Hidden Water Balances.
Strategies for an Ecosystemic Urbanism in the Vall Baixa of the Llobregat River

Los equilibrios del agua oculta. Estrategias para un urbanismo ecosistémico en La Vall Baixa del Llobregat

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Abstract

In the Barcelona Metropolitan Area, the Vall Baixa territory forms a discontinuous linear city modelled by the logics of geography and water. A historical perspective of the territorial and urban development of this area provides some interesting lessons about the relation between urban form, agriculture and water. Nevertheless, the introduction of modern mobility infrastructures since 1970 and some subsequent invasive urban developments have caused substantial changes in the "liquid" balances of this territory. An analysis of the current situation suggests some strategies for continuing to enhance the water cycle in this metropolitan fragment, which has recently undergone successful recovery of the riverbed. Through combined strategies of artificialization of water systems and naturalization of the landscape, the importance of "hidden" water that nourishes the aquifer is highlighted as a fundamental element that should guide some urban projects to upgrade the territorial metabolism.

Keywords

Vall Baixa – Llobregat – Territorial Metabolism – Water Cycle– Urban Projects.

Resumen

En el Área metropolitana de Barcelona, el territorio de La Vall Baixa conforma una ciudad lineal discontinua modelada por las lógicas de la geografía y el agua. La perspectiva histórica de su desarrollo territorial y urbano ofrece algunas lecciones interesantes sobre el buen entendimiento entre la forma urbana, la agricultura y el agua. Sin embargo, la implantación de las modernas infraestructuras de movilidad a partir de 1970 y algunas extensiones urbanas invasivas derivadas han comportado cambios sustanciales en los equilibrios "líquidos" de este territorio. El análisis de la situación actual sugiere algunas estrategias para seguir con la mejora del ciclo del agua en este fragmento metropolitano, que ha experimentado recientemente una exitosa recuperación del lecho del río. A través de estrategias combinadas de artificialización de los sistemas de agua y la naturalización del paisaje, se apunta a la importancia del agua "oculta" que nutre el acuífero como un elemento fundamental que debiera guiar algunos proyectos urbanísticos para la mejora del metabolismo territorial.

Palabras clave

Vall Baixa – Llobregat – metabolismo territorial – ciclo del agua– proyectos urbanísticos.

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Water and landscape engineering

Through an interaction between urban constructions and the water cycle, the water-urban dialogue has been the raison d'être of many territories since the origin of some civilizations (Ranzato, 2017). The construction of waterscapes, or water landscapes, has played a key role in history in shaping cities and societies (Swyngedouw, 1999).

However, the transition from pre-industrial to industrial society entailed a radical paradigm shift, when urban centres broke their dependence on the biophysical environment and moved from circular management of metabolism to a linear model (Cuchí, 2014). In this context, exploitation of water resources was at the service of urban centres based on the conviction that the water cycle could be totally controlled (Cosgrove, 1990). This was about *engineering* the landscape to obtain resources beyond the urban bio-region (Monstadt, 2009) through a progressively sophisticated system of supply and drainage infrastructures.

This systematization, which sought to guarantee universal access to water for citizens, has undoubtedly been a source of comfort and considerable progress. However, recent episodes linked to the climate crisis show that the reductionist approach of this network puts the model itself in crisis (Nolf and De Meulder, 2017). The water cycle is rationalized in such a way that, while meeting day-to-day needs, it generates management problems in extreme episodes.[1]

At this point, we must ask ourselves which paradigms should be adopted in the future to achieve responsible resource management that maintains the balance between ecosystems (Ranzato 2017). *Integrated Water Management* is a new approach that includes the various dimensions encompassed by the water cycle, as opposed to a universalized infrastructure system associated with the industrial model, where the context and the social and spatial components become the reference points (Mitchell, 1990). From this perspective, the debate becomes a matter of urban planning, urban design, landscape, spatial planning and risk management, as in some seminal works, ideological manifestos and more theoretical approaches. These include Frederich Olmsted's landscape and ecology projects, Patrick Geddes's synthetic understanding of the section of the valley, or Ian MacHarg's need to *design with nature* on a large scale.

The Vall Baixa del Llobregat in the metropolitan area of Barcelona, a territory built from water

Water has played a prominent role in the construction of metropolitan Barcelona. Besides the sea and the mountains, two rivers delimit the plain where the city is embedded. To the north, the force of the Besòs river once formed a delta that was subsequently drained and urbanized.[2] In contrast, to the south, the mighty waters of the Llobregat river produced another type of urbanization that was more natural with a greater presence of geography in the formation of the "Vall Baixa" (Lower Valley) and the still splendid "Delta del Llobregat".

The transformation of the territory of the Vall Baixa, which is secluded from the urbanizing force of central Barcelona, has been a constant subject over the decades with great expectations for the future of the metropolis, due to its topological and environmental characteristics and accessibility. Manuel de Solà-Morales (2000) eloquently described its status:[3] *"(…) the future metropolis also has its Passeig de Gràcia, the organizing backbone of its growth. The bed of the Llobregat, a humble but insistent river, a flat and shocking river, is destined to become the great central open space of urban Catalonia. (…) An agricultural, green, open avenue. An up-to-date version of what a Boulevard could be (…)."*

1 The most recent case in the local context is Gloria storm that took place on 19 January 2020 and was the most violent that Spain and the south of France have suffered since 1982.

2 Some evidence of this historical episode can be seen in the form of chimneys of factories that used to take advantage of water from the phreatic zone and a subway station called "Llacuna" (lagoon in Catalan) that evokes the landscape that once existed there.

3 Solà-Morales, Manuel de, "Un Altre passeig de Gràcia", in *Arquitectes en el paisatge,* Joaquim Español, ed. (Girona: Col·legi d'Arquitectes de Catalunya, Demarcació de Girona, 2000) p. 116.

Numerous studies have described the value and identity of this precious territory, from its geographical characteristics (Eizaguirre, 1988), the value of its agriculture (Sabaté, 2004), its socio-political connotations in the metropolitan framework (Vila, 2004) and its urban development and planning (Font, Llop and Vilanova, 1999; Torres Capell, 1999).

Based on these previous contributions, this article aims to offer a new vision of the territory through a systematic analysis of a 12 x 12 km area along the diagonal of the river course. Water logics are analysed by creating new maps, observing the characteristics and parameters of current functioning, comparing them with the logics of previous stages in the transformation of the territory, and envisaging future paradigms. For this reason, the graphic analysis is carried out at different scales, from an overview of the territory to urban detail.[4] Plans, sections and axonometries are the graphic instruments of representation and conceptualization that guide the development of the research.

The Vall Baixa del Llobregat can be defined as a hydric unit located between the Cubeta de Sant Andreu and the Delta del Llobregat. Its length is approximately 11 km. It is located at the intersection between the coastal mountain range (Collserola and Garraf) and the lands from the river, which define a strategic corridor packed with infrastructures connecting the plain of Barcelona with the inland territory. Slopes, water courses, roads and terrain topography have been modified by the uninterrupted action of humans throughout history (Eizaguirre, 1988).

For centuries, these actions were aligned with natural cycles. However, during the great urban growth derived from the industrial revolution, these cycles were altered by expansive urban dynamics. The urbanization derived from this anthropization process has a series of pernicious effects on the water cycle, which are associated with deforestation, impermeabilization of the soil and the construction of large infrastructures (Solé i Perich, 1996). Deforestation due to small fires or indiscriminate logging increases soil runoff, which leads to erosion of slopes and a large proportion of solid materials in the flow of swollen rivers. Urbanization causes almost total impermeabilization of the soil, which increases the runoff coefficient by up to 100%. The construction of large infrastructure alters the natural drainage of the land, making it difficult to pass or creating an obstruction.

The preservation of the river void in the metropolitan magma

The well-known *Geological and Topographic Map of the Province of Barcelona*, by Dr. Jaume Almera (1891),[5] is an eloquent document to understand this territory from the perspective of water. It depicts urban settlements at the turn of the century, as well as the main connections and streams and over this, overlapping it on the typology of soils that comprise the geology of the territory in the Barcelona region.

Three types of soil define the Vall Baixa: a first stretch of silt formed by alluvial lands that the river drags along the Quaternary, with a constant slope from the town of Papiol to the sea; a second limestone terrace of dry land, with a gentle slope; and rocky terrain corresponding to the Collserola and Ordal ranges. On this geological basis, the territory is organized in strips parallel to the river, with a central floodplain and a series of urban centres connected to each other along the perimeters in the foothills of the two mountain ranges.

The value of the valley as an empty space is highlighted in Rubió i Tudurí's *Regional Planning* proposal (1932),[6] which is directly related with the current structure of the Barcelona metropolis. The understanding of the city as an element within a large-scale landscape system led to preservation of the Collserola range as an extensive central green space. This reserve was complemented by the Llobregat Delta and

4 The graphic information sources are the *Base Topográfica* 1:5000 from the Institut Cartogràfic i Geològic de Cataluna-ICGC *Mapa Topográfico* 1:1000 del Área Metropolitana de Barcelona (AMB).

5 The original document is available at the Institut Cartogràfic de Cataluya (ICC) and in open access on its digital map library *https://cartotecadigital.icgc.cat/digital/collection/catalunya/id/2174*

6 In October 1931, the re-established Government of Catalonia entrusted Nicolau Maria Rubió i Tudurí with the *Anteproyecto de Plan de Distribución en Zonas del territorio Catalán*. The architect unveiled a decentralized vision of the Barcelona agglomeration influenced by the prevailing theories of Anglo-Saxon regional planning and the garden city, and from this perspective proposed the *Catalunya-City* (Ribas-Piera, M. 1995).

the Vall Baixa as agricultural reserves that could supply the future metropolis. The plan conceptualized the idea of a corridor structured in specialized areas parallel to the river, with the riverbed maintained as a productive space and road connections situated on a territorial scale on traces of existing roads. Thus the plan proposed the establishment of a garden city between these areas and the green space of Collserola.

Subsequently, the County Plan *(Plan Comarcal,* 1953), which was the first planning document on what would be called the Barcelona Metropolitan Area,[7] emphasized an asymmetric arrangement of this territory, both in relation to mobility and the urban continuity of the metropolitan core. The definitive consolidation of the territory's metropolitan nature would be determined in successive metropolitan plans: the *Plan Comarcal* of 1953, followed by the Metropolitan Master Plan (*Esquema Director del Área Metropolitana*, 1966) and the definitive and still valid General Metropolitan Plan (*Plan General Metropolitano,* 1976), which established the organization scheme of the central space of the Vall Baixa. In the succession of proposals, the space for agriculture was reduced with a progressively residual role, until the territory was considered a mere support element (Sabaté, 2004).

It was not until recent times that the Delta and the Vall Baixa were considered highly profitable agricultural territories and were included in the Special Plan of the Agrarian Park *(Plan Especial del Parque Agrario,* Joaquim Sabaté et al., 2004). This plan sought to guarantee the stability of the agricultural territory (4,000 ha) in a densely populated environment, in an effort to reconcile private interests related to economic performance associated with agricultural production and public interests related to environmental and landscape services. A few years earlier, what was known as the *Corporación Metropolitana de Barcelona* had already highlighted the value of these soils with innovative studies on the territorial construction of the Vall Baixa (Eizaguirre, 1988). These works describe the territory as a "built artifact" and precisely define the roads and water channels as the true infrastructure of the territory, drawn with the logic of maximum use of resources, which supports the current approach to urban metabolism.[8]

The construction of the territory from the water

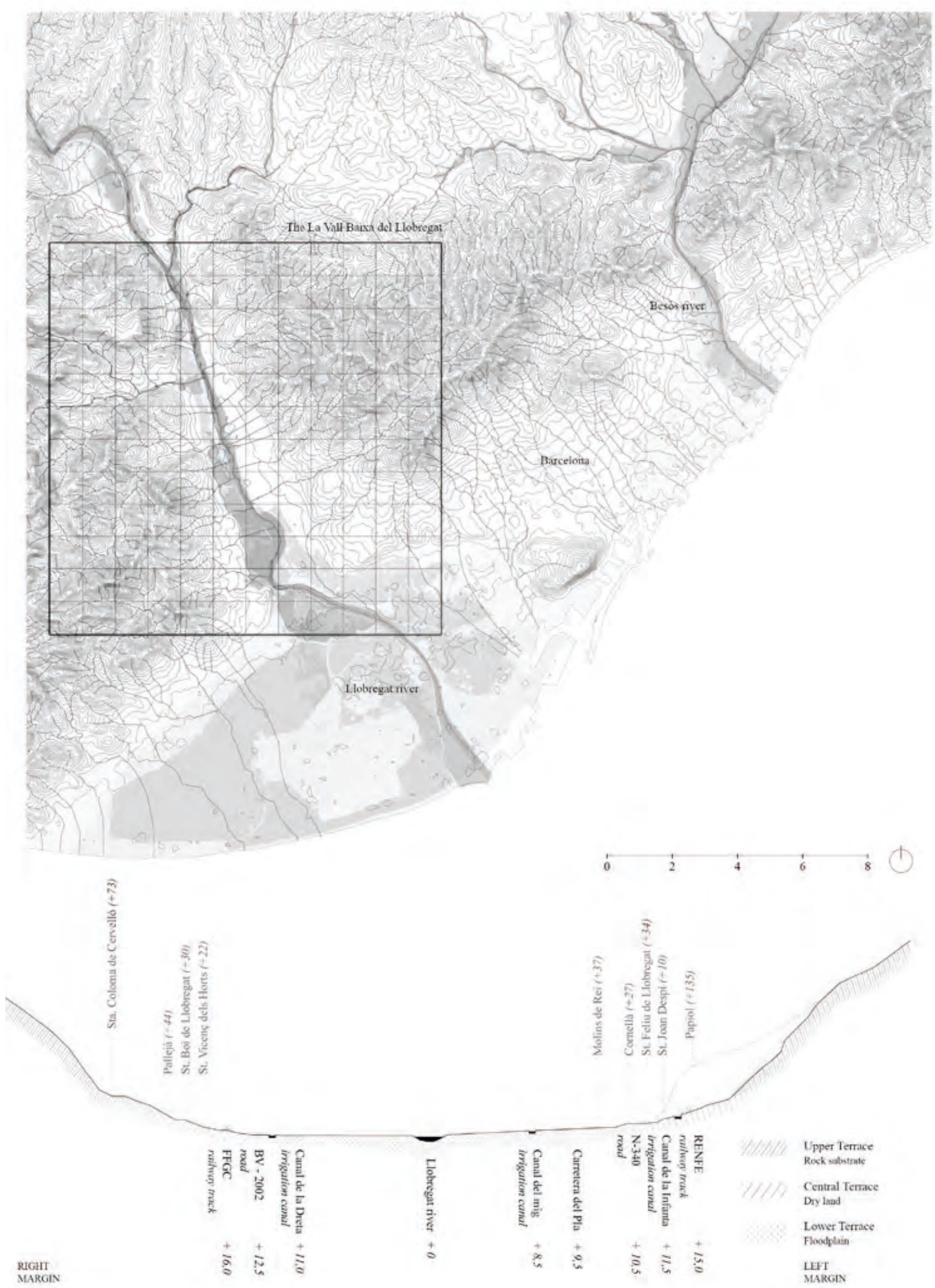
The V-shaped valley hides a marked asymmetry in the Vall Baixa, defined by the opening of the left bank towards the plain of Barcelona at the height of Sant Feliu, where the river forms a double meander before reaching its mouth in the delta. The entrances to the valley are also asymmetrical: the eastern margin is comprised of several entrances of similar dimensions, while on the western margin there are fewer but larger ones. This topographic relief modifies and determines the way in which runoff water moves transversely along the valley, defining streams of different dimensions.

The valley's urbanization occurs at the confluence of two longitudinal and transversal lines, which reflect a certain global and local condition. The valley has historically been a place that must be passed to connect Barcelona and the peninsular territory. At the same time, it is a space quickly colonized by small urban centres. The logics of the water are equally important to both, and it is crucial to determine the invisible line that marks the flood area. Fig. 1.

The first settlements are located in relation to the inflection line between the flood plain and the central space defined by very gentle slopes of the alluvial lands. Right on the foothill line, called *Samontà*, was the first Roman road that crossed the river at the height of Martorell (*Pont del Diable* bridge). This was also the reference for the establishment of urban centres, at points where perpendicular water courses (streams) intersected with this line and facilitated vertical displacements within

7 Also known as the *Plan de Ordenación de Barcelona y su Zona de Influencia*, promoted by Barcelona City Council and influenced by the greater European plans. The plan established the main arteries for the entire metropolitan territory and defined its zones and systems. In the area of the Vall Baixa, the plan highlighted some of the future industrial zones and imagined a certain development in an "extensive suburban" area around the historic centres. On the left bank, the industrial land would provide urban continuity between Sant Feliu and Molins de Rei, while Sant Joan Despí and Cornellà were transformed into a continuous conurbation. On the right bank, a lower hierarchy road connected the existing urban centres, where weak residential development was expected in the space between Santa Coloma de Cervelló, Sant Vicenç dels Horts and Pallejà. At the upper end, new industrial areas occupied the floodplain at the historic junction of Molins de Rei and Quatre Camins.

8 "*The use of these terraces begins with construction on their upper limit, that is, at the point of inflection of the relief of the mountains with the alluvial lands, the riverside roads, the irrigation channels, the settlements of populations in the upper part and, later, the railways. Based on these lines, the Vall Baixa has been structured throughout the various transformations that man has made to these lands. These two paths, parallel to the river, are the infrastructural base of the colonization of the lower terraces that is carried out with a double orthogonal structure, the paths to the river and the irrigation branches. This produced compartmentalization of the Vall Baixa in elongated strips limited in the headwaters by the road and the river.*" Eizaguirre, X. 1990 *Los Componentes formales del territorio rural*, doctoral thesis, p 187-188.

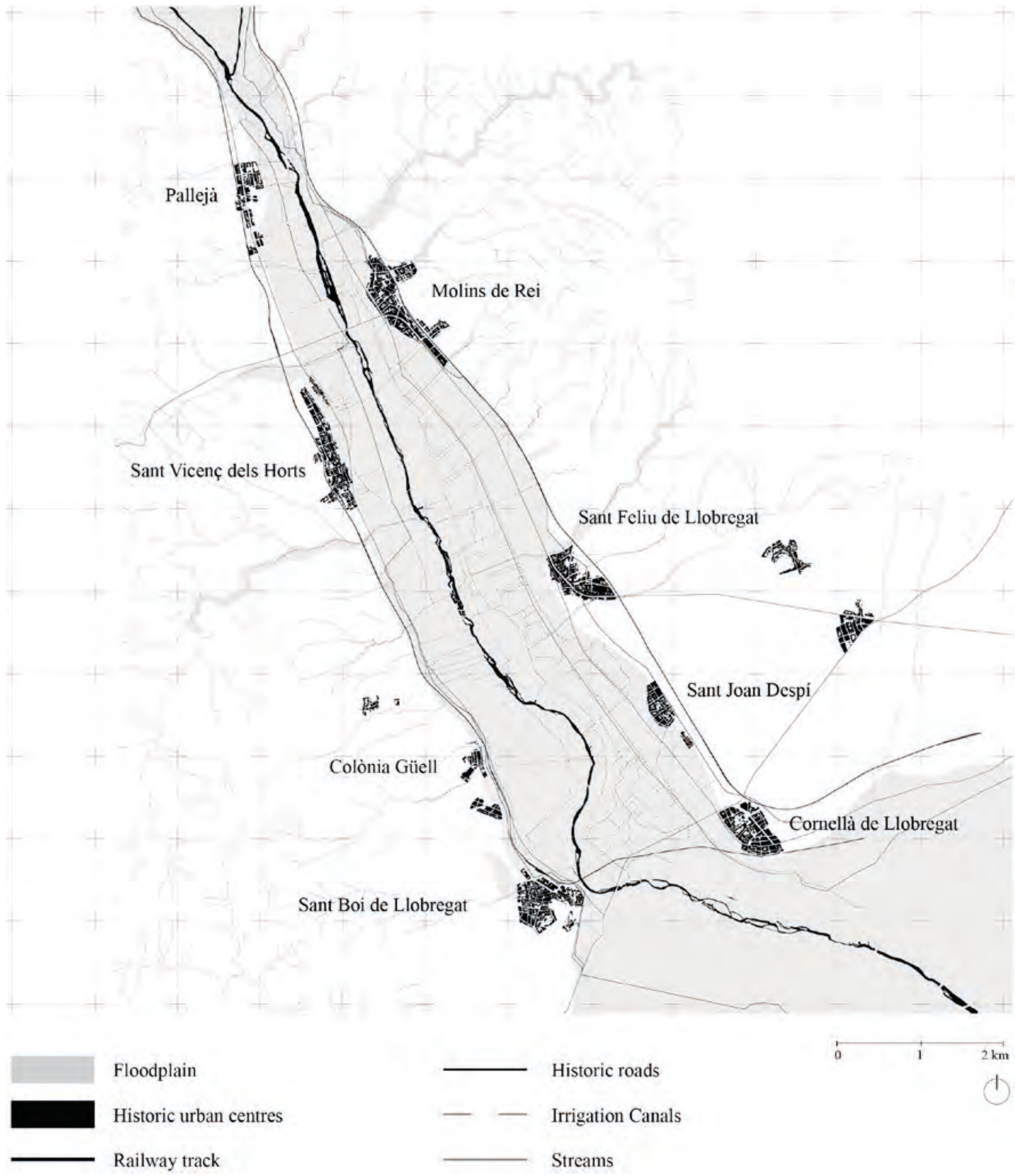


[Fig. 1] The Vall Baixa, territorial situation and cross section. Prepared by the authors.

the valley section. Located at a safe level, proximity to the floodplain was always essential, not only because of the softer topography soils, but also because of the large areas of fertile land suitable for cultivation. The conversion of the central void into a large productive space was made possible by controlling water for irrigation with the construction of two large channels: the *Canal de la Infanta* (1820) and the *Canal de la Dreta* (1855). Upstream, the locks lead the river water to the level of the *Samontà* and from there irrigate farmland following ancient irrigation techniques.

The roads and their progressive implementation also highlight the asymmetry of the Vall Baixa. The Roman road was followed by the N-II road from Madrid to France. A new bridge was constructed in Molins de Rei over the Vallirana Stream, to connect this area with Garraf and on to Vilafranca. Later this road was connected with Sant Boi and new bridges were built to reach the right bank. Both routes are located on the second terrace (at a relative elevation between 10 and 12 m with respect to the riverbed) and were built with criteria of efficiency and safety to connect urban centres. (Fig. 2).

In addition, the nineteenth- and twentieth-century railway lines were laid in relation to the logics of water. They were placed on the upper level of the *Samontà*, on land

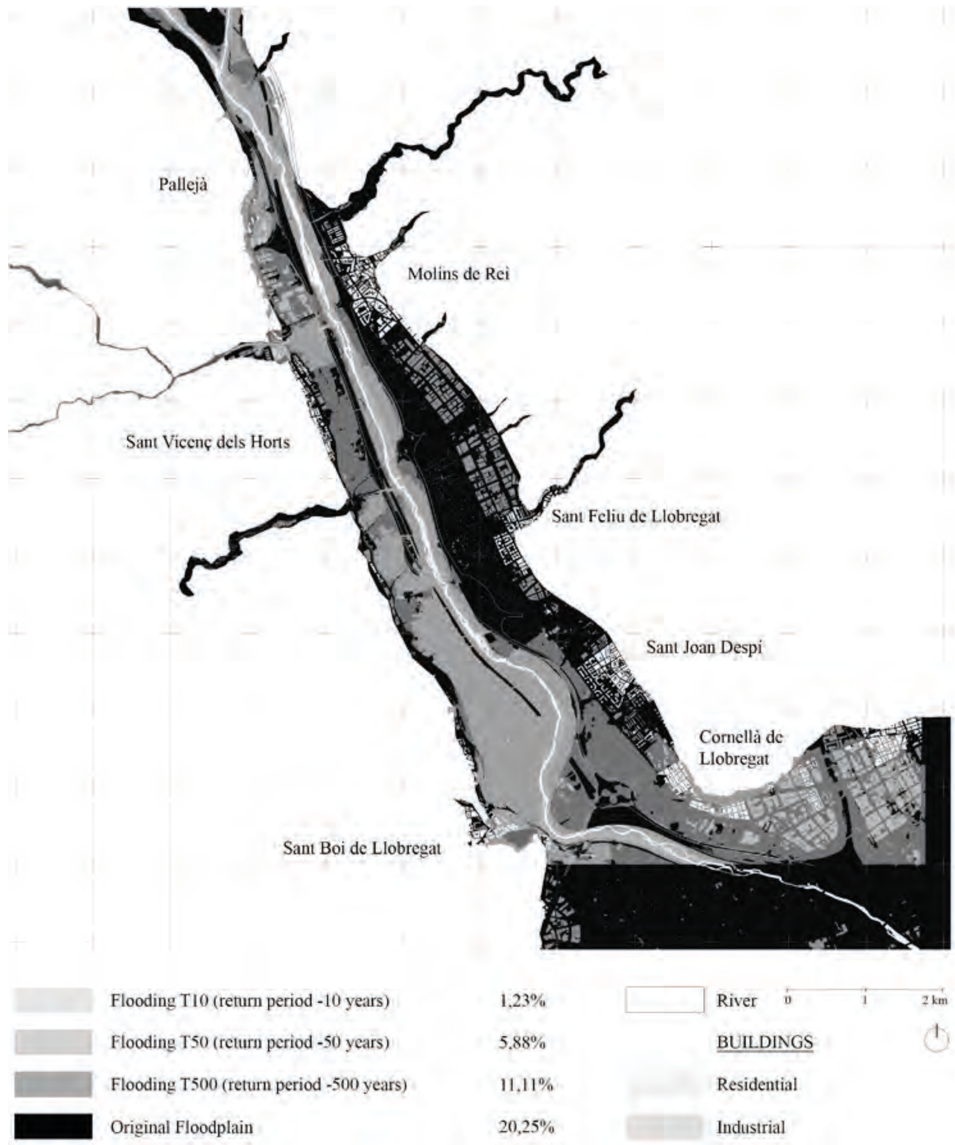


[Fig. 2] The territory of the Vall Baixa at the beginning of the twentieth century. Prepared by the authors. Data extracted from *Instituto Cartográfico y Geológico de Cataluña* (ICGC) and the *Mapa Geológico y Topográfico de la Provincia de Barcelona* (Almera 1891).

with little inclination that is with a slope of less than 2%, but safe from floods. The route of the railway was tangential to the original urban centres (organised around the historic roads) and is part of a set of transversal connections along the valley that is linked to a specific elevation (15 meters in relation to the riverbed). Later, the appearance of industrial settlements such as Colonia Güell (1890) indicates how the same territorial logics remained valid until the mid-twentieth century, when the definitive change between organic society and industrial society would take place in this territory.

The anthropization of the riverbed

The main turning point in the urbanization logic came with the construction of large infrastructures for wheeled mobility, which were located over the intact riverbed. Following the plan of the Ministry of Public Works' basic road network (*Red Arterial Básica para el Área de Barcelona*, 1963), the infrastructure in the Vall Baixa was modernized with the addition of the new A2 motorway, opened in the Barcelona-Molins de Rei section in July 1969. Occupying the left bank of the river, the current B23 (also called the E90) is one of the highways with the highest traffic intensity in the metropolitan area.



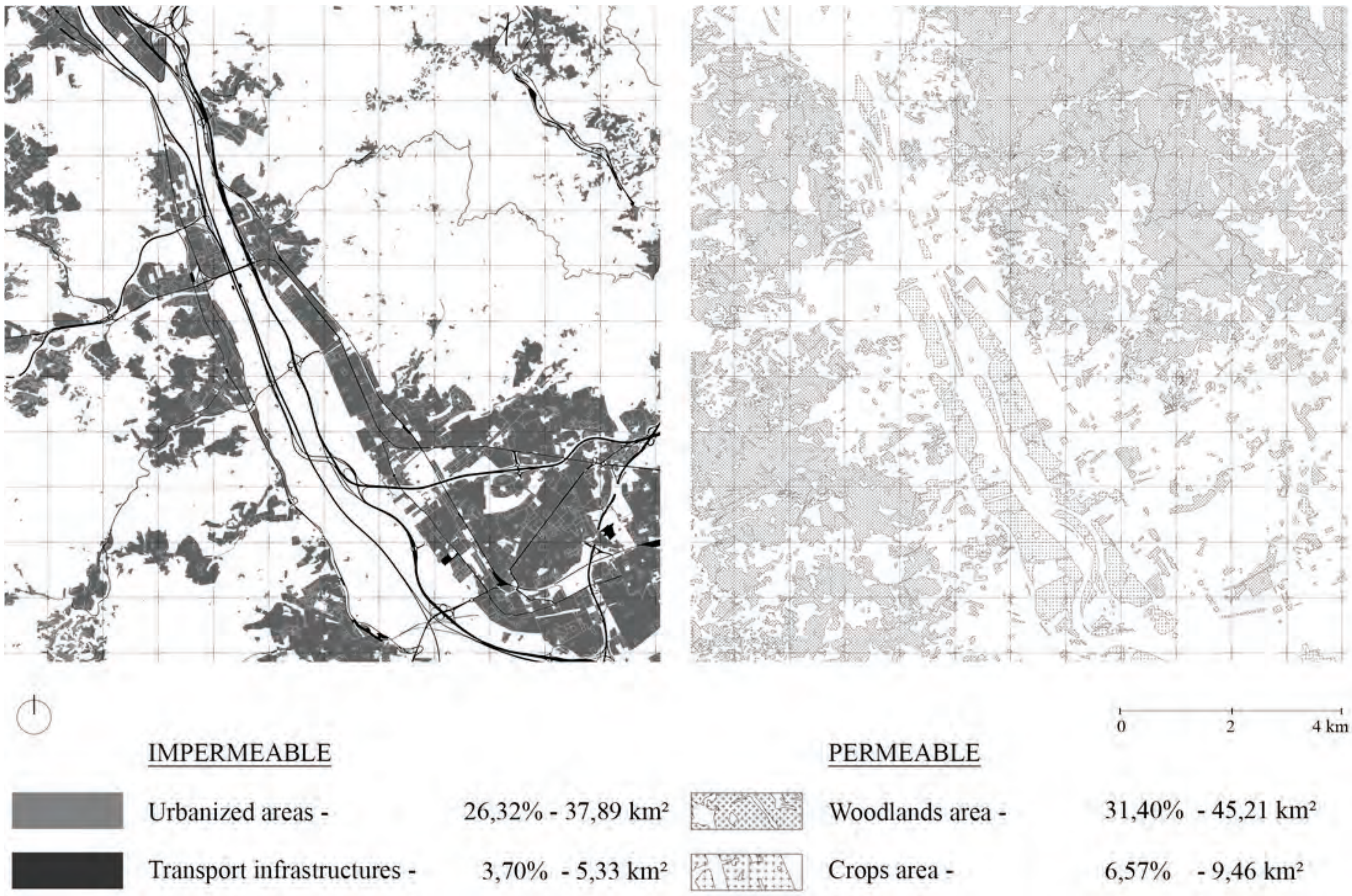
[Fig. 3] Floodplain modification. Prepared by the authors. Data extracted from the *Instituto Cartográfico y Geológico de Cataluña* (ICGC) and the *Agencia Catalana del Agua* (ACA).

In December 1998, the parallel highway, the Autovía del Baix Llobregat, which is now the current A2, was launched with a 19-km section that linked the Martorell-Igualada stretch with the post-Olympic Ronda belts, after crossing the river at the height of Sant Feliu. Finally, the arrival of the high speed train in Barcelona 2008 was resolved by inserting a last parallel stretch, next to the highway, which confirmed the scheme of diachronic asymmetry in the construction of the valley.

These infrastructures are built on slopes that interrupt the original section of the valley, and become real dikes that retain overflowing water if the river course floods, preventing total flooding of the main riverbed.[9] The engineering work that protects urban centres from rising waters led to the fixing of permanent transversal barriers that are poorly traversed with elementary fauna crossings.

This radical modification of water behaviour along the valley allowed urban growth on previously floodable territories and accentuated the asymmetry between both margins. On the left, the riverbed became a continuous urbanization with construction of the industrial area *El Pla*, which connects Sant Feliu de Llobregat with Molins de Rei. In addition, high-density residential growth has filled the river frontage of urban centres. On the right bank, a more discontinuous structure is maintained, with low-density residential developments on the slopes of the mountain, as well as the growth of pre-existing urban centres into previously flooded lands. From the *Quatre Camins* crossing to the north, industry has invaded the riverbank, taking advantage of the privileged plains.

9 An illustrative example of this situation is the effects of overflows of the Llobregat river in 1971, when the section of the Molins de Rei-Barcelona motorway had been built. The dike effect of the built infrastructure caused flooding of the Almeda neighbourhood, in the municipality of Cornellà, according to Oleguer Bellavista's chronicles: (…) *Another important cause of the terrible floods of 1971 is the construction of the Martorell motorway which caused a narrowing of the natural margin of the Llobregat river. The engineers who planned and built it did not foresee that the highway would act as a retaining wall for the river's waters and would cause, when overflowing, a much greater flood in the city of Cornellà. Before the construction of the highway, when the river overflowed, in the first place it flooded a large area of orchards that extended from Molins de Rei to Cornellà, this, obviously, reduced the strength of the waters* (...) Bellavista, O. (1995), *Evolución de un barrio obrero: Almeda-Cornellà*, Barcelona, Editorial Claret (translation by the author).



[Fig. 4] Impervious territory. Prepared by the authors. Data extracted from the *Mapa de Cobertes del Sòl* (MCS), from the *Instituto Cartográfico y Geológico de Cataluña* (ICGC).

The quantitative dimensions of these changes can be summarised with some data[10]: the floodable area in the central space has been reduced by almost 50%. In square kilometres, it has dropped from 29.16 km^2 (20.25% of the analysed territory) to an area of 16.00 km^2 (11.11%), which corresponds to the flooded area of the return period of 500 years (T500). The *Agència Catalana de l'Aigua* (ACA) also defines the return periods of 50 years (T50: 8.47 km^2, 5.88%) and 10 years (T10: 1.77 km^2 and only 1.23%).

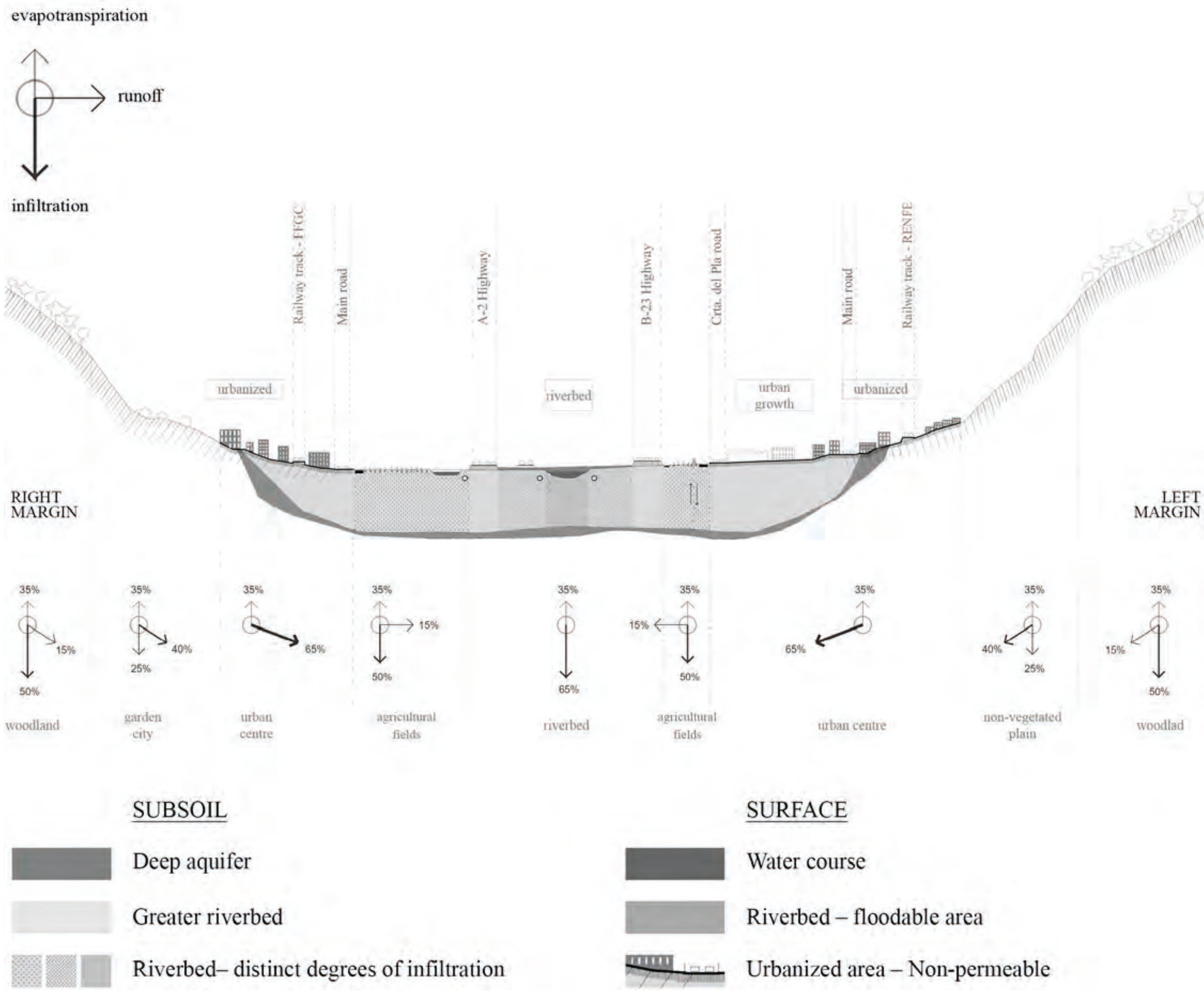
On the territory gained from flooding, there has been growth that adds up to 2.77 km^2, which represents an additional 7.29%, shared equally between residential and industrial areas. (Fig. 3).

Runoff and territory

Substantial changes in the water cycle are caused by the alteration of the original riverbed. Besides, the process of anthropization of the entire valley, also on its slopes, has direct effects. In addition to impervious soils (urbanized areas and infrastructures), the type of land also affects the water runoff, whether it is wooded masses, cultivated areas, arid soils or land with little plant mass. Water retention coefficients are very different, with wooded areas performing best (they absorb up to 50% of the rainfall on low slopes). The loss of forest mass on the slopes, due to urban growth and extractive exploitations, causes the water to run through streams until it is channelled into urban centres to go into the sewage system. This prevents it from reaching the larger riverbed. Hence, the traditional hydric behaviour of the section of the valley is broken and consequently the recharge of the aquifer is reduced. (Fig. 4).

In the overall area analysed, impermeable land occupies 30.02% of the total. It can be divided into 26.32% corresponding to urbanization and 3.70% in transport infrastructures. Here, the absorption coefficient tends to zero. A similar surface

10 The scope of the case study corresponding to the previous figures is a 12 x 12 kilometre grid that covers the territorial unit of the Vall Baixa, with a section of approximately 11 kilometres of river that runs from northwest to southeast.



[Fig. 5] Valley section. Prepared by the authors.

is occupied by forest areas (31.40%), located mainly in the high elevations of the mountains, while the cultivated surface, concentrated in the agrarian park, occupies 6.57%. In this space, the irrigation canal system prevents water from accumulating. It works as a supply system and as a drainage system in case of flooding. Finally, the remaining percentage corresponds to arid soil or land with little plant mass.

The hidden water and the valley section

Urban growth in the territory and the dike effect caused by the highways directly affect the natural infiltration of water into the Delta del Llobregat aquifer. They prevent river water from filling the larger bed of the river, at the same time as natural infiltration is not facilitated at the limits of the aquifer, which coincides with the urbanized surface.

The historical overexploitation of groundwater resources has facilitated the progressive deterioration in their quality. The aquifer[11] is a strategic source for supplying the Barcelona Metropolitan Area but currently a third of the delta's surface is already salinized (ACA, 2010). (Fig. 5).

The quality of the waters of the deep aquifer of the Delta del Llobregat is also essential to guarantee the fertility of farmland and acts as a saline barrier against the intrusion of marine waters. In order to alleviate the water deficit and reinforce this barrier, a series of interventions have been proposed. The most emblematic is the

11 The Delta Llobregat aquifer consists of two strata: the upper layer (consisting of a sand bed) and the lower layer (comprising a substrate of gravel). While the first is free and unitary, the second is captive in most of its extension, except in its limits.

[Fig. 6] Water flows in the final stretch of the Llobregat river. Prepared by the authors. Source *La recuperació en els rius de l'Àrea Metropolitana de Barcelona* (Farrero 2018).

construction of a hydraulic barrier to inject regenerated water into the delta to stop marine intrusion. Additionally, various recharge ponds have been planned along the Vall Baixa, the riverbed is scarified and various extraction wells are used as elements to drive regenerated water into the subsoil (Milagro, 1989; Queralt, 2011). Those actions have allowed a gradual increase in the piezometric levels of the aquifer, which have changed from being 20 m below sea level in 1975 to 9 m below in 2001 and reaching a maximum of 2 metres above in 2018.[12] This means that currently the infiltration potential depends on a higher level of devices that were originally conceived to extract water, instead of the natural systems of the water cycle.

Transformation scenarios

Recently, the Llobregat riverbed has become a large linear park in the Barcelona metropolis. Successive studies and projects have made this possible, based on a first "Framework Project for the environmental recovery of the river area" (2001, AMB) and the creation of a local consortium (*Consorci per a la Recuperació i Conservació del Riu Llobregat).*[13] A set of planning, engineering and landscaping actions with an investment of €32.1M in the 2006–2015 period have taken place on both banks of the river. Overall, they have managed to stop the urban dynamics that favoured the degradation of the river, so that it could be recovered as an artery of a natural space that develops ecosystem functions at the service of citizens. In accordance with Water Law 29/1985, new zoning criteria were implemented on the river area, to expand it beyond the lower riverbed and encompass the total floodplain.

The new metropolitan park is comprised of a set of permeable paths and floodable bridges that allow the adjacent landscape of the Llobregat River to be integrated into the network of open and recreational spaces of the Barcelona metropolis.

12 The main element of natural recharge is surface water, which comes from the River Llobregat and from the fields of the agricultural park and represents about 39.50 million cubic meters annually. Lateral inlets, which are points where infiltration from the surface is easier, contribute 18.4 hm^3 per year. In cases of need, pumping wells are also used to artificially recharge the aquifer, with contributions of up to 68.00 hm^3. These become the main recharge elements.

13 This is an institution created through the participation of various government bodies: the Ministerio de Medio Ambiente, the Departament de Medi Ambient, the Departament de Medi Ambient i Habitatge, the Departament de Política Territorial i Obres Públiques, the Diputació de Barcelona, the Consell Comarcal del Baix Llobregat, the Entitat Metropolitana dels Serveis Hidràulics i Tractament de Residus and the MMAMB.

The re-naturalization of the river space has been possible due to a sophisticated system of artificialization of the water cycle in the Vall Baixa. The flow of the river is multiplied, so that the waters no longer only descend by gravity, but also circulate in a reverse way through a complex metropolitan system. Wastewater pipes have been introduced parallel to the river (in the Salmorres collector, which was originally designed to displace saline waste from the Cardener river), up to the Prat de Llobregat wastewater treatment plant (WWTP), where the water is treated and pushed back upstream (along with desalinated water) for consumption. A set of treatment plants in various municipalities along the Vall Baixa supplement this system, regenerating the quality of river water and storing it or driving it to the aquifer through recharge wells.

With the progressive implementation of the great river park, new challenges have emerged beyond the banks of the river, broadening the comprehensive view of the valley section. A focus on the overlap between the limits of the aquifer and the current extension of urban soils has prompted a debate on the importance of improving the construction of the metropolitan city in relation to the water cycle, and in this sense, also focuses on less visible aspects of the water. (Fig. 6).

Opportunities and strategies on the margins

The potential flooding areas are located at the junction between the central plain and the beginning of the sloping terrain, the *Samontà*. This is the point where the impervious surface, the limit of the aquifer and the sudden arrival of runoff water that overflows the urban sanitation system converge. The deep aquifer is captive in its entirety except for its limits, so in these specific areas advantage can be taken of direct surface water infiltration.

On both banks of the river, two types of key scenarios are identified where it is convenient to design actions to improve territorial metabolism by managing flooding and infiltration: reclaimed plains from the river and urban scars. (Fig. 7, Fig. 8).

Plains reclaimed from the river

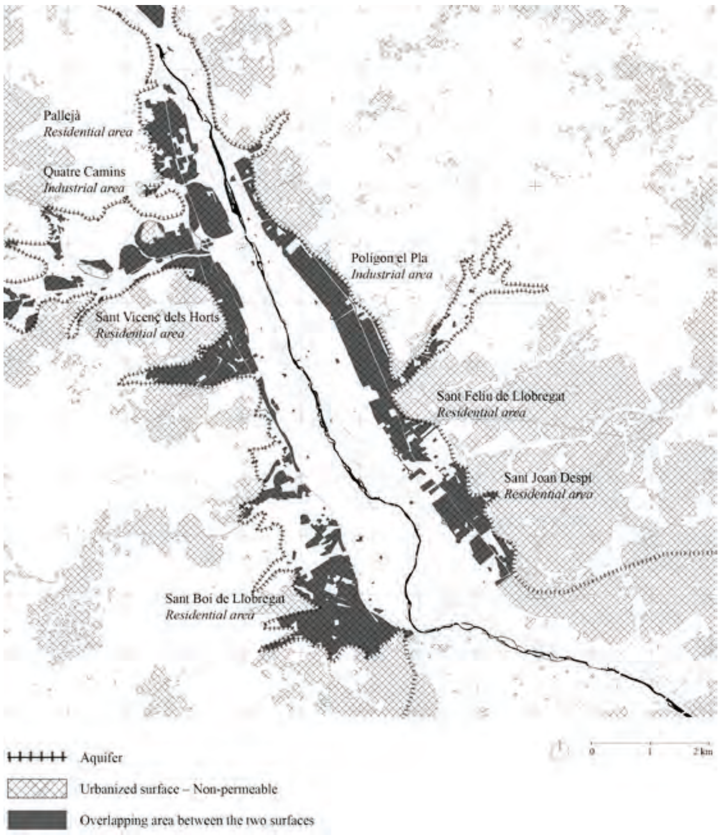
These are large urbanized areas gained from the larger riverbed that directly overlap the limits of the aquifer. Most of the land is destined for industry and logistics, as a manifest expression of the zoning urbanism that prevailed in the construction of metropolises during the twentieth century, when monofunctional sectors[14] were created that are well-connected with large infrastructures but isolated from new exclusive residential spaces. In Barcelona Metropolitan Area they occupy privileged plains and are often underused sectors. (Fig. 9).

In the Vall Baixa, the plains that occupy the industrial estates of Sant Feliu, Molins de Rei and Quatre Camins or new residential developments in St. Vicenç dels Horts or St. Boi de Llobregat are suitable for the introduction of strategies to improve the territorial metabolism, with systemic actions to collect rainwater, taking advantage of existing irrigation channels and their storage and infiltration through open spaces such as recharge ponds. Some studies carried out by CUADLL[15] quantify that direct infiltration to the aquifer is possible, up to one m^3 per one m^2, given its borderline position (Queralt, 2011). Some contemporary design proposals for the *Città Diffusa* in Veneto can be inspiring: in an area that has required a complex system of territorial engineering, upcycling historical irrigation infrastructures might provide new water self-sufficiency in this very specific type of urbanization (Ranzato and Zaccariotto, 2017).

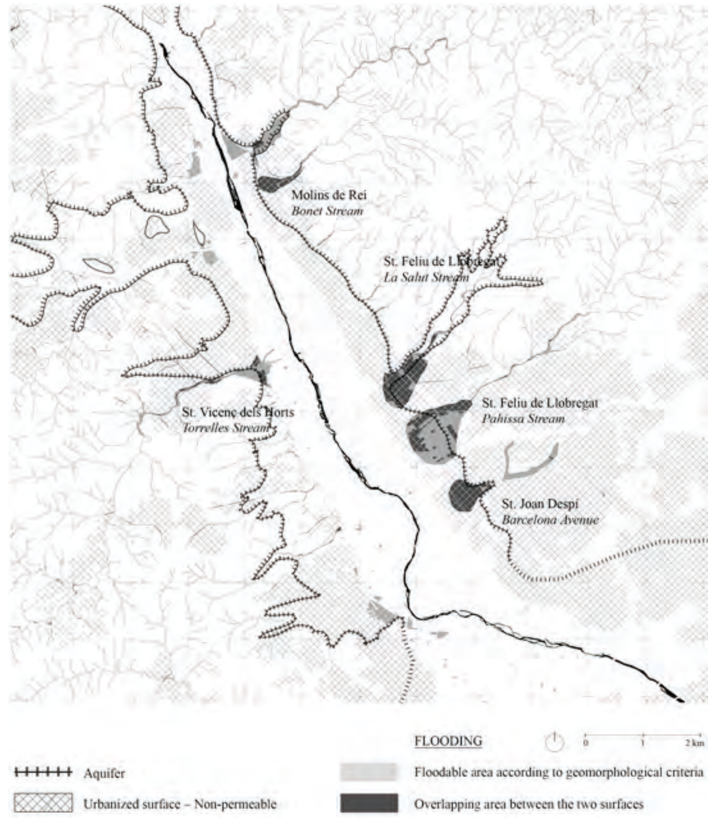
For instance, the huge El Pla Industrial Area, between Sant Feliu de Llobregat and Molins de Rei could become a laboratory for this type of interventions, with its

14 One challenge shared by many cities is to unveil their urban potential to create new productive landscapes (Crosas, C; Clua, A; 2018). The strategic location, flat topography, regularity of the layout and the large size of built elements opens up new possibilities for greater use.

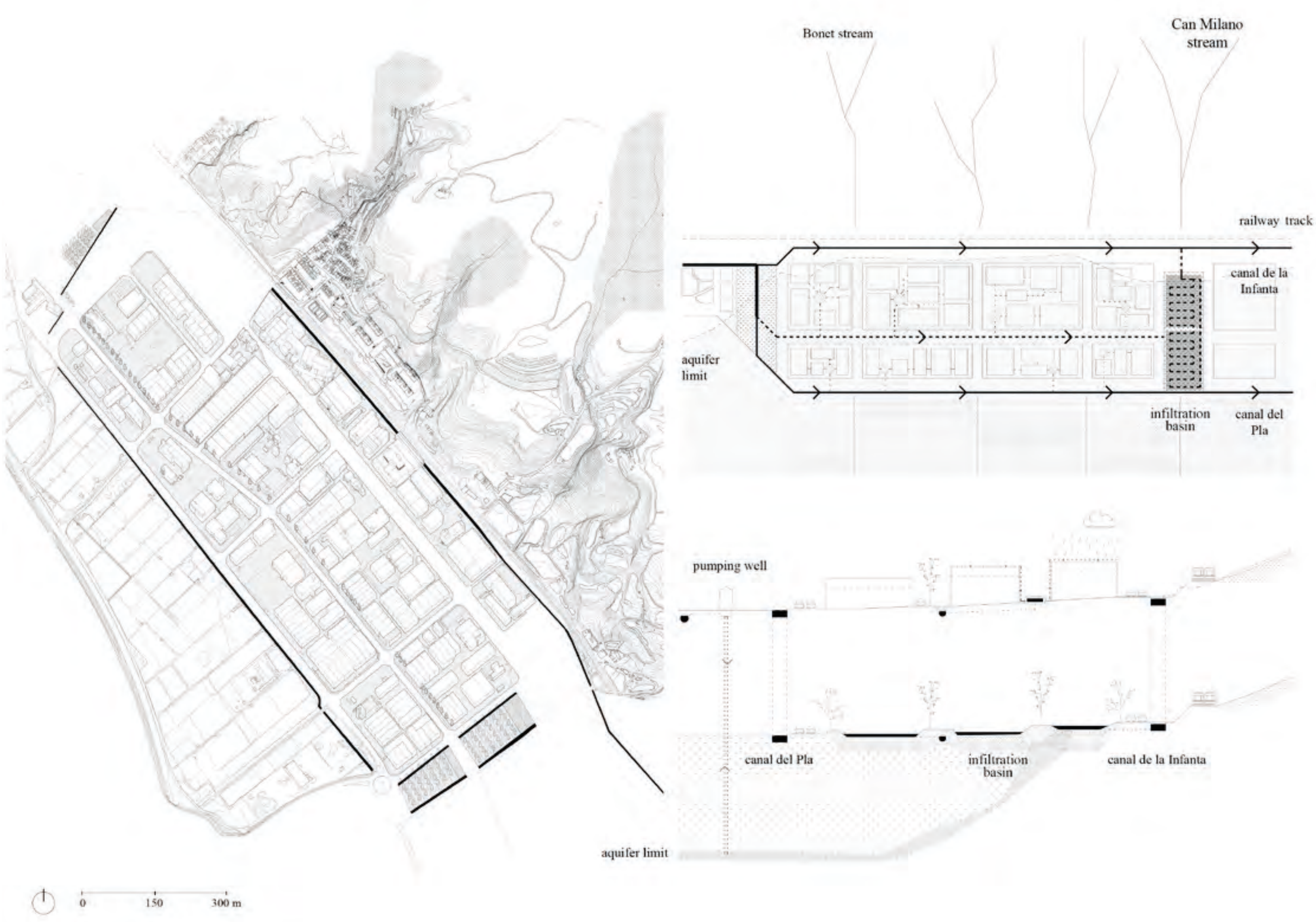
15 La *Comunitat d'Usuaris d'Aiguas de La Vall Baixa y Delta del Llobregat* (CUADLL) is a public Corporation attached to the Agencia Catalana del Agua that includes the territories of the Vall Baixa and the Delta del Llobregat, and ensures quantitative improvement and qualitative analysis of aquifer waters. https://www.cuadll.org.



[Fig. 7] Overlapping of the aquifer with the impervious surface. Prepared by the authors. Data extracted from the *Instituto Cartográfico y Geológico de Cataluña* (ICGC) and the *Agencia Catalana del Agua* (ACA).



[Fig. 8] Urban scars. Prepared by the authors. Data extracted from the *Instituto Cartográfico y Geológico de Cataluña* (ICGC) and the *Agencia Catalana del Agua* (ACA).



[Fig. 9] Intervention strategies in the Polígon Industrial el Pla, in Molins de Rei. Prepared by the authors.

extension of more than 125.72 hectares on the former fertile lands of the river. The orographic profile of this slope, in which the streams are arranged constantly without presenting a main river course that poses a danger, allows linear and extensive proposals to be made, which take advantage of the original infrastructures of the territory and complement the monofunctional fabric, integrating it into the metropolitan open space system.

Urban scars

Another type of strategic scenario for improving the water cycle are "urban scars" that are located in areas at risk of flooding according to geomorphological criteria (ACA), where the waters in streams coincide with transport infrastructures (the train), urbanized surfaces (impermeable soils) and the limits of the aquifer.

Although they are far from the riverbed, they are the most vulnerable spaces within urban fabrics during cyclical storms, when the urban canalization system overflows and the excess of water circulates rapidly, which concentrates the risk at specific points that are protected through the construction of containment infrastructures. These "hard" solutions further increase the speed of the water, oversizing an artificial system of pipes, with large channels and collectors, which consume a large amount of urban space. Given the tendency of water to recover the shape of the territory, it is advisable to slow down its advance and speed through "soft" solutions that favour the infiltration of water along river basins and courses.[16]

The excess water can be retained in smaller spaces embedded within the urban fabric, using sustainable urban drainage systems (SuDS) that allow gradual infiltration of water in strategic points located on the limit of the aquifer.

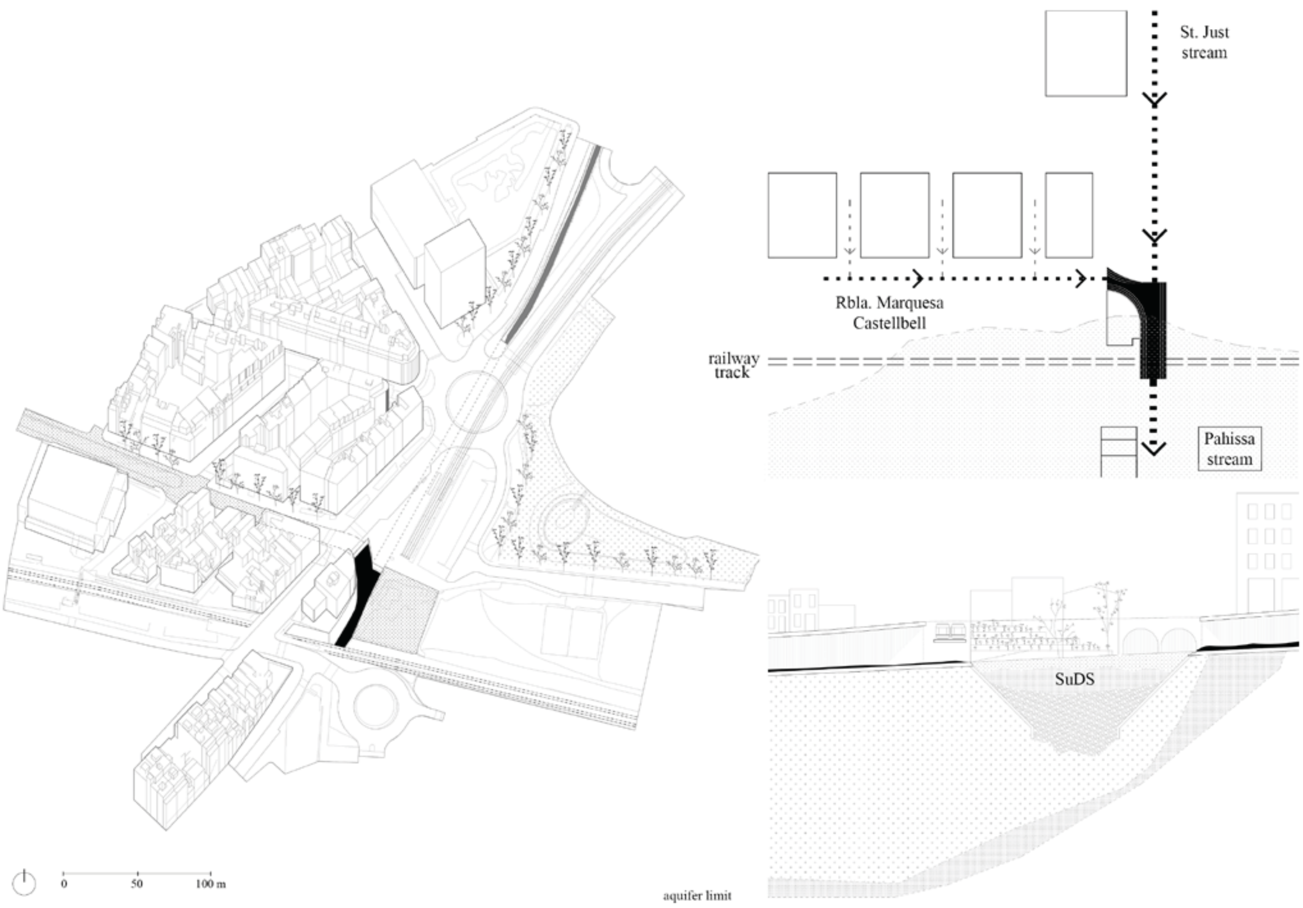
As an example, the Riera Pahissa is a canalized stream located on the border between the municipalities of Sant Feliu de Llobregat and Sant Just Desvern, where two tributary water courses of the Llobregat converge with sub-basin paths, with the line from the train and the terminus of the tram line. This situation leads to an indeterminate space, in which the pipes that structure the city are left open, resulting in unevenness and tunnels that exemplify the difficulty of integrating large drainage networks in urban spaces. The danger of these pipes lies in their impervious condition, since it is precisely this that prevents the absorption of water and increases its speed. The precise location of this point with the limit of the aquifer makes this scenario an ideal location for the application of solutions that allow the infiltration of water into the subsoil (such as SuDs) while integrating it into the municipal network of green spaces. (Fig. 10).

Territorial metabolism and blue-green infrastructure

In the context of climate change in which episodes of torrential rains are increasingly abundant, the need to incorporate excess water into urban design is accentuated, always considering the particularities of the local context. In the case of the Vall Baixa this need is even more urgent due to the importance of the quality of the "hidden" water for the maintenance of agriculture and guaranteeing the ecosystem services of the river area.

Currently, the on-going draft of the Metropolitan Urban Master Plan (2019) defines an ecological structure that aims to ensure the correct functioning of the biophysical matrix, setting the objective of preserving elements that guarantee the natural water cycle. The proposal is to delimit areas that are a priority for recharging aquifers and regulating surface runoff, to determine criteria for their correct maintenance,

16 Currently there are many experiences in which permeable green spaces are used to reduce the speed of runoff water, as well as to reduce or eliminate pipe infrastructure. An illustrative example is the Kokkedal parks (2017) in Denmark, where infiltration elements are integrated into the playgrounds.



[Fig. 10] Intervention strategies in the Riera Pahissa, in its fragment between Sant Just and Sant Feliu de Llobregat. Prepared by the authors.

through actions that must be coordinated with the competent administrations in matters of river space.

The growing awareness of the urban value of water guides the development of the “Blue-Green Infrastructure” concept, which has been used in particular in northern European countries. The Copenhagen Cloudburst Management Plan, drawn up in 2012, provides this opportunity and defines “blue-green infrastructure” as infrastructure that expresses the correlation between water in canals, green spaces, parks and urban areas. The plan establishes a set of measures to facilitate the drainage of rainwater and infiltration and proposes changes in the street’s sections and the integration of open water structures into public space projects. Water is a valuable resource and should not be led to a sewer system, but rather become a more structural element in the way of building the city.

The *Water Sensitive Rotterdam* (WSR) program of 2015 is also a benchmark for the design of these infrastructures. It is a progressive plan for the visibility of the water cycle in the city that includes water squares, alternative forms of water storage, de-surfacing projects and up to 220,000 m^2 of green roofs. The plan is developed from some flagship projects such as Benthemplein, called the water plaza and formed of three retention ponds that operate seasonally and allow the area to be used for recreational purposes the rest of the time.

These last examples illustrate the type of design actions that our cities need today. After the engineering of the territory, interventions on a more domestic scale are necessary, where testing formulas through social innovation like the participation and conviction of citizenship is essential. Architecture, landscaping and urban planning are key tools to devise ad hoc solutions so that water, both visible and hidden, predictable and unpredictable, is increasingly integrated into ever more resilient metropolises.

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