River Restoration/Rehabilitation as a New Urban Design Strategy: Learning to Re-see Urban Rivers

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Abstract: This study analyses how river restoration-rehabilitation concepts can be transferred from natural settings to constructed environments and thus form part of an urban design strategy. In contrast to conventional civil engineering, this strategy explores how hydraulic challenges can be tackled through instead of against nature. The study focuses on urban rivers in Chile where unstable geographical and environmental conditions in combination with limited budgets require innovative solutions. The methodology uses research by design. From an environmental viewpoint, river restoration know-how is shifted from a restoring tool to a spatial analysis tool focused on understanding natural spatial processes. The outcome of this study is a cartography that maps the dynamic interplay between the natural water system and the city of Concepcion's environmental conditions on the one hand and the relationship between the river landscape and urban development on the other.

Keywords: River Restoration, Landscape Urbanism, Adaptive Planning

Setting a Theoretical Framework

Urban rivers modify severely through morphodynamic processes, sedimentation, riparian landscapes, and biological structures among others. These disturbances are a key part of the urban-nature conflict and often related to natural hazards since most of the cities are built in the natural floodplains of rivers and streams. As Shannon (2013) argues in "Eco-Engineering for Water: From Soft to Hard and Back," urban design has the ability to synthesize and integrate new soft engineering approaches into the planning and development of tomorrow's cities. Thus, finding a way to forge a harmonious yet dynamic balance between city and nature. Shannon emphasizes water as a key element of nature that will play a major role in this re-balancing.

Analysing rivers as mediators between city and nature this approach embodies a critique to the imposed solutions caused by technocratic visions. In this way and in contrast to conventional engineering this research explores how urban hydraulic challenges can be tackled by understanding the landscape logics and dynamics.

Since 1967, McHarg's ideas of working with instead of against nature have found increasing resonance among designers, especially among those with ecological concern (McHarg 1967). Nowadays, there is an interdisciplinary tendency in urbanism and planning based on a better understanding of the natural strengths and weakness of the territory due to the development of environmental science.

This new attitude could be considered an outcome of the interplay between environmental science and design that started in the early 1990s. In 1990, Forman, who is known for his crucial contribution to ecology, built up spatial models of landscape processes. While in 1997, the landscape architect James Corner proposed ecology and landscape as agents of a new creative attitude to assess design proposals that follow and understand natural processes. Furthermore, in 2001 the environmental scientists Turner et al. published "Landscape Ecology," which analysed ecological processes from both theoretical and practical viewpoint, improving the applicability in spatial design methods. In 2006, the landscape architect Prominski linked the evolutionary properties of natural systems to landscape design. By integrating an evolutionary perspective and

adaptive methodology into the design process, he opposed traditional static design images (Promisnki 2006). These new insights in natural landscape systems in relation with the city have been clearly articulated by Kondolf in 2009 who focuses on environmental dynamics of urban rivers and Brierley's 2011 study elaborates further into policy engagement with the current urban river situation.

A design approach in relation with nature enables to set up this dialogue and interplay between environmental sciences (Fig. 1).

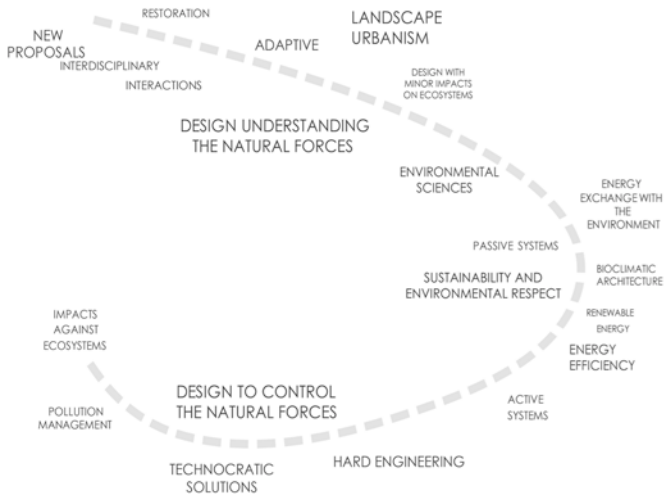

Figure 1: Synthesis of the Design Approach in Relation with Nature
Source: Author

Currently, the main discipline that studies ways to regenerate river processes with soft engineering is river restoration (here in after RR). Despite that RR is largely debated, does not yet however have a fixed definition. One generally accepted, is the activity that improves water quality, enhance aquatic and riparian habitat, and facilitates human uses (Downs et al. 2002; Bernhardt et al. 2005, quoted by Kondolf 2006) (Fig. 2). There are basically two kinds of RR: passive and active. The former is a reset action based on removing the impacts in a degraded system. It is a lengthy process to achieve the autonomous recovery of the system fundamentals, namely: structure, flows, complexity, diversity, territory, and functions (transport, regulation, and habitat). These are reinforced by virtue of their own resilience against future impacts in the appropriate space and time scale. The latter uses methods and techniques that accelerate the processes and involves major interventions with continuous maintenance, thus requiring a greater financial commitment.

In urban contexts it is almost impossible to fully achieve the RR objectives. Therefore, the "Rehabilitation concept" emerged. This concept refers to the recovery of natural functions, generally applied to places that are unable to reach the restoration aims due to the limitations of the existing pressures and impacts. In other words, it is a reset of degraded areas that is focused on the main elements and functions rather than on a complete re-naturalization. Rehabilitation also can entail the process of returning to a previous condition or status along a restoration pathway, or creation of a new previously and previously non-existent ecosystem (Fryirs and Brierley 2000).

Since the conceptual objectives of RR are very high and strict it is hard to find urban projects with comparable objectives to the interactions such this research is tackling. Most

projects in urban contexts are beautifications or simplifications of "green" aims that attract widespread criticism from the academic world. The contributions of Brierley and Fryirs in geomorphology and river management in 2006 (Brierley and Fryirs 2006) and the environmental perspective on city-river relationships of Kondolf in 2009 shaped the theoretical framework to guide the decision-making in the explorations of this research project.

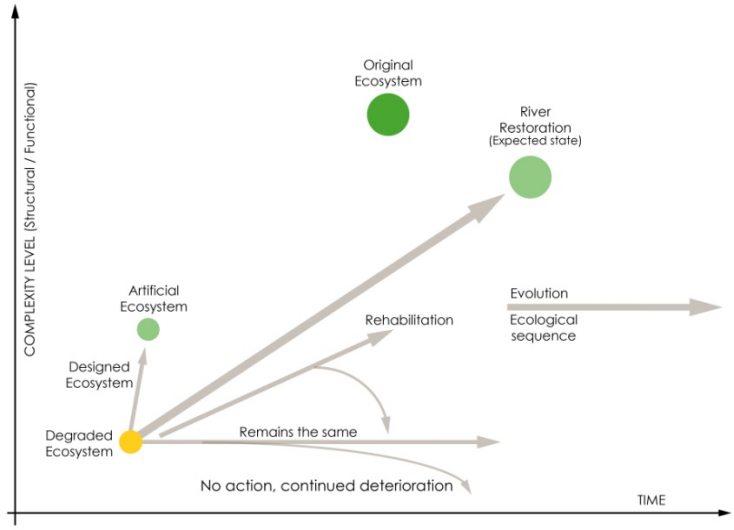

Figure 2: River Restoration/Rehabilitation
Source: Translated from Ollero's modified from Bradshaw 1987

In this approach, this study aims to shift conventional urban design and water management into a design based on urban water dynamics. Following the logic of the landscape, it is expected to start reading the environmental dynamics setting the framework to prove how geographical and ecological knowledge could be incorporated as a main part of the analysis and projecting method. Consequently, this analysis will contribute to understand the difference between an effective sustainable development and conventional urban land management. Using research by design methodology, this article explores how RR body of knowledge can be instructive for a new way to understand and envision urban river dynamics.

This paper develops a case study of a rainfall source river in Concepcion, Chile. In this interdisciplinary research, urban design and environmental knowledge are combined in the same conceptual framework. The outcome of this study is a cartography that synoptically demonstrates both the dynamic interplay between the natural water system and Concepcion's environmental conditions, and the relationship between the river dynamics and urban development; and also assesses the current regulatory framework. This research also proposes a critical exploratory mapping to address river restoration/rehabilitation as a way to re-see the rivers.

Case Study

Watersheds are the most relevant territorial and environmental configuration of Chile which can be defined as a succession of intermountain basin systems along its length (Romero and Vidal 2010). This key territorial feature is ideally suited for our critical approach, which seeks to provide a spatial dimension of conflicts between conventional urban-water design and natural spatial logic. In Chile, as in many other places, investments in river systems are geared toward conventional civil engineering and, as a result, mainly focus on containing floods with the assistance of rigid concrete sheds. These efforts evidently overlook the natural unstable state of

the territory, such as earthquakes, tsunamis, volcanoes, and the unpredictable effects of climate change.

In the last 100 years at least four major earthquakes occurred in Chile. These had a profound and well-documented impact on the country's geographical make up, causing new variations in terrain heights and for example, changing the courses of Chile's rivers. Under these circumstances Chile is presented as a good example to investigate this different vision addressing an adaptive methodology based on reinforcing resilient structures (CSN, actualised 2015).

In 1953 Chile introduced key changes in the Building and Urbanisation Law that aimed to cope with rapid demographic growth. Its importance lies in the integration of multiple variables with a systemic and coordinated scale approach from regional to city scale. During the dictatorship of Pinochet, in 1979, the government started a deregulation process by stating that the scarcity of land was artificially produced by excessive regulation, which resulted in the virtual elimination of urban growth boundaries (Smolka and Sabatini 2000). As a consequence, during the last sixty years the urban expansion dramatically altered land uses and covers increasing the vulnerability in landslide or flood risk areas. Thus, it has been demonstrated that the deterioration of the Chilean city's environmental quality is caused by a lack of institutions and specific regulations to manage the urban growth (Romero et al. 2009).

In particular, the case of Concepcion City Metropolitan area has 221.15 km² of which 61 percent presents one type of risks, having 35,575 inhabitants directly exposed to water logging and flooding (Mardones and Vidal 2001). Thus, in 2006 the flooding damages cost 42 million Euros, with 3,700 dwellings affected.

This research will be focused in the Andalien River case which has gained 700 percent of urban land between the years 1955 and 2007, dramatically decreasing its potential of rain water storage (Romero and Vidal 2010). Nowadays, the Andalien River watershed has 12,000 people exposed to natural hazards (DGA 2004). Between 1960 and 2010, there were twenty-one flooding events in this watershed with a recurrence of 2.43 years (Rojas and Mardones 2013).

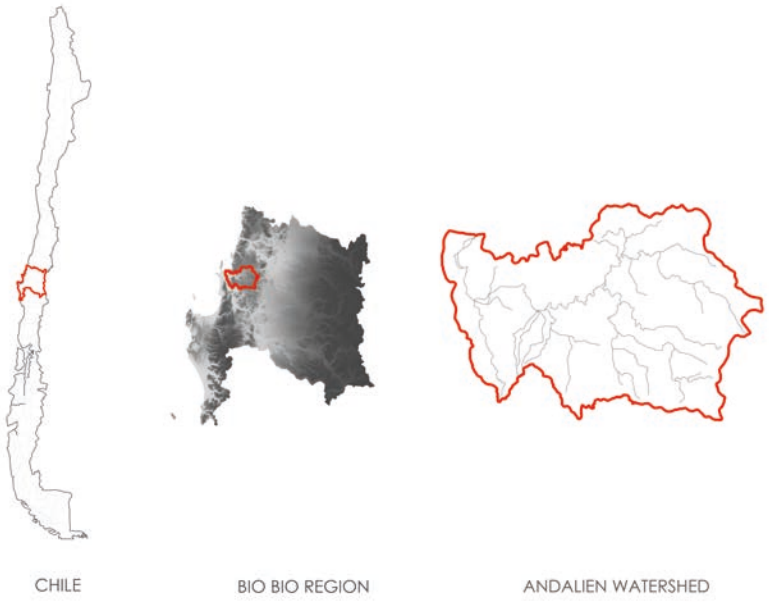

Figure 3: Situation Scheme of the Case Study
Source: Adapted by the author. Layers: Chile general map; regional-DEM in PROT, 2011and Andalien CAD layers, Jaque 1996

Learning to Re-see Urban Rivers

Combining geomorphology principles and urban observations through a scalar analysis it is expected to chart the effects of both the river dynamics over the population and the urban land regulations and dynamics in relation with the river landscape. This joint work will contribute to the reduction of the widespread conceptual simplifications that have resulted from conservative or superficially green interpretations.

Geomorphology principles to perform RR practice provide an integrative physical template with which to assess habitat associations and linkages of biophysical processes in landscapes (Brierleys and Fryirs 2006, 19). Thus, river space is defined as continuous, wide, and without obstacles. And it is the place where three main processes occur: 1) the sediments are mobilised; 2) the flow has seasonal fluctuations, and 3) the overflow speeds up the functioning periodically. All these relationships and an appropriate timescale configure the dynamics and diversity of the river's aquatic ecosystem. In this particular case study the sedimentation process is not studied because the analysis of this phenomenon needs particular measures of volume and time scale that were not considered.

> Relationships between scales, and their significance in determining measures of system functioning, vary for differing branches of enquiry. For example, predation and species-species interactions operate at differing physical scales to geomorphic interactions that shape river morphology… Characteristics that vary over small spatial and temporal scales are constrained by, or nested within, boundaries set by characteristics that vary over large scales. In general terms, the larger the scale of analysis, the greater the level of generality of forms and processes involved. Large-scale attributes are delineated using large-scale characteristics such as relief and valley slope, and necessarily include a great deal of variation in small-scale characteristics such as flow type and substrate. (Brierleys and Fryirs 2006, 19)

General Overview

In order to develop the scalar analysis it is suggested to make three main zooms. The first zoom is based on the watershed as the main river landscape unit to explore both a description and elaboration in the problems. The second zoom will highlight the interplay between the city and water system. It is a square zoom in which the city is the main element. Finally, there is a zoom in the edge between the river and the city exploring the last regulatory frameworks and also showing a walking perspective.

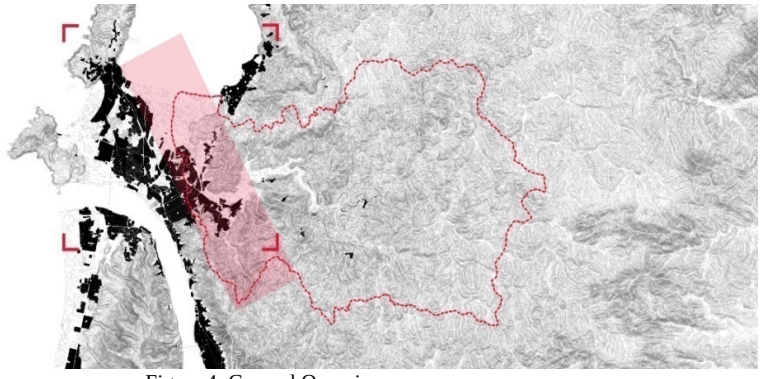

Figure 4: General Overview
Source: Adapted by the author. Layers: GIS regional information in PROT 2011 and Andalien CAD layers, Jaque 1996

Watershed Description

The interplay between water and topography clearly shows the origin of the Andalien River, with a rainfall pattern draining the west side of the Coastal Mountain (Jaque 1996). It is a 36 km long river course (DGA 2004) and has three geomorphologically defined sections: one upper reach with low levels of sinuosity in the area of coastal dry land; one middle reach semi-embedded in the valley until the beginning of the coastal area and; a lower reach where the river mouth is situated which has the largest concentration of urban activities and population (Jaque 2008). The population of about 100,000 inhabitants is unevenly distributed throughout the region. The 10 percent that live in the upper part are mainly rural. The other 90 percent is urban population living in the lower part of the river. The latter use 4 percent of the watershed area (Jaque 2010).

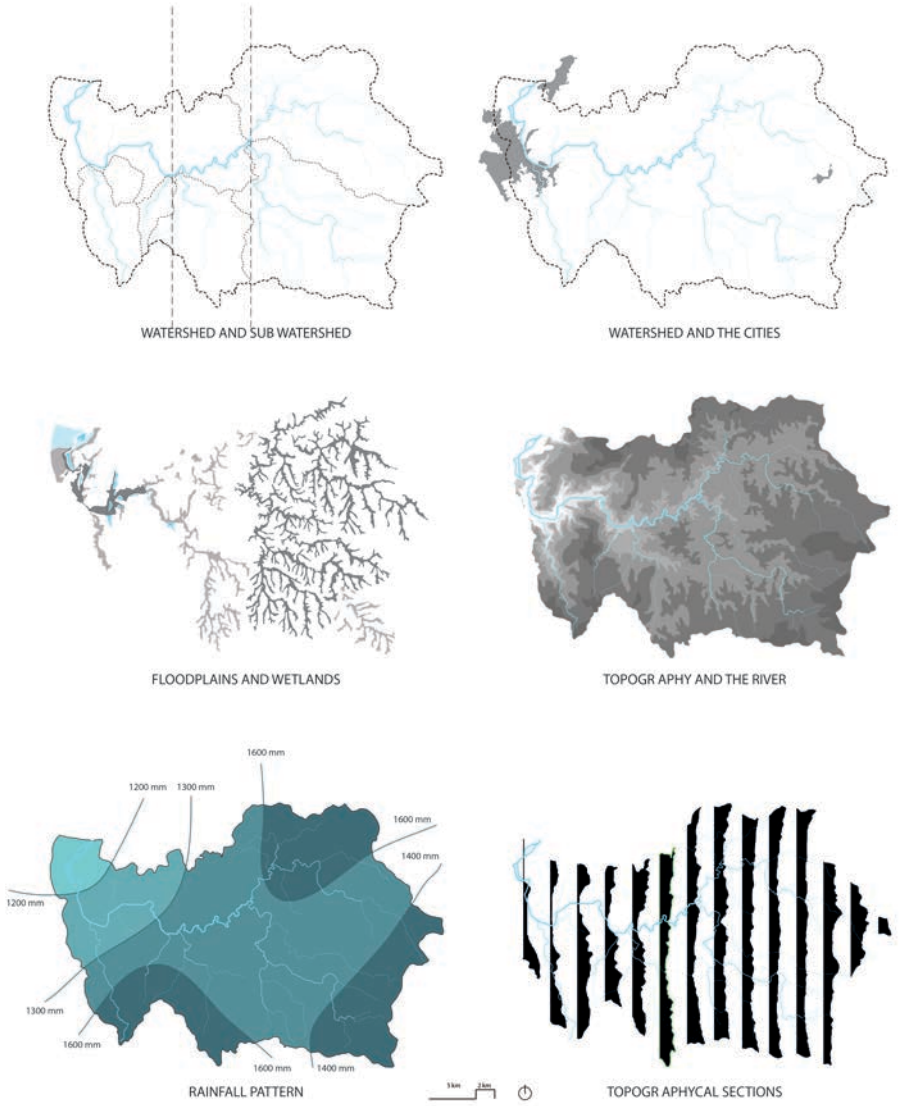

Figure 5: Watershed Description
Source: Adapted by the author. Layers: GIS regional information in PROT 2011 and Andalien CAD layers, Jaque 1996

Watershed Analysis

Exotic Monoculture Woodlands Affects "The Green Desert"

The Andalien landscape reflects the evolution of the country's economy. Due to their Mediterranean climate the natural resources of this watershed have been intensively exploited. During the 16th and 17th centuries the economy was mainly based on livestock breeding. In the 18th and 19th centuries the focus shifted to agriculture. And since the 20th century, the emphasis has come to lie on monocultural forestry (Jaque 2010).

After the first intensive exploitation period for industrial and productive purposes, the Andalien watershed started to deteriorate as a result of massive erosion. In consequence, the first regional reforestation plan was implemented in 1958. Then, due to occurrence of the problem of erosion in the major part of the country, in 1964 a national public plan for reforestation was established. After that, during the dictatorship of Pinochet, the reforestations plans were delegated to private developers that were subsidised by the government. This decision provided renewed boost for monoculture forestry. In 2008, the Bio Bio region reached 850,000 hectares of Pinus R. and Eucalyptus G. plantations (Hubera et al. 2010), about one-fourth part of the entire region and a 64 percent of the watershed (Cuenca Andalien 2004).

These foreign woodlands, based on Pinus Radiata and Eucalyptus Globulus, had detrimental effects on the hydrological dynamics of coastal watersheds. During the summer of 2009, the wilting point, (in which vegetation can no longer extract water from the soil and thus permanently loses its characteristics) was exceeded 30 cm (Hubera et al. 2010).

Monoculture has also changed the natural corridor that affects the riparian vegetation. This had a direct impact on biodiversity and has reduced the original landscape to what is now known as the green desert.

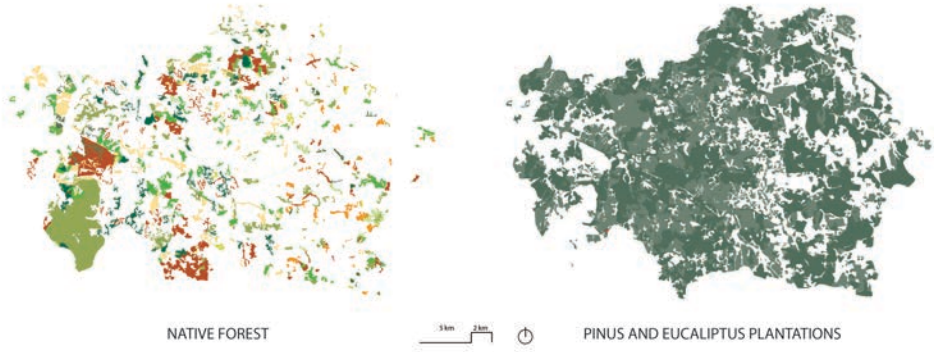

Figure 6: Native versus the exotic forest "The Green Desert"
Source: Adapted by the author. Layers: GIS information in forest cadastre CONAF 2008 and Andalien CAD layers, Jaque 1996

Seasonal Dynamics: Scarcity and Overflow

Twenty-one flooding events have been measured since 1960–2010 establishing a recurrence of 2.43 years (Rojas and Mardones 2013). The same study established a recurrence in detail of small flooding every 5.1 years, moderate flooding every 6.4 years, and big flooding every 17 years (Rojas and Mardones 2013). This watershed has a capacity of 96 mm of rainfall management in seventy-two hours but the maximum defined for a five-year recurrence event is 140 mm (Aros et al. 1995). Twelve thousand inhabitants are exposed to risks of lodging and flooding (DGA 2004).

During the summer due to evapotranspiration process of the Pinus R. and Eucalyptus G., Huber et al. 2010 established an interception loss of 68 percent and 74 percent for Eucalyptus and 60 percent and 63 percent for the Pinus plantations of the total rainfall. Every summer since 2007, the upper part of the river has been declared in agricultural emergency.

Figure 7 shows the seasonal dynamics of both the winter flows, especially in the river's lower reaches, and the scarcity of water in summer in the upper part of the watershed.

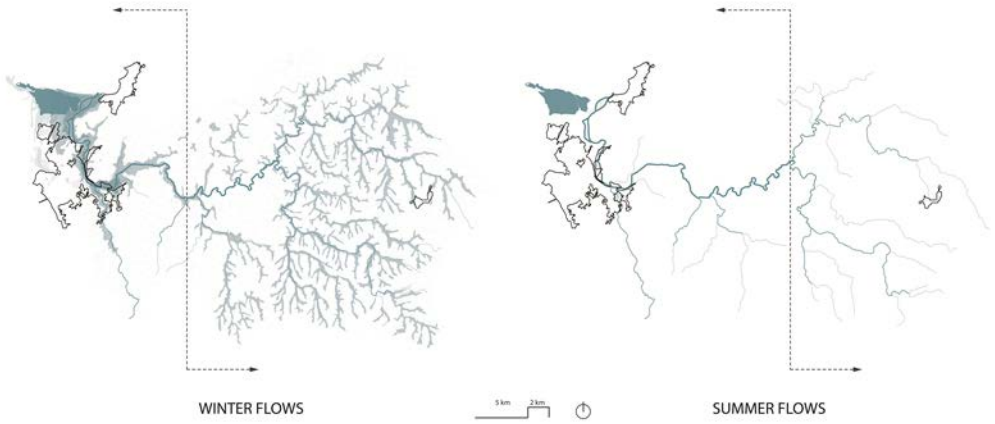

Figure 7: Winter-Summer Dynamics
Source: By the author. Layers: official information from PROT RIESGOS 2011 and Andalien CAD layers, Jaque 1996

Interactions between the City and the Water System

General Water System

The Andalien River is a part of a complex water system configured by Bio Bio River that originates in two lakes in the Andes Mountains, several rainfall pattern rivers and streams, underground water, wetlands, estuaries, and lagoons. As a result of climate change and the rainfall origin it is a fragile ecosystem. Figure 8 shows the main components of this system.

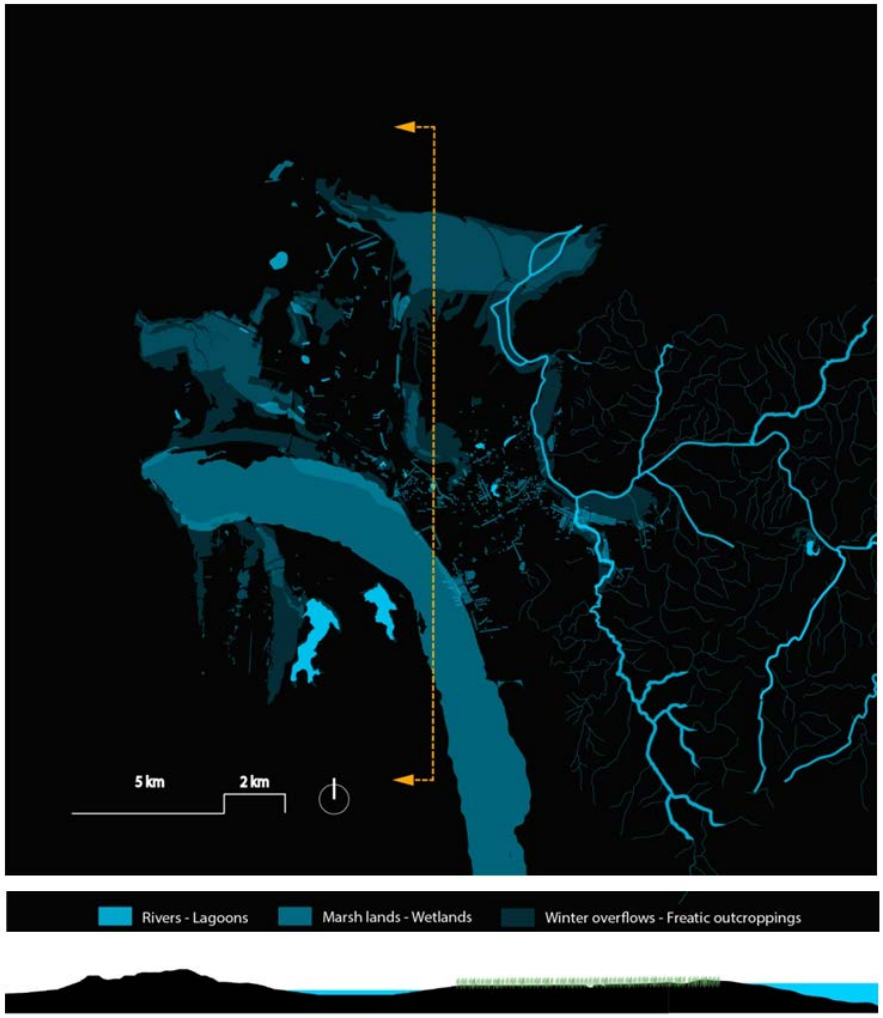

Figure 8: Water Systems
Source: Zoom 1: Adapted by the author. Layers: PROT 2011 and Andalien CAD layers, Jaque 1996

Urban Area and Water System Dynamics-Overflow

This map shows the interplay of water on the urban system. Are the cities of Concepcion, Talcahuano and Penco shaped by the water system or do they shape the system? The cities are set in the water space, so the natural performance of the water system appears, disappears, faces and shapes the entire city. It is evident that the city blocks, limits and restricts the water movement so the seasonal dynamics are not included in the urban design. Currently there is discussion on a governmental project to create a logistic platform in between the ports. It will be constructed in the wetland which is a part of the Andalien river mouth and the water system of the Concepcion harbour.

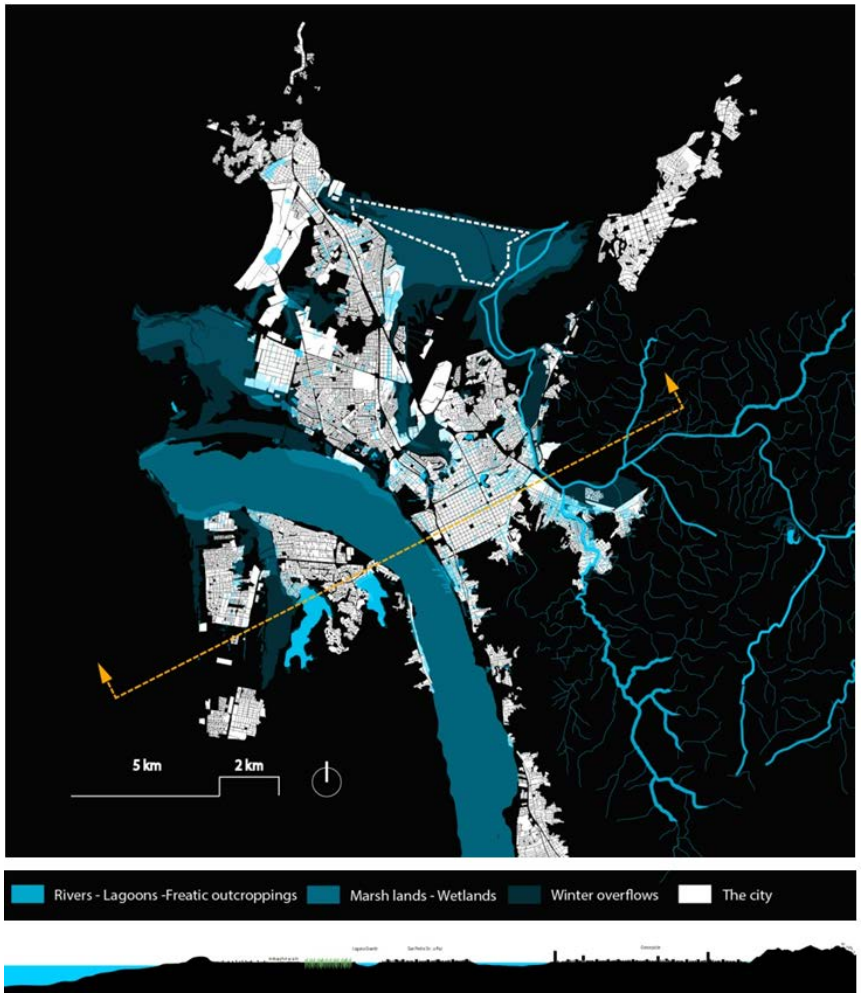

Figure 9: Interplay between Urban-Space, Overflow Fluctuations and Outcroppings and Water Logging
Source: Zoom 1: Adapted by the author. Layers: PROT 2011 and Andalien CAD layers, Jaque 1996

Water System and Infrastructure

Concepcion has been shaped by infrastructure. The main economic activities are industry and ports. The metropolitan plan enforces the connections between the cities with infrastructure that crosses perpendicularly the water system, thus creating conflicts and obstructions in wetlands and river space. Blocking the water path, cutting the water space and redirecting the water flows the infrastructure causes major alteration in the continuity of the water space. The main environmental functions of the rivers are altered such as barrier, filter, source of species, sediments, and nutrients and so on losing the continuity of the cycles that define a healthy river system.

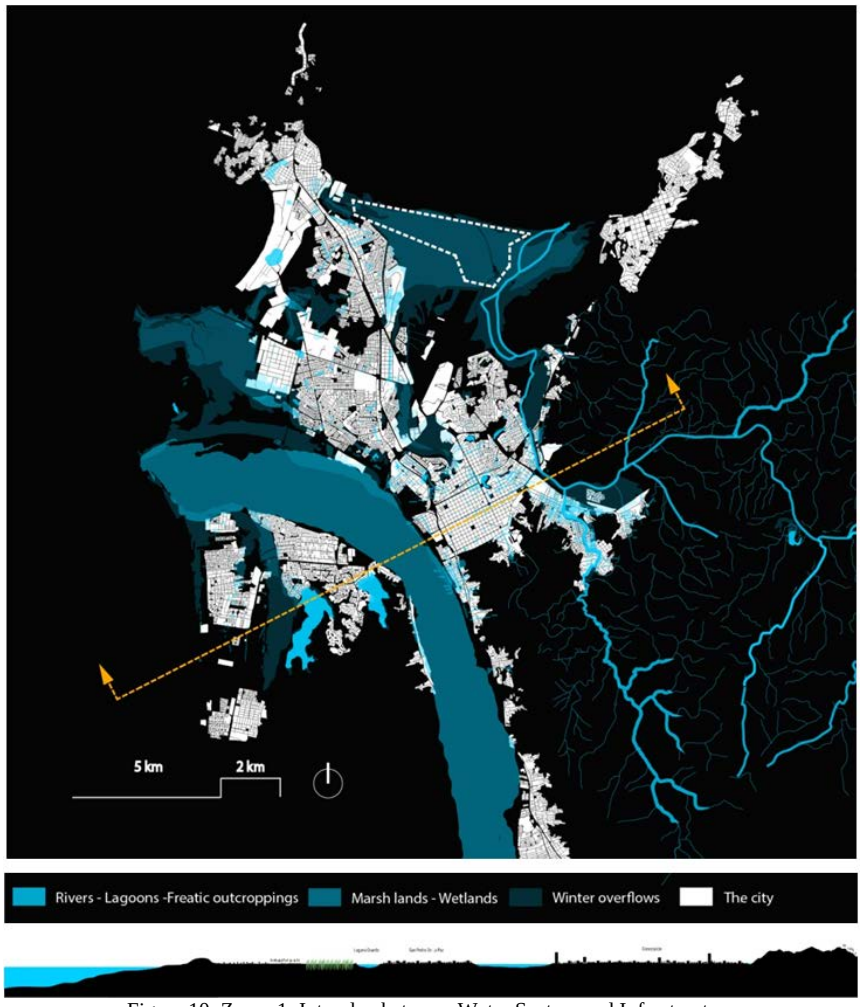

Figure 10: Zoom 1: Interplay between Water System and Infrastructure
Source: Adapted by the author. Layers: official information from PROT 2014

The Edge

The River Space and Urban Land Regulations

This interplay between urban pressures is bound to reveal not only the conflicts and contradictions, but also the margins for intervention, the overlaps and the possibilities for synergies. The urban land policy studied through the years shows the land that has already been developed as well as the land that will be used in the future. It will be impossible to maintain the natural corridor neither the flood plain. This map also shows the way on how the river space was waterproofed following the formal regulations.

Figure 11: Zoom 2: Proposed Urban Expansion Areas. From left to the right: 1962–1980–2002
Source: Adapted by the author 1. Layers: JPEG images, official information from PMRC 1962–1980–2002

Riverbank and Street Level Analysis

Walking along the riverbanks of the Andalien in Concepcion allows one to understand the interplay between citizens and the river.

It seems like Andalien River has no significance for the people, either the authorities or the urban designer. This can be inferred from three key situations: the illegal dumping of garbage on the riverbanks; the lack of public space in the subsidiary stream canalisation projects, and the inefficient use of the riverbanks as a public space. It is evident the persistent failure to see or use the river as a place for aesthetic and recreational enjoyment.

Other major interventions have occurred in the riverbanks with landfills to build over them. This alters the river space where the natural processes should occur and alters the water performance during overflow periods with unpredicted results.

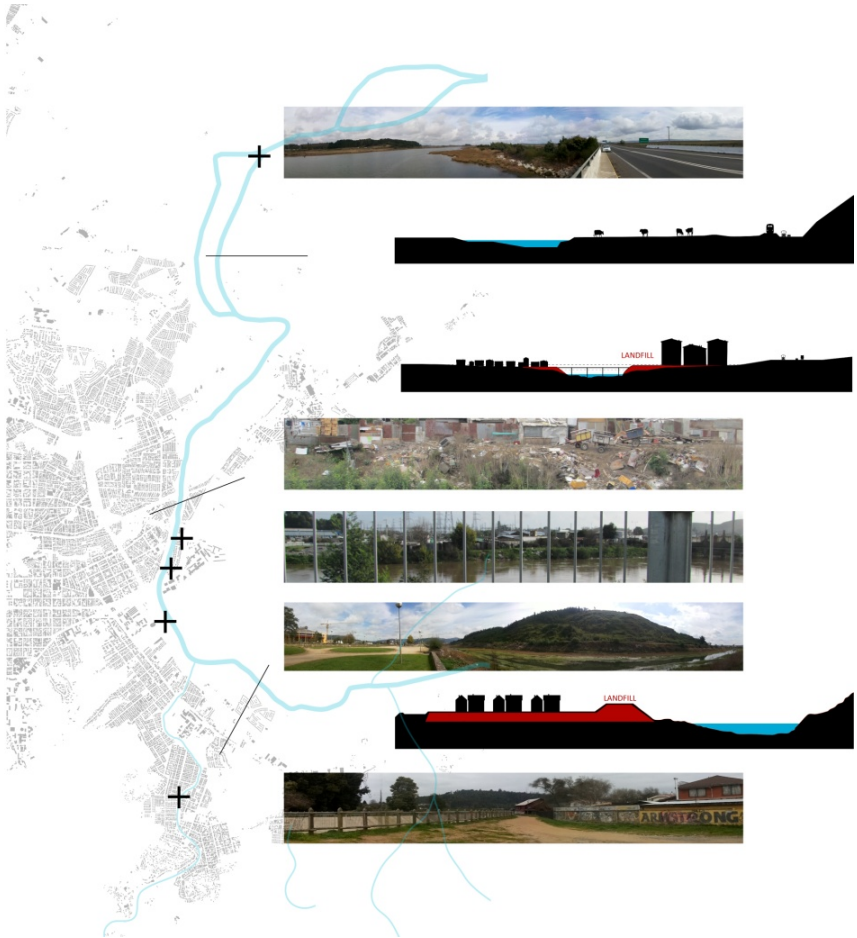

Figure 12: Walking along the Andalien. Panorama Pictures and Sections
Source: Edited by the author, based on atlas studio 2014–2015 Andalien River Project, Naulers, Demarsin

Synoptic General Diagnosis

This map shows a summary of several interventions in the watershed. It is possible to differentiate two scales of interventions. At the watershed scale, the plantations of the exotic forests that change the water dynamics both winter and summer, with the consequences being more dramatic during summers. It is also possible to recognise specific hard engineering interventions along the course of the river and streams.

These interventions are dams, bridges, highways, canalisations, profiling, landfills, changes in the course, and so on. All these elements alter the river's performance, dynamics and natural behaviour. In this specific case due to the canalisation, landfills and profiling the water course in the lower part, which is the biggest flood plain of the river, creates the false impression of having proper land to develop. The fallacy of this impression is exposed every two years when large areas of land are flooded and every seventeen years when a big flood has catastrophic consequences.

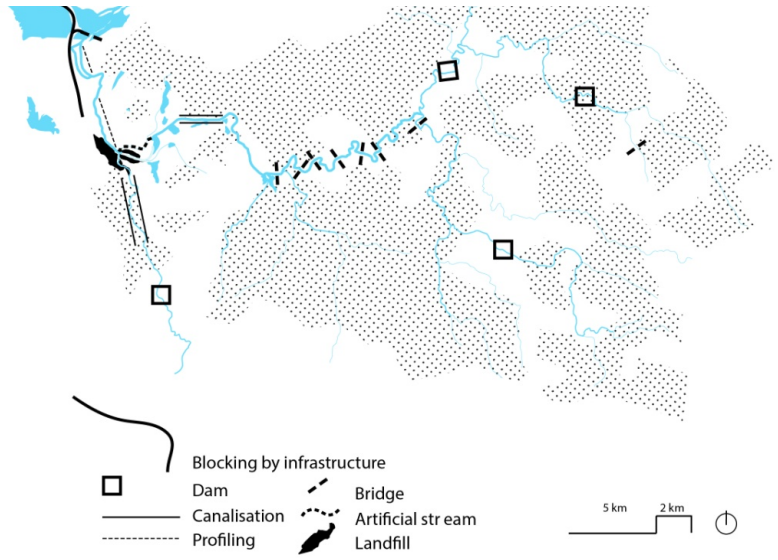

Figure 13: Synoptic map of the watershed
Source: Edited by the author, based on atlas studio 2014–2015
Andalien River Project, Naulers, Demarsin

Conclusions

Learning to re-see the (urban) rivers creates the opportunity to perform a comprehensive analysis in which the urban designer-researcher combines a wide array of perspectives in order to conceive a radically different perception of river space and, accordingly, a new method of design.

This first exercise of guiding an analysis by RR knowledge reveals some of the invisible layers that the atrophic activities cause in relation with two dynamics: the seasonal flow fluctuations and the overflow speeding up the functions periodically.

The watershed scale approach deals with the regional environmental approach and reveals that the main problem of the river water dynamics is related to the productive landscape. The city is set in the lower part of the watershed which is the biggest floodplain of the river. This means that the major amount of water during the winters coming from the upper part of the river should be managed in the same place where the city is located. During the summers there is water scarcity in the upper part. This unbalanced situation is created artificially by the unbalanced amount of exotic plantations that spread over 64 percent of the watershed.

The city and water system analysis reveals how the city is completely set over a natural water system. The influence of ancient landscapes of Bio Bio River determines a scenario where the water appears and disappears looking for places to go. Most of the functions that the overflow of water should speed up are blocked or erased in the lower part of the river.

In “the edge” analyses the river is revealed as a forgotten part of the city. It is evident that the river does not have a positive image, neither for urban planners nor for the people living in its vicinity. The space described is just an edge between water and land that has been erased of its potential as a site of natural beauty. It is also clear that the landfills work to gain some space from the river but on the rebound will cause even worse problems in the future because the winter overflows of water will anyhow find for a place to go.

One of the key contributions of this study is a conceptual enumeration of interventions in the river. By putting these interventions in their sequence, it is possible to reveal an invisible layer of the river system and the human-induced impacts that was not evident before.

To sum up, the difference between the administrative definitions of territory and landscape is that the latter has a meaning that goes beyond administrative divisions. An in-depth analysis of what happened to the landscape of Andalien River and Concepcion reveals that the distortions started when all the technocratic decision making almost destroyed the "public-common" meaning of the landscape. Forgetting the landscape characteristics and behaviours put the inhabitants in a disadvantaged and dangerous situation. If a river is transformed in something artificial, this does not only implies the loss of biological complexities, ecological dynamics and beauty. Forgetting how to understand natural elements in their seasonal logic can cost more than material damages.

REFERENCES

Acuña, Vicenç, José Ramón Díez, Lorea Flores, Mark Meleason, and Arturo Elosegi. 2013. "Does It Make Economic Senseto Restore Rivers for Their Ecosystem Services?" *Journal of Applied Ecology* 50: 988–97.

Bernhardt, Emily S., Margaret A. Palmer, David Allan, G. Alexander, Katie Barnas, Shane Brooks, J. Carr, Stephen Clayton, Clifford Dahm, Jennifer Follstad-Shah, David Galat, Steven Gloss, Peter Goodwin, David Hart, Brooke Hassett, Robin Jenkinson, Stephen Katz, Mathias Kondolf, P. S. Lake, Rebecca Lave, J. L. Meyer, T. K. O'Donnell, Laura Pagano, B. Powell, and Elizabeth Sudduth. 2005. "Synthesizing U.S. River Restoration Efforts." *Science* 308: 636–7.

Brierley, Gary, and Kristie Fryirs. 2006. *Geomorphology and River Management Applications of the River Styles Framework*. Oxford: Blackwell Publishing.

Brierley, Gary, Kirstie Fryirs, Nick Cook, David Outhet, Allan Raine, Lucy Parsons, and Michael Healey. 2011. "Geomorphology in Action: Linking Policy with On-the-ground Actions through Applications of the River Styles Framework." *Applied Geography* 31 (3): 1132–43.

Centro Sismológico Nacional (National Seismological Centre) (CSN). Actualized Information 2015. Universidad de Chile.

Corner, James. 1997. "Ecology and Landscape as Agents of Creativity." *Ecological Design and Planning*, edited by George Thompson and Frederick Steiner, 81–108. New York: John Wiley and Sons.

Dirección General de Aguas (General Directorate of Water) (DGA). 2004. "Diagnostico y clasificacion de los cursos y cuerpos de agua según objetivos de calidad. Cuenca del río Andalien (Classifications and Diagnosis of the Water Bodies through the Quality Aims)." Andalien Watershed. Gobierno de Chile, Ministerio de Obras Públicas.

Downs, Peter, Kevin Skinner, and Mathias Kondolf. 2001. "Rivers and Streams." *Handbook of Ecological Restoration: Principles of Restoration*, edited by M. R. Perrow and A. J. Davy, 267–91. Cambridge: Cambridge University Press.

Forman, Richard. 1990. "Ecologically Sustainable Landscapes: The Role of Spatial Configuration." *On Landscape Urbanism*, reprinted by Austin School of Architecture, 56–69. Texas: University of Texas. 2007.

Huber, Anton, Andrés Iroumé, Christian Mohr, and Cristian Frêne. 2010. "Efecto de plantaciones de Pinus radiata y Eucalyptus globulus sobre el recurso agua en la Cordillera de la Costa de la región del Biobío, Chile (Effect of Pinus Radiata and Eucalyptus Globulus

Plantations on Water Resource in the Coastal Range of Bio Bio Region, Chile)." *Bosque* 31 (3): 219–30.

Jaque, Edilia. 1996. "Análisis integrados de los sistemas naturales de la cuenca hidrográfica del río Andalien: Proposición para el manejo integral de la cuenca (Integrated Analysis of the Natural Systems in the Andalien Watershed: Proposal for an Integrated Management of the Watershed)." PhD Thesis. Universidad de Concepcion.

———. 2010. "Diagnóstico de los paisajes mediterráneos costeros. Cuenca del río Andalien, Chile (Diagnosis of the Mediterranean Landscapes. Andalien Watershed, Chile)." *Boletín de la Asociación de Geógrafos Españoles* 54: 81–97. ISSN: 0212-9426. Architecture, Urbanism and Geography Faculty. Universidad de Concepcion. Chile

Kondolf, Mathias. 2006. "River Restoration and Meanders." *Ecology and Society* 11 (2): 42. http://www.ecologyandsociety.org/vol11/iss2/art42.

———. 2009. "An Environmental Perspective in City River Relationships: In Cities and Rivers, Perspectives towards a Sustainable Partnership." *Livro Nº8 Da Colecção expoentes*, edited by Edições Da Parque Expo, Lisbon: Núcleo de Comunicação Da Parque Expo.

Mardones, María, and Claudia Vidal. 2001. "Zoning and Evaluation of Natural Hazards of Geomorphologic Type: A Tool for Urban Planning in the City of Concepcion." *EURE* 27 (81). Pontificia Universidad Católica de Chile. Architecture, Design and Urban Studies, Urban and Territorial Studies Institute. Santiago.

McHarg, Ian. 1969. "Process as Values, Design with Nature." *On Landscape Urbanism*, reprinted by Austin School of Architecture, 1021. Texas: University of Texas. 2007.

Prominski, Martin. 2006. "Designing Landscapes as Evolutionary Systems." *The Design Journal*, 8: 25–34.

Rojas, Octavio, and María Mardones. 2013. "River Flooding in a Coastal Basin of Central South of Chile (1960–2010): Trends, Recurrence and Relationship with ENSO Phenomenon." *XXXIV Congreso Nacional y XIX Internacional de Geografía*, Universidad del Bío-Bío, 10.

Romero, Hugo, Claudio Moscoso, and Pamela Smith. 2009. "Lecciones y Conclusiones sobre la falta de Sustentabilidad ambiental del crecimiento Espacial de Las Ciudades Chilenas (Lessons and Conclusions about the Lack of Environmental Sustainability of the Special Growing in Chilean Cities)." *Geolibros EURE* 12: 89–110. Pontificia Universidad Católica de Chile. Architecture, Design and Urban Studies, Urban and Territorial Studies Institute. Santiago.

Romero, Hugo, and Claudia Vidal. 2010. "The Watershed Urbanization of the Andalien and Bio Bio Rivers and its Effects on Flood Water Logging Risk in the City of Concepcion." *Geolibros* 14. Concepcion: Universidad de Concepcion.

Shannon, Kelly. 2013. "Eco-engineering for Water: From Soft to Hard and Back." *Resilience in Ecology and Urban Design: Linking Theory and Practice for Sustainable Cities*, edited by S. T. Pickett, M. Cadenasso, and B. Mcgrath, 163–82. London: Future City Series, Vol. 3, Springer.

Smolka, Martim and Sabatini, Francisco. 2000. "The Land Market Deregulation Debate in Chile." *Land Lines* 12: 1–3. Cambridge, MA: Lincoln Research Institute.

Turner, Monica G., Robert H. Gardner, and Robert V. O'Neill. 2001. *Landscape Ecology in Theory and Practice, Pattern and Process*, 2–23. New York: Springer-Verlag.

MAP SOURCES

Plan Regional de Ordenamiento Territorial (PROT). 2011. (Regional Plan for Territorial Planning. Vector and Raster Information), Bio Bio Region. Chile.

Coorporación Nacional Forestal (CONAF) (National Forest Corporation). 2008. Vectorial Information." Bio Bio Region. Chile.

Plan Regulador Metropolitano de Concepcion (PRMC) (Metropolitan Regulatory Plan for Concepion). 1962. JPEG Image.

———. 1980. "Metropolitan Plan for Regional Planning." JPEG Image.

———. 2002. "Metropolitan Plan for Regional Planning." JPEG Image.

———.2013. "Actualised Thematic Cartography, Minister of Housing and Urbanism."

Jaque, Edilia. 1996. "Análisis integrados de los sistemas naturales de la cuenca hidrográfica del río Andalien: Proposición para el manejo integral de la cuenca (Analysis of the Natural Systems in the Andalien Watershed: Proposal for an Integrated Management of the Watershed)." PhD thesis. Universidad de Concepcion.

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