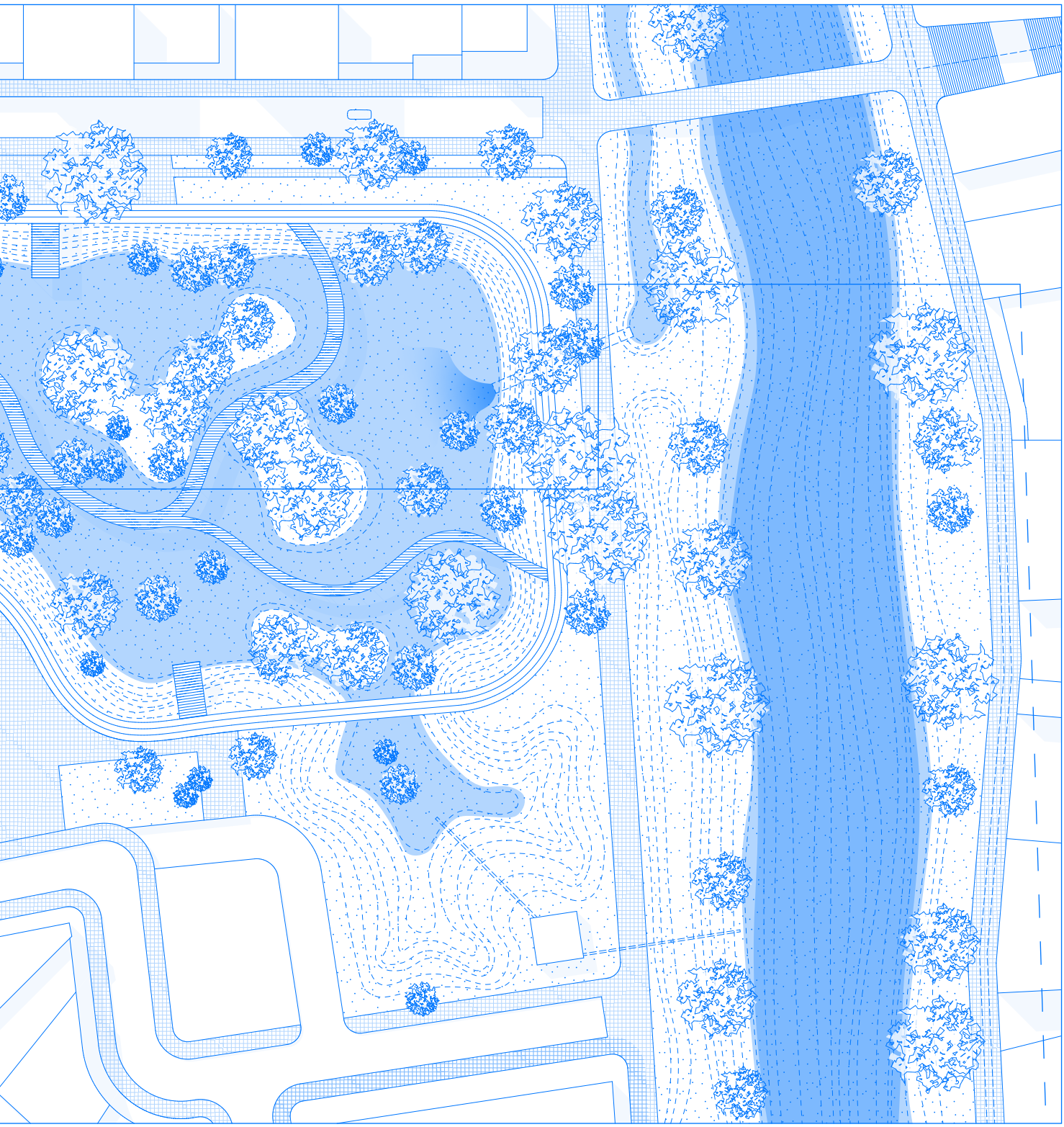
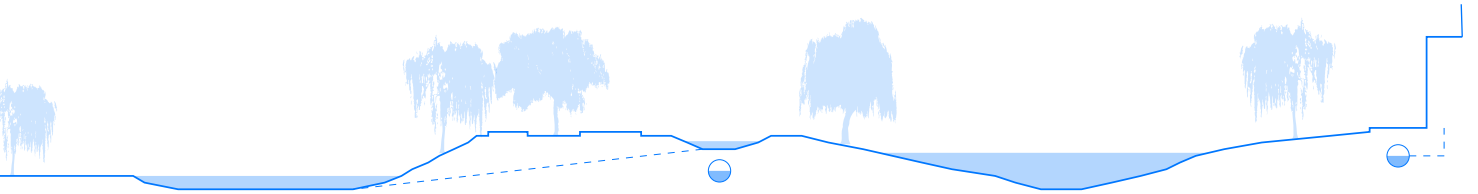
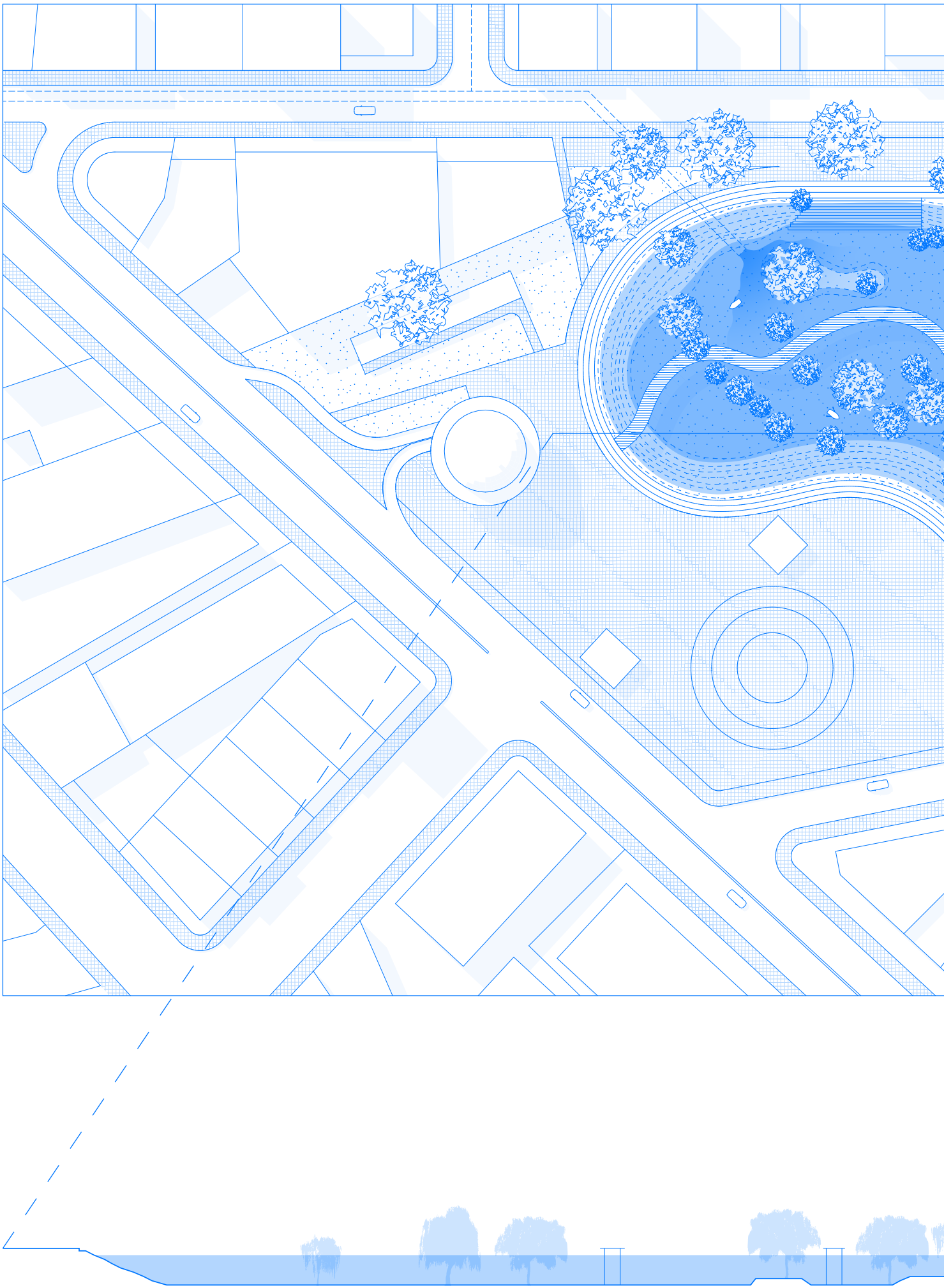
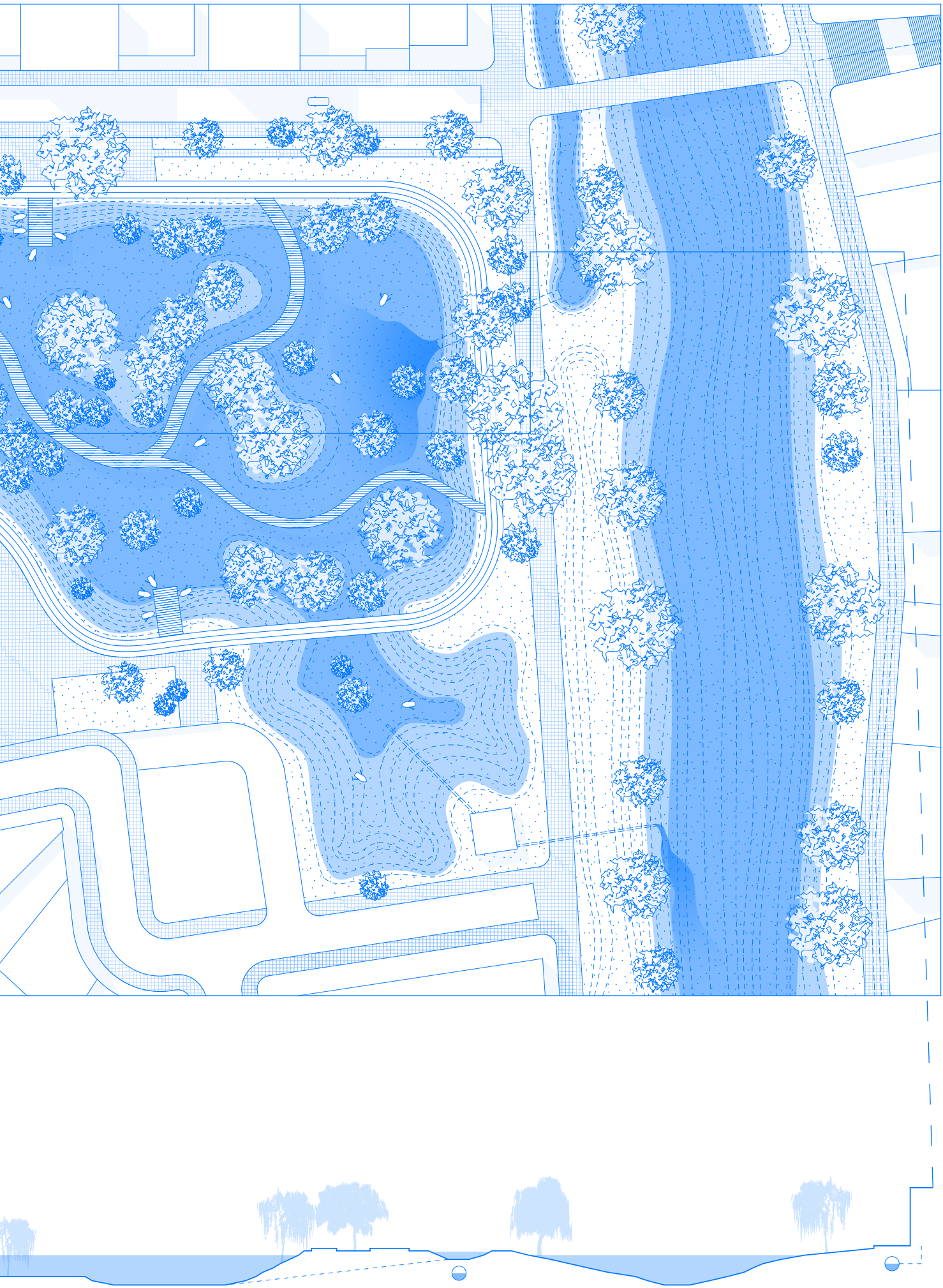
inlet pipe
wastewater
sewer
filtering vegetation
treatment intake
discharge pipe
hydrodynamic
separator















↑ Impression of stormwater buffering areas

5.6 Riverscapes as metabolic cleansers

At the lowest point of the urban area, the rivers take on a new role that could be described as practically the opposite of the one they play at higher elevations as suppliers of fresh water. In the Ucubamba area, the water reaches the outlet of the complex infrastructure system responsible for collecting, conveying, treating, distributing and discharging this resource from urban households, thereby transforming it into a resource for daily use. Here, after being treated at the city's only facility of its kind, Cuenca's wastewater is returned to the river system from which it was originally abstracted a few kilometres upstream as raw water. Within the urban area, wastewater is collected and transported via a system of interceptors to this plant, located at the eastern edge of the city. It has a processing capacity of 1.3 m^3 per second and its effluent is discharged into the Cuenca River, the watercourse formed by the confluence of the Tarqui, Yanuncay, Tomebamba and Machángara rivers.



For much of its modern history, however, Cuenca lacked the infrastructure needed to safeguard the water quality of its rivers and ensure public health. Although the construction of the first sewerage networks, which began to be laid beneath the streets of Cuenca from the 1950s onwards, represented an important first step towards the city's sanitation, there was still a long way to go. Cuenca's first sewerage network was designed with multiple outlets into the rivers within the urban area, which served as direct receiving bodies for the city's wastewater for nearly four decades. During that same period, the old practice of washing clothes in the rivers continued, particularly among the less affluent sections of the population.

It was not until the 1984 Sewerage Master Plan was drawn up that the collection, conveyance and treatment of the city's wastewater were identified as essential for improving public health in areas near rivers, as well as for preserving river water quality. The implementation of the plan, however, took a long time. It was not until 1994 that the first sections of the interceptor network, planned a decade earlier, were brought into operation, thereby preventing domestic and industrial wastewater from being discharged directly into

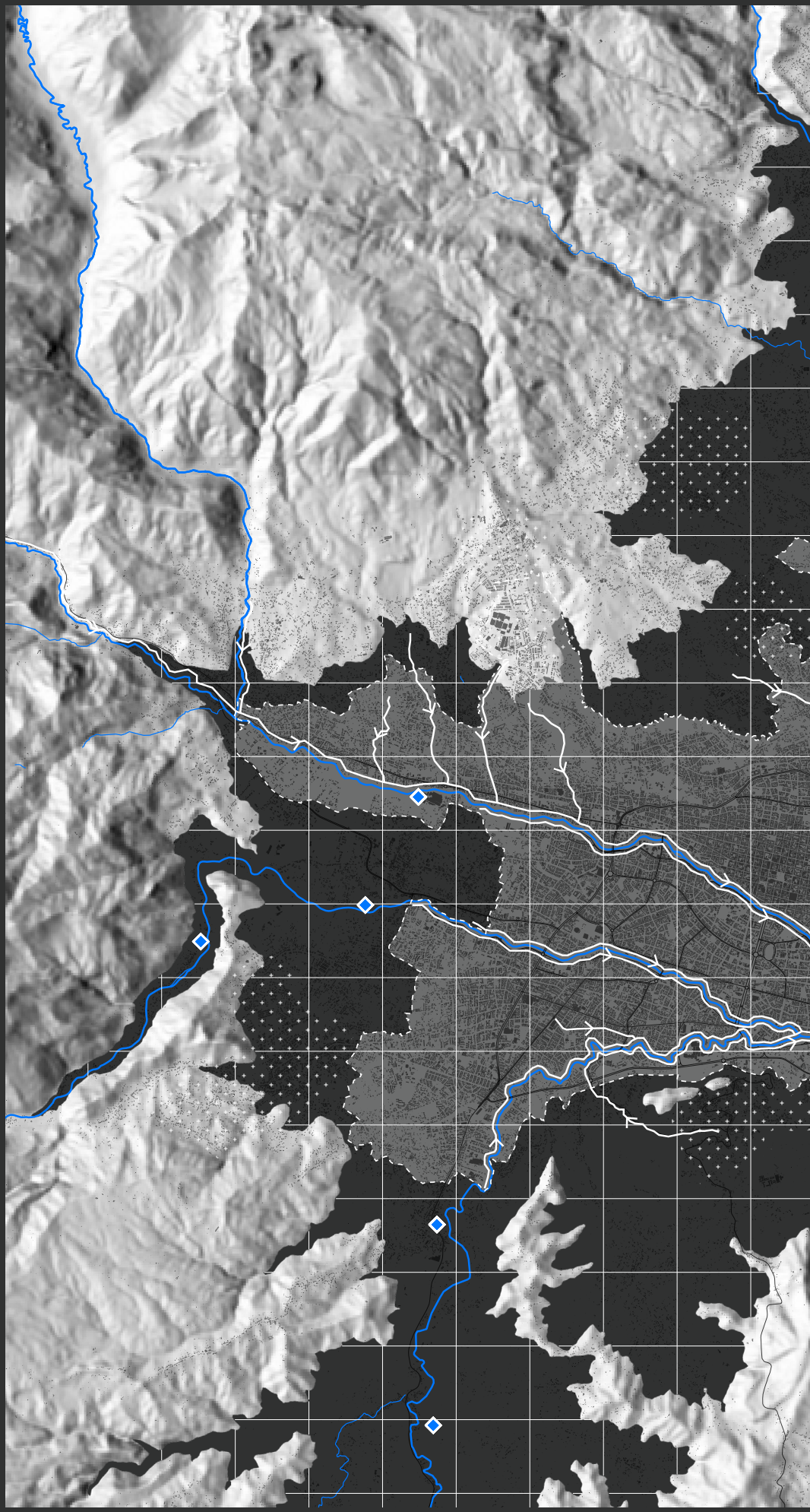


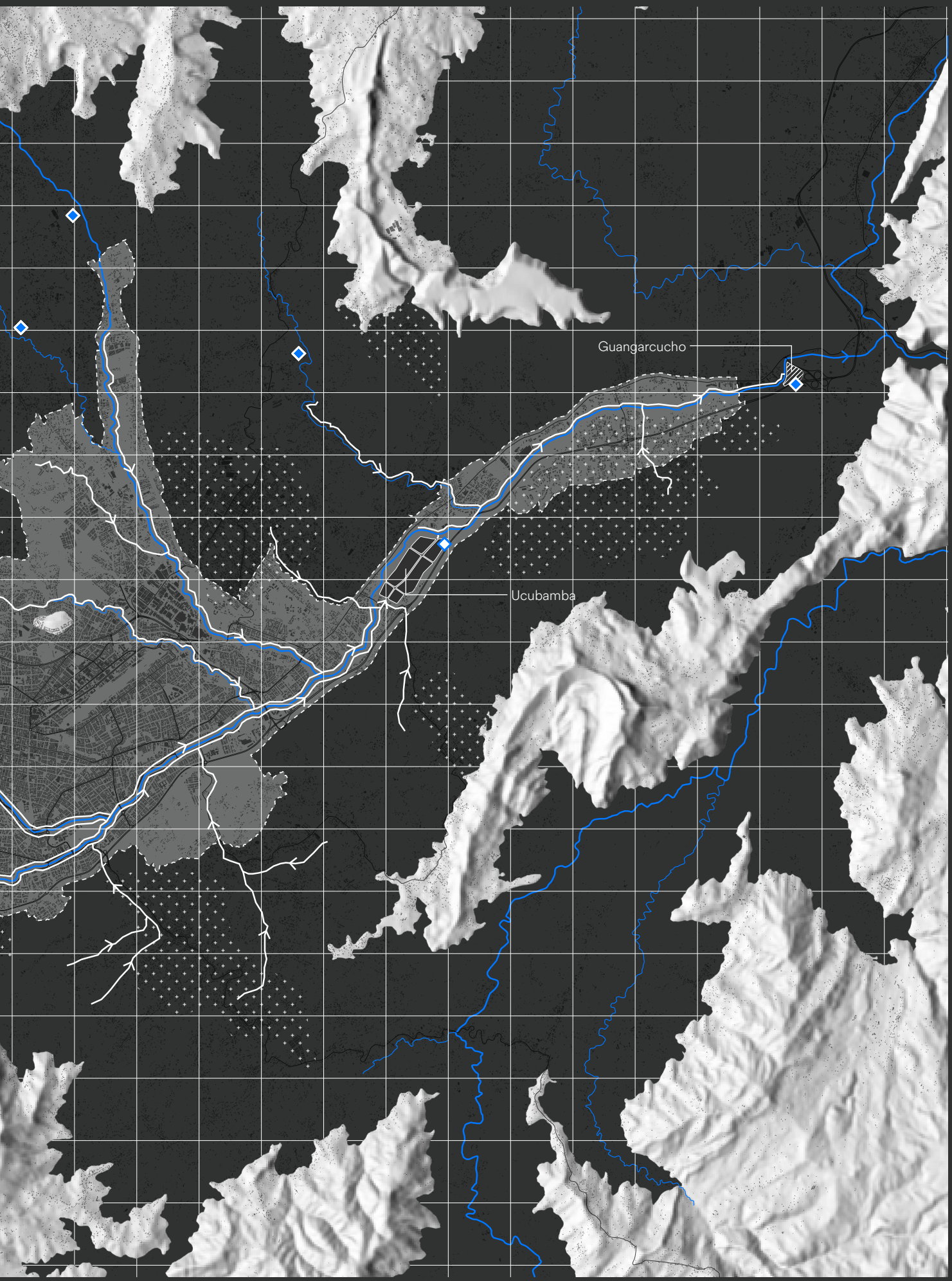
↑ Construction of the first major sewage collectors in Cuenca (1970)
Source: Galo Ordóñez

the rivers within the urban area. Over time, the network was also extended to cover the city's smaller watercourses. However, the absence of a wastewater treatment plant meant that the interceptors served only to shift the problem downstream.

The opening of Ucubamba took place five years later, in late 1999. The start of operations at this plant marked a milestone in the history of the city's public health and the preservation of its rivers within the national context, as Cuenca was one of the first cities in the country to have infrastructure of this kind. Designed with a 16-year service life based on estimates of the city's population growth, Ucubamba reached its maximum capacity in 2015. Since then, the plant has operated continuously at rates close to its maximum capacity, which has meant that at times when the system is under greater pressure (i.e. during periods of heavy rain), some of the wastewater is discharged directly into the Cuenca River.

From 2025, a second wastewater treatment plant will be built downstream of Ucubamba: Guangarcucho. Its construction is being carried out not only to handle the volume that Ucubamba is no longer able to treat, but also to process the wastewater from the new urban areas that have emerged downstream of this plant in recent years, and whose wastewater is therefore discharged into the Cuenca River without being treated.


Hydrography
Built up
Urban area
Urban expansion
Interceptor network
Treated water discharge
Untreated water discharge



↑ Interceptor network of Cuenca

Although the Ucubamba wastewater treatment plant has helped to significantly improve the quality of the water discharged into the Cuenca River after consumption, the river's water quality continues to deteriorate rapidly once the plant's effluent is discharged.

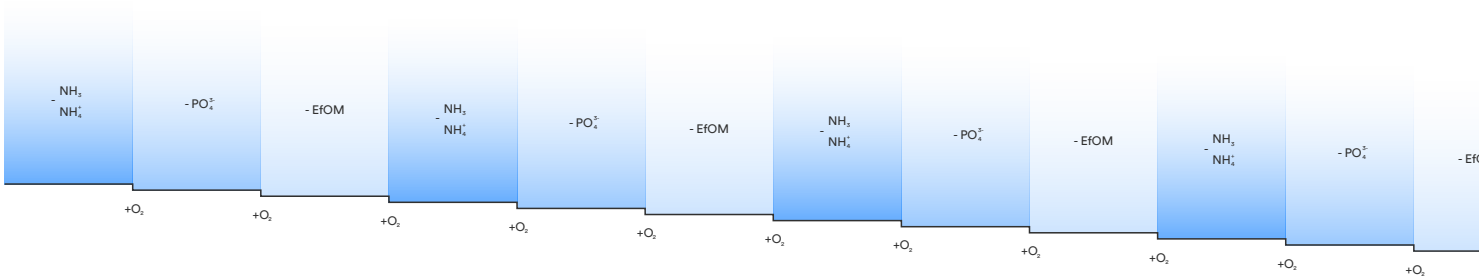
A study conducted by Espinoza and Zumba (2018) carried out an in-depth monitoring of this factor. To this end, water samples were systematically taken on several occasions under different flow conditions at two distinct points along the Cuenca River; one upstream of the plant's discharge point and the other downstream. The samples were subsequently analysed in the laboratory, and after weighing up the results, the researchers determined that, following the receipt of treated wastewater, the river water exhibits a reduction in its dissolved oxygen index, which is a a fundamental factor for the survival of riparian biodiversity, as well as a drastic increase in the levels of nitrogen and phosphorus, two nutrients that trigger algal growth in the water. This, in turn, is reflected in an extreme increase in chlorophyll levels in the water downstream from the discharge point of the wastewater treatment plant.


Test location A
-3,5% dissolved oxygen
+317% nitrogen
Ucubamba wastewater
treatment plant
+142% phosphorus
Discharge point
+2500% Chlorophyll
+17% suspended solids
Test location B

As previously reviewed in this work, the role of wetlands can be paramount when it comes to water retention and river formation. However, it has been shown that they can also have an important potential for water purification. Experiments to test the potential of wetlands for treating wastewater have been taking place since the 1950s (Vymazal, 2010). All kinds of constructed wetlands have proven to be effective for wastewater treatment, for the removal of organic matter. However, it is much more complicated to clean water up from nutrients. In this regard, Vymazal (2007) argues that the combined operation of several types of wetland to work as a system can be the most effective way to address this issue, integrating the functioning of single-stage, vertical flow and horizontal flow wetlands in order to exploit the specific advantages of the individual systems.

The application of this principle could be an important step into improving Cuenca's wastewater quality before being discharged into the Cuenca River. The banks of the Cuenca River downstream of the treatment plant are an area currently undergoing a process of transformation, as the city is expanding into this area and the riverbanks have not yet been developed as part of the urban infrastructure. This could represent a great opportunity to address two needs at once, creating a wastewater post-treatment infrastructure that could also be integrated into the city's network of green spaces as a high-quality area offering recreational opportunities. Different types of wetlands, with soil and vegetation designed to remove specific pollutants, can be arranged in a stepped configuration, which helps to increase oxygen levels in the water.

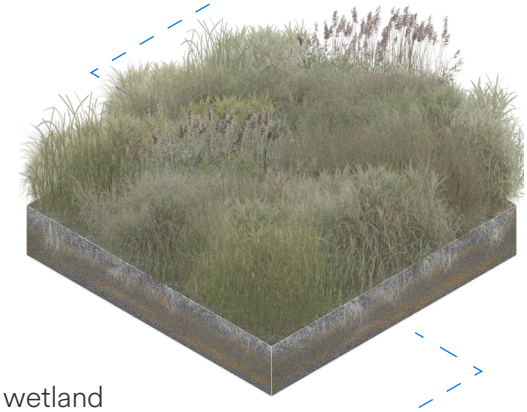
Given that water contaminated with phosphorus and nitrogen takes between three and four days to show a significant reduction in these elements (Ghosh & Gopal, 2010), and given the average effluent flow of 1.3 m^3/s from the Ucubamba plant (ETAPA EP, 2025), the constructed wetlands should be designed with a volume capacity and water velocity that ensures the water is discharged into the river after that period of time. To make this feasible over time, a phased roll-out of this infrastructure could take place along the banks of the Cuenca River, creating a direct relationship whereby the greater the extent of the wetlands, the better the quality of the water as it leaves them.



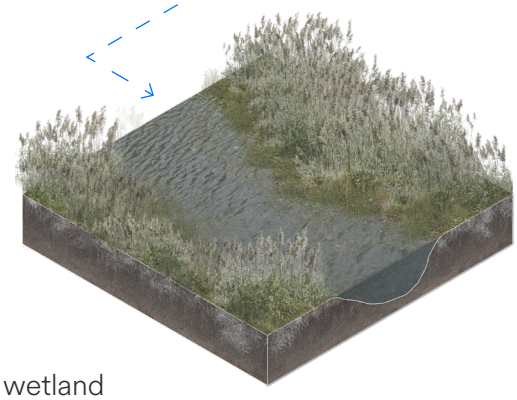
Type A wetland
Type B wetland
Type C wetland



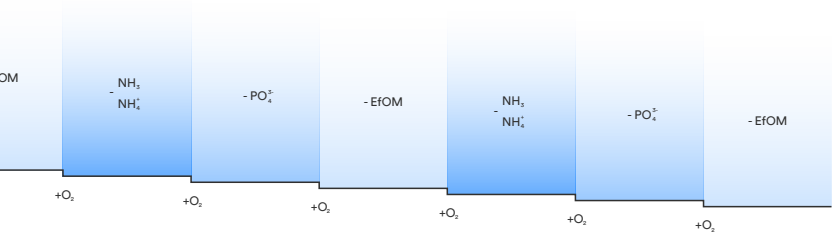
Type A wetland

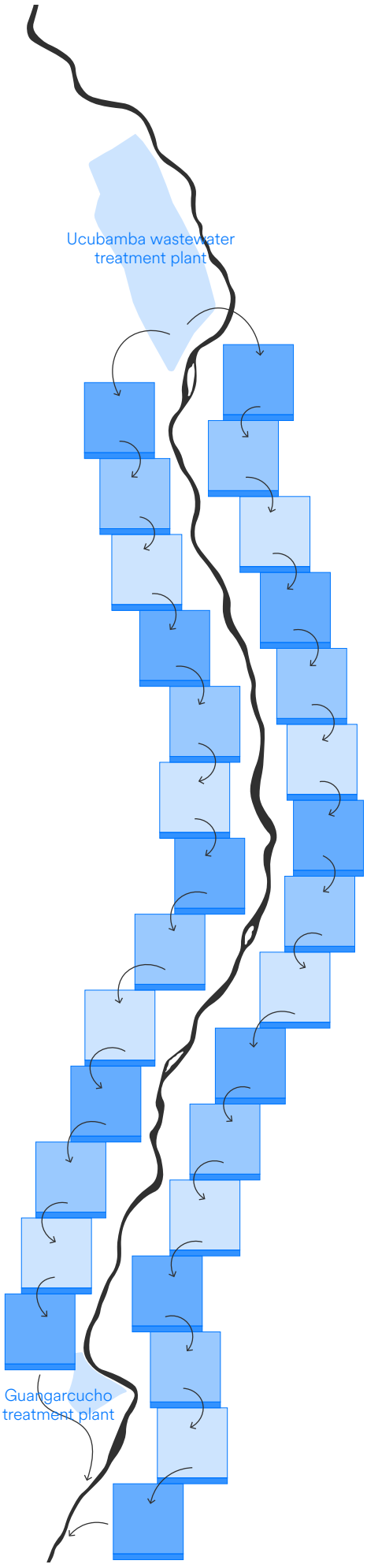


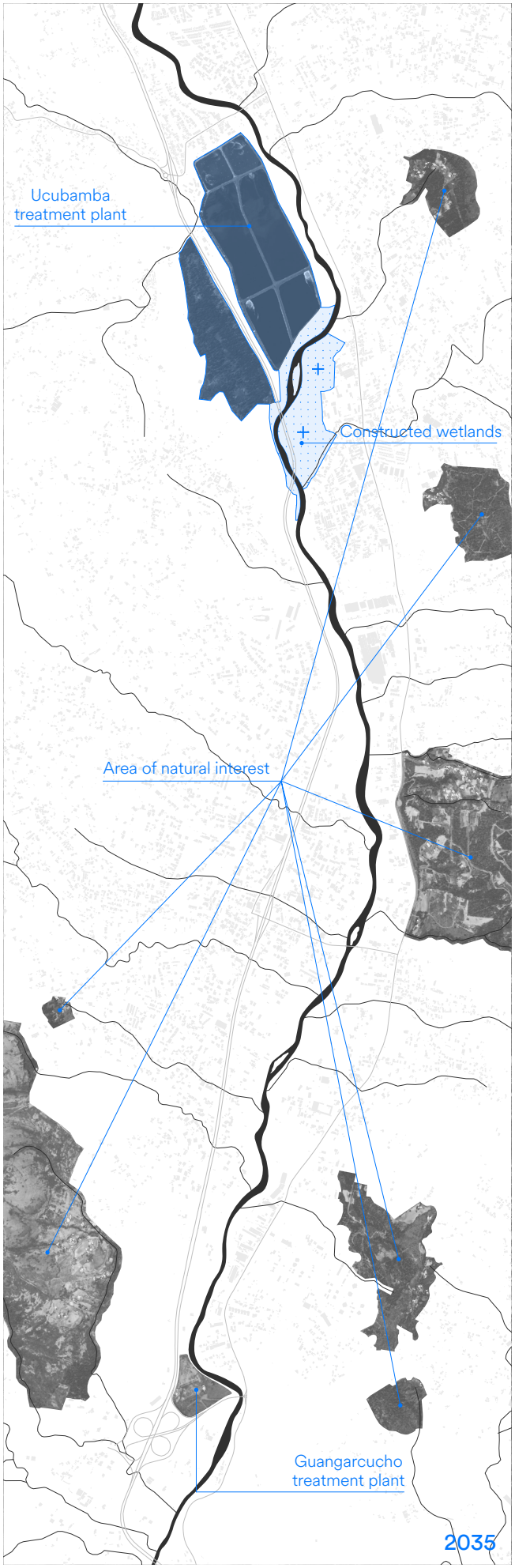
Type B wetland

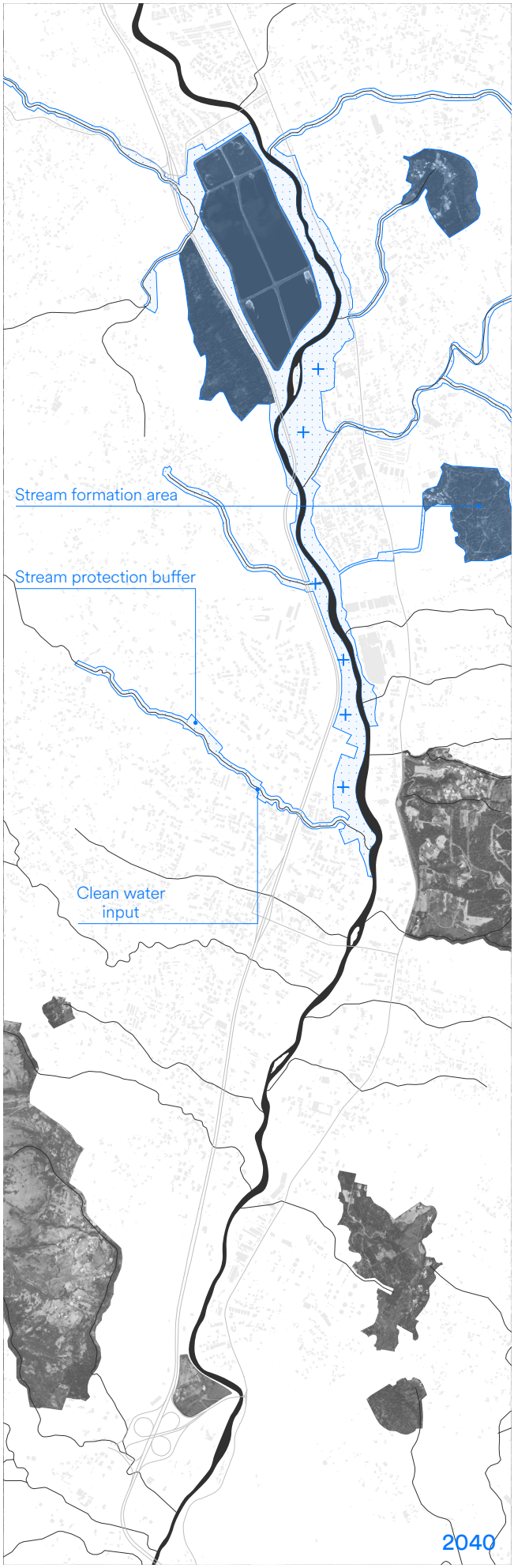


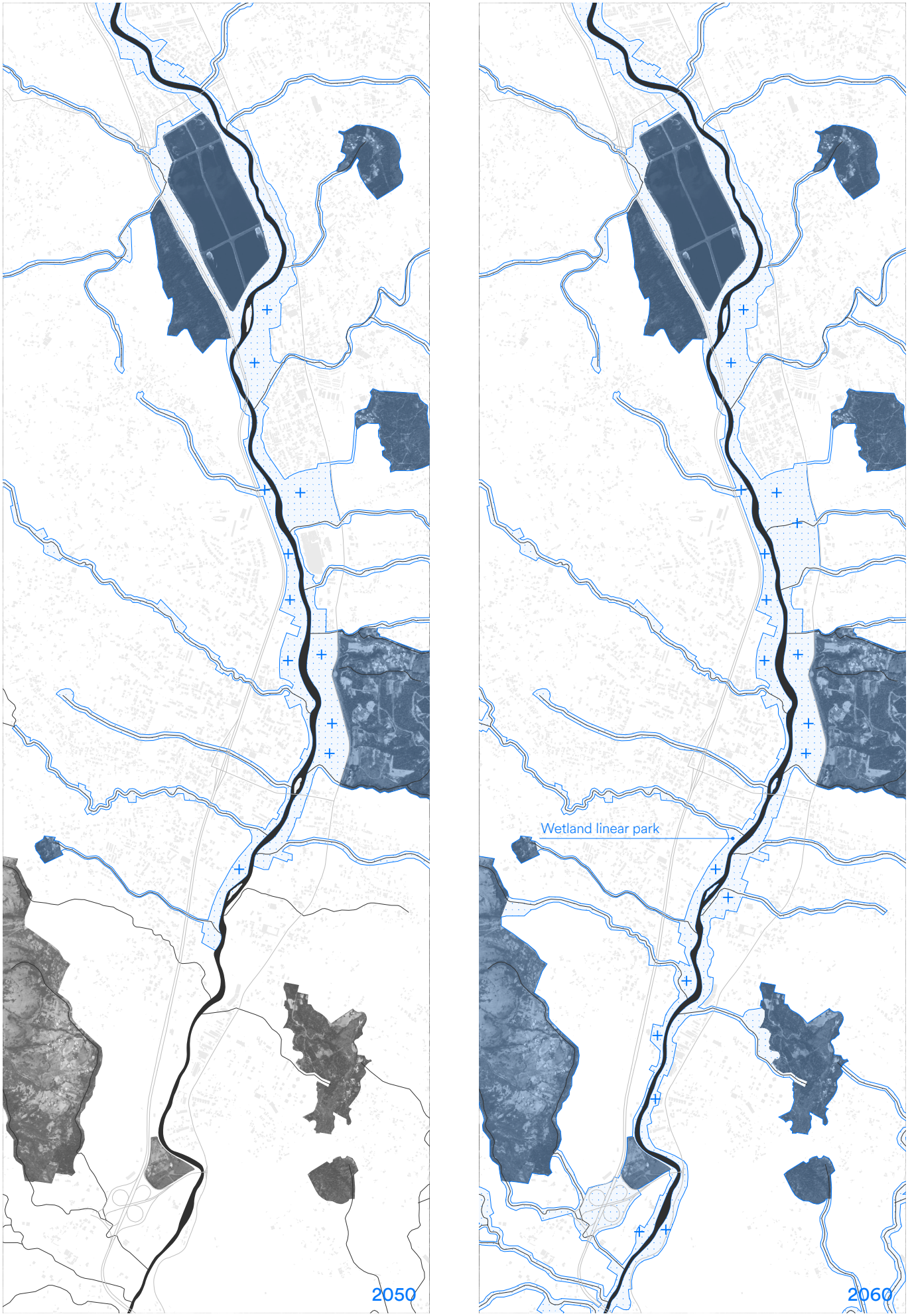
Type C wetland






Ucubamba
treatment plant
Constructed wetlands
Area of natural interest
Guangarcucho
treatment plant
2035


Stream formation area
Stream protection buffer
Clean water
input
2040



↑ Incremental integration of green-blue infrastructure with wastewater treatment and post-treatment infrastructure





↑ Impression of wastewater post-treatment wetlands

5.7 Integratet regional vision

The upscaling of the five strategies to the regional scale of the Paute River basin is based on the key water-related factors influencing the morphology of the territory: land use, slope, and the main watercourses. The main design principle is inspired by Patrick Geddes' 'Valley Section' from 1906. As one of the founding fathers of regional planning, Geddes was one of the pioneers of the support region concept; already in 1906 he wrote 'it takes the hole region to make the city' in one of his publications, acknowledging the urban-rural inderdependency. With this diagram Geddes depicts an ideal regional-urban condition; a scenario in which local economies depend on locally sourced resources and advocates for production models that operate in close relationship to the environmental conditions they develop on.

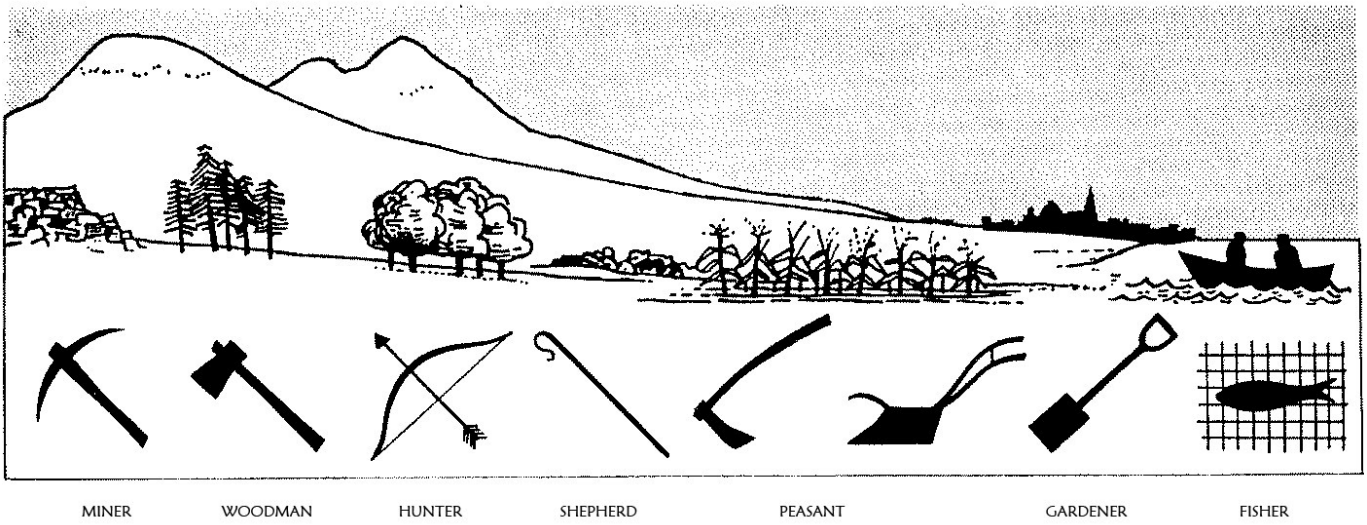
Inspired by Geddes' principle , the division of land uses is reconfigured based on the specific characteristics and opportunities offered by each ecosystem within the altitudinal range, and shaped around the protection of water. This results in a strategy that proposes a territorial division in the form of a gradient.

The highland areas comprising the páramo and sub-páramo rainforest ecosystems, which are vital for water regulation and river formation, have been designated as protected areas. Reforestation initiatives in the sub-páramo forest are taking place in some areas where remaining forest patches can be connected to form a single contiguous area. With the aim of protecting riverbanks and water quality, the gradient establishes a reduction in the intensity of agricultural and livestock use in the highlands, with land use decreasing as proximity to rivers increases. Effluents from areas of greater agricultural use are utilised in the adjacent lowlands through the implementation of catch crops that absorb the nutrients generated in the upper reaches.

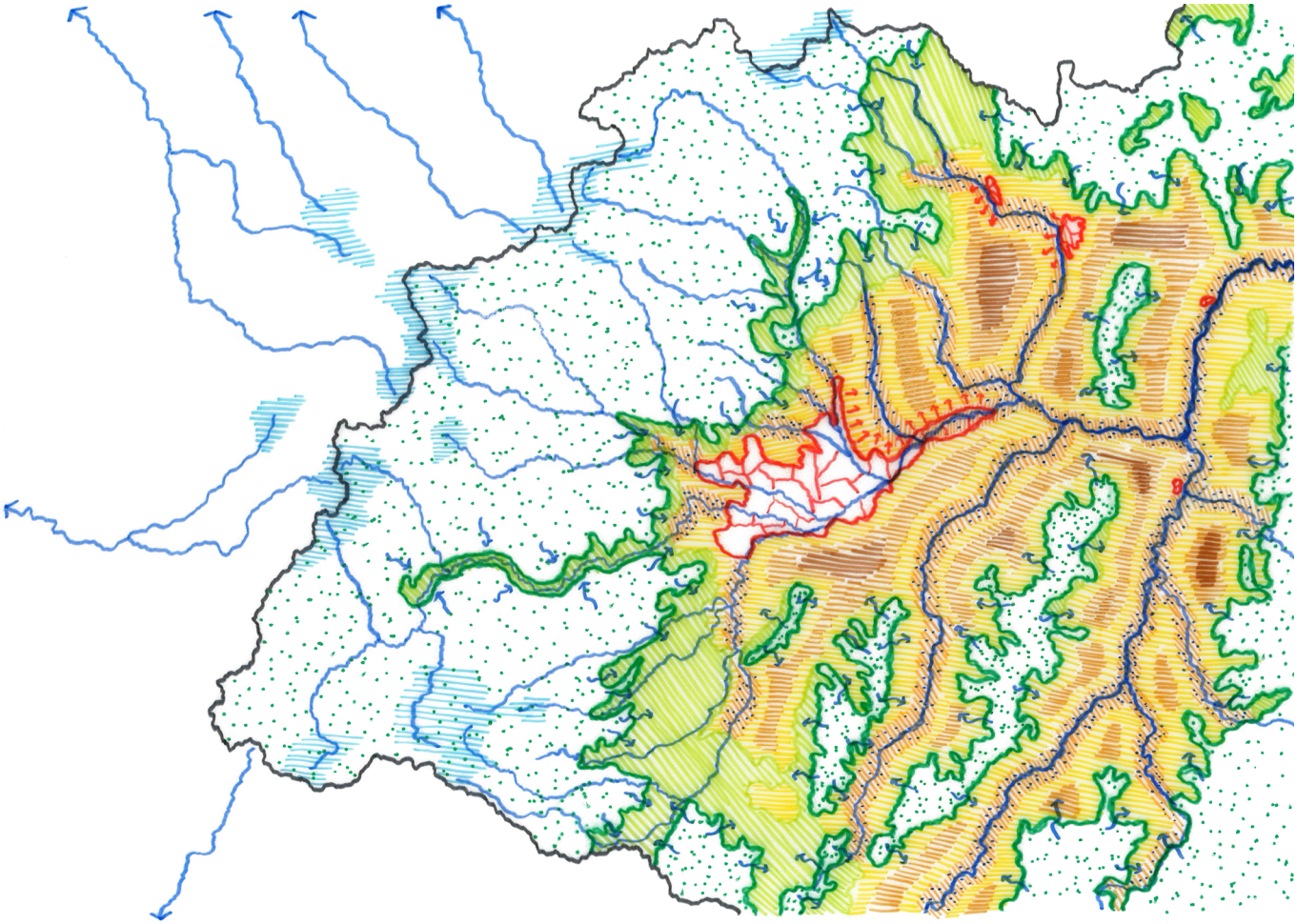
Vegetation buffer strips are created along the rivers, and constructed wetlands are established in the low-lying areas of populated areas. The water harvesting strategy, which makes use of the terrain's topography, is applied with particular intensity in the eastern part of the catchment, where agricultural and livestock farming is most intensive, thereby enabling production to be combined with an increase in the rivers' water regulation capacity.

In the urban areas, cities are subdivided into urban micro-basins for the management and treatment of runoff, and in the higher, protected areas, the new tourism model ensures the continuation of this activity and the protection of the soils along the riverbanks. Urban expansion to accommodate population growth in urban areas occurs first inwards, through a process of urban densification, and as a second resource to accomodate further population growth that will continue to develop, the urban area could expand towards the lower parts of the valley, avoiding the city's growth upwards on the slopes of the Cajas Mountain Massif.

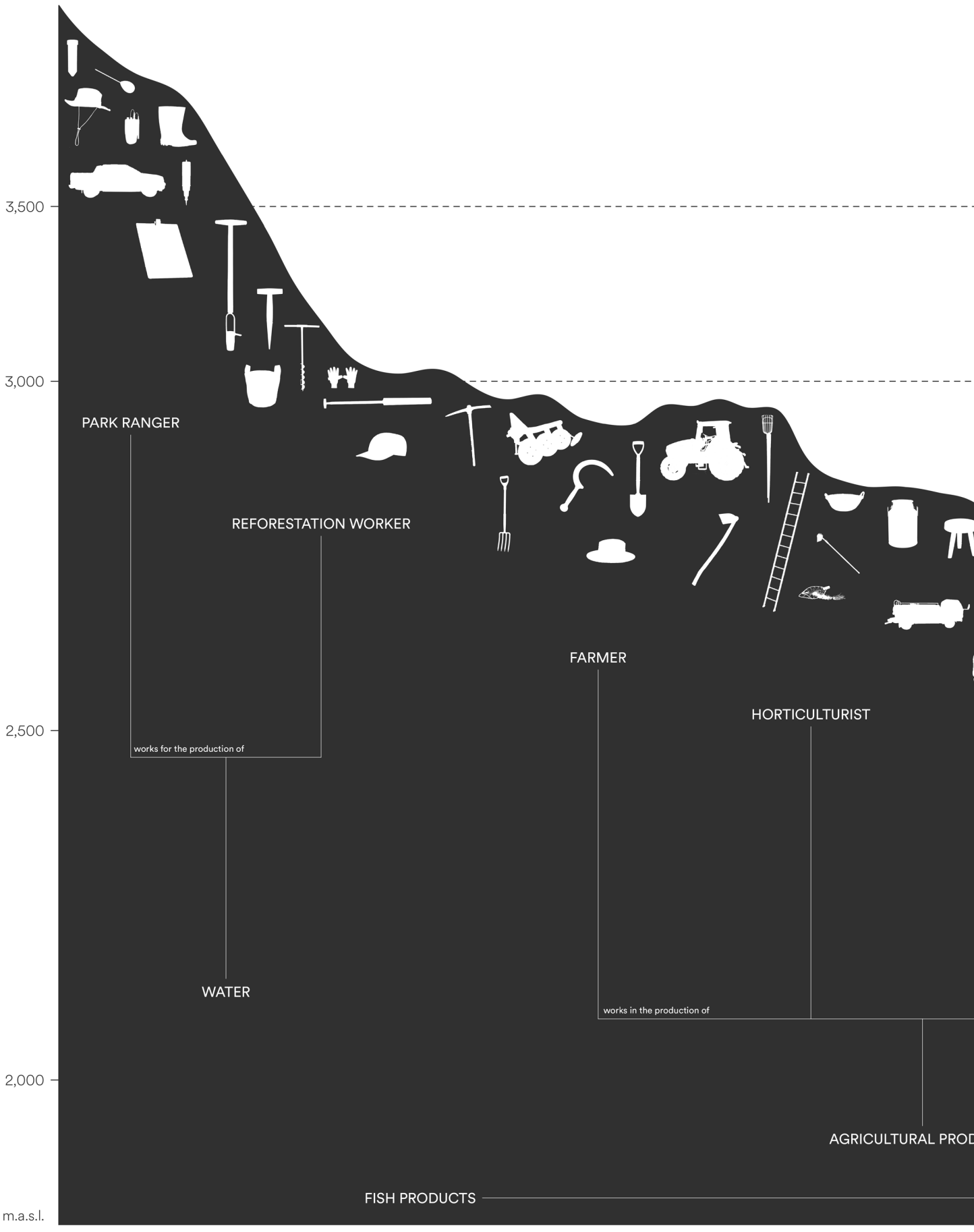
Territorial restructuring creates new opportunities for livelihoods and employment for the region's rural inhabitants, which are consistent with the protection of rivers at local and regional levels, and with the restoration of the water cycle on a global scale.

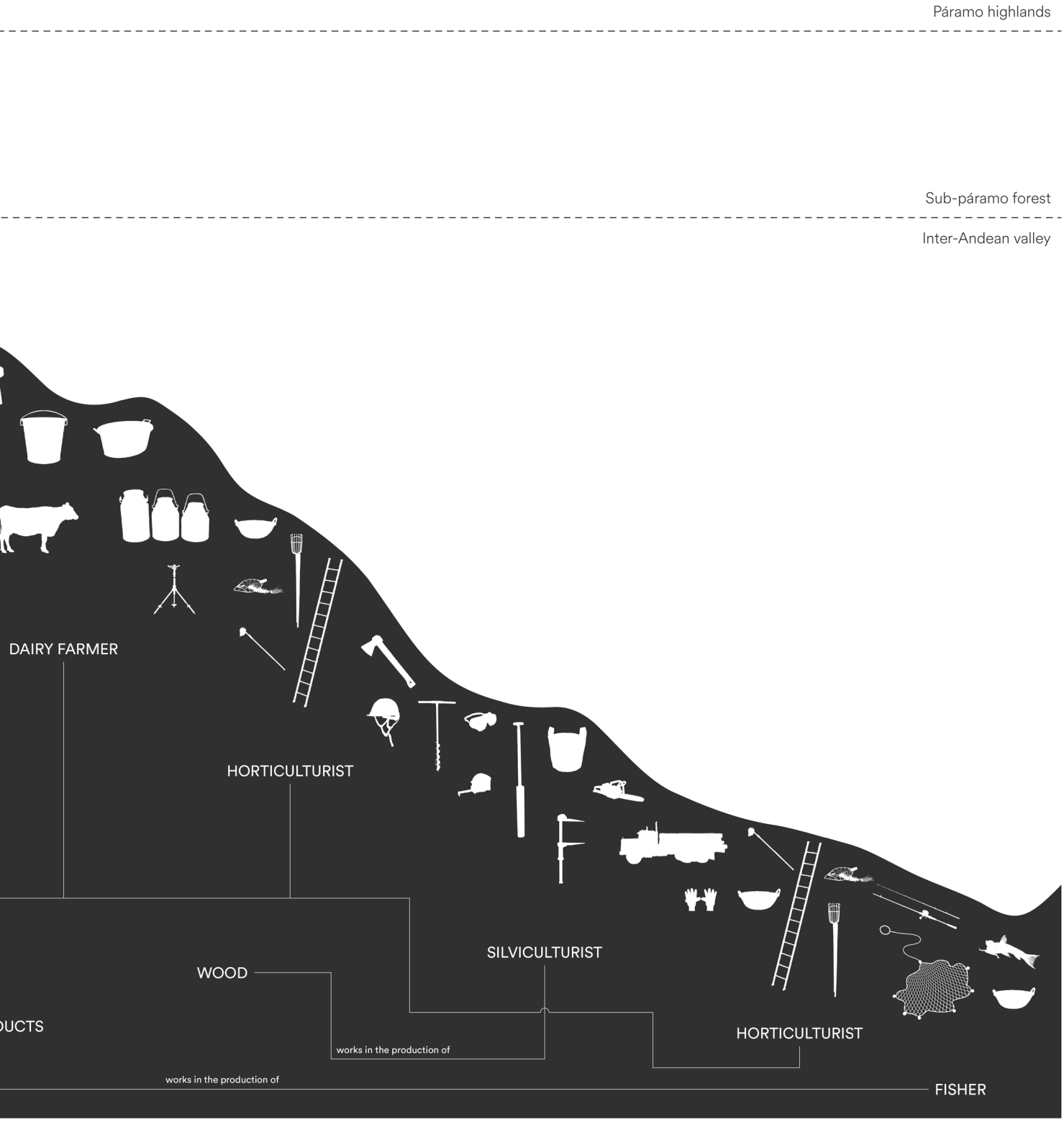


↑ Patrick Geddes' 'Valley Section' (1906)
Source: City Environment

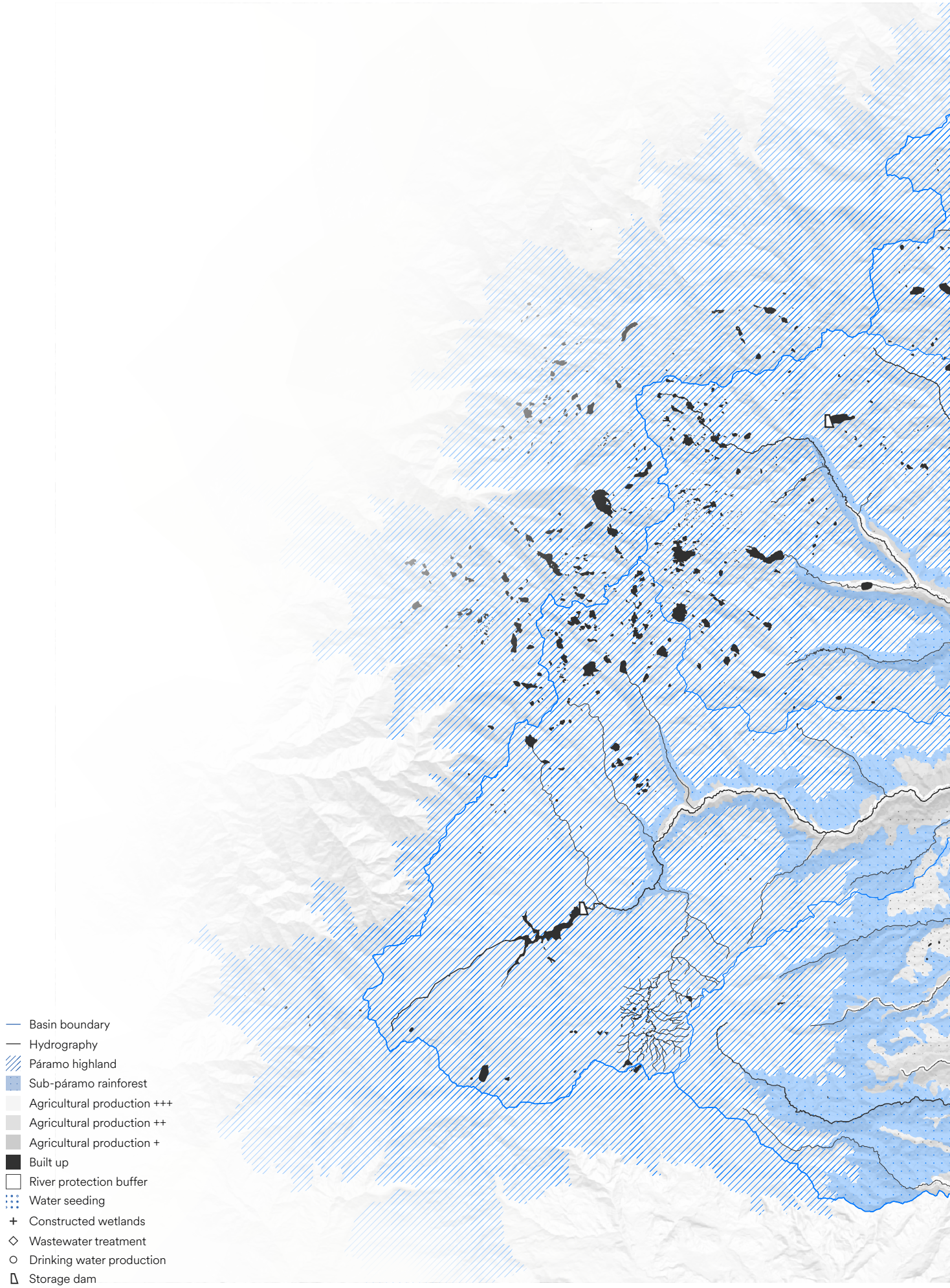


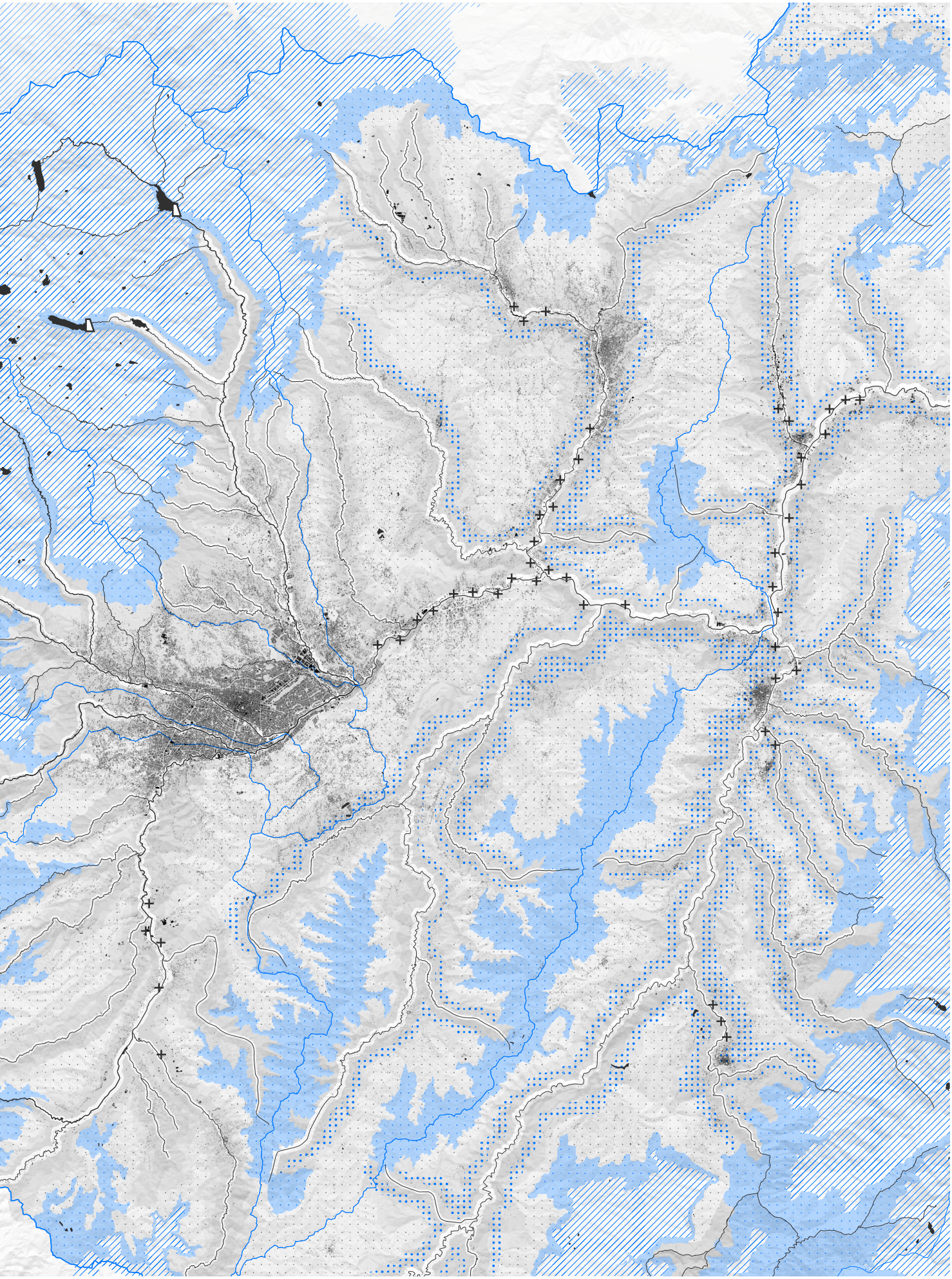
↑ Concept sketch: future vision for the Cuenca region


3,500
3,000
2,500
2,000
m.a.s.l.
PARK RANGER
REFORESTATION WORKER
FARMER
HORTICULTURIST
works for the production of
works in the production of
WATER
AGRICULTURAL PROD
FISH PRODUCTS



↑ Land use definition based on locally available resources and riverscape restoration


Basin boundary
Hydrography
Páramo highland
Sub-páramo rainforest
Agricultural production +++
Agricultural production ++
Agricultural production +
Built up
River protection buffer
Water seeding
Constructed wetlands
Wastewater treatment
Drinking water production
Storage dam
Tourism corridor



↑ Future vision for the Cuenca region



Water from the upper reaches of the Tarqui River



6. Conclusions

6.1 Conclusions

The central argument underpinning the project's approach is based on the recognition that the way water and its associated landscapes are conceived as resources in Cuenca is deeply rooted in a model that is unsustainable over time. A model influenced by the disconnection from nature that characterises the positivist thinking resulting from the modernist boom of the last century, which has spread rapidly across the globe in recent decades, shaping the infrastructure on which modern urban life depends.

Understanding the natural processes that form the global cycle through which this essential resource on which we deeply depend arrives to us, and understanding the ecosystems that form part of these processes, served to establish a yardstick against which to measure the effects of interventions, which also helped to shape them. Through this lens, the project places local environmental conditions at the centre: rather than aiming for a dichotomous approach of 'ecologically informed water management' which suggests the existence of something such as 'non-ecological water management', the intention is to position the landscape, its constituent natural systems and its own dynamics as the fundamental basis and starting point for the design.

In this context, perhaps the most radical aspect of the project lies in the attribution of the character of exploitation to practices that are widely accepted within the context of humanity's modern relationship with water, yet which silently undermine its ecological functions; they deplete it. This opens the door to exploring new ways of interacting with it, in which the reality and local constraints of the context in which the project takes place are established as a calibrating factor that contributes to the conception of an imaginative product that is grounded in real conditions.

This pragmatism seeks to be embodied through the application of an incremental dimension to the project, which suggests the possibility of gradual change at the level of the system as a whole through the exploration of specific interventions, the effectiveness of which depends on certain behavioural changes. To achieve such changes, the interventions seek to move beyond the historical dichotomy between 'countryside' and 'city' or 'urban' and 'natural', recognising that these conceptual entities do not exist in isolation, but are part of a single interconnected and interdependent territorial unit. Hence the emphasis in some interventions on bringing infrastructure to the surface, metaphorically speaking, as a strategy to highlight the costs of the way of life we lead and the ways in which we benefit from nature—costs that may not be directly visible most of the time because they occur in territories beyond the reach of our sight or below our feet, but which, given the interconnectedness of the natural systems on which they are based, sooner or later we end up paying for ourselves.

Whilst the pragmatic essence of the project is based on the recognition of this riverscape as a provider of basic living conditions for thousands of people—and for this very reason seeks to extend the benefits derived from it into the future—acknowledging the unsustainability over time of the models used to harness these benefits implies recognising that a certain degree of change must take place. This means that the way in which

these benefits are delivered and their scope may also vary in the future.

In essence, the project does not seek to further shape the riverscape in order to maintain current uses at all costs within the current context of climate crisis, but rather aims to achieve a model of adaptation through the cration of space for the ecological functions of the local landscape within current usage models, and to turn this into an opportunity to discover the new forms that the new benefits provided by the ecosystem might take while responding to this global crisis. The degree of similarity, or even apparent repetition, between strategies in different locations addressing distinct issues has revealed the enormous potential that incorporating perspectives that aim to the restoration of ecological processes holds as a method for tackling contemporary urban-environmental challenges.

6.2 Reflection

It was essentially the combination of two key factors that prompted the journey that the development of this work has represented. Experiencing first-hand in 2023 and 2024 the effects of the longest droughts in this region's history, with their consequent disruptions to services essential for basic living conditions such as water and electricity, combined with a personal attachment to the land where I was born, shaped the conception of this project. Questions about how the landscape and infrastructure of Cuenca should evolve to cope with the increasingly palpable effects of climate change multiplied and took up an ever-greater space in my mind.

Whilst the outcome of this project outlines one of many possible forms that the answer to these questions might take, the conceptual path to reach them was completely redrawn along the way, resulting in something profoundly different from what was originally envisaged. My starting point, whilst well-intentioned, was also unconsciously anthropocentric, which meant that my main questions regarding the future of this region stemmed from an interpretation of the landscape based solely on human needs, perceptions and interests, assigning it an instrumental value defined by the extent to which changes to it served our purposes as a species.

Growing up in Cuenca meant growing up surrounded by rivers, which, over the years, have become an ever-present feature, their continued existence almost taken for granted. Having been born here 26 years ago, for as long as I can remember the river landscapes have not undergone any major changes. In my mind, they always looked as a normal river should look, and were used as a river should be used; they fulfilled the natural functions of their existence. Green spaces in the city, sources of water, agricultural areas and pastures a little further upstream, and bodies of water receiving urban effluent further downstream.

The insights offered by the Deltaic Interventions study, combined with those gained through an immersion in the critical theory of authors such as María Kaika, Erik Swyngedouw and Jeremy Williams, served as the fundamental theoretical basis upon which a series of activities took place, particularly during the site visit. It was only at this point that I came to understand the true extent of the transformation and infrastructuralisation to which Cuenca's river landscape has been subjected in order to be harnessed to urban—and therefore human—needs, and turned into a socio-ecological system; this was hugely revealing regarding the indissoluble metabolic link between cities and their surrounding regions: consumption sustained by the supporting regions.

My curiosity about the evolution of this region's historical context and the extent to which shifts in eras and ways of life are reflected in the landscape became a complementary tool in this regard, insofar as it enabled me to grasp the scale of the intense wave of transformation that had begun just a few decades before I was born, when Cuenca embraced modernity. Thus, I began to observe conflict and degradation in situations that I would previously have considered inherent to the natural condition of a riverine landscape, which was probably one of the most influential factors in the approach I adopted for the development of this project.

Finding this positioning has undoubtedly been the most challenging overarching task of this experience, because it involves finding one's place within a field that is constantly transforming and reinventing itself due to the need to provide answers to ever-changing contemporary challenges.

The complex web of interactions between the ever-increasing number of disciplines that have become integrated into this field and intersect within it makes this a fluid territory, difficult to define. William Sherman, in his work 'Site Matters', clearly sets out this fluid nature of contemporary urbanism: 'A common concern for ecology has altered design thinking, binding disciplines together in significant new ways. The boundaries that formerly divided areas of design concern have become places of fertile cross-disciplinary invention'. Delving into this field, composed of areas without defined boundaries, has revealed numerous new sources of personal curiosity thanks to this rich interdisciplinarity. From this space, I have been able to glimpse, albeit very superficially, such intriguing fields as ecology and (socio)hydrology, and to construct new interpretations of landscape, infrastructure and their intersection, the study of which has sparked new fascinations previously unknown to myself.

This glimpse into other disciplines that are so crucial to tackling contemporary urban challenges has been as fascinating as it has been humbling. Unlike the conventional figure of the engineer or urban planner in total control—a product of modernism who has shaped the environments we inhabit—positioning myself within this field of undefined boundaries and blurred internal limits has meant recognising that there is very little over which we, as designers without pure expertise in one single field, have real control; this highlights once again the enormous importance of interdisciplinary collaboration in addressing contemporary crises. Thus, defining our role involves knowing how to identify how one discipline can contribute to another in order to capitalise on these partnerships. This can be achieved through processes driven by the design process rather than the final form, based on an iteration between multidisciplinary research and design that serve as tools for the necessary reconceptualisation of infrastructure as an element situated at the sensitive intersection of multiple disciplines.

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