Doctoral School in Environmental Engineering

Integrated water design for a decentralized urban landscape

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The case of the low lands of the Veneto *Città Diffusa*

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Cover photo: landscape mosiac of the Veneto *Cittá Diffusa*. M. Ranzato photo

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To Mary, Mother Most Humble and my parents

He said to me, "This water flows into the eastern district down upon the Arabah, and empties into the sea, the salt waters, which it makes fresh. Wherever the river flows, every sort of living creature that can multiply shall live, and there shall be abundant fish, for wherever this water comes the sea shall be made fresh. Fishermen shall be standing along it from En-gedi to En-eglaim, spreading their nets there. Its kinds of fish shall be like those of the Great Sea, very numerous. Only its marshes and swamps shall not be made fresh; they shall be left for salt. Along both banks of the river, fruit trees of every kind shall grow; their leaves shall not fade, nor their fruit fail. Every month they shall bear fresh fruit, for they shall be watered by the flow from the sanctuary. Their fruit shall serve for food, and their leaves for medicine."

(Ez 47, 1-9. 12)

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Summary

In the Veneto *Città Diffusa*, the decentralized urban landscape of the Veneto Region, Northeast Italy, the economic growth of recent decades brought about increased urbanization and agricultural intensification. The process of change has been accompanied by the extension and/or maximization of centralized services of drinking water, irrigation, waste water and drainage to meet greater demands for the provision and disposal of water. Accordingly, the structure of a formerly poor rural landscape has been adapted to support an affluent industrialized and urban one. However, all this has had detrimental side effects, which, in time might seriously compromise the quality of life in this landscape. On one side, the transformations that occurred have in fact given rise to unexpected problems of drought, flooding and pollution of water; and recent changes in climate patterns have further intensified these risks. On the other side, the long term fine grained carrying structures of the landscape fabric –like roads, field ditches, stream and river corridors, dirt roads, paths etc.-, as the very basis of the landscape's unique ecological diversity, and once used to convey the area's flows now risk general extinction. The existing road system is also increasingly under pressure to intensify traffic that creates congestion, pollution and unsafe conditions. From a planning and design perspective, this calls for adequate methods and tools that can help designers to tackle the needs for more sustainable water flows as well as the needs for a recovered ecological integrity (including spatial intelligibility) of this urban landscape. This can be of a great importance also for a better understanding of other territories of urban dispersion which are spreading especially over the European and –although in very different forms- the American continents. The present research aims to contribute to the planning and design answers to these urgent problems. For this purpose, the urban landscape of the Veneto *Città Diffusa* was approached with principles derived from an Integrated Water Management approach (IWM) that, recently, has been successfully applied in the urban context as an alternative to the technocratic approach of maximizing flows. Storage of water is the key principle, for it can bring about decentralized storage, which means new and different water flow management and spatial arrangements. This can ultimately be obtained through the placement and implementation of small scale and decentralized infrastructures.

By focusing on the interrelation between flow patterns and spatial arrangements in a small portion of the Veneto *Città Diffusa* –i.e. the case study landscape- the study has elaborated and confirmed two specific closely related assumptions.

The first assumption is that the recent loss of landscape diversity and the increasing problems of flood, drought and water pollution of the Veneto *Città Diffusa* are closely related and ascribable also to the processes of centralization of the water flows that accompanied the area's economic growth. The changes of flow patterns and spatial arrangements of the case study area that happened over the last decades were systematically observed in a threefold area-flow-actor perspective. Insights into the present arrangements of irrigation, drainage, drinking water and waste water at the scale of the Consorzio di Bonifica Valli Grandi e Medio Veronese waterboard also accompanied the investigation. The diagnosis showed that the centralized systems arranged to

perform greater inflows and outflows, draw heavily on resources and often risk exceeding the region's ecological carrying capacity. Moreover, the centralized arrangement often conflicts with the decentralized character of the settlements. No synergetic relations have been developed between the man-made water system and the existing pervasive fine grained elements of the landscape. Instead, this rich capital asset has been left behind and even neglected. And such forms of negligence have ultimately brought about a massive loss of biodiversity, accessibility and spatial intelligibility of the local landscape.

This leads to the second assumption that has been researched: in the decentralized urban landscape of the Veneto *Città Diffusa*, answers that design measures can give in response to increasing water-flow dysfunctions and loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes –ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements. Building on the Ecological Conditions Strategy conceived by Tjallingii (1996), a set of guiding models was developed. In the models, the principles of Integrated Water Management were tuned to those fine grained landscape elements that still structure the low plains of the Veneto –the built lot system, the agricultural field system, the road system, the stream system and the excavation site system. Principles and models of integration and decentralization drove the exploration of design options for different levels of decentralized management of water in the case study area. The creative design process of learning produced a useful toolbox of design models. The design exploration also proved that the dispersed urbanization of the *Città Diffusa* can be made suitable to accommodate modern integrated and decentralized water systems that, by re-activating the existing carrying structures, also contribute to recovering the landscape. Decentralized urbanization can actually be an ally in the search for sustainable and legible settlements that also reuse and recycle water locally.

Designing an integrated water system that fits with the *Città Diffusa* and contributes to the ecological integrity of this urban landscape remains an important challenge. The tools that can be of practical help to designers and decision-makers who are willing to undertake this challenge were investigated and worked out. Nonetheless, the way to realize the outlined strategies is complex and affected by uncertainty. In this context more research is needed to investigate the effects of decentralization at the level of the region on one side, and on the other side to investigate how these integrated systems can be set to fit present institutional and market frameworks. In conclusion, the study generated concrete proposals for one or more pilot projects that will be extremely important to creating consensus in the decision process during the testing of models and strategies.

Chapter 1

Introduction

1.1. Water issues in the urban landscape of the Veneto *Città Diffusa*

The purpose of the present studies is to investigate new and constructive ways of looking at the physical environment of the diffused city, today the dominant inhabited space of many European and American countries[1] (Indovina, 1990; Secchi, 1991; Berger, 2006). Numerous researchers have argued the negative externalities related to the dispersed urban forms (Duncan et al., 1989; Frank, 1989; Agostini and Tempesta, 1991; Kunstler, 1993; Burchell et al., 1998, Kahn, 2000 and Freeman, 2001). However, recently, the dispersed urbanization has kept a greater attention, notably among ecologists and designers. From an ecological perspective, the interaction between settlement patterns and ecosystems proves to be potentially much more consistent in the territories of dispersion than in the compact city. Green structures in urban landscapes, indeed, can create excellent conditions for biodiversity and social qualities (Werquin et al., 2005). From a design perspective, then, as the researches of many designers have demonstrated, these forms of city can support a variety of lifestyles through creative, simple and sound relations with the ground (Wright, 1963; Berger, 2006; Branzi, 2006; Secchi and Viganò, 2006).

Therefore, the research questions the attitudes of the extended dispersed urbanization of the Veneto *Città Diffusa*, Northeast Italy, to accommodate integrated and decentralized systems of water as strategy for mutually promising organizations of water and space. Grappling with the design wise role of water within the dispersed urbanization contexts is an urgent challenge for designers, notably in the decentralized urban landscape of Veneto region, Northeast Italy (Secchi and Viganò, 2006). Indeed, in these territories, as urbanization grows and land use activities intensify, water consumption and discharge prominently changes. Commonly, the inner water-retaining elements of the landscape –basically porous terrains and depressions- give way to inflow outflow standard options. Water and its storage structures are removed, their space left to land use activities. Water and its permanent structures of long duration disappear from the landscape. Often, at the same time, water demands relying on external regional water resources approach the limits of their carrying capacity stirring up problems of *too little* upstream (Tjallingii, 2011). The water-using activities rapidly release polluted waters causing

[1] European and American horizontal urbanization have very different characters, although they present numerous similarities. The focus here is more on the European context, but a few research outputs can be valid cues for the American contexts as well. Later on differences and similarities between these two contexts will be further unfolded.

problems of *too much* and *too polluted* downstream. As a result, incidental damages and long term uncertainty increase.

Spatial transformations and centralization of water resources

The plain of the Veneto Region in Northeast Italy, is today one of the most extensively inhabited and economically competitive urban landscapes in Europe, defined in the Nineties a *città diffusa*[2] (Indovina, 1990) (Figure 1.1.). The fine grained character of its arrangements, result of a multi-millenarian stratification, is at the basis of its spatial diversity. Urban and agricultural activities are interpenetrated to compose different morphologies and densities in a unique variety of landscapes of fine grained (Figure 1.2.). However, the economic development of the last decades, although leaned on the fine grained quality of the landscape (Piccinato, 1993: 181), has also triggered a process of up-scaling and centralization affecting the fine grained components of the territory. As a result, paradoxically, the spatial diversity at the basis of development is getting lost[3].

Moreover, the recent regional economic growth has been accompanied by a process of centralization in water management. This is of a particular relevance given that, in the plains of the Veneto, spatial concerns have been closely interrelated with the issues of water. For centuries the pervasive fine grained structures of the surface minor drainage network have been the carrying structures of many land use activities (Bevilacqua, 1989a; Bianchi, 1989). Nevertheless, over the last decades, the strong centralization has led to the progressive rationalization of water to meet higher standards and requirements. The water storage capacity embedded in the fine grained centuries old landscape elements has been progressively removed in favour of in-flows out-flows regulations of water resources.

Notwithstanding the systems engineering many watersystems are under strong pressures today. Indeed, problems are often solved onsite but at the cost of neighbours, increasing water risks, such as draught in the upstream areas, floods and pollution in the downstream areas. In-put out-put water flows combined with no retention draws heavily on water resources. Besides, climate change increases uncertainty. All these issues are real and they are urgent. Using an effective expression from Sijmons (2009), the Veneto Città Diffusa, as other contemporary territories, has reached a critical environmental tipping point whereby natural systems are so stressed out that, at this trend, the total landscape system risks to collapse. For this reason, there is a great need to develop a mutual approach that integrates spatial and water meanings to support and develop a sustainable urban water landscape.

[2] Recently, as functionality of the *Città Diffusa* has reached a metropolitan level and numerous spatial and functional aggregations have emerged, some authors defined this new status *Arcipelago Metropolitano* (Indovina, 2009: 27).

[3] It is well known that the 'systems of small and medium firms' played a major role in the regional industrial development of the 1970s, being able to mobilize local resources and take advantage of the urban services of the agglomeration (CUOA, 1985; Garofoli, 1991). It is commonly agreed that such a distinctive social and urban pattern helped, at least in the first phase, to contain labour costs, whilst, in the second phase, it became one of the many strategies adopted by local small and medium firms in order to remain in the market (Piccinato, 1993: 185).

1.2. The need for integration and decentralization

Today, at the institutional and political level, there is an increasing awareness that the collective freshwater footprint should be reduced[4]. Water is high on the list of the natural assets to protect[5]. Moreover, as Coombes and Mitchell (2006: 1) noted, in various part of the world, the 'big pipe' and 'end of pipe' approach in water management is gradually being replaced by integrated water cycle management approaches that aim to be more sustainable and include small scale and decentralized infrastructures. From a more ecological perspective any piece of landscape, is a system that can regulate flows by resistance and retention –resilience- more than by the traditional input and output regulations (Tjallingii 1996: 184) (Figure 1.3.). It can detain, buffer and store water before draining it. It can also keep water longer and keep water clean (Zaccariotto and Ranzato 2009: 154). Accordingly, storage of water is a condition for reuse and recycling.

Therefore, for designers the challenge is to reintegrate water in their plans looking for opportunities of water storage in the local landscape. Those cities around the world that have exploited flood storage and water treatment potentials of wetlands have demonstrated that parks and urban wilds can provide a variety of services (Spirn, 1984: 143). They have yielded an understanding of promising spatial and functional combinations related to water storage options (Zaccariotto, 2010).

In the same way, in the Veneto, recent policies focus more on sustainable strategies and models in water management (e.g. Piano di Tutela delle Acque (Regione Veneto, 2004)). However, strategies and models often consist of solutions to a narrow aspect of the water problem. Indeed, commonly, strategies and tools refer to autonomous systems of water treatment or stormwater detention or water storage. Instead, in the search for closing the eco-cycle of water, all these decentralized water concepts should be integrated in a whole. The present studies explore multifunctional storage strategies and tools where stormwater, water reclamation and water storage are integrated with mutual benefits among these storage systems.

Urban and water decentralization

The issue of decentralization of water has to be confronted with the processes of urban decentralization that concern the European and American urban systems. The main point of discussion here, is that decentralization of water can be an ally for designers in the process of spatial renovation and modernization of the contemporary urban landscapes, notably of the Veneto *Città Diffusa*. The key questions are. How can the spatial form of this urban landscape contribute to more sustainable water flows and, in turn, how can more sustainable water flows contribute to the spatial quality of this urban landscape? Issues underpinning these questions

[4] Freshwater, or blue water, is water from aquifers, rivers and lakes (Kinkade-Levario, 2007: 2).
[5] At this regard, see the Millennium Ecosystem Assessment (MEA, 2005), for example.

have to be investigated. In the Veneto, it leads to explore possible synergism between decentralized spatial conditions and decentralized water options in order to understand how they can mutually support to sustain and develop the qualities of the *Città Diffusa*. The pervasive decentralized fine grain elements still permeating the plains of the Veneto have to be interrogated in the light of principles of decentralized management of water. The challenging strategy to build up a coherent urban environment could be working with the fine grained materials and giving them back an updated functionality. The issue of decentralization of water can meet the issues of decentralized urban and social organization[6].

1.3. The hypothesis of the research

Accordingly, the twofold hypothesis of the present research is that:

- the recent economic growth and related processes of centralization concerning water flows and concerning spatial structures are threatening the diversity of the Veneto *Città Diffusa* and increasing problems of flooding, drought and water pollution;

- in such a decentralized urban landscape, answers that design measures can give in response to increasing water-flow dysfunctions and the loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes –ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements[7].

In the frame of the research, storage of water is the key concept enlightening the potential carrying capacity of the decentralized fine grain elements of the local landscape to cope with excess, shortage and pollution of water. Water should be detained, stored, re-used, or recycled to be reused, at the proximity of the users, this way closing the eco-cycle of water. The research explores options to revive the role of the fine elements at the basis of the spatial quality of the Veneto in order to adapt it to the present and the future[8]. To this purpose a set of guiding models, resulting from previous experiences with water-sensitive design, is further elaborated in interaction with the existing water flow structures of this landscape. They would be reliable

[6] According to Piccinato (1993: 195), in the Veneto, planners were confronted with new conditions. If we accept the idea that the original features of this new pattern of development are a consequence of a specific growth model, we must also be able to adopt correct planning paradigms for the situation.
[7] At this regard, from the ecological rationality perspective what one is interested in is the capacity of human systems and natural systems in combination to cope with human-induced problems (Dryzek, 1987: 36). Referring to what Dewey stated regardless human beings, Dryzek (1987: 37) defines this ability to solve or cope with these problems as the inner intelligence of the organization of a society or community.
[8] High water demanding cultivations, spread discharge of high rate of fertilizers, drainage of many covered surfaces with specific pollution loads are a few examples of the questions they have to face.

tools to promote coherent spatial arrangements –the diversity character- and a more sustainable water cycle –reduction of drought, flood and pollution of water.

1.4. A project for the Veneto *Città Diffusa*

The research would promote a process for restructuring the spatial diversity of the *Città Diffusa*, while offering arguments to the discussion about the ecological potentials of decentralized urbanism in the search for sustainable and robust living spatial arrangements. Cheaper, more socially valuable and sustainable ways of shaping this decentralized urban landscape than present practice are investigated. The explorations would be conceptual as well as realistic and practical basis for action. A focus is maintained on the existing urban fabric, the bulk of the urban landscape. In the next decades, indeed, the process of innovation of the region has to deal with the restructuring and renewal of the existing landscape in the light of the environmental concerns[9]. The research is an attempt to answer the call for a new comprehensive project embracing diversity and oddities and giving them coherence (Secchi, 1991: 22).

In short, the research investigates the vision for a pervasive multifunctional water network that rests on the traces of the historical process of extension of appropriation over the land and invades and permeates the interstices between paratactic very different materials (detached houses, parking lots, agricultural fields, petrol stations, etc.). In the search for more habitable and robust environments, the system of water as open structure is the glue permeating the whole landscape and supporting its spatial and social organization. Heterogeneity and singularity of the existing materials can refer to it. The water strategies would integrate the frame, slowly moulding it, giving it new meanings (Secchi, 1991: 22).

The case study

Spatial and water-flow organization of a small section of the urban landscape of Ronco all'Adige, south east of Verona, the case study of the research, seems to fall into the above framework (Figure 1.4.). Located in the low plain of the Veneto *Città Diffusa* between the rivers Adige and Bussè, the area is for a good part perforated by numerous basins of waters, the legacy of the former bricks industry. This condition is common to other areas of the Veneto low plain and thereby it gives the opportunity to approach water and spatial issues for a wider territory. In addition, strategies and models developed might be directly integrated in the plans the municipality intends to develop for the reclamation of this waste landscape. A central question is, indeed, how these expanses of water can contribute both to a more sustainable management of water resources and to the intelligibility of the local landscape. The studies have the great opportunity to confront scientific understanding with real actors and their interests. Guiding

[9] At this regard Sivierts (2003: 152) confirms that "urban development in Europe must in future make do with the already existing building fabric.

principles and models are thrown in the actors' arena to orient the design through a process of learning.

1.5. Outline of the research

The forthcoming chapters address in detail the above issues. They are organized in three main sections; four appendixes end the dissertation.

The first introductory section describes the context of the study and comprises three chapters (1, 2, 3). After the introduction, that presents the basic hypothesis and questions of the research study, chapter two, at first, frames the decentralized urban landscape of the Veneto *Città Diffusa* in wider context of dispersed urbanization. The purpose is to briefly outline the main features of the Veneto *Città Diffusa*, what makes it special and what makes it similar to other urban dispersions. Later on, chapter two provides a cursory understanding of the position of the design culture with regard to this form of city and its environmental challenges. Finally, the role of water in the present and the future urban arrangements is questioned. The relevance of approaches in urban design that focus on decentralized management of water is concisely reviewed.
Chapter three focuses on the methodological issues employed to corroborate the research's hypothesis. At the beginning, it gives the reasons for choosing the case study method both to disclose the recent processes of change regarding the *Città Diffusa* and to prove the consistence of the current design principles and models for the sustainable future of this decentralized form of the city. Afterwards it gives methodological information about how the concurrent mixed model study has been organized in the different phases of the studies, the specific fieldwork data collection and sample choice, the sources of evidence.

The second section of the study is analytical. It divides into three chapters (5, 6, 7). Chapter four provides a picture of the landscape's ecological potential. A short description of the local and the regional water cycle delineates the main water resources and carrying structures and infrastructures of the region across different scales, with a special focus on the case study landscape.
Chapter five briefly analyses the landscape processes that have recently changed the spatial configurations of the Veneto *Città Diffusa* and that are threatening its spatial diversity. The mechanisms are observed starting from the level of the case study to give a prompt understanding of the effects on the spatial arrangement.
Chapter six parses the relation between spatial changes, water flows and water infrastructures exploring processes of transformation, their effects both at local and territorial levels, interrelated problems and opportunities. Changes are observed from the bottom, close to the fine grain elements of the landscape –fields, streams, plots, road ditches, former pits- up to the water board level. The complex system of water flows and related infrastructures has been considered according to the water supply and water discharge functions. The chapter examines how water resources and spatial diversity are affected or changed by the up-scaling processes. Attitudes

and cultural values that these changes have engendered, are also considered. A focus is kept on the environmental problems the changes have generated. From this analytical stage the opportunities for creating a rational basis for design already emerge.

The third section is design-oriented. It divides into three chapters (7, 8, 9). Chapter seven presents a set of guiding principles of eco-rationality to design with water in the Veneto *Città Diffusa* context. It conceptually synthesizes the storing-reusing-recycling principles with the fine grain character of this decentralized urban landscape.
Chapter eight explores strategies for designing integrated and robust water landscapes. Water is used as designing principle (Tjallingii 2000: 54). At which scale the water eco-cycle should be closed? Water systems, indeed, can be organized as one unit –collective- or in more decentralized modalities –individual-, sub-units or sub-domains portions of the same domain. Individual and collective strategies are related to different spatial elements and management conditions. The process of designing with water explicitly uses the discoveries made in the analytical section. Some alternative would tip the current sectoral approaches in urban design and water management in favour of integrated actions involving mutual benefits.
Chapter nine draws the conclusions. A brief illustration of a project on the case study area and generated from the studies, demonstrates potentials and concreteness of the leaning process based on guiding models.

Finally, four appendixes complete the dissertation. The first concerns a set of guiding models. They are integrated design concepts based on ecological principles to reinstate water in the fine grain elements which occur over and over again in the low plains of the Veneto *Città Diffusa*. Some more general conceptual tools for this approach have been developed in other parts of Europe (Tjallingii, 1996). In the frame of the research these models have been adjusted and upgraded to fit with the specific condition of the Veneto low plain. Guiding models are vectors for action. They are used as starting points in the design process. In the tuning of the models, the case study area, at first, offers a fine opportunity for understanding the potential of the existing water flow patterns. Then, the same case study is the testing ground for working with guiding models through an open process of learning.
The second and the third appendixes provide respectively detailed calculations and costs analysis relating to some of the strategies of decentralization explored in the chapter eight.
The fourth appendix displays the questionnaires used to interview the institutions dealing with the case study area and people living there.

Two case study researches
The present work is part of the studies on the Venetian metropolis set up several years ago at the University of Architecture of Venice (IUAV) (Indovina, 1990; Secchi, 1991; Munarin and Tosi, 2001; Secchi and Viganò, 2006; Viganò, 2009). Recently the investigations have underlined the need to focus on the ecological and spatial role of water (and its infrastructures) in this urban landscape. Therefore, two Ph.D. researches based on a common research hypothesis have been started up to explore the topic. One research is carried out by the undersigned at the Department

of Civil and Environmental Engineering of the University of Trento, the other by the colleague Giambattista Zaccariotto at IUAV.

A large part of the two Ph.D. researches has been developed at the Department of Environmental Design of TU Delft under the supervision of the Prof. Sybrand Tjallingii. According to a common research structure each Ph.D. study has investigated the hypothesis on a specific case study of the Veneto Region[10]. Some results have been already presented at a couple of international conferences and in the Zaccariotto's dissertation (2010)[11]. It has to be noted that the *conceptual models* assumed as tools both in the analysis *(transformation models*) and the design (*guiding models*) explorations, have been conceived by Giambattista Zaccariotto who presented a first series of *conceptual models* in the X Architecture Biennale in Venice (2006). Afterwards the former models have been further developed and implemented by common explorations[12].

At the distance of a year this dissertation presents the second case study of the research and completes the project conceived at TU Delft together with Giambattista Zaccariotto and Sybrand Tjallingii. These second studies contribute to corroborate the research hypothesis, exploring its usefulness in another Veneto urban landscape of the *Città Diffusa*. As the present Ph.D. project has been supported by the technical knowledge of the Department of Civil and Environmental Engineering of the University of Trento, the design strategies detail more technical aspects and calculations. This will contribute to an understanding of the changes of perspective in the concrete arena of actors (institutional and administrative levels). Furthermore, it offers a deeper insight into the potentials of different fine grain landscape elements –as demonstrated by the details in the case of the former clay pits. In this way it widens the arguments in favour of a philosophy of design with water in the Veneto urban landscape.

[10] The two case studies are Ronco all'Adige (RA) and Ponte di Piave (PP), managed by the water boards Valli Grandi e Medio Veronese and the water board Pedemontana Sinistra Piave respectively. Ronco all'Adige refers to Ranzato's Ph.D. study. Ponte di Piave refers to Zaccariotto's Ph.D. study.
[11] Parts of this work have been presented at the 3rd International Conference on Landscape Architecture, Landscape – Great Idea!, Vienna, 29-30 April 2009 and at 1st International symposium focused on water, Blue in Architecture 09, Venice, 24-27 September 2009.
[12] The models presented in the *Appendix A* already appeared in the Ph.D. dissertation of Giambattista Zaccariotto.

Chapter 2

Dispersed urbanization and integrated water management

2.1. Introduction

The spread of urbanization and a sustainable management of water are two key issues that steer debate and raise important questions about development in our present society. These issues, often viewed as unrelated, can instead reciprocally enhance understanding under the common concept of decentralization. Before moving to review their potentially promising interaction, the debates on the processes of dispersed urbanization and integrated management of water have to be respectively examined. Consequently, this chapter briefly explores the developing trends and emerging frontiers as these two topics bring attention to the existing signs of their potential relationships.

The chapter is divided in two parts. The first outlines the recent processes of dispersed urbanization briefly focusing on their origins and specific characters, their interaction with the water system, and their capabilities in a sustainable development perspective. The second part focuses on the debate regarding the sustainable management of water, on the success of the Integrated Water Management (IWM) notably in the field of urban design, and on the opportunities to involve an integrated and decentralized management of water resources in the context of urban decentralization.

Three boxes are annexed. The first interrogates a piece of the Veneto *Città Diffusa* landscape, as the research's case study, in regard to principles of sustainable water management that emerge from experiences and scientific discussion. The second focuses specifically on the guiding principles for designing with water. The third and last box unfolds the same guiding principles in the frame of the design steps of the PROSA design approach.

2.2. Cities of dispersal

2.2.1. Dispersed urbanizations and the case of the Veneto *Città Diffusa*

Today, about eighty percent of the European population lives in urban areas and the majority of the remaining twenty percent maintains a quasi-urban lifestyle. More and more frequently, rural areas accommodate urban programmes. Consequently, a new physical articulation of space, notably, dispersed and scattered morphologies of different grains emerge[13] (Avermaete, 2002: 2).

As Italian researchers (Indovina, 1990; Secchi, 1991; Secchi, 2001; Viganò, 2008a) acknowledged these decentralized urbanizations differ substantially from the American *sprawl*. In Europe, indeed, dispersed urbanization is mostly a result of innumerable individual efforts rather than medium-sized forms of aggregation, blocks of dwellings, etc. Moreover, European *dispersion* usually transforms a given inhabited territory into a more urban situation whilst *sprawl* builds up urban pieces ex novo. Recently Viganò (2008a: 35) tried to clarify what distinguishes these two processes of urbanization. The *sprawl*, with the spreading out of the city and its inhabitants, implies the 'breaking of an equilibrium' that is the fading of the traditional city-countryside dichotomy. In the European territories of dispersion, instead, the figure of continuity is dominant given that *dispersion* results from a 'development without fractures', through a progressive process thickening existing residential settlements and related centuries-old infrastructure deposited in the landscape. What emerges is how, generally, urban *dispersion* maintains strong connections with the existing traces deposited in the landscape, encompassing historic centres and settlements, re-functioning or reusing existing carrying structures[14]. As Vermeulen (2002: 103) stated in regard to phenomena of Flemish urban dispersion, such urban development schemes move through landscapes which have inner tendencies towards sprawl, randomness, juxtaposition and paradox. Obstacle-free geography, historical agricultural and settlement patterns with a large number of centres, and many generations of anti urban policies are all recurring basic ingredients.

Urban territories of dispersion can be seen as the expression of a variety of specific historical conditions and processes. For this reason there is no one term to identify the patterns of the European dispersed urbanization. The German diffused city *Zwischenstadt*, for example, has its roots in the processes of heavy industrialization that, especially in the last century, has strongly exploited the resources of the Ruhr region, in the North Rhine Westphalia. In the same way, other dispersed regions of Europe such as the Dutch Randstad and Brabant, the *Flemish Diamond* –or *Flemish Nevelstad* –and the Veneto *Città Diffusa* have their basis in different and multiple interpretations of site conditions and resources[15]. The urbanized Netherlands, indeed, is not a recent phenomenon. According to Sijmons and van Nieuwenhuijze (2002: 35), in these low lands spread urbanization can already be detected in the seventeenth century when "there appeared to be only slight differences between the range of occupation in the city and in the countryside". In the Veneto and the Flanders, the occupation of the land is also part of a long-standing tradition and history. The fertility of the soil, the multitude of villages and small scale provincial cities, the intense division of land property together with the extremely decentralized administrative services promoted also by recent laws were fundamental conditions for the

[13] Regarding the urban landscape of Atlanta, Koolhaas (1995: 835) in the end of the last century stated: "Sometimes it is important to find out what the city is instead of what it was, or what it should be". Paraphrasing Koolhaas, what inspired research on the Veneto *Città Diffusa* is the intuition that it effectively can represent what the real city is at the beginning of the 21st century. Many European situations are, indeed, undergoing processes of urban expansion.

[14] See Indovina, 2009: 22.

[15] *Nevelstad* literally means "fog city", alluding to the fine mist of urbanism spread across the countryside (Ryckewaert, 2002: 49).

development of these very fine grained urban landscapes[16]. In these regions, a major role was also played by the anti-urban character of the catholic culture, which, for centuries, promoted social continuity by making a stand against migration of the locals to the cities (Piccinato, 1993; De Meulder, 2008: 29). As a result of such ingrained historical dynamics, in these urban landscapes, industry (dense networks of flexible small and medium-sized enterprises), commerce, residence and agriculture negligently cohabitate in an isotropic territorial continuum[17] (De Meulder, 2008: 29). Thus, these forms of urbanization are no longer peripheries, nor are they parasites of the "historical cities" or rural urbanization; rather they can be considered as new forms of urbanity/city, or expressions of the economic and cultural assets of contemporary European societies (Secchi, 1990).

The Veneto Città Diffusa

The Veneto *Città Diffusa* is one of the most extensively inhabited and economically competitive European territories of dispersion. As Luciani (2004: 3) noted, this urban landscape has its origins "in the peculiarity of the physical and human features of its geography and on the stratifications of longstanding historical traditions, so that it results as an undifferentiated densification of a strong multi-millenarian polycentrism". Here the urbanity is stretched to apparent infinity. In recent decades, indeed, cumulative and progressive individual efforts have changed an inhabited territory into a dispersed city (Piccinato, 1993). New equipment, services, spatial arrangements and city-like uses have tipped the scales of what was mainly agricultural towards something much more recognized as *urban*[18].

The Veneto *Città Diffusa* is the projection on the space of a specific socio-economic structure. From an aerial view it appears as a sparse, thin carpet of patches embedded in an agricultural matrix and varying in function, use and size. It is a hybrid composition of detached houses, villas, churches, bell towers, industries and large-scale advanced industrial platforms, parking lots, treatment plants and pits, small and medium centres whose strongest contextual layouts are vegetal and infrastructural (see Figure 1.2.). Indeed, new and old urban components perforating the matrix are held together by the infrastructural layers of roads and water, main rivers and highways and the pervasive minor surface water networks of irrigation and drainage that often accompanies the minor road network (Munarin and Tosi, 2001: 83). The visibility and rhythm of green structures enhance the water networks. The patterns of the minor surface water networks exhibit capillarity and proximity to all land use programs. Diverging structures include systems of distribution for irrigation, hydropower and drinking water. Converging structures include systems of drainage and waste water collection. All these water and road structures

[16] Regardless Pluti (1991: 166) has noted that in the late 60s the introduction of the so called *legge ponte* (L. 765/1967) has given a strong impulse in reinforcing the decentralization.

[17] Here the monopoly of the city as the centre of production and consumption, concentration of labour, population, economical and political power, as a forum of public debate, and so on, fades out (De Meulder, 2008: 29).

[18] Although its morphological character is very different from the compact city, functional and social characters are maintained. According to Indovina (2009: 26), the shift happen when the territory has been equipped with services commonly offered by the traditional urban context and, in turn, when the inhabitants have started an extended use of this territory and its related services. At this regard Indovina (2009: 26) states: "Use and equipment turn a diffused urbanization into a diffused city".

permeate the underlying agricultural matrix, turning it into porous form (Forman, 1995: 279). Notwithstanding, potable and waste water networks and the recent sub-irrigation systems remain invisible (Zaccariotto et al., 2009). All these carrying structures of different historical origins and logics frame a palimpsest of isotropic character where anything seems to be possible anywhere[19].

2.2.2. Management of water to make the territory habitable

Water infrastructures and appropriation of land

The underlying logics of the European territories of dispersion are close related to their own histories of land appropriation that are still stratified in the territorial supports. In the Veneto, as in the Flanders, for example, road and water infrastructures had deposited in the landscape over centuries and are thus the result of different forms of rationalization, which have conveyed innumerable incremental piecemeal additions and transformations over the land (Munarin and Tosi, 2001: 83). The passing of time density and the accumulation of networks of different origins has contributed to conferring accessibility to each spot of the territory, as a basic condition for dispersion (De Meulder, 2008: 29).

In the plains of the Veneto the management of water has played a major role in the process of extension of the habitability (appropriation and control) over the territory establishing basic conditions for land use throughout history (Bevilacqua, 1989a). As a result of this, different patterns of water rationalization have been superimposed over time (Figure 2.1.). Until more than two thousand years ago, yet before the great anthropic changes that occurred over the environment of the plains, the regional asset was exclusively dependent on the geographical, morphological and relief conditions generated by thousand-year natural processes. The hydrographical system was composed of a series of hydrographical catchments in the mountains and by braiding mountain rivers and spring rivers crossing the marshy plains (Rusconi, 1991: 102). Over the centuries, this original condition has been progressively engineered through anthropic works. The *acque alte* (upper waters) were separated from the *acque alte minori* (upper minor waters) according to the guiding principles that aimed at leading the mountain river flows directly to the sea, as to reduce the flood events of those same rivers in the plains. The straightening and embankments of the mountain river courses in the plain was presumably started by the Etruscans (VI sec. BC). From that time, different hydrographical catchments were sometimes interconnected for a better management of the rivers in the case of flooding (Rusconi, 1991).

However, due to the embankment of river courses in the plain, the natural drainage of the *acque alte minori* in the main rivers was hindered with the consequent increase of swamps in the

[19] A careful observer might have the sensation that the città diffusa of today is an embryo of a new form of city and that the landscape has been prepared to receive it. In this sense, it should be considered that the owners of many agricultural plots are readily willing to increase the built environment, and only specialized high-quality cultivations seem to be able to bring forth a certain resistance to urbanization.

plains. A more accurate and effective drainage system to transfer the waters in the rivers was needed. The organization of the semi-wet impermeable plain was started by the Romans in the II century BC. They arranged numerous portions of the plains according to the *aggeratio* scheme, a grid system subdividing the land in modular water drainage and road patterns. Centuries later, during the Middle Ages, when the region was under the regime of communes, the Benedictine ecclesial order reclaimed other portions of the marshy lands, which, at that time, were still very expansive and extended.

Later in history, the Venetian Republic Serenissima gave strong impulse in the arrangement of the *acque alte minori*. Starting from the XVI century, in succession to a different asset in the control of the Mediterranean Sea, the sea trading Republic adopted a course of centralized control over the water matters. It led to increasing the efforts in the *terraferma* –the inlands- for a reinforcement of the inner agricultural production. Collective and integrated reclamation works to extend cultivations over the marshy lands went along with numerous individual works for irrigation of vegetable gardens and rice paddies[20]. Works of reclamation and irrigation were intended also to reorganize the water system at the regional scale. In order to delimitate the lagoon as a salt water environment –and, this way, to avoid its sedimentation- two great river systems were diverted out of the lagoon: the Piave and the Sile to the north and the Brenta and the Bacchiglione to the south[21] (Cosgrove, 1990b: 39).

Beginning at the end of the XIX century, when engineered water pumps were being introduced, a systematic reclamation process of the remnant marshy low lands of the plain began, notably of those below sea level and others with ages-old drainage difficulties (i.e. Valli Grandi Veronesi, south of Verona). The numerous historical events straddled between the end of the XIX and the first half of the XX century stopped and started this process of polderization called *bonifica* numerous times. However, it was during the Fascist period, when the government decided to increase national food production, that the *bonifica integrale* had such a strong impulse and acceleration (Tosini, 1998: 222). This process of reclamation was extended even on through the late 1960s. In addition, from that time, in the dry plains numerous network systems of small concrete canals were also introduced as a system for irrigation connected with a system of dams to produce hydro power energy.

In the Veneto, water works had thus been a great private and collective initiative. About 80% of the regional agricultural matrix was concerned with works of reclamation (Regione Veneto, 2007b: 28). Both drainage and irrigation, have had very strong effects on the landscape. Despite

[20] Cosgrove (2000: 218) gives a picture of the complexity of the waterworks operated by the Venetian Republic: "Reclamation projects necessarily imply the raising of the main river beds in order to increase the incline in the lower reaches whose embankments needed to be consolidated to prevent spring and autumn flooding. The smaller local water courses were dredged, rectified and endowed with dykes. They were connected with artificial channels dug in order to convey spring and surface water far from fields, to a supplementary drainage system which in its turn, is connected with the main system both through weirs where, thanks to water level, this was possible, and through many other devices with the aim of raising water in the main channels".

[21] According to Cosgrove (1990b: 40), the diversion of rivers was a highly active intervention. "It involved digging new channels which were considerably longer than existing ones, constructing embankments to contain them, especially as increased length reduced gradient and thus increased deposition, constructing aqueducts to take the new courses over smaller streams and installing pumps and sluices to join tributaries to the main flow".

the recent transformations which the centuries old water networks have undergone, these infrastructures form a palimpsest that can still be read today; a basic carrying structure of the function, identity and quality of the dispersed, cultural landscape of the *Città Diffusa* (Secchi and Viganò, 2006). Any singular rationalisation in the water management, indeed, still characterizes different landscapes. In the areas where the *aggeratio* had been arranged, for example, cultivated fields are today divided by the numerous lines of the minor drainage and roads systems (Viganò, 2008a: 36). The reclamation of the Venetians, then, has extended the geometry of canals, agricultural fields, villas over uniform extended marshes. The manifold irrigation patterns have enriched and thickened the reclamation networks (Cosgrove, 2000: 229). Patterns and structures of the *bonifica* that transformed wet marshy lands into open geometrical agricultural plots and organized them into small and medium farms of a kind, are today still framing the landscape of the low lands of the region. In the same way the dry plain is still crossed by the tree mesh structures of concrete canals introduced in the XX century for irrigation purposes. This network frame of the landscape is often accompanied by rows of trees. All the great variety of rationalizations described above have enriched and reinforced the isotropic character of the plains of the Veneto, creating the essential conditions for urban dispersion.

The fine grain character at the base of development and diversity

The Veneto region today hosts about five million people distributed in settlement patterns of articulated historical origins and with no relevant hierarchy in the structure of the urban network (Piccinato, 1993: 184). Up until recently, the transformations that occurred over the territory were also the result of incremental individual efforts. These rested on the traces deposited in the landscape, and hence kept a hold on traditions and social practices more than in other places. Many fine grain elements, the legacy of historical spatial arrangements and the subdivision of the land –the small units of past drainage and cultivation patterns, like *piantata*– have been kept as they were originally (persistence) or were only moderately transformed (permanence). Ephemeral channels, micro-channels, ditches, small walls, rows of trees, all are the signs of persistence or permanence of former arrangements that today guide and oppose inertia to changes and give continuity to the past. In the run towards development, the fine grain character has been a crucial ingredient. Small agricultural properties, for example, instead of being an obstacle for the extension of habitability and the coeval process of modernization, have “fundamentally helped to raise micro-entrepreneurships on a family basis within highly integrated communities”[22] (Piccinato, 1993: 185). Today, the resulting fine grain of space flows and actors are still the ingredients of a unique variety of situations, a fundamental basis for social and economic practices. As Secchi (1991: 21) acknowledged, the case of the Veneto –and the Padana Valley in general- is “an interesting history of social emancipation, where individuals have played a crucial role in opposing collective forms of spatial transformation that connote the modern urban practice”. This history of land appropriation stands to reason that individual efforts and fine grain territorial patterns are closely integrated.

[22] In the decade 1971-1981 Census data attest that more than 50% of the houses was composed by one-family houses and two-family houses. It gives a picture of the domain of small scale/fine grain character of the elements composing the region (Piccinato, 1993: 189).

2.2.3. Urban and water transformations of the last decades

In the Veneto *Città Diffusa* the economic development of the last decades has changed a poor, mainly agricultural region into a prosperous, technologically advanced industrial one, an urbanized countryside into a city of dispersion (Piccinato, 1993: 181). The change is the result of a number of fine grained individual transformations reiterated hundreds of thousands of times over the region and accompanied by the slow adjustments of infrastructure at the regional scale. The process of change has triggered incremental centralization and up-scaling, a tendency from fine grained to coarse grained. The typical fine grained elements of the landscape become bigger and bigger, the spatial diversity which has been at the basis of development, is getting lost. The centuries old infrastructures –mainly road and water infrastructures- that for a long time proved sufficient in responding to the needs of the people, are no longer considered adequate for contemporary needs and no longer correspond to contemporary imagery. More intense urban and agricultural land uses have gone along with the occlusion of road-ditches and field-ditches (obliteration) or their substitution with pipes, the narrowing of canals and streams, their change in function (permanence). The water system networks of the past have often been demolished or modified by hundreds of thousands of small-scale (and oftentimes illegal) local actions (Rusconi, 1991: 110; Regione Veneto, 2007b: 28). As Viganò (2008a: 35) noted, making use of a Lefebvre expression (1974), "new projects bring to bear a logic of *hierarchisation, fragmentation and homogenisation*".

Water problems: environmental side effects of economic growth

In the Veneto *Città Diffusa*, as in many other parts of the world, the economic growth of the recent decades, with its heavy exploitation of land and resources and rapid urbanization, has caused a number of environmental side effects such as environmental pollution, waste of land or the irrational use of existing resources and infrastructural network[23]. Considering these problems from mankind's perspective, the more negative consequences are represented by the actual or potential shortfalls in the human life-support capacities of ecosystems.

The transformations that threaten the unique spatial diversity of the landscape imply also a number of serious hydraulic dysfunctions insomuch as water problems are more and more frequent in the region. Although water has been rationalized to meet increased standards and requirements, recently, the plight of the regional water system is characterized by problems of *too much*, *too little* and *too polluted*. They are environmental damages which the contemporary and future society of the Veneto *Città Diffusa* must confront in order for it to sustain sound and safe levels of subsistence.

[23] For the Veneto it seems appropriate what Dryzek (1987: 36) stated to describe the effects of economic development in general: "the human requirements – productive, protective, and waste-assimilative requirements- have made some special demands upon the homeostatic and adaptive capacities of the ecosystems".

Too much. Just between 1983 and 2006 in the provinces of the Veneto where dispersed urbanization is dominant –Padua, Treviso, Venice, Vicenza and Verona- the increase of urbanized areas varied from 9% of the Province of Vicenza up to 22% of the Province of Verona (PTRC Regione Veneto, 2009: 47). Increased regional building stock and covered areas have changed the way water is discharged and raised peak flows. At present, many local heavy rainfall events put the system into crisis, bringing damage to individuals, commodities and communities (Dal Paos, 1991: 58; DGR 1322/2006)[24].

Too little. Over the last forty years, about the 20% of the agricultural matrix has been urbanized. Nevertheless, the agricultural land use, the most water demanding land use of the region, still occupies 58% of the land. The agricultural production has considerably increased thanks to the introduction of industrialized techniques with much higher water requirements. Often, as the water in the landscape is not enough, episodes of drought are more and more frequent in many parts of the region. A common remedy is the uncontrolled abstraction of groundwater, a procedure that causes depletion of this high quality resource.

Too polluted. From a water quality perspective, increased use of fertilizers in agricultural practices and the increased spread of contaminants from domestic and industrial uses pollutes freshwater (Regione Veneto, 2007a: 97; Regione Veneto, 2007b: 28). According to the qualitative classification of the bodies of water introduced by the national decree D.Lgs. 152/1999, in the span of 2000-2007, the percentage of the river's monitoring stations recorded as low-quality varied between 20% and 30% (ARPAV, 2009: 2).

Climate change

Moreover, as climate change varies, the patterns of precipitation and evaporation during the year including flood and drought events, will probably increase both in frequency and intensity[25].

Spatial implications

All these water problems are closely interrelated with spatial concerns. Water problems mount up and, at the same time, water becomes invisible. There is evidence that recent transformations bring functional and formal damages to that historical fabric which, for centuries, supported the unique spatial and cultural diversity of the Veneto. Changes, indeed, strongly contribute to the impoverishment and "banalization" of the landscape and its loss of spatial diversity.

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[24] In 2006 and 2007, for example, Mestre, in the eastern side of the region, was seriously damaged by flooding during exceptional stormwater events. More recently, in October-November 2010, in various parts of the region heavy storms have caused the inundation of about 14,000 ha with strong negative effects for the regional economy (Regione del Veneto, 2010). Episodes like these undermine the sense of comfort of the people living in the region. Any heavy stormwater generates alarm in the communities.

[25] At this regard see Chiaudani, 2008: 151.

2.2.4. Sustainability of the dispersed urbanization

The weak control over the processes of development and the numerous environmental side effects that urban decentralization implies have raised strong opposition to this form of city from researchers and institutions. Indeed, environmental movement claims have traditionally called for urban growth boundaries to preserve the diversity of natural resources around cities and to funnel development into areas with already existing infrastructure (Sierra Club, 1999). In general, detractors of dispersed urbanization argue that this type of urban growth often coincides with segregated land uses and leapfrog development. The emphasis on the automobile for transit, and a reduction of prime farmland and natural areas all rest heavily on resources, polluting air and water, and promoting social segregation (Gordon & Richardson, 1997; Johnson, 2001: 721). The list of negative environmental impacts attributed to decentralized urban growth is quite long, especially in regard to urban sprawl[26]. However, the Veneto is certainly *not* a typical sprawl situation.

Moreover, the negative effects of urban decentralization are often described and only rarely quantified (Johnson, 2001: 721) while researchers have also pointed out a number of benefits coinciding with this type of urban development (Gordon & Richardson, 1997; Carliner, 1999; Easterbrook, 1999). In any case, many among researchers and urbanists consider sprawl to be the expression of the times, and should hence be deemed as an urban development model that can be better understood and, then, possibly, cleverly guided[27]. As Berger (2006) suggests, it is not a matter of being *for* or *against* the form of the decentralized urban systems, rather, what is needed is to guide and support designers of effective strategies and tools for dealing with these urban layouts and their structures[28].

2.2.5. Veneto *Città Diffusa* in the culture and history of urbanism

There is an increasing awareness that decentralized forms of city can potentially support a variety of lifestyles through creative and sound relations with the environment. Actually decentralized urbanism is not a new issue in urban planning. The *Garden City* (1989) conceived

[26] Johnson (2001: 721) acknowledges: "Researchers generally focus on those communities whose development is the source of the sprawl phenomenon in order to identify environmental impacts of urban sprawl. From this perspective, the following environmental impacts have been identified: loss of environmentally fragile lands, reduced regional open space, greater air pollution, higher energy consumption, decreased aesthetic appeal of landscape (Burchell et al, 1998), loss of farmland, reduced diversity of species, increased runoff of stormwater, increased risk of flooding (Adelmann, 1998; PTCEC, 1999), excessive removal of native vegetation, monotonous (and regionally inappropriate) residential visual environment, absence of mountain views, presence of ecologically wasteful golf courses (Steiner et al, 1999), ecosystem fragmentation (Margules and Meyers, 1992)."

[27] According to Indovina (2009: 21), the great transformations of the last decades have emphasized how the pros of agglomeration have become the cons (congestion, pollution, high costs of living etc.). At the same time the pros of agglomeration have been made obtainable even without achieving agglomeration.

[28] Berger (2009: 24) states that "designers must identify opportunities within the production modes, and economies of their time to enable new ways of thinking about landscape and urbanism". In addition to this, learning from the past can properly inspire the exploration of arrangements of future durable conditions.

by E. Howard, for example, or *Broadacre City* (1934-1935) designed by F. L. Wright, were already attempts to question the main track of urbanism, the compact city of the Renaissance and Baroque inspiration –as Indovina (2009: 18) noted- by exploring new balanced relations among residences, industries and agriculture[29]. These two utopian urban design models can be considered conceptual forerunners of the existing urban decentralizations.

Although dispersed urbanization may not be a new matter in the culture of urbanism, concepts and tools have not been developed at the speed of the processes of suburbanization, rurbanization and/or peri-urbanization that have developed over the last decades. In less than a century, what was once a sketched utopia, has now become an unplanned but concrete and dominant city form. Recently, design-oriented studies have focused on the existing European territories of dispersion. Some good examples of this can be found in the studies of Indovina and the research group DAEST on the Veneto *Città Diffusa* (Indovina, 1990) and those of Munarin and Tosi on the *Veneto Central Area* (Munarin and Tosi, 2001); the research exploration of Viganò et al. on the inhabited territories of Salento (Viganò, 2001); the research of de Meulder with the research group OSA on the landscape of Flanders (OSA, 2002); the work of de Geyter, comparing different territories of dispersion (De Geyter, 2002); the studies of Sivierts on the *Zwischenstadt* (Sieverts, 2003), or the recognition of Diener et al. on the urbanized landscape of Switzerland (Diener et al., 2006). All these studies contribute to a detailed evaluation of such landscapes of urban dispersion, in opposition to the traditional urban planning culture that still blindly focuses on the city-countryside dichotomy and often attempts to list the inherent concerns of such forms of urbanization rather than developing effective design concepts and tools to steer them towards more sustainable forms of development. Lately, Italian researchers have started to examine the potential of the urban landscape of the Veneto *Città Diffusa* to comprise a variety of life styles. Notably, the design oriented research *Water and Asphalt*, first presented in the X Architecture Biennale in 2006, focused on the reinterpretation of the character and features of this urban landscape in design tools and strategies. The research reflected upon the potential of the diffused infrastructures of water and asphalt to meet contemporary ecological and economical requirements (Zaccariotto, 2010). However, these studies can also be considered as a referential starting point rather than a comprehensive exploration on this issue.

New tools and strategies for designing in decentralized urban contexts

Despite the important explorations listed above, there is the need to devise new concepts, models and tools that do justice to the contemporary urban condition that, beyond certain

[29] According to Wright (1963: 29), the democratic spirit of man rises out of the confusion of communal life in the city to a creative civilization of the ground through the organic agronomy. Individuals should "naturally" seek for the creative civilization of the ground, forms of democracy where the man-made life concerns are based on nature-law, law for man, not over man. Form and function are as one. Broadacre is the manifesto of this Architecture of Democracy, where Wright explores potentially new, integral and simple relations of man and ground. In that vision of decentralization and reintegration lies our natural twentieth-century dawn. What is interesting in the words of Wright is the role of the individual that, when, in regards to spiritual integrity, acts according to the nature-law and spontaneously builds creative, simple and sound relations with the ground. The Wright Utopia echoes with the history of the Veneto *Città Diffusa*. But what can we define as the spirit of integrity for the citizen of this Veneto urban landscape today? In which terms has this integrity changed or exceeded the carrying capacity of the landscape?

specificities, is today a dominant inhabited space of both European and American countries[30] (Secchi, 1984; Secchi, 1991, Secchi, 2007; Piccinato, 1993; Munarin and Tosi, 2001; Avermaete, 2002; Sijmons and van Nieuwenhuijze, 2002; Berger, 2006; Viganò, 2008a; Viganò, 2009). The traditional urban practice, indeed, has no tools to deal with this type of urban space, as the modern urban design culture, normally relying on collective actions, has to deal here with individual incremental actions. Moreover, collective spatial elements of dispersion –roads and water networks- are today under the domain of technical disciplines often having little, if any, care for design. Thus, in a region dominated by individual efforts, public action is often limited to functional interventions without clear aesthetical purposes (Piccinato, 1993: 195). The challenge for designers, therefore, is twofold. In some respects designers should concentrate on the individual action, the fine grained private space, repeated hundreds of thousands of times throughout the territory. In other respects, they should reflect on public spaces, especially those systems of roadways and waterways, the very glue that permeates the patterns of urban dispersion. All of these elements are the materials to work with in order to reinstate a stronger coherence in such decentralized landscapes. To this end, a new design and planning culture is needed.

2.2.6. Veneto *Città Diffusa* and sustainable development

Città Diffusa as a potential model of the ecopolis

In our current age of sustainability, models and projects for the future of the Veneto *Città Diffusa* and other decentralized urban landscapes have to integrate processes of both natural and built environments through ‘systematic’ design schemes (Berger, 2009: 13). The land uses of any plans and projects, indeed, interact with and are framed in an ecosystem. The city itself can in fact be considered an ecosystem (Tjallingii, 1995c). The ecodevice model designed by van Leeuwen (1973) and van Wirdum (1982) perfectly describes the popular concept of self-sustainability for an area (see Figure 1.3.). The model illustrates the shift from systems relying on great input-outputs from upstream and downstream to systems relying more on their own resistance and retention capacities. In this perspective the concept of self-sustainability for an urban area concerns the capacity it has to rely on its own resources. Commonly, urban areas depend on resources of areas of wider extension, on the inputs and outputs from and to the so-called bio-region (Magnaghi, 2000). The needs at the scale of the user should be tuned according to the ecological resources of the region: the activities in the urban context should not exceed the carrying capacity of the bioregion.

A sustainable compact city can close the cycle (in terms of energy, water, waste) only at the level of the region, and the metropolis only at a much larger scale. To a certain extent, the concept of self-sustainability slightly shifts, whether it is applied to the spatial configuration of the *Città Diffusa* or the dispersed city in general. The bioregion of this special type of urban

[30] In the 80s Secchi (1984: 60) claimed because designers deepens their attention to the space of dispersion, in order to produce images, conceptual schemes and projects tailored to this new form of city.

fabric may correspond to its own urban extension. The space needed for closing the cycle of water, waste, energy, food production is potentially along the corridors for mobility, among patterns of dwellings and industries (Figure 2.2.). Moreover, researchers agree that, in the sustainable city of the future –*ecopolis*- open spaces are the 'generating figures of the new urban and territorial arrangement'[31] (Magnaghi, 2000: 170). The elements of urbanity (buildings, agglomerates, roads, etc.) will become strongly dependent on the materials and activities of opens spaces (agricultural fields, forestry and their infrastructures etc.). Furthermore, in the *Città Diffusa* the spatial dichotomy urban space-open space dissolves. In the same way the dichotomy 'city dweller-farmers' dissolves or, at least, it tails off since the city dweller is oftentimes also the owner of the agricultural grounds. This means that in the *Città Diffusa*, it is usually the citizen who makes the landscape, and the polluter is the one who usually cleans up[32]. The eco-cycle can hence potentially be closed at the level of the parcel[33]. In this view, interstices and open spaces have a key role in the project of a sustainable *Città Diffusa*. They can play a public service, produce environmental, economic, landscape, social and cultural externalities and, as such, they can be counted (and also accounted for) in public expenditures[34] (Magnaghi, 2000: 170).

Integrated design with ecological basis

At the design level, there is a certain awareness that the reanimation and revitalization of the landscape and its basic carrying structures –waterways and road networks- must be made with the help of environmental know-how. As Sijmons (2009: 96) acknowledges, environmental degradation requires a more active inclusion of ecological insights in designing the landscape. According to Sijmons, development and revitalization of the territory are "cultural projects that cannot be left to ecologists –or engineers- but must be approached as work for designers"[35].

Moreover, in order to deal with the great variety of spaces and related functions of this urban landscape an integrated design approach is needed. Fundamental ecological ingredients should be injected in the innumerable incremental individual decisions giving form to this urban

[31] See the same concept in: Donadieu, P., 2006. Campagne urbane: una nuova proposta di paesaggio della città. Roma: Donzelli.

[32] As Tjallingii (1996: 199) noted, the central in-out flows approach removes the problems from the city whilst the decentral self sustainable -self responsible and self resilient- approach seems to move people out of the city. Nevertheless, the decentral approach might fit in decentralized low density urban landscapes, with no need to move people out.

[33] In Magnaghi's opinion the overcoming of the dichotomy between polluting places and places chosen to perform reclamation, means "integration of urban design, environmental safeguard and recovering of open spaces in a unitary planning project in which the whole territory must be reordered starting from self-reproduction requisitions of the environmental systems without solution of continuity between densely urbanized spaces and open spaces, among chaotic ecomosaics (typical in the suburban spaces of metropolitan areas) and ecomosaics in which natural, agricultural and forested spaces prevail". (Magnaghi 2000, 166).

[34] Similarly, in Ecopolis, Tjallingii (1995c) proposes to take the block – park and district – green structure interactions as a basis for sustainable flow management. This implies a future for compact city-blocks and districts within an urbanised landscape.

[35] The occupation strategies should be "capable of yielding appropriate spatial configurations for cities, water, nature and agriculture", they should lead to "a future perspective for all these functions and, in any case, serve as vector for action" (Sijmons, 2009: 97).

landscape[36]. Unlike the sectoral design that has dominated in the last centuries, the integrated approach should interpret the existing conditions in promising multi-functional, multi-layered, time based strategies and combinations of agricultural and built environments (Berger, 2009: 14). In those contexts of hybrid character where the interaction between these two environments is particularly penetrating, integration implies the close collaboration among those disciplines – urban design, hydraulic and agrarian engineering, ecology-, that, commonly, follow narrow purposes through technocratic and sectoral answers.

The key role of spatial diversity

In the Veneto *Città Diffusa* and in other similar urbanized landscapes, then, the integration of the local conditions in designing have to be confronted also with the fine grained character of the landscape. Indeed, potentially, spatial diversity is a fundamental condition for the sustainable future of these urban configurations, an essential contribution for social quality and ecological biodiversity. The fine grained structures of the landscape can be the carriers for the sustainable management of water, for example. Road ditches, field ditches, streams, small depressions, all these fine grained water structures are today challenged by spatial changes and related water problems. These fine grained elements might be reinterpreted according to principles of sustainable water management to play updated water services. They might be once again building blocks supporting the process of social reproduction of the society in the territory, enhancing forms and rhythms of the activities that are spread throughout the landscape.

2.3. Towards a sustainable management of water

2.3.1. The technocratic approach of maximizing water flows

Centralization of water as a process of modernization

Traditionally, water management was small scale, informally organized and based on knowledge of local hydrological conditions (Petts, 1990: 200). Agricultural and domestic supplies used to rely on local resources, and seasonal floods and rains were among them. To a certain extent, it was under the impulse of the emerging centralized states in the later sixteen century, that water in the landscape started to be progressively engineered (Cosgrove, 1990a: 5; Petts, 1990: 203). In Northeast Italy, in the Low Countries, in the Lower Loire and the East Anglian Fenlands rivers were regulated, fenlands were reclaimed introducing legislative and financial systems to sustain drainage consortia, capitalist land markets invested in technological innovation –pumps, dredging devices, locks and sluices- and engineered a new landscape to realize the financial gains that came from the improvement of increased land values (Cosgrove, 1990a: 5). The scale of the water works increased, irrigation and drainage were made more and more dependent on larger parts of the territory. This process of modernization had been notably

[36] This is close to the tradition in urbanism to design the city as a project of elements (Viganò, 1999: 108).

extended since the second half of the nineteenth century[37]. The need to secure health to Europe's great cities by purifying their drinking water and discharging their wastewater, the increased requirements of land to cultivate for food production, the requirements of water flow for hydropower production to supply domestic and industrial activities are among the drivers of this great work of engineering that once concerned both cities and open landscapes. They found full expression in the potentials afforded by technological innovations.

In order to meet unprecedented water demands, governments and water resources managers have maximized the supply –the volume of water available for direct use: water to drink, grow and prepare food and provide power for domestic and industrial use- by diverting water from original stores through long-distance pathways to new stores or direct users (Al Radif, 1999: 148). In-flow/out-flow regulations were heavily increased. Scarcity of water was tackled with more supply from upstream sources, and excess of water with large and rapid discharge was directed to the downstream parts of catchments basins. As Cosgrove (1990a: 8) underlined, the engineer, whose role over the past centuries had become so crucial, was to be the handmaiden of this linear progress[38]. Forms of intervention in water flows and related forms of hydro-landscape were –and substantially still are- based on standardized engineering conditions of knowledge and production and a strong faith in the power of technology to control the natural environment. With the colonial expansion and ensuing international politics, technocratic approaches that were mostly developed in Europe, have been spread to the New World and, later, to the Third World[39] (Petts, 1990: 189).

As a result of what Wittfogel (1956: 153) defined a great process of *hydraulic civilization*, and given the social, political, ideological and especially environmental implications –see Cosgrove (1990a: 3)-, human order eventually and progressively replaced natural order[40]. Needless to say that through dredging, embankments, channel straightening, cancellation of riverine wetlands and islands, construction of large scale –and long distance- inter-basin transfers, building of groynes along riverbanks and pipeline systems for drinking water and sewage and other activities, engineering has improved functionality, productivity and public health of both cities and open landscapes[41].

[37] Al Radif (1999: 148) notes how "the trend that featured the development of fresh water resources management over the last three centuries is greatly interconnected with the rapid growth of world population". "The third billion mark was reached in about only 60 years (1900-1960)".

[38] In this regard, Harvey (1989: 35) states that "modernism with its belief in linear progress, has been positivistic, technocratic, and rationalistic".

[39] Throughout history, there has been an intimate link between environmental authority in the form of water control and political power. Indeed, Cosgrove (1990a: 4) noted that "control goes beyond simply preventing the dangers that free-flowing rivers might represent to human habitation and livelihood". Control of water has always meant control of food production, and only later did it start to mean control of power for machines –in the feudal period- and hydro-turbine –in more recent times.

[40] According to Cosgrove (1990a: 7), "social engineering and domestic science (both of the late nineteenth-century), indicate the penetration of the rational mode of applied science as the paradigm for human control into all the environments of human life".

[41] The faith in the power of technology has led to utopian engineering projects. Examples are the project of Atlantropa (1927) by H. Sörgel promoting the construction of dams in the Mediterranean Sea to produce hydro-power energy and extend cultivable lands; or the grandiose dream conceived by M. Roudaire (about 1874) of a great inland sea through the flood of the desert wastes of the northern Sahara.

In particular, in the urban context, as technology developed, the quick supply to the city of potable water from natural springs, aquifer points of abstraction and other drinking water sources, and the removal of rainwater and wastewater from the city to the treatment works were to become the standard of efficient engineering (Tjallingii, 1995a: 9). Water services for potable water supply, waste water treatment and disposal and stormwater management have been strongly compartmentalized in both physical terms –the infrastructures-, and institutional terms –responsibility for service provision, operation and maintenance. As Wong (2006: 1) notes, over time, this has led to a philosophical compartmentalisation and shaped the perceptions of system boundaries.

Environmental fallouts

The approach of maximizing flows by in-flow/out-flow regulations has in some cases solved problems onsite, but oftentimes at the cost of neighbours, increasing water risks, such as draught in the upstream areas and floods and pollution in the downstream areas. The incremental process of engineering of water arranged to cope with the requirements had strongly altered the interrelation between water and land resources, often working versus environment rather then within it. The engineering logic has attempted to solve water problems through the use of forceful infrastructural technology, which is often incompatible with environmental needs[42] (Viganò, 2009: 212). As a consequence, many environmental side effects upset today's societies. In many regions, the water demand as a whole tends to approach the limits of the carrying capacity of the water resource base. Excessive water consumption, indeed, draws heavily on resources, drying up groundwater and upsetting ecosystems (Massarutto, 2008: 8). Consequently, the faith in the engineering approach is falling off. The technocratic 'ready to go structures' –quoting a forceful definition of Ernst Bloch- have denied the onsite potentials. Moreover, as Cosgrove (1990a: 9) pointed out, centuries of close adjustment of locals to their environments have been ignored by the analytic mode of the engineering separating these "soft" issues from the "hard" facts of hydrological management. The change from local rural management of water to the nation-state scale has led to an excessive reliance on large-scale engineering and the denial of careful and traditional management of water resources (Petts, 1990: 204).

At the urban level, then, a result of this strong centralization is that the water budget is characterized by significant imports of water to meet urban demands, comparable volumes of wastewater discharged from the catchments, reductions in rainfall infiltration and catchments evapotranspiration, and considerable increases in the volume of catchment runoff[43] (Wong, 2006: 1). These water-engineering projects have changed landscapes as well as the carrying

[42] Despite all these efforts, today, the efficiency of irrigation schemes –accounting for nearly 80% of global water consumption (Biswas, 1983)- is only about 30% (Petts, 1990: 204).

[43] In the case of dispersed urbanization, the reduction of evapotranspiration due to increased covered areas, can be considered compensated by the recently augmented irrigation –and therefore augmented evaporation- of the remaining cultivations.

structures and the sustaining processes at their basis (Petts, 1990: 205). Thus, for example, rainwater is often no longer a visible element in the design of urban environments.

Centralized water management in the Veneto

In the Veneto, as in other territories, the economic growth of last decades, went along with centralization and separation in management of water. Local landscapes have been made more and more dependent on external resources. Here, what is more, the water system has been affected also by the incremental urbanization of the countryside. Urbanization, indeed, has been followed by strategies and technical solutions conceived for the densely inhabited patterns of the compact city. Thus, processes of water engineering concerning the agrarian landscape –strengthening of irrigation and drainage streams, intensification of drainage, elimination of small field depressions etc.- have been accompanied also by water engineering processes typical of the urban settings –that is the extension of centralized infrastructures for drinking water and wastewater, and, more recently, stormwater management.

As noted above, although the strategies adopted would assure a stronger control of the water resources and long term benefits, episodes of drought, flood and pollution are more and more frequent in the region. Moreover, the approach of maximizing water flows with its standardized solutions jeopardizes the fine grain spatial diversity embedded in the landscape, the inner quality of the Veneto *Città Diffusa*. Highly performing in-flow/out-flow systems –pipes, concrete channels etc.- replace the variety of fine grain materials –ditches, riverine wetlands, low-lying fields etc.- positioned in the landscape, that used to store and convey flows for centuries. Water progressively disappears. Its contribution to the quality of the environment faints. “Hierarchization” and standardizations, indeed, mean also loss of trees, loss of footpaths, that is loss of biodiversity and loss of accessibility (Munarin and Tosi, 2001, Viganò, 2008a). Thus, in the Veneto, as Sijmons (1990) noted for the Dutch landscape, centuries old cultural landscapes start to fade in favour of homogeneity.

In the Veneto, therefore, the separation and ‘hierarchization’ that occurred in the water network have reached their limit, producing a complex and contradictory situation[44] (Viganò, 2009: 210). Strong land uses with their related environmental damages and the changes on climate conditions –variation of precipitation and evaporation patterns, an increasing sea level etc.- push on the organization of flows and space. The traditional maximizing approach seems unable to cope with requirements, rather, it seems part of the problem since it ignores and denies the

[44] Despite the increasing debates, water and its values are underestimated. This is a major obstacle to its implementation. In regard to groundwater, for example, large numbers of individuals make unrestricted access to this free resource. According to the Hardin’s definition “tragedy of the commons” (Hardin, 1968), each user receives the entire benefit of its own increased use, but shares the cost of that increase with all other actors. Users, therefore, have no incentive to look to the overall quality of the resource (Dryzek, 1987: 32). The result is an eventual overuse and depletion of the resource. In this regard Spirn (1984: 168) argued that only once the water crisis forces societies –and cities- to charge full value for water supply, will the support for water conservation follow. “When cheap water is a thing of the past, rainfall will be cherished, run-off utilized, and flooding reduced. Short-term expediency must not prevail; the opportunity for redesign must be seized.”

specific potentials of this decentralized urban landscape for decentralised and collective activities.

2.3.2. The need for a different approach

Water issues are today increasingly high on the international agenda. Population growth and higher living standards, indeed, will cause ever increasing demand for irrigation water, good quality municipal and industrial water, and increasing sewage flows (Bouwer, 2000: 218). Moreover, changing precipitations and evapotranspiration patterns worsen pressures on the water system. Growing stresses and environmental fallouts call for a different kind of water management. In this regard, as David (1988) acknowledged, the advocated sustainable development model requires sound water engineering projects that can make the best use of nature's resources to meet human demands, without destroying their sustaining base. Currently, an ecosystem-based approach is suggested as a long-term strategy for managing water resources. It should integrate solutions for water problems at the international, regional and local levels (Al Radif, 1999: 148). Moreover, it requires scientific knowledge and better understanding of the site –both at the catchments and the local levels- incorporated at the various stages of planning [45] (Petts, 1990: 202). Traditional practices, indeed, have focused on maximizing the quantity of water available for direct use and on the costs and benefits of the projects. Seldom, if ever, were environmental side effects and design aspects ever carefully considered. In spite of that, the new ways of conceiving the hydro-environment and its management requires us to think in large-scale terms, while remaining sensitive to the local character of the consequences of the intervention (Cosgrove, 1990a: 10). New strategies must carefully consider the possible implications and effects of economic, social and cultural benefits. Moreover, the best use of water resources should ensure their sustainability for future generations (Al Radif, 1999: 151). To this end the integrated development of water, engineering and landscape is crucial in providing solutions to water problems and, at the same time, landscape protection and environmental enhancement[46].

During the 1980s, in the light of the failure of the sectoral supply-driven management model, Integrated Water Resources Management (IWRM) was advocated to cope with the current water problems (Al Radif, 1999: 147). Integration and decentralization have become two fundamental ingredients the new approach should include in order to develop sustainable systems and prevent catastrophes.

[45] According to Bouwer (2000: 221) more research needs to be done to make sure that management of water and other resources is based on sound science and engineering. Regarding integration, Bouwer (2000: 227) adds that agricultural water management, for example, must be integrated with other water practices and environmental objectives.

[46] Petts (1990: 203) acknowledged that "landscape protection and environmental enhancement would be key components of each water project". The sustainable development of water resources should simultaneously restore or enhance degraded or denuded landscapes (Petts, 1990: 205).

Integration

Up to now, engineers, ecologists, landscape architects, planners and other professionals have generally adopted divergent approaches and standards to the issue of water (Mouritz et al., 2006: 8). However, nowadays, the perspective is changed. Water-related outcomes have to be interrelated with other sustainability objectives that should be included in the urban development and re-development processes. This shift to integrated planning and design should establish the required links across disciplinary and institutional boundaries (Mouritz et al., 2006: 9). Besides, the concept of sustainable development stimulates two levels of integration: firstly, the integration of all waters of the water cycle (stormwater, groundwater, surface water but also drinking water and wastewater); secondly, the integration of those disciplines and institutions involved in the organization and maintenance of water cycles and related infrastructures. Such a comprehensive approach opens up to more cross-disciplinary opportunities and less generic standardized and normative “solutions”.

Decentralization

Minimizing the reliance of developments on external water sources is central to sustainable development (Wong, 2006: 4). Self-reliance shortens feedback channels, and, this way, ecological signals are less diffused and more readily “mapped”[47] (Dryzek, 1987: 218). It follows that land uses should be tuned on the potential of the local environment for resilient arrangements[48] (see Figure 1.3.). According to Dryzek (1987: 217), one central feature of smallness of scale is that a locality relies upon the productive, protective, and waste-assimilate functions of the ecosystems in its immediate vicinity. From this perspective water conservation, stormwater management and wastewater treatment should be organized into drainage-supply and water-wastewater management clusters rather than into regionalized ones. Long distance transfers can be minimized or eliminated enabling water reclamation and reuse in proximity to the points of use (Heaney, 2007; Novotny, 2009). Such organization networks will require steady and continuously fruitful cooperation and coordination among actors. Nevertheless, since many contemporary ecological problems do transcend the local level, cooperation and coordination among and between different scales shall also be required (Dryzek, 1987: 228).

A different urban water management

At the International Urban Water Conference (2008), Feyen and Shannon (2008: XV) acknowledged that, worldwide, also urban water challenges demand conceptual re-thinking[49]. Cities have indeed to face pressures related to climate change, population growth and urbanization, as well as the aging and deteriorating of water related infrastructures. The key

[47] Dryzek (1987: 218) notes that “ecological anthropologists interpret social and economic structures and individual beliefs, values, and behaviour patterns as adaptive devices for coping with stresses in the human or natural environment”.

[48] Self-reliance imposes a form and content upon feedback and problem-solving (notably lacking in the standard open society) (Dryzek, 1987: 221).

[49] The International Urban Water Conference held in Heverlee (Belgium) between the 15th and the 19th of September 2008, was organized by the scientific staff of the Katholieke Universiteit Leuven and the DG Joint Research Centre of the European Commission.

question is whether or not urban environments can be more sustainable and function as self-reliant ecosystems.

In this perspective, a "soft engineering" approach could work with nature to reduce or mitigate the likely impacts of natural events and anthropic action, such as floods. Mitigation can become proactive rather than reactive when urban design and planning design for resilience by remoulding landscapes and (re)constructing settlements to bend for hazards, but not break[50] (Feyen and Shannon, 2008: XIV). This alternative urban paradigm requires an integrated and proactive approach, which balances biophysical and socio-economic concerns and conceives of less generic standardized and normative strategies and "solutions".

2.3.3. Integrated water management

The Integrated Water Management (IWM) is the alternative to the traditional method. Although integrated management of water is not a new idea, the shift towards this more ecological approach has known a strong impulse only in the last three decades, with the increasing awareness that a more sustainable management of water is needed[51].

As Mitchell (1990: 1) acknowledged, integrated water management first of all implies the systematic consideration of the various dimensions of water –surface water, groundwater, their quantity and quality- and their interrelationships; secondly the unfolding of the interactions between water, land and the environment systems, considering that changes in any one may have consequences for the others; finally, in line with the recommendations of the Brundtland Commission for sustainable development, the inclusion of the interrelationships between water and social and economic development ascertaining that management and uses are sustainable in the long run. Mitchell (1990: 16) adds that such integrated approach requires thinking *comprehensively* at the strategic level, and more *integrated* –that is with more selective focus- at the operational level. The institutional level, then, should minimize the boundary problems –among the actors involved- that always exist in natural resource management. The coordinated management of water, land and environmental resources at the catchments level has thereby

[50] Feyen and Shannon (2008: XIV) continue: "such environments –if properly planned and designed- could save water resources, close biogeochemical flows of nutrients through recycling and reduce the demand on non-renewable energy resources".

[51] As Petts (1990, 201) noted, the impetus for sustainable approaches to water development was given by the World Conservation strategy (IUCN, 1980). Later, in the 1986 the United Nations launched a comprehensive programme for the Environmentally Sound Management of Inland Waters (EMINWA) involving land and water management and international co-operation. The first programme of EMINWA is the Zambesi Action Plan (1988). In the 1992 the International Conference on Water and the Environment published the Dublin Statement on Water and Sustainable Development with associated guidelines, the Dublin Principles. These statements, together with the statements of the Earth Summit held in Rio de Janeiro of the same year (1992) inspired the institution, in 1996, of the Global Water Partnership that fosters the Integrated Water Resources Management around the world (IWRM).

received considerable attention, and is being implemented in numerous management experiences and legislations[52].

Integrated Urban Water Management

In the urban context, the IWM have inspired the Integrated Urban Water Management (IUWM) approach. It aims to better tune the impact of urban development on the natural water cycle. The main task is the establishment of an inner, urban, water cycle loop through the implementation of reuse strategies. To this end, the understanding of the natural pre-development water balance and the post-development water balance is of a great importance[53] (Barton, 2009). Besides, an integrated urban water management system encompasses the three principal water streams: potable –and non potable- water supply, stormwater drainage and wastewater disposal (Wong, 2006: 1). It implies integration of water conservation –a seasonal storage system-, stormwater management –a peak storage system- and wastewater disposal –a purification system- into one system and their decentralization into drainage and water/wastewater management clusters (Novotny, 2009: 20). Water conservation and reclamation can be located near the point of use and, like this, in-puts out-puts regulations with their long distance transfers can be minimized. Planners and designers are therefore asked to investigate new strategies and tools for integrating water and its infrastructures in urban life and in the image of the city (Tjallingii, 1995a: 10). Saving water, reducing paved surfaces, retaining and infiltrating rainwater, preventing water pollution, reusing and recycling water and other integrated and decentralized measures are imperatives to be tested, improved and implemented in the context of modern and liveable cities[54].

[52] In this regard, the European Water Framework Directive 2000/60EC is a good example since it aims to improve the qualitative and quantitative status of the water bodies through the adoption of river basin management plans. Examples of integration at the catchments level are in Mitchell, 1990: 2.

[53] Recently the SWITCH project (Sustainable Water management Improves Tomorrow's Cities Health) supported by EU, has identified certain key concepts to catalyze change towards more sustainable urban water management in the City of the Future" (Vairavamoorthy, 2009: 8):

-the enhancement of resilience capacity of the urban systems to manage to face the global changes of climate population and urbanization;

-the promotion of the integrated urban water management approach managing freshwater, wastewater and stormwater and which interventions' effects are considered over the entire urban water cycle;

-the reconsideration of water use: "water can be used multiple times, by cascading it from higher to lower-quality needs, and by reclamation treatment for the return to the supply side of the infrastructure";

-the application of natural systems: "the natural capacity of soil and vegetation should be applied to absorb and treat water". Constructed wetlands, soil aquifer treatment and river/lake bank infiltration, artificial recharge and recovery for treating drinking water are considered viable alternatives to pipes and treatment plants. They prove to be simply cost-effective, efficient and reliable (Vairavamoorthy, 2009: 10). Decentralized ecosan systems to urban sanitation whether combined with pollution prevention-based approaches to wastewater handling, can facilitate new local sources of water and the use of valuable nutrients in agriculture, otherwise lost in the case of centralized wastewater management systems. This is of great importance especially in the case of a hybrid landscape such as the Veneto *Città Diffusa*, where agriculture holds the greater land use with consequential high levels of required water irrigation.

[54] As Tjallingii (1995a: 9) noted, these measures require the "integration of water in the design and management of buildings and urban open spaces".

Water storage, a key issue

Storage of water is the key principle at the basis of any integrated water management strategy. As Hough (1984: 90) acknowledged, storing water is not a new idea. “Natural floodplains and lakes are –indeed- the storage reservoirs of rivers that reduce the magnitude of peaks downstream. […] Vegetated soils and woodlands provide storage by trapping and percolating water through the ground with minimum run-off and maximum benefit to groundwater recharge”. Storage of water and vegetation, then, enhances the quality of water and contributes to the diversity of habitats. The twofold potential, hydrological and spatial/ecological of water-storage hence emerges. Water storage, indeed, can link human and environmental systems in mutually reinforcing health. Indeed, as Ferguson (2007: XI) stated, onsite storage can support land use activities by generating a new source of water. Upstream, it can reduce the demand to develop off-site water supplies. Downstream, it can protect water quantity and quality by reducing stormwater runoff and the associated pollution, erosion, and flooding.

Water storage alternatives are numerous and all depend on the nature of the place, its rainfall and drainage patterns, topography, soils and type of land use. However, according to their function, two main types of water storage can be distinguished: permanent storage and temporary storage. The first –permanent storage- is appropriate where a continuous supply is available and where inflow and outflow and soils permit a stable condition. The second –temporary storage- is appropriate where, as in densely urbanized areas, space is at a premium, and water storage can therefore be combined with other functions in order to smooth out peak loads when needed (Hough, 1984: 92).

Multifunctional space

The need for storage of water highlights how integrated water management calls for a multi-faceted design. To be rendered feasible, integrated design and management of water have to be integrated with other objectives. For this reason, infrastructures for integrated water management require a marked multifunctional character. City’s residential parks, agricultural fields and waste lands, parking lots, playgrounds, private gardens, flat roofs, basements etc., all could be adapted to serve also a hydrological function when designed as temporary –or permanent- storage areas and wetlands. As Hough (1984: 108) acknowledged, retention of water in multifunctional spaces or interstices can contribute to restore the hydrological balance and, together, can help to ameliorate urban climate, provide social and aesthetic benefits, bring nature’s processes closer to everyday life.

Box 2.1.

Possible multifunctional storage systems in the Veneto Città Diffusa

In the context of the Veneto *Città Diffusa*, different "single-purpose" spatial elements could also function for storage of water purposes. A section of Ronco all'Adige, as the case study of this research, is here interrogated by the key concepts of storage and multi-functionality (Figure 2.3.). A number of possible water-storage patterns emerge from the maps. Although they do not intend to be comprehensive, they can stimulate a possible different interpretation of this urban landscape and its spatial structures.

Hence, for example, what if water were to be temporarily stored in road ditches (Figure 2.3., 2)?

2.3.4. Design approaches of Integrated Water Management

In 1993, the International UNESCO-IHP Workshop- Hydropolis pursued the discussions which were started in the 1988 Symposium Urban Water on the role of water in urban planning[55] (Massing and Tjallingii, 1995: 7). It brought together technicians, ecologists and managers with urban designers and planners from different parts of the world. Various design experiences of integrated water management inspiration from different countries have been presented and discussed. The Dutch designing with water, the Australian Water Sensitive Urban Design, and the strategies underpinning the International Building Exhibition Emscher Park in Germany were among the integrated water management approaches discussed in the frame of the workshop. From that time, the same approaches have been further elaborated as many design experiences soon followed. As the scope of the research, the issues and principles at the basis of these well-known integrated water management design approaches are briefly discussed[56].

The Netherlands

For the Dutch society, managing water has always been the basis for managing the environment. For centuries the main question has been to keep out the sea, and river management was operated in order to prevent risks of flooding. In recent years, however, good-quality fresh water

[55] Hydropolis: the role of water in urban planning. UNESCO-IHP workshop, 28 March – 2 April 1993, Wageningen (The Netherlands) and Emscher region (Germany) was organized by Hans van Engen, Dietrich Kampe, Sybrand Tjallingii and others.

[56] Many other experiences, of course, were presented in the symposium. However, here, only the approaches that are more comprehensive and apt more at the purpose of the present work are briefly presented.

has become a scarce resource. It has led to the management of fresh water with more careful and economic methods.

In particular, the governmental memorandum: Third Memorandum on Water Management, published in 1989, defined the concept of integrated water management, as opposed to the established and more reductionist approach that consider each part of the urban water system in a segregated form (Hengeveld and Geldof, 1995: 94). The leading strategy is the creation of self responsible units in the city and in the country (Hartman and Sijmons, 1995: 85). As a result, in the Dutch design and planning practices, water systems have become an important structuring factor carrying even ecological and social issues. In the country, there are several examples where seasonal surplus of rain is detained and stored after purification to be used in dry periods. The effective utilization of the annual precipitation surplus, indeed, is often integrated in the design process.

In 2002, municipalities and water boards agreed to make water management plans and drafted guidelines for all municipalities. Consequently, many municipalities and water boards started to make urban water management plans together (van de Ven et al., 2006). A number of theoretical studies, policies and projects followed thereafter. However, until 2005, a lack of guidelines had led to the following of different procedures for the drafting of these water plans. (van de Ven et al., 2006) According to van de Ven et al. (2006), the approaches adopted can be grouped into three main families: object-oriented, guiding principles-guiding models, and negotiation.

The guiding principles-guiding models approach is of a particular interest for designers [57]. Developed by Tjallingii (1991, 1995c, 1996, 2000, 2003, 2009) this method aims to comprise ecological principles in the urban design practice, it is based on planning as a social learning process and it considers planning as a design problem[58]. The interaction between actors, areas and flows is regarded fundamental to build conditions for an efficient, long term action. The process of learning, indeed, uses the language of interaction rather than the language of control. Accordingly, the guiding models act as the starting point for the communicative design process. As conceptual schemes based on sustainable guiding principles, they do not prescribe the image or the details of the plan. Rather, they provide the tools for gearing strategic options to local conditions[59] (Tjallingii, 2003). According to van de Ven et al. (2006) the risk of this approach is

[57] The other two approaches are not design-based. The object-oriented approach has its roots on policy analysis and focus on problems. Normally it is led by technical water planners around a shared vision on the future state of the water system. Tools to evaluate alternatives are digital and or parametric (cost benefits analysis, multi-criteria evaluations). Van de Ven et al. (2006) acknowledge the weakness of this approach in the limited space for alternative solutions. The negotiation approach is based on planning as a transaction process where dialogue is the preferred tool. Therefore, the urban water management plan is designed by a negotiation process among the stakeholders according to the initiative, exploration, vision development, elaboration, implementation and monitoring phases. The largest pitfall for the negotiation approach is what is called ‘negotiated nonsense’, that is the possibility that all parties agree on something unrealistic or unfeasible.

[58] According to van de Ven et al. (2006), the main guiding principles of this approach can be summarized as follows: retaining water as much as possible before draining it; keeping clean water clean; making use of the natural processes and the local terrain conditions; learning lessons from pilots and experiments in practice.

[59] Tjallingii (1996: 242) has integrated the guiding models in the planning procedure PROSA (Programme, Rhythm, Orientation, Situation, Appliances). First the guiding principles are formulated. Then the existing conditions of the area are analysed. For the specific area a guiding model is selected as the basic idea for the new urban water

that the guiding model is used as a fixed objective rather than as a starting point for designing a plan. To present, the guiding principles-guiding models approach has been a guiding force in many experience practiced throughout The Netherlands as well as in other European contexts[60].

Australia

Water Sensitive Urban Design (WSUD) is a comprehensive design approach of integrated urban water management developed in Australia, a country where habitability is threatened by recurrent problems of drought[61]. It implies a new paradigm in the planning and design of urban environments, an approach that is 'sensitive' to the issues of water sustainability and environmental protection (Wong, 2006: 2). Since the beginning of the 90s, state and local government water authorities have gradually realized that the 'conventional' urban water paradigm is no more sustainable. For this reason a series of state and local level policies have been developed to support National Water Quality Management Strategy, a national policy that promotes system-based water management and the Water Sensitive Urban Design[62].

Water Sensitive Urban design integrates the holistic management of the urban water cycle and the conventional urban water flows –potable water, stormwater and wastewater-, into the design of the built urban form[63] (Wong, 2006: 2). Quantitative and qualitative impacts of water streams and related infrastructures on water cycle, land, biodiversity, and, in general, the spatial quality of the environment are considered since the earliest stages of the decision-making process. At first, physical and natural attributes of the site are assessed. The next step is the integration of water and related environmental management objectives into site planning and design (Mouritz et al., 2006: 4). At this purpose, appropriate Best Planning Practices (BPPs) are selected. They are defined as the best practical planning approach for achieving water resource management

management system. The model is elaborated during the design process where parties actively participated supported by technical experts.

[60] The water plans for the cities of Delft and Tilburg are good examples in the Netherlands. The Belgian experience, that also succeeded, is described in Heuts and Rombaut, 2009.

[61] The term Water Sensitive Urban Design was first referred to in various publications in the early 1990's (Mouritz et al., 2006: 1).

[62] The Water Sensitive Urban Design approach has influenced the management of water in many parts of the world. Thus, for example, it has been a reference for the recent legislations in the US. The American terminology for the WSUD is Low Impact Development (LID). Rainwater is considered a fundamental resource (Hager, 2003: 1). Essentially, LID attempts to model nature and match predevelopment hydrology by replacing the traditional hard infrastructure of conveyance-based facilities with infiltrating, storing, filtering, evaporating, and detaining runoff. Notwithstanding the influences of the Water Sensitive Urban Design, it is worth noting that, in the US, already in the 70s, a number of projects explored different management of stormwater in residential areas (Mazzotta, 2008: 23). The new town *The Woodlands* designed by Ian McHarg (1974), and *Village Home* by Robert Thayer (1975), are successful examples of mutual support of urban design and the sustainable water management which is currently being promoted by the Water Sensitive Urban Design.

[63] According to Wong (2006: 2), the underlying aim of the water sensitive urban design is to provide more economical, and less environmentally damaging ways of providing water, wastewater and stormwater solutions. It includes:

-reducing potable water demand through water efficient appliances, rainwater and greywater reuse;

-minimizing wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters;

-treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters;

-preserving the natural hydrological regime of catchments.

objectives in a given urban situation (Mouritz et al., 2006: 3). From this more strategic level, the design process moves towards more operational choices and aspects. The Best Management Practices (BMPs) guide the selection of the structural and non-structural elements of a design that perform prevention, collection, treatment, conveyance, storage and reuse functions of a water management scheme (Mouritz et al., 2006: 4).

According to Mouritz et al. (2006: 3), such an integrated approach has begun to gain favour over the traditional conveyance-oriented approach “because it has the potential to reduce development costs and minimize pollution and water balance problems”. Moreover, detention/retention facilities “have increasingly been used in a multi-purpose role, providing recreational and aesthetic value, thereby offsetting any loss in developable land by increasing land value for nearby residential areas” (Mouritz et al., 2006: 3).

Germany

The International Building Exhibition of Emscher Park was conceived in 1988 by the State Government of Northrhine-Westfalia, Germany, as a ten-year exhibition to promote the ecological renewal of the ‘Ruhrgebiet’ region through a number of projects. The Emscher region is a post mining industrial area where the quality of waters –both surface water and groundwater- has been seriously compromised by processes of industrialization and land exploitation over the last century.

Goals, instruments and efforts to repair the regional water cycle –that is the Emscher river system and its tributaries, together with the sewage and drainage systems- have been set up as one of the central aspects of the strategy for the improvement of conditions in the region. A process of decentralization and integration of water flows and infrastructures has been developed by interdisciplinary strategic studies backed up by a number of pilot projects[64] (Londong, 1995: 260). In the overall set up, the interdisciplinary approach to the role of water for the renewal of the environment and the landscape is of particular significance. The remediation of water quality in the region, indeed, has been interpreted as an opportunity for the enhancement of spatial and ecological feature of the landscape.

The aim of the IBA Emscher Park is the development of a continuous Emscher Landscape park where residential developments, industrial developments, industrial monuments and the infrastructures for new social, cultural and sport activities are successfully integrated. At the strategic level the plan considers the Emscher watershed as composed of micro-water-cycles (Schmid, 1995: 215). Experts from different disciplines –landscape planners, ecologists, biologists and hydrologists- have worked together to outline sets of goals and guidelines –defined as typical solutions for typified situations. The focus has been on the strategies for the separation of waste water from surface water; the decentralization of treatment plants; the

[64] Approximately 120 projects were implemented to achieve the objectives of the exhibition.

rebuilding of the watercourses in a more nature-like state; the reduction of stormwater run-off and its treatment before the discharge in the surface waters.

The integrated approach of the IBA Emscher Park has been a reference model for projects and plans of ecological renovation around the world. The strategy of thinking in natural micro water cycles has received comparatively high professional and public attention leading specialists, institutions and citizens to higher levels of cooperation.

Box 2.2.

Guiding principles for sustainable water management. Extracted from Tjallingii (1996) and main stream literature.

A set of guiding principles emerges from the new approaches in water management. They have been organized according to the three decision fields of Tjallingii's Ecological Conditions Strategy. How to manage and design water-flow in the landscape in order to set up responsible water passages, living areas and responsible and participatory actors (Tjallingii, 1996: 187)? The reference list of principles for the project of an area previously presented by Tjallingii has been narrowed down to the matter of water and updated in the light of other well known integrated approaches.

<u>*Flow domain*</u>
Reducing use. Water consumption and water contamination are reduced. It leads to reduction in both withdrawal of water from upstream or groundwater and discharge of water surplus downstream.

Making use of renewable or infinite water resources. Rainwater is the preferred water resource.

Re-using. Water flows of different qualities are separated at source and locally stored to be reused.

Re-cycling. Water flows of different qualities are specifically processed locally to be reused once purified. After purification also *re-cycling* of polluting substances is an option to be considered.

Detaining and storing. Water is locally detained and stored. Detention and storage of water flows close to the point of use is the condition for reducing use, making use of rainwater, reusing and recycling.

<u>*Area domain*</u>

Making use of local natural and cultural potential for storage and purification of water. Soils (wet-dry, permeable-impermeable; ridges/rises-basins/depressions etc.), vegetation (corridors, hedges group of trees etc.), natural landscape and cultural heritage (water practices, traces of previous water structures etc.) are existing site conditions actively integrated in the management of water flows.

Integrating flow management chains in spatial design. Decentralized storage equipments –and gradients- are integrated in the design to enhance the spatial configuration of the urban landscape.

Making healthy and diversified urban landscapes. The multifunctional space for water (integrated storage devices) addresses both the needs for a more sustainable water management and a liveable environment (limiting noise, enhancing intimacy etc.), while also including a wide variety of lifestyles and activities throughout the area.

Enhancing an ecological functioning of the environment. Multifunctional integrated water storage infrastructures are treated as stepping stones and corridors to enhance existing or introduce new ecological gradients.

Making water visible, and making visible the water eco-cycle. The processes of the overall water eco-cycle are made visible as an integral part of the landscape.

<u>*Actor domain*</u>

Promoting self responsibility. Conditions encouraging the direct involvement of inhabitants in the operations for management and maintenance of the local water system are promoted.

Creating conditions for cooperation and coordination among actors. Neighbours cooperate to improve and maintain both local water cycle –and related infrastructures- and the environment. At different levels actions are coordinated by appropriate organizations and/or institutions.

Promoting governance. Legal regulations and control over the integrated water systems are integrated in projects of governance (public-private covenants).

Enhancing local cultural heritage. Traditional practices related to water and its infrastructures are recovered and updated or their memory kept by new ones.

Box 2.3.

Guiding principles for the PROSA design process. Extracted from Tjallingii (1996) and main stream literature.

PROSA is the acronym for the stages –program, rhythm, orientation, situation and appliances- at the basis of the planning procedure developed by Tjallingii, its aim is to create constructive connections between research and design. It makes the research issues explicit at any and every stage of the design process (Tjallingii, 1996: 242).

PROSA design steps consist of three parts. At first the guiding principles are formulated. Bearing these principles in mind, in each step firstly the existing conditions are surveyed and then ideas, sketches and calculations for the design of future conditions are developed. Designing and planning are cyclic processes. The sequence provides a heuristic path for investigation by design. Program is the starting point for describing goals and problems. In Rhythm, the time-related consideration aspects of water flows are explored. Orientation attunes the expositional operations to the flows direction. Situation defines the positional operations by which the design concept lands in the local situation. In Appliances, the appropriate technology is selected.

The principles illustrated in the Box 2.2. are here rendered in the design steps of the design process PROSA[65].

Programme

The general principle is to design self responsible and self reliant systems. According to Tjallingii (1996: 242), a self reliant system tends to reduce inputs and outputs of drinking water, groundwater, surface water and wastewater from and to the outside. A self imposed responsibility system aims at water pollution prevention, location and abatement.

It follows that the system should be equipped by means of decentralized storage and reclamation devices. Stormwater should be buffered close to the points where peaks are generated. For this reason, peak waters storage equipment should be planned in the area to reduce peak flows downstream. Wastewater should be locally recycled. A local and natural wastewater treatment system should also be planned in the area. Rainwater and treated waste water should be locally detained. A seasonal storage

[65] Principles are organized as an attempt to update the previous work of Tjallingii (1996: 242).

device should be designed to stock up rainwater and the outflows of the local drainage system. The seasonal storage should reduce the water supply from outside and water discharge downstream by retaining the buffered stormwater. This can provide a good quality source of water locally. Decentralized and integrated water storage and reclamation capabilities should be added to the existing water structures, or new decentralized and integrated facilities should be introduced.

Rhythm

Stormwater and locally treated wastewater should be retained in the system's own storage to meet the rhythm of the local demand of water (supply). The rhythm of supply and discharge (in flow/out flow) should be replaced by a rhythm of fluctuating water levels in the landscape (Tjallingii, 1996: 247).

In some cases, the stormwater can later be buffered onsite in a temporary peak storage system that should be released to a seasonal storage facility. Locally treated wastewater should be stored in the seasonal storage facility only once it has reached the same quality of the stormwater stored. In this way buffered rainwater and treated effluents can contribute to the fluctuation of water in the landscape.

Orientation

The leading principle is that "water should flow from clean to polluted" (Tjallingii, 1996: 247). Prevention and control of water flows should start at the source. This means that different water qualities should not be mixed. Rather they should be separated at the source and differently reclaimed[66].

Situation

Optimal use should be made of existing ecological structures: soils, vegetation, natural landscape and cultural heritage (Tjallingii, 1996: 250). As they are less flexible, abiotic structures like terrain relief and soil types come first, to be followed by biotic structures (Tjallingii, 1996: 250). The existing landscape structures are integrated to perform optimized water storage functions and an optimal configuration of space. Hedges, biotopes, groups of trees etc. are dealt with and grouped together with man-made structures as ditches, dikes, excavations etc. These various elements all contribute in determining the choices for location, form and size of the integrated systems. Peak storage could be better accommodated in existing depressions. Seasonal storage looks for rises and impervious soil. Reclamation systems are best positioned on impervious soil and in the vicinity of the seasonal storage.

[66] Thus, for example, rainwater from roofs, run-off from paved surfaces, run-off from unpaved surfaces, grey water and black water effluents from dwellings, farms and industries should be separately treated. Only waters of the same quality can be mixed.

Appliances
The technical solutions for integrated water devices should enhance the selector-regulator operations of rhythm, orientation and situation. They should be integrated in the overall landscape arrangement. Indeed, as technique is not neutral, different choices regarding water management appliances have radically different spatial consequences (Viganò, 2009a: 212). Furthermore, the appliances selected should be simple to operate, easy to maintain and robust (Tjallingii, 1996: 253).

2.3.5. Integrated Water Management in the Veneto

In the Veneto, especially at the institutional level, there is a general awareness that traditional approaches to urban water management that involve profligate water use, little recycling and the generation of considerable waste are no longer sustainable as they continue to remain vulnerable to flooding risks as well as shortage of water supply and spatial degradation. This leads both regional policy and design practices to shift towards more sustainable water management principles. However, it is still far from being a full-blown integrated approach. Water management and design, indeed, are still often technocratic and sectoral. In the region's legislation, for example, strategies for water conservation –seasonal storage-, stormwater management –peak storage- and water treatment –purification system- are not yet clearly integrated into one chain. Moreover, guidelines and strategies seem inconsistent with the dominating hybrid character of the urbanized landscape. In addition, projects for ecological management and control are oftentimes placed under the domain of engineers and/or ecologists and scarce attention is placed on design[67].

Piano di Tutela delle Acque
In the 1970s, Italian legislation started to look towards a more sustainable management of water by integrating a series of prescriptions and standards based on principles of a sustainable management of water. The national law 319/1976, for example, introduced the norms to safeguard the quality of the bodies of water. The legislative measures and modifications that followed were manifold, all contributing to a more comprehensive regulation of the water flows cycle.

[67] There are, of course, a few exceptions as, for example, the pilot project for the reanimation of the gravel stone quarry Cava Merotto, in the municipality of Colle Urberto (Treviso) promoted by the Veneto Region and the waterboard Pedemontana Sinistra Piave, and the pilot project Vallette di Cerea in the municipality of Cerea (Verona) promoted by the Veneto Region, the municipality of Cerea and the waterboard Consorzio di Bonifica Valli Grandi e Medio Veronese (today, Consorzio di Bonifica Veronese) for the "renaturation" of the river Menago. In both projects, design aspects were considered from the very beginning. For Cava Merotto, the institutions involved the IUAV University of Venice in the design process and in the Vallette di Cerea, the office for environmental design Dionea S.A. guided the various stages of the design.

Notwithstanding, only the national decree D.Lgs 258/2000 effectively distinguished between stormwater and wastewater discharge, which was a fundamental step for the sustainable management of water (Mazzotta, 2008: 42). It was the national decree D.Lgs152/1999 and the replacing D.Lgs 152/2006 (Norme in Materia Ambientale) that gave a stronger impulse towards integration. In particular, the latter takes in the principles of the European Water Framework Directive 2000/60 that, in turn, promoted the integrated management of water resources [68]. These legislations push for the compilation of plans for water conservation at the regional level, the so called Piani di Tutela delle Acque. In the Veneto region, the Piano di Tutela delle Acque initially adopted in 2004 (regional deliberation 4453, 29 December 2004) and approved again in 2009 (regional deliberation 107, 5 November 2009), is the most advanced legislation of integrated water management inspiration. It integrates principles for a more sustainable regional water cycle including measures for quantitative and qualitative aspects. However, there is still no full integration with spatial issues. Although it provides specific guidelines for the different territorial units composing the region, it does not explicitly consider opportunities related to the processes of urban decentralization dominating the region. The extension of centralized pipes systems, for example, is still the main stream strategy, even in such a decentralized urban landscape.

D.G.R. 2627/2002

At the regional level, because of the growing urbanization of last decades, the excess of water has been the main driver in pushing towards the integration of water issues in planning practices. The regional council deliberation DGR 2627/2002 and its following amendments (DGR 1322/2006 and DGR 1841/2007), are the legislations introduced to control the changes in water flow dynamics due to increasing urbanization. Storage is the solution for avoiding flood risks. The coverage of agrarian land, indeed, corresponds to less storage capacity of the soil –less interception and infiltration [69]. Therefore, stormwater management standards introduced by legislation call for zero increase in stormwater rate discharge from a site as the result of a development. This means that, according to the principle of *invarianza idraulica* –hydraulic invariance-, the rate of discharge across the border of a new development area can be no greater after development than before. Plans for new urbanization have to be accompanied by a stormwater plan, *Valutazione di Compatibilità Idraulica*, based on principle of *invarianza idraulica*. The legislation promotes temporary storage as the main solution that has to be adopted to compensate the changes in coverage. The excess of water is detained onsite in a basin and, after the rainstorm, slowly released downstream. In this way, peak loads are shortened out.

PAT

A recent planning policy integrates water issues in the planning process. The regional law 11/2004 "Norme per il Governo del Territorio", indeed, rewrites the rules for designing future

[68] In the European Water Framework Directive, one of the relevant elements is the concept of catchments organization, which makes catchment planning a priority.

[69] About the concepts of interception and infiltration of precipitations in the landscape see Marsh, 2005: 148.

spatial transformations at the fine scale of the municipality. It introduces the PAT (Piano di Assetto del Territorio), PATI (Piano di Assetto del Territorio Intercomunale) and PI (Piano degli Interventi) as new municipal or inter-municipal plans. The new planning instruments overlap prescriptions from the regional plan (Piano Territoriale Regionale di Coordinamento, PTRC), the province plan (Piano Territoriale di Coordinamento Provinciale, PTCP) and, when present, the area plan (Piano d'Area). Moreover, according to the regional council deliberation DGR 2627/2002 and its following amendments, the new plans, include an hydraulic section called Valutazione di Compatibilità Idraulica (Hydraulic Compatibility Assessment) where all the upper ranks of water plan in force on the water matter are incorporated: regional and interregional river water board plans (Piano di Assetto Idrogeologico, PAI), plans from water board in charge of the management of the agricultural water network (Piano Generale di Bonifica e Tutela del Territorio Rurale, PGBTTR), and the Piano di Tutela delle Acque. The section includes also specific prescriptions based on the specific conditions of the municipality.

In general, areas subject to hydraulic risk and hazard and areas with low drainage capacity are outlined. Prescriptions are more restrictive as hydraulic risk and hazards increase. New urbanization is either prohibited in such an area or has to deal with specific prescriptions like the recommendation to avoid basement construction or to make ground floor levels higher than the ground level. Again, road ditches cannot be piped anymore –except for very short stretches- or should be resettled every time that road sections are widened; parking lots should provide for runoff purification and infiltration; or peak storage systems related to new impervious areas should temporarily retain a certain amount of water to activate natural water purification (Comune di Ronco all'Adige, 2009: 80-86). The Hydraulic Compatibility Assessment, then, makes use of the guidelines from the DGR 2627/2002 (and its amendments) to have a rough preliminary computation of the changes in discharge due to the urbanization measures planned. It is oftentimes the case however that the water flow remarks adopted still maintain a rather sectoral character. Water storage devices, indeed, are exclusively seen as standard solutions resulting from engineering calculations with no consideration of their spatial role or configuration in the landscape.

Commissario Delegato, Mestre

In the Veneto, after the heavy storm events that occurred in Mestre the 26th of September 2007, the National Government instituted a Ministerial Commission (Commissario Delegato, 2009), set out to draft specific guidelines and prescriptions for the promotion of a more robust storm-water system for Mestre and its surroundings. The commission has also been in charge of coordinating the actions of actors directly and indirectly involved in the management of water in the area, including citizens, municipalities and the water board. The legislation of reference for this endeavour is the DGR 2627/2002 and its amendments. It has since been adjusted with more severe restrictions (hydraulic assessment is, for example, compulsory for new urbanizations over 200 m2). The territory is hence to be organized into micro-water-cycles and catchments. For this reason, the municipalities of the area, according to the water board, have to work on specific water plans (Piani delle Acque) based on small scale catchments management.

Infiltration and surface storage are the key principles promoted at different levels. At the individual level, for example, household tanks are recommended to reduce the discharge on the storm-water system and to reuse storm-water for irrigation and/or other non potable uses. These individual interventions should be simple to maintain, their maintenance a duty of the private owners. In the same way, at the collective level –as it could be the case of urbanized patches-visible or underground peak storage facilities have to be integrated (Commissario Delegato, 2008: 7). At this level water re-use is not mentioned. Collective facilities become municipal infrastructures once urbanization process is concluded. Stormdrains pipes systems have to be maintained by the agency in charge of the management of local drinking water and wastewater. In general, basements are discouraged. In new constructions, the ground floor should be higher then the water level reached during the flooding event (Commissario Delegato, 2008: 7; Commissario Delegato, 2009: 19).

As a result citizens started to organize themselves into special interest groups, and exercising their own control of the spatial transformations, informing the institutions of potential critical situations, in general promoting a better organization of the place where they live. However, it is worth noting that, in the list of prescriptions, opportunities related to spatial quality and arrangements are only mentioned in brief. No particular attention has been spent in regard to a more effective handling of such relevant factors and elements[70].

A lack of integration

In general, the recently adopted important regulations often work independently, although they have the common target of pushing towards a more sustainable water cycle. Different laws have different targets. There is not yet a strong and clear integration of the water flows. Indeed, the potable and non potable water supplies, and the storm-water drainage and waste water disposal are not really integrated in a chain. As a result, opportunities to close the water eco-cycle are often missed[71].

For example, in Ronco all'Adige, the research's main case study, an urban landscape where the agricultural matrix is perforated by numerous water basins, according to the municipal PAT plan (Comune di Ronco all'Adige, 2009), new urban expansions will effectuate the legislation emanated to avoid risks of flooding (DGR 2627/2002) by introducing peak storage basins as solutions to the problem. In just a brief amount of time, therefore, new hollows will start to perforate the agricultural matrix. There has been little or no consideration on the possibility of taking advantage of the water storage capacity of the numerous clay pits located a few hundred meters downstream from the planned expansions. The project resulting from the technocratic application of legislative prescriptions seems to deny certain opportunities to the site.

[70] For more information, see: Commissario Delegato per l'Emergenza Concernente gli Eccezionali Eventi Metereologici del 26 Settembre 2007 che Hanno Colpito Parte del Territorio della Regione Veneto, 2009. Linee guida per gli interventi di prevenzione dagli allagamenti e mitigazione degli effetti.

[71] The law L. 36/1994, Disposizioni in materia di risorse idriche - Legge Galli, introduced the system of Autorità d'Ambito Territoriale Ottimale (AATO) to perform more integrated water services. However, planning and management of waters are separated. Moreover, both at the planning and management level the water system is not fully integrated since surface water is not comprised in the integrated service.

Furthermore, although new onsite stormwater devices are a step ahead towards sustainable water management, from a water conservation perspective, they fail to use the opportunity for the re-use of storm-water to meet local demand, as no water reuse considerations are included. In the recent municipal PAT plan, concepts for tuning the integrated management of water towards conditions of a more urban decentralized hybrid character landscape have not been investigated. It now emerges how current policies include both elements of "shift" and inertia. Therefore, a move towards an integrative and innovative design approach is required[72].

2.3.6. Decentralized urbanization and decentralized water management

The above description demonstrates the lack of appropriate investigation of the relations between integrated –and decentralized- management of water and the processes and patterns of urban dispersion. While many water issues have already been investigated in the context of the compact city, only a few studies have been carried out in the frame of 'cities of dispersal'. Hence, integrated and decentralized water management has to confront the processes of urban decentralization that, although differently, concerns more and more both European and American urban systems.

As noted above, the shift in water management that implies more room for water at the proximity of the user to close the eco-cycle of water, pushes towards the ecopolis city model where, abutting urbanization, there is space for closing the cycles of food, waste, energy and water. In this perspective, decentralized urbanization –as a potential ecopolis model – could have room for water. However, this capability might be of interest only when the strategies of water decentralization are fully integrated in the activities of the landscape by weaving together robust relations with the market, an essential condition of ecological rationality (Dryzek, 1987). Design strategies and models, therefore, have to consider the hybrid character typical of many territories of dispersion.

For example, as noted above, in these decentralized urban contexts the water issue intersects both urban and agricultural concerns. For this reason, the shift in water management has to seek out strategies and models, which promote mutual benefits for both agriculture and urbanization. Can the areas covered by urbanization be considered as a resource for agriculture in such an integrated water management perspective[73]? Water intercepted by pavements could be used as extra source for irrigation. The surplus water demand from agriculture due to the higher requirements of modern cultivations can be compensated by the reduction of the total agricultural areas in favour of covered-urbanized areas that, in turn, work as 'interceptors' of water for neighbouring agricultural fields. Thus, in the range of dispersed urbanization, storage systems might smooth out peak loads generated by the impervious soils of urbanization during

[72] Especially in comparison with a regulation-driven approach that today focuses more on plan testing.

[73] According to Hartman and Sijmons (1993: 86), "the time when urbanization made only consumptive, or even parasitic, use of the existing rural setting is past". It implies a form of anticipatory investment in the qualities of the rural area for urbanization and, in turn, in the qualities of dispersed urbanization for fragmented rural area.

rainstorms. The water buffered in such cases might be accumulated and stored to cover the annual irrigation demand capacity –that is the differential between evapotranspiration and precipitation. Seasonal storage might work as a diaphragm between water 'interceptors' –covered areas- and water users –cultivated areas.

Onsite water storage might open up new unexpected scenarios that can draw the attention of institutions and professions (notably engineers and designers). Therefore, principles of sustainable water management have to be tested in concrete design concepts and situations.

Storing water in the Veneto Città Diffusa

In the Veneto, this leads to an exploration of possible synergisms between decentralized urban conditions and decentralized water options. Beyond an increasing interest for the fine grained quality of the *Città Diffusa* that has emerged from some recent explorations and pilot projects, there is the need for more comprehensive investigations in unfolding how the fine grained landscape elements can be reinterpreted in the light of principles of integration and decentralization in water management [74]. Water strategies and tools of integration and decentralization must be tailored to the physical components of the landscape, as to allow for an effective restructuring and re-functioning of existing materials and infrastructures [75]. The impressive (quasi-)isotropic distribution of fine grained water infrastructures in the landscape noted by Viganò (2008a: 38) can be the strategic existing condition by which to encourage the setting up of decentralized, onsite water purification and storage clusters or systems. Therefore, these carrying structures should be updated in order to meet today's variety of water requirements. Of course, as Schuetze and Tjallingii (2008: 8) noted, they also have to fit with the economic, social and ecological characteristics of a specific decision situation[76].

The new approach can also trigger a process of social re-appropriation of the territory. Indeed, as described above, in the Veneto *Città Diffusa*, the fine grain elements of the water system (drainage and irrigation systems) are the fingers penetrating the mosaic of a hybrid character. In many cases, they are interstices of public domain or, at least, under public regulation and

[74] As mentioned above, a reference work is the design oriented research *Water and Asphalt*. It represents an important turning point in the field of study regarding the città diffusa. It started to interrogate the fine grained, isotropic character of this urban landscape –notably the existing deposits of water and road infrastructures- at the light of general principles of sustainability. Another important reference research has been carried out by the LABSLA (LABoratorio per lo Sviluppo Locale Autosostenibile), a research programme of DAEST (Dipartimento di Analisi Economica e Sociale del Territorio) at IUAV, that, since 1995, promotes integrated water management in the urban designing process. Although supporting a number of studies and projects in the Veneto, LABSLA has not yet specifically focused on design strategies and tools to integrate sustainable water management in the process of urban decentralization at present concerning the Veneto *Città Diffusa*. More recently, Ferialdi (2009) has briefly analysed the close relation between the urban tissue of a few historical centers of the Veneto and the layouts of their water systems. However, in the Ferialdi's studies the relation with the issue of urban decentralization has not been fully discussed.

[75] Viganò (2009: 209) states that "rather than considering the isotropic feature of the territory merely as a product of history, a heritage to defend it should be seen and understood as a strong rationality, a resource and an inspiration for contemporary projects".

[76] Can, for example, a process of decentralization of water be strategic for the future of European agriculture with the expected termination of EU policy of subsidies?

management. When not in public hands, their reuse for storing might imply the involvement of private owners. Thus, in a water storage perspective, caring for water and its spatial structures can again become a matter which directly involves the people inhabiting the landscape. Moreover, as for a large number existing water infrastructures, there are traces of former social practices, and their reuse gives continuity to the society living within and throughout the landscape. Besides, it should be considered that re-establishing function for existing landscape structures through works of minimal rationality may only require low energy inputs especially in comparison with standardized works extraneous to site conditions.

In conclusion, the urban landscape of the Veneto *Città Diffusa* ultimately appears as a prime testing ground for exploring strategies inspired by principles of sustainable water flows (Figure 2.4.). The unique ecological diversity and multi-functional land use of this landscape can effectively provide promising answers to today's problems of landscape-upscaling, floods, water scarcity and water pollution. It is not a question of going back to the past, rather, the approach should draw on lessons from the past and on the fine grained potential of the local landscape in addressing future challenges. It implies exploring new perspectives, testing new plans, and discovering new promising multifunctional combinations. Therefore, designers and planners are called to develop plans that can enhance the habitability of the landscape through multifunctional landscape structures as support for a variety of processes. In order to develop effective and robust integrated water chains, both water quantity and quality issues in relation to activities distribution should be in the designers agenda. Finally, designers and planners have to organize synergism, coordination and cooperation among the different actors dealing with water as the steering conditions for shared and integrated solutions. In this perspective, as Tjallingii (1995b: 65) noted, demonstration projects can be crucial to the development and promotion of new integrated approaches: "to engineers they offer the opportunity to test new measures and for planners they are the testing ground for questions of integration and to find out how people react to new elements in their environment and new regulations".

Chapter 3

Research methodology

3.1. Introduction

This chapter focuses on the methodological and conceptual issues concerning the process of analysis and design that aims to verify the hypothesis of the present work: in the decentralized urban landscape of the Veneto *Città Diffusa*, answers that design measures can give in response to increasing water-flow dysfunctions and the loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes – ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements.

This theory involves another closely related hypothesis that has yet to be corroborated, i.e., that recent economic growth and related processes of centralization concerning water flows and concerning spatial structures are threatening the diversity of the *Città Diffusa* and increasing problems of flooding, drought and water pollution.

The chapter explains the methods by which the twofold hypothesis of this research was corroborated. The first part illustrates the reasoning behind the choice of using a particular case study method as to disclose the recent processes of change that regard the fine grained materials of the *Città Diffusa* landscape and to assess whether the current design principles and models are consistent with the given specific context. The second part provides methodological information about how the concurrent mixed model study has been organized through an explanation of the questions and hypotheses related to the different phases of the study, the specific fieldwork data collection and sample choice, including also key sources of evidence.

3.2. The case study approach

In order to confirm the validity of the hypothesis, the studies turn to the *case study method*, an approach widely used in the social and behavioural research sector (Stake, 1995; Yin, 2003), but also increasingly common in the field of urbanism[77] (Francis, 2001).

[77] New York or Boston in *The death and life of great American cities* of Jacobs (1961), Los Angeles and Jersey City in the work *The image of the city* of Lynch (1960) are very well known examples of the use of the case study

Why the case study?

The use of the case study and, therefore, the use of the inductive method as a way of reasoning, are first due to the fact that thinking over the decentralization of water flows and related infrastructures imposes a focus on the fine grained materials composing local landscapes rather than a limited bird's eye overview of wide scale territories[78]. Institutional or agency reports often account macro data and interpret the processes behind data without further consideration on their interrelated connections with local arrangements and processes. Often, in light of these broad data aggregations, the burden of every day local choices and interventions appears as non-influential.

Moreover, information about local, every day landscapes is often not systematically collected and organized. Even when it is not treated as unofficial information, quite often there are no critical reviews that sufficiently integrate the data[79]. As stated by Moretto (2008: 95), for a very different urban context, a gap between the practice-based local governance processes and outputs and their formal recognition by the institutional sphere can occur[80]. Francis (2001: 16) who recognised and validated the use of the case study method in landscape studies, points out the need for research on case studies of more modest, everyday landscapes.

It must be noted that as the purpose of the research, the Ecological Conditions Strategy developed by Tjallingii (1996) is assumed as crucial conceptual framework and reference to inquire about the potentials of this decentralized urban landscape combined with a decentralization of water flows and infrastructures. The Ecological Conditions Strategy combines a general strategy with the drafting of detailed plans for local landscapes. One of the elements in this approach is the *Sandwich Strategy* that provides a conceptual frame for bottom-up and top-down actions, while also creating space for an intermediate level of collective projects (Tjallingii, 1996: 200). In line with this conceptual framework, the present study analyses the detailed situation in the case study area, to then formulate more general strategies. It then goes back to the case study area to elaborate more detailed plans. In this way the validity of the general strategy can be effectively tested. An in-depth understanding of the local and site-specific conditions of the case study is thus supposed.

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approach in the field of urbanism. More recent examples of case study approaches to landscape architecture include Anne Spirn's studios on the community garden case studies in west Philadelphia or John Lyle's former studios on regional design problems within the Los Angeles Basin (Francis, 2001: 17). Recent studies carried on the territory of the Veneto have made use of the case study as ultimate tool for inductive explorations. Remarkable studies of this kind can also be found in the Turri's (2002) research on the municipality of Caprino Veronese (Verona) or the studies of Viganò et al. (2009) on a section of the municipality of Colle Umberto (Treviso).

[78] Induction is "a way of reasoning in which you arrive at general ideas by considering particular examples". Instead deduction is "an idea which you reach about the truth of something by using information that you already know is true". Longman, 1991. Dictionary of English. Glasgow: Harper Collins.

[79] A different orientation emerges with the introduction of the Regional Law L..R. 11/2004 that aims at the reconnection between local landscape and local identities through a development that considers and integrates the multifaceted aspects of the territory.

[80] The Ph.D. studies carried out by Moretto (2008) focused on the accessibility of water in low-incomes communities of the Caracas Metropolitan Region.

According to Yin (1994: 3), the case study has the potential to 'retain holistic and meaningful characteristics of real life situations', and is thus the ultimate strategy to investigating landscapes in an ecological perspective to provide opportunities to comprise site-specific conditions in the different phases of the research. Through the case study method the empirical inquiry investigates both historical and contemporary settings within a real-life context. (Yin 1994: 13; Groat and Wang, 2002: 346)[81]. As the case study links a wide range of issues, the case has been analysed in relation to the complex dynamic processes that are at work in this area.

It is worth noting that case studies have been given instrumental and intrinsic meanings[82]. Instrumental, because they can test the validity of the thesis through an inductive process: the observation of the specific situation is directed to understand processes of general entities. Acknowledging the embedded nature of the case study situation in the local context, the research aims at exploring the potential of the general strategy in this specific situation. For this reason the case study method requires a careful thinking through of both the overall framework and the details of the research. The intrinsic meaning of the case study of the present research follows from carrying on the studies started a few years ago at the Department of Civil and Environmental Engineering of the University of Trento (DICA) in the same area[83]. The observations and planning proposals that emerged in the previous studies carried out by the department also provide planning strategies to be tested[84]. One of the observations that already appeared concerns the way actual development disregards the potentials related to the fine grained landscape elements. It is worth highlighting that the inductive strategy employed does not pretend to generate a comprehensive plan for the region. But by focusing on spatial structure elements of a landscape, these studies may become the vehicle to examine other cases and through them depict the spatial structure of the region.

Two case studies

Two different case studies were selected as testing grounds of a unique strategic inquiring framework: a portion of Ronco all'Adige in the administrative territory of the Consorzio di Bonifica Valli Grandi e Medio Veronese water board and a portion of Ponte di Piave in the administrative territory of the Consorzio di Bonifica Pedemontano Sinistra Piave water board[85]

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[81] Malbert (1994) discusses the case study as a tool to develop context-related knowledge.

[82] According to Stake (1998: 88) for researchers using the instrumental case study, the case is of secondary interest compared to the theory that can be established with it. In the intrinsic case study, the research "is undertaken because one wants better understanding of this particular case". (Groat and Wang, 2002: 355).

[83] In middle of the 00s the local bricks industry Gruppo Stabila Stabilimenti Italiani Laterizi SPA have charged the Department of Civil and Environmental Engineering (DICA) with developing a study that assess the feasibility of a park in Ronco all'Adige, south-west of Verona, by the excavation of several new hectares of clay pits (Bertola and Diamantini, 2007). For a comprehensive overview of the studio see: Bertola, P., Diamantini, C., 2007. La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Dipartimento di Ingegneria Civile e Ambientale, UNITN, Trento.

[84] According to Francis (2001: 15) case studies serve to make concrete what are often generalizations or purely anecdotal information about projects and processes.

[85] According to the Regional Law L..R. 12/2009, these two water boards have been recently unified in the Consorzio di Bonifica Veronese and the Consorzio di Bonifica Piave respectively. The Consorzio di Bonifica Veronese comprises even the former water boards Consorzio di Bonifica Adige Garda and Consorzio di Bonifica Agro

(see Figure 1.4.). The use of multiple case studies was instrumental for the comparison of information and data interpretation.

The two case studies are both literal and theoretical replications[86]. Indeed the same principles and predictions established for Ronco all'Adige were tested in Ponte di Piave. They are typical *Città Diffusa* landscapes threatened to a different degree by floods, drought, water pollution and a loss of spatial diversity. Nonetheless, a closer inspection reveals how both historical and present differences in the socio-physical structures of Ronco all'Adige in comparison with Ponte di Piave are relevant for the choice of planning strategies. For example, the territorial section observed in Ronco all'Adige deals with numerous former clay pits that are found throughout the landscape –the legacy of a flourishing brick making marking economy- which have changed the spatial form as well as the flow behaviour in the local hydrological cycle. Whereas the section in Ponte di Piave faces a recent process of concentration of industrial activities in a wide industrial platform which have changed the local spatial configuration with effects on the way water is withdrawn and discharged. At the same time, Ronco all'Adige and Ponte di Piave exhibit a variety of different flow-pattern structures, all repeated by a hundred or a thousand over the Veneto *Città Diffusa*. In these terms they are theoretical replications, displaying similarities and differences that are consistent with the variety of socio-physical situations of the Veneto *Città Diffusa* and the behaviours of its water flows.

The case studies were screened through a common research framework in order to get comparable results and, this way, prove the research hypothesis[87].

My dissertation focuses on the case of Ronco all'Adige, whereas Ponte di Piave is the object of G. Zaccariotto's Ph.D. studies (Zaccariotto, 2010). According to Francis (2001: 21) Ronco all'Adige is a landscape type because of its geomorphologic and geoanthropic features. From a geomorphological perspective, Ronco all'Adige is an example of an alluvial low plains landscape of the Veneto Region, in which the soils result from the overflowing of the Adige River, one of the main alpine rivers crossing the Region. From a geoanthropic perspective Ronco all'Adige is a typical cultural landscape of the low plain, where the recent processes of socio-economical changes have been superimposed on a rich and impressive geohistorical palimpsest (Vallerani, 2006: 32). Nevertheless, as said above, the territory has its own geomorphic and geoanthropic specificities resulting in the landscape. The numerous former clay

Veronese Tartaro Tione while the Consorzio di Bonifica Piave comprises the former water boards Consorzio di Bonifica Destra Piave and Consorzio di Bonifica Pedemontano Brentella di Pederobba. For the purpose of the studies, these new administrative boundaries were not considered, since they were to be defined once the research was further developed. Moreover, despite their being grouped, for all intents and purposes these territories are at present still separately managed.

[86] Wang and Groat (2002: 357) distinguish between literal and theoretical replications. "A literal replication is a case study -or studies- that tests precisely the same outcomes, principles, or predictions established by the initial case study. In contrast, a theoretical replication is a case study that produces contrasting results but for predictable reasons". In regard to this second definition, since the beginning of the studies, there was a certain awareness about the possibility to achieve also different if not contrasting results.

[87] Francis (2001: 27) claims how in landscape studies there is a need for a large number of case studies that use comparable methods so that findings can be identified across different cases.

pits, for example, though they might be found in other ‘città diffusa’ landscapes, are the evidence of a specific socio-economic process of exploitation of the local resources.
Ronco all’Adige represents an issue type as well, since, as many other landscapes of the Veneto *Città Diffusa*, it faces problems of drought, flood and pollution, and is fading its characteristic spatial diversity through a progressive zero setting of its fine grain features.

Landscape elements

The research explores the options of reviving the role of the decentralized fine grained elements of the Veneto città diffusa by adapting them to the present and the future. To this end, the case study granted to give special attention to the basic elements of the territory –agricultural fields, housing industrial or commercial plots, roads, streams and former pits-, as those operable materials of the landscape that, repeated in more or less complex sequences, settle to constitute a mixité of forms and functions that are typical of this urban landscape (Munarin and Tosi, 2001: 69)[88].

Agricultural fields, housing industrial or commercial plots, roads, streams and former pits are lexicon which, through recurrent syntactic rules, composes the numerous landscape patterns of the low plain. The element types, though not Platonic archetypes, are categories which are consistently useful in disassembling and reassembling the urban landscape, selected with respect to investigated issues and the gathered data. At the institutional level, while data on single element types were often adequate, there was a lack of information on their interrelations. Drains, waste pipes, layouts, pipe connections, etc. were often unknown among the technicians as the exclusive domain of the inhabitants[89].

In the case study several different recurrent landscape patterns are embedded: they are representative of the numerous combinations composing the fabric of the low plain and, as such, examined through the typological reduction of their functional and structural complexity (Gregotti, 1966: 146). The agricultural field, for example, is a material spread in a variety of inflexions over the territorial section. Its recurrent structural components –ditches, hedgerows, dirt roads…- and related functions –irrigation, drainage, water retention…- were reduced in operable schemes that allow for investigation beyond their complexity and their consistently varying combinations.

[88] The Veneto *Città Diffusa* can be interpreted as a system of units, repetitions of isolated, similar, autonomous objects in the environment. In her book “La città elementare” Viganò (1999: 151), following the thought of Kaufmann, thinks over the topic of the Pavillon-system as a particular feature of the contemporary city. She stresses the need for studies that consider the contemporary territories as compositions of elements. The interpretations of the territory must find out the rules and techniques beyond its compositions, taking into account the syntaxes of a variety of disciplines (Viganò, 1999: 206). The project of the contemporary city asks for a better tuning of the present rules of assembling and disassembling, which are partly different from the rules used in the past. Afterwards, revived rules may update and enlarge the vocabulary of the project of the city and enrich the syntax of materials and techniques (Viganò, 1999: 206).

[89] In reference to the important role of the citizen of the *Città Diffusa*, and the role he/she plays in the management of these fine grained infrastructures.

However, in regard to these building blocks composing the urban landscape, Alexander validly stated in his work "A pattern language" (Alexander et al., 1977: XII), that each landscape pattern is closely related to patterns of different level and degree[90]. Therefore, the observations of the case study proceeded across different scales. In order to disclose the interrelation among flows, areas and actors across the scales, zoom-in and zoom-out techniques were crucial operations.

Scales of observation

The investigation of the case study made use of several scales of observation: from the scale of 1.25x1.25 km, the inquiry zoom-ins were operated to observe the basic elements of the landscape and their elementary compositions, and the zoom-outs to grasp how the fine grained patterns result throughout the landscape (10.5x10.5 km) and over the entire region (210x210 km).

Upfront it appeared evident that seeking the water storage potentials of the fine grained elements of the urban landscape such as agricultural fields, housing industrial or commercial plots, roads, streams and former pits have to be carried out through a close inspection of observable pieces of territory. Indeed, at the level of the 1.25x1.25 km section, the basic materials of the landscape and the related conveyed water flows are directly observable. At the same time, the typical complexity, heterogeneity and hybrid character of the Veneto *Città Diffusa* already manifest itself on its own.

Moreover, the relatively small size of the area carefully analysed –the 1.25x1.25 km- was made necessary by the broad type of inquiry that was made and the lengthy time required for the techniques of analysis employed. Apart from the scales mentioned above, in some cases other intermediate levels were used to support the investigation or description of specific issues.

3.3. Concurrent multilevel mixed model design

Brief description of the phases

Due to the vastness and multidisciplinary facets of the investigated topic, the methodological apparatus employed to corroborate the hypothesis combines different strategies or systems of inquiry in a concurrent multilevel mixed model design (Figure 3.1.)[91]. The definition, borrowed

[90] "Each pattern is connected to certain "larger" patterns which come above it in the language; and to certain "smaller" patterns which come below it in the language. The pattern helps to complete those larger patterns which are "above" it, and is itself completed by those smaller patterns which are "below" it." (Alexander et al., 1977: XII).

[91] According to Tashakkori and Teddlie (2003: 705), a concurrent mixed model design "is a multi-strand mixed design in which there are two relatively independent strands/phases: one with QUAL questions and data collection and analysis techniques and the other with QUAN questions and data collection and analysis techniques. The inferences made on the basis of the results of each strand are pulled together to form meta-inferences at the end of the study." Whereas, a multilevel mixed model design is outlined as a system of inquiry "in which QUAL data are collected at one level (e.g., child), and QUAN data are collected at another level in a concurrent or sequential manner

from the realm of the social sciences, has been here slightly adapted to the needs of a design-oriented research. Indeed, the design process is not strictly consistent, rather it ranges over very different approaches –historical, qualitative, quantitative or experimental-, often mixed into the various stages of the study.

In the frame of the present research, this combined and integrated approach aims to gain some insight into the analytical reading of the recent processes of change and their effects on spatial and water-flows arrangements, as well as into the possible spatial and water flows win-win design combinations inspired by principles of ecological modernization.

According to this approach, the research is organized in three different but interrelated phases.

The first stage –*analysis*- concerns the investigation of the recent spatial and water flow changes at the levels of the case study (1.25x1.25 km) and water board domain (about 40x40 km), following a multilevel mixed system of inquiry that combines interpretative-historical and qualitative research/approaches[92].

The second stage –*design*- concerns the design exploration testing different levels of water flow decentralization, through a multilevel experimental design strategy employing a series of simulation, qualitative and quantitative tactics.

The third stage has been designed as an open stage embedded in the first and second. It concerns the tuning of guiding models through a process of learning, as a cyclical way of continuing comprehension between analysis and design.

Learning process

Before moving to the methodological description of the phases adopted, there should be an outline indicating how the learning process has contributed to the purposes of the research. The learning process is at the basis of the Ecological Conditions Strategy, the framework developed by Tjallingii (1996: 175) as tool for ecologically sound planning[93].

The process enables the linking of the analytical level of the research –as the context's ecological condition survey studies, the shared aims of sustainable development, and the guiding principles to orient the planning proposals- to empirical ones – such as pilot projects

to answer different aspects of the same research question." To achieve its own ends the interdisciplinary methodological apparatus of the research integrates and expands the above frameworks, harnessing strategies and tactics from different disciplines and systems of inquiry (Groat and Wang, 2002: XI). Besides, as Francis (2001: 16) asserted, in the architectural research sector the case study approach typically employs a variety of research methods: include experimental, quasi-experimental, historical, story telling/anectodal documentation as well as multi-method approaches.

[92] According to Groat and Wang (2002: 180) qualitative and interpretative-historical research are closely related, often combined so that aspects of the one can augment the characteristics of the other.

[93] According to Tjallingii (1996), the Ecological Conditions Strategy is a framework for decision makers and designers to set up conditions for ecologically sound activities

and scenarios studies[94]. The guiding models are hence the core of this framework, as they interlink guiding principles for an integrated water-flow management, including the context's ecological conditions on one side, and the process and outcomes of the empirical studies on the other side.

In the present research, as in the Tjallingii's Ecological Conditions Strategy, the guiding models link the analytical and the experimental stages in a continuous process of learning. They are used in accordance with their original meaning, as tools for the making of plans that answer the question how, according to a set of guiding principles, activities can be organized into certain categories of cases (Tjallingii, 1996: 178). For this distinctive feature the guiding models were chosen as dynamic catalysts of the analytical and experimental design outputs.

As desirable design patterns for typical landscape situations, the guiding models are contingent on the discoveries that emerged from the analysis –first stage. Furthermore, as such, they have been tested in the situations offered by the case study and upgraded through the cyclical betterments typical of the learning process –second stage. Thus, in the research, the nomothetic research on guiding models and the ideographic research on generating design are integrated in a whole. It is well-known that, often, in the realm of design, design experiments start before making any analytical insight and that analytical and experimental investigations proceed concurrently. Likewise, in the present studies the horizontal interactions between the stages of analysis and design were very frequent.

Therefore, the research aims to widen the toolkit for planners by a fine-tuning of these conceptual tools to the conditions of the low plain of the Veneto *Città Diffusa*. However, it should be stressed that the purpose of this research is not to merely fine-tune site-specific guiding models, but rather to investigate the potentials of this urban landscape as an ecologically sound city form whilst highlighting the opportunities related to the diversity and ratio of structures and activities for a decentralized water-flow management. Furthermore, the set up system of inquiry aims to contribute to the epistemological debate on the relationship between research and design. The framework adopted might be an effective model for research to be used in design studies that aim to gain knowledge from other disciplines in order to better investigate the contemporary territory.

Finally, it is worth highlighting that the investigation does not rest exclusively on information given by the administrative official data, nor does it only list the principles that should guide a water sensitive design for the *Città Diffusa* urban landscape. The local water board Consorzio di Bonifica Valli Grandi e Medio Veronese has strongly supported the present work and its methodological apparatus as it provides them with the opportunity to complement and compare their core set of quantitative data with the qualitative information gathered in the field research surveys. And this in order to have a more comprehensive overview of the area while effectively assessing the approaches already in use.

[94] For an overview of the structure of the learning process, see: Tjallingii, S., 1996. Ecological conditions. Strategies and structures in environmental planning. Wageningen: Institute for Forestry and Nature Research.

The description of the strands proceeds from *analysis* –phase one- to *design* –phase two- ending with *guiding models* –phase three. Nonetheless, as mentioned previously, this sequence does not exactly mirror the way the research was carried out.

3.3.1. The interpretative-historical research of the *analysis* –phase one

Hypothesis and questions

This strand aims at corroborating the hypothesis that recent economic growth and related processes of centralization –and separation- concerning water-flows and related spatial patterns are threatening the diversity of the *Città Diffusa* and increasing problems of flooding, drought and water pollution. The analysis has been carried out through a multilevel mixed method addressing two different levels: the unit of the local landscape of Ronco all'Adige, and the higher level of the water board Consorzio di Bonifica Valli Grandi e Medio Veronese. Passing the sample of Ronco all'Adige through a qualitative and historical interpretative investigation enables us to get to the bottom of the changes concerning the spatial and water-flows patterns; whereas, the quantitative-qualitative investigation of the water board aims do give an updated picture of the results of the local water-flow arrangements at a wider scale.

The questions this strand aims to answer are as follows:

Have the Veneto *Città Diffusa* urban landscape and its water chain infrastructures been moving towards a more sustainable dynamic of interaction? How has the water system at the local and water board levels been engineered? How does it work today? Which spatial roles do the current water chain infrastructures play? What are the problems and opportunities emerging from recent transformations? How do the actors involved in water management and urban development cope with the problems?

4 water types

Before moving to the methodological description of the analysis, it is worth noting that the complex system of water flows and related infrastructures comprised in the Veneto *Città Diffusa* water cycle has been considered at both levels of analysis. Drinking water, wastewater, irrigation and drainage systems are the categories used to structure the observation. This categorization reflects the *water supply* –drinking water and irrigation systems- and *water discharge* –wastewater and drainage systems- functions, the in-puts and the out-puts of the ecodevice model respectively (see Figure 1.3.). Each system organizes the water flows of the water system differently –rainwater, groundwater and surface water- through a variety of infrastructures –streams, ditches, pipes, wells etc.[95].

[95] According to van der Toorn Vrijthoff and van de Ven (2008: 10), "a distinction is made in urban water management between the water chain –which is the chain from the drinking water supply, through the sewers to the wastewater treatment plant- and the urban water system of surface water and groundwater". The progressive separation of the water chain from the water system has been effected also in the Veneto *Città Diffusa* as illustrated in the image Figure 6.35..

The research and narrative has progressed according to this categorization. However, the results which emerged from the different levels of observation were related and discussed together.

Level 1 (local landscape)

The span of time

The historical interpretative analysis of the local landscape of Ronco all'Adige employs the diachronic comparison of the spatial and water flow patterns of the territorial section between the 1950s and the 00s.

The span of time selected might appear as a very large one in comparison to the rapidity of changes. After the second war world in the Veneto region, a series of economic, political, technological and social changes emerged as in many other parts of Europe. Economic growth enabled the region's inhabitants to overtake poverty and it opened up a period of spatial and social innovation. In the space of fifty years, several economic slowdowns and accelerations are embedded. Examples are the growing of the industrial pole of development of Marghera in the 50s, the post-fordism clusters of small firms and workshops developed in the 1970s and 1980s, or the effects of the advanced capitalism and the globalization of the last decades, that have further increased production with new economic, political and social conditions (Vallerani, 2006: 34).

Nevertheless, for the purpose of the present research, the pictures of the two periods, of the 1950s and 00s, are instrumental to the understanding of the magnitude of the acceleration in the changes and the effects on the *Città Diffusa* urban landscape and its water chain infrastructures. From the early observation of the documents available and the literature review it was clear how in the 50s the territorial framework still maintained the main characteristics of several former decades, although a series of changes had already taken place. Habits and economic practices of the society of long duration were still engraved in the landscape. Actually, from a water perspective, the process of centralization in water management pushing for in-flow/out-flow regulations had already started years before in the Veneto. The installation of performing pumps to drain the low lands, straightening of streams and rivers etc. had already started before the Second World War. Notwithstanding these events, processes of up-scaling concerning the fine grained characteristics of the landscape and its water-flow patterns have changed significantly only after the 1950s with the shift from a poor rural economy to an affluent industrial one.

It is worth pointing out that the choice of this time reference was also due to a larger availability in the 1950s of documents and data to some extent comparable to the information of the 00s. In the frame of the research, the 50s are therefore the ultimate period to investigate the form and functioning of the spatial and water-flow patterns before the great post-war transformations that occurred in the Veneto region

On the other hand, during the 00s, economic changes have already overrun all levels of society and territory. The effects of economic growth –and water system engineering- on the fine grained structures of the urban landscape clearly emerge. Obliterations, persistence and additions that affected the fine grained landscape elements can be analysed and compared with respect to that which occurred in the 1950s.

In order to obtain a wider range of information and find agreements between inferences, data and information have been gathered by searching through documents dating even further back to a period before the span of time selected[96].

Data collection tactics

The analysis of the changes concerning the spatial and the water-flows patterns of the territorial section of Ronco all'Adige has required the gathering and screening of a number of empirical and deductive facts and data. A great limitation of this phase of the research is due to the fact that, often, the object of inquiry is not empirically available for observation; notwithstanding this, traces are still deposited and can be found in the extant landscape. The evidences to support the diachronic comparison are found in a wide variety of sources through the employment of different tactics and methods.

Documentation (maps, pictures). The claims are based on various forms of documentation: published and unpublished matter, handbooks, catalogues, newspapers articles, official and personal records, project files, photographs, notes and internet searches[97]. Notably photographic and cartographic evidence have been the crucial documents used to uncover different stages of the evolution of the water flows structures.

Interviews. The interviews with the local inhabitants were instrumental in the recollection of former spatial and functional features of the water system, the role it played in supporting diversity and the economy of the area but also to get qualitative information about its present organization, the way it functions and how it performs. A semi-structured interview scheme was designed to involve the inhabitants. The § D.1. in the *Appendix D* provides the reference list of questions that were asked to all selected interviewees. The interviews generally took between 30 minutes and one hour and were taped[98]. Interviews were run with about ten original residents of the area investigated, or encountered during the field visits either recommended for their knowledge of the area by the municipal office Edilizia Pubblica e Privata of Ronco all'Adige.

Interviews of eye witnesses allowed for the direct retrieval of information not recorded in the official regional, provincial or municipal reports. The interviewees, selected among those who were living in the area also during the period of the 1950s, had drawn inferences about facts in

[96] The IGM maps of the late XIX century, for example, were used during the research process to corroborate some interpretations and hypothesis.

[97] The data collection has been strongly supported by the 'Edilizia Pubblica e Privata' office of the municipality of Ronco all'Adige. They offered their archival documents and their experience to select the information.

[98] The interviews were carried out in three periods: October 2008, August 2009, October-November 2010. The complete list of all persons interviewed is presented in the *Appendix D*.

times past that are later organized and evaluated by their triangulation with other sources as explained below. However, the number of interviews realised with inhabitants cannot represent a statistical sample.

In addition, other pieces of information were collected among the technicians and the inhabitants through open scheme interviews that were held during the site visits described below.

Direct observation and physical artefacts (data fieldwork). As the goal is to gain a holistic overview of the context through a study relating to the issues investigated, the research was conducted through an intensive and prolonged contact within the field itself[99]. Fieldwork was crucial to getting the intimate knowledge of the issues investigated, to understand the meanings and processes of activities and artefacts spread over the case study, and to gather otherwise difficultly obtained information. The physical fine grained materials of the local landscape – pipelines, field and road ditches, streams etc- were directly observed. Crossing the case study landscape and encountering its inhabitants allowed us to come up with sketch maps, measurements and drawings, field notes, slides, and notably, to establish a better understanding of the genius of the place.

In addition to onsite familiarity, visual inspections and testimonial evidence, as well as comparisons with conditions of other similar contexts, such as the case study of Zaccariotto's Ponte di Piave research, was essential to corroborate information and inductions.

Analytical and narrative tactics (drivers, concrete models patterns, maps patterns)
The analysis proceeded by the cyclical processes of data collection, data reduction, data display and conclusion drawing and verifying[100]. The system of inquiry comprises searching for evidence, collecting and organizing the evidence, evaluating it, and constructing the narrative. The interpretation did not proceed in succession through these actions instead in parallel much of the time. Vast amounts of data and information were reduced to be made more manageable; the materials were organized under the lens of the key concepts and assumptions of the studies. The ecodevice model (Figure 1.3.), for example, was frequently used to interpret the facts at hand. The available evidence was selected, simplified, schematized and interpreted to weave together a coherent account that supports the theory above.

The investigation into physical processes of change within the complex context of the case study area, is presented in a narrative form and holistic fashion. A series of tactics have been used both with analytical and narrative purposes. Triangulation, for example, was instrumental to underpinning certain assumptions. Data from field surveys, interviews, technical reports etc. were mixed upon a claim to confirm or deny information, assumptions, and intuitions. Another

[99] The fieldwork was carried out in many and different periods. The case study was directly observed in the different seasons in order to get the variation of site conditions in relation to the rhythm of precipitation and evaporations during the year.
[100] According to Groat and Wang (2002: 151) the understanding of the reality and processes of transformation consists even of parsing the discourse that defines it. Thus, the analysis interprets "the subject matter both as causal explanations of history and, according to post structuralism, as the by-product of discourse".

tactic used for testing and confirming the findings is the so-called "testing with feedback'' (Miles and Huberman, 1994: 263), or getting feedback from experts and informants. In the narrative 'landscape patterns' and maps are the physical inventory of the structures of the water system, formal and spatial analysis[101].

Transformation models. The information was organized in identifying patterns – as schematic diagrams- and related explanations. A set of spatial models called *transformation models* were employed to illustrate how the interrelation among structures and water-flow dynamics have changed in the span of time selected. The models are the results of the analytical reduction of the features of a variety of local spaces, into basic permanent structure-water flow patterns[102] (Zaccariotto, 2010). For each fine grained element composing the local landscape – agricultural fields, housing industrial or commercial plots, roads, streams and former clay pits-, a transformation model displays the specific process of change by comparing patterns of two different periods. Furthermore, the models already reveal the basic potential of these fine grained structures for exploring specific water storage-oriented models –guiding models- to be tested through a process of learning in the design section.

Maps. Information and data were processed and organized also in CAD maps, elaborated as analytic and narrative drawings. They enable to tackle the territorial complexity throughout the *demontage* technique (Steenbergen, 2008: 411). Thus, the interpretative narration of the changes displayed by the transformation models is supported by a series of maps comparing the patterns of the two different periods at the scale of the case study area (1.25x1.25 km).

Workshops. In addition to the interviews, surveys and direct observations, the tactic of workshops with focus groups of experts helped to construct the right questions and, eventually, to triangulate information and test the interpretation drawings.

Level 2 (water board)

Level and methods

The results of many local spatial and water-flow changes at the level of the water board Consorzio di Bonifica Valli Grandi e Medio Veronese were analysed through a qualitative system of inquiry [103]. Contrary to the previous section, this part of the research used a one time reference as it focuses on the present situation only. Thus, it is mainly based on qualitative information supplemented by quantitative data.

[101] It refers to the visual and computer based analysis of the spatial flows patterns.

[102] According to Steenbergen (2008: 32), "'reduction' involves exposing and limiting the complexity of the basic morphological or typological structure. This assumes a conscious choice about what is and what is not drawn." Steenbergen (2008: 297) distinguishes three successive dynamic phases: decomposition, processing and synthesis.

[103] As mentioned above, in the studies of Zaccariotto (2010), the corresponding territorial reference is the water board Consorzio di Bonifica Pedemontano Sinistra Piave.

It is worth noting that the level of the water board was selected for very practical reasons. As it represents an administrative level, much data and information was systematically collected and organized into its administrative database. However, because different water types –and related infrastructures- are managed by different authorities with different geographical references, to a certain extent, the organization of the data regarding drinking and waste water systems at the unique level of the water board has cost some efforts[104].

Data collection tactics

This part employed a number of sources of evidence that can be mainly grouped in documentation and interviews.

Documentation. Two main types of documents were collected to develop the water board analysis. Firstly, the statistical reports of the local authorities in charge of maintaining and monitoring waters and their infrastructures. Secondly, many different documents as administrative reports from various agencies, handbooks, catalogues, newspaper clippings, etc.

Interviews. Interviews were conducted with state-owned, regional and local water company officials. Designed as semi-structured interviews they took between 30 minutes and one and a half hours and were generally taped[105]. Because of the diverse groups of interviewees, different question sets were designed while always keeping with and reflecting the same theoretical framework. These interviews at the decision making level were carried out in order to gain information over the position of the institutional framework regarding problems, opportunities and perspectives of centralized and decentralized options with respect to the specific spatial structure of the *Città Diffusa*.

Analytical and narrative tactics (map patterns)

Data and information collected were triangulated with other qualitative sources, as relevant scientific literature about the water system and open ended interviews with experts belonging to the academic sphere. Afterwards, they were organized to build up the narrative. The quantitative data was also used at drawing narrative profiles through a 'qualitizing' process[106].

Maps. GIS maps with analytical and narrative purposes were composed in making use of data provided by different agencies. Through the overlay technique, the components of the water system at the level of the water board were taken apart in order to make their relationships to

[104] The water board Consorzio di Bonifica Valli Grandi e Medio Veronese is responsible for the irrigation system and the drainage system of second order –the first order refers to the main rivers and their catchments, e.g. Adige River-. Drinking water and waste water systems are under the responsibility of the Autorita' Ambito Ottimale Veronese (AATO Veronese) that has charged the Acque Veronesi Scarl. with managing the systems.

[105] Most of the interviews to the institutional actors were carried out in October 2008. The § D.2. in the *Appendix D* displays the semi-structured interview.

[106] According to Tashakkori and Teddlie (2003: 713), 'qualitizing' is "the process by which quantitative data are transformed into data that can be analysed qualitatively".

one another more clear [107]. This way, structural and functional attributes of the water infrastructures and their interrelations across different scales of representation clearly emerge. Moreover, the maps contribute to unfolding the potentials of the water system in order to continue playing a carrying role (Corner, 1999).

Meta-inferences

Paradoxes

Meta-inferences from the two levels of analysis, the historical-interpretative inferences that emerged at the level of the local landscape, and the qualitative and 'qualitized' inferences that came out at the level of the Consorzio di Bonifica Valli Grandi e Medio Veronese water board, were processed according to a narrative integration and comparison. The integration of the results provides convergent, divergent and complementary outcomes. Conclusions are explained building a logical chain of evidence and making metaphors. Paradoxes are the rhetoric means employed to answer the question about the sustainability of the interaction between the decentralized urban landscape of *Città Diffusa* and the centralization of its water-flows and related infrastructures. The paradoxes are figures of speech that emphasize the illogical nature of the present trends in water management –centralization and separation affecting the water system- in relation to the economic and physical conditions of this special form of city –decentralization and diversity. They point out what Viganò et al. (2009: 15) have defined to be a hiatus between the society and its territorial support. The noted paradoxes have been drawn according to the decision field triangle areas-flows-actors of the Ecological Condition Strategy as it comprises all activities of the analyzed context[108] (Tjallingii, 1996: 183). In the paradoxes, the way to a more coherent future is already embedded.

3.3.2. The experimental research of *design* –phase two

Hypothesis and questions

This strand has been designed in order to argue the main hypothesis of the research, that in the decentralized urban landscape of the Veneto *Città Diffusa*, answers that design measures can give in response to increasing water-flow dysfunctions and the loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes –ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements.

[107] Steenbergen (2008: 411) defines overlay as the process of "separating the building or area into layers and projecting the layers above one another".

[108] In the view of Tjallingii (1996: 183) areas, flows and actors are general decision fields that "create a framework of decisions about all activities" in strategic planning. In the frame of the research, drawing conclusions according to these three decisions fields enables to build a bridge with the design phase, as they already call for developing ecological strategies for all activities.

The purpose is to apply principles of integration and decentralization in concrete *Città Diffusa* situations, ascertain their feasibility, explore spatial and water-flows results, measure performances and levels of acceptance. The investigation has been carried out through an experimental system of inquiries based on design explorations of three different levels of water-flows decentralization[109]: two in the settlement area of Ponzilovo –level 1.1 and level 1.2-, and one in the sub-catchment area of the Scolo Saccaro –level 2-, both areas resting on the case study of Ronco all'Adige.

Accordingly, this phase aims at answering the following questions:
Can decentralized water-flows options using the potential of the existing decentralized fine grained elements support a tighter spatial arrangement and a more sustainable water cycle of the *Città Diffusa*? Can decentralized water infrastructures make water a shared resource in the dispersed territory of the Veneto? In this way, can water participate in the arrangement of a new living territory? Is a set of guiding models tuned to the specific conditions of the Veneto low plain a reliable toolkit for designers dealing with the complexity of the *Città Diffusa*?

The three levels
The first domain selected, the settlement area of Ponzilovo, is a typical *Città Diffusa* situation resulting from the free and uncontrolled addition in the 60s, 70s, 80s and recent years of a certain number of detached houses –and workshops- to former dispersed buildings aligning the road. The housing area of Ponzilovo namely offers the opportunity to explore decentralized water-flow options for a situation repeated by the hundreds of thousands over the *Città Diffusa*.

The second domain, the sub-catchment of the Scolo Saccaro, comprising the previous area, gives the opportunity to test decentralized water options at a higher level. The sub-catchment is an instance of the smallest hydraulic units composing the low plain of the Veneto. Here, a coherent hydraulic/drainage functioning outlines an area where many different urbanized and agricultural situations are juxtaposed.

Level 1.1, level 1.2 and level 2

The strategy of scenarios
This strand was designed as an ideographic research-phase testing in concrete *Città Diffusa* situations the in-between outputs of the nomothetic research on guiding models –third phase[110]. The focus falls sharply on the case study with its peculiar emphasis and wrinkles.

[109] The design explorations aim to experiment the means to actively change and observe the responses that can giving some *treatment conditions* while also measuring the outcome variables (Groat and Wang, 2002: 272).
[110] In this design section, the studies examine concrete situations, the logic of how factors within the selected situations/areas relate to each other as the design process moves toward a specific empirical goal (Groat and Wang, 2002: 111).

The formulation of scenarios is the strategy adopted. Scenarios act as if-then tests. The *programmatic aims* structure the if-closes questioning the area selected. What if in the settlement area of Ponzilovo waters are held, treated, stored and reused at the level of the single parcel –level 1.1- or at the level of the whole settlement –level 1.2? What if the same principles are applied at the level of the sub-catchment –level 2? At the beginning of the process, for each level, a guiding model –or set of guiding models- is selected as an operational reference. Later, according to the nomothetic combinations of spaces and flows offered by the guiding models selected, the treatment conditions are tuned in simulated physical conditions –simulated environmental modifications[111]. The generative design explorations are in the form of design models –rather than in the form of design projects– attempting to determine concrete relations in the specific phenomenal contexts (the case study and its situations)[112]. The projections of the areas investigated propose a possible direction of transformation, and they are instrumental in seeking out new and different arrangements of the operable materials of the landscape, as a foundation of new possibilities, or new physically-operated experiences of the experimental settings (Gregotti, 1966: 27).

Over the design process, every model was analysed, refined, tested and analysed again until a more responsive scheme emerged. This process followed the stepwise PROSA approach developed by Tjallingii (1996: 234) in its Ecological Conditions Strategy. PROSA is the acronym for Programme-Rhythm-Orientation-Situation-Appliances, covering all steps of the working with nature design process that links research and design. The *programme* (or programmatic aims) is the starting point of the process where goals or problems are selected and described. The *rhythm* concerns the dynamic aspect of water related to climate, groundwater and soils in the context. Peak and seasonal storage performances are calculated respectively through the Rational Method and the Water Balance[113]. *Orientation* is the analysis of the existing direction of the flows. It results in the formulation of future flow-direction options. *Situation* combines the outputs of the previous steps with the concrete details of the local situation. Location, form and size of the elements are designed into possible spatial configurations of the area. Finally, *applianc*es concerns the selection of the appropriate technology to make the system operational.

In each step, the existing conditions were first surveyed to be followed later by the development of ideas, sketches and calculations for the design of future conditions. As designing is a cyclical process, the sequence is not a one-way road (Tjallingii, 1996: 241). The final proposals are reflective of systematic analyses and design finishings, a cluster of requirements is integrated into integrated solutions.

[111] According to Groat and Wang (2002: 278) simulation research involves controlled replications of real-word contexts or events for the purpose of studying dynamic interactions within that setting.
[112] According to Gregotti (1966: 19) design models are the planning tools that force guiding principles to directly address the specificity of the working field; this allows us to resume that historic struggle, and turn the design process into new research and working hypotheses.
[113] More information about the Rational Method is available in Marsh (2005: 154).

During the design process, a series of workshops with technicians and operators of the local institutions in charge of water management and spatial planning were used as a crucial tactic for a shared basic understanding of the problems and opportunities related to the design hypothesis.

It is worth noting that at the three levels of design the PROSA steps were developed differently. Due to the vastness of data and the complexity of the calculations related to the sub-catchment area, for example, at this level the PROSA approach followed a more qualitative elaboration. The same degree of elaboration regarded also the household level –level 1.1. Although important for a more comprehensive overview of the opportunities related to the decentralization of water-flows, such solutions, were considered of little interest from a landscape perspective.

Design evaluation

The final step of the experimental method adopted concerns the evaluation of the design proposals. The design schemes are conceived as progressive tools to be presented, as a means for furthered exploration and communication.

SWOT analysis. Once framed, the alternatives were presented to the experts in order to test their feasibility. The assessment is inspired by the swot analysis[114]. Notably, strengths, weaknesses, opportunities and threats of the options were revealed and discussed.

Cost analysis. For the scenario of decentralization at the neighbourhood level –level 1.2- the costs analysis was another tactic employed to asses the proposals. This analysis, typically used to evaluate the desirability of a given intervention provides here a range of the costs of the decentralization that can be approximately compared with the cost of traditional centralized solutions, while it is unable to account for long term/long distance impacts and for non-monetary aspects.

Meta-inferences

Once design and evaluation was completed, meta-inferences from the three levels of exploration were worked out according to the precepts of the research in order to argue a more generalized hypothesis. Although the case study is related to a localized reality, the design experiments are a contribution to the realm of the Veneto *Città Diffusa* that aim to have larger influence and further the discussion on the future and potential of this decentralized urban form.

[114] In planning, swot analysis is normally used at the beginning of the design process in order to identify the internal and external factors that are favourable or unfavourable in achieving the objectives. However, it is here utilized at the end of the design process to evaluate the strategic options designed.

3.3.3. The Guiding models –phase three

This part refers to the nomothetic work of the guiding models that overlooks individual idiosyncrasies, and searches instead for those water-flow patterns of integration and decentralization that appear to apply in the vast majority of situations of the low plain of the Veneto *Città Diffusa*. The models were worked out by passing through the typological analysis of basic landscape elements in the *analysis* –phase one, level 1-, the conceptual re-organization of the patterns on the basis of selected guiding principles, and the experimental process of scenario exploration in the *design* –phase two.

Accordingly, the questions this strand aims to answer are as follows:
Can a toolkit of guiding models of spatial and water-flows integration be worked out by interpreting the specific water-flow structures of the low plain of the Veneto *Città Diffusa*? Are these guiding models reliable tools to promote coherent spatial arrangements –the diversity feature- and a more sustainable water cycle –reduction of drought, flood and pollution of water- in the dispersed territory of the Veneto?

Process
The guiding models developed by Tjallingii and elaborated for different design contexts were used as initial references in the process[115]. The fundamental building blocks which can be found throughout the *Città Diffusa* environment –the basic elements of the landscape object of the *analysis*: agricultural fields, housing, industrial or commercial plots, roads, streams and former clay pits–, were envisaged in light of the strategic guiding principles worked out from the literature review and the analyses. Indeed, each guiding model is an attempt to capture the invariant and basic properties common to a number of experiences that succeed in organizing spaces and flows. Projects and pilot projects developed and realized locally or in other similar contexts were analysed, the strategic operations and concepts at their basis interpreted, adapted and, where possible, upgraded.

The guiding models provide the essential fieldwork to organizing spaces and water flows, but in a very general and abstract way. They are iconic, composed of marks resembling reality, and analogue, as action oriented strategies for changing physical flow systems/patterns in a more sustainable direction.

As for the transformation model, they display a desirable specific process of change by making comparisons between a pattern of the existing situation –resulting from the transformation models that were tuned in the *analysis stage*- and a possible future pattern of integration.

[115] The guiding models that Tjallingii have developed refer mainly to the low plain conditions of The Netherlands where the dominant hydraulic pattern is the polder system, and in general, the status of the resources is different. Tjallingii has also presented models for the upper lands and other situations (Tjallingii, 2008: 97). Despite this extensive work, guiding models were not developed for the Veneto. It therefore makes sense to critically assess their usefulness in this situation.

Evaluation
During the research process, the elaborated guiding models were tested in the experimental design of the scenarios –phase two. The case study –and its constraints- is the testing ground to evaluate their reliability. Another tactic employed to assess and upgrade the guiding models is the workshop. The models were presented to a focus group of experts. The feedback emerging from the real context of the case study, and the discussion with the experts were integrated in the models through a continual learning process.

It is worth noting that the guiding models have been designed as an open ended apparatus that aims to enter the common design practice and continuously be improved and enlarged by a learning process. Using the words of Alexander, when referring to 'patterns', he states that they are "all still hypotheses, all tentative, all free to evolve under the impact of new experience and observation" (Alexander et al., 1977: XV).

3.4. Limitations of the studies

One potential flaw of the methodology employed is related to the limitations of a single case study. For this reason the same hypothesis was investigated in two different case studies with similar conditions –as low plain conditions-, but under different administrative contexts: Ronco all'Adige, the case study of my research, and Ponte di Piave, the case study of Zaccariotto's studies. However, behind the strategy of the two case studies there is also the awareness that the theory is to remain tentative until confirmed by other case studies. In this research-by-design approach the practical validity of the strategic concepts can also be tested by the realisation of the ideas in small pilot projects. The formulation of this study actually draws upon some innovative pilot projects that are currently being developed in the Veneto area.

The same theory and principles should be tested in other different *Città Diffusa* circumstances. Among the others, the more densely inhabited situations –like villages-, and the transitional areas between these urban conurbations and even more dispersed landscapes can also be relevant cases to study. In consideration of Viganò et al. (2009) previous analyses of the high plains of the region, this area still remains a context that requires further analytical investigations and design proposals.

Chapter 4

Frame

4.1. Introduction

Any landscape investigation, however analytical or design-oriented, should rely on accurate observations of the layers composing the territorial palimpsest. The main goal of this chapter is to frame the case study area in the region while providing a description of the main water resources –and the landscape's ecological potential (Tjallingii, 1996: 23)- across different scales.

From the case study area in the municipality of Ronco all'Adige, the observations are widened towards the regional frame. Surface water, groundwater and rainwater patterns are presented together with the landform and the soil and subsoil compositions. Furthermore, the water flows crossing the case study are framed in the regional water cycle for a better understanding of the many ways water moves through the urban landscape of the Veneto *Città Diffusa*. The institutions engaged in the management of flows and infrastructures are also briefly introduced.

4.2. Hydrography and landform

The description here gives an account of the local and regional hydrographical system in relation to the area's topography.

Micro level[116]

The Figure 4.1. exhibits the bodies of the drainage system and the topography in the selected frame. The terrain gently slopes N-S with a maximum inclination of 2%. It describes a shallow and progressive hollow in the centre of the figure that has NNW-SSE direction. The progression results in a difference in level of about two metres (from 21 meters to up to 19 meters above the sea level) from the upper-left side to the lower-right side of the frame observed.

In the area stormwater flows are driven by the microtopography. Overland flows discharge into rectilinear traces carved into the land leading the water out rapidly (Figure 4.1., red lines).

[116] In the case study area a number of water expanses are embedded. Although they exchange their waters with the surface water system and the groundwater, these water basins are neither displayed in the maps nor discussed here. They are instead presented in the Chapter 6.

Ditches are arranged in a kind of mesh structure. The variety of widths of these corridors and the topography informs about a hierarchy in the drainage system. N-S, W-E and E-W ditches, indeed, deliver water from the land into streams, elements with wider cross sections and, sometimes, year-round running water. Four streams cross the framed landscape. The first is the Fossa Zerletta crossing North-South in the medium-top part of the picture. It delivers water into a second stream named Scolo Saccaro. The latter enters the picture from the left paralleling another stream named Fossa Termini that runs opposite towards the Scolo Barcagno –not visible in the image. Scolo Saccaro leads water downstream towards the lower-right corner of the frame. The fourth stream intercepted in the map is named Scolo Termini. It crosses the south part of the central depression running with N-S direction.

Meso level

From a wider-angle view (Figure 4.2.), the smooth depression informing the case study appears as part of a broader hollow, 4/6 kilometres wide, bordered South-West by a terrace hill-slope and North-East by a ridge. In the wider frame, topography variations result by a maximum of about 8 meters.

Again drainage follows landforms. Two main rivers appear in the map both following the NW-SE trends of the landform. The Adige River meanders over a ridge and describes an arch. The Bussè River runs parallel to the Adige River a few kilometres SW and tangents the southern-western terrace slope. A number of streams drain the dip in the middle of the figure. The stream Fossa Zerletta originates a few hundred meters upstream while the Scolo Saccaro originates a few hundred meters South West. Once across the case study area, the Scolo Saccaro falls downstream paralleling the Scolo Turchetto (Figure 4.3.). After a couple of kilometres and after receiving the waters of a second order stream called Scolo Carnirolo, Scolo Saccaro separates its course from Scolo Turchetto and proceeds with NW-SE direction. Finally, it delivers its waters to the stream Scolo Conduttone. The latter is a second order stream draining the left side of the northern-east ridge. Upstream there, the terrain is about 5 meters higher (around 25 meters above the sea level) than in the study area. After the confluence with the Scolo Saccaro, the Scolo Conduttone is fed, on the right (hydrographical side), by the Scolo del Corso and Scolo Turchetto, while, on the left, by the Scolo Dionisi. Around 6 kilometres downstream (17 meters above the sea level) the Scolo Conduttone flows into the River Bussè.

Macro level

The Figure 4.4. illustrates the case study area in the hydrographical and topographical frame of the Veneto Region. The landscape observed is part of a wider plain called the Padana Valley[117]. The plain begins at the foot of the northern mountain system, the Alps, almost a dozen kilometres above the area observed, and stretches down for a hundred kilometres before its mouth into the Adriatic Sea. Wide mountain ranges occupy the northern part of the region reaching north, far beyond the regional borders. The Dolomites are among these mountain

[117] The Padana Valley extends beyond the borders of the map. The description refers only to the part which crosses the Veneto Region.

ranges. Peaks are a few thousand meters high. The mountain valleys are incised several hundred meters into these mountains rocks, sometimes leaving flat-topped high-lands a few kilometres wide. Approaching the southern plain, the mountain ranges tend to degrade to form the Alpine foothills. Among them, the Monti Lessini, above the case study area, open like a fan sloping gradually towards the plain. Their mountainsides reach extensions of a few dozen kilometres and are carved by steep V-like incisions crossed by streams. Below, in the plains, two hilly topographic systems, a few hundreds meters in height outcrop, one in front of the other. From North to South they are the Colli Berici and the Colli Euganei respectively. The plain proceeds from mountains and hills towards the Adriatic Sea with an average slope of 1-2 %o. Only an accurate observation of the microtopography reveals slight variations in height; indeed, very smooth sequences of ridges and depressions stretch towards the sea. South-westward lays a band of lowlands a few meters below sea level (North-East) and dunes (South-West) a few dozen kilometres wide, between the plains and the sea.

Drainage follows this incline toward the Adriatic. In the mountains water is collected by headwaters and delivered into valley rivers. They flow down toward the sea finding an opening in the mountains. Once they reach the plain, because of the lesser gravity, their flows decrease. River courses start meandering. Slowly they cross internal and coastal depressions and, finally, they reach the sea. Crossing the lowlands some of these rivers feed lagoons –the most renowned of these is the Venice Lagoon.

The Adige River, whose course runs nearby the landscape observed, originates from a spring at the Passo Resia, more than 250 kilometres upstream from the case study area. This mountain river crosses several valleys (Val Venosta, Val d'Adige and Vallagarina) and receives the waters of many tributaries (Rio Ram, Passirio, Isarco, Noce, Avisio, Fersina and Leno). Moving southward it parallels the Monte Baldo range which divides its valley course from the western deep depression fed by the Garda Lake. Once passed trough the lands between Monte Baldo and Monti Lessini, the River Adige reaches the plain. Here a series of streams flow into the Adige. Many of them, like the Fibbio and the Alpone drain the Monti Lessini. In receiving the waters of the Alpone, whose confluence is just 3 kilometres east of the case study area, the Adige River proceeds its NW-SW run, turns South of the Colli Euganei, and takes an E-W direction to finally reach the Adriatic a hundred or so kilometres later.

Several other mountain rivers cross the mountain valleys to later reach the plain. From N-E to S-W they are the Tagliamento River, the Livenza River, the Piave River, the Brenta River, the Bacchiglione River, the Gorzone-Guà River, the Adige River and the Po River, which is the main watercourse of the Padana Valley.

The Figure 4.4. exhibits also a series of rivers which originate in the plain, either reaching the sea or flowing into other rivers. The Bussè River belongs to this second group. Its course begins 6 kilometres east of the landscape observed, in a depression called Valli del Bussè. Once it has received waters of the Scolo Conduttone, the Bussè River heads southward, paralleling the Adige River. A dozen kilometres later (around 11 km) the Bussè River diverts its course from that of the Adige, southwards for 10 more kilometres, passes over another depression called

Valli Grandi, and, finally, discharges into the Tartaro-Canalbianco River, another course originating in the plain, about 70 kilometres upstream. The Tartaro-Canalbianco River parallels the Adige River and the Po River. 80 kilometres downstream, it flows into an old branch of the Po River named Po di Levante. The Po di Levante then flows into the Adriatic sea.

4.3. Hydrography, soil and subsoil

This description gives an account of the local and regional soil and subsoil mosaic in relation to the hydrography.

Micro level

Soil. The Figure 4.5. exhibits the distribution of the soil types in the case study area. Classification follows the World Reference Base (FAO, 1998)[118]. Two main soil areas appear, one North one South. In the upper part of the frame (A), sandy-loamy soil prevails. The area (A) is part of a ridge system. The soil here is of relatively recent formation (ARPAV, 2005: 82) and it is sandy/loamy soil with low permeability ($K=10^{-4}/10^{-3}$ m/s). In the lower part (B) clay/loam prevails. This area is part of a rill zone also of recent formation. In this part clays are plastic, grey/blue in colour, rich in silicon and with a very low permeability ($K=10^{-5}/10^{-7}$ m/s) (Gajo, 2007: 93; Comune di Ronco all'Adige, 2009: 16). Both (A) and (B) are extremely rich in limestone sediments. Soil compositions of the two sectors (A, B) and stratification of their subsoil are results of river dynamics and related sequences of erosion and deposition processes that have moulded the recent alluvial floodplain valley.

Subsoil. A recent survey in an agricultural site a few hundred meters downstream, explains that the subsoil is characterized by a succession of loamy-clayey/sandy/loamy-clayey/gravelly layers (Gajo, 2007: 89) (Figure 4.7.). The first three layers (loamy-clayey/sand/loamy-clayey) vary in depth from less than 1 meter to up to 4 meters. The gravelly layer begins at a depth of 3 meters and goes up to 10 meters, even extending for dozens of meters in depth and alternated by a series of clay layers. The top of a first consistent layer of clay is located at about 25-30 meters from the ground-line (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991b: 13).

Meso level

Soil. The Figure 4.6. exhibits extensions and shapes of the soil areas intercepted by the case study. The portion (A) extends north-westwards and envelops the upper lobe (B) of the area. The latter appears almost as an isolated patch a few kilometres wide and elongated towards the Adige River. A sandy-loamy strip-like patch (C) over-run by the Adige River, borders the west side of both (A) and (B). The strip is part of the Adige ridge. Its chemical composition is only slightly different from composition (A). All the patches described (A, B, C) are part of the

[118] The Word Reference Base is the classification officially used by the Veneto Region.

recent alluvial floodplain of the Adige River that advanced in a former gully of the river. The northern and southern limits of the gully are visible respectively on the right side and lower-left corner of the map. They correspond to the slopes of two fluvial terraces.

Subsoil. The complexity of the subsoil also remains at this scale (Figure 4.6.). Though not visible in the image, a few peat layers enrich the sequence of loamy-clayey/sandy/loamy-clayey/gravelly layers.

Macro level

The Figure 4.8. illustrates the soil compositions and main water bodies of the region. Significant interactions between river courses and the surroundings are the forces behind the patchiness of the plains' mosaic. Discontinuities are illustrated by wet spots, exposed gravel areas, oxbows, levees, a hill slope and upland well-drained soil.

Soil – low plain. The patch intercepted by the study area and extended between the slopes of fluvioglacial terraces, begins a dozen of kilometres upstream. Downstream this elongated patch stretches southward to form the larger soil patch of the region. Extended from the Po River to the Brenta River, the patch ends up just few kilometres before the Adriatic Sea. The area described constitutes the recent alluvial floodplain that is the widest part of the regional low plain. It dates back to the late last glaciations (ARPAV, 2005: 82). Here a number of different trunk rivers have deposited their debris. The area borders the western end with a patch of the old fluvioglacial plain terrace of the Adige River, and the north-eastern end with other patches, old fluvioglacial plains originated from erosions and deposits of regional rivers like the Brenta River, the Piave River and the Tagliamento River. All these old low plain patches are crossed by a series of rivers originating in the low plains. The River Bussè is among these rivers. An elongated and discontinuous patch occupied by dunes and lagoons appears located between the floodplains patches and the Adriatic Sea. It extends from the Po Delta in the South up to the mouth of Tagliamento River in the North. Old fluvioglacial floodplains, recent alluvial floodplains, dunes and lagoons together constitute the broad regional low plain, stretched from the northern border with the high plain, down to the Adriatic Sea. In the low plain soils have generally medium and fine grains. Depending on their location, they range from sandy-loamy to clayey-loamy. Sandy-loamy compositions are dominant either on the ridges (old levees of the main rivers) or on the coastal dunes. Clayey-loamy terrains prevail in depressions and along the coastal ribbon of lowlands and lagoons. Peaty-clayey-loamy soils are also spread out on the plain often in proximity to river confluences. The Valli del Bussè, 5 kilometres east of the case study, where the Bussè River origins, and the Valli Grandi, 20 kilometres south of the landscape observed, where an old ridge of the Adige River encounters the current ridge of the Po River, are all good examples.

Subsoil – low plain. The conceptual cross section of the Region exhibits the subsoil variations from the high to the low plains (Figure 4.11.). The stratification in the case study area begins where the low floodplain starts. As the low plain approaches and the altitude decreases, grain of sediments tends to be finer and the gravel layers become rarer. This massive amount of river sediments is a result of alternate phases of river deposition and erosion over the bedrock. A survey in the municipality of Bovolone, not far from the study area stated that sediments are more than one kilometre deep there (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991a: 4).

Soil and subsoil – high plain. The high plain patches are stretched from the foot of the mountainous (West) and hilly (East) ranges down to the low plain. The high plain is approximately between 5 and 20 kilometres wide and is discontinuous. The triangular patch located South-West, just above the Adige floodplain, is the old high plain of the Adige. On the Eastern side of the alluvial fan of the Adige River, the recent high plain of the Monti Lessini appears. Its long fingers extend along the Monti Lessini valleys. More towards the East, old and recent fans of the Brenta River (Bassano del Grappa and Carmignano) and the Piave River (Montebelluna and Nervesa) also appear.

Old and recent fans differ by geological era and soil composition. Old fans date back to the last glaciation era. Their soil composition varies from gravel upward to gravel-sand to sand-clay downward, as the border with the low plain approaches. Here soil is an almost continuous deep layer extending to the bedrock (Figure 4.11.). Depending on the mountainsides slopes, its depth can be hundreds of metres[119]. Recent fans date back to more recent glaciations and are made up of more fine grain deposits like loam and clay.

4.4. Hydrography and groundwater

The description concerns the local and regional groundwater resources in relation to the hydrography.

Micro level

Phreatic groundwater. In the case study area the heavy soil performs poor drainage. Drainage is especially low in the lower half of the frame where clay is dominant (B). The scarce infiltration water feeds the phreatic surface. In the area the water table is a discontinuous layer whose average depth is about 1.5 meters below the surface level. The groundwater flow follows the NW-SE trend of the slope (Figure 4.10.).

Artesian groundwater. Aquifers are numerous in the area. Located into permeable layers of the subsoil, and they are bordered by clay layers. Two first semi-confined aquifers are at 4 and 6 meters below ground level respectively; a third is at 8 and up to 18 meters below ground-level. The fourth, the fifth, the sixth and seventh are confined and at depths of 27-30 meters, 30-60 meters, 60-100 meters and 100-105 meters respectively (Gregnanin, 1975: 30; Consorzio di

[119] The alluvial fan of Adige River is more then 150 meters deep. Gravel components are limestone, dolomite, porphyry, granitie (AATO Veronese, 2005b: 19).

Bonifica Valli Grandi e Medio Veronese, 1991b: 10; Comune di Ronco all'Adige, 2009: 16; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier).

In this area, whenever the first clay layer (2-2.5 meters deep) is removed by excavation, groundwater can re-ascend up to 0.3-0.6 meters from the ground level (Comune di Ronco all'Adige, 2009: 16). According to the Consorzio di Bonifica Valli Grandi e Medio Veronese water board (1991b: 8), both phreatic groundwater and the first aquifers (4-6 meters deep) of the area, are also directly related to the flows of the Adige River, generating water flow a few kilometres upstream (Figure 4.9.).

Meso level

Phreatic groundwater. Figure 4.10. shows that the ground and the phreatic surface have similar trends. The lowest points are in correspondence of the core of the clayey-loamy area. There groundwater and the surface level are almost at the same level (16 meters above sea level). From that depression, the groundwater rises scaling the slopes of the ridge of the Adige River and the Bussè River respectively. According to Dal Prà et al. (1997), in the area of the map the phreatic surface has an average depth of 1.5 meters beneath the surface level.

Contribution of precipitations to the phreatic surface recharge is limited due to the relatively high imperviousness of the soil. Drainage is low especially in the rill zone area (Figure 4.10.) and tends to be higher moving towards the ridges (ARPAV, 2005: 82). According to the water board Consorzio di Bonifica Valli Grandi e Medio Veronese (1991b: 8), in the north-east part, where the Adige River borders more permeable soils, groundwater from the river slowly comes up to partially feed the minor surface water network[120].

Artesian groundwater. The same sequence of aquifers observed at the micro scale, extends in the wider area. Variations are related to the different position of the clay layers. In the area deep aquifers have no direct communication with the Adige River. Most of the recharge comes from the high plain (Dal Prà, 1984: 16)

Macro level

Phreatic groundwater. Figure 4.12. shows the trend of the surface groundwater in the region. Again it follows landforms and soil compositions. On the map the case study area is framed in a broad zone that crosses the middle of the region from SW to NE. It corresponds to the upper part of the low plain stretching from the rim of the high plain down to the black patch of the lowlands that border the Adriatic Sea. In the upper part of the low plain, the phreatic surface is on average a few meters below the ground. Rarely is surface groundwater at level or above the soil surface.

[120] A field survey with the engineers of the water board in late March 2008, in the North-West part of the area, confirmed this upward seepage in the Scolo Ariolo. However, further studies have to be done to confirm this relation with the waters of the Adige River.

Groundwater starts to approach the land surface just a few kilometres upstream of the case study area, in correspondence with the spring line (dotted line in the map) that divides the high plain from the low plain. The spring line is extended across the entire region interrupted just where the Colli Berici and the Colli Euganei hills outcrop.

Above the spring line, indeed, another strip extends. This is the high plain made of permeable strata and steeper slopes. Here, surface water percolates through gravel deposits of the alluvial fans reaching depths of hundreds of meters. Groundwater flows freely with NW-SE direction and as a unique and undifferentiated body several meters deep (Fig. 4.11.).

For instance, in the alluvial fan of the Adige River groundwater is essentially fed by infiltration of rainwater and irrigation water, percolations from the Adige River and, most, by the groundwater flowing under the riverbed[121] (Dal Prà, 1984: 22). The latter is a conspicuous source recharged by the northern mountains. Once the Adige Valley opens onto the regional plain –that is in correspondence of the high plain- the underground flow of the river discharges into the alluvial fan.

In the high plain, as the low plain approaches, the depth of the groundwater decreases. Soil then varies from coarse grain to fine grain, from gravel to sand and clay, and clayey lens in the subsoil seep into the gravel and sandy layers more and more often (Fig. 4.11.). Up to the spring line –the border between high and low plain-, where the impermeable clay layers and the topography meet, surface groundwater comes up and gives rise to spring rivers. It happens exactly along the border between high and low plains. The spring area extends from the spring line from 5 to up to 20 kilometres over the floodplain. This section of the plain is where numerous spring rivers originate. River Bussè, River Menago and River Tregnon in the western part of region are a few examples. According to Dal Prà (1984: 22), the capacity of the groundwater in the high plain of the Adige River is around 3-4 m3/s. Its fluctuation is related to the natural melting of snow. The maximum capacity is between August and October while the minimum is between February and April (Dal Prà, 1984: 12). The delay between the rhythm of the Adige River and groundwater is at least three months.

Further downstream, in the low plain, as the altitude approaches the sea level, surface groundwater reaches the ground level. The ribbon next to the Adriatic Sea, visible in the map, corresponds to areas below sea level and where groundwater tends to emerge (upward seepage).

Artesian groundwater. In the spring area only a portion of the groundwater of the high plain reaches the surface. The remaining part seeps into permeable sandy layers in the subsoil that alternate with the clay lens. This trapped water constitutes the confined aquifers of the low plain. These aquifers are the same encountered also in the subsoil of the case study landscape.

[121] According to the Consorzio di Bonifica Valli Grandi e Medio Veronese (1991b: 7) a conspicuous recharge is provided also by the waters of the Monti Lessini.

4.5. Rainwater and evapotranspiration patterns

The case study is framed in the local and regional precipitation and evapotranspiration patterns.

Micro and meso

In the time span between 1993 and 2008, the average annual precipitation recorded in the meteorological station of Sorgà, 20 kilometres from the case study area, is 696.9 mm (Bixio et al., 2010: 194). Part of this water returns to the atmosphere in the form of evaporation. In the same time span (1993-2008), the average annual evapotranspiration recorded in Sorgà is 912 mm[122] (Bixio et al., 2010: 195).

According to Chiaudani (2008: 51), over the last three decades, a decrease of about 50 mm/y in the annual precipitation has been recorded in the area. In the 1956-1981 time span, the annual precipitation varies between 750 and 850 mm. In the 1982-2004 time span, variation of the annual precipitation is between 700 and 750 mm. Changes have regarded also the evapotranspiration patterns. In the last three decades, an annual increase of about 100 mm/y has been recorded.

Macro

In the time span between 1982 and 2004, in the region the average annual precipitation is about 1052 mm while the evapotranspiration recorded between 1996 and 2004 is ranged between 1,000 and 1,050 mm (Chiaudani, 2008: 84). Comparing the trends of precipitation and evapotranspiration balance, a trend towards dryer conditions emerges. Chiaudani (2008: 84), indeed, noted that in the last decades also at the regional scale, average annual evapotranspiration rose while, in some cases, the average annual precipitations decreased[123].

4.6. The man made water cycle and the related institutional arrangement

Water cycle

In the region the hydrological cycle has been arranged by means of a number of man made infrastructures. The complexity of the system, indeed, has been increased by the progressively imposed structures of both urbanization and agriculture. This is related to the requirements for water supply, drainage and wastewater collection.

Figure 4.13 illustrates the position of the case study area within the schematic hydrological cross section of the region. In the mountains, precipitation accumulates as ice caps and/or feeds

[122] The evaporation of the area has been computed in the *Appendix B*.

[123] The average annual evapotranspiration recorded between 1956 and 1995 was lower and approximately 956 mm (Chiaudani, 2008: 84). The average annual precipitation recorded in the time spans 1956-1966, 1967-1981 and 1982-2004 is 1235 mm, to up to 1124 mm and 1052 mm respectively.

water tables and streams. Part of the water from headwaters and rivers is diverted in reservoirs for hydroelectric production. The water released downstream is returned into rivers or else it feeds the irrigation system of the plains. In the high plain, most of the rainwater soaks into the ground, recharging groundwater. The remaining rainwater is intercepted by the ground and converted to surface runoff conveyed into surface water elements that quickly discharge water downstream. In proximity of the low plain, part of the groundwater comes up giving origin to spring rivers. The remaining groundwater ends up in deep confined aquifers crossing the ground layer of the low plain. Freshwater from aquifers is withdrawn and distributed by piped systems in the case study area and to other dispersed settlements. Once used, it is either released to the ground or converted into municipal wastewater and carried into treatment plants. After treatment, the effluents are returned to surface water. In the lower plain, infiltration is scarce and most of stormwater overflows towards the surface water system, which delivers it by force of gravity downstream. In the lowlands, where the ground level is below sea level, drainage is accomplished artificially.

Institutional arrangement

Each water flow –and the related infrastructures- of such complex hydrological system requires specific operations of extraction, treatment, distribution, regulation, monitoring etc. which are shared among different bodies at different levels. A short description of the institutions involved in the management of water in the case study area of Ronco all'Adige follows.

Drinking and waste water service. In the case study area, according to the national law L. 36/1994 and the national decree D.Lgs. 152/2006, drinking and wastewater services are under the responsibility of the Autorità d'Ambito Ottimale Veronese (AATO Veronese). The AATO Veronese is a consortium of local authorities. It comprises 97 municipalities, all situated in the Province of Verona (Figure 4.14., 1). The direct management of the service is delegated to a public company. Provision and sanitation services in 20 municipalities located in the surroundings of the Garda Lake are managed by the public company Azienda Gardesana Servizi s.p.a. while the services in the remaining 77 municipalities –and in the case study area- are managed by the public company Acque Veronesi Scarl.[124].

Irrigation and drainage. The irrigation and drainage systems in the area are managed by the Consorzio Valli Grandi e Medio Veronese water board that recently, according to the regional law L.R. 12/2009, has been merged with the water boards Consorzio di Bonifica Adige Garda and Consorzio di Bonifica Agro Veronese Tartaro Tione (Figure 4.14., 5). The water board is a consortium of owners of the area and it is identified as a public body. While the Consorzio di Bonifica Valli Grandi e Medio Veronese mainly extended in the low plain of the Adige, the new waterboard named Consorzio di Bonifica Veronese comprises also territories of the high plain with the historical centre of Verona and few portions of territory along the Garda Lake.

[124] www.acqueveronesi.it

The case study area falls within the boarders of the interregional waterboard Autorità di Bacino Fiume Fissero-Tartaro-Canalbianco established in 1994 in accordance with the national law L. 183/89. This public body is responsible for the soil conservation, the reclamation, the use and management of the surface water in the catchment area that embraces the territories drained by the Fissero River, the Tartaro River and the Canalbianco River (Figure 4.14., 4). The waterboard works to make compatible and homogeneous plans and interventions from the different bodies, regions, provinces, municipalities, consorzi di bonifica etc.

The behaviour of water in the case study area depends also on the actions and decisions of the Autorità di Bacino del Fiume Adige waterboard. Established in accordance with the national law L. 183/89, the waterboard is the public body responsible for the soil conservation, the reclamation, the use and management of the surface water in the interregional catchment of the Adige River (Figure 4.14., 3). Although the case study area is not included in the catchment area, flood control, as well as provision of irrigation water, and availability of groundwater are directly related to the waters of the catchment area of the River Adige.

Furthermore, the case study is under the institutional framework of the provincial office of the Genio Civile, the regional body responsible for the hydraulic safety and the protection of the water resources. The Genio Civile oversees all the concessions of withdrawal of water for different uses (drinking water services, irrigation etc.).

Groundwater. The use of groundwater in the area is under the responsibility of the Province of Verona and the provincial office of the Genio Civile that issues concessions for groundwater withdrawal (Figure 4.14., 2).

Finally, both surface waters and groundwater of the area are monitored by the provincial office of the regional agency for the environment ARPAV (Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto).

The strong compartmentalisation in the planning and management of the waters described above does not favour the process of integration advocated at the different levels. The relationships among these different agencies is sometimes undefined and weak. In this regard, what emerged from the interviews with the technicians (see Chapter 6) is relevantly indicative of the fact that the bodies engaged for the management of the drinking and waste water often do not have any relation with those responsible for the irrigation and drainage systems.

Chapter 5

Landscape processes

5.1. Introduction

Over the last decades a process of economic growth appeared to take place in the Veneto *Città Diffusa*. As Piccinato (1993: 185) has noted, this growth has been rooted in a social and cultural environment able to offer the resources to pass in the span of a few decades from a rural to an industrialized society. The economic changes went along with the exploitation of land and related resources leaving direct effects on physical structures –such as roads, river and stream corridors, agricultural fields, urbanized patches- and on the overall spatial configuration of the territory.

The effects of the recent economic development on the spatial configuration of this urban landscape are briefly investigated through a diachronic comparison of the land mosaics of 1955 and 2007 concerning the case study area of Ronco all'Adige[125]. Afterwards the discussion focuses on the landscape processes behind these two models of territory (1955 and 2007). Changes in the built environment that happened in the same span of time at the scale of the territory of the Consorzio di Bonifica Valli Grandi e Medio Veronese waterboard is also considered.

5.2. Models of the territory

At a first glance the same piece of landscape of 1.25 x 1.25 km appears very different in 2007 from how it was in 1955 (Figure 5.1.). Both land mosaics are the result of different spatial pattern components (matrix, patches and corridors). A closer reading instead reveals that most of the changes can be related to four main spatial processes. *Densification* of construction with the shift from only a few to an increased number of buildings. *Up-scaling* of both residential settlements and fields, that is the shift from small to bigger dimensions. *Centralization* concerning buildings and fields, which is the shift from a generalised dispersion throughout the entire landscape to a situation of polarization in few localized areas. *Separation* concerning

[125] It is worth noting that, in the span of time considered, several economic slowdowns and accelerations are embedded. The economic recession of the last years, for example, has also affected the Veneto. However, from the 50s to the 00s, the main trend has been a considerable economic growth.

again buildings, fields, roads and stream corridors, that is the shift from integration within the same area to greater specialization in different areas.

1955

The image from the 1955 exhibits a fine grain landscape made up of small sized patches.

Agricultural matrix. An extensive and almost homogenous agricultural matrix dominates the landscape. However, at a finer scale, the agricultural matrix appears highly variegated. The microheterogeneity results from the micro patches and micro corridors giving the landscape a high contrast. Micro patches and micro corridors are the physical structures of the mixed farming system named *piantata* combining herbaceous crops and narrow trees corridors (fruit trees and, sometimes, vine shrubs linked to trees) organized in regular sequences[126] (Sereni, 1961: 177; Bianchi, 1989: 484; Scola Gagliardi, 2009: 93). The integration of these two elements gives form to elongated small sized rectangular patches that are oriented North-South where the average distance between corridors varies from 25 up to 35 meters. In a few fields, located in the central and lower part of the image, the corridor density is even higher. The average longitudinal extension varies from 60 to up to 300 meters. Very few scattered agricultural fields are free from inner crossing micro-corridors and hence also have a wider transversal extension.

Settlement patches. House clearings are homogenously distributed within the matrix, mainly located along the road corridors. The built environment is a composition of scattered buildings, with very short sequences of small single buildings and scattered clusters of small and medium size buildings grouped in rural estates (*corti rurali*). A cemetery appears in the top-right corner of the frame while a small industrial site is placed just beyond the right edge.

Road corridors. A sequence of narrow wavy road corridors stretches in an East-West direction (white lines accompanied with dark narrow strips). A broken road line running along the left side of the frame functions as the North-South transportation axis. Vegetative corridors run all along the two road sides. A number of dirt roads often prolonging the courtyards into the fields, permeates the agricultural matrix.

Stream corridors. Two rectilinear stream corridors run across the area in a North-South direction (darker strips). They are the Scolo Saccaro and the Scolo Termini, both flowing in the lower part of the frame. In the upper part, their courses extend along the course of a few North-South and East-West permanent field irrigation ditches (the darker and thicker strips are clearly visible). A stream named Fossa Zerla runs North-South beyond the left edge of the frame; and another, named Scolo Carnirolo, runs in a West-East direction beyond the bottom edge. On the whole, streams, field ditches and road ditches assure a relatively high drainage density and form a dense vegetative network.

[126] The brief description of the landscape of Ronco all'Adige from Dittongo (2002: 25), a local storyteller, confirms this agricultural organization: "The countryside was rigorously fruitful. The wheat fields were ripening, almost ready for harvest. The nearby fruit groves, teeming with fat apples were a chromatic contrast to the forage's golden yellow colours".

2007

The 2007 image exhibits a medium coarse grain landscape made up of larger size patches.

Agricultural matrix. The cultivated surfaces still dominate the matrix even though, probably, connectivity and "control over dynamics" from the settlements is higher (Forman, 1995: 277). The extensive matrix appears as variegated and perforated. The microheterogeneity of the land mosaic, that was visible in 1955, leaves the ground to the macroheterogeneity of the patches. The North-South corridors of the mixed farming disappear from the agricultural fields that are now aggregated and differentiated in specialized areas for herbaceous crops and orchards respectively. Most of the patches are introduced, yet very few are remnant. The resulting broader agricultural fields have very different geometric shapes.

Water expanses patches. The lower eastern part of the frame is perforated by a number of adjacent water expanses, result from the exploitation of the local clay deposits. The basins have rectangular shapes and similar dimensions depending on the techniques of excavation employed and the ownership structure. In many cases the borders of the basins are vegetated forming a sticking mesh of shrubs and trees.

Settlement patches. New residential settlement patches appear in the landscape. Small and medium sized houses expand pre-existing built patches along the roads. Stables, shelters and workshops of medium and large size are added to the backyards of former rural estates (*corti rurali*). New detached dwellings and industrial lots are scattered within the matrix, along roads and at nodes of the road network. This incremental process of urbanization results in a settlement area located at the crossroad of the North-South and the lower East-West road axis, generating an almost uninterrupted ribbon of buildings along the East-West axis in the middle of the area. Moreover, the former industrial site previously segregated beyond the right edge of the frame extends into a big industrial platform accommodating big warehouses for bricks production, a bricks deposit and a clay deposit in the form of small hills.

Road corridors. A narrow North-South stretch of road is added. Carriageways are widened, shrub and tree corridors along the roads are cleared. Many dirt roads are cancelled.

Stream corridors. Streams are hardly visible since vegetation along the banks is removed and their cross section reduced (thin darker lines). The vegetative network that previously accompanied streams, ditches and roads corridors disappears.

5.3. Processes of transformation

The comparison clearly illustrates that through just five decades a landscape built in the course of centuries has been significantly modified (Bevilacqua, 1989b: 30; Ortalli, 2010: 24). Observations of a map of the area from 1886-8 (IGM 1986; IGM 1888), indeed, shows that the fundamental patches and corridors persist in the aerial picture of 1955. The landscape arrangement of that time (1986-1955) reflects the territorial layout of a still pre-capitalistic society composed of few landowners often living elsewhere and a number of peasants subdivided as tenant farmers (*mezzadri*) and farm workers (*gastaldi*) both living in the area

(Quaderno Ronchesano Secondo, 1990: 68; Santi, 1999a: 32)[127]. Tenant farmers were living in scattered houses provided by the landowners (which whole property was commonly at least of about 500 *campi veronesi*, that is 150 ha) and used to cultivate a few hectares in the proximity of their homes (interview Montanari-Galbier). Farm workers were living in small buildings often grouped in short sequences and were working in the medium size farms spread throughout the area (corresponding with the rural estates or *corti rurali*). As often as not, peasants (both tenant farmers and farm workers) had to struggle to survive as they were uniquely and directly depending on the harvest and the variety of resources offered by the local landscape. Still in 1946, 85% of the population of Ronco all'Adige was depending on the proceeds of their farming (Santi, 1999b: 54).The fine grain of the landscape was indeed related to the intensive exploitation of the land given that, in the logic of self sufficiency, a few hectares had to support all of the food and energy needs of a large family[128]. The mixed farming system was providing a variety of foods (like wine, fruits, meat, maize, legumes) and leaves to feed the worms for silk production. Streams and road ditches with their vegetative structures offered a supply of timber and firewood, and food like fish, frogs and land snails (Coltro, 2006: 371).

1955-2007

This socio-economic situation changes significantly from the second half of the XX century. Higher living standards, agricultural intensification and urbanization are among the main drivers of these changes. The regional economy rapidly shifts from an economy of self-consumption (the pre-capitalistic asset) to an economy of market[129]. The industrial and tertiary sectors are the ones that steer major development (Piccinato, 1993: 186). Agriculture is no longer the main activity. Due to mechanization, the number of farm workers employed in the local farms abruptly decreases. In 2007 medium and big farms employ only a few workers, and oftentimes only on a seasonal basis (interview Montanati-Galbier). In many cases tenant farmers have bought land, but farming is no longer their main activity insomuch as they spend only part of their spare time in cultivating crops (Bevilacqua, 1989b: 34; Piccinato, 1993: 194). In general the changes brought the fields to higher levels of uniformity since the number of crops tends to decrease and the extension of the plots is by custom wider and more unified (Farinelli, 2003:

[127] The *mezzadria*, is a contract for management of the land implying the subdivision of a large-scale property into a number of plots assigned to peasant families - tenant farmers-, one or a few for each family. Tenant farmers were bound by duty to divide the harvest in half with the owner (Bevilacqua, 1989b: 17; Farinelli, 1989: 230).

[128] The description from the novel of a local storyteller gives an account of the role of small scale agriculture at that time: "We only had those five fields to work, but it was enough for us. […] The family all hovered around that small piece of land and the animals in the court-yard that mother took care of there were chickens and ducks that were also nourished by what the fields produced. It was an ongoing cycle, with the five of them keeping it going". Dittongo (2002: 11, 13).

[129] Dittongo (2002: 68) in its novel briefly describes the economic growth of Ronco all'Adige after the second world war: "The entire country was in a fervour of work. A contagious frenzy got a hold of everyone. It seemed that everybody was faced with the opportunity of a lifetime: To get rich quick, landowners exploited the great demand for homes that was so rapid in the country after the destruction of the war. Workers left their meagre backgrounds with the goal of building themselves a little house and a more promising future. Everyone was stuck in the same tunnel that was grinding every thing up: the important thing was to end up with more money. So people set to strictly produce, without taking care to plan ahead and better organise the future. Everyone for themselves, whatever the costs may be. […] Everything was regulated by an obsessive frenzy that was dictated by one inexorable mandate: to produce."

67). The vegetative micro-corridors previously permeating the matrix are cleared. Conceived as a process of subdivision of land, the ownership structure is often denser, so the parcels are more and more aggregated and are oftentimes cultivated by big third party farmers who can write off costs and the low unit revenues (Farinelli, 1989: 242). Indeed, though yield per unit area is much higher than in the 50s, the surplus value is relatively low[130].

Settlements, streams and road corridors are adapted to new requirements for living and producing. Even though it led to an increased building stock, the impact of industrialization did not really change the basic structure of the urban pattern (Piccinato 1993: 188). The comparison shows that this process of urbanization has proceeded incrementally to eventually thicken existing patterns (Munarin and Tosi, 2001: 70). The buildings existing in the 50s were expanded and also improved upon, while new houses were also added. In general, while the family size became smaller, dimensions of buildings became wider (Piccinato 1993: 189). New industrial buildings appear, at first next to the existing homes, and later on upon specialized industrial platforms (an example is a small industrial platform –not visible in the image- located a few hundreds meters upstream).

Furthermore, the analysis of the changes on the built environment at the scale of the waterboard confirms this tendency (Figure 5.2.). Fragmented, linear and dispersed urban structures are clearly recognizable in the map (Figure 5.3.). In the span of less than fifty years (1955-1997), the urbanized surfaces have more than doubled. In some portions of territory, fragmented structures triple while linear and dispersed structures double. Despite high degrees of clustering, the figures exhibit that the dispersed system in fact developed in a dispersed way. In other words, the variety of urban developments has basically confirmed the existing basic urban structures. So the dispersed dynamics, indeed, have ultimately stayed dispersed.

Water expanses. Back over the small portion of landscape selected, the comparison shows that in the span of time selected (1955-2007), a number of water expanses takes the place of part of the agricultural matrix. These are also a result of the recent process of change. Here, as in many other parts of the Veneto low plains, industrialization and urbanization have led to the intensification of mining activities to feed the real estate market with building materials. In Ronco all'Adige the mining of clay was already diffused in the late 19th century. However, it was between the 50s and the 70s that this activity experienced such a great expansion and came to have a leading role in the local economy. At the beginning of the 60s, in the municipality there were twelve brick-kilns employing about 700 workers (Santi, 1999b: 56). Later on, the mechanization of the processes progressively reduced the number of employees while the crisis of the late 70s led to the closing down of most of the plants. Today, just one brick-kiln (corresponding with the big industrial patch in the aerial view of 2007) resists, and it employs about thirty people (interview Purgato). The pits, though in a different form, bring back the marshy lands of the past. Indeed, as an old map from the Venetian Republic shows (Figure 5.4.), for centuries and up to the late 17th century, that is just before the extension of the territorial colonization by the aristocracy (Bellicini, 1989: 78), this part of the Adige River's floodplain

[130] At present, despite the still wide-spread extension, the agricultural sector contributes to less than 2% of the regional GDP (Tempesta, 2010: 33).

had remained a marshy land of farms and small villages, which stood on the higher and safer ridges or levees of the river.

5.4. Conclusions

The above analysis shows that the structure of a former poor rural landscape has been adapted to support an affluent industrialized and urban one. This took place within a highly developed system of infrastructures. Researches have talked of *incremental* and *cumulative-selection processes* (Munarin and Tosi, 2001: 70) or *flexible accumulation* (Luciani, 2010: 121) to explain how the present urban landscape of the Veneto results from a progressive thickening of selected existing structures. A number of small elements are often added along existing roads, streams and/or ditches, which sometimes leads to their overall obliteration. Furthermore, the agricultural sector had furnished workers with new industrial activities and provided a fragmented ownership structure that often helped to raise micro-entrepreneurships that were also family based (IRSEV, 1985; Reho, 1986; Bellicini, 1989: 81; Piccinato, 1993: 185; Bonomi, 1997: 17).

Notwithstanding the persistence of the basic structures, the recent transformations (which Luciani called *transformissions*, to say that existing signs have been both transformed and transmitted) have modified the grain of the spatial diversity of the landscape. Heterogeneity and hybrid character have increased but only at a wider scale and at the costs of integration between the parts. The process of change has indeed brought about a *separation* of the inhabitants from the environment, as that division in the century old relationship between urban and rural structures (Farinelli, 2003: 65). Aside from those specialized cultivations diffused in other parts of the territory and turned to niche markets (e. g. risotto rice or radicchio rosso veronese), the earnings from the agricultural sector are unable to support the higher living standards of the inhabitants on their own. Consequently the scale of working and producing becomes wider. Even though many inhabitants have their vegetable gardens in their backyard, or a small-scale agricultural parcel close by, and sometimes their own company within the lot, the new economic situation blunts the relations that the locals have with the environment and its resources. They do not directly depend on the local landscape anymore. Their requirements and living standards are regulated according to resources and forces at wider scales (Bernardi, 2004:18)[131]. *The particular moulds itself on the broad-based*, this is the expression used by Farinelli (1989: 239) to depict the new condition.

[131] Regarding the role of agriculture in the regional economy, Bernardi (2004:18) remembers that in the 60s and the 70s, a land adapted for the differentiation of cultivations and the production of good quality products was reduced to uniformity and driven to compete with cultivations of countries having huge surfaces to cultivate. However, it is worth noting that, despite increased urbanization and industrialization, the Veneto is today one of the leading regions in Italy for production of beef, soy and maize. Moreover it is one of the Italian regions with the highest concentration of high quality products with PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication) quality assurance labels (Ferrario, 2007: 40).

As a result of the many changes, separation occurred extensively throughout the various parts, especially between the houses and the agricultural matrix. The matrix no longer depends on the requirements of the locals; rather it is prone to the forces of the global market and the European subsidies and regulations (Ortalli, 2010: 25). In this sense, fluctuations at the trans-regional scale have had direct effects on the local landscape.

Even though the changes exploiting the land have brought about social and economic success, at the same time there is a growing concern about the possible harmful consequences to the environment. At the local level, for example, monofunctionality and standardization forced by the economy have shifted a vibrant *bocage* landscape into a mere open landscape. Such factors also had devastating consequences on its ecological balance and quality. According to Forman (1995: 271), for example, lowering the density of the corridors in a landscape can result in a lower food density for certain species. Circuitry and connectivity thus decrease. Wind velocity augments as well as soil erosion and evapotranspiration. Drainage density decreases. Streamflow tends to augment in the wet season, and is reduced in the warm dry season. Meteorological variability through the year increases while spatial variability tends to decrease.

Moreover, it should be noted that the changes went along also with the impoverishment of the rural culture, which means the loss of folk memory and cultural identity (Ortalli, 2010: 26)[132]. A farmland populated of people and animals becomes an almost inaccessible desert (interview Montanari-Galbier). The shady roads animated with people become asphalted strips for a realm of cars. A number of recreational and social practices like walking, fishing, swimming, conversing and gathering food become nearly impossible or actually disappear (interview Montanari-Galbier; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro).

Therefore, from this brief spatial analysis it emerges that the recent process of economic, social and physical restructuring has proceeded in stratifying and reinforcing part of previous signs of the territory, but at the cost of the unique fine grained character of the landscape that has now partly disappeared. The new territorial layout accommodates a variety of highly interpenetrated land uses (residential, agricultural, industrial and commercial) that interact very little with one another. This increasing separation between the activities and the environment weighs against the habitability of the local landscape[133].

It is worth noting that the same processes of centralization and separation that have concerned the portion of landscape of Ronco all'Adige, although with different intensities, have also involved most of the low plains of the region. In some areas, the effects on the spatial arrangement have been even stronger. In the case study of Ponte di Piave in the Consorzio di Bonifica Sinistra Piave waterboard (Zaccariotto, 2010), for example, the changes have definitely

[132] See for example the cultural richness emerging from the description of the past rural world in Coltro, D., 2006. La terra e l'uomo. Verona: Cierre.

[133] "The landscape was different. At that time it was beautiful, presently it is unsightly. It was different when there were the ditches. One could see vegetation too." [*"Il paesaggio era differente. L'era belo, adesso l'è bruto vederlo. Quando c'erano i fossi era differente. Si vedeva anche la vegetazione.*"] (Interview Purgato). These are the words used by an interviewed inhabitant who complained about the loss of quality that has followed the transformations of the last decades.

destroyed the fine grained landscape, which has been replaced with a monothematic industrial platform due to policies of zoning, whose main goal is separating the territory into different land uses. This demonstrates how the economic forces supported from policies and planning devices, conceived for different urban contexts, can increase the coarseness of the landscape even further. In other words, at this rate, if adequate measures involving specific design options are not taken, the unique diversity of the Veneto *Città Diffusa* risks possible extinction.

Chapter 6

Water processes

6.1. Introduction

The spatial transformations that over the last decades occurred in the città diffusa of the Veneto, have also brought about changes in the way water is organized throughout the landscape. Water-flow infrastructures have been progressively rearranged; some of them persisted (*persistence*), some were adapted (*permanence*), others were removed (*obliteration*). In addition to having direct effects on the landscape arrangement in general, these changes have also strongly affected the overall state of health of the environment.

By focusing on the water chain infrastructures and related flows, this chapter analyses the way that a portion of the Veneto *Città Diffusa* essentially functions. The main scope is, indeed, to critically observe the complex water system in relation to the form of this decentralized urban landscape. And the leading question is whether the *Città Diffusa* and its water chain infrastructures have been developing towards a sustainable level of interaction.

The analysis moves from the level of the case study landscape in Ronco all'Adige where changes are accurately analysed, up to the level of the Consorzio di Bonifica Valli Grandi e Medio Veronese water board where the current situation is being examined and sketched out. The observations involve careful consideration of both supply (irrigation and drinking water systems) and sink functions (drainage and wastewater systems).

The chapter is organized in three parts. The first considers structures and water-flows of irrigation and drainage systems while the second concerns the drinking waters and waste systems. The third part discusses the paradoxes that have emerged from the enforcement of a centralized management of water in the context of such a decentralized urban landscape.

6.2. Irrigation and drainage water systems

Patterns. The magnitude of the changes of the last fifty years emerges at once comparing the patterns of irrigation and drainage systems of 1955 and 2007 deposited in the case study area (Figure 6.1.). The main structures remain fairly consistent, while on the whole, networks and patches are relatively different.

1955

In 1955 the surface water system was a fine mesh network made of both rectilinear and wavy corridors (Figure 6.1., left).

Corridors. Corridors are numerous, consisting of three different hierarchical levels. Fine grained corridors are prevalently horizontal, while corridors of medium and medium-large width run both vertically and horizontally. A few of these corridors run parallel. Together they give form to a mesh of mid sized variance and high continuity.

Built environment. Tiny patches are spread over the landscape and they are polarized along those parallel running corridors.

2007

In 2007 the surface water system is a coarser mesh network into which a number of patches and micro rectilinear networks are embedded (Figure 6.1., right). The network exhibits a higher degree of discontinuity.

Corridors. Many fine grained elements disappear while wider corridors instead persist. Despite the up scaling, a discrete variance in mesh size remains.

Fine networks. New and finer networks are stretched here and there among the nets of the mesh, but remain detached from it.

Patches. New small and medium sized water patches populate the lowest part of the frame. They are gathered in groups and they stretch between the corridors composing the network.

Built environment. A greater number of buildings appear distributed along some of the corridors that run together in pairs. A few new medium and large sized buildings stand freely over the frame. In correspondence to the water patches, building are only few and far between.

Conclusions

The two patterns (of 1955 and 2007) are generated from different conditions of living and producing. Specific drivers and processes insist on the structures of irrigation and drainage related to the main components –patches and corridors- of the landscape mosaic. Accordingly, first there are the changes on the patches –the field system, the built lot system and the excavation sites system-, and later, those which occurred with the corridors –the road ditch system and the stream system. Following this order, such changes must all be separately discussed, while keeping a constant focus on the analysis of drivers and processes shaping the inner elements of irrigation and drainage.

Box 6.1.

Spatial processes: main operations

A series of spatial processes concern the structures conveying water flows. A few basic operations at their basis can be distinguished. They are: filling up, excavation, levelling, rising, sealing, and piping (Figure 6.3.).

Filling up, that is to fill a receptacle until no more water can be received, hence decreasing storage and increasing discharge.

Excavating, that is to create a hollow cavity by removing the inside, hence increasing storage and nearing the groundwater levels.

Levelling, that is to make flat and smooth, hence decreasing storage.

Rising, that is to grow in respect of height, hence increasing drainage and keeping distance from groundwater levels.

Sealing, that is to render impervious to water, hence decreasing infiltration and increasing discharge.

Piping, that is to use a pipe to convey water flows, hence increasing drainage and separating water flows from the environment.

6.2.1. Field system

1955

Patterns. In 1955 the irrigation and drainage patterns of the field system appears as a composition of different sized networks, rhythm and orientation (Figure 6.4., left). The total extension of the system within the frame is about 20 kilometres.

Drivers and structures. The networks embody the elaborated hydraulic system at the basis of the mixed farming *piantata* (Figure 6.5., left). As mentioned above, still in the 1950's, the survival of the society living in the landscape is still closely dependent on the locally harvested produce. Therefore, despite a prevalence of clayey soil with little infiltration capacity, the agrarian layout has to assure a certain productivity even in case of a rainy year (Giardini, 1982: 343). A marked concave shape or steepness (*baulatura*) of the field, and a dense drainage network make the *piantata* to perform accordingly (Giardini, 1982: 337). As a matter of fact, fields slope longitudinally for 50-100 meters towards transversal depressions called *cavini* that are oriented E-W. The latter are 2-3 m wide paths, a few hundred meters long and up to 1.5 m lower than the top of the adjacent field (Figure 6.6., 1). The field gradient is oftentimes not marked. In this case the transversal depressions are wider dirt roads called *cavedagne* (*scaezzagne* or *stradele*)[134]. Other times transversal depressions are kept cultivated and marked with a furrow to favour drainage (*solco levador*). In yet other cases, the transversal depressions are field ditches called *cai* or *caeti* (interview Montanari-Galbier; Giardini, 1982: 342). *Cavini*, *cavedagne, scoli levadori* and *cai* are connected to higher ranking ditches that run N-S and are often assisted by dirt roads. Within the fields themselves there are lines of trees, as an important part of the *piantata,* traversing it in a N-S direction in order to allow for better exposure of sunlight to the plants (Oliva, 1948: 104). Often the orientation of the drainage elements is slightly distorted and it follows the terrain gradient and/or the orientation of the roads.

Drainage flows. Approximately half of the stormwater collecting in the field is infiltrated (Oliva, 1948: 111). The field functions as an earth sponge, detaining stormwater. The remaining water overflows towards the lowest parts of the field as it is gathered from *cavini*, *cavedagne, scoli levadori* or *caeti*. From there stormwater is delivered to field ditches of higher ranking, called *scoli* or *fosse,* with flowing water and vegetation. Flowing into the *scoli*, the agricultural runoff passes through the vegetation distributed all along their banks. In the case that the *scoli* do not continue to receive water, the *cavini* or *cavedagne* and the lowest parts of the fields are flooded for a few hours, and even sometimes for a few days (interview Montanari-Galbier; Oliva, 1948: 111, 133). However, thanks to the gradient, the plants located in the higher parts are not damaged[135]. For this reason, a minimal harvest is assured[136]. The various densities of the *cavini* and *cavedagne* in the area are determined by their drainage function: the lower the permeability of the terrain, the higher the density of *cavini* and *cavedagne*.

Irrigation flows. During the 1950s, structured irrigation was rarely practiced. Groundwater level was kept rather high. Generally speaking, the infiltration of rainwater in those years was hardly fostered. Therefore, due to the slow drainage rainwater was partially detained in field ditches [137] (interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro). However, only a few farmers were provided with temporary sprinkler irrigation systems (*spiansini*). They hence withdrew water from the *cai* and *scoli* or even from aquifers at about 30 meters deep, channelling it into piped networks in order to irrigate the crops (interview Montanari-Galbier; interview Purgato; Scola Gagliardi, 2009: 103). Another rarely practiced irrigation technique was the use of flood irrigation.

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[134] Though the agrarian manuals often distinguish between the *cavini* system and the system with *cavedagne* (e.g. *cavalletto* system), in this particular analysed landscape, different arrangement types of the same typology *piantata* can be mixed.

[135] The importance of these drainage/detention structures is confirmed from the byword "Ditches and dirt roads are the life of the countryside" ["*I fossi e le strade iè la vita de na campagna*"] (Coltro, 2006: 340).

[136] According to Oliva (1948: 70), a system like this has an average storage capacity of 200-300 m3/ha and can partially detain excesses of stormwater for up to 24-48 hours.

[137] In this regard, G. Pedrollo confirms that in the 1950s potatoes were difficult to cultivate in the area since these plants were suffering excessive moisture of the terrain as well as periodical floods (interview Pedrollo-Tobaldo-Pedrollo).

Low fields. Sometimes fields are lower and hence suffer a more difficult drainage (Figure 6.6., 2). From time to time, they temporarily accommodate stormwater (interview Pedrollo-Tobaldo-Pedrollo). However in 1955, there were only just a few of these low fields. Comparing the drainage structure of the 50s to that of the late XIX century, their reduction in number is clearly visible (Figure 6.2.). At that time indeed a number of water meadows and rice paddies were still present, and situated a few hundreds meters upstream and down the area respectively[138].

Maintenance and institutional conditions. *Cavini*, *cavedagne* and *cai* made at the expenses of the landowner, are directly managed by the farmers (tenant farmers and farm workers). They need a complete farming to perform well. Apart from moving herbs, cleaning and reshaping the cross section other common operations consist in cleaning out the bed, gathering wood, fishing, hunting and drawing ice (Coltro, 2006: 354).

2007

Patterns. In 2007 the minor drainage and irrigation structures of the field system figure as a collection of few lasting networks and isolated segments (Figure 6.4., right). Numerous scattered comb-like fine rectilinear networks for irrigation started to appear[139]. The drainage system crossing the frame is about 6.5 kilometres long while the irrigation networks extend for dozens of kilometres.

Drivers and structures. The system of elements supports extensive mechanized farming of produce that is intended for the market. The agriculture of the area, indeed, notwithstanding the increased productive capacity in comparison with the 50s, must now compete with the slump in prices that followed the opening up of the market (direct communication from Consorzio Agrario Lombardo-Veneto Scarl., Ronco all'Adige, 24th October 2008). Therefore the agrarian arrangements have to assure minimal losses and sufficient productivity in the fields (Figure 6.5., right). Flat profiles, extended dimensions of fields together with quick stormwater discharge are the main features required for the agricultural matrix to support the short-term, profit-oriented, simplified management of agricultural practices (Hill, 1985) that are typical of extensive (and also intensive) agriculture (Figure 6.6., 1). Moreover, intensification-mechanization-specialization of cultivations (Giardini, 1991: 154) tend to push towards an *up scaling* of the parcels of land in order to facilitate manoeuvring within the fields. Modern agriculture, with its increased use of fertilizers and weed killers, is moving closer towards a distinct *separation* of cultivations into specialized plots (Giardini, 1991: 152). Accordingly, in very little time, the fields have been forced to adapt to the new requirements. The convex section is partially flattened out (*levelling*). *Cavini*, *cavedagne*, transversal field ditches and low fields are filled up (*filling up*). Consequently, fields become wider and, despite a few distinct features of the site, monoculture plot fields with homogenous conditions in their cross section are extended (*up scaling* and *separation*). In 2007, agrarian arrangements appear as a kind of *larga ferrarese*.

[138] At that time cultivation of rice was convenient for big farmers, who had the resources to pay for irrigation waters and produce the other food-crops needed in other parts of their property.

[139] It is worth noting that only permanent irrigation structures are represented in the image. For the most part, the system corresponds with the irrigation systems supplying the orchards, which are spread throughout the analysed landscape.

Fields slope longitudinally for a few hundreds meters towards transversal field ditches called *scoline*. These are then connected with N-S *capofossi* or *scoli*. Cultivation units are 1-5 ha and patches are 200-400 m deep (Giardini, 1991: 153).

Drainage flows. A portion of rainwater infiltrates flowing towards the *scoline* in the form of an inclined water table. The remaining rainwater directly flows towards *scoline* in the form of overland flow. The *scoline*, which are dry during the most of the year, quickly discharge waters into higher ranking ditches (*capofossi* or *scoli*). No vegetative structures stand in the water's path. In the logic of modern agriculture, temporary detention of water is no longer considered as an option. Instead a rather quick discharge downstream is performed.

A few hundred meters downstream of the area, there is a select number of low fields that are arranged with different drainage systems. These fields are the result of a filling up of former clay pits that were not yet present in 1955 (*excavation* followed by *filling up*) (Fig. 6.6., 3). Unlike the system described above, the section here is almost completely flat. In compensation they are equipped with an uninterrupted series of *subsurface drains* perpendicular to *capofossi* (*piping*). As a result, land parcels are wider and have higher drainage capacity. Rainwater infiltrates the plough layer and, once collected from the small perforated buried pipe drains (*subsurface drains*), it is quickly delivered to the *capofossi*.

Irrigation flows. Groundwater is lower than it was in the 1950s and this especially occurs in the drier period. The deficit between precipitation and evapotranspiration is compensated through a periodical supply of irrigation water. Aquifers which are numerous in the subsoil are the main sources. Plots are provided with pump wells 20-30 meters deep –sometimes more- as well as piped networks for the distribution of the irrigation water (interview Romio; interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo). All of these irrigation techniques do not require a specific arrangement of the field layout (Morin, 1993: 162). Temporary removable pipes and sprinkler irrigation are the infrastructure for most of the arable lands, while orchard fields are equipped with permanent tubing networks for drip irrigation –which corresponds with the fine networks that is spread throughout the matrix (Figure 6.5., 4). In the orchards, the irrigation system is used also between mid March and mid April for frost-preventing irrigation. In the filled up former clay pits, water from streams, either pumped or by force of gravity, is delivered into the *capofossi* and from there into the subsurface drains which distribute water into the field.

Maintenance and institutional conditions. Subsurface drains, field ditches of the first rank (*scoline*), and second rank (*capofossi*), are of private domain. The owners of said properties are responsible for their efficiency. They can request annual maintenance operations: the periodic mowing of grass, the re-shaping of cross sections and, in some cases, the care of hedge-rows. The *capofossi*, having a collective drainage role, are directly managed directly by the water board. Wells used to withdraw groundwater are instead directly managed by the farmers.

Effects of changes: flows, space and actors
Water perspective. In the agrarian asset of 2007 stormwater is not stored in low spots of the microtopography anymore, instead it is collected and delivered faster downstream. On one hand, as D'Alpaos (1991: 40) has noted for another section of the Veneto plain, the drastic reduction of onsite storage volumes and the rapid draining mechanisms for water removal produce a significant increase in magnitude and frequency of the peaks discharge in receiving streams. In this regard Bixio (1990), studying an area with similar soil conditions close to Treviso, empirically observed that the introduction of subsurface drains causes the discharge of greater volumes of stormwater downstream. On the other hand, the irrigation demand is much higher to accomplish the requirements of a modern production (Giardini, 1991: 147). The increased drainage favours a lowering of the water table and the drying up of field ditches (*scoline* and *capofossi*). In this way it also contributes to increasing the demand for water in dry periods. The greater discharge downstream is compensated with increased extraction of water from the aquifers. Commonly the wells used for this purpose are not registered. Besides, the widespread use of fertilizers and weed killers pollutes stormwater discharged from fields. This water is discharged downstream without any treatment since the vegetation along the ditches has been erased.

Spatial perspective. Water that is visible for just the time of a storm almost disappears from fields. There is a general removal of the tree lines of the mixed farming patches, as well as the hedge-rows along the field ditches; and paths that were formerly related to *cavini*, *cavedagne* and ditch fields are also removed. The fields hence result monotonous, flat, boundless and almost inaccessible.

Actor perspective. Fields are deserted in comparison to 1955. The integrating activities of the rural society of the 1950s are gone. In 2007 bathing and fishing in the field ditches, gathering food like mushrooms, frogs, herbs or firewood and walking along their banks are practices reserved to just a few landowners (interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro).

6.2.2. Built lot system

1955
Patterns. In 1955 the impervious areas of the built lot system appears as a composition of scattered tiny patches mixed in with few medium sized patches (*corti rurali*) (Figure 6.7., left). Buildings have similar small-scale dimensions and, apart from the *corti rurali* and the built lots of tenant farmers, their outdoor impervious surfaces are very limited in extension. Tenant farmers' lots, and *corti rurali* in particular, have courtyards –and semi-paved surfaces- of higher extensions. Counting only the impervious areas occupied by the buildings, the surface covered in 1955 was about 2.5 ha.

Drivers and structures. The built lots of tenant farmers and the *corti rurali* perform as workplaces as well as dwellings (Figure 6.8., left). Buildings have relatively small-scale dimensions in comparison with the number of people living in them and the needs for workplaces and deposits from the intensive mixed farming. *Corti rurali*, instead, accommodates buildings with specific functions. In general, the farmyard is a hard court setting for many activities[140]. It patchily slopes towards a field-ditch or road-ditch running along one or more of its edges (Figure 6.9., 2). Built lots are often provided with a vegetable garden (*orto* or *brolo*) located in proximity to the dwelling.

Drainage flows. Rainwater from roofs and semi-paved courts runs off towards field-ditches and/or road-ditches. A portion of the overland flow is detained in the micro depressions of the courtyards (depression storage). The remainder passes through the vegetative structures placed along the ditch before falling into it.

Irrigation flows. Tomatoes, lettuce, peas and the other vegetables of the *orto* are commonly watered using the water of the ditch running along the lot border[141].

2007

Patterns. In 2007 the impervious areas of the built lots is a mass of small, medium and large patches, most of which are grouped in different convoluted shapes (Figure 6.7., right). In comparison with the 1950s, buildings today, along with their adjoining paved and semi-paved surfaces, are much more extended and diverse in dimension. Counting only the impervious areas occupied by the buildings, the surface area covered in 2007 is approximately 7 ha; that is more than double in comparison to the 1950s.

Drivers and structures. The new living standards and the sectorialisation of processes imply a separation of functions into specialized buildings for living and producing. Urbanized areas greatly increased due in great part to a higher per capita income and the normative development policies[142] (Figure 6.9., 1). Single houses were added to and expanded in order to meet new living standards (Munarin and Tosi, 2001: 76). Annexes like micro shelters, garages, sometimes other dwellings, a workshop or a stable of medium and large dimensions were added along the sides or behind the houses[143] (*sealing*) (Figure 6.8., right). Part of the ground is paved to comfortably connect the lot gates with entrance doors, garages and workshops (*sealing*) (Figure 6.9., 2, 3). Very often the built lot extends over the agricultural matrix, sometimes also gaining few meters towards the roads, by filling field ditches and road ditches or simply erasing the

[140] The farmyard is also the space for farmyard animals and the setting for cutting wood, cultivation of the silkworm and many other activities. Regarding this see for example the thorough descriptions in Coltro (2006: 386).

[141] Again the description from a novel of a local storyteller confirms these practices: “There was always much to do. One had to control the grounds, pull up grass, combat parasites and intervene if necessary. There was the project of ploughing the grounds, as well as the utilisation and maintenance of irrigation ditches, running along the border of their small property.” (Dittongo, 2002: 13).

[142] See the Chapter 2.

[143] Munarin and Tosi (2001: 76) have further described the development of the built lot type “house with garden” in the Veneto *Città Diffusa*.

vegetative structures along them (*filling up* and *sealing*). Sometimes graded smooth, the ground is most often mounded or raised to make it slope from the building to the borders of the lot which improves drainage and prevents flooding from neighbouring land uses (*rising*). The rest of the lot is arranged as gardens and portions of it are typically used as vegetable patches. Paved and semi-paved areas function as parking lots, deposits and, in the case of farms, as places for the maneuvering of agricultural machinery.

Drainage flows. Rainwater from roofs collected from pipe gutters and run off from paved and semi-paved surfaces, due to increased gradient inclinations and smoothed surfaces, flow quickly towards ditches or drains –that is the former ditch- at the lot boarder. Run-off is augmented also by that quantity of stormwater from gardens that, due to the low permeability of the terrain, does not infiltrate. In this way, overland flow gathers the pollutants deposited over impervious surfaces before spilling into the surface drainage network. A few lots are provided with sumps and piped drains that can remove stormwater more quickly.

Irrigation flows. Gardens and vegetable gardens are regularly watered during the dry season. Irrigation water is withdrawn from aquifers with pump wells and distributed through tubing – sometimes running below ground surface levels- ending up in sprinklers or drip irrigation devices (interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro).

Maintenance and institutional conditions. With the exclusion of new urban expansions which exceed certain parametric surface extensions and according to the DGR 3637/2002 and its following amendments, new building construction projects will have to detain stormwater locally. Removal of stormwater from built lots is the responsibility of private citizens. However that may be, the owner is to pay a fee to the water board, based on the extension of the built lot and other parameters; this in turn guarantees the efficiency of the surface drainage network (R.D. 215/1933; R. D. 262/1942; L.R. 3/1976; L.R. 12/2009). The wells used for withdrawing groundwater are also handled as private affairs.

Effects of changes: flows, space and actors

Water perspective. In 2007 discharge and supply related to built-up lots was much higher than in 1955. On one hand, the increase in paved areas tends to remove depression storage and reduce infiltration, which eventually generates increased stormwater run off. As a result, peak discharge in receiving streams increases in magnitude and frequency (D'Alpaos, 1991: 43). In some occasions built lots with higher ground level quota discharge stormwater into neighbouring lower lots and provoke their flooding. Moreover, waters from paved surfaces are loaded with pollutants released from cars. These contaminated flows no longer pass through vegetative structures before flowing into the surface water system. On the other hand, in 2007, during the dry season, the widespread presence of gardens and vegetable gardens requires relatively great amounts of irrigation water, while in 1955 irrigation was limited to a lower number of vegetable gardens[144]. Furthermore, irrigation water is no longer supplied from the surface water. Rather it is extracted from aquifers using wells which are not typically officially registered.

Spatial perspective. The extension of impervious areas and the cancellation of diaphragms along the lots boarders make stronger the juxtaposition between the built environment and the surrounding agricultural matrix. Built lots, indeed, appear as counterpoints in a flat cultivated background. Sound barriers, shade and the windbreaking functions performed by the vegetative structures that were formerly planted along the ditches have diminished significantly. During the weekends, the noise caused by the use of lawn movers, for example, can travel for hundreds of meters.

Actor perspective. Apart from the farms and the industrial lots, the rest of the built lots are lived in and used mainly during weekends or when people are on vacation, and hence use the outdoor space for playing, washing cars, gardening and talking.

6.2.3. Road ditches system

1955

Patterns. In 1955 the surface water elements related to the road system are an extended wavy network of parallel elements, where continuity appears to be broken only in correspondence with the bottom right corner of the frame (Figure 6.10., left). However, a closer look shows how the network exhibits a certain number of small gaps. Counting only the open air road ditches on their own, the entire network is about 15 km long.

Drivers and structures. The road system supports a poor society living and working in the local landscape, regularly moving to the centre of Ronco all'Adige, sometimes to the surrounding villages, and rarely to the centre of Verona. As a matter of fact, most of the people do not need to commute long distances for work. Just a few have the motorcycle and/or the car. The harvest and collection of other materials (timber, hay, manure, clay etc.) are transported by cart drawn horses, donkeys or oxen. Motor trucks regularly run through a few main roads to pick up bricks from the numerous kilns that are located in the area. Roads of different ranks are prevalently unpaved and narrow (Figure 6.11., left). Carriageways are irregular and often uneven. Road ditches of different ranks (*cai* or *scoli*) followed by vegetative corridors made up of different kinds of trees (commonly planes, false acacia and willows) run along both sides, interrupted for a few meters only in correspondence with the entrance to a built lot (interview Pedrollo-Tobaldo-Pedrollo) (Figure 6.12., 1).

Drainage flows. Rainwater does not easily infiltrate due to the hardness of the carriageway. Run off is partially detained in the numerous micro depressions along the carriageway (depression

[144] Quantitative aspects regarding the present irrigation demand from the area's gardens are available in the *Appendix B*.

storage). During the wet season these stagnant water puddles sometimes make the road hardly practicable. The stormwater that does not infiltrate passes through a vegetative verge before flowing into it. The road ditch drains also stormwater from adjacent agricultural fields and hard surface courts.

Maintenance and institutional conditions. According to their rank road ditches are under different institutional and maintenance conditions. However, most often they are directly maintained by the locals who, in addition to their drainage service, profit from the planted trees. They in fact use the trees for making firewood and timbers to be directly integrated in the cycle of the farm or sold (Coltro, 2006: 354). Therefore, as mentioned above for the field ditches, these hedge-rows require a more complete maintenance and management.

2007

Patterns. In 2007 the surface water elements related to the road system form a wavy discontinuous network mainly made up of parallel corridors (Figure 6.9., right). However, few parts of the network are made up of single lines alone. The mesh is visibly interrupted in the bottom left corner. However, at a closer view, a great number of small interruptions distributed all along its extension appear. Counting just the open air road ditches alone, in 2007 the whole network is about 7 km long, that is less than the half of its lengths in the 1950s.

Drivers and structures. The road system supports a capitalistic society that, even if dispersive in its distribution throughout the agricultural matrix, also has typical urban habits. Places for living, working and leisure do not always coincide any longer. Most of the people move from their lots for working, shopping, meeting, recreational activities or sports, studying etc.[145]. The pervasive road network is indeed an essential ingredient of the urban landscape of the Veneto *Città Diffusa* and cars and trucks are the means of transportation best adapted for such a decentralized living. In comparison with the 50s, carriageways are enlarged (*filling up*) and asphalted (*sealing*) to meet the requirements of the rapid means of transportation that occur there (Figure 6.11., right). These enlargements occupying part of the road ditch narrow their cross section on the road side[146] (Figure 6.12., 1). On the other side, agricultural intensification and urbanization push also on their cross section. Trees along road ditches are no longer included in the agrarian weaving factory and are erased to leave the grounds to the specialized cultivations. In correspondence of the built lots, road ditches are even piped (*piping*) and filled up (*filling up*) to give room to strips of grass, more often to gravelly and asphalted strips used as lot entrance or parking. Some stretch is not even piped but simply cancelled. In other parts of the landscape new roads are also added. According to their rank and function, the new roads are equipped with a set of stormdrains (e.g. roads of new developments) or new road ditches called *fossi di guardia* (e.g. highway).

[145] Munarin and Tosi (2001: 144) have clearly illustrated the extended use of the territory in the *Città Diffusa* analysing the movements during the day of a sample of inhabitants of the central area of the Veneto.

[146] "In the 1950s the road ditch was seventy centimetres wider." ["*Nei ani sinquanta lungo a strada el fosso l'era setanta sentimetri più largo*"] (interview Pedrollo-Tobaldo-Pedrollo).

Drainage flows. Rainwater runs off the asphalted pavement of the road that collects automobile contaminants (oil, paint, lead etc.) and quickly joins the drainage system. This overland flow either passes through a narrow strip of grass before pouring into road ditches (*scoline* or *scoli*) or directly drains into gutters and stormdrains placed along the road. From there stormwater is rapidly discharged into higher ranking drainage elements. Road ditches and piped former road ditches also collect runoff from the agricultural fields and the numerous built lots spread throughout the area.

Maintenance and institutional conditions. Road ditches are under different institutional and maintenance conditions. Road ditches along private roads are managed by private citizens. When road ditches are streams (*scoli*) they are a state property managed by the water board. However, most of the road ditches are under a hybrid regime. Commonly, indeed, they are half private –on the agricultural field side or the built lot side- and half state property –on the road side. Therefore they are jointly maintained by private citizens together with the municipality.

Effects of changes: flows, space and actors

Water perspective. In 2007 stormwater discharged from roads is much higher both in incidence and magnitude than in 1955. Detention of water in the micro-depressions of the carriageways hence disappears. Likewise, the storage capacity of the road ditches markedly decreases whilst discharge to the receiving drainage network and streams increases (D'Alpaos, 1991: 43). Moreover, in case of heavy rainfall, interruptions in the ditch road system sometimes entrap the drainage flow with the consequent occasional flood of adjacent fields and/or gardens. From a water quality perspective then, the pollutant load of the road run off is higher while the vegetative structures which perform purification are much lower. As a result, the total amount of pollution delivered downstream is higher.

Spatial perspective. Given that stormwater is rapidly discharged downstream, most of the ditches are dry during the year. Thus, there is no more water along roads. Moreover, since the hedge-rows along the roads have been eliminated, the visibility and comfort for car drivers is greater. However the higher depth of fields makes for the monotonous appearance of the landscape. Again the juxtaposition between built environment and agricultural matrix increases. There are no longer places in the shade along roads and wind blows freely.

Actor perspective. Roads are more and more the exclusive space of vehicles. They are less safe for walking and cycling. In the 00s, places to stop for rest in the shade, that were numerous in the 50s, became difficult to find (interview Montanari-Galbier). Apart from moving the grass, many activities like gathering firewood or fishing are no longer practiced. Therefore people have nearly stopped frequenting the roads all together.

6.2.4. Excavation site system

1955

Patterns. In 1955 excavation sites were just a few elongated N-S parallel patches concentrated in the middle left part of the frame (Figure 6.13., left). On the whole they occupied approximately six hectares that is less than 4% of the total framed landscape.

Drivers and structures. In 1955 the local brick industry was flourishing and the demand for clay was high. The kilns employed hundreds of workers and processes were only partially mechanized. The clay soil was dug with the shovels by numerous workers and loaded onto carts drawn by horses or donkeys to be transported in the kilns a few hundred meters far away (Dittongo, 1999: 119) (Figure 6.14., left). The average depth of the excavations varied from 1.5 up to 2.5 meters and was regulated also on the fluctuation of the water table.

Drainage flows. In the excavation sites drainage was hard. The pits accommodate stormwater which later slowly evaporates and/or infiltrates but only once the water table goes down.

Maintenance and institutional conditions. Excavation sites were private. Once the excavation was finished, farmers cultivated those former clay pits that were shallow and with a deep water table.

2007

Patterns. In 2007 the excavation site system appears as a checkerboard of rectangular patches of different dimensions concentrated in the central and lowest parts of the frame (Figure 6.13., right). The entire area occupied by the excavation sites is approximately twenty hectares, that is 13% of the framed landscape. In that area, pits had already all been fully excavated. A few still active excavation sites are located a few hundreds meters downstream.

Drivers and structures. In 2007 the local brick industry has started to suffer from the sharp drop off in the regional real estate market. Notwithstanding this, demand for clay remains quite high. The remaining kiln employs a limited number of operators in comparison with the quantity of bricks produced. The clay soil is dug with dredges, loaded onto trucks and rapidly transported by truck in proximity to the kiln. Agricultural fields rich in clay soil are excavated for a maximum depth of 6 meters (*excavating*) that is the limit established by legislation (L.R. 44/1982 and the following L.R. 26/2002) (Figure 6.14., right and Figure 6.15., 1). In many cases, the mechanized excavation technique employed allows for the formerly excavated pits to be dug deeper by a few meters (*excavating*) (Figure 6.15., 2).

Drainage flows. During the process of excavation, the water table and the first confined aquifers are intercepted causing upward pressure of water (interview Piva). The excavation site is drained using pumps that discharge water into *scoline* or *scoli* running in their proximity. From there water is quickly delivered downstream. It is worth noting that the pumping of water from an excavation site provokes the lowering of one/two meters of the water table in the surrounding area (Gajo, 2007: 94). After excavation the former pit is filled with rainwater and up-ward running groundwater. In this way the former pit ends up like a small lake. Few basins are connected with the surface water network to discharge possible excesses of water downstream. So few former clay pits are exploited for fishing, hunting or aquaculture. When used as such, they need a periodic circulation of water, that means a supply of fresh water from upstream or from the ground and the discharge of water downstream. In order to discharge the excess of water and/or stagnant water to the surface water networks, a few basins are equipped with pumps. From the field surveys it emerges that, though annual evaporation is high (about 1 meter), in many basins the water level remains stable during the year and this is because of the upward seepage.

"*Irrigation" flows*. Often in the basins used for hunting or fishing, the natural upward seepage is not enough to guarantee a sufficient circulation of water. Therefore water from adjacent streams is pumped in. In a hunting reserve located a few hundreds meters downstream the area selected, for example, during the autumn season, water from streams is let in and made to circulate into the basins in order to oxygenate the water and create better conditions for the proliferation of the fauna (direct communication from Vittorio, the guardian of a private hunting reserve, Ronco all'Adige). Moreover, the former clay pits used for aquaculture need water of a constant temperature as well as regular water circulation. For this purpose groundwater of deeper confined aquifers –having constant temperatures– is periodically pumped up (interview Purgato).

Maintenance and institutional conditions. Excavation sites and former clay pits are private domain. Supply and drainage or water related to them is not regulated by formal agreements with the waterboard. The wells themselves are in fact not registered.

Effects of changes: flows, space and actors

Water perspective. Discharge is particularly high during periods of excavation. However, in 2007 the majority of the basins were already excavated and unutilized. They deliver little stormwater downstream. In the basins used for aquaculture or fishing and/or hunting, instead, supply and discharge extensively increase in comparison with the 1950s when these sites were crops.

Spatial perspective. A good part of the agricultural matrix is transformed in a wet area of shallow rectangular lakes. They amass vegetative structures and biodiversity of the area. Moreover, they markedly augment the total extension of surface water in the landscape. However, from the field surveys it emerges that, apart from the fishing reserve where entrance is regulated, the remaining areas are almost inaccessible or even invisible.

Actor perspective. Due to mechanization and the crisis of the sector, people employed in the processes of excavation are only a few in comparison with the 50s. The number of people dealing with aquaculture and the hunting reserves is also limited. Notwithstanding, as it emerges from the accounts of the local population, until only a few years ago, the accessibility was higher and the basins were sites for many leisure activities (interview Purgato; interview Biondaro). In 2007 just the basins for game fishing are visited especially during weekends.

6.2.5. Stream system

1955

Patterns. In 1955 in the framed landscape N-S and W-E linear streams form a low density rectilinear network (Figure 6.16., left). On the whole open air streams were 3.5 kilometres long. Piped trances were just a few dozens of meters.

Drivers and structures. From age to age streams like *seriole* and *dugali* have been excavated respectively to irrigate and drain unproductive lands (Scola Gagliardi, 2009: 103). The *fosse* and *scoli* present in the 50s are indeed the result of this multi centenarian process of land arrangement and layouts. In 1955 the stream system made up of the streams Scolo Saccaro, Fossa Zerletta (that locals call *Scoletto*), Fossa Termini and Scolo Termini, again supported a pre-market economy agriculture as well as giving way to a series of field ditches (*cai* and *caeti*). Its structures are fully integrated in the agrarian chain. Commonly streams have wide cross section with slight gradients and, therefore, shallow beds keep a balanced water table in the adjacent fields (Figure 6.17., left). Trees are planted all along their longitudinal extension (Figure 6.18., 1). In the area, streams run W-E for a short extension before returning to the main N-S direction, going perpendicular to *cavini*, *cavedagne* and *caeti*. This way, these watercourses follow the N-S gradient of the catchment. Comparing a wider view of 1888 with that of 1955 (Figure 6.6.), it is noted how a trench of the Scolo Ariolo stream in the top right corner of the image exhibits a sinuous course and a different relation with the neighbouring fields. In fact, over that time span and also for a few years afterwards, a process of channelling had involved some of the main streams of the surrounding landscape (Figure 6.18., 3). The watercourse is progressively straightened (*filling up* and *excavating*), riparian wetlands and adjacent meadows are eliminated (*filling up*), the stream bed is excavated (*excavating*), the section is made trapezoidal (*filling up* and *excavating*), dykes are built where needed (*rising*), and in some cases, the cross section is partially covered with concrete plates (*sealing*)[147]. The main purpose behind channelling is to adapt streams to the needs of modern agriculture.

Drainage flows. Stormwater not retained in the field system, rather it is delivered through *cavini*, *cavedagne* and *caeti* into the streams. They receive also stormwater from adjacent fields, built lots and roads. All these waters pass through vegetative structures before falling into the streams. The stream Fossa Zerletta, as many other streams in the surrounding landscape, drains also the water from a spring a few hundreds meters upstream. Streams deliver water to watercourses of higher ranks downstream. Drainage is slightly impeded by the resistance presented by the extended banks.

[147] All the processes here mentioned are further described in the § 6.2.6..

Irrigation flows. As the map of 1888 shows, the area's streams were originally made to drain upstream fields and irrigate downstream rice paddies (Figure 6.6.). However, in the 1950s, the cultivation of rice throughout the landscape had already ended. Water from streams was periodically used by farmers to irrigate crops and/or vegetable gardens. As noted above, for this purpose, they made use of a system consisting of pumps, pipes and sprinklers.

Maintenance and institutional conditions. Fosse and *scoli* are for the most part of state domain. A few are private. Their correct functioning is crucial for the habitability of the area. Streams are prevalently managed by small water boards named Consorzi di Miglioramento Fondiario and constituted by groups of farmers whose properties are afferent to certain streams with collective drainage function[148]. As for the field ditches, all the streams have to be maintained in order to perform well (Oliva, 1948: 71). Moving herbs, reshaping the section, cleaning out the bed, pruning etc. are operations managed by the water board in agreement with the owners of the adjacent fields. Apart from the drainage of their lands, privates can also benefit from available firewood, timber, fish and the game related to them. In turn, farmers share the costs incurred by the water board.

2007

Patterns. In 2007, streams form a low density rectilinear network consist of N-S and W-E linear elements (Figure 6.16., left). Their total length in the framed landscape is 3.3 kilometres. About 0.5 kilometres of these are piped.

Drivers and structures. The agricultural intensification of the last decades goes along with a reduction of spatial and temporal dynamics and simplified gradients relating to the stream corridors. Moreover, in 2007, *fosse* and *scoli* have to guarantee a fixed and lower drainage depth (70-80 cm) to the cultivations. To this end the process of channelling has proceeded further (Figure 6.17., right). The cross section is narrowed (*filling up*) and deepened (*excavating*) (Figure 6.18., 1). Vegetation along the banks is erased. Oftentimes, built lots with their fences and/or buildings encroach the buffer zone by six meters as imposed by the water board along the streams (Comune di Ronco all'Adige, 2009: 40). In some cases, in correspondence of urbanized areas, streams are piped (*piping*) (Figure 6.18., 2). The piping is especially visible in the Scolo Saccaro crossing through the middle of the frame. Confronting the wider view of 2007 with that of 1955 (Figure 6.1.,), another process of change emerges in relation to the increase of urbanization. The Scolo Ariolo stream in the top right corner of the images, indeed, results diverted in a new N-S stream watercourse. The new course (built in 2006) bypasses the centre of Ronco all'Adige where, in the last decades, built lots have progressively reduced and hence piped the former watercourse[149]. As a result, the old watercourse became a stormwater drain for the central urbanized area of Ronco all'Adige.

[148] The streams crossing the case study area were managed from the Consorzio di Miglioramento Fondiario Ronco Tomba.

[149] In regard to this, the description from Dittongo (2002: 42) confirms these transformations: "The village's main road, where houses were positioned on only one side, changed its physiognomy when new houses started to be built on the other side of the road, where the ditch had been piped and covered."

Drainage flows. The stream system is arranged to guarantee a fixed drainage depth to the fields (*franco di bonifica*, 70-80 cm) with storms having return period up to 30 years (interview Piva). The water table and the overland flow from agricultural fields, roads and built lots are either directly drained by the streams or first drained by *scoline* (or underground drains), *capofossi* and road ditches, to later be delivered into water board streams. In the first instance, runoff from fields reaches the stream directly and rapidly since there are no vegetative structures obstructing its flow. The area's streams no longer drain springs since the springs have dried up. A perfect example of this can be found with the Fossa Zerletta stream (interview Purgato). The steep gradient channel and low resistance bed tend to speed up the discharge to higher ranking water board streams downstream.

Irrigation flows. The area's stream system is not arranged to perform irrigation. However, from the field survey of the surrounding landscape, it emerges that, during summer months, in the rare case that streams have sufficient water levels, a few farmers pump water from them into sprinklers or drip irrigation systems.

Maintenance and institutional conditions. Most *fosse* and *scoli* are of state domain, and only a few remain private. Both are managed by the water board. Small former water boards have merged. In this way the administrative domain of the water board is much more widespread as well as the number of streams to maintain. Streams have to be kept clean in order to perform a rapid discharge and avoid risks of flooding (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991l: 71). The felling of trees simplifies the maintenance operations. Several times a year (7-8) the water board mows the grass along the banks and, periodically (every 5-10 years), re-shapes the cross section and dredges the beds (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991e: 71). These operations are supported by the owners of crop fields and built lots that, according to the extension of the property and other parameters, pay a fee every year to the water board (R.D. 215/1933; R.D. 262/1942).

Effects of changes: flows, space and actors

Water perspective. Compared to 1955, in 2007 streams receive higher volumes of stormwater in shorter periods of time[150]. Similarly, the process of channelling increases and speeds up discharge of water downstream (Ercolini, 2006: 150; Siligardi, 2007: 48). However, in remaining consistent with the requirements of modern agriculture, channelling contributes also to lowering the water table. The rapid discharge results in a much lower average water level in the streams compared with the 1950s (interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro). The low average flow level is also related to the changes in the regional water cycle that affects the flow regime of springs and aquifers in the area. From a water quality perspective the load of contaminants also increases since stormwater that is rich with nutrients, fertilizers and weed killers from agricultural fields,

[150] As mentioned above, the studies from Bixio (1990) and D'Alpaos (1991: 40) conducted on other sections of the Veneto plain confirm these recent changes in the water flow dynamics.

and stormwater containing high quantities of oil, paint, lead, organic compounds etc. coming from roads and built lots is delivered into streams without any treatment at the source.

Spatial perspective. Lowering the average streams' water level, removing the vegetation along their longitudinal dimension and shrinking their cross section to leave more ground to cultivations, the landscaping role of the streams has been trivialized. All of these processes of change blur the perception of stream corridors in the landscape. Likewise the movements of people and animals along *fosse* and *scoli* are drastically reduced. This ecological and morphological simplification impoverishes the landscape. In many cases the erosion of the stream belt is so extended that operations of maintenance are difficult to accomplish (interview Piva).

Actor perspective. In 2007 stream banks are free from people. Bathing, doing laundry, fishing, the gathering of food and firewood are no longer practiced. The spatial configuration of *fosse* and *scoli*, often without parallel paths, wind and sunlight barriers, and with low water marks and contaminated waters discourages their use also for walking and/or as recreational meeting places[151] (interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Biondaro).

6.2.6. Irrigation and drainage water systems at the water board level

Patterns. In the 00s the surface water structures of the irrigation and drainage systems at the level of the Valli Grandi e Medio Veronese water board appear to be a very dense network made up of meshes of different fine grains, including three NW-SE and one W-E linear corridors of medium thickness (Figure 6.19.). At a closer look, the network exhibits a higher density in the northern and southern parts of the water board. Another zone of high density stretches from NW to SE adjacent to one of the main corridors. The system shows a certain degree of discontinuity in a few spots concentrated in the middle and in the upper parts of the area.

Drivers and structures. The multiform irrigation and drainage structures of the 00s are the result of a process of an extended transformation of long duration made of a number of operations from both the private and public domain (Morin, 1993: 154). Nonetheless, urbanization and agricultural intensification of the last decades have had, though with different intensities, strong effects on the asset of the entire water board. Most of the changes concerning the fine grained components of the landscape mosaic explored above in the small portion of Ronco all'Adige have been reiterated also on the other parts of the catchment area. Accordingly, all the irrigation

[151] Again the novel by Dittongo (2002: 14) set in the Ronco all'Adige of the 1950s, gives an account of the conditions and uses related to *caeti*, *fosse* and *scoli* at that time: "And yet it had to be there, thought Rina who was enjoying her early youth while playing in the ditch. The water was limpid and there were many fish. She would even try to catch them with her hands but unsuccessfully. More luck for her father who used the *nigossa* and, in the evenings, mum prepared a make-shift dinner from the fish he caught."

and drainage structures managed by the water board have been measured and adapted to the growing requirements for quicker and greater inflows and outflows. In particular, over the last decades the process of channelling, although (as the changes on the stream Scolo Ariolo have shown) it began several decades before, has proceeded further on involving almost the totality of the watercourses. Moreover, the longitudinal dimension of the stream is sometimes straightened. The cross section is made trapezoidal in order to give the embankments more stability. Along the banks vegetation is felled and, where needed, dykes are built or reinforced. In some case a layer of concrete is stretched over the banks, which decreases erosion and enables an increase in flow velocity. In some cases, longitudinal underground thresholds are built along the banks of the main rivers to increase the stability of the banks while reducing the percolation of groundwater from the river to surrounding areas (APAT, 2004: 28; Ercolini, 2006: 144; Siligardi, 2007: 49).

At the scale of the water board the resulting main surface water structures for drainage and irrigation can be distinguished. However, many of them have been arranged to perform mixed irrigation and drainage functions (Morin, 1987: 26).

Drainage structures and flows

The waterboard drainage system arises as a dendritic network (Figure 6.20.). Converging stream networks, indeed, stretch all over the catchment with the exception of relatively small sections in the upper and the lower parts where drainage density is high and networks are much more rectilinear. In the top end of the catchment area of gravel soil and deep water table, the drainage structures thin out. On the whole, the streams with drainage functions managed by the water board are more than three hundred, extending for more than 1,200 km (Consorzio Valli Grandi e Medio Veronese, 2004: 14).

Spring water, stormwater and irrigation surplus feeding the streams in the upper part are named *acque alte*. These waters are delivered from streams (*fosse* and *scoli*) into one of the three NW-SE river corridors, respectively called River Tregnon, River Menago and River Bussè. The divides between these three drainage systems are legible in the map (Figure 6.20.). River Tregnon, River Menago and River Bussè cross the lower part of the catchment running at a higher quota. Stormwater and irrigation surplus from this lower zone of the catchment –named *acque basse*- are delivered from rectilinear streams into the river corridor running W-E called Fossa Maestra. The River Tregnon, River Menago, River Bussè and Fossa Maestra all pour their waters into the River Tartaro-Canalbianco that eventually flows into the Adriatic Sea. The system had been greatly engineered and, after a long process, was finally completed in the 1970s[152] (Morin, 1993: 143).

[152] The separation between the *acque alte* and *acque basse* was originally proposed from the famous engineer Pietro Paleocapa in the first half of the XIX century to solve the problematic drainage of the lower part of the territory that was permanently flooded from the upper waters –*acque alte*- as well as the waters from the stream Castagnaro, a diversion of the Adige River. For a comprehensive description of the events relating to the hydrographical arrangement of the area see Morin, 1993: 135.

Irrigation structures and flows
The irrigation system at the water board level appears as a composition of slightly diverging elements that parallel the NW-SE river corridors; two dense dendritic diverging networks, one in the upper part the other in the bottom end, and a rectilinear network located in the lower part (Figure 6.23.). Two areas, the first in the middle left section, the second in the N-E section –where the framed landscape is located- are not crossed by any irrigation structure. The whole irrigation network running within the water board is about 1,000 km long and the pumping stations managed by the water board for supplying the irrigation water are thirteen (Consorzio Valli Grandi e Medio Veronese, 2004: 14).

Sources. The waters of the Adige River are the main source of the system. From April to September these waters are withdrawn –at the rate of 12 m3 per second- from the Canale Milani, a diversion of the hydroelectric system in the northern end of the catchment. The irrigation water flows by force of gravity downstream and is distributed through a series of irrigation streams into drainage streams in the upper part of the water board. In order to avoid losses related to infiltration, irrigation streams have been progressively rationalized, reducing their number and covering their cross section with slabs of concrete (Morin, 1987: 27).

The springs, which in the upper part of the catchment feed numerous *fosse* and *scoli* and the three corridors River Tregnon, River Menago and River Bussè, are another fundamental source of irrigation. On the whole springs supply about 3-4 m3 per second of irrigation water[153] (interview Piva).

The waters drained in the upper part –spring water, stormwater and the excess of irrigation water flowing into *fosse*, *scoli* and the rivers Tregnon, Menago and Bussè- and the waters of the River Tartaro-Canalbianco are an important resource for the irrigation of the lower part of the catchment. These waters are withdrawn through derivations and distributed to the dense rectilinear drainage network. An additional source for the lower area is provided again by the waters of the Adige River. A dozen or so siphons are set along its right bank. During the summer, river water is pumped up –about 1.5 m3 per second (interview Piva)- and distributed through the dendritic diverging network that stretches along the bottom end of the catchment[154].

Another fundamental irrigation source is groundwater. All throughout the catchment area, private wells with pumps extract water locally from the aquifers. According to Morin (1993: 162), these irrigation systems are particularly diffused in the northern parts of the water board, which are not reached by other irrigation structures.

Function. The water board controls the fluctuation of water in the streams using remote-controlled weirs. Most of the farmers pump waters from the watercourses of the water board or from aquifers into sprinkler irrigation systems (Morin, 1993: 164). Only a few farmers

[153] According to Morin (1993: 162) on the whole the water from springs flowing in the area is about 4-5 m3 per second.
[154] Further descriptions are available with Morin, 1993: 176.

concentrated in the northern sections use flood irrigation techniques: water from *fosse* and *scoli* flows by force of gravity into the private network that leaves water streaming into the fields. In the case of flat fields provided with underground drains, water from streams gets back to the *capofossi*, and from there it fills the drains that distribute water in the field and raise the levels of the water table.

6.2.7. Problems and challenges of the irrigation and drainage systems

From the analysis, what emerges is that, despite efforts of the last decades to engineer drainage and irrigation systems to cope with the modern requirements, these systems must consistently deal with a great number of problems. Such issues will certainly challenge the organisation of water flows and related structures and patterns in the near future.

Drainage

Water quantity. All the above changes in the irrigation and drainage system have increased both magnitude and speed of storm flow discharge. However, the minor drainage system is oftentimes unable to discharge the stormwater generated from agricultural fields, built lots and roads systems (interview Pezzetta). As a result of this, episodes of localized flooding related to high-intensity rainfalls are more and more frequent in the waterboard. In May 2002 and March 2004, for example, two heavy storms caused the flooding of some municipal roads and adjacent built lots located just below the central urbanized area of Ronco all'Adige (interview Zanoncelli). According to the waterboard, in the same periods, many localized floods happened in other parts of the catchment[155] (Figure 6.21.). In June 2010, for example, in the Valli Grandi, the agricultural area in the lower part of the waterboard, several days of consecutive rainfall on field plots with less and less storage capacity, provoked the inundation of crop fields with harmful consequences to the harvests and plantations (direct communication from the water board).

Likewise, the increased drainage weighs heavily on the water board streams that have to deliver greater amounts of water downstream. As a matter of fact, the streams in question were designed in different periods and tuned to the needs of very different landscapes. A survey of the condition of the stream network carried out by the water board, for example, shows that the system guarantees the fixed drainage depth required by modern agriculture (*franco di bonifica,* 70-80 cm) for storm events with Average Recurrence Intervals of just 5 and 10 years (Morin, 1993: 150). Storms with Average Recurrence Interval of 30 years might provoke the overtaking of the drainage depth in many areas –about 6,000 ha, that is 9% of the catchment-, the flood of extended pieces of landscape –about 10,000 ha, that is 15% of the catchment- and the spilling over of some rivers –about 18 kilometres of river banks are prone to overflowing[156] (Consorzio

[155] The map shows just the main areas flooded. Indeed, the areas flooded in Ronco all'Adige have not been noticed.

[156] The situation is even worst in the lower part of the catchment, where, according to Morin (1993: 151), under certain conditions, the river Fossa Maestra could not even drain stormwater with average Recurrence Interval of five

di Bonifica Valli Grandi e Medio Veronese, 1991c: 121). A recent estimation from the waterboard shows that with the same events (ARI 30 years) risks of flooding is low for about 800 ha, moderate for 9,600 ha and high for almost 4,000 ha (Figure 6.22.). From this survey it results that the lower part of the case study landscape in Ronco all'Adige is also under moderate risk of flooding.

Furthermore, the rapid discharge of water downstream together with the diminished inflow from the springs upstream have gradually lowered the overall level of water in the system[157]. In general this causes erosion of the stream beds and the instability of their embankments. The River Bussè, running a few hundred meters downstream the landscape observed, suffers greatly from this situation. In response to the low water flow, in 2006 the water board installed three remote-controlled weirs to retain part of the water flow in the watercourse (Comune di Ronco all'Adige, 2009: 40). However, weirs installed along the streams to avoid erosion and to retain irrigation water may generate controversial situations. During periods of irrigation, for example, localized heavy storms often generate large quantities of water requiring drainage (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991d: 66), which can sometimes provoke episodes of backwater and inundation of the landscapes upstream due to the excess of irrigation water already in the system; an occurrence that happens for example along the same River Bussè, at the confluence of the Conduttone, a stream that drains most of the territory of Ronco all'Adige[158] (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991c: 112; Comune di Ronco all'Adige, 2009: 40).

Another possible risk of flooding for the catchment area is related to the waters that might come from outside the area. The River Adige, for instance, is a mountain river that runs just a couple of kilometres upstream of the case study landscape. The last time inundations from the river, which caused severe damage to the municipality of Ronco all'Adige and numerous other parts of the Valli Grandi e Medio Veronese waterboard happened in 1882 (Sambugaro and Santi, 1996: 35). However, at present, the possibility that waters of this river spill over the dykes and inundate the floodplain is considered remote. According to the Autorità di Bacino del Fiume Adige water board, the existing dykes should guarantee the retention of flood events with Average Recurrence Intervals of up to 200 years (Comune di Ronco all'Adige, 2009: 24).

Water quality. The shift from a poor rural society to an affluent industrial one has had significant consequences on the quality of its waters. As illustrated above, sources and forms of contamination have literally increased while reducing the purification formerly performed by the landscape's vegetative structures. This has had serious consequences on both surface water and groundwater. For instance, evidence of atrazine –a herbicide widely used up until the mid 1980s- and chromium have been found in the aquifers not far from the case study area (interview Franchini; interview Zanini). In particular, the waste released in the high plains from

years. Recently, the water board has reinstalled some pumps in the lowest parts of the territory to react to this situation of uncertainty.

157 In this regard, during a field survey, an anonymous interviewee living in Ronco all'Adige has noted "Here there used to be water everywhere." ["*Qui una volta c'era acqua dappertutto*".]

158 The catchment of the Conduttone indeed can only undertake floods with ARI of up to 5 years (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991c: 112).

the numerous industrial activities located there, just below the centre of Verona, has had very strong effects on the quality of groundwater of the catchment downstream (Antonelli et al., 2002: 84). Furthermore, in various parts of the catchment, groundwater is also contaminated by natural sources (prevalently iron, manganese and arsenic) (interview Zanini). In Ronco all'Adige, for example, inhabitants complain of high concentrations of iron in the waters pumped up from aquifers that are 15-30 meters deep (interview Zanini; interview Montanari-Galbier; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo).

Moreover, the chemical analysis of the surface water of the case study area carried out in 2006 by the Department of Civil and Environmental Engineering of the University of Trento, report that the status of the streams is sufficient or poor due to the medium contamination caused by bacteria, nutrients and organics (Diamantini, 2007: 13; Bertola, 2007: 166). From the provincial reports on the status of the environment, then, it emerges that the watercourses of the catchment area are *averagely contaminated* considering the Extended Biotic Index while they are *contaminated and highly contaminated* considering also the percentage of other bacteria, nutrients and organics[159] (Provincia di Verona and ARPAV, 2006; Provincia di Verona and ARPAV, 2008: 184).

Recent project-planning directions. Over the last few years, the water board and the other institutions in charge of guaranteeing hydraulic safety have worked with more intensity on strategies reacting to these conditions of uncertainty. The planning policies, for example, set limiting conditions to urbanization in areas that are known to be at risk of flooding (Autorità di Bacino del Fiume Fissero Tartaro Canalbianco, 2002; PAT, 2009). In addition, as explained above, new urban developments that exceed certain dimensions have to detain the possible surplus of stormwater into nearby peak storage ponds (DGR 2627/2002 and its amendments).

At the same time, some projects of particular vulnerability are still presented in those areas[160]. Policies and projects are often unable to control the number of processes that, as shown above, continue to transform the landscape. Furthermore, policies and projects do not yet have a clear orientation for solving the problems at hand and, aside from the scarce promotion of retention strategies, most of the projects remain sectoral and based on the "discharge water as quick as possible" philosophy.

Irrigation

Up until quite recently, irrigation was mildly practiced throughout the area, with the exceptions of the central part of the catchment, where tobacco crops are spread, and some of the upper parts where rice paddies are traditionally farmed, which both require a regular supply of water. However, the agricultural intensification and the increased production standards of the last

[159] Dissolved oxygen, ammonia nitrogen, nitrates, BOD^5, COD, phosphorous and Escherichia Coli.

[160] Regarding the difficult drainage at the confluence of the stream Conduttone and the River Bussè, for example, the water board is looking for opportunities to create floodplains upstream in order to reduce the peak discharges downstream (interview Piva).

decades have extended the demand for irrigation water throughout the catchment (Morin, 1993: 161; Piva, 2006: 6).

Increasing inflows is a widely adopted strategy for coping with the new requirements. However, the monitoring system shows that, during the dry season, the quantity of water required is higher than the water in the system (Morin, 1993: 16; interview Piva).

The case of the observed landscape is emblematic. Until recently, the case study landscape of Ronco all'Adige used to have plenty of water. Groundwater was naturally coming up to feed streams and ditches. The rice paddies displayed in the map of 1888, which required large supplies of freshwater, are evidence of the higher availability of water in the area in the past. Moreover, up until the 1950s, in the landscape observed, surface water was the primary irrigation source. However, at present, farmers need greater quantities of irrigation water and, in summer, when they have to irrigate, the surface water system is often lacking water. Farmers are hence forced to pump up groundwater through individual wells, most of which are illegal. On top of that, this contributes to a further depletion of this valuable resource (interview Zanini).

Depletion of groundwater seriously threatens the case study area as well as the entire asset of the waterboard. Its lower level contributes to the drying up of many *fosse* and *scoli*[161] (Morin, 1993: 158). The waters of both aquifers and springs of the catchment, indeed, closely depend on the infiltration of both stormwater and the surplus of irrigation in the upper plain as well as the recharge operated in the high plains from the Adige through its hyporheic zone (Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991b: 7; Morin, 1993: 158). The same first level aquifers of Ronco all'Adige are probably directly dependent on the water of the river that infiltrates in the spring zone a few kilometres upstream (Gregnanin, 1975a: 31; Morin, 1993: 158).

On one side, over the last decades, the infiltration in the high plain has now been sensibly reduced due to the increasing coverage from urbanization and the spread of new irrigation techniques with lower irrigation surplus[162] (interview Piva). On the other side, infiltration from the Adige River has also been reduced. Increasing stabilization of the mountainsides, reforestation, hydroelectric dams and changes on the streams' cross section upstream have all contributed to reducing the total amount of sediment transport of the river which has increased erosion and diminished infiltration downstream (interview Piva). Moreover, the installation of diaphragms along some stretches of the river separating the river bed from the groundwater has also contributed to decreasing infiltration (interview Piva). Furthermore, as experts confirm (interview Angheben-Bozzolan-Iob-Zambiasi), a number of derivations diverting the waters from the Adige into long concrete channels for hydroelectric production or irrigation have also contributed to decreasing infiltration. A good example of this is the rectilinear SAVA canal whose cross section is nearly completely covered with concrete. According to the data of the of

[161] Groundwater might take a very long time to fully regenerate. This means that its uncontrolled exploitation might be sustainable only when an adequate and effective recharge is planned.
[162] The reduced infiltration of groundwater in the high plains of the region is further illustrated in Altissimo et al., 2003.

the Adige River water board (Autorità di Bacino del Fiume Adige, 2007: 45), this canal diverts even more than 50% of the waters of the river for hydroelectric purposes[163]. During the summer months, 70% of this water re-enters the river just after the end of the gravel zone with a recharge of groundwater a dozen of kilometres downstream, which is just above the case study landscape. 30% is then diverted to another canal –called the LEB- for irrigation of the grounds along the left side of the river and it no longer enters the river. Probably, the lowering of groundwater and drying up of streams recorded in the case study area are also related to this utilisation of the river water.

Recent project-planning directions. Once more the strategy adopted from the water board to cope with the need for irrigation water of the area, relies on the surface water of the river Adige. A pipe fourteen kilometres long has been designed to bring water from the Adige (approximately up to 6 m3/s) and distribute it to the drainage network of the N-E portion of the catchment not provided with a proper irrigation system (Figure 6.24.) (Piva, 2006). This project conceived in the 80s and named Collettore Zeviano, will probably solve the demand of water from the local agriculture but at the costs of the neighbours upstream and downstream. The new irrigation system, indeed, will probably worsen the open conflict between the multiple users depending on the waters of the Adige River. Along its course, indeed, the river supplies numerous irrigation systems. In addition, its waters feed the hydroelectric system which in summer already struggles for flushing water downstream with the tourism sector related to the mountain lakes. The waters of the river, then, supply also the drinking water systems distributed along its course from the bottom end of the catchment Valli Grandi e Medio Veronese down to the river delta. Moreover, a minimum flow regime is crucial for the correct functioning of the saltwater barriers built in the river delta to protect the deltaic agriculture from the intrusion of saltwater seepage and to assure the availability of freshwater to the local drinking water systems[164]. In light of this, the new irrigation system, which will further increase the total irrigation supply from the Adige, seems to not fully consider the precarious conditions of a river that, in some stretches during the summer months, risks drying up.

At different institutional levels there is an increasing awareness that to tackle the demand for water an integrated approach has to be promoted. Many experts advocate the development of strategies for a re-organisation of the regional water cycle (interview Angheben-Bozzolan-Iob-Zambiasi). Some recent projects look for storage opportunities as alternative to the logic of increasing quick inflow from a source. At this regard an example is the plan of the water board of the Adige River which aim is to guarantee a minimum river flow discharge in the delta during summer. The project proposes to retain part of the river flow in the upstream river floodplains during the year and to flush it downstream when needed (Autorità di Bacino del Fiume Adige, 2007). However, despite the promotion of water storage, using a lot of good fresh water to push back the incoming salt water might be seen as a waste of water.

[163] Over the 2000-2006 span of time, the recorded average capacity of the Adige directly above the Canale SAVA diversion is 197 m3/s, while the average capacity of the Canale SAVA is about 105 m3/s (Autorità di Bacino del Fiume Adige, 2007: 45).

[164] In order to get the barriers performing well, the minimum flow regime of the Adige downstream -which in that stretch has been estimated in 80m3/s- has to be guaranteed (Autorità di Bacino del Fiume Adige, 2007: 47; interview Piva; interview Angheben-Bozzolan-Iob-Zambiasi).

The preliminary studies promoted from the Veneto Region together with the water board of the River Adige and the water boards Consorzio di Bonifica Adige Garda, Consorzio di Bonifica Agro Veronese Tartaro Tione and Consorzio di Bonifica Valli Grandi e Medio Veronese to store the waters of the Adige River in the former pits spread over the plains are a better example. River water should be stored in the basins during the year and reused locally for irrigation during summer (CSP Engineering Consulting, 2007). At the level of the water board Consorzio di Bonifica Valli Grandi a strategy that recently entered the list of actions is the promotion of water saving irrigation techniques and the use of crops fitting with the specific conditions of the sites and the real availability of water (interview Piva).

6.3. Drinking and waste water systems[165]

Patterns. Patterns of drinking and waste water systems of the case study area appear quite different in 1955 and 2007. Systems of different nature are introduced (Figure 6.25.).

1955
The structures of the drinking and waste water systems of the 50s result in a sprawl of pair dots –not visible in the image-, approximately a pair for each tiny patch in the image (Figure 6.25., left). Each pair is made up of one device for drinking water provision and one device for waste water disposal.
Dots. Dots are of two types and organized in pairs. Pairs are made of one dot for each kind. Pairs follow the distribution of the patches of the built environment.
Built environment. Small sized spread patches polarize in small groups of rounded or elongated shapes.

2007
In 2007 the structures of the drinking and waste water systems appear as a composition of spread pairs of dots –not visible in the image- and a few rectilinear and wavy pipelines sometimes run along together (Figure 6.25., right).
Dots. Dots are still organized in pairs comprising one dot for each type. The number of pairs is higher. They always follow the distribution of the patches of the built environment.
Pipelines. Pipelines are of two types. One kind is more extended than the other and forms a wavy network. Looking back at the aerial picture of the 2007 (Figure 5.1., right), it becomes clear that pipelines follow the route of the roads crossing the area.

[165] The paragraph specifically analyses drinking and waste waters and related infrastructures focusing just on their relations with the residential built forms, the material which is more spread over the agricultural matrix. No further studies have concerned drinking and waste water flows and infrastructures in relation to industrial, zootechnical and commercial uses besides they might be important to have a comprehensive view.

Built environment. A greater number of patches appears. Their average dimension is higher. Patches polarize in rounded or elongated groups lined up along the pipelines. A few new medium and large sized patches stand freely and detached from the pipelines.

Conclusions
Both patterns (1955 and 2007) are the result of different conditions of living and producing in the built lots. Accordingly, drivers, structures and flows have to be disclosed considering the changes that regard the built lot system.

6.3.1. Built lot system

Drinking and waste water systems use distinct infrastructures although they are both related to the built lot system. Therefore their description proceeds separately[166].

Before moving on, a preliminary remark should be made. In the maps described below individual drinking and wastewater infrastructures (dots) are neither represented in their real location nor in their effective number. They have been indicated on the basis of the information gathered during interviews and field surveys, and are only intended to provide an idea of their magnitude and distribution over the case study area.

1955

Drinking water
Patterns. In 1955 the drinking water system appears to be made of distinct points of infrastructure that are spread throughout the frame (Figure 6.26., left).

Drivers and structures. Hygiene standards are modest and waters used for drinking and personal hygiene do not have to comply with particular requirements. At the same time, the resources at hand are often of a healthy standard. The use of herbicides and chemical fertilizers, indeed, is not yet widespread. Industries are very few in the landscape and cars are infrequent. Aquifers are numerous in the area and, according to the inhabitants interviewed, by perforating the soil, deep waters might naturally come up[167]. Therefore, in the middle 1950s, most of the built lots

[166] It is worth noting that, according to the data provided by the Acque Veronesi Scarl. company, in 2007, the number of people living in the framed landscape does not exceed 300. In 1955, although the number of households was lower, the family unit was much bigger. From the Pedrollo-Tobaldo-Pedrollo interview it results that in via Pozza, the road crossing E-W through the middle of the frame, the number of people living there in 1955 was almost twice as much as it was in 2007; although in 2007 there were just a few more buildings than in 1955.
[167] "Excavations where made 15 metres deep and water sprang up naturally due to its pressure alone." ["*Si facevano dei fori a 15 metri e l'acqua risaliva naturalmente per pressione*"] (interview anonymous inhabitant of Ronco all'Adige).

were already provided with wells 20-30 meters deep and hand-pumps located in close proximity to the buildings (interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier) (Figure 6.28.). However, until only a few years before, the private well was a prerogative of the *corti rurali* and the built lots of the *mezzadri*. Farm hands –*braccianti*- were once typically used to bring waters from collective wells located along roads (interview Pedrollo-Tobaldo-Pedrollo). According to the information gathered, in the 1950s some collective wells were permanently flowing with waters that came up naturally.

Flows. Water for cooking, cleaning and bathing used to be brought in from the outdoor private or collective wells by using buckets of water and/or water jugs. Washing used to be done close to the streams with permanent running water (e.g. Fossa Zerletta). Sometimes ditches and streams were even used for bathing[168] (interview Pedrollo-Tobaldo-Pedrollo; interview Purgato; interview Biondaro). Moreover, as illustrated above, the water of ditches and streams were also used for watering vegetable gardens and feeding livestock. The excess of water from non-stop wells also fed the surface water system (interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier).

Maintenance and institutional conditions. Collective wells were often maintained by the municipality while private wells were directly managed by private citizens (interview Montanari-Galbier). Regarding the management of ditches and streams, refer to the above mentioned descriptions.

Waste water

Patterns. In 1955 the waste water system was a spread of punctual infrastructure points (Figure 6.27., right).

Drivers and structures. The modest hygiene standards and regulations did not impose any specific technical solution. Instead, the reuse of manure in the agricultural processes was essential[169]. Built lots were commonly provided with an outdoor bathroom or outhouse, usually located at the corner of the lot: a hole fenced-in with bundles of reeds (Figure 6.29.).

Flows. Sewage deposited in the pit were regularly extracted, dried up and, together with that from the pigpens and the stable, reused as manure to fertilize soil (interview anonymous inhabitant of Ronco all'Adige). Undoubtedly, sewage came into contact with the higher water tables.

Maintenance and institutional conditions. The outdoor bathroom or outhouses were regularly maintained by the family. Sometimes the manure was sold –or simply given away- to landowners and *mezzadri* (interview Purgato).

[168] The spread of the practice of bathing into fosse and scoli in the 50s is confirmed in the novel from the local storyteller Dittongo (2002: 23).

[169] In this regard, a common expression states: "If you want to cut properly… you've got to learn how to spread the manure." ["*Se te vol ben taiare… impara a sluamare*"] (Coltro, 2006: 344).

2007

Drinking water

Patterns. In 2007 the drinking water system is a composition of numerous spread-out punctual infrastructures and a piped wavy network[170] (Figure 6.26., right). The new piped network crossing the area is about 3.5 kilometres long.

Drivers and structures. According to higher living and hygiene standards, cooking, cleaning, bathing, flushing toilets are indoor actions that are all rapidly supplied with water of good quality. Therefore, individual private wells are progressively connected with the new indoor appliances. In the 60s collective wells were no longer used and thus eventually removed (interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier). Later, in the 70s problems of groundwater pollution could be attributed to fertilizers, herbicides, industrial and domestic wastewater in many parts of the territory (interview Zanini; interview Franchini; interview Zanoncelli; interview Pedrollo-Tobaldo-Pedrollo). In 1976 the national law L. 319/76 (known as Legge Merli) gave a strong boost to the spread of centrally controlled drinking water systems. Therefore, between the late 1970s and the beginning of the 1980s a centralized drinking water service was introduced in the area and most of the built lots were then connected to it (Figure 6.28.). A few additional lots were connected at a later date. Others remained unconnected, either because the piped network runs at too far a distance or simply because it is economically inconvenient (interview Montanari-Galbier). The pipes of the centralized system run under the road surface connecting the point of extraction of groundwater with the final user (*piping*). The system of abstracting is made up of a group of wells with related pumps, a filter, two storage tanks and a water tower, all placed in the municipality of Bovolone, more than a dozen kilometres to the S.E. At the same time, the decentralized system of wells is extended also to the new built lots. Groundwater is used as a replacement for the water of the surface water network, which has led to its continued reduction and near depletion.

Flows. Before the introduction of the centralized system, water from wells is mechanically pumped up supplying both indoor and outdoor uses. Sometimes water is boiled to make it drinkable (interview Purgato). Once that the centralized system was introduced in the 1980s, water was pumped up from an aquifer 120-140 meters deep, to be controlled, filtered, stored and pumped to a water tower, and ultimately delivered to the final user through a piped system[171] (interview Zanini). However, many inhabitants, although connected to the centralized system,

[170] In 2007 most of the wells were no longer used for potable uses. However they are still in function and therefore they contribute to coping with the water demand at the built lot levels. It has been decided to represent them here in order to emphasise the separation of water flows concerning the built lot system.

[171] As mentioned above, according to the data provided from the Acque Veronesi Scarl. company, in the framed landscape inhabitants do not exceed 300. According to the AATO Veronese (2006: 53) the average daily consumption per person is 217 litres. The left side of the Figure 8.15 provides an appraisal of the distribution of drinking water consumption in the lot. Estimating that 10% of the population is not connected to the drinking water service, the total annual amount of drinking water consumed in the area is assumed to be about 21,400 m3.

drink mineral water bought at the supermarket. The water mechanically abstracted from underground aquifers at the lot level supplies water for watering, washing cars and other outdoor activities (interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier). In the case of the built lots not connected to the centralized system, locally extracted groundwater was used also for bathing, doing the laundry and sometimes even for potable uses.

Maintenance and institutional conditions. Private wells are directly managed by the private citizen who should report the features of the system to the region. Despite all of this, the wells in question are typically not registered. The infrastructures of the centralized system for drinking water were generally property of the municipality (interview Zanoncelli; interview Zanini). The drinking water service is administrated by the Autorità d'Ambito Ottimale Veronese (AATO Veronese), which charged the Acque Veronesi Scarl. With managing the system. Once a year, Acque Veronesi does the actual cleaning of the system (interview Zanini). The private citizen then pays a fee to Acque Veronesi for each cubic meter of drinking water consumed.

Waste water

Patterns. In 2007 the waste water system is made up of a number of spread out distinct points of infrastructure and a new piped line (Figure 6.27., right). The piped linear system crossing the area is about 1.4 kilometres long.

Drivers and structures. Already at the end of the 1950s, the lifestyle imposed the installation of indoor toilets (interview Pedrollo-Tobaldo-Pedrollo). Toilets, kitchens and washing machines were connected via pipe to a septic tank located outside of the homes[172]. The sludge collected in the tank was no longer reused in the nearby agricultural fields since modern agriculture prevalently made use of chemical fertilizers[173]. In 2007 the centralized waste water service that was introduced in the central urbanized area of Ronco all'Adige in the 80s, following the boost of the national law L. 319/76, was extended also to the settlement area in the centre of the frame (*piping*). The new pipe was connected through a pump to the sewer system that leads to a treatment plant located about three kilometres East from the analysed landscape. However, due to technical problems, the system is not yet in function and households are not yet connected.

Flows. Black water from indoor toilets and grey water from kitchen and washing machines is delivered to the septic tank. After primary treatment effluents are either discharged into the body of water running in proximity to the lot (interview Pedrollo-Tobaldo-Pedrollo) or dispersed into the soil probably coming in touch with the groundwater table (interview Montanari-Galbier; PAT relazione, 2009: 71). Once the piped line is in function, sewage from the connected households will flow by force of gravity to the pump (Figure 6.29.). There sewage will be pumped up to reach the treatment plant by force of gravity three kilometres away.

[172] In some cases sewage is collected in watertight tanks that are periodically emptied.
[173] Prescriptive constrains introducing a number of treatments to guarantee public health have also discouraged the reuse of wastewater.

Sewage will be primarily and secondarily processed and the effluents will be discharged into the Scolo Conduttone stream.

Maintenance and institutional conditions. Private septic tanks are directly managed by private citizens who are to report the features of the system to the municipality. Septic tanks have to be periodically emptied. The infrastructures of the centralized system for waste water are property of the municipality (interview Zanoncelli; interview Zanini). Once in function, the centralized waste water service will be administrated from the Autorità d'Ambito Ottimale Veronese (AATO Veronese) which has charged the Acque Veronesi Scarl. With managing the system. The private citizen will then pay a fee to Acque Veronesi for each m3 of waste water delivered to the centralized system.

Effects of changes: flows, space and actors

Water perspective. In 2007 sources of water and sink points for waste water get further away from the user in comparison with the 1950s (*centralization*). Groundwater remains the main source of drinking water (for both potable and no-potable uses) but a great part of it is withdrawn from deeper aquifers located far away and transported via pipe line with a high energy consumption to overcome the higher hydraulic head and distance. Likewise, in the near future when part of the built lots will be connected to the centralized system, wastewater will be transported far away via pipe line with a high consumption of energy and little possibility to reuse it locally. In addition, transportation via pipeline may involve the leakage of flows transported with risks of higher levels of consumption and/or contamination.

Supply and discharge also increases. Unlike before, groundwater is used in large amounts also for bathing, washing, flushing toilets and watering (see Figure 8.15, left). With the exception of watering gardens, all the flows that supply water to domestic activities, after use, are mixed and discharged together even though they are of different qualities. Today, moreover, the pollutant load is commonly higher due also to the widespread use of soaps.

Spatial perspective. Since water from lot ditches is not directly used anymore, people do not care for them and fill them up. Furthermore, bringing water, bathing and washing are no more outdoor activities that enliven the landscape.

Actor perspective. As a consequence of the changes, occasions for inhabitants to interact with each other and with the environment are constantly decreasing. In the 1950s, for example, people in queue at the collective wells used to use that time for conversation and exchange[174] (interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier). Moreover, higher levels of comfort tend to bring about lower levels of awareness and direct control of the inhabitants over the water in use. Although carefully analysed by a public administrator of drinking water, a good part of the water in use is no longer in the hands of the people.

[174] From the interviews it results that, during dry periods, when precipitations were not intense, people had to wait up to ten minutes to fill a bucketful of water (interview Pedrollo-Tobaldo-Pedrollo).

6.3.2. Drinking and waste water systems at the water board level

Drinking water system
Patterns. In 2007, the structures of the centralized drinking water system at the level of the water board form a wavy network that exhibits a homogeneous distribution in the upper part of the catchment, which is completely absent in the lower parts (Figure 6.30.). The network density suddenly increases in correspondence with the contrasts of the built environment – particularly visible in the central-right part- and decreases in dead end forms where the built environment thins out. At a closer view the system appears as a composition of three independent tree form structures, each referring to one or a maximum two nodes[175].

Drivers, structures and flows. The system results from a recent process of centralization of potable water. In the 1970s only the municipality of Zevio was provided with a centralized drinking water system and no more than 10% of the total population of the waterboard was connected. Until that time the subsoil of the low lands of Verona was indeed always plenty of water and it was relatively simple for people to have good quality water by making holes a few meters deep and setting up a pump (AATO Veronese, 2005a: 3). A public infrastructure to supply the activities in the built lots was not required. This condition has supported the spread of settlements over the plain. However, already in the 70s, the sanitary inspections revealed that groundwater was contaminated by industrial and domestic waste, agricultural pesticides and fertilizers (interview Franchini; interview Zanini). In the 80s the Veneto Region declares that the groundwater up to 18 m deep is not suitable as potable water (interview Zanini). The qualitative and quantitative depletion of groundwater of that period, together with higher standards of public health and new life styles have led to the current proliferation of centralized drinking water systems in the low plains.

In 2007 this centralized system at the water board level comprises three independent networks, each provided with a system of wells, pumps, filters, disinfection plants and storage tanks. Water is pumped up from aquifers at different depths and processed to remove contaminants (like iron and manganese), then oxidized and disinfected before being distributed (AATO Veronese, 2005a: 12). In the system located in the bottom part of the catchment –and not represented in the map-, water is pumped from the River Adige and fully processed before being distributed.

The network supplied from the well located in Bovolone, in the left side of the catchment, is the most extended and also reaches the case study landscape. The network in the upper-left side of the catchment is interconnected with the network of the municipality of San Giovanni Lupatoto, a few kilometres upstream (not visible in the map). The system in the middle-right part of the

[175] Although not represented in the Figure 6.30, it has to be noted that a fourth network is located in the bottom end of the catchment area corresponding with the municipalities of Badia Polesine, Castagnaro and Giacciano con Baruchella. This system is administrated by the Autorità d'Ambito Ottimale Polesine (AATO Polesine) and managed by the Polesine Acque S.p.A. that is under the administrative system of the AATO Polesine.

catchment extends also towards the locality of Porto di Legnago along the left side of the River Adige. According to the data provided from the AATO Veronese, the extension of the networks at present, excluding the network crossing the municipalities of Badia Polesine, Castagnaro and Giacciano con Baruchella in the bottom end of the catchment area, is more than 700 km[176]. Excluding also the system crossing the municipality of Legnago in the central east part of the catchment, the remaining two networks –labelled as *Macroarea 5 Medio Veronese*[177]- are more than 550 km long supplying about 30,000 inhabitants. The municipality of Palù, a few kilometres east of the case study area, is not provided with any centralized drinking water service. Inhabitants that are not connected extract groundwater on-site making use of independent wells.

Maintenance and institutional conditions. Private wells are directly managed by private citizens. The distribution system is commonly the property of the municipality (interview Zanoncelli; interview Zanini). Since very recently, according to the national law L. 36/1994, the three networks in the upper part of the catchment are administered by the Autorità d'Ambito Ottimale Veronese (AATO Veronese). The management has been devolved upon Acque Veronesi Scarl. A fourth system which crosses the bottom-end of the catchment –not visible in the Figure 6.30.- is administered by the Autorità d'Ambito Ottimale Polesine (AATO Polesine) and managed from the Polesine Acque S.p.A..

Waste water system

Patterns. In 2007 the structures of the centralized waste water system at the level of the water board appear to be an arrangement of micro and medium wavy networks which follow the urbanized strips of the built environment[178] (Figure 6.31.). Networks are all linked to one or more nodes that are commonly located just below the areas of urban concentrations. The systems are tree-like networks with sink-nodes at the end of the major branches. However, in the lower parts of waterboard, which lack urban patterns, there is no centralized sewage system, except for the case of a tiny networked system of pipes that has its own treatment plant.

Drivers, structures and flows. In 1976 the national law L. 319/76 imposed a regulation of wastewater discharge from industrial and dwelling lots. Consequently, most of the municipalities relying on the catchment provide service to construct centralized system to collect sewage –at least from the urbanized centres- and process it in one place –almost a sink point for each municipality- before delivering the effluents to the surface water system (*centralization*). Some municipalities get organized in a consortium with shared treatment plants

[176] The data used for the computation of the length of the networks are taken from metadata, courtesy of the AATO Veronese.

[177] The marco-areas have been introduced by the PRRA (Piano Regionale di Risanamento delle Acque, 1989). The *Macroarea 5 Medio Veronese* includes the municipalities of Angari, Bovolone, Casaleone, Cerea, Concamarise, Isola Rizza, Oppiano, Palù, Ronco all'Adige, Roverchiara, Salizzole, Sanguinetto, San Pietro di Morubio and Zevio.

[178] It should be noted that a few other wastewater networks -not represented in the Figure 6.31.- are located in the bottom end of the catchment area corresponding with the municipalities of Badia Polesine, Castagnaro and Giacciano con Baruchella. These systems are administered by the Autorità d'Ambito Ottimale Polesine (AATO Polesine) and managed by the Polesine Acque S.p.A. which is under the administrative system of the AATO Polesine.

and management systems[179]. The system observed in 2007 is a direct result of this planning policy. Each municipality is provided with at least one piped system for collection, a number of pumping systems to overcome the level differences, and a treatment plant to perform at least the primary treatment. Some municipalities are equipped with multiple semi decentralized systems, with conduits and purification plants. Commonly, sewage lines have a N-S direction since they take advantage of the slight soil gradient to perform discharge. In this way, water supplied from the drinking water service or the individual wells comes from upstream and, after use, is delivered and processed downstream.

According to the data provided by the AATO Veronese, in the *Macroarea 5 Medio Veronese* – that is the area obtained excluding the networks crossing the municipalities of Badia Polesine, Castagnaro, Giacciano con Baruchella in the bottom end of the catchment area –not visible in the Figure 6.31.-, the small system relying on Isola della Scala in the upper-left part of the water board, and the extended network which crosses the municipality of Legnago in the central east part of the catchment- the entire current extension of the networks is approximately 500 km, and it serves less than 60,000 inhabitants (AATO Veronese, 2006: 86)[180]. With the exclusion of the systems in the territories of Badia Polesine, Castagnaro and Giacciano con Barucchella, on the whole, the pumping systems are approximately 150. In the same area treatment plants performing both primary and secondary treatments are 17 while those performing just primary treatments (collective Imhoff tanks) are 7. Treatment plants have very different sizes, performing for just few hundreds inhabitants or equivalents of up to the several thousands[181]. Built lots that are not connected are commonly equipped with independent systems which can perform primary treatment and disperse effluents into the soil.

Maintenance and institutional conditions. Private wastewater treatment systems are directly managed by private citizens. The collective infrastructure of the centralized service is the property of the municipality (interview Zanoncelli; interview Zanini). Since recently, according to the national law L. 36/1994, most of the centralized sewage system is administrated by the Autorità d'Ambito Ottimale Veronese (AATO Veronese). The management has been devolved on the Acque Veronesi Scarl. The centralized systems crossing the bottom-end of the catchment –that is the municipality of Badia Polesine, Castagnaro and Giacciano con Baruchella- is administrated by the Autorità d'Ambito Ottimale Polesine (AATO Polesine) and managed by the Polesine Acque S.p.A..

[179] The municipalities in the central part of the catchment -Casaleone, Cerea, Concamarise, Legnago and Sanguinetto- rely on an extended piped network delivering sewage to a single treatment plant.
[180] The data used for computation of the networks length are taken from the metadata, courtesy of AATO Veronese.
[181] For instance, the treatment system of Legnago performs for 40,000 of equivalent inhabitants for the wide network in the central part.

6.3.3. Problems and challenges of the drinking and waste water systems

Today both drinking and waste water systems are affected by a number of problems which will challenge their arrangement throughout the territory in the near future. Some of these problems are common to the two systems. The centralized services for drinking and waste water, for example, are both struggling with high costs of construction, operation and maintenance in relation to the scattered distribution and low density of users (interview Franchini; interview Macchiella; interview Zanini; interview Venturini). This is a key problem that might open up new and promising strategies providing alternatives to centralization

Drinking water system

In Ronco all'Adige almost 80% of the population is connected to the centralized service for drinkable water. However, in the *Macroarea 5 Medio Veronese*, more than half of the population has to get water supply individually (AATO Veronese, 2006: 53). As often as not, the individual wells have no filter or treatment device and, as mentioned above, in various parts of the area, groundwater is affected by contamination. However, it should be noted that although 40% of the inhabitants have pipes of the drinking water system running just in front of their doorways, they remain disconnected from it (interview Zanoncelli; interview Zanini). This occurs mainly because of the high costs for such connections. In many cases the extension of the piped system is inconvenient unless the bills rise in cost. However, the present policy adopted by the service administrator is equal billing for all the users. This means that the higher costs for reaching dispersed users would fall also on people living in urban concentrations (interview Macchiella; interview Zanini). As a result, the strategy adopted is to extend the network to only medium and small centres (AATO Veronese, 2006: 115) and to those places where contamination of groundwater is higher (interview Zanini).

In the case study landscape, then, it occurs that the centralized system lacks in required pressure (interview Zanini). The issue, indeed, strongly persists in the N-E part of the catchment area, which is far away from the source –more than 10 kilometres- and averagely at the same altitude. In regard to this problem, the strategy for the coming years is to interconnect the existing networks. This means to shift from tree form structures to one big mesh structure (*centralization*) (AATO Veronese, 2006: 82). In such a way, it will be possible to meet the demand even in the case of problems in one or more withdrawal sites. Moreover, it will be possible to concentrate the extractions where the costs are lower (*centralization*). In fact, another line of work is to concentrate the sites of withdrawal to reduce their number and keep those that are more reliable and convenient since they entail lower hydraulic head and less consumption of energy (AATO Veronese, 2006: 85). Accordingly in this manner, the system will further up-scale (*upscaling*).

Another problem affecting the centralized drinking water system is the high rate of leakage due to the great length of the pipes and their dated status. In some municipalities with less then 1,000 inhabitants peaks of leakage are even higher than 50% (AATO Veronese, 2006). In the *Macroarea 5 Medio Veronese* –which comprises the territory of Ronco all'Adige- leakage is up to 40% (AATO Veronese, 2006: 53). Although it recharges water tables, this high quality water is mixed with the waters of lower quality discharged from agricultural fields and a number of other scattered activities. A valuable and scarce resource is thus wasted. The centralized systems in fact draw heavily on the aquifers challenging their carrying capacity. Over the last thirty years, the trend of groundwater sink is particularly high. In the extraction site of the *Macroarea 5 Medio Veronese* in Bovolone, groundwater has been lowered by 3-4 meters (interview Zanini). Moreover, the centralized service entails high energy costs. In this perspective, leakage also means wastage of the energy used to pump-up, treat and distribute the water.

Waste water system

In the *Macroarea 5 Medio Veronese* the population connected to the centralized system for sewage is about 70% (AATO Veronese, 2006: 86). In some municipalities of the same precinct the percentage decreases to 60% (AATO Veronese, 2006: 87). According to the national decree D. Lgs. 152/99, the policy adopted to react to this situation points to the extension of the service to small centres with more than 2,000 inhabitants (AATO Veronese, 2006: 117). Together, some municipalities (e.g. Ronco all'Adige) promote the use of watertight tanks to the users who are not connected[182] (interview Zanoncelli).

Moreover, in many cases, the existing centralized systems do not perform properly. Treatment plants which on average are of small dimensions have to deal with sewage from scattered industries and in some cases even cattle. A few perform just a primary treatment and therefore are not in accordance with the legislation. Moreover, effluents from small plants have little dilution and the level of contaminants risks outrunning the standards (interview Venturini). Furthermore, it risks provoking a distortion of the flora and fauna in receiving streams (interview Venturini). The strategy adopted is to concentrate the treatment plants in efficient consortium plants (*concentration*). This form of up-scaling will generate economies of scale and increase the dilution of residual contaminants in the effluents (*upscaling*) [183] (interview Macchiella).

In addition, it should be considered that about 70% of the existing piped network conveys both wastewaters and surface runoff (interview Zanini). Often, in the case of heavy rainfall, stormwater exceeds the capacity of the collection system. It provokes combined sewage overflows, which pollute the receiving streams. Moreover, the pipes of the sewer usually drain the water table or even the water running into the streams[184] (interview Zanini). Intrusion of stormwater, groundwater and freshwater forces treatment plants to process higher volumes with greater consumption of energy. Likewise, the numerous pumping stations needed in such a low gradient landscape to transport sewage from the user to the point of treatment weigh heavily on overall energy consumption (interview Zanini). However, despite all these malfunctions, the separation of surface runoff from wastewater is presently not deemed a priority and is

[182] New households have to present a signed contract with a specialized company which at regular intervals provides for the discharge of the tank (interview Zanoncelli).

[183] In 2007, for example, the treatment plant of Ronco all'Adige has been renewed and expanded to perform for double the size, from 3,500 equivalent inhabitants to 7,000 (interview Zanoncelli).

[184] From the interviews, it emerges that in the summer, in some places along the ridges (e.g. Oppeano), irrigation water raises the water table, which is directly drained from the sewage system (interview Zanini).

considered convenient merely in the cases of new urban developments (interview Macchiella; interview Zanini).

6.4. Conclusions

6.4.1. Back to spatial changes

Figure 6.32. and Figure 6.33. exhibit the results of all the above processes of change on the patterns of the green corridors and accessibility in the landscape observed.

Green corridors[185]

1955. In 1955 green corridors along *cai*, road ditches, *fosse* and *scoli* were interconnected to form a network with various high densities (Figure 6.32., left). Their width was generally limited and uniform. Corridors subdivided the matrix into green rooms of different dimensions sometimes twisting around the built lots. Green corridors, indeed, functioned also as barriers for protecting both built lots and cultivations (filter function). As noted above, hedgerows were all carefully cultivated as they provided food, water, firewood, timbers etc. (habitat and source function). Commonly paralleling roads, dirt roads and paths, conveyed movements across the landscape (conduit function). Providing shade, their spaces were often used as meeting places ("habitat" or "public space" function). (interview Purgato; interview Montanari-Galbier). The hedgerows would also retain stormwater and part of its contaminants (sink function).

2007. The vegetative corridors along *scoline*, *capofossi*, road ditches and *fosse* and *scoli* have been reduced to only a few remaining fragments. Sometimes they are simply short tree lines in a garden or, situated along the lot borders where they function as fences. Hedgerows, indeed, are neither fully integrated in modern agriculture nor in the family lifecycle. Only in the lower part of the frame do vegetative corridors of various widths form an actual network. This network is made up of abandoned vegetation which grows along the banks of the former clay pits. With such a scarce number of hedgerows, the landscape of the 00s lacks several of the ecosystem services that these elements used to perform in the 50s. Moreover, built lots appear as separated entities, or objects that abruptly juxtapose the surrounding matrix.

Accessibility

1955. In the 1950s the entire landscape was crossed by an extended and dense network of roads. The vast majority of inhabitants conducted activities in the local landscape and therefore people use to traverse and frequent it regularly. Private corridors –dirt roads, paths, passages etc.- were supported by a network of main roads that functioned as public spaces. Apart from them, other

[185] It is worth noting that the network of 1955 would be much more dense if the microcorridors of the mixed farming system were also represented.

public spaces were represented by the cemetery in the north east corner of the frame and, principally, the spaces of the church in the settlement of Ponzilovo, in the central-left part of the fame. Built in the mid 1950's, this public space was soon provided also with a primary school. Moreover, from the interviews, it emerges that, still in the 70s, in this part of the frame, there were even other services and meeting points, such as a bar and a small food store (interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier).

2007. In the 00s the network has become much coarser. Most of the inhabitants work outside the landscape observed. They always use the main road system to move in and out. Entire areas of the matrix have become inaccessible –or accessible only for agricultural vehicles. Some farmlands maintain a certain degree of permeability. However, dirt roads are not integrated into one whole network. Instead, they are isolated with a maximum of one or two access points. These temporary infrastructures are most exclusively used by agricultural vehicles only for a few days during the year. The lower part of the framed landscape preserves a high permeability density that is the road system legacy of former activities of land excavation. However, these private rectilinear networks commonly have just one access point. Moreover, apart from those in use for aqua farming, most have been abandoned and are no longer accessible. In general, the private domain is much more marked than in the 50s. Enclosures limit the access to built lots. Barriers block access to fields and former excavation sites. Stream-sides are eroded by crops. Thus streams are almost inaccessible. The stream banks are no longer the setting for complementary activities of the locals. The only public space at disposal is that of the main roads. In comparison with the 50s, most of these roads are asphalted and wider. In Ponzilovo, for example, the road section was enlarged towards the borders of the built lots. The cemetery has remained but the church in Ponzilovo and its open spaces is accessible only for a few days a year on occasion of particular devotions (interview Montanari-Galbier). The school and other small services are no longer there. As a result, thriving signs of life and activities have become more and more separate from the surrounding landscape.

Conclusions

The analysis clearly demonstrates how the technocratic approach in the management of water has recently advanced in this decentralized urban landscape to cope with the area's new requirements, by substituting local limited resources and the fine grained infrastructure of the landscape –ditches, riverine wetlands, low-lying fields etc- with highly performing in-flow/out-flow systems –pipes, concrete channels etc- along with external sources and sinks points. This process has also swept away a number of other landscape elements as well as the ecosystem services and spatial qualities related to them. Furthermore it has especially contributed to the impoverishment of the local landscape driven by recent economic and social changes.

The landscape fabric of the *piantata* gives way to mono-cultural fields that reduce the green structures to only a few borders of the properties and a few abandoned areas –like the former clay pits. Habitat fragmentation then inevitably increases. The variety of life forms and number of species gets poor and, excluding the area of former clay pits, most of the landscape is lacking an overall ecosystem value[186].

In the span of a few decades, aside from the environmental fallouts, the landscape has been losing its clear and strong image. The “sequential continuity in which each part flows from the next” –to use the words of Lynch (1960: 115)- which was once made by the ordered frame of ditches, streams and hedgerows gradually starts to fade away. In the open landscape of the 00s, the spatial elements are not clearly linked to the whole. The landscape form results weak and confused. Likewise inhabitants are more and more detached from their environment. Potential lines of movement throughout the landscape complex are reduced to a few asphalted roads. People do not directly use the open landscape anymore and they are hence often forced to take the car and drive a distance in order to go walking, biking or simply stay out in the fresh air for a few hours of the day.

6.4.2. A missed opportunity

The analysis of the changing landscape of a portion of the Veneto *Città Diffusa* shows that the technocratic paradigm has progressively built a very complex water cycle relying on sophisticated irrigation, drainage, drinking and waste water systems (Figure 6.34. and Figure 6.35.). It has made the local landscape much more reliant on external sources and sink points (*centralization* and *upscaling*). Moreover, water flows have been progressively separated (*separation*). Similarly, the infrastructures used to convey flows have been increasingly made to fit a specific and technical order. Moreover, they are separated from the existing landscape and its fine grained character (*separation*). Additionally, despite the relatively recent efforts made for the integration of drinking and waste water services, the compartmentalization at the physical and institutional levels remains strong.

All of these tendencies have been noted and reported also by Zaccariotto (2010) in his landscape case study regarding Ponte di Piave, of the Consorzio di Bonifica Sinistra Piave waterboard. This study testifies the comparable territorial conditions as well as the force exerted from the logic behind national and regional policies based on a technocratic philosophy. In particular, the process of centralization and up-scaling concerning the drinking water service appears to be already developed in the Consorzio di Bonifica Sinistra Piave water board, as it is probably fostered by an existing higher density of the networks. The system of irrigation at the level of the water board, then, exhibits there a greater variety in the top part of the catchment where a very dense irrigation network of small concrete canals, arranged in tree-form structures and extending from inlet points, has been engineered to react to the permeable soil conditions of the high plains (Zaccariotto, 2010).

[186] In regard to this, see the classification of the environmental capacity from Siligardi and Negri, 2007: 122.

The two case studies, Ronco all'Adige and Ponte di Piave with the related water boards are representative of a generalized situation and modus of organizing the water in such a decentralized urban landscape. Despite some differences, it appears clear that the conformation of this urban landscape has not been considered an opportunity for developing strategies and technical solutions that fit. The way drinking and waste water systems have been arranged is significant. The process of modernization of the last decades, indeed, has proceeded also with the advancement of sanitary systems originally conceived for spaces of the compact city. This has happened despite the fact that it implies high capital-intensive investments. From the interviews, for example, it emerges that an extension of networks for drinking and waste water is what weighs most on the total costs of these services (interview Zanini). As a matter of fact, in the logic of centralization, the more source and sink points are far away from the user, the higher the consumption of energy to provide the service and the higher the operational maintenance and construction costs. The project was developed as if the spatial diversity and the fine grained structure of this urban landscape were not even there[187]. Therefore, up until now, the opportunities for exploring possible synergies with the enormous capital assets deposited in the territory have been missed. And this also contributes to the cost of the environment's health and the quality of the landscape.

In this frame, the common desirable scenario for the interviewed operators is to provide all inhabitants with good service, while reducing costs and increasing profits. Few of them speak up for the promotion of decentralized solutions, especially in those situations where urban dispersion is stronger. Indeed, there are no clear strategies for these dispersed patterns. Collective flexible infrastructures might be practicable when carefully tested for their feasibility, considering also costs and benefits (interview Macchiella; interview Franchini). Furthermore, at different levels it is commonly recognized that a more concrete integrated management of water is needed, but this will also require enormous political and technical efforts[188].

6.4.3. Paradoxes of change[189]

The above analysis shows that centralization and separation of waters and infrastructures, imposed by the philosophy of coping with higher requirements by maximizing inflows and

[187] The mainstream position is to discourage the process of urban decentralization. However, urban decentralization is an undeniable fact. In this perspective, decentralized strategies for managing water are sometimes seen with mistrust also because they may further promote dispersion. At the level of the province, for example, a number of strategies have been introduced to limit the spread of small industrial platforms over the plains. Changing the urban pattern of the industrial settlements –that means denying a present decentralized configuration- is considered the ultimate solution even for improving the status of the water. Indeed, through a concentration of the settlements, inflows and outflows can be better controlled (interview Scamperle).

[188] In the present logic, for example, combining the drinking water network with the waste water network results extremely difficult since source and sink nodes do not match (interview Macchiella).

[189] This paragraph is based on Zaccariotto, G, Ranzato, M., Tjallingii, S., P., 2009. Water sensitive design tools for urban landscapes. In: Blue in Architecture 09. 1st International symposium focused on water, Venice: 24th-27th September 2009.

outflows, result in paradoxical situations concerning water-flows, spatial form and inhabitants of this decentralized urban landscape.

Water paradox

The water paradox relates to the processes of change in water use and water management. Paradoxically, in general, the solving of some water problems has also created other water problems. In 2007, the requirements for water resources with respect to water quantity, quality and security are stronger. At the same time, hazards such as the depletion of resources like groundwater and the risks of flooding, droughts and pollution have become higher.

Depletion of resources and risk of drought. Improved irrigation and drinking water supply networks have led to increased water use, as they draw more heavily on the available resources. The huge amount of water extraction has led to sinking groundwater tables as a sign of depletion of surface water and aquifer resource depletion. Increased water use also implies that fluctuations become more problematic than they used to be. In both areas, Ronco all’Adige and Ponte di Piave, the irrigation system is often unable to cope with the higher agricultural requirements. Water shortages frequently occurs in summer periods as the available resources of surface water and groundwater cannot meet the demand. Residential dwellings and industries also make use of groundwater extraction for non-potable uses like garden irrigation or car washing.

Risk of flooding increases. More efficient drainage with larger and straightened channels leads to higher peak discharges downstream and, as a result, more risks for downstream floods. New business and residential areas –as in the Ponte di Piave case- increase the paved surface without sufficient space for buffering the resulting storm water run-off peaks. In general, storage for peaks and storage for dry periods are missing at the level of households, farms and villages.

Pollution increases. Drinking water and waste water systems changed from decentralized to centralized. From individual shallow wells for water supply and on-site waste water disposals they became deep collective wells, bigger reservoirs and expanded piped networks on one hand, and waste water collection and transport to municipal treatment plants on the other. These plants only partly remove pollutants and thus improve the general situation, but they still pollute the surface water where they discharge their effluents. Heavy rainstorms sometime exceed the capacity of the treatment plants and, in such cases, there is an overflow of untreated wastewater. The increased use of fertilizers and pesticides further leads to increased diffused contamination that filtrates to surface waters and to groundwater.

Centralized systems do not solve all problems and they can also create other problems. Moreover, costs for construction and maintenance are quite high, especially in relation to the dispersed arrangements of settlements in the Veneto area. There are hence good reasons to also explore more decentralized options for storage and recycling.

Spatial paradox

The spatial paradox relates to the process of change in land and water use. Paradoxically, improving spatial conditions for production has also worsened spatial conditions, especially those related to the diversity of the *Città Diffusa* landscape.

Erosion of diversity. Drinking water and irrigation supplies require distributive water networks, whereas wastewater collection and drainage require contributive networks. All of those structures permeate the underlying agricultural matrix and eventually turn it into a porous form with patches and corridors. In the Veneto, this has generated different patterns in the higher plains with a gravel substrata that facilitates drainage and in the lower plains with dominating clay soils. The intermediate spring zone has artesian wells and thus, its own characteristic pattern. However, the analysis shows that the process of modernization in agriculture tends to level these characteristic differentiations. Fields are enlarged and leveled, ditches filled and trees removed. Densification of buildings and up-scaling of both fields and settlement plots bring about also a shift from a decentralized system towards a concentration and separation of the activities and related land uses. As a result, the mosaic changes from a fine grain to a coarse grain pattern. During the 1950s, the agricultural matrix of the fine grain layout was strongly supported by the surface water system. The new landscape often becomes inaccessible and less diverse for people, their livelihood and recreation. Reduced variety and fewer gradients also create reduced conditions for biodiversity. There are thus good reasons to further explore options for sustainable differentiation, using the ecological and the functional potentialities of this situation.

Actor paradox

The actor paradox relates to the changing patterns of peoples' activities in the *Città Diffusa*. Paradoxically, improving the conditions for living and producing and bringing wealth to the Veneto *Città Diffusa* sometimes threatens to reduce the quality of life in this landscape.

Up-scaling reduces self-responsibility. On its way from a local economy to a world market economy, the Veneto has embarked upon a path of specialization. The fashion and shoe industries, the manufacturing of fine mechanics and also various agricultural and food industries in the Veneto have survived by specialization. It is not the economy of scale of bulk industry, but the economy of niche markets for specialized products that best represents the economic strength of this particular region in the age of globalization. Nonetheless, the analysis demonstrates that also in the Veneto there is a tension between up-scaling and the opportunities for people to meet and interact. At the same time, development has gone along with environmental distortions such as the growth of traffic and transportation and the increasing pressure on water quality and resources. Therefore, the challenge for planning and design in the Veneto is to develop scenarios for mutual adjustment of the ecological, social and economic opportunities. Furthermore, expansion of mono-functional coarse grains in the area will eventually destroy the spatial diversity that is the core quality of the region. The further growth of resources will also jeopardize the sustainable future of the *Città Diffusa*. These issues hence require appropriate and adequate feed back mechanisms in the use of resources.

The case of water is a good illustration. In the process of centralization, water supply and wastewater disposal is taken out of the hands of the individual users. This can perhaps ultimately improve their situation. As a result, however, the cycle is no longer visible and does not really act as an incentive for water saving, reuse and recycling. Water is out of view and thus out of the hearts of inhabitants. The consuming actors are limited to turning the tap. The actors at the municipal treatment plant have to take the existing pollution for granted. Their task is purification not pollution prevention. Inhabitant equivalents of pollution and water quality standards are the leading criteria. Direct feed-back is no longer in the hands of the actors. The processes of centralization and separation result in the fading of awareness regarding the multifunctional roles that the water system was able to play, in bringing together a multiplicity of performances: water supply (drinking water and irrigation), hydraulic control (flood prevention), ecological performances (biodiversity and depuration), energy supply (hedges), social cohesion and the steering of landscape arrangements. There are therefore good reasons to further explore the options for multifunctional synergism in spatial planning and for feed-back mechanisms in environmental planning. The role of water may be a good starting point because water carries both vital environmental processes and important spatial patterns.

Chapter 7

Landscape and water strategies[190]

7.1. Introduction

The analysis of the changing landscape of the Veneto *Città Diffusa* and the discussion on the underlying paradoxes, leads to an exploration of integrated and sustainable planning and design options for this urban landscape. In this context, *integration* means the planning and design strategies that seek to work with the various water systems as a coherent whole, while also coordinating and integrating water management with activities in other fields. *Sustainability* means that, in addition to improving environmental and living conditions in the existing urban landscape, water management should ensure that the functional, recreational and nature conservation values of water be available to future generations (see Chapter 2).

The chapter is made up of three parts. The first briefly recalls the concept of resilience that should be at the basis of any integrated and sustainable design plan. The second part explains the principles which, according to the specific qualities of the Veneto *Città Diffusa*, may guide the process of designing with water in this territory. The third part focuses on the guiding model approach, where knowledge and innovating experiences from the region and other territories are organized in an open toolkit of conceptual models that can represent a reference for designers.

7.2. The shift towards integrated and sustainable design

Design that is focused on integration and sustainability implies a conceptual shift in the way waters are arranged in this landscape. The shift is illustrated by the *ecodevice model* (van Leeuwen, 1973; van Wirdum, 1982), already presented above (see Chapter 2) (see Figure 1.3.). In the ecosystem displayed on the left side of the image, the life-support conditions are regulated by input (supply from a source) and output (discharge to a sink) flow controls. The same ecosystem on the right side of the image, is more resilient as it makes use of its own capacity to resist (the concave side, not-in) and retain (the convex side, not-out) in regulating flows. Input and output, resistance and retention are the key regulating mechanisms of any urban landscape. Indeed, commonly, in an urban landscape, water scarcity is solved by

[190] A large part of this chapter is based on Zaccariotto, G, Ranzato, M., Tjallingii, S., P., 2009. Water sensitive design tools for urban landscapes. In: Blue in Architecture 09. 1st International symposium focused on water, Venice: 24th-27th September 2009.

increasing supply (input), and water surplus is solved by increasing discharge (output). This solves the problem inside the system but often at the cost of the neighbours upstream (e.g., depletion) or downstream (e.g. flooding and pollution). However, the same urban landscape can also rely more on its own resilience capacities (resistance and retention).

In this perspective, storage of water in the landscape might be seen both as a form of resistance (supply prevention) and retention (water is stored and purified to be reused) (Tjallingii, 1996:184). In agricultural practice, for instance, a rhythm of input (supply) and output (discharge) replies to periods of surplus and drought conditions respectively (Figure 7.1.). But what if the waters of heavy storms could be detained in the landscape? And what if the rainwater falling in the landscape during the year is retained? A comparison of the rhythm of precipitation (P line) with the evaporation (ET line) shows how, during the months between October and March, in the Veneto, there is a surplus of water that, when stored, may partially compensate the deficit of water between April and September (Figure 7.2.).

7.3. Guiding principles

A set of principles that can guide the design process emerges from the discussion of the paradoxes of water management, spatial development and the inhabitants' requirements. Principles also include the findings that emerged in many other planning situations and in many discussions about sustainable development (see Chapter 2). The basic principles for designing with water in the Veneto *Città Diffusa* are the following:

1. The design of water systems should focus first on storage and recycling. This implies a shift from a more traditional priority for input-output planning. The principle is a practical way to formulate the idea of closing the cycle. Storage is the basic answer to quantity issues, such as too much (e.g., risk of floods) and too little (e.g., risk of shortages). Recycling stands for the reduce – reuse – recycle priority sequence advocated by UNEP and UNESCO (see, for example, Schuetze and Tjallingii, 2008). Under this principle, water is detained and retained onsite, and reused or recycled.

2. The basic variety of ecological conditions in the local landscape should guide the planning process. This is a shift from a more traditional function-guided planning approach. The principle is also known as a part of the *layer approach* (see, for example, CEC, 1999). Underlying landscape structures (the soil and the subsoil, groundwater, surface water and the associated flora and fauna), infrastructure networks (such as water ways and road systems) and residential patterns (spaces for living, working and recreational activities) should all be considered (Adriaanse and Blauw, 2008).

3. Planning and design should seek for specialization and synergism of activities. This implies a shift from those approaches involving economy of scale and cost reduction, which brings forth more scaling-up and homogenization processes. The variety of landscape conditions of the

Veneto *Città Diffusa*, can actually support a variety of specialized productions that are oriented towards a niche market economy [191]. Such a principle plays an important role in the current discussions on territorial cohesion. Synergism means to find agreements in the form of win-win combinations. Retention and recycling, for instance, require space and therefore they have to be matched with the interests of users and owners of that space. This might open up opportunities for enhancing spaces of a more hybrid character where, for example, private domains can integrate collective functions and, in doing so, make them more publicly accessible.

4. Planning and design processes should start bottom-up. This is directly connected with the issue of *decentralization* of water and activities. The special character of the diversity of the *Città Diffusa* urban landscape in the Veneto and the need to create visible incentives for environmental feed-back processes justify this fourth principle. This does not mean that individual solutions are always better than collective systems, and these will be always better than centrally organized solutions. The design process seeks optimal solutions fitting the local landscape and the local actors. However, starting bottom-up means to first explore the decentralized perspectives, and only move up scale if there are very good reasons for it. Water should indeed be retained and processed onsite in proximity of its users. Moreover, as large flows are more difficult to contain than small ones, the latter can be handled by minimal –small scale- landscape design solutions, while the former may instead require substantial engineering treatment (Marsh 2005: 162). In any case, a continual coordination should be established between bottom-up and top-down actions. In reference to this Spirn (1984: 166) noted that the management of water requires a comprehensive effort, where operations concerning the metropolitan and regional scale and the cumulative effects of the individual actions are equally appreciated.

7.4. Guiding models

7.4.1. Learning from pilot projects

The ensemble of these four principles may guide the design process in its search for integrated solutions to fit the planning situation of the *Città Diffusa*. The best way to fill the gap between guiding principles and the real world is to set up pilot projects that are pioneering in local situations and to provide a practical basis and groundwork for the essential learning process. In the Veneto area, for example, there are interesting pilot projects that effectively demonstrate the feasibility of the aforementioned guiding principles. Some examples are the recent project of

[191] Specialization should be considered in line with the concept of diversity. The more activities are specialized, the more they differ from one another. For instance, different areas generally produce different wines that have different flavours. It makes sense for the Veneto *Città Diffusa* to invest in specialization because of the variety of its landscapes and spatial conditions. Recent efforts for enhancing value and differentiations in the food production of the region are a good example.

Cava Merotto in the high plain, between the Piave and Livenza rivers, and the Vallevecchia project in the lower plains, between the Livenza and Tagliamento rivers (Figure 7.3.).

In the Cava Merotto project, the Pedemontano Sinistra Piave water board and the IUAV University of Venice co-operated for its final implementation. The plan was to recover a former gravel stone quarry area. Water storage in the former quarries was the key concept to be carried out. The system manages flow processes in two basins set in different spatial and temporal combinations. From autumn to spring, one basin stores water from the nearby river Meschio to provide agriculture with water irrigation in the summer. Another basin acts as storage for excess waters from the rivers, buffering and thus preventing downstream floods. At the same time this water infiltrates and recharges groundwaters, thus increasing underground storage.

In the Vallevecchia project the regional agency for agriculture (Veneto Agricoltura), supported by Veneto Region and the Pianura Veneta Orientale water board rearranged a farm drainage system, situated in a reclaimed area along the Adriatic Sea, to retain rainwater surplus. The storage buffers and holds water from autumn to spring as to avoid downstream discharge. Within the system, water flows through a circuit of ditches to prevent upward saltwater seepage and to supply irrigation in dry periods.

Both projects show how, in starting from water management, interesting arrangements of the landscape can be spawned. Furthermore, they demonstrate how the rational organization of the water-flow patterns offers concrete opportunities for conceiving public spaces that can fit the dispersed territory. Both projects shape physical spaces and flows in the spirit of the guiding principles. In this context, the promising combinations, consisting of the *guiding models* themselves, were able to clearly emerge. Guiding models are just concrete models of the optimal organization of space and processes in well-defined categories of situations. Designers do not need to reinvent the wheel in every project. There is indeed a learning process that has generated promising combinations of spatial design with economic, social and ecological processes, financial planning and public and political support. It is worth noting that *guiding models* are tools for *plan making*, for the process of generating creative and innovative alternatives. To be realized these proposals have to pass a process of *plan testing*, including environmental assessment procedures. This process is essential to improving plans and turning them into realistic proposals. Plan making and plan testing need each other. In practice, spatial planning is often dominated by the standards, norms and criteria of plan testing, but without good plans all testing procedures are blind. This is why guiding models are so important; for they can improve the quality of the planning process itself.

7.4.2. A toolkit for designing with water

The findings from the analysis and from other experiences in other situations have been organized in a collection of more general guiding models, to become an open toolkit for designing with water in the low plain of the Veneto *Città Diffusa*. With this instrument, the designer may take the model that seems to fit the planning situation as a starting point of the design process (Tjallingii, 1996, 2011). Designing, models may be upgraded in a process of learning. Each model informs specific water-flow patterns that are recurrent in the landscape about the guiding principles. It generates a shift to water-flow patterns of integration and decentralization.

Two models are presented as an illustration of the toolkit of guiding models and the ways it concerns different levels. They take their own areas as systems where the shift from input and output to resistance and retention mechanisms is laid out. In this way, both models exhibit possible organizations of the typical spatial elements of the system to close the eco-cycle of water within their own area.

Before moving to the models, however, a preliminary remark should be made about the context. In the low lands of the Veneto, retention in surface water is the proper way to store water since the storage in the ground is limited because the high groundwater and soil conditions do not easily allow for infiltration. In addition, another principle of integrated water management has to be mentioned. It concerns re-using and recycling. Water should flow from clean to polluted; waters of different qualities should be separated at source and locally stored to be recycled or directly reused (see Box 2.2). The *water recycling diagram* illustrates how, in the low plain of the Veneto, the existing elements of the landscape can be recovered to perform specific recycling processes within the comprehensive water chain (Figure 7.4.). It tries to match different qualities of water with the diversity of the landscape.

Low scale: dwelling lot model

The first model represents the dwelling lot, a building block that, though with different orientations and dimensions, is repeated in thousands of cases all over the territory. The model shows how, conceptually, the storage of water can be reinstated at the low individual level of the lot.

A conventional dwelling lot system (Figure 7.5., left) rapidly removes rainwater falling onto the lot whilst taking in considerable amounts of groundwater and drinking water. After their use, it removes wastewater. In the spirit of the ecodevice model, the *resilient dwelling lot* (Figure 7.5., right), instead detains and cleans rainwater in a *peak storage* unit and, after a storm, retains it as much as possible in a *seasonal storage* unit. The system purifies its wastewater via a *purification system* and retains the effluents in a *seasonal storage* unit. Only when the system is full does it drain out the water surplus. A pond, a ditch, a water butt or a tank are examples of storage devices that combine both detention (*peak storage*) and retention (*seasonal storage*). A constructed wetland, a septic tank and a box for a trickling filter (like some membrane bio reactors) are examples of devices that can effectively purify wastewater. The system utilizes its own water (the water stored) for inner uses such as toilet flushing, cleaning, or watering a garden. The lot pumps up onsite groundwater just for potable purposes. The reuse and recycling of water reduces the external supply of groundwater, phases out the external supply of drinking water and cuts the discharge levels of storm water and wastewater.

A set of low scale guiding models regarding this and other previously analysed basic elements of the landscape –agricultural fields, housing industrial or commercial plots, roads, streams and former clay pits- is illustrated in the *Appendix A.*

Middle scale: circulation model

The second model regards mid-scale residential areas that are so very frequent throughout the territory of the low plain. The model exhibits how, conceptually, storage of water can be reinstated at the higher collective level of the neighbourhood[192].

A conventional mid-scale residential settlement of the low plain (Figure 7.6., left) regulates water flows with the same in-out mechanisms that were previously described. It rapidly pours out rainwater whilst taking in a considerable amount of groundwater and drinking water. After their use, the area discharges the wastewater. By contrast, the *resilient neighbourhood circulation model* (Figure 7.6., right), in addition or alternatively to preventive measures at the lot scale, detains and cleans rainwater in a *peak storage* unit, and, after the rainfall, retains it as much as feasibly possible in a *seasonal storage* unit. The area purifies its wastewater in a purification system and retains the effluents in a *seasonal storage* unit. It makes the water stored to flow through a *circulation system* that combines peak storage, seasonal storage and purification. Only when it is full does the system drain out the water surplus. A circuit of ditches, a pond, a lake, a stream section are examples of storage devices combining detention (*peak storage*) and retention (*seasonal storage*). A forested buffer strip and a constructed wetlands are examples of devices to purify wastewater. A circuit of ditches is also a good example of the circulation system. The system can utilize its own water (the water stored) for internal use like the watering of the gardens. The reuse and recycling of water reduce the external supply of groundwater and drinking water and the discharge of storm water. Moreover, through this process, the discharge of wastewater is eventually phased out.

The *circulation model* developed by Tjallingii (1996: 208) for lowland situations has been used as initial reference and has been upgraded through a process of learning. The number of problems that affect the centralized sewer system, the strong evaporation patterns and the availability of open spaces related to the hybrid character of the territory, have suggested the addition of a decentralized system to purify and therefore recycle wastewater as well.

7.5. Conclusions

The shift from removing to holding water makes the illustrated systems less dependent on inflow from surrounding areas and thus less vulnerable. The retention of rainwater and wastewater effluents in the system's own storage and the integration of the complete water

[192] The scenarios presented in next chapter (Chapter 8) will exhibit how the *circulation model* encompasses different levels and situations of the low plain of the Veneto *Città Diffusa*.

management system into one chain contribute to making up for periodic water needs. The rhythm of supply and discharge (in-flow and out-flow) is replaced by a rhythm of fluctuating water levels in water bodies of the area. The integrated water strategies therefore have direct effects on the landscape. The water cycle hence becomes more visible and recognised as a true carrying structure of the landscape, so water can ultimately go back to being under the control of local inhabitants.

The proposed models are solutions by principle, representing ideal organization of flows and space. As such, they are still greatly conceptual. Therefore, during the design process, they always have to be confronted with the specific qualities and limitations of the site. To test the developed models and demonstrate the validity of the design strategy, the investigation goes back to the case study of the analysis and elaborates concrete scenarios of integration and decentralization of water at different scales.

Chapter 8

Scenarios of integration and decentralization

8.1. Introduction

This part of the study articulates the main research hypothesis that in the decentralized urban landscape of the Veneto *Città Diffusa*, answers that design measures can give in response to increasing water-flow dysfunctions and the loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes –ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements.

Accordingly, the key questions are: Is the storage of water a key concept in realising the carrying capacity potentials of the decentralized fine grain elements of the local landscape to cope with excess, shortage and pollution of water? What if water is detained, stored, re-used or recycled in the local landscape? Is this an effective strategy for the *Città Diffusa* to close the eco-cycle of water and develop a tighter spatial arrangement? Does it provide any intriguing and effective options for the design of new public spaces and to move people back and closer to the local landscape?

The analysis of the case study area has indeed shown that the process of change based on the philosophy of maximizing inflows and outflows has triggered a number of water dysfunctions –water excesses, water pollution and water shortages- as well as the trivializing of the local landscape and impoverishment of the relation the inhabitants have with it. As mentioned previously, these tendencies are common to the entire low plains area of the Veneto *Città Diffusa*. It follows that more water conserving and flood and drought-tolerant landscape-options must be explored (Spirn, 1984: 152).

The guiding principles and models of integration and decentralization are tested in concrete *Città Diffusa* situations. The aim is to seek for win-win combinations of flows, space and actors. In this sense, the research explores also the practical questions related to working with guiding models. Different levels of water management decentralization are investigated. Devices of detention, retention, reuse and recycling –peak storage, purification system and seasonal storage- are differently organized in individual and collective options. To this end, two areas have been selected as testing grounds, both located in the case study area of the analysis: the small settlement area of Ponzilovo, and the Saccaro catchment basin, in which Ponzilovo is situated. (Figure 8.1.).

The chapter is composed of three parts. The first part concerns individual and collective storage strategies situated in the settlement area of Ponzilovo. To start with, the ecological conditions in the design area are illustrated. Later, the design steps concerning respectively the *household level* –individual- and the *neighbourhood level* –collective- are unfolded according to the stepwise approach named PROSA (see Chapter 3). The scenario at the *neighbourhood level* is further detailed because it is considered of particular interest in regard to the aims of the research and for the abundant availability of data. For the same reason, an alternative collective storage strategy is also sketched out. The second part focuses on the scale of the entire Saccaro catchment basin –*catchment level*. Likewise, the basic site conditions that were first needed for designing at this collective level are presented, to be followed by the corresponding design steps that are then explained. Finally, the third part compares and discusses the above mentioned design proposals.

8.2. The settlement area of Ponzilovo

The settlement area of Ponzilovo is the first area selected for testing the storage strategy.

Physical and functional description

The small housing area of Ponzilovo is a pattern that results from an incremental process of urbanization started in the late 1960s (Figure 8.1.). Detached houses, a few apartment buildings, shelters, a small workshop, and a church have been set up along two secondary road axes, one N-S, the other W-E. Two watercourses run along the W-E road. They are the Scolo Saccaro and the Fossa Termini, both managed by the water board. The urban expansion over the agricultural matrix produced a few remnant field fragments, mainly made up of crops and orchards.

Existing conditions

The site and its potential are examined in order to orient the design. This includes a study of the area's relief, land cover, soil and subsoil composition, groundwater, inflow and outflow structures and rhythms.

Relief. The terrain gently slopes NW-SE. The lots have different elevations and few were raised to be at least a few dozen centimetres higher than the surrounding agricultural fields. The maximum difference in level is 0.5 m (Figure 8.2.).

Land cover. The surface is 5.1 ha. Paved areas are about 1.5 ha, that is 30% of the area, while semi-paved areas are at 1.3 ha, that is 25% (Figure 8.2.). The remaining 2.3 ha of gardens, make up 45% of the total area.

Soil and subsoil composition. The topsoil is loamy-clayey resulting in mediocre drainage[193]. Permeability (K), is in fact estimated at 1,6 x 10^{-5} m/s (Gajo, 2007: 93). The subsoil is characterized by a succession of loamy-clayey/sandy/loamy-clayey/gravelly layers (Gajo, 2007: 89). The first three layers (loamy-clayey/sand/loamy-clayey) vary in depth from less than 1 meter to up to 4 meters. The gravelly layer begins at a depth of 3 meters and goes up to 10 meters, even extending for dozens of meters in depth and alternated by a series of clay layers. The top of a first consistent layer of clay is located at about 25-30 meters from the ground-line (see § 4.3.).

Groundwater. In absence of great abstraction, groundwater flows in a NW-SE (Figure 8.3.). The average phreatic level is at 1.5 m (Gajo, 2007: 93). The permeable-gravel layers among the clay layers of the subsoil accommodate the aquifers which are numerous in the area. The two first semi-confined aquifers are at 4 and 6 meters below ground level; respectively; a third is at 8 and up to 18 meters below ground-level. The fourth, the fifth, the sixth and seventh are confined and at depths of 27-30 meters, 30-60 meters, 60-100 meters and 100-105 meters respectively (Comune di Ronco all'Adige, 2009: 16; Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991b: 10; Gregnanin, 1975: 30; interview Purgato; interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier).

Inflow and outflow structures and rhythms. Understanding the local water cycle is of great importance in developing strategies for integrated water management.

A drinking water service supplies the near 135 inhabitants living in the residential housing lots (Figure 8.5.). Water is extracted a dozen or so kilometres away, from a deep confined aquifer and delivered to the area via a piped network. The average consumption is 217 litres per person a day with little variations from winter to summer[194] (AATO Veronese, 2006: 53). The whole settlement consumes 29 m3 of drinking water a day that is 10,700 m3 a year.

From mid-April to mid-September irrigation is used routinely to maintain gardens and vegetable gardens by withdrawing groundwater at the level of the single parcel. Groundwater is sometimes used for car washing, even though the high concentrations of iron discourages this use. Each parcel is provided with a well and an electric pump that extracts groundwater from depths of 16 to 30 meters, that is from the third and the fourth aquifer (Figure 8.3.). This practice is illegal, as most of the wells are not officially registered. Considering the optimal consumption of about 3.6 litres of water a day per square meter of garden, on the whole, the daily consumption of groundwater for garden irrigation amounts to 87 m3[195]. Accounting that

[193] A recent survey (January 2002) in Ponzilovo carried out by the brick factory Stabila registers a percentage of 75-90% of loamy-clayey soil under a layer of 0.8 m of vegetative terrain. The survey has analyzed three samples with a maximum depth of 5 m. In all the samples the depth of the loamy-clayey soil is at least 1.5 m.

[194] The data used refers to the area labelled as *Macroarea 5 Medio Veronese* in the Piano d'Ambito of the AATO Veronese plan.

[195] According to Leveson (1980: 43) watering a garden of 750 m2 (8000 square feet) requires 360 l a day (80 gallons a day) in a humid climate and 2250 l a day (500 gallons a day) in an arid climate. This means an amount of 3 l/d/m2. From the calculation of the irrigation demand illustrated in the *Appendix B* and based on the differentials between

gardens are commonly irrigated from mid-April to mid-September –about 22 weeks, that is 153 days-, the annual consumption of groundwater is about 13,300 m3. It is clear that the use of groundwater for non potable use is quite high, and thus comparable with the use for drinking water.
The area's average annual precipitation is 700 mm, while the average annual evaporation is 900 mm (Bixio et al., 2010: 195). Notwithstanding the high demand for water, rainwater is quickly removed from roofs, paved surfaces and gardens and discharged into road-ditches, field-ditches and streams (Figure 8.4.). Only a small group of buildings along the N-S road axis drains through a piped underground storm-drain system. All these waters are finally released into the Scolo Saccaro stream. Waters drained from the elongated catchment are discharged into the Conduttone stream, which pours into the River Bussè further downstream. From the River Bussè water flows into the Tartaro Canalbianco canal and, from there, eventually to the sea.

Waste water (grey and black) is primarily treated at the level of the lot through lot scale primary treatment devices (Figure 8.6.). Effluents are then released to the soil or to the surface water network. Recently (2007), a trunk of the centralized sewage network was introduced to bring the wastewaters of the settlement area to the treatment plant located only a few kilometres away. However, for technical reasons, the centralized system is not yet operating. The average wastewater discharge is estimated at 80% of the average drinking water consumption (α = 0,80), that is 174 litres per person a day. On the whole, it results in 23.4 m3 a day and 8,600 m3 a year.

Table 8.1. Ponzilovo housing area, main data

inhabitants	135
drinking water demand	23 m3/day
paved surface	1.5 ha
semi-paved surface	1.3 ha
gardens	2.3 ha
irrigation demand	13,300 m3/year

Threats
A number of circumstances jeopardizes the habitability of the settlement area.

Water flow perspective. The domestic use relies on great inflows of drinking water and groundwater while it contributes to depleting the aquifers. At the same time, the area drains out

precipitation and evapotranspiration and on the saturation of the soil required from the vegetation (Metcalf and Eddy, 2006: 1343), it results that, in the area, irrigation of gardens requires about 3.6 mm/d, that is 3.6 l/m2 a day with monthly variation that goes from 1.7 mm/d in September up to 4.8 mm/d in July.

great amounts of partially treated wastewater and relatively clean rainwater. Discharge of wastewater contributes to polluting both surface water and phreatic groundwaters, while discharge of stormwater causes stress over the drainage system downstream. According to the data provided from the waterboard, the lower part of the settlement is at risk of flooding in case of storm events with an Average Recurrence Interval of 30 years[196] (Figure 6.22.). In the future, the trend towards dryer conditions and, in general, changes in the precipitation and evaporation patterns will probably make both supply and discharge a bit stronger.

Spatial perspective. From a spatial perspective, then, notwithstanding the number of open spaces surrounding the area or embedded in its fabric, the settlements do not offer any shared or collective public spaces. The church and its green area are accessible for only a few days during the year. Likewise, there is no direct access to the area’s agricultural fields. The only places where inhabitants can meet are the roads and the interstices between roads and plots, which are today sometimes even used as parking sites. The practical consequence of this is the fencing of the lots, which gives the inhabitants the space for fresh air and safer recreation. However, it also reinforces a stronger juxtaposition between housing lots and the farmland.

Actors perspective. What is more, inhabitants have no direct control over water flows. They just turn on the tap and flush the toilet with no understanding of the results of their actions on the environment. In the town meetings, every so often, they speak out about the puddles along the roads and the high level of stormwater in the few remaining open ditches after heavy storms –a condition which creates some nuisance- or they complain about the high quantity of iron in the water they pump from the aquifers (interview Pedrollo-Tobaldo-Pedrollo).

It follows that the landscape fabric should be adapted to accommodate the possible excess of water that can later be differently reused or recycled locally. This diminishes the dependency of the area on external resources, making a lasting and enjoyable spatial arrangement while also promoting self-responsible behaviour among its inhabitants.

8.3. Household level

Starting bottom-up, principles of integration and decentralization first addresses the individual level of the single parcel lot. What if, in the Ponzilovo housing area, water is detained, retained, reused and/or recycled at the level of the single parcel? The 39 dwelling lots and the lot with a workshop composing the housing area are all separately considered for exploration. However, though the design has been extended to the entire settlement, the exploration details the case of a single parcel lot used as reference model for the others (Figure 8.8.).

[196] In this regard, see the problems of *too much* affecting the stream. Conduttone in the Chapter 6.

The lot selected is a typical dwelling lot of the 1970s (Figure 8.7.)[197]. The surface area covers about 650 m2. The building occupies the central part of the lot and is organized with a ground floor and first floor levels. A paved surface extends from the gate to the garage, the entrance of the ground floor and the staircase for access to the first floor. The remaining open space is covered with grass. Paved areas are 300 m2 and the garden is about 350 m2.

At present only two persons live in the lot. Drinking water use is 0.4 m3 daily (217 litres per person a day) and 150 m3 annually. The groundwater that, from mid April to mid September, is pumped up for irrigation through the onsite well, is about 190 m3 [198]. Waste water charged daily is 0.35 m3 (80% of the drinking water consumption), and annually measures at 128 m3. Wastewater, after sedimentation in a septic tank, is discharged to the ground. As noted above, a new wastewater pipe collector runs just in front of the lot, but it is not yet in function.

Table 8.2. Household, main data

inhabitants	2
drinking water demand	430 l/day
paved surface	300 m2
garden	350 m2
irrigation demand	190 m3

Programme

The main programmatic aim is to develop a storage strategy to close the eco-cycle of water at the individual level of the single parcel as a common answer to the spatial and water flow issues threatening the area.

Guiding principles

The practicable objective is to reduce exchanges of the lots with the surroundings (inflows and outflows) that is the supply of drinking water from upstream, the abstraction of groundwater onsite, and the discharge of rainwater and waste water downstream.

[197] The lot is not represented in the 1975 IGM map.
[198] This quantity has been computed on the data of precipitation and evaporation from Bixio et al., 2010 and the specific soil conditions of the area. From the calculations, what resulted was indeed the need for approximately 3.5 litres a day of irrigation water. However, the actual total quantity of irrigation water in use might be quite different.

Guiding model
Given the low permeability of the soil, and the high phreatic levels, water should be stored in surface water. The *dwelling lot guiding model* is the appropriate model for the dwelling lots, while the *industrial lot guiding model* is the appropriate model for the lot accommodating the workshop (see the *Appendix A*). Both models suggest a disconnection from the centralized drinking water system and the complete reclamation of wastewater onsite. However, for the existing fabric of Ponzilovo, it seems more reasonable to limit the programme to reducing the consumption of drinking water by recycling grey water and adopting other water saving measures (Figure 8.9.). As a matter of fact, it should be considered, that, in accordance with the national decree D.M. 185/03, pathogens should be preventively abated before reusing wastewater effluents for irrigation. It implies a number of changes in the pipe systems of the buildings that prove to be convenient only in the case of a complete building renovation. Therefore, in Ponzilovo, the recycling of grey waters in a *grey water reclamation system* to be positioned at the level of the single lot seems to be a feasible programmatic option. The effluents should be reused to cope with the demand for service water (e.g. cleaning water and flushing toilet). Black water, instead, should be delivered through a connection to the centralized pipe collector that will eventually rapidly be made to function.

Another feasible programmatic option is the reduction of groundwater extraction for the watering of gardens. This purpose can be matched with another. The lot, indeed, could be made more self reliant by buffering stormwater in a lot level *peak storage* unit. After a rainstorm, rainwater detained into the peak storage unit could be stored in a *seasonal storage* unit to be reused later for irrigation.

As a result, the lot’s exchanges with its surroundings (inflows and outflows) could be considerably reduced. A lesser amount of drinking water is let in and a lesser amount of waste water is let out. Groundwater is then used only when the water stored is not sufficient for irrigation.

Rhythm

In principle, inflow and outflow rhythms should be replaced by onsite systems of water detention, retention, re-use and recycling.

Peak storage. According to the regional council decree DGR 2627/2002 and its following amendments (DGR 1322/2006 and DGR 1841/2007), the lot should buffer heavy rainfall events with 50 years return time[199]. The extra storage capacity needed to retain the runoff caused by this heavy rainfall in the lot can then be calculated by utilising a spreadsheet that is generated and operated by the water board. Accordingly, as paved surfaces make up almost 45% of the lot,

[199] It is worth noting that the regional council decree DGR 2627/2002 imposes the onsite buffering of rainwater only to new urban expansions which are above certain extension. However, assigning this measure also to the existing building stock might significantly contribute to reducing flood risks.

the peak storage should hold at least 13 m3 of rain. The rainwater stored is released to the seasonal storage unit through an outlet that guarantees an emptying time of 24 hours after cessation of rainfall. According to the regional decree, excesses of water can be released by a pipe to the stream Saccaro downstream at the maximum rate of 0.65 l/s (10 l/s/ha).

Purification system. At present, grey waters, which typically come from bathing, laundry, dishwashing and food preparation are assumed as more than 50% of the total drinking water consumption. The adoption of a number of indoor water saving devices (like shower heads and low-flow faucet aerators) could diminish consumptions up to 30%. However, this would also decrease the amount of grey water available for recycling. Moreover, in order to minimize the changes on the pipe systems of the building, recycling should be restricted to waters from bathing and laundry, that is 46 litres per person a day (Figure 8.9.). The water saving strategy also entails the installation of water-saving toilets that should reduce flush volume up to 50%. In this way, the grey water treated should cover the needs for flushing toilets and the consumption of drinking water could be reduced to about half of what it is at present[200].

Seasonal storage. From mid-April to mid-September, when the irrigation of garden is needed, an average of 322 mm of rainwater falls in the area (data set: 1993-2008, Bixio et al., 2010: 195). This means that, in that period, rainwater intercepted by the paved surfaces of the lot amounts to 97 m3 (322 mm/m2 x 300 m2). In the same span of time, the garden requires about 190 m3 of irrigation water a year, that is an average of 1.2 m3 a day. In theory, the stormwater detained in peak storage, if retained, may cover approximately half of the irrigation demand. Therefore, a seasonal storage unit with a capacity of 5 m3 where retaining buffered rainwater may guarantee the irrigation supply for at least 3-4 consecutive no-rain days. In this way, consumption of groundwater is sensibly reduced.

Orientation

The general principle is that water should flow from clean to polluted. This means that different qualities of water should not be mixed; rather they should be separated at their source and treated differently accordingly to their water-type before being reclaimed (see Figure 7.4.).

At present, relatively clean rainwater from the lot is directly discharged into the Saccaro stream, which is a stream that already conveys waters of different qualities. As a matter of fact, in the area, wastewater from households and other activities, is often infiltrated into the soil after

[200] Unfortunately no official data has been provided by the agency in charge of the management of drinking and waste water in the territory analysed. For this reason the layout of consumption has been developed comparing different information at the national level. Another important reference have been the strategies designed by UNEP and UNESCO (see Schuetze and Tjallingii, 2008).The model should be confronted with more reliable data. In particular, it is worth noting that, in the scheme the consumption of water for cleaning is associated with other uses comprising also the extra leakage, that in the *Macroarea 5 Medio Veronese* is up to 40% (AATO Veronese, 2006: 53). In a water saving perspective, leakage should be reduced to a maximum of 20%.

primary treatment. This way, lower-quality waters reach the surface water network and, therefore, the Saccaro stream.

Within this particular storage strategy, rainwater from roofs and runoff from paved surfaces, pass through a small filtering system before being retained in the seasonal storage. Grey water is then separated from black waters and processed locally by a chain of treatment facilities. Black water is delivered to the new centralized piped collector and, only after the primary and secondary treatments are performed by the centralized treatment plant, it is discharged to the surface water network

Situation

In principle, the peak storage should be close to the point of peak generation and accommodated at the lower and less vulnerable parts. The seasonal storage should be located in proximity to the peak storage from which water should slowly flow in.

Despite these principles, the rational positioning of the storage devices has also to consider the specific conditions of the parcel. The ratio between garden and covered areas is crucial. The more the garden is extended, the wider the seasonal storage should be. The less paved surfaces are extended, the less water should be accumulated in the seasonal storage. A finer analysis of the lots reveals how not all the lots have enough open space to accommodate the storage units. Moreover, there are very different sizes and ratios between garden spaces and covered areas, and thus not all the parcels can reach high levels of autonomy. Nonetheless and at any rate, considerable amounts of water can be saved by retention, reuse and recycling.

The lot selected has enough space to accommodate both a peak storage and an open air seasonal storage (Figure 8.11.).

Peak storage. The back of the lot is the rational position for the peak storage unit. Here a portion of the garden is excavated to form a rainwater garden, a small depression 0.5 m deep which covers 8% of the lot. Stormwater can fluctuate up to 0.3 m. Excesses of water are discharged via pipes into the Saccaro stream that runs along the front side of the lot.

Seasonal storage. The seasonal storage unit is also located in the garden and in proximity to the peak storage unit. It is an open air concrete tank covering less than 2% of the lot and 1 m deep, where water can fluctuate up to 0.5 m. Stormwater buffered in the peak storage unit slowly flows in by force of gravity.

Purification system. The onsite treatment technology for the treatment of grey waters is located inside the building, and possibly in the vicinity of the toilet.

Appliances

Apart from the rainwater garden, a retention tank is required as well as a pipe connection between peak and seasonal storages, and between the building and the waste water collector. Moreover, a pump is employed for using the waters stored into the retention tank (Figure 8.11.). The selected technical device options for recycling grey waters are trickling filters, activated sludge facilities and membrane bio-reactors (Schuetze and Tjallingii, 2008: 137). The system comprises a storage tank where treated grey waters are retained to be reused later.

Conclusions

Consumption of drinking water and groundwater as well as discharge of waste-water and stormwater are sensibly reduced. From a spatial perspective, the design exploration demonstrates that most of the gardens of the households of the Città Diffusa have enough spaceto accommodate the devices needed to make the decentralized strategy concrete. Small, individual micro spatial operations repeated over the territory can give form to vibrant and intriguing spatial arrangements (Figure 8.12.). On the other side, storage devices are under the supervision and direct control of the inhabitants.

However, it should be noted that at the lot level, as long as the space available decreases, storage devices tend to augment their technical character and to diminish their landscaping value. For example, a rainwater tank located under the ground or in the headroom, or a technical grey water reclamation device located in the basement, while representing reliable options, they have no direct spatial implications on the landscape. Moreover, the storage strategy at the household level does not provide any answer or solutions to the claims for shared public spaces at the settlement level.

The individual option seems to give a moderate contribution to the spatial arrangement of the *Città Diffusa* while it has interesting implications for flows and actors. Moreover, often, in the existing built environment, not all of the results from the guiding models can be easily concretised, as is the case with the reclamation of black water for the lot selected. In general, the individual levels seem interesting especially for isolated dwellings or industrial lots. For these settlements in fact, collective options are often difficult and costly to arrange. Besides, these solitary settlements commonly have greater open spaces in which to accommodate the storage devices.

Guiding model

As a result of the design process, a different version of the dwelling guiding model emerges (Figure 8.10.). This new model can be a useful reference for the existing hundreds of thousands of detached houses of the Veneto low plains. It comprises grey water treatment, peak storage and seasonal storage.

8.4. Neighbourhood level

What if the Ponzilovo area waters could be detained, retained, reused and recycled at the level of the entire housing area?

The purpose is to unfold a collective strategy that enables the settlement area of Ponzilovo to reach higher levels of hydraulic safety. The area should hence be able to cope with the increasing intensity of storm events and drought seasons, reduce exploitation of groundwater and make visible the water cycle. Once upgraded, the settlement of Ponzilovo might be a reference model for closing the eco-cycle of water in the Veneto *Città Diffusa* at the neighbourhood level[201].

General programme

The first programmatic aim relates to storm runoff and is based on the assumption that the more stormwater is delayed, the more floods are reduced (Spirn 1984: 134). As for the single dwelling lot, according to the regional council decree DGR 2627/2002 and its following amendments (DGR 1322/2006 and DGR 1841/2007), the area's discharge of stormwater downstream should be reduced through a buffering heavy rainfall events with 50 years return time. The second aim is to arrest the discharge of polluted water downstream though the complete recycling of wastewater onsite. The third aim is to reduce external supplies of drinking water and groundwater by retaining enough water to make up for the summer deficit of garden irrigation as is advised by the national decrees D.M. 185/03 and D.Lgs 152/2006 [202]. The ultimate aim is to operate an increased visibility and awareness of water as well as public access to it. The development of a local community-based water system can put the people of Ponzilovo back into a position to take care of the site and to enjoy its inherent values.

[201] A reference project is the Fig Tree Place (Newcastle, New South Wales, Australia) where the objectives of the development were to retain stormwater onsite and reduce the demand on potable water supplies (Mouritz et al., 2006: 118).

[202] Irrigation of cultivations for the production of food for humans and animals is among the possible re-uses of water, as advised by the national legislative decree D.M. 185/03.

Circulation model
As for the housing level scenario, the high groundwater and the low permeability of the soil do not easily allow for infiltration. Retention in surface water seems to therefore be the suitable way to store water. The *circulation model* is appropriate for further investigation (Figure 7.6.). However, the model has to be inflected to the conditions of the site in order to integrate specific restrictions and opportunities. According to the *circulation model*, in the settlement area heavy rainfalls should be buffered into the bodies of water of the local landscape and adapted to perform as *peak storage* systems; waste water from households should be locally purified in a collective *purification system*; buffered stormwater should be at first purified and later released into an onsite *seasonal storage* system where it can be retained for as long as possible; effluents from the purification system should also be retained as much as possible in the *seasonal storage* unit to be reused later. The waters stored in seasonal storage should be oxygenated through circulation processes in order to maintain their quality.

A step-wise strategy
The water sensitive devices –peak storage, purification system and seasonal storage- might be differently combined to form complementary decentralized water-flow-spatial patterns (Table 8.3.). The combinations might be seen as different possible stages of a common strategy for closing the eco-cycle of water at the collective level of the settlement.

Table 8.3. Ponzilovo housing area, collective level alternatives

collective level alternatives[203]			
peak storage + seasonal storage	peak storage + purification system	purification + seasonal storage	peak storage + purification system + seasonal storage

The exploration focuses on the most comprehensive and challenging alternative including peak storage, purification system and seasonal storage. In addition, the opportunity to combine peak storage with an infiltration system is briefly discussed.

In the explanation, peak storage, the purification system and seasonal storage are each examined, but it should first be known that these water sensitive devices play multifunctional roles and are therefore integrated in their design and function. For each storage device, programme, rhythm,

[203] It is worth noting that the purification of grey water through a collective grey water treatment system is not considered a feasible alternative. The collective treatment of grey water could indeed imply a number of interventions at the house level to separate grey water from black water. This means that the costs to arrange a collective grey water system should be augmented with the costs for the devices at the level of the single parcel. Therefore, the separated treatment and reuse of grey water seems to be profitable when both treatment and reuse occur at the level of the single parcel.

orientation, situation and costs are presented. The cost analysis is further displayed in the *Appendix C*. It is worth noting that this analysis is not fully comprehensive, for instance, maintenance costs and benefits are not considered. The analysis intends rather to provide initial insight, which can be useful as the starting points for later discussion.

8.4.1. Peak storage

Programme

Run off should be detained locally. Maintaining pre-development peak discharge for the fifty-year Average Recurrence Interval (ARI) event is, at this point, the main design objective to be address together with the other objectives of water reuse and recycling and, in general, the purpose of enhancing spatial arrangement and public spaces.

The permanence of a good part of the former agricultural drainage system and the proximity with small agricultural fields suggest the selection of two reference design models: the agricultural field guiding model and the forested buffer strip guiding model[204].

Rhythm

The peak storage unit buffers stormwater periodically. The maximum precipitation series with a recurrence of 50 years has to be related to the coverage of the entire settlement area. Once filled, the stormwater detention system should discharge stormwater either to the seasonal storage or downstream. In the last option, water flows can be released with a maximum discharge of 10 l/s/ha, that is the predevelopment drainage capacity of the area –corresponding to the average drainage capacity of the agrarian surface water network. There are different methods for computing the dimensions of peak storage. The *rational method* is considered appropriate and reliable for this level of exploration.

Move 1. First the Intensity Duration Frequency curve (IDF) of the area is calculated by making use of the records of the monitoring station of Roverchiara, located a few kilometres downstream (Bixio et al., 2010: 108).

Move 2. Secondly, the average runoff coefficient is computed considering the extension of paved surfaces (roofs, roads, parking lots), semi-paved surfaces (hard outdoor places) and gardens (lawns and vegetable gardens) (Table 8.4.). The “effective area” resulting from the calculations is 25,900 m2.

[204] More information about these two models in the *Appendix A*.

Table 8.4. Ponzilovo housing area, land cover

	paved surfaces	*semi-paved surfaces*	*gardens*	*effective area*
area	14,700 m2	13,300 m2	23,400 m2	25,900 m2
runoff coefficient[205]	0.9	0.5	0.2	-

Move 3. Thirdly, the peak rainfall curve is singled out interpolating the rainfall series with the land cover of the housing area. A spreadsheet in use from the water board is employed (see the spreadsheets in the *Appendix B*). The resulting curve shows a critical rainfall depth of 59.6 mm at 55 min return time 50 years. The corresponding peak storage capacity is 1314 m3, which is the maximum amount of water that might occur in any one rainstorm over a fifty-year period (Table 8.5.). The same computation is developed for the Average Recurrence Interval of 5 years. In this second case the curve shows a critical rainfall depth 40,74 mm at 55 min return time 5 years and the corresponding peak storage capacity is 830 m3 (see the spreadsheets in the *Appendix B*).

Table 8.5. Ponzilovo housing area, peak storage volumes required

	average annual maximum precipitation	*duration precipitation*	*peak storage*
return period 5 years	40.74 mm	55 min	830 m3
return period 50 years	59.58 mm	55 min	1,314 m3

Move 4. Fourth, another rhythm is considered. Over a certain period of time, indeed, the peak storage has to be emptied thus it is ready for the following storms. According to the rainfall patterns an average of 24 hours is regarded as a reasonable emptying time for a temporary storage situation[206].

Orientation and situation

The upgraded local drainage system makes use of the subtle changes in topography and soil and the other existing landscape elements. Therefore, the surface water network crossing the housing area is adapted by adding more room for water collection –like ponds or small depressions- to be accommodated in portions of private gardens and agricultural fields. The resulting *peak storage* is made up of both a linear and an area system (Figure 8.14.).

[205] The runoff coefficients have been selected with the help of the Consorzio di Bonifica Veronese waterboard.
[206] According to the experience of the Consorzio di Bonifica Veronese water board, the emptying time of 24 hours is assumed as reliable. However, more detailed studies should take place regarding the calculation of the emptying times.

Linear system. A few existing ditches are retrofitted and new ones are designed to form a chain of ditches (*circulation system*). In some places, the ditches cross section is widened to have more room for water (Figure 8.13.). The system of ditches designed crosses the entire area and smoothes out runoff peaks where they occur. With a storage capacity of 860 m3, this peak storage device can detain rainfall with Average Recurrence Intervals of up to 5 years (ARI 5 = 830 m3) (Table 8.6.).

Table 8.6. Ponzilovo housing area, linear system dimensions and capacity

	c section	*d* section	*c* + *d* section
width	2 m	4 m	-
linear extension	1,070 m	370 m	-
capacity x m	0.39 m3	1.2 m3	-
capacity	420 m3	440 m3	860 m3

Area system. The new forested buffer strip adjoining the north east side of the settlement and employed to perform tertiary wastewater treatment also has room for other water (Figure 8.13.). The converging ditches of the forest have a storage capacity of 674 m3 that can be used in case of rainfall events with more than 5 years return time (Table 8.7.).

Table 8.7. Ponzilovo housing area, area system dimensions and capacity

	c section (collector) 0.39 m3 x m	*e* section (converging ditches) 0.93 m3 x m	*c* + *e* section
width	2 m	1.3 – 7.25 m	-
linear extension	190 m	645 m	-
capacity x m	0.39 m3	0,93 m3	-
capacity	74 m3	600 m3	674 m3

Area system and linear system together have a storage capacity of 1,534 m3, which is enough to smooth out peak loads with an Average Recurrence Interval of fifty-years (ARI 50 = 1,314 m3) (Table 8.8.).

Table 8.8. Ponzilovo housing area, peak storage capacity

	linear system	*area system*	*entire system*
capacity	860 m3	674 m3	1,534 m3

Function. Overland water flows into the circuit of ditches crossing the area. Waters expand into the ditches –*c* and *d* sections- flooding selected portions of gardens and cultivations. Once the circuit is full, water spills over the converging ditches of the forested buffer strip and floods half of the forested area –*e* sections. Further excesses of water are released to the Saccaro stream at the maximum rate of 51 l/s (10 l/s/ha). After rainfall, the waters buffered in the forested buffer strip and in the circuit of ditches flows into a seasonal storage basin within 24 hours (see § 8.4.3.).

Appliances

Four fixed weirs are designed to control distribution of flows among the parts of the system and between the system and its surroundings. Two weirs are located along the circuits of ditches, a third between the linear system and the area system, and a fourth between the whole system and the Saccaro stream (Figure 8.14.). In case of overloading, the third of these weirs can drain out excesses of water slowly over a period of time, in less than 24 hours.

Costs

The costs analysis for the peak storage comprises only the linear system (see *Appendix C*). Costs for the area system are in fact added to the costs of the purification system. It turns out that the overall cost for the linear system is 98,200 euro. This sum diminishes to 66,000 euro when the floodable areas along the ditches remain private.

8.4.2. Purification system

Programme

Wastewater from lots should be collected and treated locally though a chain of treatments. Primary, secondary and tertiary treatments can make the waters free from heavy pollutants –like pathogens- and available for unrestricted non-potable reuse. After treatment, the effluents should be retained in a seasonal storage –where they can be mixed with the stored periodic runoff- to be reused for irrigation purposes.

The reference model is the *forested buffer strip,* as the guiding model to be integrated with primary and secondary treatments[207].

[207] More information about the model is available in the *Appendix A*.

Table 8.9. illustrates the characteristics that wastewater commonly has before treatment. The same table also illustrates the characteristics the effluents should have after treatment, before being reused for watering lawns and vegetable gardens. Data is gathered from the main current legislations for reuse of waste water: the ministerial decree D.M. 185/03, concerning the reuse of wastewater effluents for watering; tab. 4 of the national decree Dgls. N. 152/2006, referring to the characteristics that effluents released on soil can have; the ministerial decree D.M. 2/5/2006 that follows the Dgls. N. 152/2006, concerning the characteristics of effluents reused for irrigation. Among them, the requirements from the ministerial decree D.M. 2/5/2006 are considered for designing the purification system.

Table 8.9. Composition of wastewater before and after treatment

	BOD^5	*NKL (N tot)*	*NH4*	*P*	*SS*	*escherichia coli*	*salmonella*
before treatment (per person)	60 g	10.00 g	6.00 g	1.00 g	-	-	-
before treatment[208] *(per litre)*	280 mg/l	46 mg/l	28 mg/l	4.6 mg/l	-	-	-
after treatment D.M. 185/03	20 mg/l	35 mg/l	2 mg/l	10 mg/l	10 mg/l	200[209] UFC/100ml	100% absent
after treatment D.Lgs. 152/2006	20 mg/l	15 mg/l	15 mg/l (tab. 3)	2 mg/l	25 mg/l	5000 UFC/100ml	no data
after treatment D.M. 2/5/2006	20 mg/l	15 mg/l	2 mg/l	2 mg/l	10 mg/l	200[210] UFC/100ml	100% absent

Rhythm

Every day, the onsite purification system should treat the wastewater discharged from the near one hundred people living in the settlement. It should be noted that once the storage system is made to operate, the effluent's discharge only slightly diminishes and the quantity of sewage water can be considered at 80% of the total consumption of drinking water (α=0.80)[211]. The purification system can therefore reclaim 23.4 m3 of waste water a day (Table 8.10.). The average flow in a 24 hour time period results as 0.975 m3/h.

[208] This amount has been calculated on the basis of the 217 litres of wastewater that are assumed to be discharged per person on a daily basis.

[209] Wastewater treated through a system of wetlands has to respect the following criteria: a maximum of 80% of the samples can reach values of 50 UFC/100 ml; admissible peak values of 200 UFC/100 ml.

[210] Ibidem.

[211] At present, the drinking water used to irrigate gardens is assumed to be about the 3% of the total drinking water consumption. Indeed, as mentioned above, the main source for irrigation is groundwater. This means that, even after the introduction of storage devices, most of the daily consumption of drinking water will result in wastewater requiring later treatment.

Table 8.10. Ponzilovo housing area, daily and annual volumes of drinking water

	drinking water consumption per person	*house drinking water (135 inhabitants)*	*house waste water (α=0.80)*
daily	217 l	29.3 m3	23.4 m3
annual	79,205 l	10,700 m3	8,600 m3

Orientation and situation

Wastewater from the lots is released to the existing collector which is designed to bring waste waters to the municipal treatment plant. After collection the pipe is diverted to an onsite purification system located in a field next to the north-eastern edge of the settlement. There, a chain of treatments purifies waste water –grey and black waters (Figure 8.16.). The available space is enough to accommodate natural treatment devices consisting of two constructed wetlands as *secondary treatment* and a forested buffer strip as *tertiary treatment* (Figure 8.15.). These natural treatments are integrated with a mechanical *pre-treatment* device –for waste water screening – and a septic tank for sedimentation which works as *primary treatment*. The *secondary treatment* integrates a disinfection system for the waters. Treatment devices are organized in a downward cascade that uses the existing differences in the micro topography, and this helps to minimize pumping to direct effluents among the treatment cycles.

Appliances

The train of treatments is composed of screening, a septic tank, a horizontal subsurface wetland flow, a vertical subsurface wetland flow (nitrification system), a chlorine contact chamber (disinfection system), an activated carbon contractor and a forested buffer strip (denitrification system) (Table 8.11.).

Table 8.11. Ponzilovo housing area, purification system appliances and related dimensions

	screening	*septic tank*	*HW*	*VW*	*chlorine contact chamber*	*activated carbon contractor*	*forested buffer strip*
dimensions[212] *(m)*	1x1.7x1.3	2.5x7.5x2.5	38x10.5x0.6	17.5x8x0.8	1x1.7x1.3	0.4x0.4x1.7	~150x60

Screening[213]. Wastewater is pumped from the point of diversion to a tank in the field. The wastewater let in then passes through a bar screen. Coarse elements are intercepted. An outlet pipe directs the screened effluents to the following cycles of treatment.

[212] Dimensions are determined comparing the characteristics of the effluents (quantity and quality) with the systems presently on stream and their performances.

[213] Screening is the first unit operation used for treating wastewater (EPA, 2003: 1). This primary treatment removes solids that wastewater might contain and, as such, avoids interferences of these elements with the next treatment processes reducing maintenance of wastewater treatment equipment.

Septic tank[214]. Screened effluents are let into a tank where sediments settle at the bottom. Afterwards effluents are conveyed to the following treatment by an outlet pipe. The septic tank abates between 20% and 30% of the total BOD^5 and total nitrogen (TKN) (Bonomo, 2008: 452).

Horizontal subsurface flow wetland (HW). An inlet pipe conveys the effluents from the septic tank to the horizontal wetlands. Waters pass through the roots of the reeds populating the wetland and infiltrate through the gravel bed (diameter of the stones, 5-10 mm). An outlet pipe conveys the effluents to the following treatment. The horizontal wetland abates up to 60% of the BOD^5 (Bonomo, 2008: 451). It is effective also in reducing the concentrations of suspended solids (SS). According to parameters in use from the Province of Trent, north-eastern Italy, three square meters is the extension of subsurface horizontal wetland needed when it is combined with a vertical wetland. Accordingly, the horizontal wetland has an extension of about 400 m2 and a depth of 0.6 m. The existing clayey soil is used as liner.

Vertical subsurface flow wetland (VW). An inlet pipe conveys effluents from the horizontal flow wetland to the vertical flow wetland. Here waters flowing from the top to the bottom pass through the roots of the reeds populating the gravel bed (diameter of the stones, measuring from 5 mm to up to 60 mm). The wetland is equipped with a ventilation system improving the process. An outlet redirects the effluents to the following treatment device. The vertical subsurface flow wetland (VW) performs a process of nitrification[215]. It abates up to 60% of the total nitrogen (TKN) and 20% of the BOD^5 (Bonomo, 2008: 451). In order to turnover the inflows, at least two units are needed. According to parameters in use from the Province of Trent, two square meters per person is the extension of vertical subsurface flow wetland needed when it is combined with a horizontal wetland. Each vertical subsurface flow wetland has an extension of about 140 m2 and a depth of 0.8 m. As for the horizontal wetland, the onsite clay soil performs as liner.

Chlorine contact chamber. Effluents from the vertical flow wetland are conveyed to a tank where they remain in contact with chlorine. After a while effluents are directed to the following treatment through a pipe. This treatment is needed to reuse wastewater for irrigation of vegetable gardens and agricultural fields. The chlorine contact chamber, indeed, disinfects waters from disease-causing micro-organisms (human enteric organisms). In this way, fencing the irrigated areas is not needed (Matcalf and Eddy, 2008: 1312)[216].

[214] Sedimentation in an Imhoff tank tool involves the gravitational settling of heavy particles suspended in the effluents (United Nations, 2003: 7). Sedimentation process is used for the removal of grit and other biological and chemical particles.
[215] In the vertical subsurface flow wetland the ammonia (NH4) produced in the horizontal wetland is oxygenated in the pools of the vertical subsurface flow wetlands and transformed in nitrates (NO3).
[216] It has to be noted that, as Bouwer (2000: 225) acknowledged, “while chlorination effectively kills bacteria and viruses to avoid infectious disease outbreaks from sewage irrigation, it also creates chemicals that may have adverse long-term health effects”. Alternative disinfection procedures that do not use chlorine, like ultra-violet irradiation, can and should also be considered.

Activated carbon contractor. Effluents from the chlorine contact chamber are directed to the activated carbon contractor where they remain for a while. The activated carbon contractor reduces organic substances and possible chlorine residuals from the previous treatment.

Forested buffer strip[217]. Effluents are pumped from the activated carbon contractor to a series of diverging ditches in the agro-forest system. Waters naturally infiltrate through roots and soil, and are later drained by the converging ditches alternated to the diverging ones. The forested buffer strip works as a denitrification system reducing the total dissolved nitrogen load in the effluents. Through the combined action of roots and soil, nitrates (NO3) are reduced and nitrogen gas (N2) returns to the atmosphere[218]. 60% of the total nitrogen (NTK) is hence abated (Gumiero et al., 2008: 31). Considering the absorption of polluted waters by plants, adsorption by clay particles and evapotranspiration, the outlets of the denitrification system can be counted in 18.8 m3 a day, that is 80% of the total inlet[219]. Considering that the forested area has an infiltration capacity of 0.3 l/s/ha, its total extension should be of at least 0.9 ha in order to treat all of the effluents (Gumiero et al., 2008: 31). Extra liner to avoid risks of groundwater contamination is not needed since the soil has low permeability. The previous disinfection treatment (chlorination) avoids risks of contamination of groundwater due to residual pathogens, while the treatment from the activated carbons contractor avoids risks of chlorine residuals for plants.

Pumps and pipes. A pump and a few hundred meters of pipes are needed to transfer wastewater from the point where the wastewater collector is diverted to the field where treatments devices are located. Another pump and other pipes are employed also to transfer effluents from the activated carbon contractor to the diverging ditches of the forested buffer strip.

Costs

Costs for arranging the forested buffer strip amount to 11,800 euro while the overall cost for the collective purification system is 208,200 euro (see *Appendix C*). It is worth noting that this sum also comprises the peak storage service performed by the multifunctional forested buffer strip.

[217] At this stage, the effluents have to be treated in order to abate the nitrogen (NO3) that develops in the previous process used for reducing ammonia (NH4). Typically, for this purpose, the re-passing of effluents through the existing horizontal wetland is also a feasible solution. The reuse of the existing wetland does not imply any restructuring but a simple pipe and a pump is sufficient.

[218] The forested buffer strip is a living filter where effluents and nutrients are considered resources. Treatment is provided by natural, biological and chemical processes as the water moves through organisms and related ecosystems (Hough, 1984: 83).

[219] This consideration is inferred from the experimental data of the pilot project Nicolas, developed by Veneto Agricoltura, the regional agency for agriculture.

8.4.3. Seasonal storage

Programme

Onsite buffered stormwater and treated waste water should be retained in a seasonal storage unit to be reused for irrigation purposes when needed. The seasonal storage should also be dealt with in regard to its potential for enriching social and spatial objectives.

Again the circulation system is the reference guiding model as it organizes, among other things, a seasonal storage device with a circuit through which water can circulate and be distributed among users.

Rhythm

In the housing area of Ponzilovo the rhythm of irrigation water supply from groundwater should be replaced by a rhythm of fluctuating both stormwater and wastewater treated in the bodies of water of the local landscape. The volume of irrigation water required is calculated in considering the gardens that can effectively be supplied by the circulation system (Table 8.12.)[220].

Table 8.12. Ponzilovo housing area, gardens and supplied gardens

all gardens	23,400 m2
effectively irrigated gardens	19,900 m2

Waste water treated in the system's own purification system should be retained daily in the seasonal storage unit. Periodical run off buffered in the peak storage unit should also be retained in the same seasonal storage unit. The water stored, which decreases from evaporation, should be enough to cope with the seasonal irrigation demand –from mid April to mid September. All these onsite ins and outs have been organized according to a hydraulic model used to compute the dimension of the permanent pond (see the spreadsheets in the *Appendix B*). From the model, it emerges that, to irrigate 2 ha of gardens, the retention of stormwater is sufficient. No retention of treated waste water is needed. The resulting retention pond (*seasonal storage version a*) should have an extension of 2,200 m2 and a depth of 3.8 m. In the pond fluctuation is 3.2 m, so the water from the peak storage can flow in by force of gravity. The seasonal storage releases 2,300 m3 of water downstream a year.

The model used for the computation also exhibits how, alternatively, treated waste water might be retained and used for the irrigation of up to 2.5 ha of surrounding corn fields. In this case, the seasonal storage (*seasonal storage version b*) should be 3,300 m2 wide and 3.8 m deep.

[220] Only the gardens of the lots that are in proximity with the circulation system –which corresponds to the peak storage- are computed.

Fluctuation is 3.4 m, so the waters from the peak storage and those from the purification system can still flow in by force of gravity. In this version, the seasonal storage releases 1,300 m3 of water downstream a year. Despite the interesting potential of this option, it is not fully developed in the coming design steps, but it will be found again in the conclusions regarding the collective strategy (see § 8.4.4.).

Another rhythm to consider is that which is related to the distribution of irrigation water. On the whole, from mid April to mid September, the effectively irrigated gardens required 71 m3 of water per day. In order to reduce the stress over the system for distribution of water, irrigation might be organized on a hourly time-basis (e.g. 5-6; 6-7; 7-8).

Orientation and situation

The seasonal storage should be located at the proximity and downstream of both the peak storage and the purification system. This way the buffered runoff and treated waste water can flow into the storage device by force of gravity. The seasonal storage should integrate a small wetland for additional treatment of stormwater run-off. Figure 8.18. illustrates the seasonal storage as it is designed. It is composed of a linear system and an area system.

Area system. A portion of an agricultural field is excavated to make room for a retention pond (Figure 8.17.). The pond is positioned along an existing field ditch skirting the southwest side of the agricultural field. A small part of the pond is a shallow surface flow wetland purifying waters that enter the pond.

Linear system. The same circuit of ditches used for drainage performs also as circulation system for distribution of the waters stored in the pond.

Function. The water flows around the system; in each cycle water passes through the surface flow wetland and this way each cycle can start off again as clean water.

Appliances

Weirs. Four weirs are designed: two fixed ones control distribution of flows among the parts of the circulation system and two others are built flexible to regulate inflows and outflows between the circulation system and the retention pond (Figure 8.18.). The two fixed weirs designed along the circulation system are likewise considered for the peak storage.

Pumps. The storage system is equipped with a pump delivering waters from the pond to the circuit of ditches[221]. In addition, a well with a pump can function in case of emergency conditions. The capacity of the pump which creates water circulation is based on the demand for irrigation that amounts to 71 m3 (0.8 l/s). The irrigation system makes use of the waters held in

[221] When the seasonal storage retains water also for the irrigation of agricultural fields (*seasonal storage version b*) an additional pump might be needed.

the circulation system for which capacity –excluding the peak storage service- is about two times higher than the demand for irrigation water per day (213 m3 > 71 m2) (Table 8.13.). During the day, a pump with a capacity of at least 1 l/s withdraws water from seasonal storage to refill the circulation system. The well is designed to perform at the same capacity. Pumps are provided with solar panels to supply the necessary power.

Table 8.13. Ponzilovo housing area, circulation system capacity

	circulation system
extension	1,010 m
capacity (excluding extra capacity for storing peaks)	213 m3

Costs

Excluding the expenses for the circulation system, the overall costs for the seasonal storage, which supplies water for garden irrigation (*seasonal storage version a*) amount to 223,800 euro. This sum is lowered to 144,100 euro when the excavation to make the retention pond becomes a free service provided for by the local bricks industry (see *Appendix C*). In the case that treated wastewater is retained for supplying irrigation water to the surrounding agricultural fields (*seasonal storage version b*), the seasonal storage is wider and costs 324,500 euro, or else 225,900 euro with free excavation.

8.4.4. Integration of peak storage, purification system and seasonal storage

Peak storage, purification system and seasonal storage are complementary storage devices integrated in their shape and function. On the whole they form a unique collective structure supporting the living, providing benefits for flows, spaces and actors (Figure 8.19.).

Water flow perspective. The deployment of the storage devices minimizes the area's inflows and outflows. Pumping of groundwater is restricted to episodes of extreme drought conditions. Stormwater stored onsite is, indeed, sufficient enough to cope with the demand for irrigation of gardens and vegetable gardens. Discharge of stormwater runoff downstream is replaced with detention onsite. Discharge of polluted waters downstream is limited by full local reclamation of waste waters. Moreover, recycling of wastewater at the neighbourhood level might lead to enlarge the storage strategy involving other portions of the landscape that might benefit from the purified water.

Spatial perspective. The system for water storage bears a new fabric of public spaces (Figure 8.20.). The traces of ditches formerly present but gone today, accommodate ditches again and walkways that allow accessibility to the fields. The existing orchards and ploughed fields are reconnected to the built environment enriching the perception of public spaces, directly participating in their spatial and functional definition. The little forest patch, for example, is a green infrastructure that provides also cool air and oxygen while protecting the settlement from blowing winds. The vegetated strips accompanying the ditches, then, form a vegetative framework that can support a variety of sports and leisure activities; they also increase ecological circuitry and handle the complex transition between plots and agricultural fields. The spread over the plains of these micro linear structures for buffering stormwater, wooded patches for purifying waters and small water expanses for retaining waters, can all give form to a continuous park, as a lasting framework for both existing activities and future developments.

Actors perspective. The water cycle starts to become readable once again. In Ponzilovo, indeed, apart from drinking water, all water flows and related infrastructures surround the plots and shape the environment. Therefore the community of Ponzilovo, in controlling its water flows, can profit from higher levels of habitability (safety, accessibility, self-responsibility etc.).

Cost analysis. Considering the *seasonal storage version a*, the overall cost to realize the collective storage strategy is 529,100 euro (Table 8.14.) (see the *Appendix C*). In the case that the floodable areas of the peak storage system remain as private land and the excavation of the retention pond is costless, overall costs diminish to 430,900 euro. In any case, the investment per person is comparable to the average maximum cost per person that the agency for management of drinking and wastewater spends for the extension of the service for wastewater alone –that is 5,000 euro per person (interview Macchiella). However, this investment should be confronted with the amortization schedule that is commonly 30 years long considering a fee of one euro per cubic meter of wastewater treated. In this case, costs end up being double compared to standards. Nonetheless, from a finer analysis, it emerges that a great part of the investment relates to the construction of the retention pond. These costs might be shaved in connecting the processes of clay excavation from the local brick industry with the residential settlements' needs for storing water. Another incentive might come from selling the state-owned strips of land that were recently obtained for pipe connections of former portions of streams and presently used as parking areas – an example of this is the Saccaro stream where it crosses Ponzilovo. The benefits deriving from these sales could be directly reinvested for the improvement of the water system[222].

[222] The strategy of matching water storage with parking might be spread throughout the entire territory. In fact, as mentioned in the analysis, the piping of road ditches is a spatial operation that was repeated hundreds of thousands of times over the plains. However, this implies a better understanding of whether parking lots are a matter of public responsibility; and this has become a controversial issue that is currently debated in various parts of Europe.

Table 8.14. Ponzilovo housing area, total costs of the storage strategy with the *seasonal storage version a*

	peak storage	*purification system*	*seasonal storage* version a	*total*
costs	98,200 euro	208,200 euro	222,700 euro	529,100 euro
costs (peak storage with no expropriation and seasonal storage with free excavation)	66,000 euro	208,200 euro	156,700 euro	**430,900 euro**
cost x person (peak storage with no expropriation and seasonal storage with free excavation)	490 euro	1,550 euro	1,160 euro	**3,200 euro**

As mentioned above, the storage strategy may employ a larger seasonal storage for retaining all the waste water treated from the purification system, and reuse it later for the irrigation of adjacent agricultural fields (*seasonal storage version b*). In this case, the multifunctional retention pond is wider and costlier and, therefore, it weighs more heavily on the overall costs (Table 8.15.).

Table 8.15. Ponzilovo housing area, total costs of the storage strategy with the *seasonal storage version b*

	peak storage	*purification system*	*seasonal storage* version b	*total*
costs	98,200 euro	208,200 euro	324,500 euro	598,700 euro
costs (peak storage with no expropriation and seasonal storage with free excavation)	66,000 euro	208,200 euro	225,900 euro	500,100 euro

Guiding model

In order to not impose extra costs on the community of Ponzilovo, the waste water purified from the settlement's own treatment system might be retained in the nearby ecosystem requiring water (agricultural field or settlement). Accordingly, a different version of the circulation model emerges. In the model peak storage, seasonal storage and purification system of a settlement area are integrated with a seasonal storage of another system (for example an agricultural field) for the separate retention of treated wastewater (Figure 8.21.). Once treated, wastewater from the settlement is a source for the adjacent agricultural field. The model would inspire initiatives of networking among the different systems and land uses composing the decentralized urban landscape of the Veneto *Città Diffusa*. It exhibits how, if interpreted within a storage perspective, spread-out dispersed urbanization and juxtaposition of activities may generate a number of promising opportunities.

8.4.5. Subsurface storage, a feasible alternative?

A question emerges from the above investigations and as a result of the learning process: whether in Ponzilovo the waters held can be stored in the underground aquifer and, if so, what kinds of possibilities are there for storing water in the ground. This option is supported by the following inductive reasoning.

Firstly, it has to be noted that in addition to the storage of stormwater and treated wastewater at the surface level –seasonal storage-, the other feasible alternative to the present exploitation of the aquifers, is the use of potable water for watering the gardens. This however presents a dilemma in that it would mean shifting the problem to the deeper aquifers, a dozen or so kilometres away, on which the drinking water service presently depends.

Secondly, the Veneto Region, which is responsible for the regulation of the aquifers of the area, imposes that the waters injected be at least of the same quality as the waters of the aquifer (Regione Veneto, 2004). On one hand, it follows that stormwater should be carefully cleansed before being made for infiltration, and that infiltration of effluents of waste water is not allowed, as the treatments designed above for the purification system cannot guarantee wastewater effluents of such a high quality. However, on the other hand, it should be accounted that, in Ronco all'Adige, the waters of the third and fourth aquifers already suffer from natural pollution as they are rich in iron and manganese, a condition common to many other parts of the low plains (Boscolo and Mion, 2008: 78; Gregnanin, 1975: 30; interview Pedrollo-Tobaldo-Pedrollo). Moreover, studies demonstrate that an impermeable layer of a previous geological era confines these relatively shallow aquifers from the waters of the deeper aquifers (see Figure 4.7.) (Gregnanin, 1975: 30).

Thirdly, the high costs for building a seasonal storage together with the considerable loss of stored water due to evaporation (more than 1 meter a year, see the *Appendix B*) suggests a further investigation of feasible storage alternatives.

Finally, it should be considered that, if adequately adapted, an aquifer recharge system could better preserve the existing decentralized system of wells, which, at the level of the single parcel, can effectively extract sufficient supplies of groundwater.

With this in mind, it seems reasonable to further investigate the subsurface storage options, precisely in order to make use of the held and cleansed stormwaters for replenishing the very same aquifers that are presently used for watering. Although this is not yet an explored practice in the Veneto, in many parts of the word there are examples where this storage strategy has succeeded efficiently[223].

Programme

Under controlled conditions, in Ponzilovo, stormwater with a fifty-year Average Recurrence Interval should be buffered onsite and, after purification, stored in the underground aquifer. Wastewater should be discharged to the existing centralized system. On the whole, the system combines a peak storage and an aquifer recharge system inclusive of stormwater treatment.

The reference guiding model is once again the circulation system even though no surface seasonal storage is expected.

Rhythm

As illustrated for the detention system designed for the above scenario, the peak storage should periodically buffer stormwater. To smooth out peaks with a fifty-year Average Recurrence Interval, a storage capacity of at least 1,314 m3 is needed (see § 8.4.1.). Afterwards, the water detained should be made to infiltrate at a rate that makes the peak storage operable for successive rainfall events. Again, according to the rainfall patterns of the area, an empting time of 24 hours after cessation of rainfall is assumed (see § 8.4.1.)[224].

Orientation and situation

Peak storage. Once again, the surface water network crossing the housing area is adapted by adding repository rooms for water. However, here the peak storage is made up of a linear system alone, since the forested buffer strip for treatment of wastewater is no longer needed. Therefore the chain made up of existing and new ditches has been redesigned. The rooms along the circulation system have been widened and extended to perform the total required storage capacity (Figure 8.23.). The overall capacity of the updated linear system results in 1,380 m3, which is more than the storage volume required (AVR 50 = 1,314 m3) (Table 8.16.).

[223] A reference project is, for example, the New Brompton Estate –Adelaide, South Australia. Here cleaned runoff congregates at a central location, where it is conveyed to an aquifer 30 metres below present ground level. During the summer months, water stored in the aquifer is reused to irrigate the area of a public garden (Mouritz et al., 2006: 22).

[224] According to Argue and Pezzaniti (2003: 16) an important aspect of the performance of an infiltration device is its ability to empty between storms. In the Australian practice, emptying times vary between 12 hours and 3.5 days. Here, according to the Consorzio di Bonifica Veronese water board, the emptying time of 24 hours has been assumed as a fully preventive standard.

Table 8.16. Ponzilovo housing area, subsurface storage scenario, linear system dimensions and capacity

	c section	*d* section	*c* + *d* section
width	2 m	5.5 m	-
linear extension	1,070 m	580 m	-
capacity x m	0.39 m3	1.65 m3	-
capacity	420m3	960 m3	1,380 m3

Aquifer recharge system. The linear system of ditches playing a peak storage service is elaborated to integrate also an infiltration function (Figure 8.22.). Some of the portions with enlarged drainage ditches are equipped with a wadi system complete with infiltration trenches. The detained waters infiltrate through wadi and trenches for further purification[225]. It is additionally worth noting that flush devices and water/oil separators (e.g. coalescence separators) are first spread among the plots in proximity to the verges located along side the ditches. This way a large part of pollutants can be removed upstream. Once infiltrated and cleansed, waters are redirected through a pipe system to a recharge well. The wadis are located in proximity to the lowest point, thus all of the buffered stormwater can effectively infiltrate (Figure 8.24.). They are designed to be close to one another in order to reduce the number of points of injection. Wadi and infiltration trenches have been dimensioned in considering the emptying time required from the detention system. According to the parameter provided by van de Ven (2007: 271), in order to perform an emptying time of 24 hours, the ratio between wadi surfaces and paved surfaces should vary from 1:10 to up to 1:12. In Ponzilovo the effective paved area is about 19,900 m2 (Table 8.17.). It follows that the surface of the wadi is at least 1,700 m2.

Table 8.17. Ponzilovo housing area, subsurface storage scenario, effective paved area

	paved surfaces	*semi-paved surfaces*	*effective paved area*
run-off coefficient	0.9	0.5	1
area	14,717 m2	13,295 m2	19,900 m2

The pipe system collecting the water infiltrated, discharges flows by gravity into an underground tank where a pump, through a well, injects waters into the fourth aquifer up to 30 meters deep (Schuetze, 2005: 195)[226]. An outlet connects the tank to the surface water network for discharging water downstream when needed.

[225] Regardless the infiltration through system of wadi, another reference project is the Khernen Urban development Area in Ede (The Netherlands).
[226] According to Bouwer (2000: 221) if the aquifers are confined, i.e. between layers of low permeability, artificial recharge can be achieved only through the recharge or “injection’ wells drilled into the aquifer.

Appliances

Peak storage. Three fixed weirs direct flows through the parts of the circuits (Figure 8.23.).

Aquifer recharge system. The infiltration system comprises wadi, infiltration trenches, a pipe network and a recharge well (Figure 8.24.). The wadi consists of a an improved layer of soil, which allows water to infiltrate through –humus-like soil mixed with sand so that grass can develop well- and an infiltration trench with a drainage pipe at the bottom of it. The trench is made of aggregate packed –expanded clay particles- on a sand proof textile –geotextile (van de Ven, 2007: 267). The slowly buffered stormwater infiltrates through the sandy layer of the top soil and then through the aggregate to the drainage pipe; in this way the water can be further purified. The improved soil is made up of a layer of sand of 0.2 m, and a layer of humus of 0.2 m. Trenches are 1 m wide and 0.6 m high. The recharge well is made of a tank and a pump to inject waters (Schuetze, 2005: 195). The pump injects a maximum of 1,314 m3 of buffered stormwater a day (24 hours), that is 15.2 l/s. This capacity is augmented to contrast the pressure from the aquifer. The pump is provided with solar panels to supply the necessary power. It is worth noting that, if the technical analysis of the water flows attests the needs for further purification, an additional purification system might be inserted before the tank so that waters can be more thoroughly purified before injection. The additional treatment train might include a carbon filter as well as ultraviolet or ozone disinfection[227].

Costs

The overall costs of the system are estimated at 207,100 euro (see the *Appendix C*). When those floodable areas which are not equipped with wadi remain private, the cost diminishes to 178,700 (Table 8.18.). Costs for additional individual or collective stormwater treatments (notwithstanding those performed by the wadi and the infiltration trenches) are not considered.

Table 8.18. Ponzilovo housing area, subsurface storage scenario, total costs of the storage strategy

	peak storage (no expropriation)	*aquifer recharge system (with expropriation of the wadi areas)*	*total*
cost	71,200 euro	107,500 euro	**178,700 euro**
cost x person	530 euro	800 euro	1,330 euro

[227] See, for example, the purification process proposed by Kinkade-Levario (2007: 86) to treat stormwater to reach potable qualities.

Conclusions

Peak storage and recharge well system are merged in a circuit of ditches framing the settlement area (Figure 8.25.)

Water flow perspective. In the collective subsurface storage scenario, inflows and outflows are reduced. Stormwater is a resource retained to replenish groundwater. As a result of this, a great part of the households maintains their wells for watering gardens. The use of groundwater is regulated. This way, problems of evaporation affecting the permanent pond in the seasonal storage scenario are avoided. No storage strategies directly concern waste water. In this regard, only for connections with the centralized sewer network are there recommendations to avoid discharges of polluted waters into surface water and phreatic groundwater. The water system might also be provided with the same purification system designed for the *surface storage scenario* including additional surface storage for retaining the treated waters from the purification system (see the Figure 8.21.)[228].

Spatial perspective. The subsurface storage strategy results in a stronger spatial arrangement, where a multifunctional linear vegetative infrastructure supports accessibility to the farmland and a variety of activities. This also regulates transitions between built environments, fields and enhances local biodiversity. The wadis form a permanent and floodable linear park since these depressions need to be free from crops to perform well (Figure 8.26.).

Actors perspective. A part of the water cycle is made visible. The community of Ponzilovo reaches higher levels of self responsibility and, in the meantime, benefits from a safer environment.

*Costs analysi*s. Considering an amortization schedule of 30 years, the costs needed to cover the expenses are still comparable to that of drinking water, that is a bit less then half a euro per cubic meter. However, to avoid the use of drinking water for watering gardens, the fee for groundwater should be slightly lower than that for drinking water. It is important to note that, regularizing the consumption of groundwater as suggested in the scenario, means also that with no additional costs, the settlement area can reach higher levels of safety and self responsibility – regarding peak storage service and aquifer recharge- and ultimately benefits from new shared public spaces.

In general the subsurface storage strategy seems to be a sound alternative. However, the above design process has to be corroborated through a pilot project where testing its effective feasibility. What should further be explored, is whether the quality of cleansed stormwater is compatible with the quality of the receptor aquifer. The quality of water downstream the

[228] It is worth noting that the replenishment of the aquifer might also contribute to preserve water levels in those surroundings former clay pits where, according to Piva (interview Piva), water is fed by the first aquifer layers.

infiltration treatments (wadi and infiltration trenches) should also be monitored. The treatment train should eventually be fine tuned to perform well. Once the water tests are passed, injection can be started. When the system is operative the effects on the aquifer should also be carefully monitored. .

Guiding model

Subsurface storage was not considered before in the guiding models for the low plains. Notwithstanding this, from a better understanding of the conditions of the site, an updated version of the circulation model emerges. It organizes peak storage and aquifer recharge system in a piece of urban landscape of the low lands where confined groundwater is a resource (Figure 8.27.).

8.5. The Saccaro catchment area

The Ponzilovo area is part of the Saccaro catchment that deserves further comprehensive discussion as a means to investigate this area's potential in relation to principles and models of integration and decentralization of water-flows (Figure 8.28.).

Physical and functional description
The area is an elongated patch, a rough polygon of about 2,500 x 1,500 m which, to the north, borders with the Ariolo stream and the Ronchesana Road, both E-W oriented; to the east there is the recent bypass of the Ariolo stream and the centre of Ronco all'Adige, to the south there is the Carnirolo stream and a private hunting reserve, to the west there is the Zerla stream, a medium size industrial area, a recent farm and an ancient farm villa with its entrance avenue. The Saccaro stream and its confluents, Fossa Zerletta and Fossa Termini, cross the area with N-S and W-E directions respectively. The Scolo Termini stream crosses W-E at the south part of the catchment area and then converges to the Carnirolo stream that flows into the Saccaro stream[229]. The catchment area is a checkerboard of diverse land use patches. Housing lots and farms are positioned along the roads, as a result of an incremental process of urbanization, forming ribbons that stretch W-E in the central part of the polygon –*zone 1*, *2*, *3* in the image (Figure 8.30.). A group of housing plots polarizes in the confluence of a W-E with a N-S road axis and forms the housing area of Ponzilovo –*zone 5* in the image. A big industrial platform located in the middle of the eastern part of the catchments accommodates a brick industry with its deposits of clay –*zone 4* in the image. A small industrial platform, a dwelling lot and a farm are located a few hundred meters downstream of Ponzilovo –*zone 6* in the image. All these elements –streams, roads, industrial and dwelling lots- are embedded within an agricultural matrix that is mainly composed of arable lands –mainly corn, wheat and soy, orchards- and

[229] For a further description of the surface water system see the § 4.2..

perforated in the southern part by a number of water expanses resting on former clay pits. The arrangement of the fields is the result of recent processes of intensification and up-scaling (see chapter 5 and 6).

Existing conditions

Apart from those conditions that are common to the housing area, like rhythms of precipitation and evaporation and soil and subsoil composition, other more specific ones have to be disclosed before the designing process starts.

Relief. The terrain gently slopes from North North-West to South South-East with a gradient of one in one thousand having a difference in level of 3 meters from upstream to downstream. Commonly, roads, dwelling lots and industrial lots are from 0.1 m up to 0.5 m higher than the surrounding agricultural fields. Former clay pits coincide with the more depressed areas of the catchment. A few low fields are embedded in the agricultural matrix. They are former clay pits that have been filled up to be cultivated.

Land cover. The catchment area is about 365 ha (Figure 8.29.). Dwelling and industrial lots and roads are 71 ha, that is 19% of the catchment whereas the former clay pits occupy an area of 48 ha that is 13% of the catchment. Arable lands are 146 ha, 40% of the catchment area whilst orchards cover 70 ha, i.e. 19%. Agro forest cultivations are 23 ha, 6% of the catchment.

Inflows and outflows infrastructures and rhythms. Drinking water supplies residential use and other activities in the area (Figure 8.32.). The average consumption of drinking water is 217 litres per person a day that, multiplied by the approximately 450 inhabitants, results in 98 m3 a day.

The main water consumption, however, relates to irrigation of gardens, arable land and orchards. For this purpose, due to the lack of a surface water irrigation system, water is withdrawn onsite from aquifers through individual wells. Irrigation of gardens depends on aquifers that go from 16 to 30 metres deep, while some cultivations are also supplied with waters from deeper aquifers (interview Purgato; interview Montanari-Galbier; interview Pedrollo-Tobaldo-Pedrollo; interview Montanari-Galbier). The total amount of water that is pumped up during summer months for the irrigation of gardens, arable lands and orchards is estimated to be about 722,000 m3 (Table 8.19.). Aquifers are also exploited to provide water for cattle, poultry and fish breeding facilities that are spread over the catchment.

Table 8.19. Saccaro catchment area, irrigation demand

	arable land (3,000 m3/ha)	*orchards* (3,000 m3/ha)	*agroforestry*	*gardens*[230] (5,500 m3/ha)	*total*
surface	146.4 ha	70 ha	23.3 ha	13 ha	
annual irrigation demand[231]	440,000 m3	210,000 m3	-	72,000 m3	722,000 m3

Again, as for the settlement area of Ponzilovo, though demand for water is high, the rainwater from roofs, paved surfaces, gardens and fields is quickly discharged into road-ditches, field-ditches and streams (Figure 8.31.). All these waters pour into the Saccaro stream. Rhythms of average annual precipitation and evaporation are those considered for the housing area of Ponzilovo, that is 700 mm and 900 mm respectively. The average rainwater falling into the catchment basin is about 2.5 millions of m3 per year[232]. A great part –approximately one-third- is directly discharged into the surface water network and removed from the catchment, downstream[233]. The remaining part probably infiltrates by feeding the water table that is later drained by the surface water network. It is worth noting that, two streams Scolo Barcagno and Scolo Carnirolo, cross the catchment area and drain water from other surrounding catchments.

Wastewater from households and industries is commonly discharged to the soil or the surface drainage network after the primary treatment operated through individual septic tanks. The centralized sewage system runs, indeed, only along the Ronchesana Road and along the road axis that crosses the settlement of Ponzilovo (Figure 8.32.). The last collector, however, is not yet in function. Households and industries connected to the centralized wastewater network quickly discharge grey and black waters to a pipe network which delivers wastewater to a treatment plant a few kilometres downstream. On the whole, wastewater is about 78 m3 a day – that is the 80% of the consumption of drinking water. In addition to pollution from households and industries, the surface water network suffers from the considerable amount of polluted water discharged from the cattle, poultry and fish breeding, which are present throughout the catchment[234].

Threats

Water flow perspective. In general, the lack of an integrated and comprehensive water strategy results in a number of environmental dysfunctions. Irrigation draws heavily on aquifers causing

[230] Garden surfaces are considered as 60% of the lots. Clearly, the large-scale platform of the brick industry is excluded from this computation.

[231] The unit irrigation demands of the cultivations are gathered from Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo (1984: 8) and the Regione Emila-Romagna (2004: 58).

[232] This amount is the result of a rough calculation: the average annual precipitation (0.7 m) multiplied for the entire surface of the catchment basin (3,650,000 m2).

[233] In regards to the runoff, further computations are reported in the next § 8.6..

[234] From the field survey, results show that not all these activities fully process and/or reuse the manure they produce.

the onward depletion of this high quality resource. Cattle, poultry and fish breeding consume high amounts of groundwater. Discharge of untreated or partially treated wastewater from households, industries and breeding, and nutrients from fields threatens the quality of both phreatic groundwater and surface water network. A great amount of rainwater is discharged downstream contributing to overloading the drainage system downstream, while in dry periods there is no water in the surface water network of the area. According to the waterboard, almost one third of the catchment area is at risk of the flood in case of storm events with an Average Recurrence Interval of 30 years (Figure 6.22.). Moreover, the low water mark in the streams jeopardizes the stability of their banks[235]. The agricultural activities on the filled former clay pits, then, suffer from difficult drainage because they are lower than the surrounding farmland. All these tendencies and problems will probably be further exacerbated by climate change.

Spatial perspective. From a spatial perspective, the catchment area presents two very different conditions: the upper inhabited part of the catchment which is threatened by the processes of up-scaling and homogenization; and the lower mostly uninhabited part that accommodates the former clay pits and is rich in water and vegetation. Aside from roads, both areas suffer from the absence of any shared public space. Both agricultural fields and former clay pits are presently inaccessible. This marks the separation between housing and other activities with the surrounding environment. Moreover, during summer months, the lack of water in the surface water network has negative consequences for biodiversity and, in general, for the quality of the environment.

Actor perspectives. People living in the catchment do not feel that the control and management of water is really in their hands. The environmental fallouts of their pumping from groundwater and their discharging polluted waters are generally ignored. Moreover inhabitants are not aware of the potential that the former clay pits might have in supporting and providing for their water requirements.

8.6. Catchment area level

Programme

What if water is detained, retained, reused and recycled at the scale of the Saccaro catchment area?

The main issue is the shift from a system that withdraws water upstream and discharges water downstream to a resilient system holding water onsite as a strategy for mutually benefiting both spatial layouts and water-flows. In the design investigation, the existing materials of the landscape should be engaged to work out a storage strategy that leads to significantly diminish

[235] In regard to this, see the problems of too much and too little in the Chapter 6.

both the pumping of groundwater –at least to quantities that are in accordance with its natural recharge- and the discharge of stormwater runoff and polluted waters.

Finding room for storing water, however, is not a simple task. Earmarking part of the fields for retaining water to cope with the irrigation demand, for example, is not economically competitive due to the cost of land and the reduction of harvest it implies. This leads to exploring options that look for synergies between the diverse land uses and related water-flow patterns. To this end, for example, the majority of the existing former clay pits can be seen as waste land water expanses that might be moulded to perform a variety of water services. For example, in addition to providing extra storage capacity for buffering and retaining, they can also process the waters themselves.

Guiding model. The *circulation model* previously illustrated is the reference used for unfolding the storage strategy also at this level of inquiry. The area should accommodate a *peak storage* for retaining rainwater, a *purification system* for purifying wastewater and a *seasonal storage* system for retaining buffered peaks and treated waste. However, a storage strategy for the catchment area has to deal also with those great inflows and outflows related to the agricultural activities that rely on it.

It is worth noting that waters –drinking water, irrigation, stormwater and wastewater- from dwellings and workshops located along the northern edge –*zone 1*- are not considered in the strategy as their supply and discharge are managed through water infrastructures that might be more easily included in the rearrangement of other surrounding catchments. On the contrary, the agricultural activities in the northern part of the Saccaro catchments –and therefore at the proximity of the *zone 1*- are also included in the design exploration.

Rhythm

Peak storage

According to the regional council decree DGR 2627/2002, peaks of water with up to 50 years return time, generated by impervious surfaces and roads, should be smoothed out at the point where they are generated, by means of storage units that act as floodplains.

The storage capacity required has been computed on the basis of a swift method – currently in use by the water board- that assigns a certain storage capacity to those land uses that are different from agriculture. Accordingly, coverage of dwelling lots, industrial lots and roads should be calculated and later multiplied for the specific unit storage capacity these land uses require. The computation proceeded by valuating the covered surfaces and storage capacity for each of the five zones composing the area (Table 8.20.). Excluding *zone 1*, the storage capacity required for buffering stormwater amounts to 25,300 m3.

Table 8.20. Saccaro catchment area, paved surfaces and peak storage volumes required

		dwelling lot 300 m3/ha	*industrial lot* 500 m3/ha	*roads* 800 m3/ha	*house covered area*
zone 2	*area*	13.9 ha	-	0.9 ha	14.8 ha
	peak storage	4,170 m3	-	720 m3	4,890 m3
zone 3	*area*	6.8 ha	-	0.8 ha	7.6 ha
	peak storage	2,040 m3	-	640 m3	2,680 m3
zone 4	*area*	4.2 ha	21 ha	0.6 ha	25.8 ha
	peak storage	1,260 m3	10,500 m3	480 m3	12,240 m3
zone 5	*area*	9.1 ha	-	1.3 ha	10.4 ha
	peak storage	2,730 m3	-	1,040 m3	3,770 m3
zone 6	*area*	1.1ha	2.3 ha	0.3 ha	3.7 ha
	peak storage	330 m3	1,150 m3	240 m3	1,720 m3
zone 2-3-4-5-6	*area*	1.1ha	2.3 ha	0.3 ha	3.7 ha
	peak storage	10,530 m3	11,650 m3	3,120 m3	25,300 m3

Purification system

The area is equipped with a semi-decentralized treatment system for wastewater (black and grey) from households and industries and with a treatment system to purify waters discharged by agricultural fields. Moreover, individual decentralized treatment systems are designed for the breeding activities spread over the catchment. In these locations, waters are purified to be directly reused[236].

Wastewater purification. Excluding the inhabitants living in *zone 1*, the other 350 inhabitants discharge 61 m3 of wastewater a day, that is about 22,400 m3 a year[237] (Table 8.21.). These waters, once treated, can be stored to be reused when needed.

[236] A possible reference for recycling wastewater at the level of the stable is the system proposed from Rob van Deun and available from www.rietvelden.be.

[237] This amount has been computed considering wastewater as the 80% of the total consumption of drinking water (α=0.80)

Table 8.21. Saccaro catchment area, volumes of drinking water supply and waste water discharge

	drinking water consumption per inhabitant	*total drinking water consumption (350 inhabitants)*	*total waste water effluents (α=0.80)*
daily	217 l	76 m3	23.4 m3
annual	79,205 l	28,000 m3	22,400 m3

Surface waters purification. For a very rough computation, according to Mazzotta (2007: 107), in order to purify waters from nutrients from agriculture, a system of surface flow wetlands that is the 2% of the total cultivated drainage basin is needed. In the catchment area, cultivated land amounts in about 240 ha, excluding agro forested areas. Therefore, purification of surface waters requires an area of surface flow wetland of at least 4.8 ha.

Seasonal storage

The seasonal storage is sized to supply the irrigation of both gardens and the crops of the catchments area. The size and scale of the seasonal storage units depend, of course, also on the catchment's availability of water to store.

Irrigation demand. In the first place, irrigation demand should be reduced and farmers should be encouraged to adopt well known water saving techniques (e.g. drop irrigation). In the case of apple orchards, for example, water saving strategies can diminish the annual irrigation demand from 3,000 m3/ha to 1,000 m3/ha with little production loss (Regione Emilia Romagna, 2004: 63). Cereal crops might be substituted with less water demanding and still competitive crops that can guarantee the halving of water consumption (Regione Emilia Romagna, 2004: 63). Accordingly the total irrigation demand results in 318,000 m3 a year (Table 8.22.)[238].

Table 8.22. Saccaro catchment area, irrigation demand after introduction of water saving strategies

	arable land (sunflower, 1,200 m3/ha)	*orchards* (apple orchard, 1,000 m3/ha)	*agroforesty*	*gardens* (5,500 m3/ha)	*total*
surface	146.4 ha	70 ha	23.3 ha	13 ha	
annual irrigation demand[239]	176,000 m3	70,000 m3	-	72,000 m3	318,000 m3

Waters to reuse. Rainwater and treated wastewater are important water resources. Paved surfaces from lots and roads intercept high amounts of stormwater that, detained, cleansed, and

[238] Whether the cereal crops are not substituted with other less water demanding crops, the total irrigation demand results in 582,000 m3 a year.

[239] Data regarding requirements for irrigation are deducted from the Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo (1984: 8) and the Regione Emilia Romagna (2004: 58).

stored, can be reused for later irrigation. It is worth noting that the runoff from cultivations should also be comprised in the storage strategy. Overflows that are discharged into the surface water system have been roughly estimated on the basis of runoff coefficients, the extension of land uses and the average annual amount of rainwater (700 mm). Accordingly, the total rainwater discharged that can be stored is estimated at 872,000 m3 a year (Table 8.23.). The volume of waste water that is treated from the purification system (22,400 m3) has also to be accounted. This way, storable water can total to almost one million cubic meters, which is conceptually much higher than the overall water demand for irrigation.

Table 8.23. Saccaro catchment area, annual stormwater discharge

	dwelling lots	*industrial lots and roads*	*cultivated land*	*total*
runoff coefficient[240]	0.5	0.9	0.3	
surface (excluding zone 1)	35.1 ha	27.2 ha	216.6 ha	278.9
annual stormwater discharge (excluding zone 1)	246,000 m3	171,000 m3	455,000 m3	872,000 m3

From the above computation it emerges that the seasonal storage should have a capacity of at least 318,000 m3, that is the volume of water irrigation required from cultivations.

Orientation

The various waters flowing in the catchment basin –runoff from dwellings, industrial lots and roads, runoff from cultivations, wastewater from households and workshops-, should be differently managed and purified before being stored and reused. For this purpose, according to the *water recycling diagram* of the Veneto low-plains (see Figure 7.4.*)*, a number of both spread and concentrated treatment devices are designed for the catchments. In general, in the designing of an integrated system of water, purification devices come before storage devices. Stormwater from dwellings, industrial lots and roads should be processed to remove heavy metals and oils prior to their storage. Stormwater from cultivations should be purified of nutrients and later stored. Likewise, grey and black waters should be processed through a specific train of treatments before being stored.

In order to treat the study area as an independent system, the catchment basin should be disconnected from upstream and surrounding water courses. To this end, waters of adjacent catchments crossing the area and flowing into the Saccaro stream – through the Scolo Barcagno and Scolo Carnirolo streams – are diverted though bypasses into the Fossa Zerla stream and the

[240] Runoff coefficients for residential areas, industrial areas and roads are inferred from Marsh (2005: 156) and the experience of the water board Consorzio di Bonifica Veronese.

Scolo Turchetto respectively. These receiving streams have to be widened in order to cope with a greater discharge. This way, the catchment is made independent of the quality and quantity of waters from different areas.

Situation

The existing conditions of the catchment area determine the rational positioning of the storage devices. The consistent number of former clay pits and their status of wastelands suggest their reuse and integration into a water sensitive strategy.

Peak storage
Specific off-channel peak storages are designed for each single zone composing the catchments area (Figure 8.35.). Peaks from *zones 2*, *3* and *4* are collected by the existing stormwater drains, field ditches and road ditches and are redirected into adjacent fields that are marked down to make room for water. Peaks from *zone 6* and those from the depressed agricultural area in the south-west corner of the catchment area are collected and delivered into existing filled up former clay pits that are now recovered to function as floodplains (Figure 8.34.). The floodable fields are hydrophilic forests where stormwater can fluctuate up to 0.3 m. Their total extension is more than 9 ha, that is the 2% of the catchment area. The stormwater open air collector ditch of *zone 4* is enlarged; new banks follow the former meandered shape inferred from the IGM map of the 1886. Surpluses of stormwater from *zone 5* expand into a former clay pit located along the Saccaro stream (see the guiding models for excavation sites in the *Appendix A*).

Purification system
Wastewater and polluted surface water are differently processed before being retained.

Wastewater purification. The existing pipes network for wastewater serving *zones 4* and *5* is prolonged to collect also waste waters from *zones 2*, *3* and *6* (Figure 8.35.). Activities in *zone 5* are also connected to the existing wastewater collector. Grey and black waters from households and industries are conveyed through the pipe network to a chain of treatments, whose components are the same as the ones designed for the neighbourhood level. However, location and dimensions have been updated, and a surface flow wetland has been added for replacing the tertiary treatment that was accomplished by the forested buffer strip. The purification system recovers a few grouped former clay pits located in the central part of the catchment. Among the treatment options employed, wetlands have also a landscape value. (Figure 8.34.). The wetland with horizontal subsurface flow stretches in a portion of waste land wedged among pits. The wetlands with vertical subsurface flow occupy an adjacent shallow tiny former clay pit. The wetland with horizontal subsurface flow is 1,050 m2 (3 m2 x 350 inhabitants), whereas on the whole the wetlands with vertical subsurface flow are 700 m2 (2 m2 x 350 inhabitants)[241]. The wetlands with surface flow reclaim three consecutive shallow former clay pits combined into one system with an extension of 5,250 m2 (15 m2 x 350 inhabitants)[242]. On the whole, the wastewater purification system occupies less than the 0.5% of the catchment area.

Surface water purification. Surface waters are purified in the off-channel surface flow of wetlands recovering a few former clay pits located along the Saccaro and Scolo Termini streams (Figure 8.36.). Banks are reshaped to perform purification of water. According to the requirements, the extension of the designed surface flow wetlands is measured at 4.8 ha, about 1.5% of the whole catchment area.

Seasonal storage

The former clay pits inserted in the catchment area, even those employed for purifying surface water, are all connected and used for retaining both buffered stormwater and treated wastewater (Figure 8.36.). In these water basins, with total extensions of more than 30 ha –that is 8% of the catchment area-, water can fluctuate up to 1.1 m and circulate through the basins. They offer a storage capacity that corresponds approximately with the total irrigation demand of the catchment.

Circulation system

Waters that flow from upstream to downstream as parts of the catchment basin are no longer let out, but are made to circulate through a new downstream-upstream water course paralleling the Fossa Zerla stream. The Saccaro stream, the Fossa Zerletta stream and the new water course are all combined to form a circulation system (Figure 8.37.). The Scolo Termini stream and a few others field ditches and road ditches also merge with the circulation system. Six pumps are set all along the east side of the circuit. They are used to pump water from the downstream parts up to those upstream. The waters that are then stored can be made to circulate and be distributed to all users when needed. Considering the average differences in level of 0.5 m and segments from 500 to up to 800 meters long, the new water course is 4.0 m wide with a depth varying from 0.8 m downstream, just after the pump, to up to 1.6 m upstream, just before the next pump.

Function. During the year, stormwater periodically expands into the hygrophilous forests and the former clay pits. After storms, waters are slowly released either into the circulation system or, passing through shallow former clay pits that perform purification, they are retained in the deep pits for seasonal retention. Wastewater from households and industries is treated daily in the purification system. After tertiary treatment in the shallow surface wetlands water is also released either to the circulation system or the seasonal storage basins. These seasonal storages are filled slowly and as much as possible. Eventual excesses of water are released downstream

[241] The surfaces of the subsurface wetlands are designed according to parameters in use by the Province of Trent (Italy).

[242] The extension of the surface wetlands is designed according to the guidelines from the Commission of the European Community (CEC, 2001: 16).

to a remaining segment of the Saccaro stream, and through it to the Scolo Conduttone stream. From April to September, the water is pumped from the seasonal storages up to the circulation system where it is then distributed among users.

Appliances

The storage system employs a number of pipes, fixed and movable weirs and pumps to regulate and redirect flows among the parts. The main selector-regulators designed for the peak storage, the purification systems, the seasonal storage and the circulation system are separately illustrated above (Figure 8.35.; Figure 8.36.; Figure 8.37.).

Conclusions

The integrated water system designed proves to be an interesting option for flows, spaces and actors of the catchment (Figure 8.38.).

Flow perspective. The arrangement of a circulation system with off-channel storage devices for buffering purifying and retaining water, and the promotion of water saving irrigation practices, leads to the immediate reduction of groundwater extraction. The water stored in the system is enough to cope with the demand for irrigation. In general, apart from drinking water, the catchment area makes use of its own resources and no longer has to depend on upstream and downstream areas.

Spatial perspective. Spatial intelligibility and permeability increases (Figure 8.39.). Where the circulation system passes through, following the preemption of the few meters that separate the parcels from one another, walkways are to be inserted. These routes accompanied by ditches and stream segments can be shared by all inhabitants. Through them inhabitants can approach the agroforested areas that are spread over the catchment and used for buffering peaks. Forests are private spaces that can be progressively added to the fabric to form a sequence of spaces with a collective function. Water courses, passageways and forest patches all compose a strong vegetative framework which enhances ecological connectivity and circuitry and accompanies the transition between different land uses. The very strong presence of water in the lowest part of the catchments also becomes a legible and integral part of the spatial arrangement. The former clay pits are made accessible and can hence contribute to an enhanced perception of public spaces. The scenario demonstrates how, by arranging a water management regime that fits, it is also possible to find answers to the lack of public spaces which affects this urban landscape (Munarin and Tosi, 2001; Viganò et al., 2009: 15). Through operations of minimal rationality, the catchment area is equipped with multifunctional carrying structures that refer to practices and structures that exist or that existed for centuries, which can be redesigned to support the current activities of this decentralized urban landscape.

Actors perspective. Water is no longer perceived as a threat to be quickly discharged, rather it is an essential element to be carefully handled for supporting and enriching living sites. On one hand, inhabitants are asked to cooperate in order to build up a robust and legible environment. On the other hand, the new water infrastructures provide support to inhabitants who can benefit from the landscape where they live.

The strategy of closing the cycle of water at the catchments level might be repeated over the low plain of the Veneto since this is all organized in micro catchments. Moreover, the water sensitive storage network designed for the Saccaro catchment might also be linked to water sensitive initiatives from neighbouring catchment areas or storage infrastructures envisaged at lower and/or higher levels. With a few changes regarding quantities, and within the frame of the catchment, the different little steps of a common storage strategy can also be applied in smaller inner areas. This means that, in the process of change, the storage system at the neighbourhood level of Ponzilovo might be comprised and integrated in the storage system at the catchment level.

Guiding model

The learning process led to an updated version of the circulation model. Its goal and function is to organize peak storage, purification system and seasonal storage in the catchment area (Figure 8.40.). These storage devices are merged in a circulation system that on one side employs the existing streams for drainage and, on the other side, parallels the water courses that drain the upstream adjacent catchments areas.

8.7. Conclusions

The above design experiments prove that it is actually possible to find water management options which fit better with this urban landscape and ensure a more sustainable use of water while also enhancing local biodiversity as well as landscape accessibility and social cohesion. On the one hand, the proposed different levels of water flow decentralization show the variety of flow arrangements, spaces and actors that the *Città Diffusa* can accommodate. On the other hand, each strategy addresses specific issues and constraints that should critically be discussed.

8.7.1. Alternatives evaluation

The performances of the proposed water management strategy must be benchmarked against current conventional design (Wong, 2006: 7). In this regard, individual and collective scenarios were presented to a group of experts to be evaluated. The assessment was conducted by experts who manage water flows in the real world as well as the related infrastructures at stake. The design proposals, indeed, would have influence on the current approach. Nevertheless it should be noted that it is a true risk to pass directly at once from research to practice. Experts from the real world are usually concentrated on solving the problems at hand rather than on discovering new approaches, notably when innovations seem to challenge well-established practices.

During a workshop, experts were asked to evaluate each design proposal according to the strengths-weaknesses-opportunities-threats categories of the SWOT analysis[243]. A discussion was held at the conclusion of the meeting. The main findings are here briefly presented according to the sequence used for the presentation (Table 8.24.).

Household level

According to the experts, the main strength of the strategy at the household level (*individual level*) is that it might favour a higher degree of accountability to the citizens of the *Città Diffusa* with respect to the issues of water. Nevertheless it could end up being difficult to promote the farming of water at the level of the lot without adequate policies that create incentives for these initiatives. The reduce-reuse-recycle alternative might indeed imply higher costs of both construction and maintenance and water is not yet perceived as a scarce resource by the inhabitants.

Neighbourhood level

The collective strategy at the neighbourhood level (*collective level 1 – surface storage, subsurface storage*) is seen with favour for the potentials it has to enhance “district” identity, local biodiversity and to give a “true” public image of the site. Furthermore, the proposals embedded in the scenario could actually contribute to design the municipal water plans which recently have been established in other parts of the Veneto low plains[244]. Notwithstanding this, the experts remarked the tough process of negotiation that such arrangements entail. This is typical when, as is the situation in this case, several stakeholders are involved. All of them should have a clear idea about the benefits that each strategy can offer. Moreover, there needs to be a serious joint effort of the various institutions involved; and, at the same time the aspects concerning the maintenance of the systems should also be clarified. In regards to the subsurface storage option (*collective level 1 – subsurface storage*), it was deemed viable and convincing for the potential it has to generate new shared public spaces. Nevertheless it was also seen with distrust for the high degree of artificiality of its components and for the technical constraints it entails.

[243] The workshop was held the 16th of December 2010 in Legnago at the headquarters of the former Consorzio di Bonifica Valli Grandi e Medio Veronese. The representatives of two water boards, Consorzio di Bonifica Veronese and Consorzio di Bonifica Acque Risorgive, attended the workshop. Although invited, the representatives of the integrated management of drinking and waste water and the representative of the municipality of Ronco all’Adige were not present.

[244] The water plans have been introduced from the provincial plan of the Province of Venice (Provincia di Venezia, 2008) that prescribed the compilation of such a plan to each of its municipalities.

Table 8.24. Scenarios evaluation: SWOT analysis

	individual level (household)	*collective level 1* (neighbourhood)		*collective level 2* (catchment)
		surface storage	subsurface storage	
strengths	- citizen accountability	- "district" identity - increased biodiversity - landscaping	- innovation - new public spaces	- storage of considerable amount of water
weaknesses	- maintenance operations - probable higher costs of construction and maintenance - lacking computation of costs and benefits	- difficult negotiation - maintenance operations - lacking computation of benefits	- artificiality - lacking computation of benefits	- complexity - probable high costs of construction and maintenance - lacking computation of costs and benefits
opportunities	- eco house incentives - promotion of civic mindedness	- synergy with other water plans - re-landscaping - promotion of civic mindedness	- synergy with other storage strategies - promotion of civic mindedness	- integration with the new planning tools
threats	- opposition and scarce willingness of the inhabitants - legislative restrictions	- risk of controversy among the owners - lack of preparation at the institutional level	- difficult to export - quality standards difficult to achieve - legislative restrictions - low flexibility at the institutional level	- lack of preparation at the institutional level

Catchment level

The collective strategy at the catchment level was held as valuable for the considerable amount of water which it allows to store. The strategy could, indeed, partially meet the present demand for irrigation water as well as the need to reduce the magnitude and frequency of peak discharged downstream. However, major doubts appeared among the experts about the option of making the stored water to also circulate from downstream to upstream. It actually sharply shifts the present organization of the water in the landscape which flows by force of gravity from upstream to downstream. Though technically possible, the solution proposed to overcome the difference in level brings with it a high degree of complexity and, probably, high costs of construction and maintenance. Again a careful costs-benefits analysis was advised and advocated.

Conclusions

A few experts were at first astonished by the conceptual shift that the scenarios propose. For them to store, reuse and recycle waters are accepted as true and valid ideas only at the theoretical level, while they are rather hard to translate in practice in the coming future. For all of them however, the shift towards an integrated management of water is desirable; and a few of these technicians believe that it is likely to become a wide-spread practice only in the distant future. On the one side, it was a common opinion that the designed solutions make the integrated management of water more tangible while promoting a greater respect for this scarce resource. However, on the other side, some technicians emphasised that the issues at stake are often not perceived as urgent by the citizens. Therefore it is likely considered difficult for the proposals to achieve an acceptable consensus among the inhabitants. Furthermore, some technicians were sceptical about the likelihood that the strategies adopted could be effectively integrated within the existing settlements. For them, the principles and models should instead be put forward only within the context of new urban developments. Indeed, even when entirely publicly financed –with no major costs for the inhabitants-, the decentralized proposals would still encounter strong opposition of the inhabitants. Why should they start to collect stormwater in their garden? A convenience for citizens has to be self-evident since their perception of risk of drought, flood and pollution of water is not yet strong enough to justify such interventions. A careful estimation of the benefits as well as the costs of maintenance was indeed generally thought necessary and requested.

Technicians were prone to many of the ideas that each scenario integrates, but the logic of a complete decentralization found little support. Likewise the guiding models presented were generally considered clear and effective to spread the culture and practice of designing with water, however more technical details and maintenance considerations that can make them more concrete were recommended. Furthermore, it was a common opinion that the decentralized management of water, at any level it is done, implies the negotiation of the institutions involved as well as the reorganization of their tasks.

In conclusion, the experts agreed on the importance of integrating the decentralized storage options in the present decision process. It would allow for obtaining a wider range of alternatives at readily available disposal. Furthermore, in this way, the decentralized strategies could directly influence the final plans and be effectively confronted with those that are currently in use. However, given the various remarks that emerged in the discussion, it is clear that a *pilot project* is the next advisable step. This would allow for more precise estimations of costs and benefits. It would also bring to light other constraints and opportunities of maintenance while also making known the attitude of users and institutions.

Chapter 9

Conclusions

9.1. Introduction

The main goal of the present studies was to develop new concepts, models and tools which bring to light the spatial and ecological potentials on the basis of the decentralized urban landscape of the Veneto *Città Diffusa*, and dispersed urbanization in general.

A review of contemporary dispersed urban developments and integrated water management highlights a substantial lack of studies that question the sustainability of the interaction between the present centralized approach in the management of water and the decentralized urban form, notably that of the Veneto *Città Diffusa*.

The work evolved to corroborate two specific closely related assumptions:

- economic growth of the last decades and related processes of centralization concerning water flows and spatial structures are threatening the diversity of the *Città Diffusa* urban landscape while also increasing problems of flooding, drought and water pollution;

- in the decentralized urban landscape of the Veneto *Città Diffusa*, answers that design measures can give in response to increasing water-flow dysfunctions and the loss of diversity can be based on decentralized water storage systems that make use of the existing fine grain structures of local landscapes –ditches, streams, land depressions, former pits, hedge-rows, dirt roads, paths etc.- and promote a local-based utilisation of resources (resilience), while fostering a stronger local identity, biodiversity and accessibility for more coherent spatial arrangements.

The intent of the research investigation was not, of course, to go back to the past. Rather, it drew on lessons from the past and on the fine grained potential of the local landscape in order to better address future challenges regarding the arrangements of space and water. This implies exploring new perspectives, testing new plans, and discovering new promising multifunctional combinations.

In the chapter, the main research findings are discussed, and recommendations for future research are proposed. The arguments are organized according to the twofold research hypothesis discussed in the analytical and design parts respectively. Main findings and recommendations for future research are also briefly outlined for the toolkit of guiding models resulting from the learning process.

9.2. Analysis

Main findings

The analysis provides a fine description of the spatial changes of the last decades at the two scales of the local landscape and the territory of the water board. It is among the first attempts to systematically describe the changes of a decentralized urban landscape addressing the consequences on space, water flows and actors.

The diachronic comparison of the case study area between the 1950s and the 00s clearly exhibit how the urban landscape of the *Città Diffusa* is challenged by densification, up scaling, concentration and functional separation of activities and related structures, which however also brought considerable wealth to the Veneto. The observation of the different water flow patterns arrangements in the same periods shows that some processes of change were successful in bringing about substantial improvements in the provision of water services. The overall water system has been made more centralized. The supply of water from upstream sources and the discharge of water to downstream sink points have been intensified. The analysis however also points out that centralization has brought about a number of controversial issues.

First of all, the arranged centralized systems draw heavily on resources and often risks exceeding the carrying capacity of the region. In practice, the articulation of the water cycle in more centralized systems, to a certain extent, seems to fail in providing sustainable effects. Problems of drought, floods and pollution as well as conflicts among users are rising. In regard to this, the difficulties, in guaranteeing the environmental flow of the Adige River or the depletion of groundwater, as the analysis revealed, are emblematic.

Secondly, the imposed centralized systems, have led to a clash with the decentralized horizontal extension of the settlements and they do not take advantage of the hybrid character of this territorial palimpsest. This investigation shows that there is a discrepancy between formal centralized prescriptions and organizations on the one side, and the current modus operandi on the other. The formal logic is to extend a more centralized control. Nevertheless the extended centralized systems of services are difficult to control and, oftentimes do not perform properly. Moreover, many inhabitants do not have access to the centralized drinking water and sanitation systems, nor are farmers always provided with irrigation water. Commonly the gap is bridged through the use of individual decentralized systems. In any case, the provision of centralized services does not mean that the decentralized infrastructures are dismantled and, in most of cases, there end up being more hybrid centralized/decentralized equipments. The decentralized systems -that are often illegal- are simply ignored by the institutions, which, up to now, have not yet designed suitable alternatives. A modernized decentralized arrangement of water, indeed, is not yet an option. To solve this situation, research and politics are often intended to limit the phenomenon of landscape consumption. Furthermore, the analysis also showed that the reduced local retention of stormwater operated from the extended urbanized areas and the modern agriculture threatens the drainage system downstream. The onsite retention imposed from the law to the new urbanized areas does not solve the problems related to the existing fabrics.

Thirdly, the analysis clearly illustrates how the prolongation of the centralized systems has gone along with the spread of infrastructures that are increasingly detached from the landscape. The fine grained field-ditches, road-ditches, streams etc. and their related vegetative and accessibility structures, all make up part of this rich capital asset, which is at the basis of the landscape's diversity. Unfortunately, this is all frequently abandoned or neglected, so the local landscape and the social practices therein result impoverished. The diachronic comparison in fact demonstrates that the negative effects on local biodiversity, accessibility and spatial legibility appear quite eloquent.

Limitations of the studies and recommendations for future research

The analytic frame allows for the development of a shared basic understanding of the problems -as well as the opportunities-related to the management of water in this decentralized urban landscape. While raising issues that do really matter in regards to identifying the limits of the present centralized arrangement of the water services, the findings should be corroborated with further qualitative and quantities studies in this field. The present research project, indeed, focuses on two case studies of the Veneto low plains –Ronco all'Adige the case study area of my Ph.D. studies and Ponte di Piave, the case study area of Zaccariotto's Ph.D. studies- in order to bring the current approach into question from the spatial-flows and actors perspectives. The path has thus been opened. The, discussion should however also be supported by arguments and contributions from investigations operated in other fields of knowledge. This could do justice to the complexity of this research topic. Regarding this, the initiation of one or more pilot projects can, for instance, generate a broader knowledge of different disciplines about the options for change.

The research clearly shows that this urban form is much more than the result of a process of urbanization. The rich stratification of the landscape should be displayed also for other areas of the plains. Another major field of improvement, indeed, concerns the spread of the analysis on other parts of the territory of the Veneto to build up a taxonomy of case studies, as a kind of atlas that can effectively portray a variety of landscapes of the *Città Diffusa* and explain how they have been recently developed. This could also potentially provide a sound basis for designing the future development of the region.

9.3. Scenarios

Main findings

The scenarios clearly illustrate that, from a water perspective, the città diffusa can actually perform as an ecopolis. In such decentralized landscapes, indeed, with relatively simple changes and not much energy input, the cycle of water can be closely compared and made to fit the scale of local landscape.

At the very beginning, a set of theoretical assumptions –guiding principles and guiding models- was assumed from the integrated water management approach and adjusted on the findings of the analysis. Focusing first on storage and recycling, making use of local diversity, seeking for synergism between the activities and starting bottom up, are the basic principles used to interrogate different parts of the *Città Diffusa* landscape. The household, the neighbourhood and the sub-catchment area are the three levels of decentralization explored. In the designed arrangements, rainwater and wastewater are the renewable resources to be differently detained, reused and/or recycled within the system, and they can reduce that system's dependence on external inputs and outputs.

A number of interesting issues result from the explorations.

First of all, the design strategies prove that the extended dispersed urbanization of the Veneto *Città Diffusa* is actually suitable to accommodating modern, integrated and decentralized systems of water. Private gardens, interstices between lots and roads, ditches, streams, former pits, agricultural fields etc. - i.e., the fine grained materials of this urban form- were adapted to convey, retain or process flows often by means of even minimal re-design strategies. Each scenario led to reactivate specific elements of the landscape, in order to minimize and control the excess, shortage and pollution of water. In the household strategy, roof and paved surfaces provide an extra amount of water that is detained and retained in small depressions of the private garden. The water stored there is reused for watering the same garden. In the neighborhood strategy, instead, stormwater intercepted from paved surfaces is buffered into re-shaped ditches crossing the area and in a small nearby forest patch. Wastewater is processed from the same little forest. The waters processed and detained, are stored in a pond which occupies a portion of a nearby agricultural field and are later used for watering gardens that are located in the same neighbourhood. In the catchment strategy, peaks relating to the spread-out urban sealed surfaces and modern "low-water-retention" agricultural fields are reduced into small depressed agro-forested patches spread throughout the catchment. Waste water from households and run off from fields is instead purified in a number of re-shaped former clay pits in the bottom part of the area. All of these processed and detained waters are then stored in the remaining former clay pits. In order to irrigate the crops of the catchment, the stored waters are distributed through a circuit of rearranged water board streams.

Secondly, the design strategy shows that the decentralized management of water is a tangible way for recovering the landscape. While providing suitable alternatives to the current practice of centralization of flows and infrastructures, it offers the opportunity to design new shared public spaces, for example, and, in general, to generate coherent spatial arrangements which enhance the ecological diversity of the sites and reconnect people to the local landscape. The water stored in the private gardens –at the household level-, for example, enlivens the image of the landscape and creates the conditions for species to move through a new cluster of small patches. Moreover, the dweller/owner of the garden is directly involved in the management of water. The circuit of new or retrofitted ditches and/or streams with permanent water –at neighbourhood and catchment levels- accompanies the transition between different land uses while supporting species and citizen movements. The periodically flooded agro-forested patches and the basins storing water all merge to the corridors of the circuits for water, while also providing resting places for species, hikers and cyclists. Lines and patches, as the integral parts of the decentralized water systems, are potentially new public spaces that can be shared and enjoyed by the inhabitants. Often they require the direct participation of citizens to operate their maintenance. In Ponzilovo, for example, the decentralized arrangement of the water service could increase the collective responsibility for the management of the housing environment. The inhabitant of the house is reintegrated to the landscape through direct functional relationships. New/updated reciprocal interests can hence be established. In this way, the residential settlements seem to answer the true demand for green living and the need for space and social cohesion required by the modern citizen who will probably spend more time in their local residential domain (van den Bout and Ziegler, 2002: 66). However, the major operations that can in effect be activated by “modern” citizens of the *Città Diffusa* according to their way of life have yet to be investigated.

Finally, the design explorations also show how the synergism between activities and actors increases the multifunctionality of the water systems. The collective woodlands, for example, may combine wastewater purification and firewood production for biomass power plants matching water services and agriculture. In the frame of integrated management of water, then, the urbanized surfaces are a resource for agriculture and vice versa. The decentralized options might even end up to be costlier than the conventional centralized design, but, at the same time, they can offer a number of ecosystem services. They can enhance the cohesion between elements in the environment, in order that dwellings, landscape and the *use* of the landscape can all become more connected.

Limitations of the studies and recommendations for future research

The bottom-up approach, taking advantage of the details in the local landscape, generates design proposals that fit in with the *Città Diffusa*. These design proposals are open for assessment and debate. Their results can be further evaluated in terms of consistency, feasibility and compatibility with the spatial, social and economic context in order to better understanding what makes most sense in the real physical environmental realm and what doesn’t. For example, the workshop with the experts revealed that the decentralized options have to be preceded and accompanied by a likely burdensome process of negotiation. In the decentralized perspective, indeed, institutions and citizens should be ready to cooperate. Local governance and community-led initiatives should definitely be set up. These procedures might bear numerous complications and constraints with respect to the present institutional framework. Regarding operations of maintenance, for instance, the water company, the waterboard, the municipality and private citizen groups should find new forms of agreement. In the frame of the research all these aspects were not dealt with in full. More research should certainly be conducted on these issues for there to be a valid evaluation of the matter.

Moreover, it appears clear that the decentralization of water is of a great interest when it is framed in the logic of its multifunctionality. In this way, the water system can effectively return to match a number of services and assets[245]. In the present research project, all these aspects were only briefly touched upon. Future studies should investigate this factor more carefully. This aspect in particular was also highly advocated and recommended by the experts during the workshop. The factor of multifunctionality is in fact crucial to achieving consensus regarding decentralized options. Can, for instance, the EU reforestation subsidies also be used to meet the need for onsite storage? Or, again, how can the storage of water be matched with the storage of solar energy[246]? As Dryzek (1987) noted in reference to the promotion of ecological rationality, weaving robust relations with the market is also an essential condition for the true success of the strategy. For instance, recycling water onsite, in general, means more vegetative structures on the landscape, such as forested patches, linear buffer strips, reeds etc. The vegetation of these facilities requires specific and regular maintenance operations. The resulting biomass can however be valuable for construction as well as for producing energy. Can an entrepreneur be interested in providing such a service while also benefiting from its waste products? This could all lead to the generation of a new market and new workplaces. Again, all of these issues and opportunities have to be further investigated.

Further, the scenarios showed possible scales and forms of reorganization of the local landscape that, on its own, might be seen as the hardware of the region. Nevertheless, how the implications of an eventual reiteration of the proposed decentralized systems would affect the broad scale of the region has still to be explored. On the other hand, all of these actions at the fine scale should be integrated with actions at a higher institutional and political level in order to build up a coherent vision for the entire region. In this regard, as it has emerged from the discussions with the panel of experts, decentralized and centralized approaches should better cooperate rather than exclude each other[247]. The elaborated design strategies worked out systems of complete decentralization of water -with the sole exclusion of drinking water provision. This effectively demonstrates the true potential of this kind of urbanised landscape.

[245] The analysis also showed that, during the 1950s, the water system was widely tuned to a multiplicity of requirements of the society of that time.

[246] The permanent storage of water requires space and the rough costs analysis showed that the expropriation of this space is what weighs most on the total costs. Now, the eco-incentives have recently promoted the spread of the photovoltaic systems all over the country. As a result, also in the Veneto, numerous solar fields cover the agricultural matrix. In the logic of multifunctionality, can they also perform water storage? In the case that the storage of water can be integrated within these decentralized water systems, part of the profits that these storage patches generate can be reinvested towards the improvements of the linear systems –e.g. the circulation system.

[247] Regarding this, the Sandwich Strategy designed by Tjallingii (1995: 86), proposes a way to avoid the central – decentral dilemma.

Nonetheless, in passing from research to practice, the decentralized options, while making the possibilities at hand more accessible, are likely to be combined with the presently used centralized systems. The decentralized water strategies could at least enter the lists of alternatives in use in current decision planning processes based on generating scenarios (e.g. Environmental Impact Assessment).

9.4 Guiding models and the learning process

Main findings

A set of models has been worked out by "injecting" guiding principles from the integrated water management approach into the water-flow structures of the low plains of the Veneto. The models are intended as a repertoire of action, or as a list of key moves that can be simply adapted and upgraded. As such, they resulted from a continual learning process that was developed from a combination of the literature review, the analysis and the explorative design. The models were finally all reviewed by experts from different fields of knowledge. A set made-up of eight models regards the fine grained operable elements detected as the building blocks of the *Città Diffusa* landscape (see the *Appendix A*). A number of other models are different versions of the main eight and were worked out through processes of design. A few others are the guiding models for higher levels of complexity: the first is the circulation model for a neighbourhood –and its different versions- devised by Tjallingii (1996: 208), and adapted to the conditions of the low plain of the Veneto, used and updated further along during the design exploration; the second is the circulation model for a catchment area, as another outcome of the design exploration (Figure 9.1.).

The guiding models proved to be reliable tools for employment in a design process that seeks for coherent and sustainable water flows and spatial arrangements. As a matter of fact, unlike a list of standards or maps with limiting conditions, the guiding models steered the overall design itself. The proposals based on the same guiding models sometimes criticized the models themselves and generated new guiding models. This is how the learning process effectively works.

Limitations of the studies and recommendations for future research

Consistent with the process of learning, models should be disseminated among institutions, and professionals (notably engineers and designers). On the one side, as the experts have noted, the models are ready and willing, suitable for making technicians and inhabitants more aware of the possibilities at hand. On the other side, it is just using them that they can continuously be implemented.

A possible weak point of this methodology is that, unlike the "ready to go" standards, it requires a great knowledge of the local landscape and it might thus result in design processes which are costly and time-consuming. The models indeed are not fixed objects to apply. Rather, the ideas about the basic organization of space and flows have to be carefully adjusted to the specificities of the site at hand.

Finally, from the discussion with the operators it emerged that, although in the Veneto a number of projects already internalized the ecological know-how, many of the ideas proposed in the designed strategies and models are not yet ready for daily decision-making on normal work. As the Tjallingii's Ecological Conditions Strategy proposes, pilot projects might play a role in creating consensus. They can concretely prove that in such a decentralized urban landscape decentralized water management options can perform much better than the current centralized ones. In turn the pilot projects can provide feedbacks to improve the conceptual models further on.

A concrete design proposal

At the very end of this study, it should be acknowledged that the research process was carried out with the help and the direct participation of a number of local actors, like the inhabitants and technicians from both the municipality of Ronco all'Adige and the bodies for the management of water in the area. This has generated an interesting process of interaction and learning. As a result, the municipality and the waterboard became aware of the high potential of the former clay pits that can create conditions for mutual benefits at the spatial and water management level. They have therefore started to cooperate in a project for a "water park" where win-win combinations for flows, space and actors –with multifunctionality advocated as a crucial point- are made concrete. The plan developed integrates the knowledge on the site from previous researches as well as those provided by the present study. Guiding models guided the design research and, in turn, new guiding models were elaborated. Various hydrological functions were established for the park that would traditionally be devoted to recreation and biodiversity conservation alone. As an example, the project further provides guidelines for possible future processes of excavation. In this way it can bring together devices for environmental needs with economic, social and aesthetic targets (Figure 9.2.). The plan is ready for public discussion and the institutions involved are now looking for the funds needed to start a part of it as pilot project.

The research offers arguments for the project of restructuring the image of the city of dispersion. The study also confirms that the città diffusa can actually compete with other urban forms under the condition that the process of its system's infrastructure improvements plays on the inner capacity of this urban landscape to carry on more sustainable kinds of development. To this end, specific models, plans and tools, like those that were developed by the present research, have to be further elaborated, while keeping an eye on the advanced concepts that are being generated for the compact city form and, some particular alternative opportunities that dispersed urbanization can offer. In this respect the study opens up a new path-way and shows how design concepts that fit decentralized urban contexts can be elaborated and enhanced.

Appendix A

Guiding models[248]

Small basic types of spaces of fine scale are the most common building blocks of a variety of patterns in the urban landscape of the Veneto *Città Diffusa*. Agricultural fields, detached dwelling and industrial lots, roads, water board streams, former quarry areas, are all inflow-outflow systems, which undergo spatial arrangements and functioning are repeated by the hundreds or thousands in the broader regional scale. Starting bottom up, good models or generic solutions for these small operable elements are envisaged. They all propose a shift from inflow-outflow systems to resilient systems which detain, reuse and recycle water on their own. Reiteration of these self reliant and self responsible fine grained systems could mean a quite significant cumulative effect at higher levels[249].

As "solutions in principle" the models might appear as stubborn theoretical assumptions. During the design process, indeed, they must be adjusted to the local opportunities, namely the specific areas, flows and actors of the site at hand.

A.1. Built lot system

A.1.1. Dwelling lot[250]

The guiding model illustrates the shift from a conventional residential dwelling lot to a *resilient dwelling lot*.

[248] A large part of this chapter already appeared in the Zaccariotto's Ph.D. dissertation (2010). The models conceived by Giambattista Zaccariotto were afterwards developed further by common explorations at the at the Department of Environmental Design of TU Delft under the supervision of Prof. Sybrand Tjallingii.

[249] According to Tjallingii (1996: 242), a self reliant system tends to reduce inputs and outputs of drinking water, groundwater, surface water and wastewater from and to the outside. A self imposed responsibility system aims at water pollution prevention, location and abatement. Using the words of Marsh (2005, 182), each system proposed forms "a water management unit, a parcel of land designed to integrate water, soils, plants and landscape aesthetics into a manageable and, ultimately, sustainable subsite or landscape cell". Each unit is, in turn, framed within a larger landscape to which it directly contributes.

[250] Lots of different scales and coverage can be isolated or grouped within housing areas. Usually the lot presents premises, private open spaces of paved surfaces, a garden and, sometimes, a vegetable garden.

Conventional residential dwelling lot site (Figure A.1., 1a, 1b)
The conventional dwelling lot uses water of good quality from upstream and discharges water of worse quality downstream.

Structures and flows. Drinking water is let in by a centralized service (*dw*). Rainwater, collected by a stormwater system (*dr*), is quickly removed from the lot (*rw*) and discharged into surface waters (*sw*). Grey water and black water are mixed and collected by a sewer (*ww*) that leads to a purification system far away from the lot. At the parcel level ground water (*gw*) is pumped up and used for watering and car washing (*ir*).

Maintenance and institutional conditions. Connections to public services are in the private domain and therefore maintained by the owner. Maintenance operations of private surface water bodies are also the owner's duty.

Resilient dwelling lot site (Figure A.1., 2a, 2b)
A *resilient dwelling lot* retains, stores and recycles flows, making use of its own lot resistance and retention potential.

Structures and flows. Rainwater (*rw*) from roofs is detained and retained in a rainwater storage unit and directly reused for non-potable water services. Overflow from the roof-rainwater storage unit and runoff from paved surfaces and gardens (*dr*) flow through a purification system (like a buffer strip) before being buffered by a surface water body like a lot-ditch that can either combine peak and seasonal storage functions or not[251] (Figure A.1., 2b, *storage*). Controlled groundwater (*gw*), abstracted onsite, serves potable uses and bathing (*dw*). Gray water, if not separately recycled, is processed together with wastewater (*ww*) that is recycled by a lot-scale purification system consisting of primary, secondary and finishing treatments (Figure A.1., 2b, *treatment*)[252]. The effluents are retained in the storage facility (Figure A.1., 2b, *storage*). The water stored is reused for water services like cleaning water (*cw*) and watering (*ir*)[253]. Groundwater makes the system capable of coping with extreme droughts. Water surplus is discharged into the surface water network by means of an outlet (*sw*). In the model purification system, peak and seasonal storage units are integrated in a flow chain. Water is circulated (Figure A.1., 2a) or is otherwise oxygenated to keep its quality.

Maintenance and institutional conditions. The owner regularly maintains the system following defined procedures[254]. Treatment facilities are periodically monitored by experienced and

[251] Dimensions of the peak storage should be computed according to the regional council deliberation DGR 1841/2007.
[252] A good example for a wastewater purification system is a chain consisting of a sedimentation tank (primary treatment), gravel/sand filter (secondary treatment) and a constructed wetland (Schuetze and Tjallingii, 2008: 141). Nonetheless a lot scale disinfection system has also to be integrated within the treatment chain.
[253] Cleaning water (cw) stands here for non-potable domestic water uses like washing clothes and flushing toilets. See Schuetze and Tjallingii, 2008: 88.
[254] For example, in the case of a constructed wetland serving as a tertiary purification facility, the reeds need to be harvested to remove the nutrients absorbed into leaves and stems (Schuetze and Tjallingii, 2008: 141). The harvested

skilled guidance representatives employed in the company which provide drinking and wastewater services. The quantity and quality of ground water are also monitored by a remote system run by the same company. In case of extreme pollution, the system is automatically blocked. Fees for excessive abstraction are charged. The private owner is responsible for the efficiency of the other parts –a lot-ditch system, storage facilities, pumps, weirs and connections.

Costs and benefits. The extra costs for the water-storage equipment can be flattened in the long run. In fact, the storage of rainwater and treatment of wastewater lead to disconnection from the centralized water services for drinking and waste, and this results in lower fee payments. Besides, the biomass produced from storing and recycling facilities (like wetland and buffer strips) could be reused to supply the dwelling heating system.

Examples

Best Management Practice for residential parcel. In: Marsh, W., 2005. Landscape planning: environmental applications. Hoboken: John Wiley & Sons Inc., 252.

Schuetze, T., Tjallingii, S.P., (ed.), 2008. Every drop counts, environmentally sound technologies for urban and domestic water use efficiency. TUDelft/UNEP, Delft/Osaka, 146-148.

Quelques exemples de promotion des techniques alternatives. In: Chouli, E., 2006. La gestion des eaux pluviales urbaines en Europe: analyse des conditions de developpement des techniques alternatives, Ph.D. diss., Ecole Nationale des Ponts et Chaussees, Paris.

The Sustainable House – Sydney, New South Wales, Australia. In: Mouritz, M., Evangelisti, M., McAlister, T., 2006. Water sensitive urban design. In: Wong, T., H., F., (ed.), Australian runoff quality: A guide to water sensitive urban design, Crows Nest: Engineers Media, 26.

A.1.2. Industrial lot[255]

The guiding model illustrates the shift from a conventional industrial lot to a *resilient industrial lot*.

reeds can be used as raw material for biogas production. This activity can be maintained by the municipality in accord with the water services company. As an instance, the by-product (sludge) can afterwards be spread on farmland (Hansson and Fredriksson, 2003).

[255] Lots of different scales and coverage can be either isolated or grouped to form industrial areas. Commonly in a lot the open spaces are, to a large extent, impervious and used for storing materials or parking.

Conventional industrial lot site (Figure A.2., 1a, 1b)
The conventional industrial lot lets in water of good quality and discharges a considerable amount of polluted water downstream.

Structures and flows. Drinking water (*dw*) that is let in from the centralized service is used for both potable and not potable uses. Groundwater (*gw*) is often abstracted at the level of the lot and used as an additional source to supply industrial processes (*se*)[256]. Rainwater from roofs (*rw*) and rainwater from paved surfaces (*dr*) is collected by storm drains, mixed and rapidly discharged into surface waters (*sw*). Grey water and black water are collected by sewers (*ww*) and delivered to a purification system far away from the lot[257].

Maintenance and institutional conditions. Connections to public services, lot purification facilities and lot drainage facilities, like gutters and ditches, are private and therefore maintained by the owner.

Multifunctional resilient industrial lot site (Figure A.2., 2a, 2b)
The *resilient industrial lot* retains, stores and recycles flows, making use of its own lot resistance and retention potential.

Structures and flows. Rainwater (*rw*) from roofs is held and stored in a rainwater storage unit and directly reused for non-potable uses. Overflow from the roof-rainwater storage unit and runoff from paved surfaces (*dr*) flow through a first flush purification facility that traps stormwater pollutants like metals and oil (Figure A.2., 2b, *buffer strip*). From there water flows into a surface body of water having enough capacity to buffer peaks[258] (Figure A.2., 2b, *storage*). The composition this storage facility might depend on whether re-functioned or new lot-ditches are used, and whether they can or cannot combine peak storage and seasonal storage functions. Controlled groundwater (*gw*) is abstracted on-site to serve potable uses only (*dw*)[259]. Black waters, grey waters and the effluents of the industrial processes (*ww*) are locally retained and processed by a lot-scale purification system, composed of primary, secondary and finishing treatments[260] (Figure A.2., 2b, *treatment*). The outlets are stored in the storage facility (Figure A.2., 2b, *storage*). The water stored and recycled supports cleaning services like washing and flushing toilets and non potable industrial processes (*se*). When the requirements for an industrial process are larger than the amount of rain falling in the lot, water is let in from the surface water network (*sw*). In turn, water surplus from storage can be discharged into the surface water network by means of an out-let (*sw*). In the model purification system, peak and

[256] The acronym 'se' is used here for generic water services. Potable uses are excluded.
[257] Often highly polluted industrial wastewaters are locally treated and afterwards discharged to the surface water.
[258] Dimensions of the peak storage unit are computed according to the regional council deliberation DGR 1841/2007.
[259] In case of industrial processes making use of water of potable quality, groundwater is a suitable local source. However, its exploitation is not unlimited and is thus controlled by the company for drinking and wastewater water services.
[260] A good example of a wastewater purification system is a chain consisting of a sedimentation tank (primary treatment), gravel/sand filter (secondary treatment) and a constructed wetland. In case of high levels of pollution, an individual or semi-collective mechanical wastewater treatment plant can be a suitable treatment alternative. Moreover a lot scale disinfection system has also to be integrated within the treatment chain.

seasonal storage are integrated in a flow chain. Water is circulated (Figure A.2., 2a) or is otherwise oxygenated to maintain its quality.

Maintenance and institutional conditions. The owner regularly maintains the system following defined procedures[261]. Treatment facilities are periodically monitored by experienced and skilled guidance representatives employed by the company that provides drinking and wastewater services. The quantity and quality of ground water are also monitored by a remote system run by the same company. In case of extreme pollution, the system is automatically blocked. Fees are charged for abstraction excesses. The private owner is responsible for the efficiency of the other devices – ditches, storage facilities, pumps, weirs and connections.

Costs/benefits. The investment on the storage facilities can be flattened in the long run. Indeed storage of both rainwater and treated wastewater leads to disconnection from the centralized water services for drinking and waste. This means a reduction of the owner's fee payments. The biomass produced from storing and recycling facilities (like wetlands and buffer strips) can also be sold. The high level of self-responsibility reached by the firm can be redistributed in the form of tax breaks.

Examples.
Industrial site management. In: Marsh, W., 2005. Landscape planning: environmental applications. Hoboken: John Wiley & Sons Inc., 181.

A.2. Agricultural field system[262]

A.2.1. Resilient agricultural field

The guiding model illustrates the shift from a conventional agricultural field to a *resilient agricultural field*.

Conventional agricultural site (Figure A.3., 1a, 1b)
The conventional agricultural field withdraws a considerable amount of surface water from upstream, and sometimes from the ground (aquifer), and discharges polluted water downstream.

Structures and flows. Rainwater surplus is quickly removed from the field through a drainage system of ditches and drains to a receiving stream (Figure A.3., 1a, *sw*). In summer surface

[261] See the resilient dwelling lot guiding model. In addition, attention has must be paid to the maintenance of first flush facilities.
[262] Fields packed in the agricultural matrix might present a variety of arrangements and extensions.

water from stream is let in and differently distributed into the field for irrigation (*ir*)[263]. When surface water is insufficient, groundwater is locally pumped up and distributed (Figure A.3., 1b, *groundwater* and *well*).

Maintenance and institutional conditions. Field ditches are in the private domain. The owner is responsible for their efficiency.

Resilient agricultural field (Figure A.3., 2a, 2b)
The *resilient agricultural field* retains, stores and recycles flows, making use of its own resistance and retention potential.

Structures and flows. Stormwater (*dr*) flows through a buffer strip before reaching field ditches (Figure A.3., 2b, *buffer strip*). In this way overland and subsoil flows are treated by the combined action of roots, soil and microorganisms contained in the soil. In turn nutrients stimulate the growth of trees and shrubs. Water is then retained in the ditches re-shaped to have more room for water (Figure A.3., 2b, *ditch*). The retained stormwater also fluctuates into the field ditches, and only the excess is released downstream. Ditches merge to form a water-course circuit –circulation system- through which the water stored is circulated and further processed by reeds (Figure A.3., 2a). The recycled and harvested water is afterwards reused onsite for irrigation (Figure A.3., 2b, *ir*). In the case storage unit has in sufficient capacity, pre-treated wastewater from nearby settlements can be let in, and reused after being recycled further on in the circulation system. Buffer strips and retrofitted ditches make the agricultural site more resilient, combining flow purification, peak and seasonal storage as a whole[264].

Maintenance and institutional conditions. The owner maintains and controls the system. The use of additional inlets, like pre-treated wastewater, is overseen by the water company in charge for the drinking and wastewater services.

Costs/benefits. The costs for the additional land used to retain and process water locally can be flattened by benefits related to the multiple services that the system provides. The *agricultural field* stores and recycles water that can be used for irrigation. the buffer strip is a source of biomass and carbon credits as well as a number of products like mushrooms, herbs and honey (Antonini et al., 2002: 30).

Examples.
Pilot project *Vallevecchia*, Veneto Agricoltura and Consorzio di Bonifica Pianura Veneta Orientale. Project: 2000. Realization: 2004-2005.

[263] There is a wide range of irrigation systems and arrangements. For example, water from the ditches is pumped and distributed through sprinklers or drop irrigation systems. For a comprehensive overview see Giardini, 1982: 285.
[264] The water stored tends to make the water table higher with possible loss of cultivation. In order to avoid such loss, the use of clay soil to cover the slopes of ditches can reduce their permeability. The shift to hydroponic cultivation might also be an alternative.

Bendoricchio, G., Bixio, V., Giardini, L., 1994. Ricerche Sperimentali sugli effetti del drenaggio controllato nella riduzione del rilascio inquinanti da sorgenti diffuse. XXIV Convegno di idraulica e costruzioni idrauliche, Napoli, 20-22 Settembre 1994.

A.2.2. Forested buffer strip

The guiding models illustrate the shift from a conventional agricultural field to a *resilient agricultural field* named *forested buffer strip*.

Conventional agricultural site (Figure A.4., 1a, 1b, 1c).
The conventional agricultural field withdraws a considerable amount of water from upstream and sometimes from the ground (groundwater) and discharges polluted water downstream.

Structures and flows. Rainwater surplus is quickly removed from the field and discharged into receiving streams (Figure A.4., 1a, 1c *sw*). In summer surface water is let in from the streams and distributed into the field for irrigation[265]. When surface water is insufficient, groundwater is locally withdrawn and distributed.

Maintenance and institutional conditions. Field ditches are in the private domain. The owner is responsible for their efficiency.

Forested buffer strip (Figure A.4., 2a, 2b, 2c)
The *forested buffer strip* recycles water and contributes to preventing floods.

Structures and flows. Polluted water from a stream (Figure A.4., 2a, 2b, *sw*) or a wastewater pre-treatment facility (performing primary, secondary and tertiary treatment as well as disinfection) (Figure A.4., 2c, *treatment plant*) is delivered to a system of distributing ditches. Water slowly filtrates into collecting ditches. Trees are planted along ditches to form forested buffer strips[266]. Overland flow and subsoil flows are purified by the combined action of roots, soil and microorganisms contained into the soil (Figure A.4, 2b, small inclined red arrows)[267]. Collecting ditches deliver purified flows to either a storage facility or back to the surface water

[265] There is a wide range of irrigation systems and arrangements. For example, water from the ditches is pumped and distributed by sprinklers or a drop irrigation system. For a comprehensive overview see Giardini 285-305.

[266] Distances between ditches can vary from 7 meters (one meter of plantation per each side plus 5 meters for a maintenance passage) to few dozens of meters. It depends on the imperviousness rate of the soil. Each buffer strip can have a width varying from a few to several meters. The species planted can also be very different, but they should be possibly native and in accordance with the species already in the area.

[267] Nitrates are removed in a quantity depending on soil permeability, the height of the water table and concentration of inlet pollutants. According to Gumiero et al. (2008, 20), from the third year the total amount of nitrates can be reduced by 60%.

system (Figure A.4., 2a, 2c, *sw*). The forested area lets in water of low quality and slowly releases water of better quality downstream. Nutrients stimulate the growth of trees. Small dykes encircling the field system can foster retention potential of excess water from either a stream or sewage system (Figure A.4., 2a, *peak storage*; 2c, *overflow)*[268]. The *forested buffer strip* buffers and recycles flows, making use of natural processes and conditions of the local terrain. The agricultural site abates water pollution, reduces either flooding risk downstream or the risk of sewage overflow. Water purification becomes integrated in the local landscape.

Maintenance and institutional conditions. The agricultural site continues to be in the private domain. Maintenance operations are the owner's duty. However, when the forested buffer strip works as a surface water purification facility, the water board oversees the maintenance operations. If the system functions as a finishing treatment for wastewater, the water service company controls the quantity and quality of both inflows and outflows.

Costs/benefits. A portion of the agricultural matrix is retrofitted to provide a variety of functions benefiting farmers. The agro-forestry system purifies water; the owner can get part of the fee for the water purification service. The agricultural site produces biomass that can be sold. The agricultural site contributes to the reduction of CO2; it can mean getting subsidies or, according to the European Union Emission Trading Scheme, carbon credits to sell.

Examples
Pilot project *Sito sperimentale 'Nicolas"*, Mogliano Veneto, Treviso. In: Gumiero, B., Boz, B., Cornelio, P., 2008. Il sito sperimentale "Nicolas". Legnaro: Veneto Agricoltura.

A.3. Road system

A.3.1. Minor road[269]

The guiding model shifts a conventional minor road to a *resilient road strip*.

Conventional minor road (Figure A.5.1., 1a, 1b, 1c)
In the conventional minor road rainwater is quickly driven out and discharged downstream.

[268] Water of different quality is kept separate. This resistance function is very important especially when the system purifies pre-treated wastewater.
[269] Roads selected are municipal, provincial, regional and even state roads. They cross and connect different environments and communities of the Veneto *Città Diffusa*.

Structures and flows. Stormwater from the roadway on the one side, the adjacent built lots and field lots on the other side rapidly flow either to a ditch (Figure A.5.1., 1b) or to underground pipe (Figure A.5.1., 1c). From there it is delivered downstream to the surface water network.

Maintenance and institutional conditions. Depending on their rank different institutions provides for maintenance and control of ditches and pipes.

Resilient road strip (Figure A.5.1., 2a, 2b, 2c, 2d)
In the *resilient road strip* interstices between roadway and lots (agricultural, industrial or dwelling lots) are recovered to play as a whole that locally buffers, recycles and stores water.

Structures and flows. Rainwater runoff from asphalt flows through a strip of grass (*verge*) before reaching the drainage bodies (Figure A.5.1., 2b, 2c, 2d). Iron metals and oil washed in with the water are trapped. Water then either flows into a ditch where reeds further recycles water (Figure A.5.1., 2c), or slowly penetrates though permeable layers that remove sediments and pollutants (*infiltration trench*) (Figure A.5.1., 2d). Where possible the strip expands and stormwater from fields and lots has a longer way to reach the drain (Figure A.5.1., 2b). Water flows along the drainage system and is retained into linear storage facilities placed where space is available and water is demanded. Stormwater can fluctuate into the road strip system which has an extra capacity to flatten peaks at source. Earth mounding, trees, grass, shrubs meet stop and extend one beyond one another supporting recycling and storing of water.

Maintenance and institutional conditions. The road strip or singular segments are managed by locals and the users of the water stored. The water board oversees maintenance activities and distribution of the waters.

Costs/benefits. The road strip recovers waste lands like interstices and residual spaces overlapping a variety of programs. As linear, varied and dynamic infrastructure the road strip percolates the matrix supporting activities of the local landscape: besides water storing and recycling, the ’ecotone’ buffers noise and supports walking, orientation, biodiversity and biomass production.

Examples
Austin, Texas. In: Marsh, W., 2005. Landscape planning: environmental applications. Hoboken: John Wiley & Sons Inc.

Investigations into alternative treatment options for road runoff. In: Ryan, B., 2004. Stormwater infrastructure. In: Raxworthy, J., Blood, J., (ed.) The MESH book: landscape / infrastructure. Melbourne: RMIT Publishing.

Lynbrook Estate – Melbourne, Victoria, Australia. In: Mouritz, M., Evangelisti, M., McAlister, T., 2006. Water sensitive urban design. In: Wong, T., H., F., (ed.), Australian runoff quality: A guide to water sensitive urban design, Crows Nest: Engineers Media, 20.

A.3.2. Highway corridor

The guiding model regards a shift from a generic highway system to a *resilient highway corridor*.

Conventional highway (Figure A.6., 1a, 1b)
In the conventional highway rainwater is buffered and, after pre-treatment, is discharged downstream[270].

Structures and flows. Stormwater is rapidly removed from the road and delivered to a *rut* (Figure A.6., 1b) alongside the asphalt-ribbon. After *mechanical treatment* (Figure A.6., 1b) water is delivered to a parallel surface water body (*stream*) where it is buffered (Figure A.6., 1a, black weirs as contractions). From there water is slowly released to the surface water network downstream. Excess flow (overflow) is flushed to the surface water network without any treatment.

Maintenance and institutional conditions. The highway company provides for maintenance and control of the system.

Resilient highway corridor (Figure A.6., 2a, 2b)
The highway corridor is a system consisting of a first flush detention device (*verge*), an infiltration trench (*filter berm*[271]) and a storage facility (*storage*) combining bioremediation, detention and retention of water into an integrated whole. After recycling, indeed, water is retained and stored.

Structures and flows. Rainwater runoff from asphalt flows into the road ditch (*rut*), passing before through a strip of grass (*verge*) that retains contaminants, such as oil. From the rut water slowly filtrates through a sandy mound (*filter berm*) (Figure A.6., 2b). Afterward infiltration water fluctuates in the storage facility, where it is further purified by wetland bioremediation. Only excess is slowly released to the surface water network. Runoff and groundwater flowing

[270] The conventional highway system represented is based on recent highway projects in the Veneto Region, like the new bypass called Passante di Mestre.
[271] Filter berms are elongated earth mounds constructed along the contour of a slope. They are usually constructed of soil containing different grades of sand and a filter fabric and are designed to function in the same fashion as soil infiltration trenches, which have been shown to be highly effective in contaminant removal (Marsh, 2005: 211).

into the storage from the surroundings is processed by shrubs and tree roots of a buffer strip (Figure A.6., 2b). The water stored in the highway corridor can be locally reused.

Maintenance and institutional conditions. Maintenance and control of the system continues to be the duty of the highway company. In addition, grass should periodically be mowed, reeds harvested and polluted sediments in the verge and the storage facility periodically removed.

Costs/benefits. The costs for the additional land required can be flattened by the benefits from the multiple services that the system provides. The highway stores and remediates water that can be reused by the activities set along its corridor. The buffer strips and wetlands produce biomass (and carbon credits) that can be sold. The corridor reduces noise pollution and noise. As linear park, besides fast transport, the retrofitted highway can support a variety of full-free mobility such as walking and cycling.

Examples
Northeast-southwest highway, Slovenia. Bulc, T., Sajn Slak, A., 2003. Performance of constructed wetland for highway runoff treatment, Water Science and Technology, 48, 315–322.

A 70 motorway, Germany. Association of a motorway stormwater tank and the treatment of runoff from roads. In: Izembart, H., Le Boudec, B., 2003. Waterscapes. Barcelona: Editorial Gustavo Gili.

A.4. Stream system[272]

The guiding models illustrate the shift from a conventional stream to a *resilient streams corridor*.

Conventional stream (Figure A.7., 1a, 1b, 1c, 1d)
The conventional stream collects flows of different qualities (and from different sources) from surroundings and delivers them rapidly downstream.

Structures and flows. Run off from urbanized patches and roads, overland flows from agricultural sites, treated and untreated wastewater effluents, overflow from sewers, water from road ditches and field ditches and groundwater flows, all discharge quickly into the stream that rapidly delivers its flows to water bodies of higher ranks downstream. In summer a huge amount of water derived from upstream sources or, sometimes, stored before along the stream, gets back to the private surface water network via streams and then is used for irrigation. Weirs allow control of fluctuation and exchanges.

[272] The guiding models refer to streams of different rank and dimensions.

Maintenance and institutional conditions. Commonly streams are state property managed by the water board. Maintenance operations like removing of vegetation along the banks are turned towards keeping the streams own discharge capacity. The water board manages and controls weirs, gates and in general any structure installed along the streams needed to control water in the landscape.

Resilient stream corridor (Figure A.7., 2a, 2b, 2c, 2d)
The *resilient stream corridor* slows down, purifies and retains its waters making better use of resistance and retention mechanisms along its course.

Structures and flows. The widening of the cross section of a stream (Figure A.7., 2b, *riverine wetland*) or the adding of by-passes (Figure A.7., 2d, *riverine wetland/floodable area*) both provide the *stream corridor* with extra room for water. Runoff from urbanized patches and roads, overland flows from agricultural sites and groundwater pass through the buffer strips set along the stream banks (Figure A.7., 2b, 2d, *buffer strip*). This leads to slow down overland flow and to trap the pollutants[273]. Stream water can also flow through the riverine wetlands[274] (Figure A.7., 2b, 2d). In the wetlands water is cleaned. Infiltration rate and groundwater recharge increase. In case of high water level, water surplus fills the expansions. Discharge delays. The enhancement of longitudinal and transversal ecological functionality enables the *resilient stream corridor* to purify water and released it slowly downstream[275].

Maintenance and institutional conditions. A path along the bank allows the water board to maintain the system (Figure A.7., 2b, 2d, left bank side). The operations like mowing of grass and harvesting of reeds should cause as few disturbances as possible to habitats.

Costs and benefits. The stream expansions possibly retrofit former meanders or paleo-channels that are often state property[276] (Figure A.7., 1a, 1c, grey dotted line). Therefore costs for land expropriation can be significantly reduced. Moreover, in case of by-pass, expansions that are above phreatic groundwater can still be cultivated. In this case the water board refunds farmers only when water expands. However, the stream corridor plays multiple functions that can further justify the costs for its restoration. For example the *stream corridor* considerably pulls down the total amount of pollutants coming from the in-flows. It reduces the risk of back effects downstream and polluters should pay a fee for this service[277]. The *stream corridor* slows down and retains flows reducing risk of flooding both upstream and downstream[278]. As linear park the

[273] Regarding to this see for example Siligardi (2007) and Gumiero et al. (2008).
[274] The shift considers even the removal of any concrete layers covering the stream beds.
[275] In his book Indice di Funziuonalità Fluviale, Siligardi emphasis the role of the transversal dimension of the rivers (Siligardi 2007, 80).
[276] At least one bank is re-shaped in a stepped profile that performs a more ecological gradient.
[277] The retrofitted stream contributes to improve the quality of the water in the landscape. Indeed the purifying systems and processes typical of a stream environment are improved or reactivated.
[278] In case of heavy rainfall the stream can accommodate more stormwater from upstream and therefore water does not go back to the drainage system upstream.

stream corridor supports recreational activities such as walking, cycling and canoeing. The stream corridor produces biomass (both from wetlands and buffer strips) that the water board can use for biogas production. Finally, when playing as irrigation system, the *resilient stream corridor* has greater storage capacity with benefits for farmers.

Examples
Interventi di riqualificazione ambientale dei corsi d'acqua della terraferma veneziana, Regione Veneto & Consorzio di Bonifica Dese Sile.

Room for River, Holland. In: Ministry of Transport, Public Works and Water Management, 2006. Spatial Planning Key Decision 'Room for the River'. Investing the safety and the vitality of the Dutch river basin region. The Netherlands.

A.5. Excavation site system[279]

The guiding model illustrates the shift from a conventional quarry site to a *resilient excavation site*.

Conventional excavation site (Figure A.8., 1a, 1b, 1c)
The conventional former excavation site retains water. Surplus waters are discharged downstream.

Structures and flows. Rainwater falling into the site is retained by the quarries and, often, mixed with groundwater seepage. When water exceeds a certain level, surplus is discharged downstream in the surface water network.

Maintenance and institutional conditions. Pits are private domain. Maintenance operations depend on their use and function[280].

Resilient quarry area (Figure A.8., 2a, 2b, 2c)
The *resilient excavation site* stores and recycles waters by making better use of its own ecological potentials.

Structures and flows. Quarries are reshaped to perform as storage and water purification facility. Onsite rainwater and groundwater seepage are retained into the wetlands. Waters that enter from

[279] Pits area can be composed of holes of various depth and extension often ranked in groups, the quarries selected are result of land digging to obtain minerals such as clay, sand and, sometimes, interposed gravel stone.
[280] After the exploitation pits sites are differently retrofitted or turn into wastelands. Common uses are aquaculture, game fishing and hunting reserve.

surroundings like overland flow and interflow are treated by the buffer strips encircling the site (Figure A.8., 2b, *buffer strip*). Flows of different quality like stream water or the effluents of a wastewater treatment[281] are also let in (Figure A.8., 2b, *sw*; 2c, *treatment plant*). Excesses of water from streams or overflow from wastewater treatments can therefore be buffered into the wetlands that might be grouped and connected in a whole chain. In this case water easy circulates and is processed and oxygenated. Waters harvested and recycled can fluctuate till a certain level and be reused for different purposes. For example, from the wetlands water can get back to the surface water network and be used for irrigation. As a result the *resilient excavation site* gets in waters of different qualities and serves the surroundings with water of better quality.

Maintenance and institutional conditions. The *resilient excavation site* is a private domain managed by the water board that monitors quantity and consistence of inflows and outflows. When the system functions as finishing treatment of wastewater, the water service company controls quantity and quality of inlets and outlets. Periodically reeds have to be harvested.

Costs/benefits. The *resilient excavation site* retrofits former pits (that are often wastelands) to play a number of functions. The *resilient excavation site* recycles water and offers flood prevention and water supply. The *resilient excavation site* produces biomass (reeds and wood) that can be reused as construction material or for energy production (like biogas). The *resilient excavation site* can integrate recreation activities like bird-watching and canoeing.

Examples
Cave di Noale restoration, Noale, Venezia. Consorzio di Bonifica Dese Sile.

Cave Cavalli restoration, Marcon, Venezia. Consorzio di Bonifica Dese Sile.

Cave di Salzano restoration, Salzano, Venezia. Consorzio di Bonifica Dese Sile.

Crailoo sand quarries, Zanderij Crailo, Vista Landscape and Urban Design (1998-2004).

[281] Effluents from treatment plant or other primary, secondary and disinfection treatment facilities can be further recycled by the system. Attention is recommended in the case of groundwater seepage.

Appendix B

Rhythms computation

Rhythms regarding the scenario at the neighbourhood level are carefully studied for the computation of both the peak storage device and the seasonal storage device. As Wong (2006: 7) acknowledged, the performance of an urban water cycle management strategy is not determined by any individual event or dry spell, but is the aggregate of a continuous period of typical climatic conditions. Therefore modelling of peak storage and seasonal storage capacity involves the use of historical or synthesised long-term rainfall and evapotranspiration information, expected water consumption data etc. as well as the spatial features of the area. First step is the presentation of computations and modelling regarding the peak storage. Afterwards, computations and modelling concerning the seasonal storage will be illustrated.

B.1. Peak storage

According to the regional council deliberation DGR 2627/2002 and its following amendments (DGR 1322/2006 and DGR 1841/2007), in the settlement, the peak storage system buffers periodical stormwater with a recurrence of 50 years (ARI = 50 years). There are different methods for computing the dimensions of the peak storage. The *rational method* is considered appropriate and reliable for this level of exploration[282].

The rainfall runoff system is driven predominantly by climatic factors such as the occurrences of storm events and dry weather conditions (1). These factors are highly variable in seasonality, magnitude, and duration. Another fundamental condition is the coverage of the area since different types of land cover generate different runoff volumes (2). Rhythm of stormwater and coverage of the area are then closely interrelated (3).

According to the rational method:

(1) First the Intensity Duration Frequency curve (IDF) of the area is calculated by making use of the records from the monitoring station of Roverchiara, located a few kilometres downstream (Bixio et al., 2010: 108). The Gumbel distribution is the model used for quantifying risks associated with extreme rainfall with a return time of 5 years and 50 years. For the Gumbel

[282] Further explanations about the rational method are available from Marsh, 2005: 151.

distribution two parameters (α, ε) are used to fit the available precipitation data set related to different rainfall durations. Sub-hourly (5, 10, 15, 30, 45), hourly (1, 3, 6, 12, 24) and daily (1, 2, 3, 4, 5 consecutive days) rainfalls and related α, ε are considered for the parameterization of the Intensity Duration Frequency curve (IDF).

(2) Secondly, the average runoff coefficient is computed in considering the extension of paved surfaces (roofs, roads, parking lots), semi-paved surfaces (hard outdoor places) and gardens (lawns and vegetable gardens) (Table B.1.). The "effective area" resulting from the calculations is 25,900 m2.

Table B.1. "Effective area". Ponzilovo housing area

	paved surfaces	*semi-paved surfaces*	*gardens*	*total area*	*effective area*
area	14,700 m2	13,300 m2	23,400 m2	51,400 m2	25,900 m2
runoff coefficient[283]	0.9	0.5	0.2	0.504	

(3) Thirdly, the peak rainfall curve is singled out by interpolating the rainfall series with the percentage of covered surfaces of the housing area. The peak storage capacity has been computed with the assistance of the Consorzio di Bonifica Veronese water board and the Department of Civil and Environmental Engineering of the University of Trento. A spreadsheet in use from the water board is employed (Figure B.1.). In the model an outlet of 10 l/s/ha is considered that is the predevelopment drainage capacity of the area –corresponding to the average drainage capacity of the agrarian surface water network. The curve shows a critical rainfall quantity of 59.6 mm at 55 min return time 50 years. The corresponding peak storage capacity resulting from the model is 1,314 m3, which is the maximum amount of water that might occur in any one rainstorm over a fifty-year period (Table B.2.).

Table B.2. Rainfall curve, ARI 50 years. Ponzilovo housing area

	average annual maximum precipitation	*duration precipitation*	*peak storage*
return period 50 years	59.58 mm	55 min	1,314 m3

The same computation is used in considering the parameterization of the Intensity Duration Frequency curve (IDF) for rainfall events of 5 years return time (Figure B.2.). The curve shows a critical rainfall quantity of 40.74 mm at 55 min return time 50 years. The corresponding peak

[283] The runoff coefficients have been selected with the help of the Consorzio di Bonifica Veronese waterboard.

storage capacity resulting from the model is 830 m3, which is the maximum amount of water that might occur in any one rainstorm over a five-year period (Table B.3.).

Table B.3. Rainfall curve, ARI 5 years. Ponzilovo housing area

	average annual maximum precipitation	*duration precipitation*	*peak storage*
return period 5 years	40.74 mm	55 min	830 m3

B.2. Seasonal storage

The permanent pond receives daily waste water treated from the purification system and, periodically, rainwater from the atmosphere (precipitation) and buffered stormwater from the peak storage[284]. The seasonal storage releases water to the atmosphere daily (evaporation) and, periodically, to the irrigation systems for private gardens. All these inlets and outlets depend on a number of factors: number of inhabitants (treated waste water), patterns of precipitation and evaporation (buffered stormwater, irrigation demand) and the land cover (buffered stormwater, irrigation demand). Ins and outs are organized in a hydraulic model used to verify dimensions of the permanent pond designed. In the model, precipitations and evaporations are considered with reference to covered surfaces (Z), gardens extension (Y) and the area occupied by the pond (X). The resulting equation is as follows:

treated ww [IN] + (precipitation [IN] – evaporation [OUT]) x X – irrigation demand x Y [OUT] + runoff x Z [IN] = 0

(1) (2) (3) (4)

X= area of the seasonal storage
Y= area of the gardens
Z= area of the paved surfaces

In the equation, the unknown variable is the area of the seasonal storage (X). In fact, the area of the gardens to irrigate (Y) to which the irrigation demand is related, refers to the gardens of the settlements and that value is already known. Likewise, the area of the paved surfaces (Z) to which stormwater run off is related, refers to the covered areas of the settlements, a value which is also already known.

[284] As Wong (2006: 6) has noted, the adoption of alternative sources of water through roof-water and storm-water harvesting, and the reuse of reclaimed water increase the influence of climatic factors on the design and operation of the system.

At first the addends of the equation are revealed:

(1) *waste water treated [IN]*

Waste water is a daily contribution based on the consumption of drinking water per person and the number of inhabitants. After tertiary treatment, considering the 135 inhabitants, treated wastewater that can be stored is 18,8 m3 a day, with little changes during the year. It follows that, according to the number of days per month, treated wastewater per month varies from 526 m3 up to 583 m3 (Figure B.3.).

(2) *(precipitation [IN] – evaporation [OUT]) x X*

The addend (2) concerns the external contributions which result from the patterns of precipitation [IN] and evaporation [OUT] physically related to the area of the seasonal storage (*X*).

precipitation [IN]
The average monthly precipitation is computed on the basis of the data available from the monitoring station of Sorgà, considering series gathered over the 1993-2008 span (Figure B.4.) (Bixio et al., 2010: 195).

evaporation [OUT]
The average monthly evaporation is computed on the basis of the Penman-Monteith formula, neglecting the soil heat flux and the ratio between the bulk surface and aerodynamic resistances (i.e. r_s and r_a), as it follows[285]:

FORMULA

$$E = \frac{0.408\,R_n + \dfrac{900\,\gamma\,u_2\,(e_s - e_a)}{T + 273}}{\Delta + \gamma}$$

[285] The guidelines published from the Food and Agriculture Organization of the United Nations (Allen, R., G., Pereira, L., S., Raes, D., Smith, M., 1998. Crop evapotranspiration: guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56, FAO, Rome) are used as support for the computation.

LEGEND

E = reference evaporation $[mm\ day^{-1}]$,
R_n = net radiation at the crop surface $[MJ\ m^{-2}\ day^{-1}]$,
G = soil heat flux density $[MJ\ m^{-2}\ day^{-1}]$,
T = mean daily air temperature at 2 m height $[°C]$,
u_2 = wind speed at 2 m height $[m\ s^{-1}]$,
e_s = saturation vapour pressure $[kPa]$,
e_a = actual vapour pressure $[kPa]$,
$e_s - e_a$ = saturation vapour pressure deficit $[kPa]$

The data considered are again those available from the monitoring station of Sorgà gathered over the 1993-2008 time span (Figure B.5.) (Bixio et al., 2010: 166).

(3) *irrigation demand x Y [OUT]*

The addend (3) concerns the external outlet related to the irrigation demand of the gardens (*Y*). According to Metcalf and Eddy (2006: 1343), the irrigation of the backyards in Ponzilovo directly depends on
two conditions:

1) the differential between precipitation and evapotranspiration should be positive (≥0);
2) the soil moisture: the terrain should be saturated at a certain rate during the irrigation period.

This second condition (2) has to be uniquely met during the summer months and part of the spring. During the rest of the year, grass can be considered in a status of quiescence and does not absorb the percolated water. During winter time, water that percolates remains in the terrain and only when the terrain is saturated, excesses of water flow towards the drainage system. Absorption of rainwater from terrain depends on the permeability of the soil (K). In Ponzilovo, according to the clayey-loamy character of the soil, permeability is registered at about 37 mm a day.

At first, the monthly natural percolation (*PE n*) is calculated by subtracting the average monthly evapotranspiration (*ET*) from the average monthly precipitation (*P*) [286]. When the evapotranspiration is higher than precipitations, the natural percolation is equal to zero. In this case, indeed, the water to be supplied should only cover the saturated capacity of the soil.

Secondly, the monthly total percolation (*PE tot*) is computed by multiplying the permeability (37 mm a day) by the application factor (0.04) and the number of days corresponding to the irrigation period[287].

[286] Available evapotranspiration data set from (Bixio et al., 2010: 195).
[287] The formula is: saturated conductivity x 0.04 x number of days (irrigation period). The application factor is inferred from the experience of the Istituto Agrario di San Michele all'Adige, Fondazione Edmund Mach.

Thirdly, the monthly applied percolation (*PE a*) is calculated by subtracting the monthly natural percolation from the monthly total percolation.

Fourth, the monthly net evapotranspiration (*ET net*) is computed by subtracting the monthly precipitations from the monthly evapotranspiration. When the precipitation is higher than the evapotranspiration, the net evapotranspiration is assumed to equal zero.

Fifth, the monthly unit irrigation supply (*IR u*) is computed by adding the monthly net evapotranspiration to the monthly applied percolation. The fist refers to condition 1; the second refers to condition 2.

As in the area, water irrigation is supplied only between mid April and mid September, for the remaining months, the irrigation supplied is hypothesized to equal zero, and that of April and September is halved (*IR u hyp*).

In order to compute the total irrigation demand (*IR out*), the unit irrigation demand is then multiplied by the area of the garden (*Y*) of the settlement that are effectively irrigated with the waters of the storage system. This area is 19,900 m2. On the whole, the irrigation demand amounts to 10,900 m3 (Figure B.6.).

(4) runoff x Z [IN]

The addend (4) concerns the stormwater run off from paved areas (*Z*) that can be stored in the seasonal storage. It is worth noting that, although overflows from gardens and fields occur frequently in the area, the magnitude of these flows is considered as irrelevant in the computation of the seasonal storage. At first the runoff coefficients are assigned to paved surfaces (roofs, roads, parking lots) and semi-paved surfaces (hard outdoor places) (Table B.4.). The coefficients are then multiplied by the related surfaces to obtain the “effective area” (*Z*) or “contributing area”. From the calculation this area results as 20,000 m2.

Table B.4. The “effective area” (*Z*) generating stormwater runoff. Ponzilovo housing area

	paved surfaces	*semi-paved surfaces*	*effective area*
runoff coefficient[288]	0.9	0.5	
area	14,700 m2	13,300 m2	20,000 m2

[288] The runoff coefficients have been selected with the help of the Consorzio di Bonifica Veronese waterboard.

Subsequently, the runoff volume (*R in*) is computed by multiplying the average monthly precipitation for the "effective area" (*Z*). On the whole, the runoff volume amounts to 13,940 m3 (Figure B.7.).

The model results as illustrated in the Figure B.8.. The model exhibits that no storage of waste water (*WW in*) is needed to cope with the requirements. During the year, more than 11,000 m3 of stormwater runoff are stored in seasonal storage. Considering losses due to evaporation, the storage basin (seasonal storage, *version a*) has a capacity (*STO tot*) of 7,000 m3, an extension (*X*) of 2,200 m2, and a depth of 3.8 m. Maximum fluctuation in the pond is calculated at 3.2 m (*STO d*). The model shows that the seasonal storage discharges a maximum of about 2,300 m3 of water downstream per year (*DR out*).

The water from the purification system, as a daily contribution, might be stored to be reused for the irrigation of surrounding agricultural activities. For this purpose the model is updated, adding the contribution of treated waste water from the settlement (*WW in*) and the irrigation demand of a hypothetical corn filed 2.5 ha wide (*IR out (K)*) (Figure B.9.). The monthly irrigation demand of the field is inferred from the research worked out by the Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo (1984: 8) and the Regione Emilia Romagna (2004: 58) for a territory with comparable conditions.

In this case, during the year, about 19,500 m3 of water are stored into the seasonal storage in order to irrigate 2 ha of gardens (*Y*) and 2.5 ha of corn fields (*K*). The storage basin (seasonal storage, *version b*) has a capacity (*STO tot*) of 11,100 m3, an extension (*X*) of 3,300 m2, and a depth of 3.8 m. In the pond, maximum fluctuation is calculated at 3.4 m (*STO d*). The pond discharges a maximum of 1,300 m3 of water downstream per year (*DR out*).

Appendix C

Costs analysis

The storage devices designed for the scenario at the neighbourhood level are briefly examined and explained to make the proposed design options more concrete. The analysis does not pretend to be comprehensive, it instead aims to provide a general idea of the order of magnitude. The first four paragraphs (C.1., C.2., C.3.1., C.3.2.) all refer to the surface storage strategy comprising a peak storage unit, a purification system and a seasonal storage unit. The last two paragraphs (C.4., C.5.) concern the subsurface storage strategy employing a peak storage and a recharge well system.

C.1. Surface storage option, peak storage

Costs include expropriation, inclination of ditches, excavation, and appliances. In this paragraph, the paragraph for the linear system alone are presented. Costs for the area system -the multifunctional forested buffer strip- are not comprised as they are grouped with those for the purification system in the § C.2..

Expropriation. According to the current practice of the water board Consorzio di Bonifica Veronese, the cost for expropriation of cultivable land is about 15 euro/m2, whilst the cost for the expropriation of private gardens is about 80 euro/m2. Total cost for expropriation amounts to 63,400 euro (Table C.1.). However, floodable areas along the ditches might remain private, through payment of compensation to farmers when floods damage the cultivations. This way costs for expropriation would attest only the surfaces for the *a-c* sections, that is 31,200 euro.

Table C.1. Expropriation costs. Peak storage, surface storage option

	a-c section agriculture *(15 euro/m2)*	*a-c* section garden *(80 euro/m2)*	*d* section (4 m) agriculture *(15 euro/m2)*	*d* section (4 m) garden *(80 euro/m2)*	*a-c* + *d* section
linear extension	240 m	220 m	270 m	100 m	-
surfaces	480 m2	300 m2	1,080 m2	200 m2	4,330 m2
costs	7,200 euro	24,000 euro	16,200 euro	16,000 euro	63,400 euro

Inclination of ditches. According to the Consorzio di Bonifica Veronese water board, changing the inclination of ditches costs 3 euro/m. This operation would then cost 4,300 euro (Table C.2.).

Table C.2. Costs for the arrangement of the inclination of the ditches. Peak storage, surface storage option

	a-c section	*d* section	*a-c* + *d* section
linear extension	1,067 m	370 m	1,440 m
costs (3 euro/m)	3,200 euro	1,100 euro	4,300 euro

Excavation. According to the current practice of the Consorzio di Bonifica Veronese water board, the cost for the excavation of ditches and floodable areas ("scavo a sezione obbligata") amounts to 10 euro/m3. The total cost for excavation is then 14,500 euro (Table C.3.).

Table C.3. Excavation costs. Peak storage, surface storage option

	a-c section (0.96 m3 x m)	*d* section (2.75 m3 x m)	*a-c* + *d* section
linear extension	740 m	370 m	1,110
volume	710 m3	740 m3	1,450
costs (10 euro/m3)	7,100 euro	7,400 euro	14,500 euro

Appliances. Weirs are fixed and made up of a concrete foundation and a plate. According to the Consorzio di Bonifica Veronese water board, the unit cost for the weirs is 4,000 euro. Thus, the total cost for appliances amounts to 16,000 euro (Table C.4.).

Table C.4. Costs for the appliances. Peak storage, surface storage option

	weirs (4,000 euro)	*total*
n.	4	-
costs	16,000	16,000 euro

Total. The overall cost for the linear system of peak storage is 98,200 euro. This sum diminishes to 66,000 euro when the floodable areas along the ditches remain private (Table C.5.).

Table C.5. The total costs for the peak storage. Surface storage option

	expropriation	*inclination of ditches*	*excavations*	*appliances*	*total*
costs (all public)	63,400	4,300	14,500	16,000	98,200 euro
costs (private ditch enlargements)	31,200	4,300	14,500	16,000	66,000 euro

C.2. Surface storage option, purification system

Costs include expropriation, excavation, levelling and appliances. It is worth noting that although the forested buffer strip remains a private agro-forest area, costs for its arrangement (digging, shaping the surface, appliances) should rest on the entire community of Ponzilovo, while the plantation of the system is the duty of the landlord. In compensation, the farmer can greatly benefit from the newly provided irrigation.

Expropriation. The portion of the agricultural field occupied by the wetlands and other devices for purification of waste water -with the exclusion of the area occupied by the agro forest system- are all to be expropriated. According to the current practice of the Consorzio di Bonifica Veronese water board, the costs for expropriation of cultivable land is about 15 euro/m2. The total expropriation costs then amount to 27,800 euro (Table C.6.).

Table C.6. Expropriation costs. Purification system, surface storage option

area	1,850 m2
costs (15 euro/m2)	27,800 euro

Excavation. Only the excavation for the arrangement of the forested buffer strip is considered in this case. In fact, costs of excavation related to the other purification devices are incorporated in the costs for each single device. According to the current practice of the Consorzio di Bonifica Veronese water board, the cost for the excavation ("scavo a sezione obbligata") is 10 euro/m3. The total cost for excavations then amount to 6,300 euro (Table C.7.).

Table C.7. Excavation costs. Purification system, surface storage option

	diverting ditches (0.24 m3 x m)	*converting ditches (0.85 m3 x m)*	*collector ditch (0.96 m3 x m)*	
linear extension	329 m	465 m	164 m	-
volume	79 m3	395 m3	157 m3	631 m3
costs (10 euro/m3)	790 euro	3,950 euro	1,570 euro	6,300 euro

Shaping the surface. The surface of the forested buffer strip has to be moulded to provide for its proper hydraulic functioning. According to the current practice of the Consorzio di Bonifica Veronese water board, costs for the arrangement of the agrarian soil is 0.5 euro/m2. Costs for shaping the surface is then calculated at 5,500 euro (Table C.8.).

Table C.8. Costs for shaping the surface of the agro forested area. Purification system, surface storage option

	forested buffer strip
area	11,000 m2
costs (0.5 euro/m3)	5,500 euro

Appliances. Excluding those appliances that are integrated in each single device –whose price is incorporated in the single device price-, the system comprises a few hundred meters of pipes and two pumps. Each pump is provided with a solar panel system supplying the necessary power. According to the online pricing catalogue of the Veneto Region (2008), the cost for the pipes is 30.25 euro x m. The required capacity of the pump is 0.65 l/s (39 l/min = 2.34 m3/h). According to the current practice of the Consorzio di Bonifica Veronese water board, the cost considered for the single pump is 4,400 euro. On the whole costs for the appliances amount to 21,100 euro (Table C.9.).

Table C.9. Costs for the appliances. Purification system, surface storage option

	weirs	*pipes (30.25 euro x m)*	*pumps (4,400 euro)*	*total*
n.	-	406 m	2	-
costs	-	12,300	8,800	21,100 euro

Total. Costs for excavation of ditches and shaping the surface of the forested buffer strip amounts to 11,800 euro. The overall cost for the collective purification system considering expropriation and the other devices is 208,200 euro. It is worth noting that this sum comprises even the peak storage services provided by the multifunctional forested buffer strip (Table C.10.).

Table C.10. The total costs for the purification system. Surface storage option

	screening	*septic tank*	*HW*	*VW*	*chlorine contact chamber*	*activated carbonco ntractor*	*forested buffer strip*	*appliances*	*expropria tion*	*total*
costs[289]	2,700	9,000	61,200	66,000	4,600	4,000	11,800	21,100	27,800	208,200

C.3.1. Surface storage option, seasonal storage *version a*

When the seasonal storage holds only stormwater (*seasonal storage version a*), a permanent pond that is 2,200 m2 wide and 3.8 m deep is needed (see *Appendix B*). Costs include expropriation, excavation, liner and appliances. It is worth noting that costs regarding the circulation system are not comprised as they are illustrated above in the above § C.1..

Expropriation. The area of the agricultural field occupied by the pond has to be expropriated. As accounted above, according to the current practice of the Consorzio di Bonifica Veronese water board, the cost for expropriation of cultivable land is 15 euro/m2. The total costs for expropriation amount to 42,000 euro (Table C.11.).

Table C.11. Expropriation costs. Seasonal storage *version a*, surface storage option

	permanent pond
surface (considering a belt 2.5 m wide to access the pond)	2,800 m2
costs (15 euro/m2)	42,000 euro

Excavation. A portion of the agricultural field accommodating the seasonal storage has to be excavated to make room for water. According to the online pricing catalogue of the Veneto

[289] Costs of the appliances ‘with the exclusion of the forested buffer strip- have been furnished by Carra Depurazioni s.r.l, a company that specializes in selling wastewater treatments systems.

Region (2008), the cost for the excavation (“scavo di sbancamento”) is 7.86 euro/m3. Excavation costs then amount to 66,000 euro (Table C.12.).

Table C.12. Excavation costs. Seasonal storage *version a*, surface storage option

	permanent pond
volume (2,200 m x 3.8 m)	8,400 m3
costs (7.86 euro/m3)	66,000 euro

Liner. As the pond intercepts the phreatic groundwater, a liner is needed. For this purpose, the bottom and walls of the pool are lined with tar-bitumen roof, geotextile, a sand layer (0.2 m) and a gravel layer (0.2 m). The overall cost for lining the pond is 95,900 euro (Table C.13.; Table C.14.).

Table C.13. Surfaces of the permanent pond to be lined. Seasonal storage *version a*, surface storage option

	bottom	*walls*	*total*
surface	2,200 m2	860 m2	3,060 m2

Table C.14. Costs for the liner. Seasonal storage *version a*, surface storage option

	tar bitumen (15.18 euro/m2)	*geotextile (2.51 euro/m2*	*sand layer (40 euro/m3)*	*gravel layer (28.40 euro/m3)*	*total*
surface	3,060 m2	3,060 m2	-	-	-
volume	-	-	610 m3	610 m3	-
costs	46,500 euro	7,700 euro	24,400 euro	17,300 euro	95,900 euro

Appliances. Costs for appliances comprise those for the movable weirs, the well pump and the pump. Weirs are movable and made of a concrete foundation, a plate and a mechanism for regulation. The total cost is 18,800 euro (Table C.15.).

Table C.15. Costs for the appliances. Seasonal storage *version a*, surface storage option

	movable weirs (5,000 euro)	*well pump[290] (4,400 euro)*	*pump (4,400 euro)*	*total*
n.	2	1	1	-
costs	10,000 euro	4,400 euro	4,400 euro	18,800 euro

Total. The overall costs for the *seasonal storage version a* are 222,700 euro, excluding expenses for the circulation system. This sum diminishes to 156,700 euro when the excavation is a service provided by the local bricks industry (Table C.16.).

Table C.16. The total costs for the seasonal storage *version a*. Surface storage option

	expropriation	*excavation*	*liner*	*appliances*	*total*
costs	42,000	66,000	95,900	18,800	222,700 euro
costs (free excavation)	42,000	-	95,900	18,800	156,700 euro

C.3.2. Surface storage option, seasonal storage *version b*

When the seasonal storage held also the waste water treated by the purification system (*seasonal storage version b*), a permanent pond 3,300 m2 wide and 3.8 m deep is needed (see *Appendix B*). Costs include expropriation, excavation, liner and appliances. It is worth noting that costs regarding the circulation system are not included, since they are illustrated above in § C.1..

Expropriation. The area of the agricultural field occupied by the pond has to be expropriated. As accounted above, according to the current practice of the Consorzio di Bonifica Veronese water board, the cost for expropriation of cultivable land is 15 euro/m2. Expropriation costs then amount to 61,500 euro (Table C.17.).

[290] The pump should have a capacity of at least 1 l/s, that is 3.6 m3/h, in order to cope with the irrigation demand.

Table C.17. Expropriation costs. Seasonal storage *version b*, surface storage option

	permanent pond
surface (considering a belt 2.5 m wide to access the pond)	4,100 m2
costs (15 euro/m2)	61,500 euro

Excavation. A portion of the agricultural field accommodating the seasonal storage has to be excavated to make room for water. According to the online pricing catalogue of the Veneto Region (2008), the cost for the excavation ("scavo di sbancamento") is 7.86 euro/m3. Excavation costs amount in 98,600 euro (Table C.18.).

Table C.18. Excavation costs. Seasonal storage *version b*, surface storage option

	permanent pond
volume (3,300 m x 3.8 m)	12,540 m3
costs (7.86 euro/m3)	98,600 euro

Liner. As the pond intercepts the phreatic groundwater, a liner is needed. For this purpose, bottom and walls of the pool are lined with tar-bitumen roof, geotextile, a sand layer (0.2 m) and a gravel layer (0.2 m). The overall cost for lining the pond is 141,200 euro (Table C.19.; Table C.20.).

Table C.19. Surfaces of the permanent pond to be lined. Seasonal storage *version b*, surface storage option

	bottom	*walls*	*total*
surface	3,300 m2	1,200 m2	4,500 m2

Table C.20. Costs for the liner. Seasonal storage *version b*, surface storage option

	tar bitumen (15.18 euro/m2)	*geotextile (2.51 euro/m2*	*sand layer (40 euro/m3)*	*gravel layer (28.40 euro/m3)*	*total*
surface	4,500 m2	4,500 m2	-	-	-
volume	-	-	900 m3	900 m3	-
costs[291]	68,300 euro	11,300 euro	36,000 euro	25,600 euro	141,200 euro

Appliances. Costs for appliances comprise those for the movable weirs, the well pump and the pumps. Weirs are movable and made of a concrete foundation, a plate and a mechanism for regulation. Their total cost is 23,200 euro (Table C.21.).

Table C.21. Costs for the appliances. Seasonal storage *version b*, surface storage option

	movable weirs (5,000 euro)	*well pump*[292] *(4,400 euro)*	*pump*[293] *(4,400 euro)*	*total*
n.	2	1	2	-
costs	10,000 euro	4,400 euro	8,800 euro	23,200 euro

Total. The overall costs for the *seasonal storage version b* are 320,100 euro, excluding expenses for the circulation system. This sum diminishes to 221,500 euro when the excavation is a service provided by the local bricks industry (Table C.22.).

Table C.22. The overall costs for the seasonal storage *version b*. Surface storage option

	expropriation	*excavation*	*liner*	*appliances*	*total*
costs	61,500	98,600	141,200	23,200	324,500 euro
costs (free excavation)	61,500	-	141,200	23,200	225,900 euro

[291] The unit costs are based on the online pricing catalogue of the Veneto Region (2008) and the current practice of the Consorzio di Bonifica Veronese water board.
[292] As indicated above, the pump should have a capacity of at least 1 l/s.
[293] In the *version b* an extra pump is needed for the irrigation of the agricultural fields.

C.4. Subsurface storage option, peak storage

Costs include expropriation, inclination of ditches, excavation, and appliances

Expropriation. According to the current practice of the water board Consorzio di Bonifica Veronese, the cost for expropriation of cultivable land is about 15 euro/m2, while the cost for the expropriation of private gardens is about 80 euro/m2. Accordingly, the total cost for expropriation amounts to 172,200 euro (Table C.23.). However, floodable areas along the ditches might remain private through payment of a compensation to farmers when floods damage the cultivations. This way costs for expropriation would attest only those concerning the surfaces of the *a-c* section, that is 31,200 euro.

Table C.23. Expropriation costs. Peak storage, subsurface storage option

	a-c section agriculture *(15 euro/m2)*	*a-c* section garden *(80 euro/m2)*	*d* section agriculture *(15 euro/m2)*	*d* section garden *(80 euro/m2)*	*a-c* + *d* section
linear extension	240 m	220 m	480 m	100 m	-
surfaces	480 m2	300 m2	2,640 m2	550 m2	3,970 m2
costs	7,200 euro	24,000 euro	39,600 euro	44,000 euro	114,800 euro

Inclination of ditches. According to the Consorzio di Bonifica Veronese water board, changing the inclination of the ditches costs 3 euro/m. This operation then costs 4,900 euro (Table C.24.).

Table C.24. Costs for the arrangement of the inclination of the ditches. Peak storage, subsurface storage option

	a-c section	*d* section	*a-c* + *d* section
linear extension	1,070 m	580 m	1,440 m
costs (3 euro/m)	3,200 euro	1,700 euro	4,900 euro

Excavation. According to the current practice of the water board Consorzio di Bonifica Veronese, the cost for the excavation of ditches and floodable areas (“scavo a sezione obbligata”) amount to 10 euro/m3. The total cost for excavation amounts to 23,100 euro (Table C.25.).

Table C.25. Excavation costs. Peak storage, subsurface storage option

	a-c section (0.96 m3 x m)	*d* section (2.75 m3 x m)	*a-c* + *d* section
linear extension	740 m	580 m	1,110
volume	710 m3	1,600 m3	2,310
costs (10 euro/m3)	7,100 euro	16,000 euro	23,100 euro

Appliances. According to the Consorzio di Bonifica Veronese water board, the unit cost for the weirs is 4,000 euro. Weirs are fixed and made of a concrete foundation and a plate. The total cost for these appliances is calculated at 12,000 euro (Table C.26.).

Table C.26. Costs for the appliances. Peak storage, subsurface storage option

	weirs (4,000 euro)	*total*
n.	3	-
costs	12,000 euro	12,000 euro

Total. The overall cost for the linear system of the peak storage is 154,800 euro. This sum diminishes to 71,200 euro when the floodable areas along the ditches remain private (Table C.27.).

Table C.27. The total costs for the peak storage. Subsurface storage option

	expropriation	*inclination of ditches*	*excavations*	*appliances*	*total*
costs (all public)	114,800	4,900	23,100	12,000	154,800 euro
costs (private ditch enlargements)	31,200	4,900	23,100	12,000	71,200 euro

C.5. Subsurface storage option, aquifer recharge system

Costs include expropriation, excavation, infiltration soil and appliances. Costs for additional individual or collective stormwater treatments (even with those performed by the wadi and the infiltration trenches) are not considered.

Expropriation. The expropriation costs should be considered only when, all floodable areas (the enlargements of the ditches) remain as private lands. In this case, agricultural fields and gardens occupied by the wadi have to be expropriated as they shall accommodate permanent infrastructures. As accounted above, according to the current practice of the Consorzio di Bonifica Veronese water board, the cost for expropriation of cultivable land is about 15 euro/m2, while the cost for the expropriation of private gardens is about 80 euro/m2. The overall expropriation costs then amount to 55,200 euro (Table C.28.).

Table C.28. Expropriation costs. Aquifer recharge system, subsurface storage option

	wadi on private gardens (80 euro/m2)	*wadi on agricultural fields (15 euro/m2)*	*wadi total*
width	*5.5 m*	*5.5 m*	
length	*65 m*	*320 m*	*385 m*
surface	360 m2	1,760 m2	2,120 m2
costs	28,800 euro	26,400 euro	55,200 euro

Excavation. Those parts of the ditches equipped with wadi are excavated to accommodate infiltration soil and trenches. According to the current practice of the Consorzio di Bonifica Veronese water board, the cost for the excavation ("scavo a sezione obbligata") amounts to 10 euro/m3. The total costs of excavation then amount to 7,500 euro (Table C.29.).

Table C.29. Excavation costs. Aquifer recharge system, subsurface storage option

	infiltration soil	*trench*	*total*
volume	519 m3	231 m3	750 m3
costs (10 euro/m3)	5,190 euro	2,310 euro	7,500 euro

Infiltration soil. A layer of sand (0.2 m) is needed to make the infiltration soil, while humus is collected and used onsite. Total costs for this material is 14,000 euro (Table C.30.).

Table C.30. Cost for the infiltration soil. Aquifer recharge system, subsurface storage option

	infiltration soil – sand (40 euro/m3)
volume	350 m3
costs (40 euro/m3) [294]	14,000 euro

Appliances. Costs for appliances comprise those for trenches (expanded clay, geotextile and drainage pipes) and the recharge well. Considering the tank and the pump, costs for the recharge well amount to 10,000 euro. According to the online pricing catalogue of the Veneto Region (2008) and the current practice of the Consorzio di Bonifica Veronese water board, sand costs 40 euro/m3, expanded clay costs 30 euro/m3, geotextile 2.51 euro/m2 and the installation of drainage pipes costs 30.25 euro/m. The total costs for appliances are hence calculated at 30,800 euro (Table C.31.).

Table C.31. Costs for the appliances: expanded clay, geotextile, drainage pipes, total. Aquifer recharge system, subsurface storage option

	expanded clay – trench (30 euro/m3)
volume	231 m3
costs	6,930 euro

	geotextile (2.51 euro/m3)
volume	850 m2
costs	2,130 euro

[294] The unit costs are based on the online pricing catalogue of the Veneto Region (2008) and the current practice of the Consorzio di Bonifica Veronese water board.

	drainage pipes – trench (30.25 euro x m)
length	385 m
costs	11,650 euro

	expanded clay – trench	*geotextile*	*drainage pipes – trench*	*pump*	*total*
costs	6,930 euro	2,230 euro	11,650 euro	10,000 euro	30,800 euro

Total. The overall costs for the aquifer recharge system amount to 107,500 euro. This amount diminishes to 52,300 euro when all the floodable areas of the peak storage are expropriated (Table C.32.).

Table C.32. The total costs for the aquifer recharge system. Subsurface storage option

	expropriation	*excavation*	*materials*	*appliances*	*total*
cost	55,200	7,500	14,000	30,800	107,500 euro

Appendix D

Questionnaires

The interview is among the tactics employed to conduct the analysis of the changes concerning the spatial and the water-flows patterns of the case study area in the time spam selected. Inhabitants on the one side and technicians (state-owned, regional and local water company officials) on the other side were asked to answer a number of different questions. The first paragraph contains the questionnaire followed to interview the inhabitants. In the second paragraph the questionnaire that has guided the interviews with the technicians is presented.

D.1. Semi-structured interview with the inhabitants - phase one, level 1

Drainage and irrigation system

1. What were the agricultural practices in the 50s, in what did they differ from today's ones? Can you explain, in particular, what were the prevailing elements in those times' agricultural system (capezzagna, cavino, ditch, vite maritata, legumes, maize, wheat, orchard, etc.)?

2. What were the elements and the working system of the water surface network (drains, ditches, channels) in the 50s? What were the irrigation sources and forms? Had the surface water network a different relation between the present space form and the previous one?

3. Had the surface network a different density in the 50s compared with today?

4. Was there a greater or a smaller water abundance in the 50s surface network?

5. Along the elements of the surface network, had vegetation a density/form/contents different from the present one?

6. What were the other roles of ditches and drains in the 50s? Can you remember some agricultural and/or social practices connected with the ditch and drain network in the above mentioned years?

7. Do you think there have been considerable transformations, with regard to the form/function and density of the surface network (drains, ditches, rivers) from 1950 till today? If this has happened what are, on your opinion, the spurs which have guided these transformations?

8. What are the irrigation supply sources in your estate or in the surrounding (for the well precise the depth)?

9. How does irrigation work in your estate or in the surrounding territory?

10. What are irrigation present conditions in your estate or in the surrounding territory? Is irrigation resource sufficient?

11. Do you own a garden and/or a vegetable garden? How do you irrigate them? What is your supply resource? Is the available water sufficient?

12. Did you irrigate the garden and/or the vegetable garden in the 50s? If you did, what way? What was the supply source?

13. Where do you drain rainwater intercepted from the impervious areas of your lot? Which is the system? Where did you drain rainwater intercepted from the impervious areas of your lot in the 1950s? Which was the system?

14. Has the ditch along the road been interrupted? In affirmative case when and why?

15. Have there been flood events (from the 50s till today) which concern your property and/or the surrounding area?

16. Do you consider flooding a real risk?

17. Do the quarries in the territory perform a water supply function?

18. Looking back at the 50, was drainage stronger where, presently, there are the quarries?

19. What kind of future do you think possible for the quarries in Ronco all'Adige?

Drinking water system

20. Is your house connected to the drinking water network?

21. In affirmative case, when was the connection effectuated?

22. In affirmative case, besides the traditional drinkable uses (drinking, personal hygiene, food preparation) what other functions do you utilize the drinking water for (car washing, garden / vegetable garden washing, etc.)?

23. In negative case, what's the reason why your house is not connected to the network?

24. In negative case, what are the supply sources for drinkable uses?

25. What were the drinking water supply sources in the 50 – what about the elements and their working?

Waste water system

26. Is your house connected to the sewer network?

27. In affirmative case, when was the connection set?

28. In negative case, what's the reason why your house is not connected to the network?

29. In negative case, what are the elements of for the disposal of waste water (Imhoff tank, fat condensation, subdrains)?

30. What was the system for the disposal of waste water in the 50? What were the elements and their working?

Groundwater system

31. How many wells do you own?

32. What depth do they reach? How do you withdraw water?
33. What functions do you use the well water for?
34. What’s the resource quality? Have you noticed changes as to quantity/quality?
35. How many wells did you own on the 50?
36. What was the well depth in the 50? How did you withdraw water?
37. What were the functions of well water use in the 50?

What do you think about the changes? Is good as it is now?

38. What do you think about all the changes occurred from 1950 till today?

D.2. Semi-structured interviews with the technicians - phase one, level 2

1. Which are the water sources that you managed in the frame of the water cycle?
2. Which territory do you manage?
3. How is the organization financed?
4. Who are the users of your service?
5. Which are the responsibilities of the Region with respect to the water infrastructures and sources?
6. Which are the main physical components of the system? When was the system introduced?
7. Which are the main transformations that occurred between 1950 and 2003 with relevant effects on the water cycle?
8. Which are the major problems of water resources and infrastructures?
9. What are the strategies adopted to cope with those problems?
10. What are the problems that arise in the interrelation between the form of the infrastructures and the form of the territory?
11. Which are the strategies adopted to cope with those problems?
12. Which are the opportunities with respect to the form of the infrastructures and the form of the territory?
13. What are some of the conflicts that arise with other stakeholders?
14. Do you have any long term strategies?
15. How does the organization consider decentralized strategies?
16. What could be a desirable scenario from the point of view of the organization?

References

Bibliography

AATO Veronese (Autorità Ambito Territoriale Ottimale Veronese), 2005a. Analisi dello stato attuale del servizio idrico integrato e delle strutture disponibili. In: Il Piano d'Ambito dell'AATO Veronese.

AATO Veronese (Autorità Ambito Territoriale Ottimale Veronese), 2005b. Analisi dell'utilizzo della risorsa idrica. In: Il Piano d'Ambito dell'AATO Veronese.

AATO Veronese (Autorità Ambito Territoriale Ottimale Veronese), 2006. Il Piano d'Ambito dell'AATO Veronese. Relazione di sintesi. Verona: Grafiche Aurora.

Adelmann, G., W., 1998. Reworking the landscape, Chicago style. The Hastings Center Report 28(6) 6-11.

Adriaanse, L., Blauw, T., 2008. Towards new Deltas. In: Zeelandboek 11. Stichting Zeelandboek, The Netherlands.

Al Radif, A., 1999. Integrated water resources management (IWRM): An approach to face the challenges of the next century and to avert future crises. Desalinati, 124 (1-3), 145-153on.

Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto, 2009. Stato delle acque superficiali del Veneto – anno 2007.
Available from:
http://www.arpa.veneto.it/acqua/docs/interne/superficiali/Stato_delle_acque_superficiali_Veneto-2007.pdf

Agostini, D. Tempesta, T., 1991. Modifiche nella destinazione del suolo agricolo. In: Istituto Veneto di Scienze, Lettere e Arti, Trasformazioni del territorio e rete idrica del Veneto, Venice 1st December 1989. Venezia: La Garandola, 129-143.

Alberti, S., 1684, Dissegno delli beni sogetti al retratto delle ville di Ronco, e Tomba. Archivio di Stato di Verona, Dionisi-Piomarta, dis. 007.

Alexander, C., Ishikawa, S., Silverstein, M., 1977. A pattern language: towns, buildings, construction. New York: Oxford University Press.

Allen, R., G., Pereira, L., S., Raes, D., Smith, M., 1998. Crop evapotranspiration: guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56, FAO, Rome.

Altissimo, L., Dal Prà, A., Mozzi, G., 2003, Il sistema idrogeologico della pianura veneta e la diminuizione progressiva delle risorse idriche sotterranee. In: Acque sotterranee, 82: 9-22.

Antonelli, R., Marcolongo, B., Pilli, A., Zaja, A., Zambrano, R., 2002, Nuovi contributi sull'inquinamento della falda freatica nella pianura alluvionale a sud di Verona. In: Quaderni di geologia applicata, 9: 75-88.

Antonimi, E., Conte, G., Pandolci, G., Pettenella, D., Viola, F., 2002. Le funzioni delle FTB. In: Veneto Agricoltura & Consorzio di Bonifica Dese Sile, Fasce tampone boscate in ambiente agricolo. LIFE99/ENV/IT000083. Noale: Centro Grafico, 13-35.

APAT (Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici), 2004. Atlante delle opere di sistemazione fluviale. Roma: I.G.E.R.

Argue, J., R., Pezzaniti, 2006. Infiltration systems. In: Wong, T., H., F., (ed.), Australian runoff quality: a guide to water sensitive urban design, Crows Nest: Engineers Media.

ARPAV (Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto), 2005. Carta dei suoli del Veneto. Note illustrative.

Autorità di Bacino del Fiume Adige, 2007. Piano stralcio per il recupero naturalistico e morfologico del fiume adige. Tratto Pontoncello-Tombazosana.

Autorità di Bacino del Fiume Fissero Tartaro Canalbianco, 2002. Piano di Assetto Idrogeologico (PAI). Relazione.

Avermaete, T., 2002. Rus in urbe. OASE, 60: 2-7.

Barton, A., B., 2009. Advancing IUWM through an understanding of the urban water balance. Available from:
http://www.mssanz.org.au/modsim09/I9/barton.pdf

Bellicini, L., 1989. La campagna urbanizzata. In: Bevilacqua, P., (ed.), Storia dell'agricoltura italiana in età contemporanea. Venezia: Marsilio, 77-131.

Bendoricchio, G., Bixio, V., Giardini, L., 1994. Ricerche Sperimentali sugli effetti del drenaggio controllato nella riduzione del rilascio inquinanti da sorgenti diffuse. XXIV Convegno di idraulica e costruzioni idrauliche, Napoli, 20-22 Settembre 1994.

Berger, A., 2006. Drosscape: Wasting Land in Urban America. New York: Princeton Architectural Press.

Berger, A., 2009. Systematic design can change the world. Zeist: SUN Publishers.

Bernardi, U., 2004. Fondamenti del buon governo del territorio. In: Regione del Veneto, Carta di Asiago. Venezia, 13-21.

Bertola, P., 2007. Caratteri idrogeologici e idraulici. In: Bertola, P., Diamantini, C., (ed), La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale, 139-167.

Bertola, P., Diamantini, C., 2007. La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Dipartimento di Ingegneria Civile e Ambientale, UNITN, Trento.

Bettinetti, R., Crosa, G., Galassi, S., 2007. Ecologia delle acque interne. Torino: Città Studi.

Bevilacqua P., 1989a. La Rivoluzioni dell'Acqua. In: Bevilacqua, P., (ed.), Storia dell'agricoltura italiana in età contemporanea. Venezia: Marsilio, 255-318.

Bevilacqua, P.,1989b. Tra Europa e Mediterraneo. In: Bevilacqua, P., (ed.), Storia dell'agricoltura italiana in età contemporanea. Venezia: Marsilio, 5-36.

Bianchi, B., 1989. La nuova pianura. In: Bevilacqua, P., (ed.), Storia dell'agricoltura italiana in età contemporanea. Venezia: Marsilio, 451-494.

Biswas, A., K., 2004. Integrated Water Resources Management: A Reassessment, Water International, 29: 2, 248 – 256.

Bixio, V., 1990. Effetti del drenaggio sotterraneo sulla formazione dei deflussi di piena. In: Irrigazione e drenaggio, 3.

Bixio, V., Celegon, E., A., Fanton, P., Fiume, A., Vazzoler, C., Zanetti, S., Bixio, A., C., Rech, F., 2010. Caratteri fisici e climatici dei comprensori di bonifica del Veneto. Regione Veneto.

Bonomi, A., 1997. Il capitalismo molecolare. Torino: Einaudi.

Bonomo, L., 2008. Trattamenti delle acque reflue. Milano: McGraw Hill.

Boscolo, C., Mion, F., 2008. Le acque sotterranee della pianura veneta. I risultati del progetto SAMPAS. ARPAV. Padova: Grafiche Brenta.

Bouwer, H., 2000. Integrated water management: emerging issues and challenges, Agric. Water Manage. 45 (2000), pp. 217-228.

Branzi, A., 2006. Modernità debole e diffusa. Milano: Skira.

Bulc, T., Sajn Slak, A., 2003. Performance of constructed wetland for highway runoff treatment, Water Science and Technology, 48, 315–322.

Burchell, R. W., Shad, N.A., Listokin, D., Phillips, H., Downs, A., Seskin, S., Davis, J.S., Moore, T., Helton, D., & Gall, M., 1998. The cost of sprawl-revisited. TCRP report 39, Washington DC: National Academy Press.

Carliner, M., S., 1999. Comment on Karen A. Danielsen, Robert E. Lang, and William Fulton's 'retracting suburbia: smart growth and the future of housing'. Housing Policy Debate, 10(3), 549–553.

CEC (Commission of the European Communities), 1999. European Spatial Development Perspective: towards balanced and sustainable development of the territory of the EU. Luxembourg: Office for the Official Publications of the European Communities, Luxemburg

CEC (Commission of the European Communities), 2001. Processi estensivi di depurazione delle Acque reflue, specifici per piccoli e medi insediamenti. Luxembourg: Office for the Official Publications of the European Communities.

CENSIS, (data gathered from various years). Rapporto sulla situazione sociale del paese. Milano: Franco Angeli.

Chiaudani, A., 2008. Agriclimatologia statica e dinamica del Veneto. Ph.D. diss., Universita' degli Studi di Padova, Padova.

Chouli, E., 2006. La gestion des eaux pluviales urbaines en Europe: analyse des conditions de developpement des techniques alternatives, Ph.D. diss., Ecole Nationale des Ponts et Chaussees, Paris.

Coltro, D., 2006. La terra e l'uomo. Verona: Cierre.

Commissario Delegato per l'Emergenza Concernente gli Eccezionali Eventi Metereologici del 26 Settembre 2007 che Hanno Colpito Parte del Territorio della Regione Veneto, 2008. Oggetto: Primi indirizzi e raccomandazioni per l'applicazione delle ordinanze 2, 3 e 4 del 22.01.2008 in materia di prevenzione dal rischio idraulico.

Commissario Delegato per l'Emergenza Concernente gli Eccezionali Eventi Metereologici del 26 Settembre 2007 che Hanno Colpito Parte del Territorio della Regione Veneto, 2009. Linee guida per gli interventi di prevenzione dagli allagamenti e mitigazione degli effetti.

Comune di Ronco all'Adige, 2009. Valutazione di Compatibilità Idraulica. In: PAT (Piano di Assetto del Territorio).

Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo, 1984. Schede irrigue. Bologna: Edagricole.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991a. I caratteri fisici del comprensorio. In: PGBTTR (Piano Generale di Bonifica e Tutela del Territorio Rurale), charter 3B.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991b. I caratteri fisici del comprensorio. In: PGBTTR (Piano Generale di Bonifica e Tutela del Territorio Rurale), charter 3C.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991c. Lo stato delle opere idrauliche. In: PGBTTR (Piano Generale di Bonifica e Tutela del Territorio Rurale), charter 8.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991d. Lo stato delle irrigazioni. In: PGBTTR (Piano Generale di Bonifica e Tutela del Territorio Rurale), charter 9.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 1991e. Tutela dell’ambiente. In: PGBTTR (Piano Generale di Bonifica e Tutela del Territorio Rurale), charter 11.

Consorzio di Bonifica Valli Grandi e Medio Veronese, 2004. Informazione e sintesi di un quinquennio di attività. Legnago: Grafiche Stella.

Coombes, P., Mitchell, G., 2006. Urban water harvesting and reuse. In: Wong, T., H., F., (ed.), Australian runoff quality: a guide to water sensitive urban design. Crows Nest: Engineers Media.

Corner, J., 1999. The Agency of Mapping: Speculation, Critique and Invention. In: D. Cosgrove, ed. Mappings. London: Reaktion.

Cosgrove, D., 1990a. An elemental division: water control and engineered landscape. In: Cosgrove, D., Petts, G., (ed). Water, engineering and landscape: water control and landscape transformation in the modern period. London: Belhaven Press, 1-11.

Cosgrove, D., 1990b. Platonism and practicality: hydrology, engineering and landscape in sixteenth-century Venice. In: Cosgrove, D., Petts, G., (ed). Water, engineering and landscape: water control and landscape transformation in the modern period. London: Belhaven Press, 35-53.

Cosgrove, D., 2000. Il paesaggio palladiano: la trasformazione geografica e le sue rappresentazioni culturali nell'Italia del XVI secolo. Sommacampagna: Cierre.

CSP Engineering Consulting, 2007. Interventi Strutturali per lo stoccaggio di volume d’acqua utilizzabili a fini irrigui a salvaguardia del bilancio idrico del Fiume Adige. Technical report.

CUOA, 1985. Organizzazione del territorio ed evoluzione del sistema produttivo veneto. Vicenza: CUOA.

D' Alpaos, L., 1991. Trasformazione dell'uso del suolo: influenza sulle portate di piena delle reti idrauliche minori. In: Istituto Veneto di Scienze, Lettere e Arti, Trasformazioni del territorio e rete idrica del Veneto, Venice 1st December 1989. Venezia: La Garandola, 35-60.

Dal Prà, A., 1984. Studio preliminare delle condizioni idrogeologiche dell'alta pianura veronese. Rovigo: Consorzio di 2° grado per l'irrigazione del Polesine.

Dal Prà, A., De Rossi, P., Siliotti, A., Sottani, A., 1997. Carta idrogeologica dell'Alta Pianura veronese orientale. C.N.R., GNDCI and Università degli Studi di Padova.

David, L., J., 1988. Environmentally sound management of the Zambesi river basin. Water Resources Development, 4 (2), 80-102.

De Geyter, X., (ed.), 2002. After sprawl. Rotterdam: NAI Publishers.

de Meulder, B., 2008. Old Dispersions and scenes for the production of public space the constructive margins of secondarity. Architectural Design, 78: 28–33.

Diamantini, C., 2007. La riqualificazione ambientale di un'area estrattiva dismessa come prodotto della concertazione tra pubblico e privato. In: Bertola, P., Diamantini, C., (ed), La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale, 7-18.

Diener, R., Herzog, J., Meili, M., De Meuron, P., 2006. Switzerland: An Urban Portrait. Basel: Birkhäuser.

Dittongo, A., 1999. La storia orale. In: Dittongo, A., Santi, E., Il laterizio, un'industria, un paese. Cologna Veneta: Grafiche Ambrosini, 71-125.

Dittongo, A., 2002. La casa sul fiume. Cologna Veneta: Grafiche Ambrosini.

Dittongo, A., Santi, E., 2009. Il laterizio, un'industria, un paese. Cologna Veneta: Grafiche Ambrosini.

Donadieu, P., 2006. Campagne urbane: una nuova proposta di paesaggio della città. Roma: Donzelli.

Dryzek, J., 1987. Rational Ecology: Environment and Political Economy. New York: Basil Blackwell.

Duncan, J. E., et al., 1989. The search for efficient urban growth patterns. Tallahassee, FL: Florida
Department of Community Affairs.

Easterbrook, G., 1999. Comment on Karen A. Danielsen, Robert E. Lang, and William Fulton's 'retracting suburbia: smart growth and the future of housing'. Housing Policy Debate, 10(3), 541–547.

EPA (United States Environmental Protection Agency), 2003. Wastewater technology fact sheet screening and grit removal.
Available from:
http://water.epa.gov/aboutow/owm/upload/2004_07_07_septics_final_sgrit_removal.pdf

Ercolini, M., 2006. Dalle esigenze alle opportunità. Thesis (Ph.D.). University of Florence.

European Commission, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
Available from:
http://ec.europa.eu/environment/water/water-framework/index_en.html

European Commission, 2003. Common Implementation Strategy for the Water framework Directive (2000/60/CE).
Available from:
http://www.europa.eu.int/comm/environment/water/waterframework/ index_en.html

FAO (Food and Agriculture Organization of the United Nations), 1998. World reference base for soil resources. Rome: FAO.

Farialdi, A., 2009. Infrastrutture liquide. Sistemi d'acqua nelle aree urbane. Thesis (Ph.D.). University IUAV of Venice.

Farinelli, F., 1989. Lo spazio rurale nell'Italia di oggi. In: Bevilacqua, P., (ed.), Storia dell'agricoltura italiana in età contemporanea. Venezia: Marsilio, 229-247.

Farinelli, F., 2003. Geografia: una introduzione ai modelli del mondo. Torino: Einaudi.

Ferguson, B., K., 2007. Foreword. In: Kinkade-Levario, H., Design for Water: Rainwater Harvesting, Stormwater Catchment and Alternate Water Reuse. Gabriola Island: New Society Publishers, XI-XII.

Ferrario, V., 2007. Lo spazio agrario nel progetto di un territorio, trasformazioni dei paesaggi rurali nella pianura e nella montagna veneta. Thesis (Ph.D.). University IUAV of Venice.

Feyen, J., Shannon, K., 2009. Preface. In: Feyen, J., Shannon, K., Mattew, N., (ed.). Water & Urban development paradigms. Towards and integration of engineering, design and management approaches. London: Taylor and Francis Group, XIII-XV.

Forman, R. T. T., 1995. Land Mosaics: The Ecologies of Landscapes and Regions. Cambridge: Cambridge University Press.

Francis, M., 2001. A case study method for landscape architecture. Landscape Journal. 20 1, pp. 15–29.

Frank, J. E., 1989. The costs of alternative development patterns: a review of the literature. Washington, DC: Urban Land Institute.

Freeman, L., 2001. The effects of sprawl on neighborhood social ties. Journal of the American Planning Association, 67, 69–77.

Gajo, A., 2007. Aspetti geotecnici. In: Bertola, P., Diamantini, C., (ed), La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale, 83-112.

Garofoli, G., 1991. Modelli locali di sviluppo. Milano: Angeli.

Giardini L., 1982. Agronomia Generale. Bologna: Patron.

Giardini, L., 1991. Evoluzione delle tecniche agronomiche e modifiche del territorio agricolo che coinvolgono il regime idrologico. In: Istituto Veneto di Scienze, Lettere e Arti, Trasformazioni del territorio e rete idrica del Veneto, Venice 1 december 1989. Venezia: La Garandola, 145-161.

Gordon, P., Richardson, H., W., 1997. Are Compact Cities a Desirable Planning Goal?. Journal of the American Planning Association, 63: 1, 95 -106.

Gregnanin, A., 1975. Insieme estrattivo di Ronco all'Adige. Relazione geomorfologica, idrologica e paesaggistica del comprensorio.

Gregotti, V.,1966. Il territorio dell' architettura. Milano: Feltrinelli.

Groat, L., Wang, D., 2002. Architectural research method. Canada: John Wiley &Sons.

Gumiero, B., Boz, B., Cornelio, P., 2008. Il sito sperimentale "Nicolas". Legnaro: Veneto Agricoltura.

Hager, M., C., 2003. Low-Impact Development. Stormwater, January/February 2003.
Available from:

http://www.forester.net/sw_0301_low.html

Hansson, P-A., and Fredriksson, H., 2003. Use of summer harvested common reed (Phragmites australis) as nutrient source for organic crop production in Sweden. Agriculture, Ecosystems & Environment, 102, 365-375.

Hardin G. 1968. The tragedy of the commons. Science, 162, 1243-1248.

Hartman, W., Sijmons, D., 1995. Environment, a source of inspiration for urban design. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 82-93.

Harvey, D., 1989. The condition of post modernity. Oxford: Basil Blackwell.

Heaney, J., 2007. Centralized and decentralized urban water, wastewater & stormwater systems. In: Novotny, V., Brown, P., (ed.). Cities of the future: towards integrated sustainable water and landscape management. London: IWA Publishing.

Hengeveld, H., Geldof, G., D., 1995. Integrated water management in urban areas in The Netherlands. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 94-110.

Heuts, E., Rombaut, E., 2009. Duurzame stedebouw in woord en beeld. Antwerpen: VIBE.

Hill, S., 1985. Soil, food, health and holism. The search for sustainable nourishment. Montreal: MacDonald College, Mc-Gill University.

Hough, M., 1984. City form and natural process: towards a new urban vernacular. New York: Van Nostrand Reinhold Company.

Indovina, F., 1990. La città diffusa. In: Indovina, F., (ed.), La ciità diffusa. Venezia: Iuav-DAEST.

Indovina, F., 2009. Dalla città diffusa all'arcipelago metropolitano. Milano: Angeli.

International Union for the Conservation of Nature, 1980. World Conservation Strategy: Living resource conservation for sustainable development. Gland: IUCN.

IRSEV, 1985. Lo sviluppo territoriale del Veneto negli anni '70: decentramento urbano e diffusione industriale. Venezia: IRSEV.

Izembart, H., Le Boudec, B., 2003. Waterscapes. Barcelona: Editorial Gustavo Gili.

Johnson, P. M., 2001. Environmental impacts of urban sprawl: a survey of the literature and proposed research agenda Environment and Planning, 33, 717 - 735.

Kahn, M. E., 2000. The environmental impact of suburbanization. Journal of Policy Analysis and Management, 19: 4, 569–586.

Kinkade-Levario, H., 2007. Design for Water: Rainwater Harvesting, Stormwater Catchment and Alternate Water Reuse. Gabriola Island: New Society Publishers.

Koolhaas, R., 1995. Atlanta. In: Koolhaas, R.. S, M, L, XL. New York: The Monicelli Press, 833-859.

Laws, S., Harper, C., Marcus, R., 2003. Research for development: a practical guide. London: Sage.

Lefebvre, H., 1974/86 La production de l'espace. Paris: Anthropos.

Leveson, D., 1980. Geology and urban environment. Oxford University Press, New York.

Luciani, D., 2010. Il caso veneto. Lunga durata e carichi di rottura nella forma e nella vita dei luoghi. In: Ortalli, G., (ed.), Le trasformazioni dei paesaggi e il caso veneto. Bologna: Il Mulino, 115-129.

Luciani, F., (ed.) 2004. Nella città diffusa. Idee, indagini, proposte per la nebulosa insediativa veneta, Fondazione Benetton Studi Ricerche, Treviso.

Londong, D., 1995. Rehabilitation concept for the Emscher system. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 260-263.

Lynch, K., 1960. The image of the city. Cambridge: The MIT Press.

Magnaghi, A., 2000. Il progetto locale. Torino: Bollati Beringhieri.

Malbert, B., 1994. Ecology-based Planning and Construction in Sweden. Stockholm: Byggforskningsradet.

Margules, C., R., Meyers, J., A., 1992. Biological diversity and ecosystem fragmentation - an Australian perspective. Ekistics, 59 (357), 293-300.

Marsalek, J., Jimenez-Cisneros, B., Karamouz, M., Malmquist, P., Goldenfum, J., Chocat, B., 2008. Urban water cycle processes and interactions. London: Taylor & Francis.

Marsh, W., 2005. Landscape Planning: Environmental Applications. Hoboken: John Wiley & Sons Inc.

Massarutto, A., 2008. L'acqua: un dono della natura da gestire con intelligenza. Bologna: Il Mulino.

Massing, H., Tjallingii, S., P., 1995. Preface. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 7.

Mazzotta, A., 2007. L'acqua materia per l'immagine del costruito. Firenze: Alinea editrice.

Metcalf, E., Eddy, H., 2006. Ingegneria delle acque reflue. Trattamento e riuso 4/ed. Milano: McGraw Hill.

Miles, M., B., Huberman, A., M., 1994. Qualitative data analysis. Thousand Oaks: Sage.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Wetlands and Water Synthesis. Washington: World Resources Institute.

Ministry of Transport, Public Works and Water Management, 2006. Spatial Planning Key Decision 'Room for the River'. Investing the safety and the vitality of the Dutch river basin region. The Netherlands.

Mitchell, B., 1990. Integrated water management. In: Mitchell, B., (ed). Integrated Water Management: International Experiences and Perspectives. London: Belhaven Press, 1-21.

Moretto, L., 2008. Urban governance and water provision access: an application of the UN-Habitat 'Urban Governance Index'. Thesis (Ph.D.). School for Advance Studies in Venice Fundation.

Morin, G., 1987. L'irrigazione con acque derivate da Adige a Sorio. In: Lavorenti, G., Morin, G., Sorio tre. Legnago: Grafiche Stella, 13-31.

Morin, G., 1993. L'attuale sistema irriguo. In: Morin, G., Scola Gagliardi, R., Un territorio e le sue acque. Legnago: Grafiche Stella.

Mouritz, M., Evangelisti, M., McAlister, T., 2006. Water sensitive urban design. In: Wong, T., H., F., (ed.), Australian runoff quality: A guide to water sensitive urban design, Crows Nest: Engineers Media.

Munarin, S., Tosi, M. C., 2001. Tracce di Città, Esplorazioni di un Territorio Abitato: l'Area Veneta. Milano: Franco Angeli.

Novotny, V., 2009. Sustainable urban water management. In: Feyen, J., Shannon, K., Mattew, N., (ed.). Water & Urban development paradigms. Towards and integration of engineering, design and management approaches. London: Taylor and Francis Group, 19-31.

Oliva, A., 1948. Le sistemazioni dei terreni. Bologna: Tipografia Compositori.

Ortalli, G., 2010. Paesaggi: fra trasformazioni e permanenze. In: Ortalli, G., (ed.), Le trasformazioni dei paesaggi e il caso veneto. Bologna: Il Mulino, 7-27.

OSA (Onderzoeksgroep Stedelijkheid en Architectuur + Standbouw), 2002. Atlas Southwest Flanders. Ferraris.

Petts, G., 1990. Water, engineering and landscape: development, protection and forestation. In: Cosgrove, D., Petts, G., (ed). Water, engineering and landscape: water control and landscape transformation in the modern period. London: Belhaven Press, 188-208.

Piccinato, G., 1993. Urban landscapes and spatial planning in industrial districts: The case of Veneto. European Planning Studies, 1: 2, 181-198.

Piva, A., 2006. Progetto per il completamento del collettore Zeviano e di altri collettori primari per l'irrigazione di terreni asciutti e/o serviti da prelievi sotterranei nei comuni di Zevio, Ronco all'Adige, Palù e Roverchiara. Relazione tecnica.

Pluti, C., 1991. Uso del suolo e programmazione: evoluzioni e tendenze della recente pianificazione territoriale. In: Istituto Veneto di Scienze, Lettere e Arti, Trasformazioni del territorio e rete idrica del Veneto, Venice 1 december 1989. Venezia: La Garandola, 163-170.

Provincia di Venezia, 2008. Piano Territoriale di Coordinamento Provinciale (PTCP).

Provincia di Verona, ARPAV, 2006. Rapporto Sullo Stato dell'Ambiente. Scheda 10.18.

Provincia di Verona, ARPAV, 2008. Rapporto Sullo Stato dell'Ambiente.

PTCEC, 1998. Report of the Pennsylvania 21st Century Environment Commission. Pennsylvania
21st Century Environment Commission, Harrisburg, PA.

Quaderno ronchesana secondo, 1990. Albaredo d'Adige: Tipolitografia Seber.

Regione Emilia Romagna, 2004. Le buone pratiche agricole per risparmiare acqua. I supplementi di agricoltura,18, Roma: Litosud.

Regione Veneto, 1989. Piano Regionale di Risanamento delle Acque.

Regione Veneto, 2004. Piano di Tutela delle Acque.

Regione Veneto, 2007a. Piano di sviluppo rurale per il Veneto 2007-2013.

Regione Veneto, 2007b. L'agricoltura nella aree di bonifica. In: Piano di sviluppo rurale per il Veneto 2007-2013. Chapter 5.

Regione Veneto, 2008. Prezzario regionale dei lavori pubblici.

Regione Veneto, 2009. Piano Territoriale Regionale di Coordinamento. Relazione Illustrativa.

Regione del Veneto, 2010. Veneto ferito. Alluvione del 31 ottobre 2010. Trebaseleghe: Grafica Veneta.

Reho, M., 1986. Modificazioni dell'uso del suolo: soggetti e comportamenti residenziali e insediativi. Oltre il Ponte, 16, 13-46.

Rusconi, A.,1991. Evoluzione della rete idrografica di ieri e di oggi attraverso il confronto delle osservazioni. In: Istituto Veneto di Scienze, Lettere e Arti, Trasformazioni del territorio e rete idrica del Veneto, Venice 1 december 1989. Venezia: La Garandola, 101-118.

Ryan, B., 2004. Stormwater infrastructure. In: Raxworthy, J., Blood, J., (ed.) The MESH book: landscape / infrastructure. Melbourne: RMIT Publishing.

Ryckewaert, M., 2002. The Minimal Rationality of Housing Patterns in Flanders' Nevelstad. OASE, 60: 49-75.

Sambugaro, G., Santi, E., 1996. Le inondazioni nella media pianura veronese. Collana Athesis, 2. Cologna Veneta: Grafiche Ambrosini.

Santi, E., 1999a. La protoindustrializzazione. In: Dittongo, A., Santi, E., Il laterizio, un'industria, un paese. Cologna Veneta: Grafiche Ambrosini, 13-40.

Santi, E., 1999b. Le fornaci. In: Dittongo, A., Santi, E., Il laterizio, un'industria, un paese. Cologna Veneta: Grafiche Ambrosini, 41-70.

Schuetze, T., 2005. Decentralized water systems in housing estates of international big cities considering as example the cities Hamburg in Germany and Seoul in South Korea (Dezentrale Wassersysteme im Wohnungsbau internationaler Groebstradte am Beispiel der Staedte Hamburg in Deutschland und Seoul in Sued-Korea). Ph.D. diss., Leibniz Universitat Hannover, Hannover.

Schuetze, T., Tjallingii, S.P., (ed.), 2008. Every Drop Counts, Environmentally Sound Technologies for urban and Domestic Water Use Efficiency. TUDelft/UNEP, Delft/Osaka.

Schmid, A., S., 1995. The interdisciplinary significance of water in the ecological renewal of the Emscher region. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 215-222.

Scola Gagliardi, R., 2009. Cenni storici sul paesaggio agrario della pianura veronese. In: Morin, G.,

Scola Gagliardi, R., (ed.), Dalle grandi valli al Benaco. Verona: Cierre, 81-125.

Secchi, B., 1984. Nuove tecnologie. Casabella, 503.

Secchi, B., 1991. La periferia. Casabella, 583, 20-22.

Secchi. B., 2001. Tracce di città per la città europea. In: Munarin, S., Tosi, M. C., Tracce di Città, Esplorazioni di un Territorio Abitato: l'Area Veneta. Milano: Franco Angeli, 213-217.

Secchi, B., 2007. Permacity: on dispersion and densification. In: Rosemann, J., (ed.), Permacity. Barcelona.

Secchi, B., Viganò, P.,+ Ph.D. students in Urbanism, Universita' IUAV di Venezia, 2006. Water and Asphalt: The Project of Isotropy. The Venetian Metropolis, 2006. 10th Biennal of Architecture in Venice.

Sereni, E., 1961. Storia del paesaggio italiano. Napoli: Laterza.

Sierra Club, 1999. Stop sprawl: sprawling cities, spreading malaise. Sprawl report 2001b. Available from:
http://www.sierraclub.org/sprawl/reports/. Accessed July 3, 2003.

Sijmons D., 1990. Regional Planning as a Strategy, Landscape Urban Plann., 18: 265-273.

Sijmons D., 2009. Utopia's practical cousin. In: Systematic design can change the world, Berger, A., Zeist: SUN Publishers, 88-98.

Sijmons, D., van Nieuwenhuijze, L., 2002. Contours In Aqua Scribis? OASE, 60: 31-46.

Siligardi, M., 2007. IFF 2007, Indice di Funzionalità Fluviale. Trento: Linea Grafica Bertelli Editori.

Siligardi, M., Negri, P., 2007. Analisi degli aspetti ambientali e indicazioni per la riqualificazione. In: Bertola, P., Diamantini, C., (ed), La riqualificazione ambientale di un'area estrattiva dismessa: il parco urbano di Ronco all'Adige. Università degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale, 113-137.

Sivierts, T, 2003. Cities without cities. An interpretation of the Zwischenstadt. London and New York: Spon Press.

Sivierts, T, 2003. Cities without cities. An interpretation of the Zwischenstadt. Oxon: Spon Press.

Spirn, A., 1984. The Granite Garden. New York: Basic Books.

Stake, R., 1995. The art of case study research. Thousand Oaks: Sage.

Stake, R., 1998. Case Studies. In: Strategies of Qualitative Inquiry, Denzin, N., K., Lincoln, Y., S., Thousand Oaks: Sage, 86-109.

Steenbergen, C., 2008. Composing landscapes. Basel: Birkhauser.

Steiner, F., McSherry, L., Brennan, D., Soden, M., Yarchin, J., Green, D., McCarthy J., M., Spellman C., Jennings, J., Barrè, K., 1999. Concepts for alternative suburban planning in the northern Phoenix area. Journal of the American Planning Association, 65, 207-222

Tashakkori, A., Teddlie, C., 2003. Handbook of Mixed Methods in Social and Behavioural Research. Thousand Oaks: Sage.

Tempesta, T., 2010. Qualità del paesaggio e qualità dell'economia: nuovi paradigmi per uno sviluppo sostenibile. In: Anguillari, E., Bonini Lessing, E., Musco, F., Ranzato, M., Tosi, M., C., (ed.), Paesaggi deltizi e territori fragili. Comparazioni. Venezia: Università Iuav di Venezia, 19-36.

Tjallingii, S., P., 1991. The responsible city, planning for flows in the urban ecosystem. In: Berlin Congress Report, International Federation for Housing and Planning, The Hague: 51-58.

Tjallingii, S., P., 1995a. Introduction. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 9-10.

Tjallingii, S., P., 1995b. The water system in the city: summary of discussions. In: van Engen, H., Kampe, D., Tjallingii, S., P., Hydropolis: the role of water in urban planning, Leiden: Backhuys Publishers, 64-65.

Tjallingii, S., P., 1995c. Ecopolis: strategies for ecologically sound urban development. Leiden: Backhuys Publishers.

Tjallingii, S., P., 1996, Ecological Conditions. Strategies and Structures in Environmental Planning. Wageningen: Institute for Forestry and Nature Research. Thesis (Ph.D.). Delft University of Technology.

Tjallingii, S., P., 2000. Ecology on the edge: landscape and ecology between town and country, Landscape and Urban Planning, 48, 103-119.

Tjallingii, S., P., 2003. Sustainable and green: ecopolis and urban planning. In: Konijnendijk, C., C., Schipperijn, J., Hoyer, K., K., proceedings of the Conference IUFRO "Forestry serving urbanized societies", Copenhagen 27th-30th August 2002. Vienna: IUFRO, 43-66.

Tjallingii, S., P., 2008. The water issued in the existing city. In: Hooimeijer, F., van der Toorn, W., V., More Urban Water: Design and Management of Dutch Water Cities. London: Taylor & Francis, 83-99.

Tjallingii, S., P., 2011. Water Flows and Urban Planning. In: Bueren, E., van Bohemen, H., Visscher, H., (ed.), Sustainable built environments: an ecosystem approach. Springer.

Tjallingii, S. P., van den Top, I. M., Jonkhof, J. F., Wentink, R., 2000. The blue transformation. Wageningen: Alterra, Green Word Research (Alterra-rapport 093).

Tosini, L., 1998. Aspetto idraulico di bonifica, In: Mainardi, R., Gambardella, F., Tosini, L., Borgo, P., Zambon, M., La cultura delle acque. Rovigo: Nike Kai Dike.

Turri, E., 2002. La conoscenza del territorio: metodologia per un'analisi storico-geografica. Venezia: Marsilio.

United Nations, 2003. Waste-water treatment technologies: a general overview. New York: United Nations.

Vallerani, F., 2006. Il territorio tra oggettività geografica e contesto di identità. IN: (intervento) Veneto: dal policentrismo alla città diffusa, 5 maggio 2006, Treviso, Sala degli affreschi Palazzo Rinaldi. Available from: http://www.ripensareilveneto.it/documents/5_maggio/Vallerani_5_maggio_2006.pdf

van de Ven, F., H., M., 2007. Watermanagement in urban areas. Lecture notes, Technische Universiteit Delft, Delft.

van de Ven, F., Tjallingi, S., P., Baan, P., J., A., van Eijk, P., J., Rijsberman, M., A., 2006. Improving urban water management planning. In: Hayashi, S., Arak, H., Hokao, K., (ed.). Proceedings of the International Symposium on Lowland Technology, Saga, 573–578.

van den Bout, J., Ziegler, F., 2002. Living in the country or inhabiting the landscape. OASE, 60: 63-75.

van der Toorn Vrijthff, W., van de Ven, F., 2008. Water's changing context. In: Hooimeijer, F., van der Toorn, W., V., More Urban Water: Design and Management of Dutch Water Cities. London: Taylor & Francis, 1-18.

van der Toorn Vrijthoff, W., van de Ven, F., H., 2008. Water's changing context. In: Hooimeijer, F., van der Toorn Vrijthoff, W., More urban water: design and management of Dutch water cities. London: Taylor & Francis.

van Leuwen, C., G., 1973. Ekologie. Faculty of Architecture, Delft University of Technology.

van Wirdum, G., 1982.The ecohydrological approach to nature protection. In: Research Institute for Nature Management, Annual Report1981, Arnhem, Leersum, Textel, 60-74.

Vermeulen, P., 2002. Countryside in the Nevelstad. OASE, 60: 103-107.

Viganò, P., 1999. La città elementare. Milano: Skira

Viganò, P., (ed.) 2001. Territori della nuova modernità/Territories of a New Modernity. Napoli: Electa.

Viganò, P., 2008a. Water and asphalt the projection of isotropy in the metropolitan region of Venice. Architectural Design, 78: 34–39

Viganò, P., 2008. Water: on the Power of Form and Devices, In: Water and Urban Development Paradigms, Feyen J., Shannon K., Neville M., CRC Press, 207-212.

Viganò, P., 2009. Water: on the power of forms and devices. In: Feyen, J., Shannon, K., Mattew, N., (ed.). Water & Urban development paradigms. Towards and integration of engineering, design and management approaches. London: Taylor and Francis Group, 207-212.

Viganò, P., Degli Uberti, U., Lambrechts, G., Lombardo, T., Zaccariotto, G., 2009. Landscape of water: paesaggi dell'acqua un progetto di riqualificazione ambientale nella città diffusa di Conegliano. Pordenone: Risma.

Vairavamoorthy, K., 2009. Innovation in water management for the city of the future. In: Feyen, J., Shannon, K., Mattew, N., (ed.). Water & Urban development paradigms. Towards and integration of engineering, design and management approaches. London: Taylor and Francis Group, 3-14.

Werquin, A.C., B. Duhem, G. Lindholm, B. Opperman, S. Pauleit, Tjallingii S., P., (ed.) 2005. Green Structure and Urban Planning. Final report of COST C11. Luxemburg: EU publication, 1-438

Wittfogel, K., A., 1956. The hydraulic civilizations. In: Thomas, W., L., Jr., (ed). Man's role in changing the face of the hearth. Chicago: University of Chicago Press, 152-164.

Wong, T., H., F., 2006. Introduction. In: Wong, T., H., F., (ed.), Australian runoff quality: A guide to water sensitive urban design, Crows Nest: Engineers Media.

Wright, F. L., 1963. The living city. New York: The New American Library.

Yin, R., 1994. Case study research: Design and methods. Thousand Oaks: Sage.

Yin., R., 2003. Applications of case Study Research: Design and Methods. California: Sage.

Zaccariotto, G., 2010. Integrated urban landscapes. Thesis (Ph.D.). University IUAV of Venice.

Zaccariotto, G., Ranzato, M., 2009. Veneto Integrated Water Landscapes. In: Licka, L.,
Schwab, E., (ed.), Landscape –Great Idea! 3rd International conference on landscape architecture Vienna, 29-30.April 2009. Mattersburg: Wograndl Druck GmbH, 152-155.

Zaccariotto, G, Ranzato, M., Tjallingii, S., P., 2009. Water sensitive design tools for urban landscapes. In: Blue in Architecture 09. 1st International symposium focused on water, Venice: 24th-27th September 2009. Forthcoming.

National legislation (Italy)

R.D. 215/1933 del 13 Febbraio 1933. Nuove norme per la bonifica integrale.

R.D. 262/1942 del 16 Marzo 1942. Approvazione del testo del Codice Civile.

L. 765/1967 del 6 agosto 1967. Modificazioni ed integrazioni alla legge urbanistica 17 agosto 1942, n. 1150.

L. 319/1976 del 10 Maggio 1976. Norme per la tutela delle acque dall'inquinamento (Legge Merli).

D.M. 185/1985 del 12 Giugno 1985. Regolamento recante norme tecniche per il riutilizzo delle acque reflue in attuazione dell'articolo 26, comma 2, del D.Lgs. 11 maggio 1999, n. 152.

L. 183/1989 del 18 Maggio 1989. Norme per il riassetto organizzativo e funzionale della difesa del suolo.

L. 36/1994 del 5 Gennaio 1994. Disposizioni in materia di risorse idriche – (Legge Galli).

DPCM 47/1996 del 4 Marzo 1996. Disposizioni in material di risorse idriche.

D.Lgs. 152/1999 del 11 Maggio 1999. Disposizioni sulla tutela delle acque dall'inquinamento e recepimento della direttiva 91/271/CEE concernente il trattamento delle acque reflue urbane e della direttiva 91/676/CEE relativa alla protezione dall'inquinamento provocato dai nitrati provenienti da fonti agricole.

D.Lgs. 258/2000 del 18 Agosto 2000. Disposizioni correttive ed integrative del decreto legislativo 11 maggio 1999, n. 152, in materia di tutela delle acque dall'inquinamento, a norma dell'articolo 1, comma 4, della legge 24 aprile 1998, n. 128.

D.Lgs. 152/2006 del 3 Aprile 2006. Norme in materia ambientale.

D.M. 2/5/2006 del 2 Maggio 2006: Norme tecniche per il riutilizzo delle acque reflue, ai sensi dell'articolo 99, comma 1, del decreto legislativo 3 aprile 2006, n. 152.

Regional legislation (Regione Veneto)

DGR 3637/2002 del 13 Dicembre 2002. L. 3 agosto 1998, n. 267 - individuazione e perimetrazione delle aree a rischio idraulico e idrogeologico. Indicazioni per la formazione dei nuovi strumenti urbanistici.

DGR 1322/2006 del 10 Maggio 2006. L. 3 agosto 1998, n. 267 - individuazione e perimetrazione delle aree a rischio idraulico e idrogeologico. Nuove indicazioni per la formazione degli strumenti urbanistici.

Allegato A, DGR 1322/2006 del 10 Maggio 2006. Valutazione di compatibilità idraulica per la redazione degli strumenti urbanistici. Modalità operative e indicazioni tecniche.

DGR 1841/2007 del 19 Giugno 2007. L. 3 agosto 1998, n. 267 – Individuazione e perimetrazione delle aree a rischio idraulico e idrogeologico. Nuove indicazioni per la formazione degli strumenti urbanistici.
Modifica D.G.R. 1322 del 10 maggio 2006, in attuazione della sentenza del TAR del Veneto n. 1500/07 del 17 maggio 2007.

L.R. 44/1982 del 7 Settembre 1982. Norme per la disciplina dell’attività di cava.

L.R. 26/2002 del 16 Agosto 2002. Disposizioni di riordino e semplificazione normativa, collegato alla legge finanziaria 2002 in materia di cave e torbiere, commercio e immigrazione.

L.R. 11/2004 del 23 Aprile 2004. Norme per il governo del territorio.

L.R. 12/2009 del 8 Maggio 2009. Nuove norme per la bonifica e la tutela del territorio.

List of interviewees

Cited interviews *(inhabitants)*

Anonymous inhabitant of Ronco all'Adige. Interviewed October 24th 2008, Ronco all'Adige.

Biondaro, Bruno, architect. Interviewed August 4th 2009, Ronco all'Adige.

Montanari, Graziano, agricultural entepreneur; Galbier Agnese, house-wife. Interviewed November 16th 2010, Ronco all'Adige.

Pedrollo, Gregorio, pensioner; Tobaldo, Maria, pensioner; Pedrollo, Claudia, housewife. Interviewed August 30th 2010, Ronco all'Adige.

Purgato, Giovanni, mason. Interviewed August 5th 2009, Ronco all'Adige.

Romio, Giovanni, pensioner. Interviewed October 24th 2008, Ronco all'Adige.

Cited interviews *(technicians)*

Angheben, Renato; forest scientist, Bozzolan, Mirco, geologist; Iob, Donato, engineer; Zambiasi, Marcello, forest scientist; technicians of the waterboard of the Autorità di Bacino del Fiume Adige. Interviewed October 28th 2008, Trento.

Franchini, Luciano, engineer, director of the AATO Veronese – authority for the integrated drinking and wastewater service. Interviewed November 4th 2008, Verona.

Macchiella, Diego, manager, Acque Veronesi Scarl. - service agency for drinking water supply and management of waste waters. First interview, June 19th 2008, Verona. Second interview, June 26th 2008, Verona. Third interview, June 9th 2010, Verona.

Pezzetta, Michele, engineer of the Genio Civile di Verona, Regione Veneto – responsible for the flood water safety of the Province of Verona. Interviewed November 4th 2008, Verona.

Piva, Alberto, engineer, responsible of the technical office of the waterboard Consorzio di Bonifica Veronese (former Consorzio di Bonifica Valli Grandi e Medio Veronese). First interview, November 21st 2008, Legnago. Second interview, January 30th 2010, Legnago.

Scamperle, Gianluigi, architect, project leader of the Provincial Plan of Verona 2009 (PTCP Verona), Province of Verona. Interviewed October 31st 2008, Verona.

Venturini, Enzo, manager, responsible for the district of Legnago of the Acque Veronesi Scarl. - service agency for drinking water supply and management of waste waters. Interviewed June 19th 2008, Legnago.

Zanoncelli, Nicola, surveyor of the municipal technical office of Ronco all'Adige. Interviewed October 24th 2008, Ronco all'Adige.

Zanini, Paolo, surveyor, responsible for the district of Bovolone of the Acque Veronesi Scarl. - service agency for drinking water supply and management of waste waters. First interview, October 24th 2008, Bovolone. Second interview, October 27th 2008, Bovolone.