Scalar Mismatches in Metropolitan Water Governance:

A Comparative Study of São Paulo and Mexico City

SCALAR MISMATCHES IN METROPOLITAN WATER GOVERNANCE: A COMPARATIVE STUDY OF SÃO PAULO AND MEXICO CITY

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FRANCINE VAN DEN BRANDELER

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PUBLICATIONS AND TRAININGS

Peer-Reviewed Journal Articles and Book Chapters

Brandeler, F. van den, J. Gupta (Forthcoming) The Evolution of Water Resources Management. In Fath, B. (Ed) Managing Water Systems and Hydrological Systems, Volume Four.

Brandeler, F. van den, J. Gupta and M. Hordijk, (2018) Megacities and Rivers: Scalar Mismatches between Urban Water Management and River Basin Management. [Special Issue: Water and Megacities]. Journal of Hydrology.

Hordijk, M. A., F. Van Den Brandeler and M. E. Filippi (2016) Facing the Floods: Community Responses to increased rainfall in Guarulhos, Brazil and Arequipa, Peru. In Roy, M., S. Cawood, M. A. Hordijk, D. Hulme (Eds) Urban Poverty and Climate Change: Life in the slums of Asia, Africa and Latin America, Routledge, London.

Brandeler, F. van den, Hordijk, M., von Schönfeld, K., Sydenstricker-Neto, J. (2014) Decentralization, Participation and Deliberation in Water Governance: a case study of the implications for Guarulhos, Brazil. *Environment and Urbanization*.

Other Publications

Brandeler, F. van den, Hordijk, M., Sara, L. M., Sutherland, C., Sydenstricker-Neto, J. and Batata, A. (2013) Convergence or Divergence in Metropolitan Water Governance? Comparing Changes in Guarulhos (Brazil), Lima (Peru) and Durban (South Africa). 4° Encontro Internacional da Governança da Água Governança da Água: Dimensões Institucionais.

Brandeler, F. van den (2017) Conflicts of Interest Around Urban Water: Informal Settlements, Endangered Species and Cultural Heritage in Mexico City. *Voices*, Global South Study Center, University of Cologne.

Trainings

- Research School for Resource Studies for Development (CERES), Training 2015
- Young Summer Scientist Programme, Water Programme Group, International Institute for Applied Systems Analysis (IIASA), Summer 2017

Executive Summary

Between 2013 and 2015, a major drought brought São Paulo to the edge. Water was running so low that even in the central areas of the city, bars and restaurants shut doors or started using plastic cups because they had no water to rinse dishes. In 2018, Cape Town was within weeks of 'Day Zero', when municipal water supplies would be shut off, leaving a population of roughly 3.75 million people without access to water. Jakarta and Mexico City are sinking. Groundwater over-exploitation has contributed to land subsidence of 10 inches a year in Jakarta, further exposing the mega-city to coastal flooding and rising sea levels; In Mexico City, aquifer depletion has led some areas of the city to sink by more than 10 metres, causing deaths and the destruction of buildings and public infrastructure. Ironically, land subsidence has inverted the slope of canals expelling drainage waters out of the city, and these now need to be pumped out – a failure to do so causes heavy floods.

The world is urbanizing rapidly and without planning, especially in the Global South. More people are living in cities and these are getting larger - the UN estimates that by 2030 at least a billion people will reside in metropolises of more than five million inhabitants. Larger cities heavily impact their surrounding areas. Although the world's 100 largest cities occupy less than 1% of the planet's land area, the basins that provide their water resources cover more than 12% of it (ARUP, 2018). Estimates indicate that cities with populations of more than 750,000 people obtain water from almost half of the global land surface and transport it over a cumulative distance of 27,000 km (McDonald *et al.*, 2014). In addition, in 2000, about 30% of global urban land was in high-frequency flood zones. By 2030, this will rise to 40 per cent (Güneralp *et al.*, 2015). The examples above illustrate the escalating tensions between cities and the very river basins they depend upon to exist. The policy community is trying to deal with the challenges of urban issues and water issues. In 2015, the UN General Assembly adopted the Sustainable Development Goals, which highlight areas of priority for the global community to work on following the expiration of the Millennium Development Goals (UNGA, 2015). Goals 6 (Ensure availability and sustainable management of water and sanitation for all), 11 (Make cities and human settlements inclusive, safe, resilient and sustainable) and 13 (Take urgent action to combat climate change and its impacts) and their associated targets and indicators are particularly relevant for this research.

While scholars have written extensively about River Basin Management and Urban Water Management, they are yet to develop a cohesive framework that addresses both the complexity of large metropolises and their river basins: currently, cities and their water systems are mostly studied in isolation.

This thesis helps fill-in this gap by examining in-depth the tensions between urbanization and river basins through interactions between urban water governance regimes and basin management regimes. Hence, this thesis aims to answer: **How do interactions between drivers and institutions at different spatial and institutional scales levels shape metropolitan water challenges, and how can policy instruments from river basin and urban water governance frameworks be (re)designed to foster more sustainable and**

inclusive metropolitan water governance? This research question is further divided into four sub-questions:

(i) What does the literature on urban water governance and on river basin governance tell us about how to understand and address metropolitan water challenges?
(ii) How do multiple drivers as well as river basin and urban water governance institutions shape current metropolitan water challenges? (enabling the understanding of causality);
(iii) Which policy instruments are effective, and which are not, in dealing with these water challenges and their drivers? (enabling the understanding of policy performance); and
(iv) Based on this analysis, how can more appropriate instruments be designed to address metropolitan water challenges, with the aim to guide metropolitan regions towards inclusive and sustainable development? (enabling the potential redesign of policies)

In sum, the thesis studies São Paulo and Mexico City, two large metropolises that are facing important (yet different) water challenges, to explore: (i) the role that institutions play in urban water challenges; (ii) how effective existing policy instruments are in addressing these challenges within metropolitan regions; and (iii) how more sustainable and inclusive institutions could be designed for this purpose. It develops the concepts of Scalar Mismatches and of Metropolitan Water Governance. The first concerns the design of governance frameworks at spatial scales that are inadequate for the issue they address. The second, defines the key elements that must be considered in water governance in metropolitan regions.

In order to do so, this thesis is divided into ten chapters. The **first chapter**, the introduction, outlines the challenges summarized above, the knowledge gap (developed further in Chapters 3 and 4), the nature of and the multi-disciplinary scope of the study.

The **second** chapter presents the methodology which combines a literature review on Urban Water Management and River Basin Management, a case study approach which links qualitative content analysis of policies with data collection through interviews, and applies an institutional analysis approach based on the environmental change framework of the IHDP/IDGEC Science Plan and its research foci of causality, performance and design. The adoption of the comparative case study method in general is important to understand complex dynamics. This chapter justifies the choice of Mexico City and São Paulo as large metropolises of the Global South that have urbanised rapidly and without proper city planning. Both cities are economic capitals of their respective countries, Mexico and Brazil, and are also within federal regimes where responsibilities are shared between federal, state and municipal governments. Both cities are the conurbation of dozens of different municipalities. They have also been striving to implement Integrated Water Resources Management and Urban Water Management (see below). Notwithstanding, both cities have been facing important and different water challenges, which is likely to be further exacerbated by climate variability and change. These characteristics allow me to learn important lessons that are not only applicable to these cities (with a combined population of more than 40 million people), but also to other metropolises in developing countries that are facing or will face similar problems. This chapter also presents the three units of analysis of the thesis: drivers, institutions and instruments (further divided between regulatory, economic, infrastructure and suasive). Finally, it introduces the fieldwork approach, focused on document analysis and semi-structured interviews with around 100 key water policy stakeholders.

The **third** chapter reviews the relevant literature on urban water governance. For decades, Urban Water Management (UWM) was the dominant paradigm in urban water. UWM emphasized supplying affordable water and expelling sewage out of the city rapidly, through large-scale, standardized infrastructure. With time this concept evolved into Integrated Urban Water Management ('IUWM') and Sustainable Urban Water Management ('SUWM'), which embrace sustainable and inclusive development principles. They all define responsibilities mainly at the local level (although the national government often issues norms and regulations) and there is an increasing focus on decentralization and participation, which can empower local actors and strengthen localist tendencies. However, UWM and its more recent iterations lack consideration for the metropolitan level. Metropolitan regions are not just large urban areas, but experience water-related problems of a different nature. Political fragmentation is recurrent, peripheral metropolitan municipalities often face greater water challenges and have fewer capacities to address these alone; and large conurbations increase the possibility of cities imposing negative externalities on their neighbours. In addition, UWM and its variations largely ignore the linkages to the river basin, as the spatial boundaries of cities do not align with those of the rivers basins and aquifers they depend upon. For example, even IUWM/SUWM actors do not interfere in water allocation or biodiversity and ecosystem services beyond city borders. All in all, UWM and its variations fail to properly account for the challenges of the river basin.

The **fourth** chapter flips the coin to demonstrate how current paradigms in river basin governance, Integrated Water Resources Management ('IWRM') and Integrated River Basin Management ('IRBM') fail to acknowledge the challenges of urban management. These concepts have shifted from conventional views that focused on large-scale infrastructure, centralized control and linear approaches of taking, using and discharging water, towards new paradigms that are more aligned with sustainability and inclusiveness. However, the literature mostly takes for granted that the river basin is the ideal spatial scale for addressing water-related challenges, even while it ignores certain types of water and water flows, as well as the fact that, due to human interventions, the 'natural' scale of the basin loses relevance. Moreover, although IWRM/IRBM promote the integration of all needs and interests within the basin, they assume that water management institutions will have influence over urban actors. The inverse is normally true – large metropolitan regions comprise a wide range of actors that need to be coordinated, and these (e.g. the mayor of São Paulo or a State public housing company) are recurrently much more powerful than river basin committees that lack resources, expertise, political capacity and more. All in all, IWRM/IRBM face important limitations in effectively shaping metropolitan water governance by failing to consider that the river basin is not always the ideal spatial scale and that metropolises host a plethora of actors and institutions whose interests and mandates many times clash with those of the river basin.

The **fifth** chapter is the first of the four addressing the case studies. It discusses the implementation of IWRM in São Paulo. The chapter starts by discussing the main drivers behind São Paulo's water challenges, the relative water scarcity it faces and how changes in climate and in land uses are making the problem worse (e.g. agricultural land becoming urbanized around the city). It then introduces a multitude of actors that compose the institutional framework of IWRM in São Paulo, from those at national level to state (e.g. water utilities such as SABESP, the DAEE; environmental secretariats) and the river basin (Alto-Tietê River Basin committee, sub-basin committees) – identifying competencies that are complementary, competencies that overlap, and how these dynamics impact policy coordination. The chapter then analyses and assesses specific instruments used to coordinate water policy at basin level in São Paulo's Alto-Tietê River Basin. It finds that inter-basin transfer policies have increased water supply but have discouraged water demand reduction and are not a long-term solution to São Paulo's challenges, in part because transfers disproportionally impact donor basins without giving them voice or compensation. Water permits also face important limitations, as they are improperly designed (e.g. they do not account for underground water use) or enforced/monitored. Water use and wastewater discharge fees, while mostly limited because of their low values, present some potential for improvement because of their possible future growth and their support to river basin committees. Policies to protect and rehabilitate springs are also important in theory but of limited practical impact because of restrictions on the coordination between the mandates of different governmental branches. The chapter concludes by proposing the redesign of some important instruments, such as the need to limit inter-basin transfer policies, increase the scrutiny and value of water permits and water use fees and expand programmes to protect springs – something that necessarily must be done with an integration of water and sanitation and housing policies at municipal and state levels. It also suggests the incorporation of new instruments to the mix, such as suasive instruments, to diminish water demand and Payment for Ecosystem Services programmes to preserve spring areas.

Main instruments analysed

	Brazil	**Mexico**
River basin	Water use permits	Water use permits
	Wastewater discharge permits	Wastewater discharge permits
	Water use and wastewater discharge fees	Water use and wastewater discharge fees
	Inter-basin transfers	Inter-basin transfers
	Areas for the protection and rehabilitation of springs	Payment for ecosystem services + Conservation land
Urban water	Water tariffs	Water tariffs
	Macro-drainage	Metropolitan drainage system
	Integrated sewage system	Metropolitan wastewater infrastructure

The **sixth**, examines the implementation of UWM in São Paulo. Urbanization, characterized by rapid growth and a lack of planning, is a particularly important driver of urban water challenges. This is enhanced by climate drivers at local levels (i.e. heat island effect) and higher levels (i.e. climate variability and change). Multiple actors influence UWM in São Paulo. The national level sets important standards and a regulatory framework, but the key actors are at state and local levels. For instance, SABESP, the state water and sanitation company, provides water services to most of the Metropolitan Region of São Paulo (MRSP), and half of the state. Many UWM responsibilities have been delegated to local levels, but these actors often lacked adequate capacity to fulfil their mandates, and struggle to coordinate their policies and actions within the metropolis. The instrument assessment reveals that water tariffs are central to furthering UWM goals. Their design includes lower rates for low-income households, higher tariffs for industrial and commercial consumers, cross-subsidies between municipalities where service provision is profitable or costly for the utility and increasing block rates. However, water tariffs do not sufficiently incentivize rational water use, nor do they lead to adequate investments in sewage treatment. São Paulo has also implemented a macro-drainage plan to foster a regional approach to drainage and flood challenges. This has led to effective coordination between local governments and the state, but less so between local governments, and with other sectoral agencies. It focuses on hard engineering solutions that still fail during heavy rains. Sewage management has also been integrated at metropolitan level, with smaller systems in peri-urban areas and a mega-sewage plant downstream of the city. The differentiation of infrastructure between urban areas, financed through cross-subsidies, has been effective, but informal settlements remain excluded and the larger plants are under-used. As a result, sewage still ends up untreated in waterways, which is particularly problematic in areas of springs. The chapter proposes several suggestions for redesign including but not limited to rational water use, harmonizing local stormwater plans and integrating urban and water policies.

The **seventh** chapter concerns the implementation of IWRM in Mexico City. The city is facing severe water shortages as it has over-exploited its aquifers. Current challenges have been driven by rapid and uncontrolled urban growth, the combination of an overall dry climate with intense summer rains and drastic changes in land use over the past centuries, as the lake city of Tenochtitlán was drained. In Mexico, CONAGUA, the national water commission, plays a central role in water resources management. As the metropolitan region of Mexico City has expanded across three federal entities, national level actors play a crucial role, but Mexico City proper (formerly, the Federal District) also has immense power. IWRM was introduced through the creation of basin organizations at different levels. This has led to the deconcentration of CONAGUA at regional level, but state entities, and their conventional views, maintain control over water management decisions. This translates into the implementation of inter-basin transfers as a main approach to guaranteeing water supply, which has been effective although water is not equally distributed across the metropolis. This has reduced pressure on local aquifers, but impacts have been externalised to donor basins, while there are few incentives to reduce water demand. Water use permits, meanwhile, imply restrictions on extractions from the aquifer, but poor enforcement had led to widespread irregular use and the unregulated transfer of permits between large users. This has caused the groundwater table to fall each year, and real estate developers and industries have been able to access water resources while many neighbourhoods have struggled with inadequate water supply. Fees for water use have also not been enforced properly, as many users lack metres and fees are generally low, and revenue does not return to the areas where water was abstracted. Payment for ecosystem services programmes have tried to remedy this disconnect between areas that provide ecosystems services and areas that use them, but they lack the budgets to make a significant impact. Among its recommendations, the chapter proposes to expand metering and water use fees to incentivize rational water use. Revenue from this can contribute to compensate donor basins and their communities and protect crucial ecosystem services.

The **eighth** chapter studies the implementation of UWM in Mexico City. At national level, there is no overarching framework for UWM, which results in significant differences across the country. CONAGUA still plays an important role as it controls large infrastructure such as deep drainage and sewage canals. Responsibilities for water and sanitation have been decentralized to local levels since the mid-1980's. Municipal governments sometimes choose to delegate water supply and sanitation services to a state entity, as is the case with Mexico City. Other municipalities of the metropolitan area choose for local service provision. Drainage and sewage management is partly coordinated at metropolitan level, through top-down decisions between CONAGUA and the three state-level governments. As with São Paulo, water tariffs are a central instrument of UWM. They promote equitable access through high subsidies. However, almost all consumers' tariffs are subsidized, ultimately preventing cost-recovery. Residents of informal settlements remain excluded from services, while the rest of the population has high rates of water consumption. Storm and floodwaters are expelled through the metropolitan drainage system, which involves a concerted and constant effort at regional level through large infrastructure. This is costly as pumps have to expel waters from the city due to land subsidence and the use of combined sewer systems for stormwater and sewage means that these waters become contaminated and cannot be reused. The metropolitan wastewater infrastructure is therefore connected through piping and converges into a gigantic sewage treatment plant just outside the metropolis. Although this reduces the impacts of contaminated waters, this system is very costly and limits the potential of reusing treated wastewater within the metropolitan region.

The **ninth** chapter compares the findings of both case studies in terms of drivers, institutions and instruments (their effectiveness in terms of actors' mandates, impact on sustainability and development and suggested redesign), highlighting similarities and differences. Overall, the MRSP's policy instruments are deemed more aligned with sustainable and inclusive development objectives, although both metropolises could learn lessons from each other. Developing coherent water governance at metropolitan level is a challenge in both cases due to the multitude of jurisdictions and the fragmentation of responsibilities between actors at multiple levels of government. The metropolises are also interlinked with areas far beyond their borders. Despite these interconnections, the spatial scale of policies and policy instruments do not always correspond to the actual flows of water, infrastructure networks, shared ecosystems or land use and urban planning. This means that there are many externalities from the policy frameworks. These affected areas are not compensated for the direct and indirect damages they receive, nor for the ecosystem services they provide. Consequently, the chapter proposes a (re)design of policy instruments with both scalar and non-scalar dimensions.

Finally, the **tenth** chapter reviews the lessons learnt from the case studies and identifies five scalar mismatches that impede sustainable and inclusive metropolitan water governance. These are related to bulk water supply, surface and groundwater management, storm and wastewater, water services and the links between water and land. These findings are then extrapolated to consider their implications for metropolitan regions around the world, in particular those within federal regimes, as this system of government has important implications for the characteristics of actors and institutions. The chapter then proposes a framework to address and overcome scalar mismatches in metropolitan water governance, based on four pillars and one overarching ‘umbrella’. This umbrella refers to a collective definition of metropolitan water governance, and more specifically, identifying metropolitan water resources that are used or impacted and metropolitan actors that need to be included. This umbrella rests on four interdependent pillars: if one is ignored, metropolitan water governance cannot be sustainable and inclusive. The first pillar concerns the consideration of different types of water, their diversification and conjunctive use. The second pillar refers to infrastructure and the need to combine and interconnect small and larger-scale systems, as well as grey and nature-based solutions. The third pillar addresses the sharing and compensating for ecosystem services. The fourth pillar focuses on containing urban sprawl by integrating land use management, environmental protection and pro-poor housing policies. These four pillars are aligned with the four dimensions of sustainable and inclusive development (i.e. ecological, social, economic and relational).

This framework is then translated into a recommendation for global policy and the SDGs with a suggestion for including a regional, metropolitan approach into IWRM. This approach can be promoted through an additional indicator under SDG 6.5 (“Implement IWRM at all levels”) that would evaluate the implementation of regional plans for cities with more than one million inhabitants. Such plans would require elaborating a common framework for metropolitan water governance (the overarching ‘roof’) by drawing the relevant boundaries, developing knowledge systems, elaborating a regional plan to ‘close the loop’ of the urban water cycle, and developing Strategic Water Assessments. This regional planning framework for integrating urban and basin concerns in large cities can then be used to design, implement and evaluate policies and policy instruments related to different types of water, infrastructure, ecosystems and urbanization.

SAMENVATTING

Tijdens een grote droogte tussen 2013 en 2015 maakte São Paulo een ernstig watertekort mee. In centrale delen van de stad moesten bars en restaurants hun deuren sluiten of plastic bekers gebruiken omdat ze geen water hadden om af te wassen. In Kaapstad dreigde in 2018 'Day Zero': het moment dat de gemeentelijke watervoorziening zou moeten worden afgesloten en 3,75 miljoen mensen zonder water zouden komen te zitten. De aanhoudende overexploitatie van grondwater heeft bijgedragen aan een bodemdaling van 25 cm per jaar in Jakarta, waardoor de mega-stad steeds kwetsbaarder wordt voor overstromingen en een stijgende zeespiegel. Sommige delen van Mexico-Stad zijn meer dan 10 meter gedaald, met doden en grote schade aan infrastructuur en gebouwen tot gevolg. Ironisch genoeg zijn als gevolg van diezelfde bodemdaling de oevers van de afvoerkanalen zo veranderd, dat riool- en regenwater nu de stad uit moet worden gepompt om overstromingen te voorkomen.

De wereld verstedelijkt snel, en vooral in het Zuiden op ongeplande wijze. Steeds meer mensen leven in steden, en de steden worden ook steeds groter. De Verenigde Naties (VN) schat dat tegen het jaar 2030 minstens één miljard mensen in metropolen van meer dan vijf miljoen inwoners zullen wonen. De grote steden trekken een zware wissel op de omliggende gebieden. Hoewel de honderd grootste steden ter wereld minder dan 1% van het landoppervlak van de aarde beslaan, vormen de stroomgebieden die hun watervoorraden leveren meer dan 12% ervan (ARUP, 2018). Schattingen geven aan dat steden met meer dan 750.000 inwoners hun water onttrekken van bijna de helft van het wereldoppervlak en dit over een cumulatieve afstand van 27.000 km transporteren (McDonald et al., 2014). In 2000 bevond ongeveer 30% van het wereldwijde stedelijke oppervlak zich in hoogfrequente overstromingszones. Tegen 2030 zal dit stijgen tot 40% (Güneralp *et al.*, 2015). De bovenstaande voorbeelden illustreren hoe verstedelijking en stroomgebiedbeheer steeds meer op gespannen voet komen te staan. Beleidsmakers proberen deze uitdagingen aan te pakken. In 2015 keurde de Algemene Vergadering van de VN de Duurzame Ontwikkelingsdoelstellingen (SDGs) goed, en daarmee de beleidsprioriteiten aangeven voor de komende decennia (UNSDKP, 2015). Met name doelstelling 6 (Verzeker toegang en duurzaam beheer van water en sanitatie voor iedereen), 11 (Maak steden en menselijke nederzettingen inclusief, veilig, veerkrachtig en duurzaam) en 13 (Neem dringend actie om de klimaatverandering en haar impact te bestrijden) en de bijbehorende doelen en indicatoren zijn relevant voor dit onderzoek.

Hoewel wetenschappers uitgebreid hebben geschreven over zowel stroomgebiedbeheer als stedelijk waterbeheer, is er nog geen samenhangend kader ontwikkeld dat zowel de complexiteit van grote metropolen als hun stroomgebieden omvat. Momenteel worden steden en hun watersystemen meestal afzonderlijk bestudeerd.

Dit proefschrift beoogt deze leemte op te vullen door de spanningen tussen verstedelijking en stroomgebieden te analyseren via de interacties tussen enerzijds de stelsels van stedelijk waterbeheer, en anderzijds de beheersstelsels van de stroomgebieden. Dit proefschrift beantwoordt de volgende vraag: ***Hoe beïnvloeden de interacties tussen drivers en instituties op verschillende ruimtelijke en institutionele schaalniveaus de grootstedelijke waterproblemen en hoe kunnen beleidsinstrumenten voor stroomgebiedbeheer en stedelijk***

waterbeheer (opnieuw) worden ontworpen om duurzamer en inclusiever grootstedelijk waterbeheer te bevorderen? Deze onderzoeksvraag is onderverdeeld in vier deelvragen:

(i) Wat leert de literatuur over stedelijk waterbeheer en stroomgebiedbeheer ons over hoe stedelijke waterproblemen moeten worden begrepen en aangepakt?

(ii) Hoe geven meerdere *drivers*, evenals instituties voor stroomgebied- en stedelijke waterbeheer vorm aan de huidige grootstedelijke problemen? (waardoor de onderzoeker causaliteit kan vaststellen);

(iii) Welke beleidsinstrumenten zijn effectief en welke niet bij het aanpakken van deze waterproblemen en hun drivers? (waardoor de onderzoeker de uitvoering kan bestuderen); en

(iv) Op basis van deze analyse, hoe kunnen beter geschikte instrumenten worden ontworpen om grootstedelijke waterproblemen aan te pakken, ten einde meer inclusieve en duurzame ontwikkeling in grootstedelijke regio's te bewerkstelligen? (waardoor de onderzoeker mogelijke herontwerp van beleid kan voorstellen)

Dit proefschrift bestudeert São Paulo en Mexico Stad, twee grote metropolen die geconfronteerd worden met belangrijke (maar verschillende) waterproblemen, om de volgende vragen te onderzoeken: (i) de rol die instituties spelen bij het veroorzaken en aanpakken van stedelijke waterproblemen; (ii) hoe effectief bestaande beleidsinstrumenten zijn om deze uitdagingen in grootstedelijke regio's aan te pakken; en (iii) hoe meer duurzame en inclusieve beleidsinstrumenten voor dit doel kunnen worden ontworpen. Het ontwikkelt de concepten van "Scalar Mismatches" en "Metropolitan Water Governance". De eerste betreft het ontwerpen van management-kaders voor schalen die ontoereikend zijn voor het probleem dat ze aanpakken. Het tweede concept, definieert de belangrijkste elementen die moeten worden overwogen voor waterbeheer in grootstedelijke regio's.

Het proefschrift is verdeeld in tien hoofdstukken. Het **eerste hoofdstuk**, de inleiding, schetst de hierboven samengevatte uitdagingen, de kenniskloof (beter ontwikkeld in hoofdstuk 3 en 4), de verschillende soorten water die in waterbeheer onderscheiden worden, en de multidisciplinaire reikwijdte van de studie.

Het **tweede** hoofdstuk presenteert de methodologie. Deze combineert een literatuuronderzoek over stedelijk waterbeheer en stroomgebiedbeheer, een case-study benadering die een kwalitatieve inhoudsanalyse van beleid koppelt aan dataverzameling door middel van interviews, en een institutionele analyse. De institutionele analyse is gebaseerd op het IHDP / IDHGEC (International Human Dimensions Programme / Institutional Dimensions of Global Environmental Change) Science Plan gehanteerde analysekader voor milieuverandering, en de daarbij horende onderzoeksfocus op causaliteit, uitvoering en ontwerp. De toepassing van de vergelijkende case-study methode is belangrijk om complexe dynamieken te begrijpen. Dit hoofdstuk rechtvaardigt de keuze voor Mexico-stad en São Paulo als grote metropolen in het Zuiden die snel en zonder een adequate stadsplanning zijn gegroeid. Beide steden zijn de economische hoofdsteden van hun respectievelijke landen, Mexico en Brazilië, en vallen ook binnen federale staten waar de verantwoordelijkheden worden gedeeld tussen nationale, staats- en gemeentelijke overheden. Beide steden zijn agglomeraties van tientallen verschillende gemeenten. Ze streven naar geïntegreerd waterbeheer en stedelijk waterbeheer (zie hieronder). Desalniettemin zien beide steden zich geconfronteerd worden met belangrijke en verschillende waterproblemen, die hoogstwaarschijnlijk nog zullen worden versterkt door klimaatvariabiliteit en verandering. Deze kenmerken stellen mij in staat om belangrijke lessen te trekken die niet alleen van toepassing zijn op deze twee steden (met een gecombineerde bevolking van meer dan 40 miljoen mensen), maar ook op andere metropolen in ontwikkelingslanden die met soortgelijke uitdagingen worden geconfronteerd, of zullen worden geconfronteerd. Dit hoofdstuk presenteert ook de drie analyse-eenheden van het proefschrift: *drivers*, instituties en instrumenten (verder verdeeld tussen regulerend, economisch, infrastructureel en suasief). Ten slotte beschrijft het hoofdstuk het veldwerk, gericht op een documentanalyse en semigestructureerde interviews met ongeveer honderd toonaangevende belanghebbenden in het waterbeleid gebied.

Het **derde** hoofdstuk geeft een overzicht van de relevante literatuur op het gebied van stedelijk waterbeheer. Decennialang was *Urban Water Management* (UWM) het dominante paradigma in stedelijk waterbeheer. UWM benadrukt het leveren van betaalbaar water en het snel afvoeren van rioolwater uit de stad via grootschalige, gestandaardiseerde infrastructuur. Na verloop van tijd ontwikkelde dit concept zich tot *Integrated Urban Water Management* (IUWM) en *Sustainable Urban Water Management* (SUWM), waarin principes voor duurzame en inclusieve ontwikkeling zijn opgenomen. Alle drie de benaderingen definiëren de verantwoordelijkheden voornamelijk op lokaal niveau (hoewel de nationale overheid vaak normen en voorschriften uitvaardigt) en er is daarnaast een toenemende aandacht voor decentralisatie en participatie. Dit kan de lokale actoren versterken, maar ook de tendens tot localisatie. UWM en meer recente varianten daarop houden echter geen rekening met de grootstedelijke schaal. Grootstedelijke regio's zijn niet alleen grote steden, maar ervaren watergerelateerde problemen van een andere aard. Politieke fragmentatie treedt vaak ernstiger op in metropolen bestaand uit vele gemeenten. Gemeenten in de stadsrand moeten vaak omgaan met grotere wateruitdagingen en hebben minder capaciteiten om deze alleen aan te pakken. Grote agglomeraties vergroten de mogelijkheid dat steden negatieve externe effecten veroorzaken in de naastgelegen gemeenten. Bovendien is er binnen UWM en vergelijkbare benaderingen nauwelijks aandacht voor de interacties met de stroomgebieden, omdat de ruimtelijke grenzen van steden niet overlappen met die van de stroomgebieden en de grondwaterlagen waarvan ze afhankelijk zijn. Zelfs IUWM/ SUWM-actoren bemoeien zich bijvoorbeeld niet met toewijzing van water, of biodiversiteit en ecosysteemdiensten buiten de stadsgrenzen. UWM en de verschillende variaties daarop zijn dus niet in staat de uitdagingen in het stroomgebied te verklaren.

Het **vierde** hoofdstuk toont aan hoe de huidige paradigma's in stroomgebiedbeheer – *Integrated Water Resources Management* (IWRM) en *Integrated River Basin Management* (IRBM) – de uitdagingen van stedelijk beheer niet onderkennen. Deze concepten zijn veranderd van conventionele opvattingen die gericht waren op grootschalige infrastructuur, gecentraliseerde controle en lineaire benaderingen van het nemen, gebruiken en lozen van water, in de richting van nieuwe paradigma's die beter zijn afgestemd op duurzaamheid en inclusiviteit. In de literatuur wordt echter meestal als vanzelfsprekend aangenomen dat het stroomgebied de ideale schaal is voor het aanpakken van waterproblemen, ook al negeert het bepaalde soorten water en waterstromen, evenals het feit dat, door menselijke interventies, de ‘natuurlijke’ schaal van het stroomgebied relevantie verliest. Hoewel IWRM/ IRBM de integratie van alle behoeften en belangen binnen het stroomgebied bevorderen, zijn ze gebaseerd op de veronderstelling dat instituties voor waterbeheer invloed zullen hebben op stedelijke actoren. Het omgekeerde is normaal gesproken waar; grootstedelijke regio’s kennen een breed scala aan actoren die moeten worden gecoördineerd, maar deze actoren (zoals bijvoorbeeld de burgemeester van São Paulo of een staatswoningbouwcoöperatie) hebben meestal veel meer invloed dan de comités die de stroomgebieden beheren. De comités die de stroomgebieden moeten beheren ontberen onder andere financiële middelen, expertise, en politieke capaciteit om invloed uit te kunnen oefenen. Al met al hebben IWRM/ IRBM significante beperkingen bij het effectief vormgeven van grootstedelijk waterbeheer. Het feit dat het stroomgebied niet altijd de ideale schaal is voor het waterbeheer van metropolen, en dat metropolen een overvloed aan actoren en instellingen omvatten waarvan de belangen en mandaten vaak conflicteren met die van het stroomgebied wordt in IWRM/ IRBM buiten beschouwing gelaten.

Het **vijfde** hoofdstuk is het eerste van de vier hoofdstukken over de case-studies. Het bespreekt de implementatie van IWRM in São Paulo. Het hoofdstuk begint met de belangrijkste drivers van São Paulo’s waterproblemen, de relatieve waterschaarste waarmee het wordt geconfronteerd en hoe veranderingen in klimaat en in landgebruik het probleem verergert (bijv. landbouwgrond wordt verstedelijkt rondom de stad). Vervolgens introduceert het hoofdstuk de veelheid aan actoren die het institutionele kader van IWRM in São Paulo bepalen, van het nationale niveau tot van de staat (bijvoorbeeld waterbedrijven zoals SABESP of CETESB) en het stroomgebied (Alto-Tiête comité voor het stroomgebied). Het hoofdstuk behandelt de complementaire en overlappende competenties en de invloed van deze dynamiek op de beleidscoördinatie. Het hoofdstuk analyseert en beoordeelt vervolgens specifieke instrumenten die worden gebruikt om het waterbeleid op stroomgebiedniveau in het Alto-Tietê stroomgebied in São Paulo te coördineren. De watertoevoer en daarmee de watervoorziening is vergroot dankzij waterimport uit andere stroomgebieden. Er is echter onvoldoende aandacht voor de noodzaak tot vermindering van de vraag naar water. Import vanuit andere stroomgebieden is op de langere termijn geen duurzame oplossing, deels omdat het onevenredig grote gevolgen heeft voor de gebieden waarvan het geïmporteerde water afkomstig is zonder hen een stem of compensatie te geven. Vergunningen voor de exploitatie van water blijken ook belangrijke beperkingen te hebben, omdat ze niet goed zijn ontworpen (bijvoorbeeld omdat ze geen rekening houden met het gebruik van grondwater) of niet worden gecontroleerd. De tarieven voor watergebruik en de afvoer van afvalwater zijn relatief laag. Dit biedt mogelijkheden voor verbetering, omdat de inkomsten van deze heffingen bij de comités van de stroomgebieden terecht komen. Een tariefstelling die de reële kosten meer reflecteerd, kan een lager watergebruik stimuleren en ook de inkomstenbasis van deze comités versterken. Beleid om waterbronnen te beschermen en te rehabiliteren was in theorie ook belangrijk, maar bleek van beperkte praktische impact vanwege belemmeringen in de coördinatie tussen de mandaten van de verschillende actoren. Het hoofdstuk sluit af met een voorstel voor het herontwerp van enkele belangrijke instrumenten, zoals de noodzaak om het beleid voor import vanuit aangrenzende stroomgebieden te beperken, de controle en de waarde van watervergunningen en watergebruikskosten te verhogen en programma's om waterbronnen te beschermen uit te breiden, dat noodzakelijkerwijs moet per definitie moet worden gedaan met een integratie van water- en sanitaire voorzieningen en huisvestingsbeleid op gemeentelijk en provincie niveau. Het bevordert ook de integratie van nieuwe instrumenten in de mix, zoals suasieve instrumenten, om de vraag naar water te verminderen en Betalingen voor Ecosysteemdiensten-programma's om waterbronnen te beschermen.

Belangrijkste geanalyseerde instrumenten

	Brazilië	**Mexico**
Stroomgebied	Watergebruik vergunningen	Watergebruik vergunningen
	Afvalwater vergunningen	Afvalwater vergunningen
	Kosten voor watergebruik en afvalwaterafvoer	Kosten voor watergebruik en afvalwaterafvoer
	Import uit andere stroomgebieden	Import uit andere stroomgebieden
	Bescherming en herstel van brongebieden	Betaling voor ecosysteemdiensten + landconservatie voor milieubehoud
Stedelijk water	Water tarieven	Water tarieven
	Drainagesysteem (macroschaal)	Drainagesysteem (metropool)
	Geïntegreerd rioleringssysteem	Afvalwaterinfrastructuur (metropool)

Het **zesde** hoofdstuk onderzoekt de implementatie van UWM in São Paulo. Verstedelijking, gekenmerkt door snelle groei en een gebrek aan planning, is een bijzonder belangrijke motor voor het ontstaan van de stedelijke waterproblematiek. Dit wordt versterkt door *drivers* voor het lokale klimaat (d.w.z. hitte-eiland effect) en hogere niveaus (d.w.z. klimaatvariabiliteit en verandering). Meerdere actoren beïnvloeden UWM in São Paulo. Het nationale niveau stelt belangrijke normen en een regelgevingskader vast, maar de belangrijkste actoren bevinden zich op het niveau van de deelstaten en lokaal niveau. SABESP, het staatsbedrijf voor water en sanitaire voorzieningen, biedt bijvoorbeeld diensten aan het merendeel van de grootstedelijke regio van São Paulo (MRSP) en de helft van de staat São Paulo. Veel UWM-verantwoordelijkheden zijn gedelegeerd naar lokaal niveau, maar deze actoren hebben vaak onvoldoende capaciteit om hun mandaten te vervullen en hebben moeite om hun beleid en acties binnen de metropool te coördineren. Uit de instrumentbeoordeling blijkt dat watertarieven een bijdrage leveren aan het bevorderen van UWM-doelen. Ze zijn relatief betaalbaar, dankzij speciale tarieven voor huishoudens met lage inkomens. Dit is mede te danken aan kruissubsidies tussen gemeenten waar dienstverlening duurder of minder duur is voor het waterbedrijf, en aan stijgende bloktarieven en hogere tarieven voor industriële en commerciële consumenten. De lage watertarieven stimuleren echter onvoldoende rationeel watergebruik en leiden evenmin tot voldoende investeringen in afvalwaterzuivering. São Paulo heeft een macroschaal-drainageplan op de schaal van het stroomgebied verwezenlijkt, om een regionale aanpak van problemen met drainage en overstromingen te bevorderen. Dit leidde tot betere coördinatie tussen lokale overheden en de staatsoverheid, maar minder tussen lokale overheden en andere sectorale instanties. Het richtte zich op harde technische oplossingen die nog steeds faalden tijdens zware regenval. Rioolwaterbeheer is ook geïntegreerd op metropolitaan niveau, met kleinere systemen in rondstedelijke gebieden en een megawaterzuiveringsinstallatie stroomafwaarts van de stad. Het is effectief om infrastructuren op verschillende schaalniveaus (bijv. kleinere of grotere zuiveringsinstallaties) dan te bieden in combinatie met een financieel systeem van kruissubsidies, maar informele nederzettingen blijven uitgesloten en de grotere installaties werden onderbenut. Als gevolg hiervan komt rioolwater nog steeds ongezuiverd in het oppervlaktewater terecht, wat vooral problematisch is in gebieden met waterbronnen. Het hoofdstuk stelt een aantal suggesties voor herontwerp voor, waaronder rationeel watergebruik, harmonisatie van lokale plannen voor regenwaterbeheer en integratie van stedelijk- en waterbeleid.

Het **zevende** hoofdstuk betreft de implementatie van IWRM in Mexico-stad. De stad wordt geconfronteerd met ernstige watertekorten vanwege grondwater overexploitatie. De huidige problemen zijn ontstaan ten gevolge van snelle en ongecontroleerde stedelijke groei, de combinatie van een algeheel droog klimaat met intense regen in de zomer. Tevens is er sprake van drastische veranderingen in landgebruik in de afgelopen eeuwen, ten gevolge van het draineren van de oorspronkelijke meren rond Tenochtitlán. In Mexico speelt CONAGUA, de nationale watercommissie, een centrale rol in het waterbeheer. Aangezien de grootstedelijke regio van Mexico-stad zich over drie deelstaten heeft uitgebreid, spelen actoren op nationaal niveau een cruciale rol, maar Mexico-stad zelf (voorheen het Federale District) heeft ook enorme macht. IWRM werd geïntroduceerd met de oprichting van organisaties voor stroomgebiedbeheer (1992) op verschillende niveaus. Dit leidde tot de deconcentratie van CONAGUA op regionaal niveau, echter staatsentiteiten en hun conventionele opvattingen behouden hun controle over de beslissingen ten aanzien van het waterbeheer. Dit vertaalt zich in de implementatie van import van water uit aangrenzende stroomgebieden als belangrijkste wijze om de watervoorziening te garanderen. Hoewel in absolute termen effectief, wordt dit water niet gelijkmatig over de metropool verdeeld. De import van water heeft de druk op het lokale grondwater verlaagd, maar de negatieve effecten worden nu gevoeld in de stroomgebieden waar het water wordt gewonnen, terwijl er weinig prikkels zijn om de vraag naar water te verminderen. Hoewel er beperkingen zijn gesteld aan vergunningen voor grondwaterwinning, heeft een totaal gebrek aan handhaving geleid tot wijdverbreid onrechtmatig gebruik en de niet-gereguleerde overdracht van vergunningen tussen grote water gebruikers. Hierdoor daalt de grondwaterspiegel elk jaar en kunnen vastgoedontwikkelaars en industrieën toegang krijgen tot watervoorraden, terwijl veel stadsdelen worstelen met onvoldoende watervoorziening. De tarieven voor watergebruik worden ook niet correct toegepast, omdat veel gebruikers geen watermeters hebben en de tarieven over het algemeen laag zijn. Bovendien worden opbrengsten niet geherinvesteerd in de gebieden waar het water wordt gewonnen. Met het ontwikkelen van programma’s voor Betalingen voor Ecosysteemdiensten is geprobeerd deze discrepantie tussen gebieden die ecosysteemdiensten bieden of gebruiken te verhelpen, maar de programma’s hebben onvoldoende middelen om een significante impact te hebben. Het hoofdstuk beveelt onder meer aan om het gebruik van watermeters uit te breiden en tarieven voor watergebruik te verhogen, ten einde rationeel watergebruik te stimuleren. Opbrengsten hiervan kunnen bijdragen aan financiële compensatie voor stroomgebieden die water exporteren, hun gemeenschappen en het beschermen van hun cruciale ecosysteemdiensten.

Het **achtste** hoofdstuk bestudeert de implementatie van UWM in Mexico-stad. Op nationaal niveau is er geen overkoepelend kader voor UWM, wat leidt tot aanzienlijke verschillen over het hele land. CONAGUA speelt nog steeds een belangrijke rol omdat het de grootschalige infrastructuur beheert, zoals ondergrondse afwatering en rioleringskanalen. De verantwoordelijkheden voor drinkwatervoorziening en sanitatie zijn sinds het midden van de jaren tachtig gedecentraliseerd naar lokale niveaus. Gemeentelijke overheden kozen er soms voor om water en sanitaire voorzieningen te delegeren aan een staatsentiteit, zoals het geval was met Mexico-stad. Sommige gemeenten van het grootstedelijk gebied kozen voor lokale dienstverlening. Drainage- en rioolbeheer worden ten dele gecoördineerd op grootstedelijk niveau, door top-down beslissingen tussen CONAGUA en de drie regeringen op staatsniveau. Net als bij São Paulo zijn drinkwatertarieven een belangrijk instrument van UWM. Ze bevorderen toegankelijkheid via hoge subsidies. Door dat de tarieven van bijna alle consumenten worden gesubsidieerd is de watervoorziening niet kostendekkend. Inwoners van informele nederzettingen blijven verstoken van voorzieningen, terwijl de rest van de bevolking een hoog waterverbruik heeft. Dankzij inspanningen op regionaal niveau wordt hemelwater afgevoerd via het grootschalige metropolitane drainagesysteem. Dit is duur, omdat het water ten gevolge van de bodemdaling de stad uit moet worden gepompt. Het gebruik van een gemengd rioleringssysteem voor zowel regenwater als rioolwater betekent bovendien dat al het afvalwater vervuild raakt en niet geschikt is voor hergebruik. De grootstedelijke afvalwaterinfrastructuur is daarom verbonden met een gigantische rioolwaterzuiveringsinstallatie net buiten de metropool.

In het **negende** hoofdstuk worden de bevindingen van beide case-studies vergeleken ten aanzien van de *drivers*, instituties en instrumenten (hun effectiviteit in termen van mandaten van actoren, impact op duurzaamheid en inclusieve ontwikkeling, en voorgesteld herontwerp), met aandacht voor overeenkomsten en verschillen. Hoewel beide metropolen van elkaar kunnen leren, blijken de beleidsinstrumenten van São Paulo over het algemeen meer in overeenstemming met doelstellingen voor duurzame en inclusieve ontwikkeling dan Mexico-stad. Het ontwikkelen van coherent waterbeheer op grootstedelijke schaal is in beide gevallen een uitdaging, vanwege de veelheid aan jurisdicties en de versnippering van verantwoordelijkheden tussen actoren op meerdere overheidsniveaus. De metropolen zijn ook verbonden met gebieden ver buiten hun grenzen. De ruimtelijke schaal van beleid en beleidsinstrumenten komen echter niet altijd overeen met die van waterstromen, infrastructuurnetwerken, gedeelde ecosystemen of landgebruik en stadsplanning. Dit kan leiden tot incoherentie en onbedoelde gevolgen van de beleidskaders. Gebieden die directe of indirecte schade ondervinden van deze externaliteiten worden niet gecompenseerd, ook niet voor de ecosysteemdiensten die zij leveren. Het hoofdstuk besluit met verschillende voorstellen tot (her)ontwerp van beleidsinstrumenten (sommige met en andere zonder de dimensie van schaal).

Ten slotte worden in het **tiende** hoofdstuk de lessen uit de case-studies besproken en worden vijf 'mismatches' tussen schaalniveaus geïdentificeerd die duurzaam en inclusief grootstedelijk waterbeheer belemmeren. Deze hebben betrekking op bulkwatervoorziening, oppervlakte- en grondwaterbeheer, hemel- en afvalwater, drinkwatervoorziening en de relatie tussen landgebruik en water. Deze bevindingen worden vervolgens geëxtrapoleerd om hun implicaties voor grootstedelijke regio’s wereldwijd te overwegen, met name die binnen federale landen. Deze specifieke staatsvorm heeft immers belangrijke gevolgen voor actoren en instituties. Hierna presenteert dit hoofdstuk een kader voor grootstedelijk waterbeheer waarin de mismatches tussen schaalniveau zijn opgelost. Dit kader is gebaseerd op vier pijlers en één overkoepelende 'paraplu'. Deze paraplu verwijst naar een collectieve definitie van grootstedelijk waterbeheer, en meer specifiek naar de identificatie van grootstedelijke waterbronnen die worden gebruikt en/of grootstedelijke actoren die moeten worden betrokken. Deze paraplu is onderbouwd door vier pijlers die onderling afhankelijke zijn; door er één te negeren, kan grootstedelijk waterbeheer niet duurzaam en inclusief zijn. De eerste pijler betreft de erkenning van verschillende soorten water, hun diversificatie en conjunctief gebruik. De tweede pijler verwijst naar infrastructuur en de noodzaak om kleinschalige en grotere systemen te combineren en onderling te verbinden, evenals grijze en groene infrastructuur. De derde pijler heeft betrekking op het delen en compenseren van ecosysteemdiensten. De vierde pijler richt zich op het tegengaan van stadsuitbreiding door het integreren van beleid voor landgebruik, milieubescherming en woonarmoede. Deze vier pijlers zijn afgestemd op de vier dimensies van duurzame en inclusieve ontwikkeling (d.w.z. ecologisch, sociaal, economisch en relationeel).

Dit kader wordt vervolgens omgezet in een aanbeveling voor wereldwijd beleid en de Duurzame Ontwikkelingsdoelstellingen (SDGs) met een suggestie om een regionale, grootstedelijke aanpak in IWRM op te nemen. Deze aanpak kan worden bevorderd door een indicator toe te voegen onder doelstelling 6.5 ("Implementeer IWRM op alle niveaus") die de implementatie van regionale plannen voor steden met meer dan een miljoen inwoners zou evalueren. Zulke plannen hebben een gemeenschappelijk kader voor grootstedelijk waterbeheer (de overkoepelende 'paraplu’) nodig die de relevante grenzen bepaalt, kennissystemen ontwikkelt, een regionaal plan uitwerkt dat de kringloop van de stedelijke watercyclus sluit en strategische waterbeoordelingen ontwikkelt. Dit regionale planningskader voor de integratie van stedelijke en stroomgebied problemen in grote metropolen kan vervolgens worden gebruikt om beleid en beleidsinstrumenten met betrekking tot verschillende soorten water, infrastructuur, ecosystemen en verstedelijking te ontwerpen, implementeren en evalueren.

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ANA	Agência Nacional de Água (National Water Agency)
APRM	Áreas de Proteção e Recuperação dos Mananciais (Areas of Protection and Recovery of Springs)
ATB	Alto-Tietê Basin
ARSESP	Agência Reguladora de Saneamento e Energia do Estado de São Paulo (Regulating Agency for Sanitation and Energy)
BESS	Biodiversity and Ecosystem Services
CBH-AT	Comitê de Bacia Hidrografica do Alto-Tietê (Alto-Tietê River Basin Committee)
CETESB	Companhia Ambiental do Estado de São Paulo (São Paulo State Environment Agency)
CHR	Conselho Estadual de Recursos Hídricos (State Council on Hydrological Resources)
CNHR	Conselho Nacional de Recursos Hídricos (National Council on Hydrological Resources)
CODEGRAN	Conselho Deliberativo da Grande São Paulo (Deliberative Council of Greater São Paulo)
COFEHIDRO	Conselho do Fundo Estadual de Recursos Hidricos (Council for the State Fund for Water Resources)
CONAFOR	Comisíon Nacional Florestal (National Forestry Commission)
CONAGUA	Comisíon Nacional De Água (National Water Commission)
CSO	Civil Society Organization
DAEE	Departamento de Águas e Energia Elétrica (Department of Water and Electricity)
EMAE	Empresa Metropolitana de Águas e Energia (Metropolitan Company of Water and Electricity)
EMPLASA	Empresa Paulista de Planejamento Metropolitano S.A. (São Paulo Company of Metropolitan Planning)

FABHAT	Fundação da Agência da Bacia Hidrografica do Alto-Tietê (Foundation for the Agency of the Alto-Tietê Basin Committee)
FEHIDRO	Fundo Estadual de Recursos Hídricos (State Fund for Water Resources)
FIESP	Federação das Indústrias do Estado de São Paulo (Federation of Industries of the State of São Paulo)
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
IDB	Inter-American Development Bank
INECC	Instituto Nacional de Ecología y Cambio Climático (National Institute for Ecology and Climate Change)
IPT	Instituto de Pesquisa Tecnológica (Institute for Technological Research)
ITB	Instituto Trata Brasil
IWRM	Integrated Water Resources Management
MASL	Metres above sea level
MMP-ATB	Macro-drainage Master Plan of the Alto-Tietê Basin
MRSP	Metropolitan Region of São Paulo
MVMC	Metropolitan Valley of Mexico City
PES	Payment for Ecosystem Services
PLANASA	Plano Nacional de Saneamento (National Basic Sanitation Plan)
SABESP	Companhia de Saneamento Básico do Estado de São Paulo (Company of Basic Sanitation of São Paulo State)
SAAE	Serviço Autonomo de Agua e Esgoto (Autonomous Water and Sanitation Service)
SACMEX	Sistema de Aguas de la Ciudad de Mexico (Water Systems of Mexico City)
SDG	Sustainable Development Goal
SEMARNAT	Ministry for the Environment and Natural Resources
SIGRH	Sistema de Informações sobre o Gerenciamento de Recursos Hídricos (System of Information on the Management of Hydrological Resources)

SINGREH	Sistema Nacional De Gerenciamento De Recursos Hídricos (National Hydrological Resources Management System)
SMA	Secretaria do Meio Ambiente do Estado de São Paulo (São Paulo State Environmental Secretariat)
SNIS	Sistema Nacional de Informações sobre Saneamento (National Sanitation Information System)
SNSA	Secretaria Nacional de Saneamento Ambiental (National Secretariat for Environmental Sanitation)
SSRH	Secretaria de Saneamento e Recursos Hídricos do Estado de São Paulo (São Paulo State Sanitation and Water Resources Secretariat)
UGRHI	Unidades de Gerenciamento de Recursos Hídricos (Units of Management of Hydrological Resources)
USP	Universidade de São Paulo (University of São Paulo)
VMB	Valley of Mexico Basin
Wat&San	Water and sanitation
WRM	Water Resources Management

1. INTRODUCTION

1.1 INTRODUCTION

Large cities have heavy impacts on their rural hinterlands, while also depending on these and the natural resources they provide. In 2018, the city of Cape Town made international news headlines for months as it was battling a severe water shortage and heading closer to 'Day Zero', the day that municipal water supplies would be shut off (Alexander, 2019). The reallocation of water earmarked for agriculture to urban residents helped mitigate the looming disaster. In 2003, a dam that supplies water to Mexico City through an inter-basin water transfer flooded 300 ha of fields cultivated by the Mazahua indigenous community (Marcos and Fernández, 2016). The Federal government did not respond adequately to their claims, leading to peaceful but long and highly mediatized protests by Mazahua women for compensation and access to drinking water[1]. Such examples illustrate the rising tensions between cities and their river basins, leading to challenges in terms of water quantity, quality and climate change adaptation. These tensions are triggered by a combination of population growth, urbanization, economic growth, consumption patterns, anthropogenic climate change, land use and other driving forces at multiple levels (Vörösmarty *et al.*, 2000; Elmqvist *et al.*, 2013; Nobre and Marengo, 2016; UN-HABITAT, 2016). Water challenges are particularly severe in megacities of the Global South, marked by stark inequalities within the urban agglomeration and between the city and its rural hinterlands, and where the urbanization process is unfolding at an accelerated pace (Elmqvist *et al.*, 2013; Azzam *et al.*, 2014). Although the world's 100 largest cities occupy less than 1% of the planet's land area, the basins that provide their water resources cover more than 12% of it (ARUP, 2018). Estimates indicate that cities with populations larger than 750,000 people draw water from almost half of the global land surface and transport it over a cumulative distance of 27,000 km (McDonald *et al.*, 2014).

This thesis examines the tensions between urbanization and river basins through interactions between metropolitan governance regimes with integrated basin management regimes. More specifically, it explores the role that institutions play in urban water challenges, how effective existing policy instruments are in addressing these challenges within metropolitan regions and how more sustainable and inclusive institutions could be designed for this purpose. It does so by focusing on the cases of São Paulo in Brazil and Mexico City, in Mexico (see 2.2.2 for details).

This chapter presents the growing worldwide tensions between water use at urban and river basin scales, their theoretical underpinnings, the gap in scholarly knowledge, and their policy implications (see 1.2). It then introduces the ensuing research questions that this thesis aims to answer, as well as its focus and limits (see 1.3), provides a background on the nature of water (see 1.4), discusses the position of the researcher (see 1.5) and, finally, the overall structure of the thesis (see 1.6).

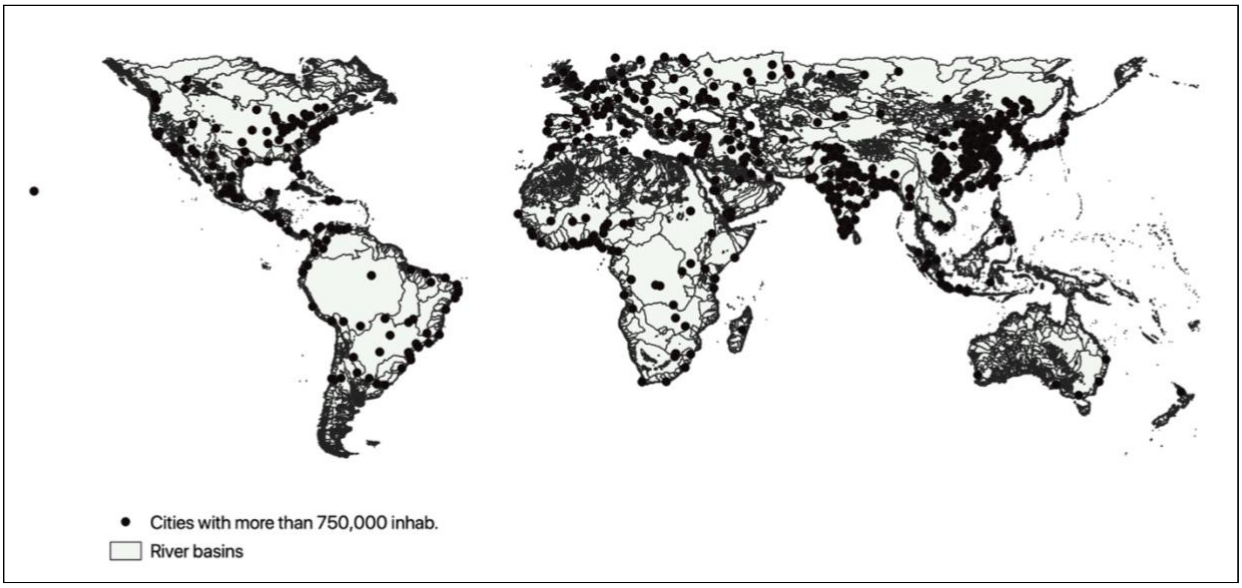
1 Despite living near the large dam, local Mazahua communities were not connected to the public water supply network.

1.2 WATER CHALLENGES AND METROPOLITAN REGIONS

1.2.1 RISING WATER CHALLENGES IN AN URBANIZING WORLD

Today, around 55.3% of the global population is urban (UN-DESA, 2018).[2] As this number rises in the coming decades, the burden cities impose on their river basins is likely to intensify, even if in an uneven manner (see Map **1.1**). The Global South will lead this urban growth. Asia and Africa will add 2.5 billion urban residents by 2050 (see Figure **1.1**) (UN-DESA, 2018). Latin America, already one of the world's most urbanized regions, should see urban populations increase from 81% in 2015 to 88% by 2050 (see Figure **1.2**) (UN-DESA, 2018). By comparison, 82% of Northern America's population lived in urban areas in 2018 (UN-DESA, 2018).

Map 1.1 Large cities and basins around the world in 2015



Source: Author

[2] Recent research suggests that urbanization levels are much higher, due to the fact that countries self-report their demographic statistics and use very different standards (Scruggs, 2018).

Figure 1.1 Global expansion of urban population, 1950-2050 (thousands)

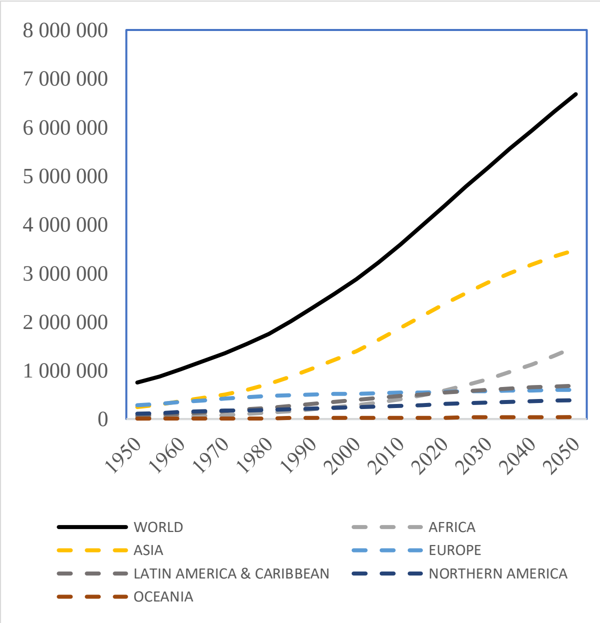


Figure 1.2 Urban population per region (percentage)

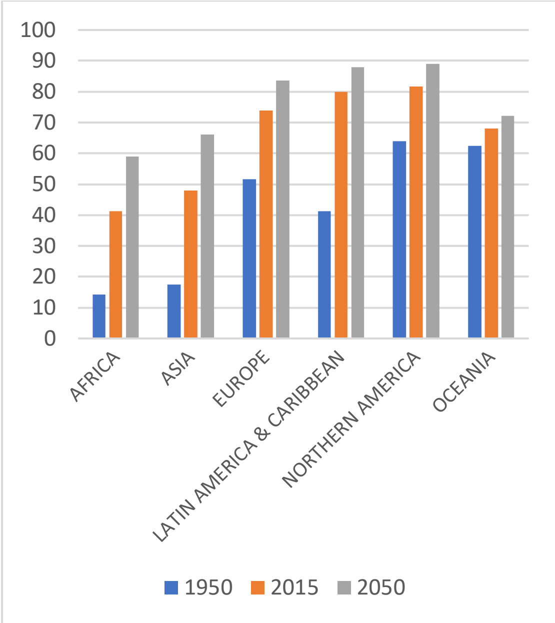
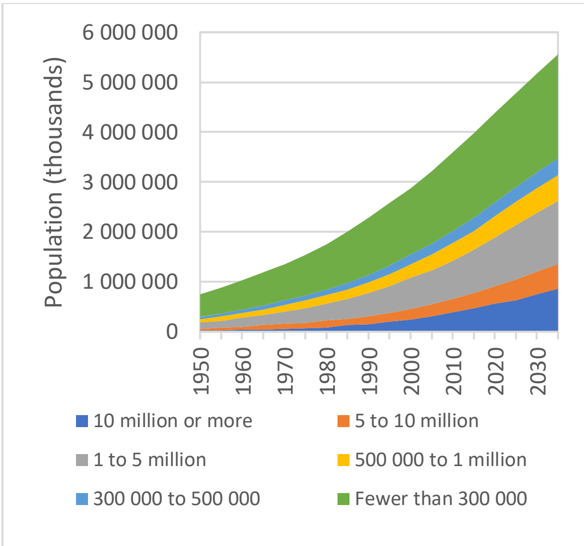


Table 1.1 Evolution of the number of urban settlements per population size

Population size	**Number of urban settlements**		
	1950	**2015**	**2030**
10 million or more	2	29	43
5 to 10 million	5	45	66
1 to 5 million	69	439	597
500 000 to 1 million	101	554	710
300 000 to 500 000	129	707	827

Figure 1.3 Evolution of population per size classes of urban settlements



Source: Based on raw data from UN-DESA (2018)

As the global urban population rises, so does the number of cities of various sizes. More and more people are living in metropolitan regions, characterized by a contiguous urban area often governed by multiple political jurisdictions (see Box **1.1**). In 1950, 177 cities had more than 500,000 inhabitants. This increased to 1,067 by 2015 and it is expected to further rise to 1,416 by 2030 (see Table ***1.1***) (UN-DESA, 2018). Megacities, the focus of this thesis, are defined as cities of 10 million inhabitants or more; they have increased from 2 in 1950 to 29 in 2015 and possibly 43 in 2030 (UN-DESA, 2018). Urban settlements with less than 300,000 inhabitants will remain the largest in number and in total population. Nevertheless, the population of larger cities is increasingly predominant both in relative and in absolute terms. In 1950, there were over 250 million inhabitants in cities larger than 500,000 inhabitants (less than 10% of the global population); by 2015 this population had increased to over 2 billion (more than 27%), and it is projected to reach almost 3 billion by 2030 (more than 33%) (see Figure **1.3**) (UN-DESA, 2018). This recent, yet accelerated, worldwide transformation of the natural environment through urbanization is a characteristic of the 'Anthropocene'.[3]

As cities around the world grow, so does their demand for goods and services, including resources such as water, food and energy, which come largely from surrounding areas (Jenerette and Larsen, 2006). Besides population growth, the economic development that often follows urbanization further increases per capita water use in cities (McDonald *et al.*, 2014). Urban water demand is expected to increase by 80% by 2050 while total available freshwater remains more or less constant (Flörke *et al.*, 2018). This demand is unevenly distributed across the world's river basins. Between 1.6 and 2.4 billion people live in river basins that experience water scarcity (Gosling and Arnell, 2016). In quantitative terms, 'chronic water shortages' take place when an area's annual water supply drops below 1000m^3 per person, and 'absolute water scarcity' takes place below 500m^3 per person (FAO, 2012).[4] Managing water resources across large cities and their river basins has led to increasing competition, tensions and conflicts (Varis *et al.*, 2006; Tortajada, 2008). Despite the far-reaching impacts of these cities, and their potential to influence basin management, cities invest very little in their basins (ARUP, 2018).

3 The term 'anthropocene' is a geologic term for an epoch that starts when human activities began to have a significant global impact on the Earth's ecosystem (Crutzen and Stoermer, 2000).

4 Population growth and climate variability and change may lead to as many as 3.1 billion people (37% of the global population) living in water scarce river basins by 2050 (Gosling and Arnell, 2016).

Box 1.1 Definitions of large cities

There are multiple terms to refer to cities, but no internationally-recognized definitions with standardized criteria for determining the boundaries of any given urban area (Slack, 2007; Knieling, 2014; United Nations, 2016b). 'City proper' is generally used to define a city according to an administrative boundary (United Nations, 2016b). Terms associated with large, multi-jurisdictional urban areas include metropolis, metropolitan area, metropolitan region, megacity, urban agglomeration, and more. Definitions generally refer to a large urban core with adjacent urban and rural areas that are socially and economically integrated with the core (Slack, 2007). The key terms are:

Urban agglomeration: This definition is based on physical characteristics as it considers the extent of the contiguous urban area, or built-up area, as the limits of the city's boundaries (United Nations, 2016b).

Functional urban areas: Urban area defined by a method that relies on settlement patterns and commuting flows rather than administrative borders (OECD, 2012).

Metropolitan regions: The term 'metropolitan region' is used by international institutions (OECD, World Bank, etc.) and European authors (Herrschel and Newman, 2002; Salet *et al.*, 2003; Sellers *et al.*, 2013) to describe highly urbanized, city-regional areas characterized by high population densities and the concentration and interconnectedness of economic, political and cultural activities (Knieling, 2014; United Nations, 2016b). These cities are typically composed of multiple jurisdictions with independent political authorities. Minimum population thresholds for the city core are not necessarily very high (i.e. 50,000 or 100,000 in some cases), but adjacent areas of lower density are connected to the core and under its influence (United Nations, 2012; Knieling, 2014).

Megacities: The term 'megacity' has been defined by the United Nations as an urban agglomeration of at least 10 million inhabitants (United Nations, 2012).

Metacities: UN-Habitat introduced the term 'metacity' to describe "massive conurbations of more than 20 million people" (UN-Habitat (United Nations Human Settlements Programme), 2006).

Megalopolis: This term refers to a clustered network of cities. There is no consensus on population size, with definitions ranging between 10 million (Doxiadis, 1970) and 25 million (Gottmann and Harper, 1990).

The definition of a city's boundaries has implications for population assessments (United Nations, 2016b). Although the two case studies in this study – São Paulo and Mexico City are 'megacities', this study favours the terms metropolitan region or area as these are the terms used by the relevant authorities of each jurisdiction.

Rapid urbanization and land use changes have also caused water quality deterioration through drastic interferences in ecosystems and the hydrological cycle (Azzam *et al.*, 2014). Deteriorating water quality poses significant risks to human and environmental health (OECD, 2015b). Estimates indicate that around one third of all rivers in Latin America, Africa and Asia are affected by severe pathogen pollution[5], although it is not clear how many people are at risk of coming into contact with polluted waters as current estimates only account for rural populations (UNEP, 2018). Water quality in urban rivers is often heavily impacted by point source pollution, such as untreated wastewater discharge, and this is worsened by high population density and the concentration of polluting activities (Vlachos and Braga, 2001; Elmqvist *et al.*, 2013). Diffuse pollution from agriculture (e.g. fertilizers and pesticides) and urban sources (e.g. runoff from sealed surfaces and roads) also affects urban areas and is particularly challenging to regulate (Martinez-Santos *et al.*, 2014). Water contamination by large and mega-cities aggravates issues such as regional water stress and unequal access to water resources (Varis *et al.*, 2006). In addition, treating water to meet adequate drinking water standards can represent a considerable cost for some countries (OECD, 2015b). However, inaction is also costly, as contaminated water bodies can lead to outbreaks of waterborne diseases and negatively impact both urban residents and communities and the environment far downstream (Vlachos and Braga, 2001; OECD, 2015b).

Extreme weather events can cause floods, landslides and droughts with devastating effects on urban and rural settlements. Many large urban agglomerations are located in the Global South and have limited coping capacities (Kraas *et al.*, 2014). As cities grow, they tend to expand into risk-prone areas as available land becomes scarcer and more expensive (UCLG, 2016). In 2000, about 30% of global urban land was in high-frequency flood zones. By 2030, this will rise to 40 per cent (Güneralp *et al.*, 2015). These hazards can be part of seasonal variations (e.g. monsoons) and climate variability, but climate change is expected to aggravate their frequency and intensity by causing changes in hydrological patterns, with more evaporation and melting through warming, and more frequent and intensive extreme weather events (Engel *et al.*, 2011). Large cities are particularly vulnerable to climate change, as they are often located in coastal areas, flood-prone areas or areas suffering from water scarcity and droughts (Biswas, 2004; Varis *et al.*, 2006; Hansjürgens and Heinrichs, 2014). In addition, water-related risks are compounded by human factors such as population density, socio-economic inequality, poor urban planning and the environmental impact of land use changes (e.g. erosion from deforestation, rapid urbanization) (Rietveld *et al.*, 2016).

1.2.2 The policy challenge: Implementing IWRM is key to advancing

There have been many discussions within global policy circles on water-related challenges since the UN Conference on the Human Environment in 1997, including special attention paid to Agenda 21 adopted in 1992 (see Conti, 2017; Obani, 2018 for details). The most recent global discussions on water-related goals took place in 2015 within the context of Agenda 2030, where the UN General Assembly adopted water-related goals within its Sustainable

5 Severe pathogen pollution occurs where monthly in-stream concentrations of faecal coliform bacteria are >1000 cfu/100ml.

Development Goals (UNGA, 2015). These Goals highlight areas of priority for the global community to work on. Goals 6 (Ensure availability and sustainable management of water and sanitation for all), 11 (Make cities and human settlements inclusive, safe, resilient and sustainable) and 13 (Take urgent action to combat climate change and its impacts) and their associated targets and indicators are relevant for this research. These goals are linked to water quantity, water quality and climate change adaptation in multiple ways (see Table ***1.2***).

SDG target 6.5 promotes the implementation of IWRM (Integrated Water Resources Management) at all levels, implicitly recognizing it as the most appropriate management approach to the world's diverse water-related challenges and necessary to attain all other SDG 6 targets (UNEP, 2018). The suggestion that this implementation should take place "at all levels" highlights the multi-scalar nature of these challenges. IWRM is deemed critical for the 2030 SDG agenda as a way of allocating water resources efficiently, equitably and sustainably and coordinating sustainable development in the global context of increasing water scarcity and pollution. Progress on SDG 6.5 is measured by two indicators: a score of 0 to 100 on the degree of IWRM implementation and the proportion of transboundary basins with cooperation agreements.[6] Nonetheless a 2018 self-assessment survey answered by 172 countries as part of a UN Progress Report on SDG 6, indicates that around 60% are unlikely to implement IWRM by 2030 (UNEP, 2018). Survey results further revealed that sub-national and lower levels lag even further behind and emphasized the need for coordination across levels to ensure the flow of resources to where they are most needed and effective.

The survey results mention links with SDG 11 on 'Sustainable Cities and Communities' and SDG 13 on 'Climate Action', but they do not provide clarifications on how to develop synergies between them. There seem to be clear interlinkages between the goals: SDG target 6.5 (Implement IWRM) relates to SDG 11.5 (Reduce effects of water-related disasters) and to SDG 13.1 (Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters). In fact, the first indicators for the SDGs 11.5 and 13.1 are identical: "Number of deaths, missing persons and persons affected by disaster per 100,000 people". In addition, targets 6.1 and 6.2 (access to drinking water and sanitation) are closely intertwined with target 11.1 (ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums). Target 6.3 (reduce pollution, including from untreated wastewater) could be linked to target 11.6 (reduce the adverse per capita environmental impact of cities), but the latter is only focused on pollution from solid waste and air pollution. Moreover, IWRM planning has potential synergies with SDG 11.B and SDG 13.1, which both promote the adoption of local and national disaster risk reduction strategies.

This brief review demonstrates that there are clear interlinkages between these three Goals. Nonetheless, the abovementioned report does not clarify how countries can explore these links, allowing for coordinated responses and promoting win-win strategies. This research aims to help fill this gap, contributing to the SDGs by focusing on how these inter-linkages positively and negatively impact urban water challenges and how these synergies can be harnessed.

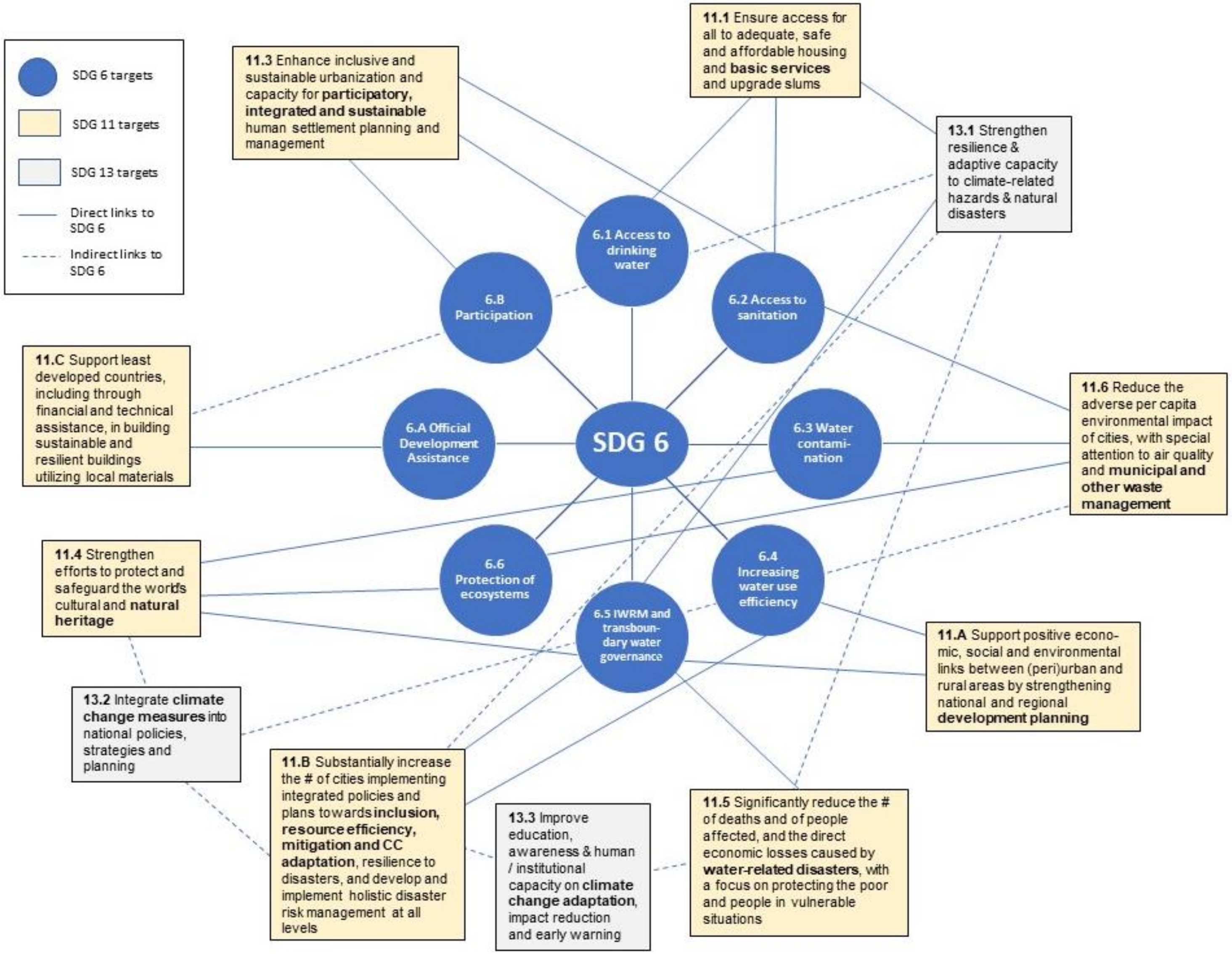
[6] Indicator 6.5.2 on transboundary agreements concerns basins and aquifers shared by at least two countries.

Table 1.2 The SDGs and Targets and their links to water quantity, water quality and climate change adaptation

<table>
<tr><th>Water quantity</th><th>Water quality</th><th>Climate change adaptation</th></tr>
<tr><td colspan="2">6.1 Access to drinking water
6.2 Access to sanitation</td><td>11.5 Reduce effects of water-related disasters</td></tr>
<tr><td colspan="3">11.1 Access to housing, basic services & slum upgrading</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">6.3 Reduce water contamination
11.6 Reduce cities' environmental impact, including through waste management</td><td>11.B Increase the number of cities with integrated policies & plans for inclusion, resource efficiency, climate change adaptation & disaster resilience. Develop holistic multilevel disaster risk management</td></tr>
<tr><td>13.1 Strengthen resilience & adaptive capacity to climate-related hazards & natural disasters
13.2 Integrate climate change measures into national policies, strategies and planning
13.3 Improve education, awareness-raising & human/ institutional capacity on climate change adaptation, impact reduction and early warning</td></tr>
<tr><td>6.4 Increase water use efficiency
11.B Increase the number of cities with integrated policies & plans for inclusion, resource efficiency, climate change adaptation & disaster resilience. Develop holistic disaster risk management at all levels</td><td></td><td></td></tr>
<tr><td colspan="3">6.5 Implement IWRM at all levels
6.6 Protect and restore water-related ecosystems
11.4 Protect the world's natural heritage</td></tr>
<tr><td colspan="3">6.A Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes</td></tr>
<tr><td colspan="3">11.C Support least developed countries, including through financial & technical assistance, in building sustainable & resilient buildings using local materials</td></tr>
<tr><td colspan="3">6.B Support & strengthen local communities' participation in improving water & sanitation management
11.3 Enhance inclusive & sustainable urbanization & participatory planning</td></tr>
</table>

Source: Compiled from https://sustainabledevelopment.un.org/?menu=1300

Figure 1.4 Links between SDGs 6, 11 and 13



1.2.3 THE GAP IN SCHOLARLY KNOWLEDGE: THE DISCONNECT BETWEEN CITIES AND RIVER BASINS

The above-mentioned social and policy challenge has led to a growing literature on River Basin Management (see Chapter 3) and Urban Water Management (see Chapter 4). While extensive, I see three main gaps on how the existing literature addresses water-related challenges in large metropolitan regions.

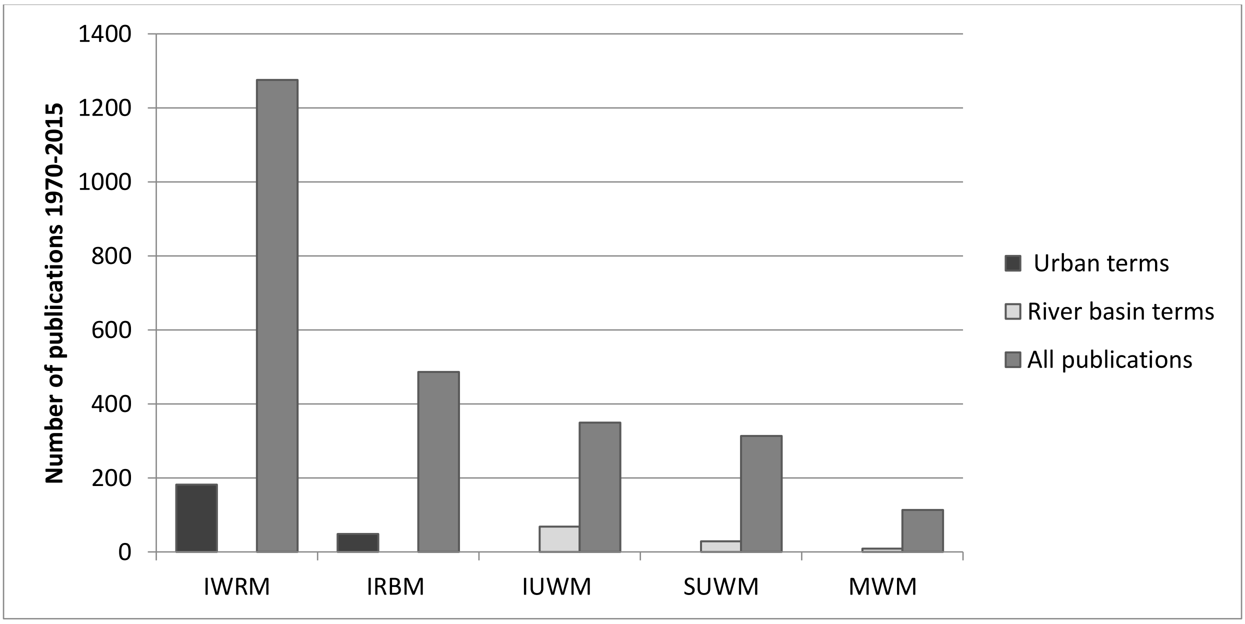
First, the dominant scholarly bodies of literature that analyse water management in river basins are the Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) literatures (see Chapters 2 and 3). IWRM and IRBM adopt the river basin as the ideal unit for water management, although IWRM also has a national spatial focus (Watson, 2004; Jones *et al.*, 2006; Bahri, 2012). They address water quantity concerns such as managing water resources for multiple users and avoiding conflicts, water supply through large-scale infrastructure, and the need for more water demand-focused measures and soft approaches (Abdullah and Christensen, 2004; Watson, 2004; Barrios *et al.*, 2009). Concerns about water quality centre on contamination risks within the river basin and the adoption of ecosystem-oriented approaches (Renner *et al.*, 2017). Adaptation to climate change risks is not a focus of the literature, being only laterally addressed through specific topics such as droughts (Hurlbert, 2016) and irrigation practices, minimum environmental flows, water allocation, and others (Barrios *et al.*, 2009; Brandeler *et al.*, 2019). Both IWRM and IRBM take a holistic approach to water management, emphasizing the need to integrate upstream and downstream issues, surface and groundwater, land and water systems, humans and ecosystems, multiple sectors, and viewpoints (Jønch-Clausen and Fugl, 2001; Watson, 2004; Grigg, 2008; Medema *et al.*, 2008; Savenije and Van der Zaag, 2008; Barrios *et al.*, 2009; Molle, 2009a; Agyenim, 2011; Closas *et al.*, 2012; Foster and Ait-Kadi, 2012; Anokye, 2013). However, it is not clear how water services and planning at local levels should be addressed. Although IWRM/IRBM aim to integrate urban water concerns, including water services, this is challenging in practice, as natural hydrological borders rarely coincide with political-administrative borders (Bahri, 2012; OECD, 2016). A review of the literature on IWRM/IRBM in titles, abstracts and key words in ScienceDirect indicated that, despite an exponential increase in the number of publications in the last 15 years, few contained terms referring to the urban scale (urban, city/ies, megacity/ies and metropolitan) (see Figure ***1.5***).

Second, the (social sciences) literature on urban water has largely focused on the provision of water services and infrastructure, as well as issues of risk and adaptation (Engel et al., 2011; GTT, 2014). However, adaptation and 'resilience thinking' are often limited to the field of disaster management (Baud and Hordijk, 2009). It has evolved from a technocratic and sectoral approach with a focus on public health and risk control, towards including considerations for sustainability, integration and participatory decision-making (Brown and Farrelly, 2009; Rauch and Morgenroth, 2013). This has led to new paradigms, such as Sustainable Urban Water Management (SUWM) and Integrated Urban Water Management (IUWM). Yet, the literature often leaves out the broader context of the river basin, and the relationship between the city and its rural hinterlands, including that of their respective water systems (Pearson *et al.*, 2010; Brandeler *et al.*, 2019). Only a fraction of the literature reviewed with 'SUWM' or 'IUWM' in titles, abstracts and keywords included terms related to the river basin scale (see Figure ***1.5***).

The pressure on local officials to provide certain services within their jurisdiction and the relatively short time span and scope of their mandates mean that they often lack strong incentives to consider the long-term impacts on the wider basin. The SUWM literature emphasizes local level, infrastructure-oriented initiatives (Marlow *et al.*, 2013; Rietveld *et al.*, 2016). However, as the river basin is typically considered as the ideal unit for water resources analysis and management, addressing water problems at the local level could lead to issues of administrative/institutional mismatch between the basin and city scales, with various social, environmental, economic and relational implications.

Third, neither the RBM nor the UWM literature clarifies how their principles apply to the context of large metropolitan regions, despite the multiplication of the world's large urban agglomerations (Brandeler *et al.*, 2019). A review of publications with the term 'metropolitan water management' revealed only 113 results between 1970 and 2015, compared with 314 for SUWM and 349 for IUWM (see 2.3). They made virtually no mention of the river basin. Megacities sometimes expand across large parts of river basins and even beyond their boundaries and impacts are felt even further. They are often composed of a multitude of local governments with autonomous decision-making powers, and the coordinated management of urban water and water resources is particularly challenging in these contexts. A relevant question is thus whether institutions dealing with the metropolitanization of cities should be coordinated with those for water management (Roche *et al.*, 2001). Despite their unique characteristics and challenges, the existing scholarship fails to address whether metropolises should receive special consideration in urban water or river basin management, or whether they require a completely different approach.

Figure 1.5 The occurrence of terms linked to the urban and river basin within the main concepts



Source: (Brandeler *et al.*, 2019)

1.3 RESEARCH QUESTIONS, APPROACH AND LIMITS

1.3.1 RESEARCH QUESTIONS

Hence, this thesis investigates river basin and urban water governance in relation to metropolitan water challenges through the following overarching question: **How do interactions between drivers and institutions at different spatial and institutional scale levels shape metropolitan water challenges, and how can policy instruments from river basin and urban water governance frameworks be (re)designed to foster more sustainable and inclusive metropolitan water governance?**

This thesis is grounded within the water governance literature. More specifically, in the absence of a theory of metropolitan water governance, it explores what the literature on river basin governance and on urban water governance can tell us about how to understand and address metropolitan water challenges. The ensuing theoretical chapters combine a more normative perspective to evaluate how the literature frames urban and river basin governance in relation to inclusive and sustainable development and are critical to examine the spatial scalar dimensions of water governance. Chapters 3 and 4 engage with the literature on IWRM and IRBM and UWM respectively. River basin governance and urban water governance are focused on different spatial scales and have a different scope, which determines the actors that are involved and the institutional arrangements that shape water-related decision-making and policy. This thesis adopts and integrates elements of IWRM/IRBM and UWM to analyse the relevant institutions, instruments, actors and drivers that shape water-related challenges in metropolitan areas. Based on this theoretical framework, the empirical analysis follows three steps, inspired by the three research foci of causality, performance and design of the Science Plan of the International Human Dimensions Programme's Institutional Dimensions of Global Environmental Change (IHDP/IDGEC, 2005).

As a first step, this study examines causality, which means understanding the role that institutions in general, and more specifically river basin and urban water governance regimes, play in causing and confronting metropolitan water challenges. Institutions are often treated as intervening variables that affect the impact of underlying forces (or drivers) but are not such forces themselves (Young *et al.*, 2008: 9). However, institutions can affect the behaviour of a variety of individual actors, something critical in shaping outcomes of human/environmental relations (IHDP/IDGEC, 2005). In addition, institutions at multiple levels interact with other forces, such as biophysical and cultural systems. Studying institutions thus requires understanding 'joint effects', as institutional mechanisms interact with other mechanisms to coproduce outcomes (Underdal, 2008: 66). Within environmental and resource regimes there are so many underlying factors (biophysical and socioeconomic forces) that contribute to collective outcomes that it is almost impossible to separate the causal linkages from different elements and evaluate the salience of each for explaining collective outcomes (Young *et al.*, 2008). This thesis then relies on a case study method and comparative analyses as a methodology that enables the assessment of the profound complexities of the interactions between human and biophysical systems, although it has limitations in terms of providing generalizations (see 2.2).

The second step is to evaluate the performance of existing institutions on actors' behaviour towards urban water challenges, given the drivers and contextual factors that affect their behaviour. According to the environmental governance literature, specific regimes are established to address well-defined problems, and performance analysis is used to evaluate how successfully it solves, or at least alleviates, these problems (Young, 2003a: 100; Mitchell, 2008). As a more normative lens for looking at institutions, performance analysis can be used to evaluate various dimensions (or criteria), such as sustainability or equity (Young *et al.*, 2008: 21). It corresponds to an 'actual-versus-aspiration' comparison that establishes how much an institution has contributed to a specified goal (Mitchell, 2008: 79). This thus requires using a performance scale or measurement system for each dimension being evaluated, as well as a reference point to which outcomes can be compared, leading to a numeric or non-numeric performance score (Mitchell, 2008: 80). Thus, this research selected and evaluated instruments of each governance regime in relation to four dimensions of inclusiveness and sustainability, defined below (see 1.5.1).

The final step considers how to improve institutional design so as to better address urban water challenges in metropolitan regions. It consists in the (re)design of policy instruments for both Mexico City and São Paulo in order to enhance the sustainability and inclusiveness of policy responses to metropolitan water challenges. This is built on the greater understanding of the interactions between the urban water and river basin governance regimes and the effectiveness of existing policy instruments. The specific format and purpose of these instruments therefore depends on the findings of the first two steps (causality and performance).

Consequently, to answer the main research question, this study explores the following sub-questions:

1) What does the literature on urban water governance and on river basin governance tell us about how to understand and address metropolitan water challenges?
2) How do multiple drivers as well as river basin and urban water governance institutions shape current metropolitan water challenges? [**causality**]
    a. What are the current drivers of urban water challenges in the metropolitan regions of São Paulo and Mexico City and in their respective river basins?
    b. What IWRM/IRBM actors and institutions exist at multiple levels to address urban water challenges in São Paulo and Mexico City?
    c. What UWM actors and institutions exist at multiple levels to address urban water challenges in São Paulo and Mexico City?
3) Which policy instruments are effective[7], and which are not, in dealing with these water challenges and their drivers? [**performance**]
    a. In relation to water sharing (Quantity)
    b. In relation to water preservation (Quality)
    c. In relation to unpredictable and extreme water-related weather events (Climate Change)

[7] "Effective" here should be understood to mean: Enhance sustainability and inclusiveness.

d. How are the policy instruments at the urban scale linked to those at the river basin scale, and are these coherent within the metropolitan region and across multiple levels of governance?

4) Based on this analysis, how can more appropriate instruments be designed to address metropolitan water challenges, with the aim to guide metropolitan regions towards inclusive and sustainable development? [**(re)design**]

1.3.2 Focus of the research

This research focuses on large cities and their unique characteristics and water-related challenges, within Latin America. The urban population produces about 80% of global wealth, counts for over half of the global population, accounts for three quarters of global demand for natural resources, produces 50% of its waste (IRP, 2018). Latin America is the most urbanized region of the Global South and is still urbanizing. As most of the world's future urbanization will happen in the Global South, the experiences of Latin America's cities may provide lessons or insights that are more relatable for other growing cities than the experiences of cities in the Global North, which underwent very different development paths.

1.3.3 Limits of the research

A first limitation of this research is in terms of the spatial scope, as it focuses on large metropolitan areas. Smaller cities and rural areas far from large cities also face important water-related challenges. However, the thesis argues that the size and complexity of large cities, and political and economic factors, lead to challenges of a different nature.

For both case studies, historical developments of the past centuries shaped their water-related problems and their water governance regimes. However, the thesis mainly focused on developments dating back to the early 1990's, when IWRM received international recognition and began to be implemented in Brazil and Mexico. Moreover, the research limits its forward outlook to 2030, as this is the timeframe for attaining the Sustainable Development Goals. This corresponds to 15 years from the start of the research, which is enough to estimate medium-term challenges and implement significant reforms. The timeframe of 2050 is occasionally considered for longer-term dynamics, such as climate change effects. This study favours scope over depth by considering a wide range of water-related challenges and responses to these within the metropolitan regions of Mexico City and São Paulo. Analysing these challenges and the effectiveness of existing responses to attain sustainable and inclusive metropolitan water governance regimes requires considering the metropolitan water cycle as a whole, including both the ecosystem functions it depends on and land use considerations, and the efforts of actors across different sectors and within governments at multiple levels. This limits a deeper understanding of large metropolitan regions' specific water-related challenges, in order to shed light on the complexity, transdisciplinarity and multi-dimensionality of metropolitan water governance. Moreover, the research mostly addresses the governance of 'blue water' (water resources in surface and groundwater bodies), as well as 'grey' and 'black' waters (wastewater), as current water governance regimes and policies are mainly limited to these types of water. Further research is first needed on ‘green water’ (soil moisture) and ‘rainbow water’ (atmospheric moisture), before policies can be designed to better manage these within and around large cities.

1.4 The nature of water

Before delving deeper, it is important to briefly overview the elementary features of water. Water has one simple chemical formula composed of two hydrogen atoms and one oxygen atom, but there are multiple types or ‘colours’ of water, notably: rainbow water, green water, blue water, grey water, black water (see Table ***1.3***) (Hayat and Gupta, 2016). Most freshwater is not (easily) accessible as it is stored in saltwater in oceans and seas or locked away in the polar caps.

Table 1.3 Colours of water and their characteristics

Colours of water	Characteristics
Blue water	Accessible clean freshwater resources (surface and groundwater). Blue water availability is the volume of water that can be consumed without causing adverse ecological impacts
Rainbow water	Waters in their vaporized stage (atmospheric moisture). It can travel long distances as clouds, is depleted by precipitation and replenished through evaporation
Grey water	Volume of water required to dilute pollutants so that water quality remains above agreed water quality standards. This includes water polluted by pesticides from agriculture and household wastewater (excluding inputs from toilets)
Black water	Water polluted with human faeces (sewage). Ecological buildings nowadays separate blackwater and greywater
Green water	Rainwater that is stored in the soil, absorbed by plant roots and evaporates through plant transpiration. It corresponds to 60% of freshwater flow

Source: Hayat and Gupta (2016: 1233-1237)

Blue water can be captured for human uses and is discharged as grey or black water. Besides taking different forms, water also flows through the hydrological cycle, and does not follow socially constructed boundaries such as national or sub-national borders. Managing these flows is necessary to sustain and protect human settlements, in particular in large cities.[8] The delimitation of river basins and aquifers as governance scales developed as societies were particularly concerned with blue water and led to the emergence of IWRM/IRBM as dominant paradigms for water resources management. Given that water flows can be transformed

8 The circulation of water and other material inflows and outflows in and out of cities is sometimes referred to as “urban metabolism” (Heynen *et al.*, 2005; Carlo Delgado-Ramos, 2015).

through engineering for the benefit of certain groups (Swyngedouw, 2009), choosing the river basin as a management unit is also a political process as it transforms these spaces into territories of governance and raises questions about who will take decisions and how (Warner *et al.*, 2008). Consequently, the flow of water can then be understood as a hybridization of physical and social processes.

Furthermore, water contributes in multiple ways, directly or indirectly, to humans and human well-being (Hayat and Gupta, 2016). Green water, largely ignored by research and policy until recently, is the largest freshwater water resource, the basis of rain-fed agriculture and all life on land and performs crucial functions by sustaining water-dependent ecosystems such as forests and wetlands and their biodiversity (Ringersma *et al.*, 2003). These ecosystems are essential for sustaining blue water as they often hold the springs of rivers and streams. Therefore, the degradation of ecosystems in the urban/rural interface impacts sustainable water resources management and water supply for urban users (Avissar and Werth, 2005). The disruption of water-related ecosystem services/nature's contributions within the hydrological cycle leads to challenges in terms of water quantity and water quality, and risks related to climate change.

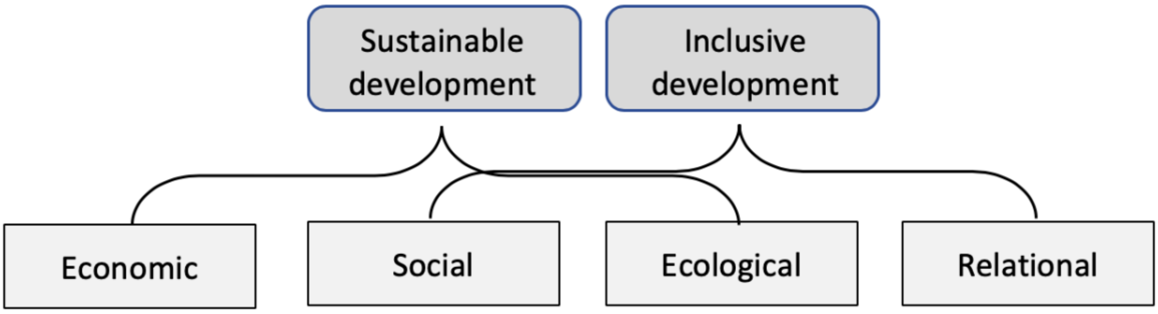
1.5 POSITIONALITY

This study aims for a multi-disciplinary approach to examine the social, economic, environmental and relational impacts of metropolitan water governance regimes. It is multidisciplinary in that it builds on existing knowledge in the natural and social sciences disciplines, including diverse and alternative knowledge claims, and comparisons between two different case studies, with the aim to frame questions in a broad manner (IDGEC 2005). This is done by combining a sustainable and inclusive development approach and a political science and geography perspective.

1.5.1 SUSTAINABLE AND INCLUSIVE DEVELOPMENT PERSPECTIVE

This research combines both a sustainable development and inclusive development perspective. The former is well-established and was institutionalized within the Sustainable Development Goals. It is typically defined by the balance of three pillars: Economic, social and ecological. The latter is a pull away from the neoliberal bias towards economic growth, through its focus on marginalized people, environmental sustainability and empowerment (Gupta, Pouw, *et al.*, 2015). The SDG framework does not mention 'inclusive development' but includes the term 'inclusive' 41 times (Gupta and Vegelin, 2016). Combining both perspectives allows for integrating social, ecological, economic and relational dimensions (see Figure ***1.6***). This thesis will consider these four dimensions to analyse the impact of policy instruments on the multiple water challenges experienced by large cities and their river basins and in the process clearly focuses on the more marginalized people in society.

Figure 1.6 Dimensions of inclusive and sustainable development



These four dimensions have the following characteristics:

- Social inclusiveness implies accounting for the multiple dimensions of poverty and striving for the social inclusion of specific individuals and groups. It reduces their exposure to various risks and enhances their well-being by investing in human capital and increasing opportunities for participation, meeting basic needs, reducing inequality and promoting equal rights (Gupta and Vegelin, 2016; Pouw and Gupta, 2017).
- Ecological inclusiveness requires recognizing that the growing demand for limited natural resources due to population growth and economic development may lead to 'ecospace' grabbing (i.e. large-scale transfer of these resources from local communities to governments, corporation and the private sector) (Gupta, Pouw, *et al.*, 2015; Gupta and Vegelin, 2016). It aims for local to global sharing of water resources, protecting equitable access to and ownership of resources and preserving ecosystems and their biodiversity (Gupta, Pouw, *et al.*, 2015; Gupta and Vegelin, 2016). People's well-being, particularly the poorest, is closely related to investments in preserving ecosystem services (Chopra *et al.*, 2005; Gupta, Pouw, *et al.*, 2015).
- The economic pillar is understood here as cities' ability to manage their resources and develop (Gupta, Pouw, *et al.*, 2015). Water is crucial for economic activities that sustain lives and livelihoods within and outside urban areas. Large cities are embedded in local to global political economic structures (Hordijk *et al.*, 2015), but are also important economic actors that can spearhead changes in economic development models and push for economic efficiency (e.g. rational water use, cost-efficient technology and infrastructure) to ensure the viability of various policy instruments. The focus of the economic pillar has often been on profit-maximization, reproducing inequalities and allowing for environmental degradation to persist through neo-liberal thinking and market-driven approaches (Pahl-Wostl, 2018). This thesis aims to rectify this imbalance and considers that sustainable and inclusive economic development should occur within planetary boundaries and without limiting the potential economic development of future generations.
- Relational inclusiveness recognizes the role of politics and local and global drivers of inequality in shaping poverty and ecological degradation (Gupta, Pouw, *et al.*, 2015; Gupta and Vegelin, 2016). These relations operate at multiple levels, and addressing

these requires dealing with all actors (Gupta and Vegelin, 2016). This requires addressing inequality and aims for the redistribution of power and resources, and ensuring that the most vulnerable and marginalized populations have access to affordable water services and receive protection from water-related risk (Swyngedouw, 2009; Pouw and Gupta, 2017).

This framework is used to examine the impact of institutional responses to water-related challenges. Institutions and instruments can empower social actors to respond to water quantity, water quality and risks related to climate change through planned or creative measures that stimulate certain types of behaviour and discouraging others (Gupta *et al.*, 2010; Majoor and Schwartz, 2015). Their effectiveness determines whether cities and their river basins can develop sustainably and inclusively. This thesis focuses on institutions and instruments derived from IWRM/IRBM and UWM, as these were identified as the dominant paradigms. IWRM and IRBM emphasise the sustainable management of all water and related ecosystems (linking to SDGs 6.4, 6.5 and 6.6), with an emphasis on decentralized and participatory decision-making (SDG 6.B) (Watson, 2004; Medema *et al.*, 2008; Molle, 2009a; Huitema and Meijerink, 2014). UWM addresses the provision of water and sanitation services (SDGs 6.1 and 6.2), including the treatment of wastewater and its recycling (SDG 6.3), as well as mitigation and adaptation to risks from extreme weather events (SDGs 13.1, 13.2 and 13.3) and control of waterborne diseases (SDGs 6.1 and 6.2) (Barraqué, 2011; Engel *et al.*, 2011; GTT, 2014). The linkages between the three SDGs are useful to consider the policy implications of metropolitan water governance.

1.5.2 MULTI-LEVEL GOVERNANCE THROUGH A POLITICAL SCIENCE AND GEOGRAPHY PERSPECTIVE

This thesis also adopts elements from geography and political science disciplines to analyse actors and institutions, and their interactions, within and across spatial scales. Metropolitan water challenges are shaped by biophysical and social factors at multiple levels. While environmental impacts, such as water scarcity, are often experienced locally, the complex web of factors behind them cannot realistically be addressed by local governments alone. When externalities appear in different jurisdictions than those that caused them, this requires multilevel responses (Hooghe and Marks, 2003; Newig and Fritsch, 2009; Termeer *et al.*, 2010). Yet, many analyses of urban sustainability have divorced the local from other governance levels (Marvin and Guy, 1997). A multilevel governance perspective allows for examining how local problems are constructed and contested at different scales of governance and through multiple political spaces (Hooghe and Marks, 2003; Bulkeley and Betsill, 2005)[9]. This is also the case for addressing water-related challenges in metropolitan regions, which are nested within social, economic and political contexts at local, national and global levels.

9 I interpret the concept of 'governance' as a process, and more specifically as "the shaping and sustaining of the arrangements of authority and power within which actors make decisions and frame policies that are binding on individual and collective actors within different territorial bounds" (Hanf and Jansen, 1998, p. 3). I take this perspective to examine (urban water and river basin) management approaches and their associated policy instruments.

Multilevel governance is broadly understood as the participation in decision-making processes of governmental actors and non-state actors at different administrative levels and across administrative jurisdictions (Pierre and Peters, 2000; Hooghe and Marks, 2003; Bache and Flinders, 2005; Papadopoulos, 2007; Kluvánková-Oravská *et al.*, 2009; Newig and Fritsch, 2009). This involves vertical interactions across administrative levels and horizontal interactions between agencies at central level, and different actors at sub-national level (Peters and Pierre, 2004; OECD, 2011, 2015b). These interactions may involve continuous negotiation among nested governments at multiple territorial levels (Pierre and Peters, 2000; Hooghe and Marks, 2003). Multilevel governance can also be an alternative to hierarchical government, with more complex and contextually defined relationships. In fact, the concept of multilevel governance emerged in order to make sense of the "unravelling of central state control" and the diffusion of authority more generally (Hooghe and Marks, 2003). Nevertheless, the traditional state-centric and constitutional perspective has not lost relevance (Peters and Pierre, 2004: 75). Rather, the "'shift' towards multilevel governance" is occurring in an incremental manner, where relations between institutions at different government levels are "fluid, negotiated and contextually defined".

In addition, multilevel governance allows for a more flexible approach to issues of spatial fit between natural and institutional (governance) scales, thereby striving for better institutional performance in terms of sustainability (Young, 2003b; Newig and Fritsch, 2009). For instance, the provision of public services and policy responses can be designed at the most appropriate scale in each context (Pahl-Wostl, 2015). This flexibility is necessary in order to face rapid and unpredictable environmental changes and to foster sustainable development (Bavinck and Gupta 2014: 78). However, designing institutions to fit natural scales should not be considered a panacea. Such institutions are more likely to face coordination challenges with other actors, particularly in terms of financing due to the difficulty of sustaining joint funding schemes (Ingram, 2008; Newig and Fritsch, 2009). It requires collaboration between actors who may otherwise compete for political and financial support. Political leaders whose constituencies have little relationship to the territory defined by river basin institutions also tend to feel estranged from the latter. Indeed, they are not directly held accountable to the population within the institutionalized river basin territory (Ingram, 2008).

Furthermore, dynamics at multiple levels not only shape metropolitan water challenges, and the institutions that address these, but also the power of actors at different levels. This research recognizes the fundamentally political nature of these regimes in both shaping and responding to water-related challenges and the responses to these, from the dominant discourses to the chosen policy instruments. However, it is beyond the scope of this study to formulate recommendations that require important shifts in the political, economic, social and cultural fabric of the two case studies and of other large metropolitan regions. The objectives of this study are limited to (re)designing policy instruments that can lead to changes within existing metropolitan water governance regimes. Nevertheless, such changes can have broader repercussions when there is sufficient political will and public support.

1.6 Structure of thesis

Following this introductory chapter, Chapter 2 grounds the research methodology and methods. The theoretical framework unpacks the literature on RBM and UWM from a multilevel governance perspective in Chapters 3 and 4 respectively. The four following chapters discuss the findings from the empirical research on the two case studies. Chapters 5 and 7 analyse the driving forces causing metropolitan water challenges and the institutions and instruments of IWRM/IRBM in place to address them in São Paulo and Mexico City respectively. In Chapters 6 and 8 a similar analysis focuses on UWM. Chapter 9 draws comparisons between the two cases, with a particular focus on the interactions between IWRM/IRBM and UWM, and reflects on the scalar mismatches that arise in each case's metropolitan water governance regime. It answers the research questions in relation to São Paulo and Mexico City, discusses the policy implications and proposes a redesign of their policy instruments. Finally, Chapter 10 concludes this thesis by answering the research questions in relation to the literature review, reflecting on the implications for international development studies and providing recommendations, not least in the context of the Sustainable Development Goals.

2. METHODOLOGY

2.1 INTRODUCTION

This chapter develops the qualitative methodology employed to answer the research questions. The methodology has several components: the comparative case study method (see 2.2), a literature review (see 2.3), an analytical framework (see 2.4), the units of analysis (see 2.5), the qualitative content analysis of the policies (see 2.6), the fieldwork and ethical considerations (see 2.7) and the integration of these different elements (see 2.8).

2.2 THE COMPARATIVE CASE STUDY METHOD

2.2.1 JUSTIFICATION FOR THE COMPARATIVE CASE STUDY METHOD

This research adopts an inductive comparative case study approach examining São Paulo in Brazil, and Mexico City in Mexico. The case study methodology is useful when studying phenomena that are highly context-dependent, where predictive theories may not be valuable (Flyvbjerg, 2006). Case studies, through in-depth analysis of a single unit, may allow for the identification of causal mechanisms between an X and a Y (Gerring, 2018). This can be for phenomena too complex (i.e. too many potential variables) for surveys or experimental strategies, or to describe an intervention and the context in which it occurs. For this research, this means investigating the metropolitan water challenges in Mexico City and São Paulo in the context of the interrelations between water governance at urban scale and at river basin scale. Many driving forces and institutional factors shape such challenges and a case study may help elucidate their links (Gehring and Oberthur, 2008). This type of 'instrumental' case study provides insights into an issue or helps refine a theory (Stake, 1995).

Comparative analyses allow me to build upon case studies of institutions in different settings (IDGEC 2005). This study uses a relational approach to comparison, where the purpose is not to measure cases against a universal yardstick, but rather to gain insights that could not be attained by observing a single case (Ward 2010). In the urban context, the comparative case study method is developed to press toward generative theoretical insights relevant beyond the observed location, although not universalized (McFarlane and Robinson 2012). Comparisons brings attention to similarities but also to differences between case studies, and the latter is a productive means for conceptualizing contemporary urbanism (McFarlane and Robinson 2012). Considering similar problems in different locations and contexts is important to gain valuable insights on policy processes at multiple levels and the performance of similar regimes (e.g. the inclusiveness and sustainability of water governance regimes in metropolitan regions) (Young *et al.*, 2008; Kuzdas and Wiek, 2014). Comparisons may thus enable me to gain a clearer perspective on or understanding of phenomena in two or more cases, without necessarily aiming for generalizations or falsifications. In other words, the use of case studies can help to "learn something" rather than to "prove anything" (Eysenck, 1976).

2.2.2 THE CHOICE OF SÃO PAULO AND MEXICO CITY

Latin American countries have played an important role in global debates on the causes and solutions to environmental challenges and climate change (Hogenboom *et al.*, 2014). In this region, environmental governance has been reshaped by the emergence of social movements and their promotion of social and environmental justice and new environmental discourses (de Castro *et al.*, 2016). Nevertheless, inequality, poverty, weak institutions and the concentration of power by elites remain rampant and hinder the effective implementation of governance initiatives at multiple levels (Hogenboom *et al.*, 2014).

Brazil and Mexico are the most populated countries of Latin America and are both highly urbanized.[10] In both countries, people and water resources are unevenly distributed, and the population is more densely concentrated in relatively water scarce regions. Besides experiencing seasonal climate variation, both countries are likely to suffer increases in extreme weather events due to climate change (see 5.2 and 7.2).

Brazil and Mexico have relatively similar GDP per capita (i.e. USD 9,812 in Brazil and 8,910 in Mexico in 2017) and both are upper middle-income economies with stark socio-economic inequalities (high Gini coefficients of 53.7 in Brazil and 43.4 in Mexico in 2016) (World Bank, 2019a, 2019b). In Mexico, economic growth has been concentrated in the drier parts of the country, while the humid Southeast has only 16% of economic output (Hearne, 2004). In Brazil, the South and Southeast are significantly wealthier than the rest of the country. Both experienced rapid population growth, have inadequate urban planning, and serious water-related challenges for urban dwellers (Tortajada, 2008; Kelman, 2015).

Both countries are federal regimes, with responsibilities shared between three levels of government (federal, state and municipal), which has important implications for water resources management, water services and water-related risks.[11] The implementation of IWRM is estimated to be relatively advanced in comparison to other Latin American nations, and slightly above average for their HDI (Human Development Index) score (UNEP, 2018). They were also the first two countries in Latin America to have legally mandated river basin organizations (Tortajada, 2001). These are significant developments for the relatively young democracies: Brazil began transitioning to democracy in 1985, and Mexico initiated democratic reforms in the early 1990's (Martínez-Lara, 1996; Vegelin, 2016; Ginsburg, 2017).

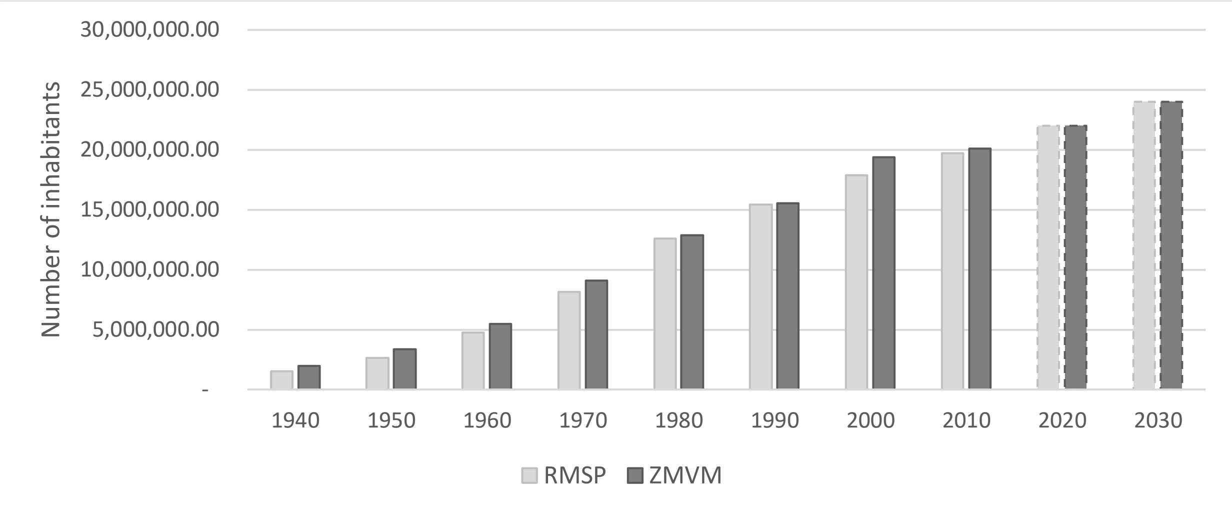
São Paulo and Mexico City are two of the world's largest urban agglomerations, and the largest in Latin America. Throughout the 20th century, they experienced explosive demographic growth and rapid industrialization prompted by the Import Substitution Industrialization policies of the 1930's (see Figure ***2.1***) (Blouet and Blouet, 2015). As of the 1970s and 1980s, their population growth was concentrated in their peripheries (Escamilla and Santos, 2012). They have similar population and surface area sizes and are composed of a large

10 According to the 2010 census, Brazil had a population above 190 million inhabitants, 87% of which was urban (IBGE 2010). In Mexico, nearly 77% of the population was urban out of approximately 119 million inhabitants in 2010 (Kim and Zangerling 2016; INEGI 2015). Mexico's population quadrupled since 1950 and went from being predominantly rural (57.4%) to mainly urban (76.5%) (INEGI 2015).

11 Mexico has 31 states and the federal entity of Mexico City. Brazil has 26 states and the Federal District.

number of municipalities (see Table ***2.1***). Mexico City is the capital of Mexico, whereas São Paulo is a state capital. However, both are the financial and economic centres of their country. The former spreads over three different federal entities, whereas São Paulo is contained within one state.

Figure 2.1 Demographic Growth in the metropolitan regions of São Paulo and Mexico City

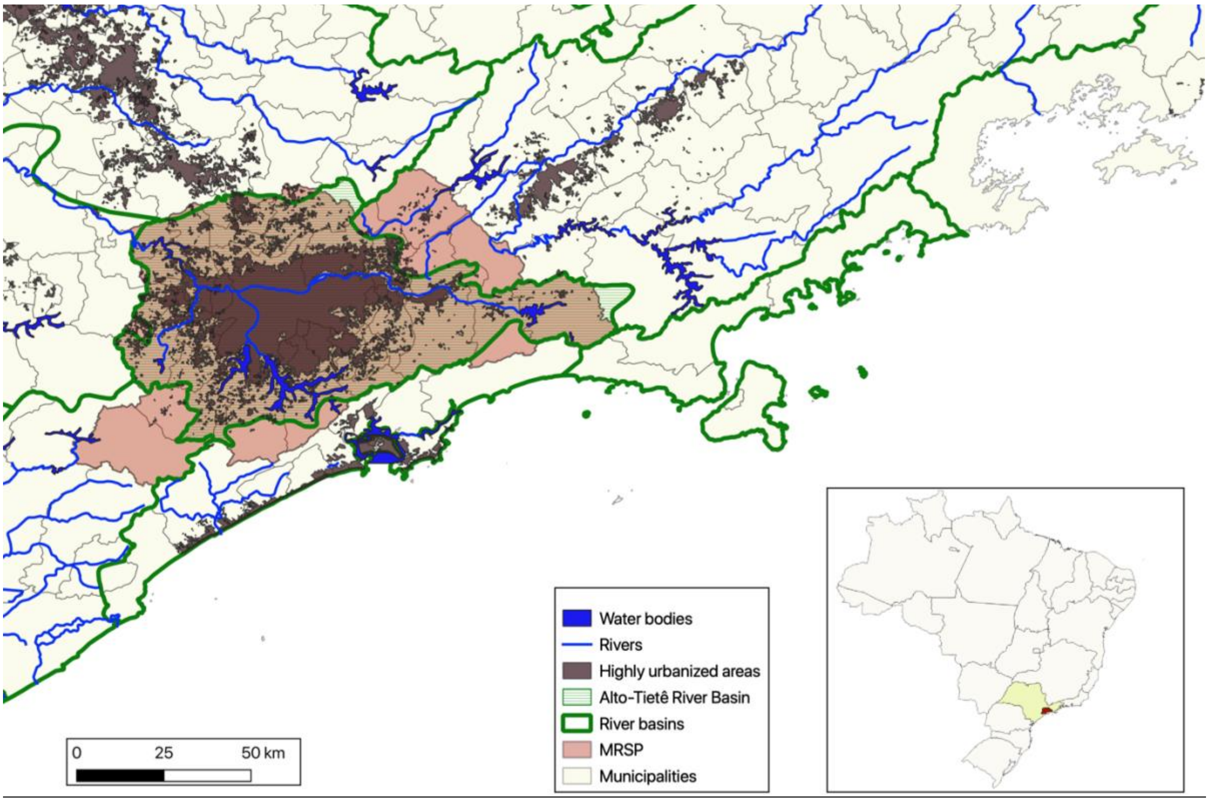


Source: Based on raw data from São Paulo Pref. (2018); UNDESA (2018); Pradilla Cobos (2016)

The two megacities are both located inland and upstream in their river basins (see Map ***2.1*** and Map ***2.2***). They are experiencing extreme transformations of their natural landscape to accommodate growing populations and their demand for water, and to protect themselves from flood risks. However, they both continue to struggle with water-related challenges in terms of quantity, quality and the effects of extreme weather events. The Valley of Mexico Basin endured a water crisis in the Spring of 2009, after facing floods months earlier. Similarly, in 2010 and 2011 the Upper-Tietê Basin, where São Paulo is located, experienced heavy precipitations and floods. In 2013-2015 the region suffered a historical drought. These extreme contradictions in such short timeframes could be linked to climate change, but also indicate a failure in the water management model.

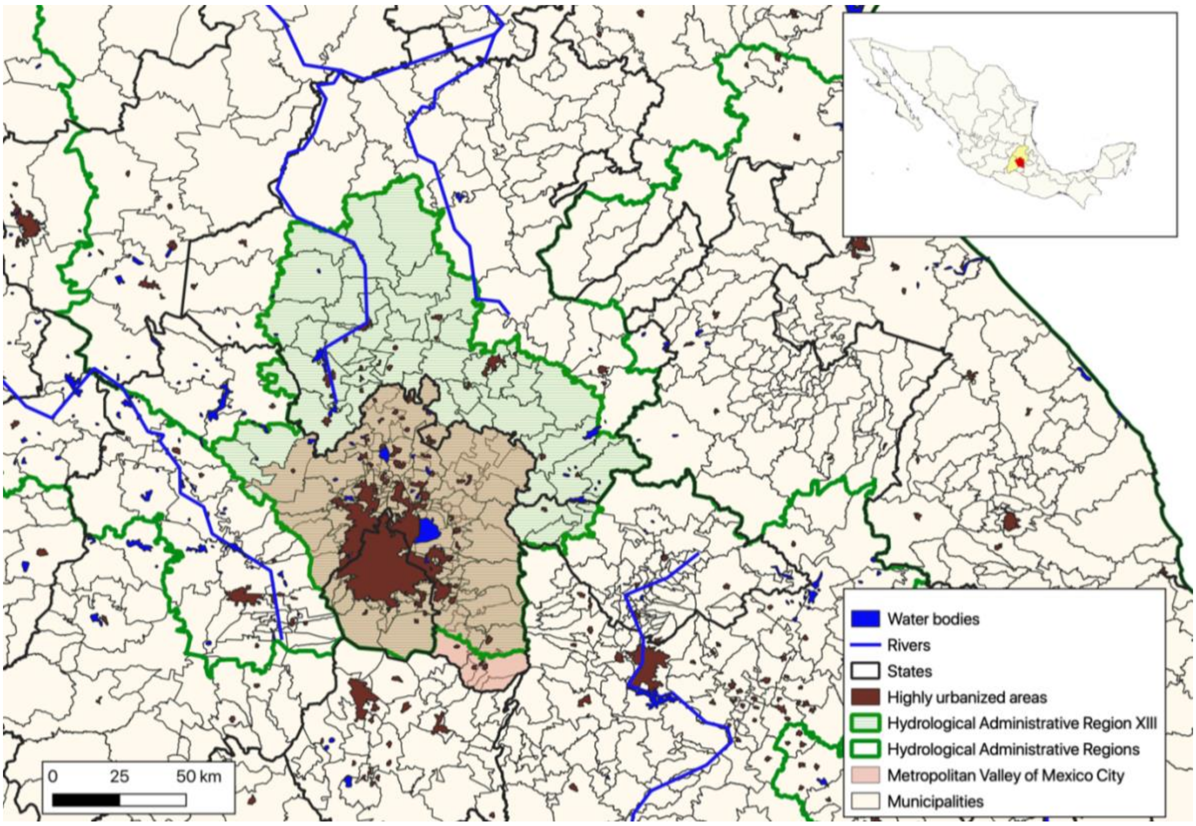
In sum, the two cases share many common features in terms of size, economic development and historical background. Their experiences addressing water-related challenges – both successful and unsuccessful – can bring valuable insights to many cities in the Global South that have similar biophysical, political, economic and demographic characteristics, and that are likely to face growing water-related challenges.

Map 2.1 Spatial characteristics of São Paulo



Source: Author

Map 2.2 Spatial characteristics of Mexico City



Source: Author

Table 2.1 Characteristics of Mexico City and São Paulo

	National capital	**National GDP per capita**	**City proper pop.**	**Metro pop.**	**# of munici-palities in metro area**	**# of federative entities in metro area**	**Surface area of metro area**
São Paulo	No	9,821.4 USD in 2017	12 million	21.5 million	39	1 state	7,946 km^2
Mexico City	Yes	8,902.8 USD in 2017	9 million	21.6 million	60 + 16 districts of Mexico City	3 states	7,866 km^2

Sources: (EMPLASA, no date; World Bank, no date; World Population Review, no date; State, 1994; INEGI, 2014; Brazil, 2015)

2.3 Literature review

2.3.1 Literature review on key concepts

To address the research questions, I conducted an extensive literature review on UWM, IWRM, IRBM and MWM, Inclusive and Sustainable Development, Multilevel Governance and Institutional Analysis. I identified the scholarship on the relevant principles and instruments and included scholarship from both the Global North and Global South. For UWM/IWRM/IRBM/MWM, the literature survey first took 1970 as a starting date, but then focused on articles published between 1990 and 2018, as earlier literature on these topics was virtually non-existent. I short-listed approximately 100 articles from the initial search. These were published in journals, including Current Opinion in Environmental Sustainability, Ecology and Society, Geoforum, Global Environmental Change, Nature Sustainability, Urban Studies and Water Policy (see Table ***2.2***).

The literature review on IWRM/IRBM and Integrated Urban Water Management (IUWM)/ Sustainable Urban Water Management (SUWM)/ Metropolitan Water Management (MWM) allowed for an assessment of the evolution of publications over time. This search was conducted in ScienceDirect and was limited to the occurrence of these terms in titles, abstracts and key words between 1970 and 2015. The resulting graph (see Figure ***2.2***) reveals the quasi non-existence of all five terms prior to 1990. IWRM shows the steepest rise, increasing from 19 publications in 1995, to 54 in 2005 and 183 in 2015. IRBM is marginally ahead of IUWM and SUWM, with 62, 38 and 50 publications respectively in 2015. Finally, the graph shows that the publications on MWM are negligible, with results only entering the double digits in 2013, and 113 results in total for the 1970-2015 period. When the search is conducted with quotation marks (which limits search results to publications where the term 'metropolitan water management' appears as a whole), results were significantly lower for all terms (see Annex A – Literature review). In the case of MWM, there were no results between 1970 and 2015. This indicates that there is no clearly defined metropolitan water management approach.

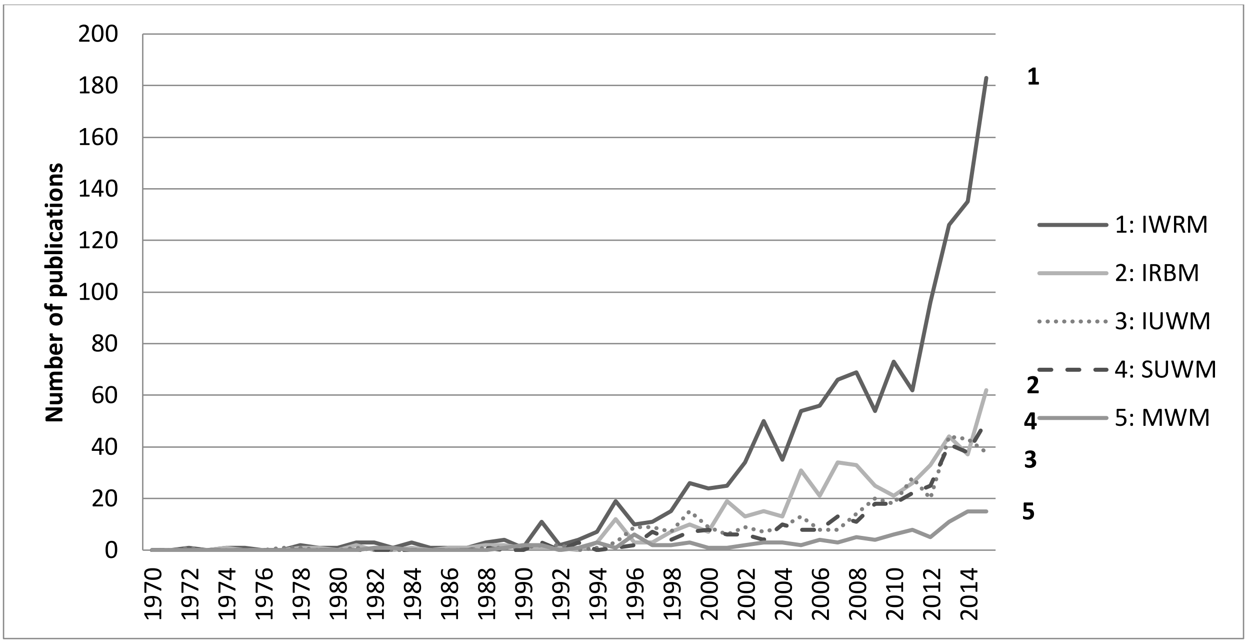
Table 2.2 Journals selected in the literature review

Concept	Selected journals
IWRM	Ecology and Society; Environmental Science and Policy; Hydrogeology Journal; International Journal of Water Resources and Environmental Engineering; International Journal of Water Resources Development; Journal of Environmental Management; Journal of Water Resource and Protection; Physics and Chemistry of the Earth; Sustainability: Science, Practice, & Policy; Water Alternatives; Water International; Water Policy; Water Resources Management
IRBM	Climate and Development; Environmental Monitoring and Assessment; Environmental Science and Policy; Geoforum; International Journal of River Basin Management; Water International; Water Policy
UWM	Built Environment; Ecology and Society; Environmental Innovation and Societal Transitions; Global and Planetary Change; Global Environmental Change; Environment and Urbanization; Nature Sustainability; OECD; Rainwater and Urban Design; Science; Science of the Total Environment; Utilities Policy; Water Research; Water Resources Management; Water Science and Technology
MWM	Hydrology and Earth System Sciences; International Journal of Water Resources Development; Journal of the American Water Resources Association (JAWRA); The Professional Geographer; Urban Studies
Inclusive and Sustainable development	Current Opinion in Environmental Sustainability; Environmental Science & Policy; Habitat International; International Environmental Agreements: Politics, Law and Economics; The European Journal of Development Research
Multilevel governance	American Political Science Review; Current Opinion in Environmental Sustainability; Ecology and Society; Environmental Policy and Governance; Environmental Politics; Policy Studies; Nature Climate Change
Institutional analysis	Current Opinion in Environmental Sustainability; Ecology and Society; Environmental Science and Policy; Global Environmental Change; Institutions and Environmental Change; Policy Sciences; Journal of Hydrology

Source: Author

In a second step, I analysed the urban-river basin linkages by examining the incidence of terms in titles, abstracts and key words between 1970 and 2015 associated with the urban (i.e. urban, city/ies, megacity/ies and metropolitan) in the IWRM/IRBM literature, and to the river basin (i.e. river basin, watershed and catchment) in the IUWM/SUWM/MWM literature. The results did not coincide or overlap between the two sets of literature (see Figure ***1.5***). Of the articles that included the term *Metropolitan Water Management* in their titles, abstracts or keywords, only 7 contained the terms *river basin*, *catchment* or *watershed* in the body of the article. The literature therefore does not differentiate water management in metropolitan regions from other urban areas, nor does it link to the scales relevant for IWRM/IRBM.

Figure 2.2 Evolution of concepts between 1970-2015



Source: Author

2.3.2 LITERATURE REVIEW ON CASE STUDIES

Prior to conducting fieldwork, I conducted literature reviews for each case study on the existing scholarship on water governance, urban governance, multilevel governance and environmental issues in Mexico City and São Paulo. This included international journals such as Environment and Urbanization, Journal of Latin American Geography, Climate and Development, Water Resources Research, Current Opinion in Environmental Sustainability, Journal of International Affairs, World Development, Earth Perspectives, as well as national journals such as Cadernos Metrópole; Estudos Avançados; Revista Latinoamericana de Recursos Naturales; Tecnología y Ciencias del Agua; and Revista Iberoamericana de Ciencias.

In addition, fieldwork preparation involved the review of approximately 50 policy documents and a dozen legal documents for each case study. This involved legal and policy documents at local, state and federal levels on water resources management and urban water management, but also environmental policy, climate change and urban planning.

2.4 ANALYTICAL FRAMEWORK

To address my research questions, I use the institutional analysis model of the Institutional Dimensions of Global Environmental Change (IDGEC) as the foundation for my methodological framework (IHDP/IDGEC, 2005). This framework is part of a stream of analysis known as 'new institutionalism', which focuses on how institutions affect society. More specifically, it examines environmental and resource regimes, which are types of institutions that address situations where actions can degrade ecosystems through overuse of natural resources or due to unintended side effects (Young *et al.*, 2008). This led to the following six-step framework, which allows for examining the causal mechanisms of metropolitan water challenges, the effectiveness of instruments that address these and the (re)design of such instruments for more sustainable and inclusive water governance:

(1) Define the major drivers of water challenges in the metropolitan region

First, I analysed the driving forces of the water-related tensions between the metropolises and the river basins (see 5.2 for São Paulo, and 7.2 for Mexico City). This evaluation was initially done through document analysis and the results were then triangulated through semi-structured interviews with a variety of respondents. This answered Research Question 2a.

(2) Actor and Institutional analysis

The next step was to identify the key actors addressing water challenges in the metropolitan regions of São Paulo and Mexico City at multiple levels (Research questions 2b and 2c). A crucial element when examining environmental and resource regimes are the spatial boundaries of specific institutions and their environments. To examine metropolitan water challenges, this research considers both the institutions addressing water-related issues at the urban scale (UWM regime) and at the hydrological scale (IRBM regime). This further required awareness of the linkages between cities and the surrounding environment that sustain them (i.e. assessing urban water demand and appraising investment needs beyond the traditional city boundaries) (OECD 2015a).

I defined actors as entities that represent specific interests and have mandates relevant for addressing metropolitan water challenges. Who the actors are and how they frame the policy problems is crucial as this process is highly political and reflects power imbalances in society (Majoor and Schwartz, 2015: 121). Their behaviour is shaped by driving forces but also by the institutions in place. More specifically, the institutions analysed were chosen because they aim to influence challenges linked to water quantity, water quality and climate variability and change in terms of sustainability and inclusiveness (see 5.3, 6.3, 7.3 and 8.3).

(3) Instrument design analysis

The institutional framework in place determines the policy instruments that help or hinder key actors to address metropolitan water challenges. The instrument analysis serves to identify the regulatory, economic, suasive, coordination and infrastructural instruments in place within the urban water and river basin governance regimes that target challenges linked to water quantity, water quality and climate change adaptation (Research questions 3a. 3b and 3c). A comparable mix of instruments for both case studies was selected based on their estimated salience for water-related challenges (see 5.4 and 6.4 for São Paulo and 7.4 and 8.4 for Mexico City). The design of each instrument is examined in terms of its objectives, scale of implementation and its main characteristics. Instrument design is assessed in terms of whether it considers sustainability and inclusiveness criteria.

(4) Effect on actors given drivers

Driving forces and institutional factors can both influence actors' behaviour. This thesis assesses the effectiveness of policy instruments in terms of key actors' behavioural changes given contextual drivers (Research question 3). To determine the effectiveness of instruments, this thesis looks at whether UWM and IWRM/IRBM actors fulfill their mandates in relation to the instruments' specific objectives (see 5.4 and 6.4 for São Paulo and 7.4 and 8.4 for Mexico City). It measures this effectiveness based on the instruments' stated goals (identified through content analysis) and the perception of respondents on the extent to which these goals are met (based on semi-structured interviews and other sources[12]). Beyond the focus on actors' compliance, this step also involves evaluating additional changes in behaviour (Underdal, 2008).

In addition, policy instruments are usually created and used by those in power (Gupta *et al.* 2015: 218). This is important to consider when analysing these instruments for a comprehensive understanding of their effects. The analysis may also highlight whether the current instruments in place fail to address certain drivers.

(5) Impacts

Ultimately, the goal of designing institutions is to effectively address the challenges deriving from human/environment interactions. Changes in actors' behaviour do not guarantee impacts on the challenges at hand, in this case metropolitan water challenges, and as such they can prove unsatisfying if they remain the only dimension for evaluating institutional performance (Mitchell, 2008). The impact of instruments is therefore considered (based on semi-structured interviews, technical and scientific assessments, newspapers) in the context of existing driving forces and assessed in terms of the four dimensions of sustainable and inclusive development, defined in section 1.5.1.

The instruments' design, their effect on actors given drivers and their impacts in terms of sustainability and inclusiveness have been measured through an ordinal scale and inductive 'calculations' of institutional performance. This calculation is an estimation of each instrument's aggregated effects, symbolized by "--" (very negative), "-" (negative), "0" (neutral effect), "+" (positive) and "++" (very positive). The choices of scores reflect estimates based on available quantitative and qualitative data and perceptions from key actors. They mainly should be considered in relation to each other to assess which instruments have a comparatively more positive or more negative effect. A score of "--" or "++" therefore does not mean that an instrument could not perform any worse or better. A neutral effect means either that there is no discernible effect of the instrument in question, or that the positive effects are balanced out by the negative effects. It is important to distinguish between the potential positive and negative effects of each instrument when considering suggestions for redesign (Research question 3).

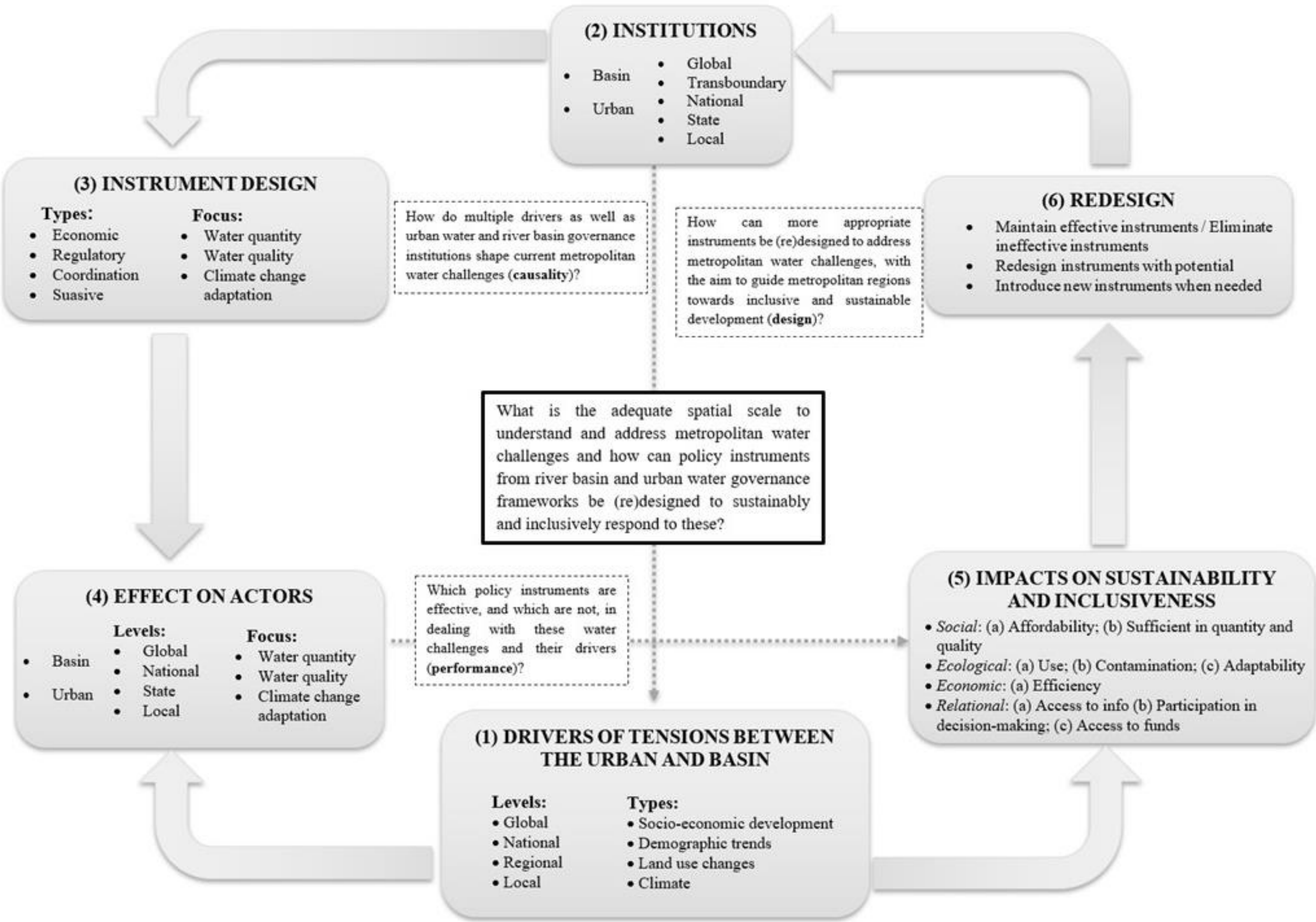
12 Newspaper articles, evaluation reports and technical assessments.

(6) Redesign (of instruments)

Finally, the proposals to redesign policy instruments of the urban water and river basin governance regimes are based on the instruments' effects on actors and impacts in terms of sustainability and inclusiveness. The thesis proposes to maintain instruments that met these goals, to discard or alter ineffective instruments, and to redesign existing or design new instruments that could address gaps (see 5.5, 6.5, 7.5 and 8.5). It considers overall policy coherence across multiple levels and between urban and river basin scales (Research question 4).

The analytical scheme below illustrates the analytical framework (see Figure ***2.3***).

Figure 2.3 Analytical framework for an institutional approach to urban water challenges



2.5 Units of analysis

This research is based on three units of analysis – drivers, institutions and instruments – and the linkages between them.

2.5.1 Direct and indirect drivers

Drivers unfold at multiple levels, they can be direct or indirect and they need to be addressed by governance systems (Gupta and Pahl-Wostl, 2013; cf. GEO 2019). Examples of drivers are demographic trends, socio-economic development patterns (i.e. concentration of wealth, water use that is proportional to population growth), or land use changes that affect regional ecosystems and biodiversity. Direct drivers include land use change such as deforestation, and pollution, whereas indirect drivers concern climate change and variability, demography, economy, infrastructure and technology (Postel and Richter, 2003; Gupta and Pahl-Wostl, 2013).

2.5.2 Institutions

Institutions consist of formal and informal norms, laws, and policies, and can both cause and solve problems with environmental governance (Vatn and Vedeld, 2012). Within the context of the *Anthropocene*, where human action has increasing influence over the environment, creating effective institutions becomes crucial. Institutions play a prominent role both "as sources of large-scale environmental problems and as elements in the responses humans make to actual or anticipated environmental problems" (IHDP/IDGEC, 2005: 35). This research examines institutions of both the urban water governance regimes and river basin governance regimes at multiple levels within each case study.

2.5.3 Typology of instruments

This thesis defines policy instruments as the mechanisms and techniques of governance used by state or non-state actors and involving the utilization of state resources or their conscious limitation, in order to achieve policy goals (Howlett and Rayner, 2007; Anderson, 2010). The potential of a policy instrument lies not in its isolated application but in its contribution to a policy mix (Chapman, 2003; Howlett and Rayner, 2007). The choice of instruments reflects the mode of governance, and changes in instruments tend to signify a shift in governance modes (Majoor and Schwartz, 2015, p. 114). This choice is not neutral, but rather reflects the balance of power between actors (Kassim and Le Galès, 2010; Majoor and Schwartz, 2015). Policy instruments may also shape and shift power relations. This research distinguishes four types of instruments:

- Regulatory instruments

These instruments consist of regulatory measures enforced by government or institutions with legal mandates (Hurlbert, 2016), and which prohibit (i.e. bans), empower (i.e. property rights) or compel behaviour (i.e. standards) (Majoor and Schwartz, 2015). They tend to be effective as they have a direct impact on their goals and are relatively predictable (Ibid). On the other hand, they are top-down and often inflexible, they do not provide incentives for actors to achieve more than the minimum standards and their coercive nature may lead to resistance (Ibid). These instruments may enhance sustainability and inclusiveness by applying legally binding principles (e.g. equity, human rights), social norms (e.g. good governance), standards and mandatory inclusion targets, inclusive spatial planning, the provision of civic amenities and public infrastructure (i.e. water and sanitation), safety net schemes and target subsidies (Gupta, Pfeffer, *et al.*, 2015).

- Economic instruments

These instruments follow market rather than government directives and aim to encourage and discourage certain behaviours (rather than enforcing or prohibiting them, as in the case of regulatory instruments) through financial incentives and disincentives (Stavins, 2003; Majoor and Schwartz, 2015). They are seen as more politically feasible than regulatory instruments as they do not directly intervene in actors' affairs (Bähr, 2010; Majoor and Schwartz, 2015). However, their costs can vary considerably according to the instrument and context, and they are less self-enforcing than regulatory instruments. They often have to be supported by regulatory mechanisms.

- Suasive instruments

Suasive instruments aim to internalize behaviour into individual decision-making through persuasion (Majoor and Schwartz, 2015, p. 112). This requires the provision of information, such as general education programmes, guidelines and codes of practice, training programmes, and research and development (Aramyan *et al.*, 2016). They are most effective when applied in combination with other types of policy instruments (Majoor and Schwartz, 2015). While relatively cheap and less intrusive than regulatory instruments, as they rely on voluntary compliance, their impact is uncertain and dependent on the quality of information available (Majoor and Schwartz, 2015).

- Infrastructural instruments

Infrastructural instruments can directly shape actors' behaviour and impact the goals they are designed to attain, by physically generating certain behaviour (Majoor and Schwartz, 2015). To be effective, they require considerable knowledge of social and biophysical processes (Ibid).

Table 2.3 Examples of potential instruments

Instruments	Examples
Regulatory	Water quality standards: Regulatory limits for the amounts of certain contaminants in water provided by public water systems (Helmer and Hespanhol, 1997) Environmental Impact Assessments: Evaluation of the likely environmental impacts of a proposed project or development, and development and assessment of measures to avoid or minimize these (Komínková, 2008) Water use permits: Rights to withdraw water from rivers and aquifers, typically allocated by national or state governments for different water uses (i.e. domestic, industrial and agricultural uses) (OECD, 2011). These are meant for quantitative and qualitative control of water resources, and to guarantee the right to access water resources Environmental licensing: Legally binding requirements to protect human health and the environment applied by a public authority. It should be carried out as part of the planning process, prior to the approval of projects (World Bank, 2012)
Economic	Payment for ecosystem services (PES): Incentives offered to people in exchange for preserving ecosystems and their services. Some argue that protecting certain ecosystems is only viable if their economic value is considered. Others claim that this valuation should be a strategy to create a new 'rural-urban compact', where cities reward rural dwellers for their provision of private and public goods (Corbera et al., 2009) Polluter-pays principle: Those who pollute must internalize its costs into their production costs (Porto and Costa, 2004) Other instruments include subsidies and bounties, tax concessions, special purpose grants, performance bonds and guarantees, tradable quotas, resource rents and royalties, and sliding charges for utilities (Buckley, 1991)
Infrastructure	From small-scale technology to large-scale infrastructure, this includes water metres, water-saving technology, public toilets, rainwater harvesting systems and inter-basin water transfers
Suasive	Campaigns to reduce water consumption, environmental education programmes, demonstration projects, labelling schemes (i.e. trademarks and brand names that assure buyers of the authenticity of a seller's product(s) or service(s)), the provision of information to the public, flood warnings, and more

Source: Author

In practice, instruments can frequently be classified in more than one category. For instance, Payment for Ecosystem Services (PES) programmes are an economic instrument as they involve a financial incentive for a certain behaviour, but they may also be considered a suasive instrument as they are usually voluntary. Nonetheless, using the labels above to reflect their primary goals is useful in terms of classifying and evaluating the effectiveness of these instruments. Furthermore, in practice instrument mixes are more effective than single instruments.

2.5.4 *INSTRUMENT SELECTION AND EVALUATION CRITERIA*

To be selected for this study, instruments had to fulfil multiple criteria to ensure relevance in relation to the research questions and comparability between the two cases (see Table ***2.4***). First, selected instruments had to, directly or indirectly, address metropolitan water challenges through the urban water or river basin governance regimes, in order to determine how they affect these (positively or negatively). The focus of each instrument must be on water quantity, water quality or climate change adaptation, or a combination of these. They should be designed to impact water-related challenges in terms of inclusiveness and sustainability. Moreover, they must be either a regulatory, economic, infrastructural or suasive instrument. The instruments may be implemented at national, state, basin, metropolitan or municipal levels, as long as they aim to address the water-related tensions between cities and their basins.

This led to a comprehensive list of instruments to potentially analyse in both case studies (see Annex ANNEX B – COMPREHENSIVE LIST OF POLICY INSTRUMENTS). This was further refined to a selection of several instruments by considering available data and feasibility, and these were analysed in Chapter 6 and Chapter 8 (for an overview of selected instruments see ANNEX C – POLICY INSTRUMENTS SELECTED FOR ANALYSIS). The major focus is on regulatory and economic instruments, the most common and relevant in both cases. The same or similar instruments are often implemented at different administrative levels in each case.

Table 2.4 Criteria for instrument selection

Criteria	Options
Scope	UWM and IWRM/IRBM
Focus	Water quantity; Water quality; Climate change adaptation
Instrument goal	Inclusiveness and sustainability, in terms of environmental, social, economic and relational dimensions
Type of instrument	Regulatory; Economic; Coordination; Suasive
Levels of implementation	National; State; Basin; Metropolitan; Municipal

Source: Author

Generally, policy instruments are not implemented in isolation, but rather different types of instruments are used simultaneously and interact with each other (Howlett and Rayner, 2007). This mix of instruments is embedded within a particular socio-political context and reflects a particular ideological foundation (Majoor and Schwartz, 2015). While a large range of instruments may be available, government authorities tend to use specific combinations of instruments, based on cost, effectiveness, feasibility and an estimation of their joint effect (Lascoumes and Le Gales, 2007; Perevochtchikova and Torruco Colorado, 2014). However, their design and use also reflects the power balance between actors and are therefore political (Kassim and Le Galès, 2010; Majoor and Schwartz, 2015). Consequently, it is essential to consider the context in which instruments are selected and the possible motivations and constraints behind this. Instruments are not a panacea and have often had mixed results in practice, and their potential to induce behavioural change has to be put in perspective, especially for complex systems such as large cities (Majoor and Schwartz, 2015).

2.6 CONTENT ANALYSIS

Content analysis can be defined as a method for "making inferences by objectively and systematically identifying specified characteristics of messages" (Holsti, 1969: 14). The purpose is to examine meanings and patterns in certain documents in a way that allows the researcher to understand social reality (Zhang and Wildemuth, 2017). This thesis makes use of a qualitative analysis of content through a directed analysis of content with coding categories derived from the problem definition and the literature review.

As a first step, it uses content analysis to assess the SDGs and linkages between their specific targets and urban/metropolitan water challenges in a context of anthropogenic climate change. It identified SDG 6 (Clean water and sanitation), 11 (Sustainable cities and communities) and 13 (Climate action) as the main SDGs aiming to address these issues (see 1.2.2). This was based on the SDGs' targets and indicators, as well as progress reports.

Following this, this thesis uses content analysis to identify and analyse the drivers, institutions and instruments at multiple levels of governance in both case studies that related to urban water and river basin challenges. This was done through a systematic examination of the relevant laws, policies, regulations and other information such as planning documents (master plans, plans for the metropolitan regions, river basin plans), newspaper articles and local government publications. The purpose is to describe and make inferences about the characteristics of drivers, institutions and instruments that related to metropolitan water challenges. Materials were categorized in terms of policy problem (i.e. water quantity, water quality, climate change), different geographic levels (i.e. international, transboundary, national, provincial and local) and focus on the urban or river basin scales. Instruments were also categorized according to their typology (i.e. regulatory, economic, infrastructural and suasive). The literature identified UWM and IWRM/IRBM as the main paradigms from which institutions and instruments are derived to address such challenges. Documents were analysed for language relating to the main characteristics of these paradigms, the effectiveness of instruments and impacts in terms of sustainability and inclusiveness. This was further supplemented by a review of previous studies on Mexico City and São Paulo. The resulting themes were then complemented and triangulated with the transcripts from semi-structured interviews. This forms the core of chapters 5, 6, 7 and 8.

2.7 FIELDWORK

2.7.1 FIELDWORK RESEARCH APPROACH

I conducted fieldwork to collect primary and secondary data on metropolitan water challenges and how these are addressed by the urban water and river basin governance regimes in the metropolitan regions of São Paulo and Mexico City. Semi-structured interviews were used to discover perceptions of key informants on the drivers, institutions and instruments related to metropolitan water challenges. The more structured approach of content analysis was thereby complemented with the more open, inductive nature of semi-structured interviews, enabling me to access complicated themes and get at deeper issues of meaning and attitudes (Corbetta, 2003; Cloke *et al.*, 2004). These were particularly useful to analyse the effects of instruments on actors and their impacts in terms of sustainability and inclusiveness. The difficulty to establish causal linkages within environmental and resources regimes means that it is difficult to use statistical procedures to explain the causal significance of institutions (Young *et al.*, 2008, p. 20). The combination of the results from the content analysis and a wide range of perspectives from key informants allowed for a balanced assessment. However, this method includes certain limitations such as the bias of the interviewer and power relations between the interviewer and the respondent that can influence the data produced (Cloke *et al.*, 2004).

The fieldwork took place in two stages: From February to August 2016 in Mexico City, and from September 2017 to January 2018 in São Paulo.[13] Sixty respondents were interviewed in Mexico City and 38 in São Paulo (see ANNEX D – INTERVIEW LIST). Interviews were conducted with state and non-state actors at multiple levels of governance with influence on the metropolitan and river basin spatial scales. These were then coded through Atlas.ti, which allowed identification of a set of themes and classification of interview responses to allow for interpretation and addressing the research questions (Ritchie *et al.*, 2013). In addition, I attended academic and professional events related to the research topic, attended meetings of basin organisations and public hearings on water services, visited neighbourhoods affected by severe water-related challenges as well as sites such as wastewater treatment plants and flood control infrastructure.

13 The second fieldwork was shorter as I was more familiar with the context thanks to previous research.

2.7.2 Ethical aspects and reflections on the fieldwork research process

As this research involved qualitative methods, including semi-structured interviews and participant observation, ethical considerations were important in the research design and implementation. In both case study sites, there are significant tensions around the topic of urban water challenges and their governance, as well as corruption and illegal activities. I was aware that exposing certain respondents could lead to repercussions in their personal and professional lives.

Obtaining informed consent from participants is crucial and I considered this throughout the data collection process. Respondents were contacted by email or through a phone call through which I first introduced myself and explained the purpose of the study, the interview procedure and their role in the process to each potential respondent. Their participation was entirely based on their own choice and they could refuse to answer questions or withdraw their participation at any moment. I also asked for their permission to record the interviews and explained that the recordings and transcripts will be kept in a secure location that only I can access. In the large majority of cases, respondents agreed to be recorded.

The water challenges in São Paulo and Mexico City are highly political in nature and involve multiple interests. Cases of corruption, criticism of politicians and administrators, and other sensitive issues were brought up by respondents during interviews. Respondents also highlighted – directly or indirectly – issues within their own organization. Therefore, it was critical to protect their anonymity and right to privacy, and this allowed for building a relationship of trust with respondents. This was done by using codes when transcribing interviews, and respondents' answers were described such that they could not be identified. The identity of activists and residents of areas affected by water-related challenges were protected. Respondents were promised a digital copy of the thesis upon completion.

As most of the fieldwork took place in offices of key informants, there were no significant safety risks. I was aware of my position as a young, foreign, female researcher and took basic precautions in my movements around both cities. This involved avoiding specific neighbourhoods or visiting these with a gatekeeper who was familiar with the surroundings.

2.8 Integration

This chapter has explained the value of conducting a comparative case study to gain in-depth knowledge of specific cases and identify causal mechanisms, and then identify similarities and differences that support theory-building. As this research investigates only two cases, it aims to provide insights on the causal mechanisms of metropolitan challenges and the effectiveness of institutions and instruments that address these and, if possible, to identify lessons learnt for other metropolises. This is supported by an analytical framework based on the IDGEC's institutional analysis approach and that focuses on water related challenges and their drivers, and the institutions and instruments that address these. Such an approach allows for exploring the roles of both urban water governance regimes (see Chapter 3) and river basin governance (see Chapter 4) in shaping water challenges in the metropolitan regions of São Paulo and Mexico City.

3. URBAN WATER GOVERNANCE

3.1 INTRODUCTION

This chapter explores the literature on urban water governance.[14] It addresses the secondary research question: What does the literature on urban water governance tell us about how to understand and address metropolitan water challenges? I address this question through a literature review and content analysis. First, I examine the evolution of urban water governance over time, in particular the paradigmatic shift towards more integrated and sustainable approaches to water management in cities (see 3.2.1). I then describe the main characteristics of Urban Water Management (UWM) (see 3.2.2), as well as the main drivers, institutions and instruments influencing this approach (see 3.2.3). Following this, I debate the strengths and weaknesses of UWM using as reference the reviewed literature (see 3.3). Finally, the chapter links back to the knowledge gaps identified in 1.2.3, and provides insights from the literature on how UWM can address metropolitan water challenges are discussed (see 3.4).

3.2 OVERVIEW

3.2.1 EVOLUTION TOWARDS MORE SUSTAINABLE AND INTEGRATED UWM

Urban water governance has undergone significant changes over the past decades, starting with the concept of Urban Water Management (UWM) and subsequently evolving to Integrated Urban Water Management (IUWM), Sustainable Urban water Management (SUWM), and a number of other concepts with overlapping goals.[15] During the 20th century, modernist visions of city planning rose to prominence around the world. This reshaped UWM to reflect a technocratic approach, aiming for controlling water flows, promoting public health, safety, and property protection, while ignoring environmental considerations (Kaika, 2005; Swyngedouw, 2006; Brown and Farrelly, 2009; Farrelly and Brown, 2011; Rauch and Morgenroth, 2013; Winz *et al.*, 2014). Actions focused on bringing water in and wastewater out of the city in a centralized, hierarchical and linear manner, with less attention to upstream and downstream linkages or longer-term environmental and social impacts (Engel *et al.*, 2011; Donoso, 2014; Winz *et al.*, 2014; Jacobi *et al.*, 2015). Scholars and policymakers considered that water should circulate constantly in the city, to wash it off waste and then leave it as sewage (Swyngedouw, 2006) – a process enabled through standardized and large-scale infrastructure and technological solutions (Farrelly and Brown, 2011; GTT, 2014; Winz *et al.*, 2014).

The modernist paradigm behind UWM reinforces dichotomies that separate the city and nature (i.e. human/non-human, urban/rural, culture/nature, centre/periphery) (Zimmer, 2010; Follmann, 2016). This transpires in practice through the drawing of boundaries between ontological spheres, giving order and a framework from where to proceed (Forsyth, 2003).

14 This chapter draws heavily on Brandeler *et al.* (2019).

15 Other concepts include Water-Sensitive Cities and Water-Sensitive Urban Design, for instance. The literature review found SUWM and IUWM to be the dominant concepts.

Land use planning institutionalizes boundary-making as it "formalizes the separation between nature and abstract space through the written codes of legal statute and professional conduct which impose a site-based, rather than system-based, narrative structure on its treatment of the environment" (Whatmore and Boucher, 1993: 169). While land use planning addresses the physical space, it often leaves out ecological processes and the fluidity of multiple relations between different spaces and places (Murdoch, 2006: 127).

The Political Ecology scholarship is critical of conventional UWM and highlights the tension between the 'modern' and 'non-modern' by arguing that the separation between the 'natural' and the 'social' will be undermined by ecological relations, as nature will eventually overcome human society and disrupt economic and social relations (Murdoch, 2006). It also illustrates how urban works and UWM create mechanisms of exclusion to access adequate quantities of potable water (Swyngedouw, 2006). This remains stark in cities of the Global South, where the urban elites often live in permanently irrigated tropical gardens, while the poor live in urban deserts.

Since the 1990's, the urban water literature has shifted towards a greater emphasis on social, cultural, environmental and economic aspects (Winz *et al.*, 2014). In recent years, the concept of Integrated Urban Water Management (IUWM) has emerged to help policymakers and local governments think about urban water. IUWM is nested within the broader framework of IWRM (Bahri, 2012), and is aligned with the 'sustainable development' paradigm formalized by Agenda 21 at the 1992 UN Earth Summit (Gabe *et al.*, 2009). IUWM is defined as a "participatory planning and implementation process, based on sound science, which brings together stakeholders to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits" (GDRC, 2015: 1).

IUWM promotes a holistic view of the urban water cycle, with a coordinated and flexible mode of strategic planning, and decision-making processes that must involve broad stakeholder participation (Brown, 2005; Varis *et al.*, 2006; Closas *et al.*, 2012). The participation of marginalized communities and the inclusion of gender issues aim to enhance equitable access to water (GDRC, 2015).

Parallel to IUWM, scholars also developed SUWM (Sustainable Urban Water Management), an approach that also departs from traditional UWM through a focus on the urban water cycle, emphasizing adaptation, decentralization, participation and integration (Brown and Farrelly, 2009; Daigger, 2011; Marlow *et al.*, 2013). SUWM considers water a central element of sustainable urban areas and a potential starting point for urban planning (Daigger, 2011). This requires that water professionals and urban planners become strategic partners. This view promotes a circular rather than linear approach to managing the urban water cycle, one where water is collected to respond to urban demands, treated to meet quality requirements, distributed to end users, collected again as wastewater and treated for reuse (Daigger, 2011). This combines large, centralized infrastructure with alternative, local and distributed technologies and participation (Van de Meene *et al.*, 2011; Younos, 2011; Closas *et al.*, 2012). However, the emphasis is particularly on local level, infrastructure-oriented initiatives (Marlow *et al.*, 2013; Rietveld *et al.*, 2016). Integrating infrastructure and biophysical systems (e.g. stormwater treatment and rainwater harvesting systems) requires considering social, economic, environmental and political contexts (Vlachos and Braga, 2001; Mitchell, 2006; Brown and Keath, 2008). In addition, it requires changing the existing (traditional) management structure, which will involve institutional reform (Daigger, 2011). The barriers to transitioning to SUWM are more often socio-institutional than technological (Brown and Farrelly, 2009).

Along with the shift from modernist to sustainable and integrated approaches to UWM, the end of the 20th century also experienced an evolution from state led UWM towards private management, inspired by neoliberal principles. Neoliberalism promotes a shift from "state responsibility for providing services to provision of services by private economic actors in which the role of the state is limited to enabling and regulating" (Ahlers *et al.*, 2014: 3). It is also associated with liberal notions of state reform, where decentralization reduces the burden of inefficient central bureaucracies and market incentives lead firms to incorporate the economic value of water into production costs (Abers and Keck, 2013: 50–51). Under this approach, UWM embraces full cost pricing, competition and privatisation (Bakker, 2002; Van de Meene *et al.*, 2011). Although there are claims that market governance aims to allocate resources efficiently and empower citizens (Pierre and Peters, 2000), this market-driven approach has also been criticized for leading to private monopolies, restrictive contracts limiting citizen access to previously accessible water resources and institutional fragmentation (Van de Meene *et al.*, 2011). In recent years, municipalities and regions have been re-municipalising water services in areas where these had been privatized (Parker and Sewell, 1988; Bakker, 2002, 2003; McDonald, 2018).[16] This trend is far from uniform however, with forms of re-municipalisation that are autocratic (i.e. aimed at enhancing control by a ruling elite), highly marketized (i.e. focused on market-based performance indicators), or observing social democratic principles (i.e. committed to promoting social and economic justice), among others (McDonald, 2018).

3.2.2 MAIN CHARACTERISTICS OF UWM AND IUWM/SUWM

UWM and IUWM/SUWM have similarities and differences in their goals, their scale of implementation, their approach to urban water, key actors and their mandates, water users, and what constitutes 'inputs' and 'outputs' of water. These are summarized in Table ***3.1***.

16 Since the turn of the 21st century, France has shifted towards the re-municipalisation of water services, defined as the transfer of water services from private companies to municipal authorities, with Paris in 2010 as the most notable case (Pigeon *et al.*, 2012; Hall *et al.*, 2013). This was spurred by corruption between large private water companies and local politicians, and a report by France's public audit body highlighting widespread lack of transparency and overcharging in the water sector (Hall *et al.*, 2013). In Paris, re-municipalisation led to economic savings and a reduced water tariff (Pigeon *et al.*, 2012; Hall *et al.*, 2013). The focus is the shift from private to public management, rather than the territorial scale of this management.

Table 3.1 Main characteristics of UWM/SUWM/IUWM

Characteristics	**UWM**	**SUWM/IUWM**
Goals	Affordability, universalization and public health. Flood control	Also concerned with sustainability, adaptation, human welfare
Principle scale of policy implementation	Urban	Urban Sub-basin (within municipal boundaries)
Approach	Technocratic, centralized, sectoral, linear	Integrating grey and green infrastructure. Combining centralized and participatory, traditional and alternative technology, hard and soft measures
Actors	City departments, water utility/ies	City departments (including environmental department, transport), water utility/ies, civil society organizations, private sector
Mandates	Drinking water, sewage collection, treatment and disposal, stormwater management, flood protection and pollution control for diverse users (i.e. domestic, commercial, industrial) with divergent abilities to pay	In addition to conventional mandates, they strive for synergies with environmental management/ conservation and with other urban actors (e.g. planning, housing)
Users	All users within the urban area (mainly public/urban users)	All users within the urban area (mainly public/urban users)
Water 'inputs'	Blue water (i.e. groundwater from within urban area and surface water often imported from beyond urban area)	Blue water, including local water sources after rehabilitation and rainwater Greywater (i.e. treated wastewater)
Wastewater / stormwater 'outputs'	Expelled out of the urban area Focus on hygiene and controlling urban flood/mudslides risks	Recycled and reused or infiltrated Climate change adaptation increasingly considered

Source: Author

Goals: UWM's main goals are to address the need for drinking water, sewage collection, treatment and disposal, stormwater management, flood protection and pollution control for diverse urban users (i.e. domestic, commercial, industrial). Historically, UWM has focused on affordability (in some cases, recognizing diverging abilities to pay), universalization and public health. The shift towards alternative approaches such as SUWM/IUWM reflects a concern for broader social, economic and environmental outcomes than improving water quality and quantity (Gabe *et al.*, 2009; Maheepala, 2010; Daigger, 2011; Porse, 2013). This means recognizing the ecological functions of water, diversifying water sources, and promoting adaptation, health and human welfare, social and economic vitality, overall community improvement and stakeholder satisfaction (Maheepala, 2010; GDRC, 2015; Neto, 2016). Examples include improving urban biodiversity, exposing and rehabilitating urban water flows to create more 'liveable' cities, extending the life of urban water infrastructure, and developing green infrastructure that manages stormwater, removes pollutants and recharges aquifers (Gabe *et al.*, 2009). The IUWM framework also strives for optimizing the interface between urban water and other urban sectors (e.g. housing, transportation), as well as with relevant activities beyond urban boundaries (e.g. agriculture, downstream water use) (Brown, 2005; Varis *et al.*, 2006; Closas *et al.*, 2012; GDRC, 2015).

Spatial scale: Scholars (Niemczynowicz, 1996; Lee, 2000; Daigger, 2011) and practitioners (Bahri, 2012; OECD, 2015b) emphasise the local level as the most appropriate for managing urban water, particularly for water services and water-related risks. This involves municipal, district and lower levels, such as the neighbourhood and household. The form of urbanization, the type of urban planning and the demand for water in urban areas and its use and discharge, requires policies at the urban scale (Jha *et al.*, 2012). The shift to IUWM/SUWM leads to an emphasis on the use of small-scale infrastructure and technology (i.e. rainwater harvesting devices, smart water systems) and community infrastructure (Gabe *et al.*, 2009; OECD, 2015b).

Water-related risks may be addressed by local actors (e.g. municipal civil defence) but certain risks require interventions by higher levels of government or multi-level responses, when drivers of risk originate beyond the local level. Similarly, water distribution in cities can be entirely under the authority of local governments (e.g. groundwater extraction within municipal borders) but often involve higher levels of government as water must be transported from parts of the basin beyond the city. Moreover, cities lack authority over the ownership of water resources and their allocation as higher levels of government generally decide *who* owns water and *how* it can be allocated to different users.

Approach: UWM has historically been implemented through large-scale infrastructure and technocratic, centralized management (Farrelly and Brown, 2011; Rauch and Morgenroth, 2013). UWM promotes managing different steps of the urban water cycle separately, through sectoral entities that do not coordinate the needs for water supply, environmental quality and flood management (Niemczynowicz, 1999; Abdullah and Christensen, 2004; Brown, 2008; Daigger, 2011; GTT, 2014). The result is a linear approach of taking, using and rapidly discharging water (Kayaga *et al.*, 2007; Brown and Farrelly, 2009; Barraqué and Zandaryaa, 2011; Gregory and Hall, 2011; GTT, 2014). This approach reflects the human desire to control nature and translates into flood protection infrastructure (e.g. dikes, dams), long-distance transfers of water, elevation of water with pumps and a networked water distribution system (Barraqué and Zandaryaa, 2011; Nastar, 2014).

SUWM attempts to integrate infrastructure and biophysical systems (e.g. stormwater treatment and rainwater harvesting systems), thereby considering social, economic, environmental and political contexts (Vlachos and Braga, 2001; Mitchell, 2006; Brown and Keath, 2008; Brown *et al.*, 2008). It combines large, centralized infrastructure with alternative and distributed technologies and participation (Van de Meene *et al.*, 2011; Younos, 2011; Closas *et al.*, 2012). Similarly, IUWM uses structural and non-structural measures (e.g. new knowledge and information technologies, education programmes, water pricing and regulations) (Maheepala, 2010; Iacob, 2013). This shift in approach also emphasises coordination between government levels and between different types of actors (i.e. private sector, civil society, government, educational and research institutions) (Jha *et al.*, 2012).

Actors: UWM actors are generally centralized (at local or regional government level) and hierarchical (Elzen and Wieczorek, 2005; Saleth and Dinar, 2005; Farrelly and Brown, 2011; Porse, 2013), although in the Global South, informal, decentralized providers of water services also play important roles (Ahlers *et al.*, 2014), as do local and international NGOs (Brocklehurst, 2004). Higher levels of government generally design legal and regulatory frameworks and provide financing. SUWM/ IUWM promote decentralization, the devolution of administrative functions, inter-sectoral coordination, innovative funding solutions, co-management with communities and the private sector, and flexible institutional frameworks (i.e. public-private partnerships) (Bahri, 2012; Closas *et al.*, 2012; Whitler and Warner, 2014). Within the IUWM framework, local governments are seen as well-placed to oversee urban water programmes, in combination with top-down regulatory responsibility and bottom-up user needs and obligations (GDRC, 2015).

Mandates: The core UWM functions are drinking water supply, sewage collection and treatment, and urban drainage (Barraqué and Zandaryaa, 2011; Engel *et al.*, 2011), supplemented by flood mitigation and control of waterborne diseases (GTT, 2014). These are often the responsibility of local governments, although they may delegate certain functions to higher levels of government or private actors or call in help from outside (e.g. to deal with disasters) (Baud and Hordijk, 2009). However, local governments are rarely in the forefront of developing policies that address these challenges (Ibid). More recent approaches to UWM promote coordination between a wider range of stakeholders, such as urban planning, and in the Global South sometimes the development community (Whitler and Warner, 2014). The IUWM/SUWM literature further advocates broadening mandates to incorporate ecosystem health, basin management, biodiversity conservation, conflicts and competing water uses, wastewater treatment and disposal, risk prevention, and integrating all urban activities (Coccossis and Nijkamp, 2002; GTT, 2014).

Since 1990, urban rivers have gained prominence in urban planning (Levin-Keitel, 2014) and urban river rehabilitation projects have multiplied (Deason *et al.*, 2010; de Haan *et al.*, 2015). Green infrastructure and Low Impact Development (LID) Best Management Practices (BMPs), such as infiltration basins, grass swales and green roofs manage stormwater runoff as close as possible to the source and reduce impacts on downstream receiving rivers (Jia *et al.*, 2013). However, such projects are usually municipal projects and rarely extend beyond city boundaries. While IUWM emphasises urban-rural relationships (Bahri, 2012), mandates are restricted to areas under the jurisdiction of the local authorities and/or water utility (Engel *et al.*, 2011). Overall, responsibilities often remain unclear, fragmented and overlapping, leading to tensions between professionals and politicians with different values and views (Brown, 2008; OECD, 2016).

Users: Water users within UWM are generally those who receive water from utilities for public/urban use, commerce, industry and other purposes, as opposed to users who are issued permits for water abstraction. In some cases, this may include informal users, for instance, residents of informal settlements, particularly where legal frameworks for water management have incorporated principles such as the human right to water (e.g. South Africa). In other cases, providers only serve registered consumers, as is the case of Hyderabad in India (Nastar, 2014), despite the growing recognition of the human right to water (Obani and Gupta, 2015). UWM generally prioritizes public/urban uses above other uses by higher levels of government, but this is not always accompanied by incentives at local levels for rational water use, even as urban water use has increased (Lee, 2000). Cities also attract industries and increase water demand for energy generation, recreation and irrigation in their surrounding rural hinterlands (Lee, 2000). This leads to an increase in the frequency of multiple and successive water uses, which affects river regimes and water quality (Lee, 2000).

While SUWM/IUWM highlight the need to consider upstream and downstream users, and non-urban users (Gabe *et al.*, 2009; Closas *et al.*, 2012; GTT, 2014), no specific instruments or arrangements are promoted to implement equitable water allocation among all users within a river basin. Additionally, SUWM/IUWM is increasingly recognizing ecosystems as water users, for instance through efforts to maintain the minimum ecological water requirement (EWR) (Jia *et al.*, 2011).

Inputs and outputs: UWM relies on a combination of surface and groundwater from within or beyond the basin, treating these as never-ending sources of water (GTT, 2014; Porse *et al.*, 2015; Conti, 2017), exhausting them until they dry up or are too contaminated for use due to inadequate pollution-control systems, and then turning to dams and inter-basin water transfers (Daigger, 2011; Richter *et al.*, 2013; OECD, 2015b). Large cities, due to their higher demand for water resources, frequently import water from sources beyond their watersheds and struggle to maintain a reliable flow (Barrios *et al.*, 2009; Daigger, 2011; OECD, 2015b). Meanwhile, IUWM/SUWM promote the use of alternative sources to water through decentralized infrastructure and technologies, such as rainwater harvesting systems and stormwater treatment, which can support aquifers, waterways and vegetation (Marlow *et al.*, 2013; GTT, 2014), and the reuse of greywater (Daigger, 2011). However, such initiatives remain scattered and limited in practice. Land use regulation and preserving catchment areas is needed for surface and groundwater sources to maintain sustainable flows, but this is less emphasized than in the IWRM/IRBM literature (see Chapter 4) (Bahri, 2012; Closas *et al.*, 2012). In part, this may be because urban water managers and city officials do not have mandates over these water producing areas.

Furthermore, grey and black waters have conventionally been seen as externalities that have to be rapidly expelled beyond the city to protect urban health, ignoring environmental sustainability, population growth, urbanization, industrialization and climate change (Kayaga *et al.*, 2007; Makropoulos *et al.*, 2008; Daigger, 2011). IUWM/SUWM approaches wastewater as an opportunity and a potential resource by including it into the urban water cycle through infrastructural and institutional integration and reusing it in industrial activities, urban irrigation and groundwater recharge (Jia *et al.*, 2005; Closas *et al.*, 2012; GTT, 2014). Wastewater can be used to extract heat and nutrients, and produce energy and soil-conditioning products (Daigger, 2011). This shift requires an overhaul of urban water and wastewater infrastructure and coordination between water resources management and urban planning (Daigger, 2011). However, combined sewers continue to affect human health and ecosystems (Porse, 2013), especially in megacities which concentrate humans and polluting activities.

3.2.3 DRIVERS, INSTITUTIONS AND INSTRUMENTS

A number of drivers shape urban water challenges, such as population growth and concentration, leading to rising demand for water for residential, agricultural and industrial use within and around the city (Lee, 2000; Darrel Jenerette and Larsen, 2006; Maheepala, 2010; Gregory and Hall, 2011; Van de Meene *et al.*, 2011). Whereas countries in the Global North face aging populations and migration from abroad, countries in the Global South have rapidly growing populations and rural-urban migration (Neto, 2016). Urbanization without proper sanitary infrastructure leads to environmental degradation and public health risks (Lee, 2000; Van de Meene *et al.*, 2011; Neto, 2016). Moreover, agricultural, urban and industrial activities that pollute supply catchments also threaten urban water (Maheepala, 2010). Meanwhile, droughts and heat waves caused by climate variability or climate change, are likely to reduce water supplies and affect water quality (Maheepala, 2010; Van de Meene *et al.*, 2011).

UWM institutions have been designed at multiple levels to address the provision of urban water services and promote measures against water-related risks. Legislation, regulatory frameworks and norms are often set at higher levels of government. However, these have not always accompanied the rapid changes and complex challenges facing urban water management (Lee, 2000). They must keep up with new developments in innovation, technology, science, and changes in mandates and policy (Farrelly and Brown, 2011). Local governments and citizens play an important role in implementing national and international legislation that shape and regulate urban water governance (OECD, 2015b).

Part of the UWM scholarship argues that institutions can only effectively address urban water challenges if users and polluters pay "adequately and justly for the services they enjoy from the water resource" (Lee, 2000: 77). This perspective grants a greater role to the private sector in the provision of urban water services, claiming that removing decision-making from political arenas will allow for more competent water and sanitation (Wat&San) utilities (Lee, 2000).

Historically, UWM was associated with "the strong professional identities and powerful elite cultures that co-evolved with water systems and flowered in isolation from other professions and society" (Sofoulis, 2011: 807). Shifting towards IUWM/SUWM also requires that institutions can evolve in contexts of rapid changes and uncertainty, and function in an integrated fashion (Porse, 2013; GTT, 2014; Braga, 2016). This involves flexible institutions and institutional arrangements that enable multiple actors to collaborate and meet a variety of objectives (Niemczynowicz, 1999; Brown and Farrelly, 2009; Floyd *et al.*, 2014; GTT, 2014). Flexibility and collaboration are crucial for large cities facing water-related challenges that are multi-dimensional, multi-sectoral and multi-regional (Tortajada, 2008). Resulting redundancies in institutional structures sometimes increases complexity, but may also lead to enhanced resilience (Lebel, 2005).

Furthermore, other institutions relevant for UWM involve laws and regulations on spatial planning and land use, such as construction, zoning, land use parcelling, sanitary control and environmental conservation (GTT, 2014). Rules regarding the delimitation and amalgamation of administrative regions also have important implications for the allocation of roles and responsibilities and the spatial scale at which urban water is managed (OECD, 2014). In addition, informal institutions may play an important role at household and community levels, especially in cities of the Global South where formal institutions are absent in certain areas or highly bureaucratic (Jha *et al.*, 2012). This can involve flood adaptation measures such as building structures around houses to block flood waters, raising the house's floor, moving furniture to higher floors, helping more vulnerable neighbours, or unclogging drains in surrounding streets (Simarmata, 2015; Hordijk *et al.*, 2016).

The institutional setting determines the instruments of UWM. Table ***3.2*** provides an inventory of commonly used instruments in UWM/IUWM/SUWM. Economic and suasive instruments are often targeted at the level of the individual, household, or municipality, and aim to change behaviour through incentives or persuasion. Many of the UWM instruments are biased towards the economic and social dimensions of sustainability and inclusiveness (e.g. financial incentives or educational measures to reduce water consumption), and to some extent towards relational dimensions (e.g. subsidies, differentiated tariff systems that address urban inequality). More recently, environmental concerns have led to an increase in instruments that promote sustainability (i.e. wastewater reuse, protected areas).

Table 3.2 Types of instruments of Urban Water Management

Types of instruments	**UWM**
Economic	Water tariffs (user pays principle); Water metering (linked to tariffs); Subsidies for connecting to the piped network; Sewage tariffs (polluter-pays principle); Financial incentives for water/wastewater reuse; Subsidized retrofits; Fines for improper solid waste disposal
Regulatory	Quality standards (minimum standards for drinking water quality); Access to sanitation with minimum standards; Zoning restrictions in flood prone areas; Stormwater ordinances; Ordinances for source water protection
Suasive	Water saving campaigns; Education programmes for promoting culture of civil protection; Flood risk warnings
Coordination	Flood control plans; Climate change adaptation plans

Source: Author

3.3 UWM FOR SUSTAINABLE AND INCLUSIVE DEVELOPMENT

3.3.1 STEPS FORWARD

While conventional UWM is supply-oriented, adjusting infrastructure to meet water demand, IUWM/SUWM aims to manage water demand to better match water availability (Maheepala, 2010; Gregory and Hall, 2011; GTT, 2014). This is crucial as urban water demand is increasing not only in absolute volume (as cities grow) but also per capita, as urban dwellers in the Global South become more affluent. Increasing competition between users adds stress, pollution reduces water availability and extreme weather makes future availability less predictable (GTT, 2014; OECD, 2014). In the Global North, population ageing means water demand could decrease, with implications for infrastructure investments and potential risks of bacterial after-growth in drinking water (Hummel and Lux, 2007). Therefore, flexible approaches to UWM can help reorient investments in infrastructure according to demand (Neto, 2016). In addition, IUWM/SUWM seeks to diversify water sources (i.e. wastewater reuse, rainwater harvesting), further providing water security (Maheepala, 2010).

IUWM/SUWM has the potential to reduce negative environmental impacts by considering upstream and downstream impacts and the basin as a whole (Closas *et al.*, 2012). This can be through protecting green areas, including native flora and fauna in urban waterways and estuaries and around urban areas (Maheepala, 2010).

Decentralized, collaborative and participatory forms of water management, promoted by IUWM/SUWM, are also more inclusive of different views, interests and environmental values (Brown, 2008; Maheepala, 2010). Deliberation and decision-making processes are iterative, long-term and consider the total water cycle rather than one-time, localized processes (Closas *et al.*, 2012).

3.3.2 Lingering obstacles

Despite the paradigm shifts towards greater sustainability and integration, the water sector's path dependent nature means that the shift towards IUWM/SUWM is slow. Retrofitting existing infrastructure and technology involves high transitioning costs and can lead to stranded assets (Brown and Farrelly, 2007; Brown, 2008; Closas *et al.*, 2012; Marlow *et al.*, 2013; OECD, 2015b; Bos and Gupta, 2018). Investment and technological 'lock in' delays the uptake of alternatives (Marlow *et al.*, 2013). Local governments often lack the necessary funds or capacity to leverage capital investments, and they remain dependent on higher levels of government (Closas *et al.*, 2012). Water management institutions tend to be resistant to change and have low adaptive capacity (Van de Meene *et al.*, 2011; Marlow *et al.*, 2013). Transitioning to IUWM/SUWM also relies on a change in values throughout society (Gabe *et al.*, 2009). It is mainly pushed for by social groups with more inclusive views regarding UWM (Gabe *et al.*, 2009; Winz *et al.*, 2014). Moreover, switching to new infrastructure and processes may involve trade-offs that require careful consideration. For instance, SUWM encourages innovative solutions that may be energy-intensive (e.g. desalination, pumps for rainwater tanks) or risky (e.g. wastewater reuse) (Marlow *et al.*, 2013).

The IUWM/SUWM literature remains largely prescriptive, and the few empirical studies available reveal a failure to go beyond ad hoc demonstration projects (Harding, 2006; Mitchell, 2006; Brown and Farrelly, 2009). Learning experiments and innovation at local and basin levels are not easily transferred to urban decision-making processes and policy (Pearson *et al.*, 2010; Farrelly and Brown, 2011). Such knowledge transfers require adequate social learning mechanisms and coordination mechanisms (e.g. bridging organizations), long-term strategic planning and the identification of new solutions through the inclusion of research and development partners in key projects (Farrelly and Brown, 2011; Van de Meene *et al.*, 2011; Colenbrander, 2018). Limited human and financial resources, a lack of available information, a lack of industry-wide experience and knowledge, a lack of monitoring and evaluation and poor communication processes further represent obstacles to the implementation of SUWM/IUWM (Brown and Farrelly, 2007; Adank *et al.*, 2011).

Institutional inertia further represents a barrier to the implementation of SUWM/IUWM, in particular for proactive responses to increasingly complex urban water challenges (Lee, 2000; Brown and Farrelly, 2007). This includes over-centralisation, bureaucratic inefficiencies and lack of sustainable finance, inconsistent regulatory approvals processes, conflicting or unclear mandates amongst organisations, institutional and sectoral fragmentation (despite the aim to integrate the total urban water cycle), unproductive intergovernmental relations and poor collaboration, limited data sharing, unclear property rights and lack of authority of operational organizations (Lee, 2000; Brown and Farrelly, 2007; Adank *et al.*, 2011). The result is often inadequate, fragmented planning and a lack of enforcement of existing plans (Adank *et al.*, 2011). While it is increasingly recognized that institutions contribute to the slow pace of change, there is little understanding on how to overcome this (Brown and Farrelly, 2007, 2009).

Moreover, IUWM/SUWM does not address power relations, nor implementation challenges resulting from a lack of political will, political leadership or political incentives to do so (Brown, 2008; Pearson *et al.*, 2010; Van de Meene *et al.*, 2011). While IUWM promotes local governments' participation in basin-wide planning spaces, these usually lack decision-making powers (Vlachos and Braga, 2001). Community participation is often considered inadequate and expert knowledge tends to dominate decision-making to the detriment of local, lay knowledge (Brown and Farrelly, 2007; Van de Meene *et al.*, 2011; Brandeler *et al.*, 2014). IUWM/SUWM also mainly applies to formal settlements, and its references to informal settlements focuses on the need for land use management and land tenure (Porse, 2013).

3.4 Scalar limitations of urban water governance paradigms

3.4.1 Metropolitan areas have unique challenges and opportunities

A limitation of UWM, and the more recent SUWM/IUWM paradigms, in the context of metropolitan water challenges is their lack of consideration for the spatial scale of the metropolis. The limited MWM literature covers principles of water management for the metropolitan context, and the expansion of decision-making structures and urban water networks to suburban constituencies or peripheral municipalities (Kallis and Coccossis, 2002; Keil and Boudreau, 2006) – topics left unaddressed by the IUWM/SUWM literature. However, inadequate UWM can lead to externalities across a metropolitan region that are difficult for UWM actors to address unilaterally. For instance, a lack of sanitation infrastructure in one metropolitan municipality may affect the neighbouring municipality downstream, through the health risks of contaminated water and the reduced available water for consumption. It can also lead to externalities in the broader basin (i.e. between a municipality and the basin). For instance, high urban water demand means that there is less water available for the basin's other users, such as farmers. Aquifers within metropolitan regions are affected by land use and inadequate wastewater management (Foster and Ait-Kadi, 2012). Metropolitan regions are therefore not just large urban areas, but experience water-related problems of a different nature than smaller urban areas. Peripheral metropolitan municipalities often face greater water challenges and have fewer capacities to address these alone.

Megacities and large metropolitan regions also present a number of opportunities due to their size (economies of scale), their greater capacity (financial, human) relative to smaller urban or rural areas and the markets (for jobs, products) that they provide for the broader region (GTT, 2014; Kraas *et al.*, 2014; UN-HABITAT, 2016). The resulting "fragmentation of policy making among multiple governmental units diminishes problems of concentrated powers and can promote competition and innovation" (Feiock, 2009, p. 356). Their unique position also makes them centres for research and innovation, including on environmental practices (GTT, 2014; Kennedy *et al.*, 2015). These elements bring significant advantages for facing a range of challenges, including those relating to water.

On the other hand, responsibilities for water distribution, wastewater collection, drainage and flood management often remain at local levels, involving a large number of local governments and private utilities within megacities. Municipalities, the administrative units that form a metropolitan region, are frequently the level at which policy is implemented, but they are often arbitrary and reflect ancient patterns (OECD, 2015b). This can result in incoherent and even contradictory water management practices, as well as inefficiencies, as decisions by one municipality may impose positive or negative externalities on others (Richardson, 1989; Feiock, 2009; OECD, 2011; Sorensen, 2011; Li *et al.*, 2015). It may also hamper the capacity of cities to build the necessary coalitions of actors or structures of governance (Aguilar, 2008) and to foster productive cooperation (Kim *et al.* 2015). Metropolitan regions often experience governance fragmentation, through "overlapping or disconnected institutional structures, national government intervention overpowering local authorities, and disconnections between land and water sectors" (Li *et al.* 2015: 603) and environmental planning and resource management (Kim *et al.* 2015). Local governments within the same metropolis may be affiliated to different, even rival, political parties. They often struggle to develop cohesive responses to shared challenges due to the inconsistency of available data, data dispersion across agencies and the lack of information-sharing mechanisms (OECD, 2016).

The growth and multiplication of metropolitan regions and megacities puts pressure on service delivery and infrastructure development, as well as on adequate management (Vlachos and Braga, 2001, p. 4). Municipalities within a metropolitan region often share water resources, and their water-related activities affect each other (e.g. lack of sewage treatment upstream, deforestation around areas of springs), but due to their politically fragmented nature, they struggle to develop coherent policies and plans to address these shared concerns. An exclusive focus on local practices in urbanized basins leads to water resource degradation, irrational investments and sector-oriented management (Toledo Silva and Amaral Porto, 2003; Foster and Ait-Kadi, 2012). This is even more complex in metropolitan regions with large numbers of jurisdictions within the urban area. Moreover, many of the world's largest cities are located in the Global South, in areas particular vulnerable to climate change, they hold pockets of extreme vulnerability and lack coping mechanisms (Kraas *et al.*, 2014). They often experience rapid growth, especially on their margins, challenging an already fragmented institutional set up and further weakening regional planning and coordination (Adank *et al.*, 2011).

3.4.2 UWM IGNORES THE LINKAGES TO THE RIVER BASIN

The mismatch between the spatial boundaries of institutions (with administrative functions) and the biophysical systems they are dealing with (river basins and aquifers) can be an obstacle for addressing urban water challenges (Abdullah and Christensen, 2004; Cumming *et al.*, 2006; Young *et al.*, 2008; Salzman *et al.*, 2014; OECD, 2015b).[17] UWM focuses on urban (often municipal-level) concerns and needs and does not address those of the river basin and the links between the two spatial scales, which hinders sustainable and inclusive policies (Brown, 2008; Van de Meene *et al.*, 2011). The scholarship on IUWM and SUWM does so to a greater extent, by highlighting the importance of urban-rural relationships (Pearson *et al.*, 2010; Bahri, 2012) and advocates for broadening mandates to incorporate ecosystem health, basin management, biodiversity conservation, conflicts and competing water uses, wastewater treatment and disposal, risk prevention, and integrating all urban activities (Coccossis and Nijkamp, 2002; GTT, 2014). This is evidenced by the increased prominence since the early 1990's of water and rivers in urban planning (Levin-Keitel, 2014). As water resources become scarcer, interlinkages between urban and rural areas need to be better understood (Pearson *et al.*, 2010). However, although more projects incorporate basin considerations, they usually are municipal projects with strong technical components and they rarely extend beyond city boundaries to focus on the interaction between people and the natural environment (Neto, 2016).

IUWM/SUWM actors also do not interfere in water allocation, which is typically the mandate of higher levels of government. Local governments have limited (or no) mandates on how water resources are used outside their borders, even if these resources are part of the same basin (e.g. in irrigation or hydropower), which may have enormous implications for water availability (Maheepala, 2010). They also generally do not focus on managing surface and groundwater systems within their borders, reducing evapotranspiration and preserving environmental flows (Pearson *et al.*, 2010). In addition, responsibilities for urban water are not clearly coordinated with basin actors. Rather, mandates are often unclear, fragmented and overlapping, leading to tensions between professionals and politicians with different values and views (Brown, 2008; OECD, 2016; Brandeler *et al.*, 2019). As decisions within the river basin are (mainly) made by different actors than those within UWM, learning is not easily transferred between the two scales (Pearson *et al.*, 2010).

Urban areas depend on biodiversity and ecosystem services (BESS) or nature's contributions as they are currently referred to, which can be produced within their borders, but more often in their rural hinterlands, or further away (e.g. virtual water through food imports). These ecosystem services play essential roles for the sustainable and inclusive development of cities, and cities can have profound effects on them. Ecologists have only recently started to show interest in urban areas and how to address urban environmental problems (Grimm *et al.*, 2008). Urban water scholars and urban planners also increasingly recognize the benefits of BESS within cities (e.g. urban forests can reduce stormwater runoff (Xiao and McPherson,

[17] This issue is also referred to as "hydro-administrative mismatch" by the OECD (2013).

2016) and prevent pollution in urban waterways and groundwater resources (Livesley *et al.*, 2016)) and those from the wider watershed (e.g. protecting upstream areas for urban water supply and water purification services (Kenny, 2006)). However, despite this convergence between scholarly disciplines, cities continue to create externalities related to their management of water resources and related ecosystems (i.e. contamination from sewage affecting communities downstream, high water demand requiring reallocation to urban uses from other uses, soil sealing affecting infiltration and aggravating risks within the city and downstream). Conflicts between environmental sustainability and the right to housing agendas are common at the urban/rural interface of large cities, as low-income populations are pushed to the margins through a real estate driven process of social-spatial exclusion and occupy watershed areas (Refinetti, 2006; Klink, 2009).

3.5 Inferences

This chapter reviewed the urban water management literature to gain insights on how it understands and addresses metropolitan water challenges. It explored this in relation to two knowledge gaps identified in 1.2.3, namely (a) how the literature relates to the river basin context and conceptualizes urban/rural relations, (b) how the literature relates to the metropolitan context as a multi-jurisdictional and often heterogenous urban environment. Multiple factors were identified by the UWM literature review that may facilitate or hinder sustainable and inclusive development. In conjunction with these factors, the research examined whether political fragmentation within metropolises and the lack of mandates over rural areas of their basin also play a role in determining the effectiveness of UWM institutions and instruments in terms of sustainability and inclusiveness.

UWM elements for Sustainable and Inclusive Development

The literature review highlighted a shift from conventional approaches towards paradigms such as IUWM and SUWM, which embrace sustainable and inclusive development principles. These principles are promoted through institutions and instruments that implement water demand management, diversify water sources, protect valuable ecosystem services, foster decentralization and participation and facilitate social learning. Common obstacles that hinder effective implementation are path dependency, a focus on technological fixes, the difficulty to scale up local initiatives, rapid demographic changes (shrinking cities in the Global North and rapid, unplanned urban growth in the Global South), limited local budgets (especially in the Global South) and a lack of knowledge sharing. The empirical chapters evaluate whether such measures are part of the responses to metropolitan water challenges, and if so, how effective they are.

Political fragmentation within metropolitan areas

Metropolitan regions tend to be composed of multiple local governments that have more or less autonomy in decision-making. However, UWM is normally restricted to the mandates of local level actors, which means that metropolitan regions can concentrate a significant number of UWM actors. IUWM and SUWM embrace decentralization and participation, which may ensure more context-relevant policies and social and relational inclusion, particularly in highly unequal metropolises of the Global South. However, a constant prioritization of local interests, policies and practices can lead to political fragmentation within the metropolitan area. Localism could further create difficulties in addressing shared problems, as actors have no incentives or authority to spend resources beyond their jurisdiction's boundaries. This may be aggravated when there are strong political differences in metropolitan regions. Affiliations with different political parties can lead to tensions between metropolitan municipalities and a lack of political will to coordinate actions on UWM. Differences in human and financial capacity, and power relations, also shape the ability of different local governments to coordinate on an equal footing. Based on this framework, the empirical chapters explore the coherence of UWM across the metropolitan regions in terms of characteristics identified in 3.2.2 (i.e. goals, mandates, approaches, users), and how the shortcomings of this framework increase shared water challenges.

Urban dependency on rural areas

Large cities often rely on areas that provide water resources and other ecosystem services beyond their boundaries. There is growing recognition of the importance of preserving these areas, particularly as cities expand. However, UWM actors do not have mandates to do so directly, in particular when these areas fall outside the borders of their jurisdiction. Urban water governance regimes therefore generally fail to recognize these dependencies and address drivers that affect water resources and ecosystem services at the adequate level. This research therefore explores the coherence of UWM across the urban/rural interface, in terms of characteristics identified in 3.2.2 (i.e. goals, mandates, approaches, users), and its implications for addressing shared water challenges.

4. RIVER BASIN GOVERNANCE

4.1 INTRODUCTION

This chapter reviews the literature on river basin governance.[18] It addresses the secondary research question: What does the literature on river basin governance tell us about how to understand and address metropolitan water challenges? First, it examines the evolution of river basin governance over time, and more specifically its shift towards Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) (see 4.2.1). It then describes the main characteristics of IWRM and IRBM (see 4.2.2), as well as the main drivers, institutions and instruments shaping these concepts (see 4.2.3). Subsequently, the chapter debates the strengths and weaknesses of IWRM/IRBM based on the literature reviewed (see 4.3). Finally, the chapter links back to the knowledge gaps identified in 1.2.3 and provide three main insights relevant for analysing metropolitan water challenges from an IWRM/IRBM perspective (see 4.4).

4.2 OVERVIEW

4.2.1 EVOLUTION OF RIVER BASIN GOVERNANCE

Water resources management (WRM) can be traced back to the first river basin civilizations, with water rules defined in the Indus Valley around 2500 BCE and flood management and irrigation techniques developed in Ancient Egypt (Dellapenna and Gupta, 2009). For many early civilisations, controlling rivers was part of the formation of the centralized state (Wittfogel, 1955). Already in prehistoric times, people learned to adapt to seasonal changes in water availability, and water management was crucial during the transition from hunting-gathering to farming (Mithen, 2010). Rivers and coasts have historically attracted populations, as they provide resources, allow for navigation and serve as natural borders.

From the early 20th century onwards, the hydraulic paradigm permeated water management worldwide, aiming to control the natural environment through human transformations at the service of society (Swyngedouw, 1999; Lopez-Gunn, 2009; Custódio, 2012). Water resources management practices developed mainly through the knowledge of technical experts working under the auspices of the state (Pahl-Wostl *et al.*, 2007). The assumption was that water resources could be controlled, especially through large-scale infrastructural. These engineering works required large investments and centralized coordination and management, and became synonymous with state-building and the emergence of powerful bureaucracies (Huitema and Meijerink, 2014). Different sectors requiring or impacting water were managed separately, leading to a 'silo effect' (Xie, 2006).

Only relatively recently, during the nineteenth century, did ideas emerge about the need to protect, preserve and conserve water resources, with the beginning of the conservation

[18] This chapter draws heavily on Brandeler *et al.* (2019).

movement in the United States (Agyenim, 2011, p. 31). The persistence and aggravation of a range of water-related problems (e.g. Wat&San, energy, food production, transboundary conflicts), increased awareness on the urgent need for water resources management (Agyenim, 2011: 32). Global climate change and its implications for water governance have further brought attention to this urgency.

Despite rising environmental awareness, water crises are often portrayed as issues of physical scarcity rather than the inadequate governance of a renewable resource (Biswas and Tortajada, 2010), or a deeply political challenge from global to local ('glocal') level (Gupta *et al.*, 2013a). This position reinforces technocratic approaches based on standardized large-scale technological solutions at the expense of more innovative and sustainable technologies and practices (Farrelly and Brown, 2011; GTT, 2014). However, persistent and worsening water challenges reveal the limitations of engineering to solve these problems (Li *et al.* 2015). Consequently, there is growing consensus that the global water crisis is first and foremost a 'crisis of governance' (Castro, 2007; Tortajada, 2008; Biswas and Tortajada, 2010; Vörösmarty *et al.*, 2010; Gupta *et al.*, 2013a).

IWRM is an empirical concept developed by practitioners from on-the-ground experience and promoted as early as at the first global water conference in Mar del Plata in 1977 (WWAP, 2009). It gained global attention during the International Conference on Water and the Environment in Dublin in 1992. During this event, participants defined the *Dublin Principles*, which call for integrated, participatory management (ICWE, 1992). The concept has since been adopted by international agencies such as the World Bank (Abers, 2007; Abers and Keck, 2013), contributing to its influence among academic and professional circles worldwide. The Hague Forum, in 2000, pushed IWRM further by including a wide range of water management stakeholders from around the world, as opposed to the Mar del Plata and Dublin events, where participants exclusively consisted of intergovernmental participants and experts (Rahaman and Varis, 2005). During this forum, participants suggested applying equity criteria in water management and called for collaboration and partnerships at all levels, meaningful participation and cooperation with international organizations and the UN (Rahaman and Varis, 2005). In 2001, the International Conference on Freshwater in Bonn suggested IWRM as the best approach for meeting the water-related needs of the poor and for promoting decentralization and new partnerships. It also recommended prioritizing efforts towards better governance, mobilizing financial resources, building capacity and sharing knowledge (Rahaman and Varis, 2005). The concept was also integrated into the European Union's Water Framework Directive of 2000 and subsequent programmes such as the EU Water Initiative (Wallington *et al.*, 2010).

Although it is not clearly apparent in the description of the IWRM principles, privatization and public-private partnerships are often considered to go hand in hand with IWRM, which can be considered as part of the neo-liberal trend (GWP-TAC, 2000; Rahaman and Varis, 2005; Gupta and Pahl-Wostl, 2013). In theory, privatization can bring many benefits to Wat&San services. It can increase the predictability of Wat&San investments and services, ensuring that they are properly maintained. The rationale is straightforward: Wat&San services are costly, long-term projects with few immediate political gains. By delegating services to private parties, governments can bring in capital they do not have, diminish costs by tapping into private efficiency and ensure that investments will be maintained despite potential political changes as companies are less subject to political influence (Wolff and Palaniappan, 2004). Nonetheless, privatization of water management may also have downsides as it can lead to fragmentation, single-purpose planning and management and a lack transparency, and make water unaffordable for the poor in developing regions through full cost-recovery (Rahaman and Varis, 2005).

Integrated River Basin Management (IRBM) is a subset of IWRM focused on the river basin scale. IWRM is a broader concept with an administrative logic, where the national level also plays a crucial role. A literature review of papers on IWRM focusing on the main trends within the period 2000-2011 showed that 44.4% of papers were dominated by a focus on the river basin management unit (Gallego-Ayala, 2013). Within IRBM, the basin is the main arena for building relations of collaboration, cooperation and coordination at different levels and scales of organization (Burgos and Bocco, 2014). The main idea behind this is to match the system's natural sphere, the "hydrologically-defined basin", to the management scale, thereby allowing for comprehensive problem analysis and the internalization of otherwise externalized problems (i.e. downstream effects of upstream activities) (Pahl-Wostl *et al.*, 2008; Lindborg *et al.*, 2017). A number of governments and institutions (e.g. EU Water Framework Directive) have adopted this principle (Molle, 2009a). In practice, water resources management at the basin level is carried out through River Basin Organizations (RBOs) often composed of representatives of a variety of interests and this can go beyond the level of the nation state and involve several states. Participatory processes that include marginalized groups may promote greater equity in water resources management, including in access to water (Swallow *et al.*, 2006).

4.2.2 Main characteristics

IWRM and IRBM have many characteristics found across the literature in terms of their goals, the spatial scale at which they are implemented, their approach to water resources, key actors and their mandates, water users, and what constitutes 'inputs' and 'outputs' of water (see Table ***4.1***).

Goals: As water resources management shifted towards IWRM/IRBM, its objectives moved from a pure resource exploitation ethic to include social equity and environmental sustainability (Hooper, 2005). IWRM and IRBM aim to integrate water uses for people (i.e. public/urban use), food production (i.e. irrigation), nature (i.e. maintaining ecosystems), industry and other uses (i.e. energy, commerce) ('GWP Integrated Urban Water Management', no date).

Approach: The modernist-inspired water resources management paradigm has a linear approach, focusing on supply augmentation rather than demand management, and addressing water resources concerns separately from matters of land use, planning and environmental management (Xie, 2006). Within IWRM/IRBM, water systems are considered as a whole, including surface (e.g. wetlands) and groundwater, upstream and downstream, as well as quantity and quality concerns through both supply and demand management (Chenoweth *et al.*, 2001; Jønch-Clausen and Fugl, 2001; Jones *et al.*, 2006; Savenije and Van der Zaag, 2008; Molle, 2009a; Butterworth *et al.*, 2010). Besides the natural system, IWRM/IRBM also integrate the human system, through a holistic institutional approach (Jønch-Clausen and Fugl, 2001; Abdullah and Christensen, 2004; Molle, 2009a), considering links to both land and water resources, including social and economic activities, and environmental management functions such as pollution control, development planning and biodiversity conservation (Abdullah and Christensen, 2004; Medema *et al.*, 2008; Savenije and Van der Zaag, 2008; Molle, 2009a; Molle and Mamanpoush, 2012; Koç, 2015). This involves integrating sectoral responses and blending viewpoints and objectives (Jønch-Clausen and Fugl, 2001; Medema *et al.*, 2008), and emphasizing stakeholder participation and cross-agency coordination for equitable allocation and the protection of ecosystems (Jønch-Clausen and Fugl, 2001; Hooper, 2005; Agyenim, 2011; Gain *et al.*, 2013). Furthermore, IWRM/IRBM treats water as an economic good, pricing it at levels that promote cost recovery and allocation to the most beneficial uses (Xie, 2006). Responses involve both hard and soft measures that go beyond technical solutions (Chenoweth *et al.*, 2001; Abdullah and Christensen, 2004).

Table 4.1 Main characteristics of IWRM/IRBM

Main characteristics	IWRM/IRBM
Scale	Basin (for IRBM) and national (for IWRM)
Goals	Integrate water uses for people, food, nature, industry and others. Balance economic, environmental and equity goals
Approach	Integrate all water resources and related concerns within the basin. Integrate sectors and multiple interests
Actors	Basin organizations (for IRBM), national and state/provincial departments for (IWRM)
Mandates	Water allocation and bulk supply; wastewater/water quality; flood mitigation; participatory planning; monitoring/evaluation; conflict resolution; community development
Users	All users within a river basin. Agriculture is often the biggest user
Water 'inputs'	IWRM/IRBM aim to consider all water resources in the basin (including within urban areas), but focus is on blue water
Wastewater / stormwater 'outputs'	Concern for impacts downstream communities and ecosystems. Efforts to regulate and reduce pollution (industrial and urban, and diffuse pollution). Climate change adaptation increasingly considered (focus on droughts)

Source: Author

Spatial scales of IWRM and IRBM: IWRM/IRBM emphasize the river basin unit as the ideal management level[19], although IWRM also has a spatial national focus through the integration

19 The boundaries of surface watersheds are generally delineated from topographic maps based on land elevations (Vaughan *et al.*, 2016). The rain and snow that falls within this area is stored, filtered, seeped or drained into a common water body through a network of streams that drain the surface area and the groundwater that contribute to those streams.

of its principles in national-level legislation, policies and institutions (Abdullah and Christensen, 2004; Watson, 2004; Hooper, 2005; Rahaman and Varis, 2005; Jones *et al.*, 2006; Butterworth *et al.*, 2010). While the river basin level dominates, IWRM can be implemented from the local to the transboundary and global levels (Butterworth *et al.*, 2010). Moreover, the large size and population of some catchments means that management at the scale of polders, wetlands or aquifers may be more logical (Butterworth *et al.*, 2010). Transformations of the natural environment, for instance, through irrigation schemes and inter-basin transfers, and the administrative boundaries of different government levels further complicate basin management (Butterworth *et al.*, 2010; Moss and Newig, 2010).

Organization: Conventional WRM is hierarchical, centralized and top-down, with central governments often directing water supply development, water service provision and water use regulation (Xie, 2006). IWRM/IRBM embraces (a) decentralization and subsidiarity, with preference for the basin or sub-basin level (Xie, 2006; Molle, 2009a); (b) transparent participatory decision-making, including access to information (Rahaman and Varis, 2005; Jones *et al.*, 2006); and (c) implementation through special purpose organizations, such as RBOs, rather than general purpose government layers (Molle, 2009a; Huitema and Meijerink, 2014). A diverse range of actors can be involved, including user associations, environmental NGOs and affected communities.

Mandates: Conventional WRM's mandates are limited to river basin planning and policy "with no enforcement, regulatory or water-resource development functions, and no direct representation of local interests and stakeholders, other than through state agencies" (Molle, 2009a: 490). As IWRM/IRBM aims to integrate stakeholder needs and interests at basin level, its mandates concerns all water-related activities (e.g. basin-wide evaluation, planning, strategy implementation, monitoring, water allocation mechanisms, water quality maintenance, basin guidelines, negotiation/ dispute resolution mechanisms, flood warning and mitigation, and community development) (Chenoweth *et al.*, 2001). These mandates are shared between actors, including RBOs and other multi-stakeholder platforms, but are often blurred (Jønch-Clausen and Fugl, 2001; Grigg, 2008). IWRM/IRBM supporters argue that adequate implementation requires clearly delimited responsibilities that match to authority and capacities for action (Jønch-Clausen and Fugl, 2001). In some cases, government bodies are responsible for regulating water uses but do not have the administrative and political power needed to oppose traditional line agencies (Molle, 2009a; Agyenim, 2011). In other cases, quantitative functions (e.g. water supply, irrigation, flood mitigation) are managed separately from qualitative functions (e.g. water pollution, land use), and a single organization may facilitate an integrated approach (Abdullah and Christensen, 2004).

Users: IWRM/IRBM considers all users and economic interests within a river basin, including domestic, agricultural, industrial and recreational users (Savenije and Van der Zaag, 2008). The agricultural sector is the largest user of water resources in most countries, followed by the energy sector (i.e. hydropower), making the water/food/energy nexus crucial for integrated water management, particularly in the context of climate change (Biswas, 2008; OECD, 2016). Domestic and recreational users represent a relatively small portion of total water use.

In river basins with low population densities, ecosystems such as grasslands or woodlands may be major water users (Harrington *et al.*, 2009). However, in heavily urbanized basins, water resources' allocation can be a source of competition and conflict between urban and rural users (Butterworth *et al.*, 2010; Molle and Mamanpoush, 2012; OECD, 2016). Downstream users are particularly vulnerable to variations in the water regime occurring in upstream areas (Molle, 2009b). Users also differ in their access to natural or financial resources and in their political power (Swyngedouw *et al.*, 2002; Molle and Hoanh, 2007; Molle, 2009b). Effective and legitimate norms and instruments for water allocation among users are therefore crucial in heavily urbanized basins, but are often lacking, especially in cases with large informal economies (Watson, 2004; Butterworth *et al.*, 2010; OECD, 2016).

Inputs and outputs: IWRM/IRBM consider the hydrological cycle as a unitary whole, and are therefore concerned with all water resources within a river basin (including rainwater and snowmelt) (Savenije and Van der Zaag, 2008; Harrington *et al.*, 2009). They call for awareness on how different types of water (blue water, green water, grey water) interact and how this interaction impacts equitable use and the distribution of costs and benefits (Savenije and Van der Zaag, 2008). However, IWRM/IRBM have largely focused on 'blue water' (i.e. surface and groundwater), often ignoring 'grey water' (i.e. water after basic treatment), and 'green water' (i.e. water in the unsaturated zone of the soil and plants which has critical ecosystem services, and is sensitive to land degradation) (Jewitt, 2006; Molle and Mamanpoush, 2012; Hayat and Gupta, 2016). 'Rainbow water' (i.e. atmospheric moisture) is not included in IWRM/IRBM, yet perturbations in moisture recycling, often linked to changes in land use, can affect precipitation in distant locations. Water availability in one river basin can therefore be modified due to activities (i.e. deforestation, irrigation) in regions on the other side of the planet (Wang-Erlandsson *et al.*, 2018). Furthermore, IWRM/IRBM does not address virtual water, through which the import of items, such as food, reduces the need to use water resources for their production locally (Dalin *et al.*, 2017).

The linear approach of conventional WRM facilitates the contamination of water downstream, with little concern for the environmental impact. The focus is on economic development, especially following World War II, and water quality is not a priority for the industrial and agricultural sectors (Xie, 2006). IWRM and IRBM call for protecting water resources and ecosystem services through adequate wastewater management (i.e. collecting and treating wastewater before discharge, wastewater recycling, and waterway restoration) (Martinez-Santos *et al.*, 2014). This may involve (de)centralized infrastructure, but also regulating and reducing diffuse pollution, most of which derives from agricultural activities (Xepapadeas, 2011).

4.2.3 Drivers, institutions and instruments

The rise of IWRM and IRBM was in part spurred by drivers of water resources challenges such as increasing competition for water resources through population growth and economic development, climate change and variability, and land use changes due to human interventions or natural processes (Hooper, 2005; Gallego-Ayala, 2013; Wang-Erlandsson *et al.*, 2018). Major shifts in societal behaviour have also played an important role in driving a shift in WRM

(Hooper, 2005).

Political, legal and institutional factors also play an important role in the shift towards IWRM/IRBM (Tortajada, 2001; Grigg, 2008; Agyenim, 2011). Institutions rooted in centralized structures, sectoral fragmentation and weak local capacity, with low political awareness or will and inadequate data and information management hinder the successful implementation of IWRM/IRBM (Jønch-Clausen and Fugl, 2001; Medema *et al.*, 2008; Molle, 2008). Latin American countries that adopted IWRM/IRBM principles all shared strong support for decentralization policies within political reforms more broadly (Lee, 2000; Tortajada, 2001). User representation and public participation in river basin institutions balance the power of public sector institutions and may prevent bureaucratic infighting (Lee, 2000). Weak implementation of IWRM/IRBM in the Global South may also be explained by the fact that it requires a stable political context and institutional environment (Agyenim, 2011; Cameron and Katzschner, 2017). Property rights regimes may be different from those in the Global North and stable financing and administrative capacity is more likely to be lacking, as is the ability to enforce laws and regulations (Agyenim, 2011). On the other hand, in the Global South, IWRM can be compatible with local water rights that are participatory, self-regulatory, sensitive to the vulnerable and able to contain conflicts (Agyenim, 2011; Agyenim and Gupta, 2012).

IWRM/IRBM institutions are often designed at the basin level, under the premise that they “fit” their context and are therefore more effective (Young *et al.*, 2008; Agyenim, 2011). Nonetheless, institutions shaping IWRM/IRBM have been developed at multiple levels, combining central-local, river basin specific and public-private organizations (Medema *et al.*, 2008). At global level, International Financial Institutions (IFIs) have financed large-scale water resources development projects in the global South (Lebel, 2005). The national level is crucial for IWRM through the design and implementation of laws, norms, regulations and rules (Gallego-Ayala, 2013). National governments set standards for water quality and water allocation. Some nations also possess a water regulatory agency at the national level (OECD, 2011). The national level is often the level for hydropower planning and management as this enables better distribution and economies of scale. When water becomes an issue of national security (i.e. during drought), governments may take control over water resources (Gupta *et al.*, 2013b). A literature review of papers on IWRM focusing on the main trends within the period 2000-2011 showed that 22.5% adopted the country level as the scale of analysis. The allocation of water policy roles and responsibilities across national and sub-national levels varies significantly, making it impossible to capture a “national model” with comprehensive institutional mapping (OECD, 2011). Additionally, in federal countries significantly more water policy responsibilities are devolved to subnational governments. States usually have sovereignty over water resources within their territory and establish the basic rules about how individuals and groups can access these (Gupta *et al.*, 2013b).

In some cases, multiple institutions are superimposed onto each other, such as communal irrigation institutions combined with more recent water use allocation systems (Lebel, 2005). The multiple actors involved have differing objectives, responsibilities, and interests, which can lead to conflicts (Koç, 2015). The institutional integration expected of IWRM may not be realistic, and fostering coordination, cooperation and collaboration may be a more adequate alternative (Biswas, 2004; Koç, 2015).

The 'Dublin Principles' defined four principles that aim to guide concerted action from the international to the local level. The first principle defines fresh water as a "finite and vulnerable resource, essential to sustain life, development and the environment" (ICWE, 1992: Guiding Principles). The second principle emphasizes that water governance should be participatory and that decisions should be taken at "the lowest appropriate level with full public consultation and involvement of users in the planning and implementation of water projects" (Ibid). Participation is also seen as essential for balanced and sustainable water use (Jønch-Clausen and Fugl, 2001). The third principle recognizes the central role that women play in water governance and aims to empower them so that policies can better answer their needs. The final principle defines water as an economic good, under the auspice that giving water an economic value will prevent wasteful and environmentally damaging uses.

Table 4.2 Instruments of IWRM/IRBM

Types of instruments	IWRM/IRBM
Economic	Bulk water use fees; PES programmes; pollution fees, and economic and financial tools for investment, cost recovery and behaviour change (e.g. subsidies for water efficient technology and infrastructure, royalties)
Regulatory	Bulk water use permits; Transfers of bulk water use permits; land use regulation within basin (restricting development); Licensing (of polluting activities); Conservation measures (e.g. easements and zoning)
Suasive	Anti-pollution campaigns; Public awareness and education programmes on environmental protection; Water resources assessment and information
Coordination	Pollution monitoring systems; Meteorological monitoring systems; Participatory spaces for negotiation and conflict-resolution on water resources management

Source: Author

From these principles, the IWRM/IRBM frameworks derive a variety of possible instruments to address water challenges (see Table ***4.2***). Among their key instruments are policies concerning water (re-)allocation among users. In particular, *who* has priority to use water resources in water scarce environments (in many cases, but not all, the priority is granted to domestic water use) (Butterworth *et al.*, 2010; Agyenim, 2011). Other influential instruments include regulatory and economic instruments to manage pollution, such as wastewater discharge fees for Wat&San utilities, industries and other bulk water users), the identification and licensing of polluters (i.e. permits for wastewater discharge), effective monitoring systems, identification and responses to infringements of laws, regulations and permits, and regulations and incentives to preserve areas with important ecosystems (i.e. conservation areas, compensation to municipalities for conservation efforts, PES programmes). Other crucial instruments, especially in water scarce areas, are those that establish rules for water diversions from streams, rivers, lakes and groundwater (Agyenim, 2011). IWRM/IRBM instruments interfere at national and basin levels, and focus on environmental and economic dimensions, with social and relational goals appearing more secondary.

4.3 IWRM/IRBM FOR SUSTAINABLE AND INCLUSIVE DEVELOPMENT

4.3.1 STEPS FORWARD

The shift from conventional WRM approaches towards IWRM/IRBM create conditions for more inclusiveness. IWRM/IRBM can challenge centralized expertise and decisions when water-related challenges require adaptive, polycentric (Sneddon *et al.*, 2002; Molle, 2009a) and contextual solutions (Jønch-Clausen and Fugl, 2001; Xie, 2006). Decentralization and participation, by integrating actors with knowledge of the local environment and local users' needs, may lead to superior equity and efficiency in resource management (Andersson and Ostrom, 2008). By emphasizing the need to blend different viewpoints, they enable a more holistic and inclusive approach to water-related issues (Grigg, 1999, 2008; Medema *et al.*, 2008). IWRM/IRBM strives for a fair allocation of water resources among upstream and downstream users within a basin or sub-basin, between current and future generations, and for both human and ecosystem needs (Harrington *et al.*, 2009; Molle, 2009b; Molle and Mamanpoush, 2012).

IWRM/IRBM may enhance sustainability by recognizing the role of ecosystems in WRM (Molle, 2009a) and promoting demand management (Grigg, 2008). In the context of population growth and the overexploitation of water resources, IWRM/IRBM have the potential to restore a vision that considers both humans and ecosystems (Molle, 2009a).

4.3.2 LINGERING OBSTACLES

Continued environmental degradation, including of water systems, in areas where IWRM/IRBM has officially been implemented highlights the limitations of these principles for fostering ecological sustainability. There is no consensus on how to implement IWRM/IRBM. Moreover, the focus of IWRM/IRBM has been on 'blue water', to the detriment of 'grey water', 'rainbow water', 'green water', and the 'embedded water' or 'virtual water' in imported food products and other goods (Molle and Mamanpoush, 2012; Hayat and Gupta, 2016; Dalin *et al.*, 2017; Wang-Erlandsson *et al.*, 2018; Brandeler *et al.*, 2019). An understanding of 'green water' flows can lead to more efficient irrigation for instance. There is also no consensus on whether IWRM/IRBM enhances adaptability, which is problematic in a context of climate change (Medema *et al.*, 2008; Foster and Ait-Kadi, 2012; Gain *et al.*, 2013).

In addition, the principle of water as an economic good is frequently criticized as it may foster the notion of water as a commodity, ignoring its non-monetary value and shifting perception away from water as a common good that brings shared duty and responsibility (Rahaman and Varis, 2005). Pushing for cost recovery in areas with large pockets of poverty, such as nations in the Global South, can lead to eliminating vital subsidies for basic water infrastructure and services (Rahaman and Varis, 2005).

Furthermore, IWRM/IRBM aims to move from a fragmented to an integrated and coordinated approach to resources planning and accommodating the needs and interests of all stakeholders within the basin (Chenoweth *et al.*, 2001). Yet, while this idea has become mainstream, its implementation is still lacking (Chenoweth *et al.*, 2001; Medema *et al.*, 2008; Jacobi *et al.*, 2015). There are several reasons for this. For example, the integration goals are ambitious as they assume political will and the adequate availability and sharing of data and knowledge (Allan, 2003; Molle, 2008). However, they ignore uncertainty (Agyenim, 2011), tensions between developing basin-wide approaches and more decentralized resource management[20] (Miller and Hirsch, 2003), the antagonistic nature of IWRM goals (Efficiency, Equity and Environmental sustainability) and their necessary trade-offs (Molle, 2008), and the jurisdictional complexity of river basins that cross national or even state borders (in the case of federal regimes) (Choudhury and Islam, 2015).

Also, the Dublin statement on IWRM does not provide suggestions on how to implement effective participation mechanisms (Rahaman and Varis, 2005, p. 16). While integrating different views is generally considered a positive aspect of IWRM/IRBM, by allowing for greater social inclusiveness, in practice it requires significant resources and time-commitments (i.e. time spent in meetings, travel time and costs of attending meetings), and participants lacking expert knowledge often struggle to follow and intervene in discussions (Brandeler, 2013). Decision-making spaces are often still dominated by state-affiliated experts and traditional power relations, and the broad goals of IWRM/IRBM can lead some groups to hijack these to legitimize their own agendas (Wester and Warner, 2002; Molle, 2008). For instance, urban elites and state bureaucracies may use it to facilitate upstream interventions by downstream stakeholders (Molle, 2009b). Marginalized voices and interests struggle to gain representation and negotiate on equal footing (Swyngedouw *et al.*, 2002; Molle, 2009b; Brandeler *et al.*, 2014; Varis *et al.*, 2014). This especially concerns indigenous and rural communities as well as the urban poor (Boelens, 2009; Brandeler *et al.*, 2014). Besides a lack of representation and participation of diverse interests and stakeholders, RBOs often struggle with limited enforcement, regulatory or water-resource development functions (Molle, 2009a). IWRM/IRBM cannot be established in contexts of war and conflict and require stable democratic processes and institutions (Hooper, 2005), but beyond that it is not clear how to address unequal power relations (Jønch-Clausen and Fugl, 2001; Brandeler *et al.*, 2019). This may require broader political reforms beyond the scope of water management institutions.

4.4 Scalar limitations of IWRM/IRBM

4.4.1 The "naturalness" of the river basin scale as a social construction

The spatial scale of the river basin has been framed by the IRBM and, to a large extent, by the IWRM literature, as the ideal unit for water resources planning and management (see 4.2.2). However, this simplifies hydrological dynamics. First of all, river basins are generally formed

[20] Although the river basin management approach has often been framed as one of decentralization, it represents a scaling up from municipalities (Cohen and Davidson, 2011).

by multiple watersheds nested into each other, as each tributary forms a sub-division, so deciding where to draw the boundaries for a management area can be a challenge in itself (Cohen and Davidson, 2011; Perreault, 2014).[21] These boundaries are constantly shifting as our understanding of surface and groundwater flows and GIS technology improve (Cohen and Davidson, 2011). Second, the hydrological cycle is not restricted to the boundaries of the river basin. Land-atmosphere feedback, such as local and regional land use change and moisture recycling patterns can have effects on remote precipitation and, thereby, on distant river flows (Wang-Erlandsson *et al.*, 2018). Model simulations have suggested that complete deforestation of central Africa could decrease February precipitation by 35% in the Great Lakes region (Avissar and Werth, 2005), while irrigation in India may support up to 40% of the precipitation in some arid regions in eastern Africa (Vrese *et al.*, 2016). Third, river basins usually share the same boundaries as granular, unconfined aquifers (i.e. just below the surface), but the recharge areas of karstic and confined aquifers mostly do not match those of river basins (Demiroğlu, 2017). Aquifer boundaries may be the more appropriate spatial framework to address groundwater management and protection in the latter case (deep aquifers in arid regions) (Garduno *et al.*, 2006; Foster and Ait-Kadi, 2012).

Moreover, the view of river basins as closed ecological systems characterized by stability and predictability has lost relevance in the context of human interventions (e.g. climate change, pollution, loss of wetlands) that lead to increased uncertainty, change, complexity and conflict (Holling, 1978; Watson, 2004). As Europe’s river basins are now linked by canal networks, inland navigation no longer relies on natural waterways and is coordinated nationally and regionally rather than at basin scale (Muller, 2018). River flows have also been altered to allow for water supply in expanding human settlements through inter-basin transfers, the drilling of deep wells and desalination (Cohen and Davidson, 2011; Perreault, 2014; Muller, 2018). Unintended human interventions, such as the accidental introduction of invasive species into a river basin, can also have devastating biological and economic impacts (Cohen and Davidson, 2011).[22] As these transformations and challenges, as well as the governance systems that respond to these, transcend across spatial scales, effective solutions are beyond the reach of any single agency or organization (Watson, 2004; Varis *et al.*, 2014). An exclusively basin-scale approach may therefore limit flexibility and lead to transboundary problems.

Ultimately, the choice of scale for water resources management is socially produced and inherently political, emerging from social practices, perceptions and relationships over time (Molle, 2009a; Perreault, 2014). Treating the river basin as the ‘natural’ scale can lead to a technical approach that ignores political struggles and power relations (Perreault, 2014). On the other hand, territorial governance units based on conventional electoral boundaries (i.e. municipal, provincial, state, or national boundaries) rarely correspond to hydrological

21 For instance, the US Geological Survey (USGS) divides the United States into 21 regions, 222 sub-regions, 370 basins, 2,270 sub-basins, approximately 20,000 watersheds and around 100,000 sub-watersheds (USGS, 2013).

22 The introduction of zebra mussels into the Great Lakes, from ship ballast water, is estimated to have cost the North American economy over US$ 100 million and wreaked havoc on food webs and water supply systems (Cohen and Davidson, 2011), requiring States around the region to spend significant sums trying to address the problem.

boundaries, leading to a mismatch between institutional and hydrological logics that blurs the allocation of responsibilities across multiple scales and complicates the relationships between elected representatives, local authorities, water agencies, resource managers and end users (Bahri, 2012; Söderbaum and Granit, 2014; OECD, 2015b). Government participants in river basin initiatives are more likely to be responsive to the concerns of the jurisdictions where they were elected and to which they are accountable (Cohen and Davidson, 2011). This creates obstacles for coordinating different actors, particularly for financing (Newig and Fritsch, 2009) and land use management (Tucci, 2007), and may contribute to management failures within water governance, such as a lack of cooperation, participation and transparency (OECD, 2015b). Additionally, the socioeconomic drivers and power relations that shape WRM are not necessarily contained within the basin (Molle, 2009a).

4.4.2 IWRM/IRBM IGNORE THE URBAN

While basin-level management has become the dominant paradigm within the water governance literature, River Basin Organizations (RBOs) struggle in heavily urbanized environments, raising doubts about the adequacy of the basin as the spatial scale for addressing urban water challenges (Formiga Johnsson and Kemper, 2005; Jacobi and Francalanza, 2005; Rahaman and Varis, 2005; Alvim, 2006; Roggero and Fritsch, 2010; Brandeler, 2013; Freitas and Fracalanza, 2013). The IWRM and IRBM literature do not clearly address how water management at basin scale can be reconciled with the urban scale. A search within ScienceDirect for articles on IWRM published between 1970 and 2015 revealed that only around 14% contained any of the terms ‘urban’, ‘city’, ‘cities’, ‘megacity’, ‘megacities’ or ‘metropolitan’ in their title, abstract or keywords (Brandeler *et al.*, 2019). The same search within IRBM articles gave a result of 10%. Many of the IWRM/IRBM publications that do refer to the urban context have a narrow focus (e.g. urban demand management, pollution abatement tools, leakage control, wastewater recycling, public-private partnerships), and ignore IWRM’s broader dimensions (Rees, 2006; Bahri, 2012). The particular challenges for IWRM implementation in large metropolitan centres, including coordinating across urban jurisdictions that may have competitive or conflictive relations, have also not been clearly addressed.

A straightforward explanation for this is that in most basins most of the water use is for agricultural use (i.e. irrigation). The purpose of WRM entities has often largely been to regulate flows for irrigation (70% of the world’s water withdrawals, even reaching 90% in countries of the Global South) and power generation, with little influence over water quality management (Lee, 2000; Molle, 2008). In addition, irrigation’s heavy water use is often also inefficient, with more than half of the water deliveries percolating into groundwater or returning to streams without watering crops, evaporating or otherwise lost (Molle, 2008). However, when demand within a basin exceeds supply, surface and groundwater resources become over-exploited, which affects development prospects (Tortajada, 2008; Barrios *et al.*, 2009). As basins urbanize and industrialize, and rural and urban water users compete for increasingly limited water resources, appropriate supply and demand management and water resources allocation mechanisms are crucial (Butterworth *et al.*, 2010; Molle and Mamanpoush, 2012).

Furthermore, implementing IWRM/IRBM in heavily urbanized river basins is a significant challenge as integrated decision-making processes must address trade-offs and externalities between rural and urban areas. One key trade-off concerns the allocation of scarce water resources between public/urban users, other sectors as well as the environment. This is especially pertinent in basins where all available water is committed, and new developments require reallocation (Rees, 2006). As domestic water use typically has priority over other uses, this translates into reallocation from agricultural to urban uses (Rees, 2006). The import of water from other basins allows actors and users within the recipient basin to avoid this contentious, and potentially conflictual decision. Although this may increase the economic efficiency of water use, such transfers also imply economic, social and political costs to the donor basin (Rees, 2006). Large cities around the world are increasingly relying on neighbouring basins.

The IWRM/IRBM literature promotes integration between water and land resources and management. However, land use changes in rural areas (e.g. deforestation) of river basins and diffuse pollution from agriculture are difficult to regulate and their impacts on cities cannot easily be traced to specific sources. The expansion of human settlements and intensification of their use of land and water resources in urban areas strengthens interlinkages between spatial planning and water management (Hartmann and Spit, 2014). Nevertheless, there seems to be no comprehensive analytical framework for assessing the coordination of IWRM/IRBM with urban and territorial planning (Neto, 2016). RBOs often have some (limited) influence over land and water uses upstream and across the basin, but little leverage over policy fields that directly impact water quantity, quality and risks, such as land use planning, agriculture, hydropower, stormwater management, conservation, economic development and more (Moss, 2004: 85). The mismatch between hydrological and political-administrative borders may further lead to poor cooperation, particularly in basins with large metropolises and megacities, and many stakeholders and interests (Aguilar, 2008; Feiock, 2009; Sorensen, 2011; Li *et al.*, 2015). In addition, climate variability and change can also lead to droughts or floods, impacting both river basins and the cities within them. If IWRM/IRBM measures do not take steps to prepare for and adapt to these risks, cities may be left struggling to cope, or these frameworks may be overruled by urban water frameworks, as major cities gain prominence in water management. Droughts impact water supplies, and in basins with large cities even short droughts can have significant impact.

4.5 Inferences

This chapter reviewed the water resources management literature to gain insights on how it understands and addresses metropolitan water challenges. It explored this in relation to two knowledge gaps identified in 1.2.3, namely (a) how the literature relates to the local context and integrates urban water concerns such as water services and water-related risks, (b) how the literature relates to the metropolitan context as a multi-jurisdictional and often heterogeneous urban environment. Several factors were identified by the IWRM/IRBM literature review that may facilitate or hinder sustainable and inclusive development.

Sustainable and inclusive development

First, the literature review highlights a shift from WRM based on modernist ideals towards IWRM, and its subset of IRBM, that embrace sustainable and inclusive development principles. IWRM and IRBM aim for decentralization to the river basin level and stakeholder participation, which can lead to the design of institutions and instruments that foster the inclusion of multiple viewpoints and interests, greater efficiency in resource management for multiple users, the protection of ecosystems and the promotion of water demand management. The review identified aspects of IWRM/IRBM that could hinder sustainable and inclusive development, such as limited considerations for types of water other than 'blue water' and for water as a hazard (water is defined as a resource). Participatory processes may struggle to include diverse, and particularly under-represented voices, as they require significant time commitments, finance (Anggraeni *et al.*, 2019) and as expert knowledge dominates to the detriment of local, tacit knowledge. Municipal representatives involved in these participatory processes are also likely to defend their constituents' interests, even at the expense of the general interest within the basin. The approach to water as an economic good can also lead to the exclusion of the poor and marginalized. The empirical chapters of this thesis evaluate whether such measures were part of the responses to metropolitan water challenges in São Paulo and Mexico City, and if so, how effective they were.

The river basin scale may not always be ideal

One of IWRM/IRBM's core principles is the idea that the river basin is the ideal unit for water resources management, as this allows for overcoming the mismatch between hydrological and administrative scales. However, the literature review points out important limitations when parties take for granted the superiority of the river basin as a planning unit. This thesis recognizes that choosing the basin as a unit for water resources planning and management is a social construction and attempts to consider other relevant scales (for drivers, institutions and instruments) into a broader framework for understanding metropolitan water challenges. This includes scales related to elements of the hydrological cycle (e.g. groundwater dynamics, atmospheric water, green water) and scales that gain relevance due to human interventions on the 'natural' environment. For this purpose, a governance framework that addresses metropolitan water challenges must therefore go beyond the main characteristics of IWRM/IRBM identified in 4.2.2.

Influence of basin entities over specifically urban drivers and institutions

IWRM/IRBM has had a strong focus on agriculture and rural areas, even though it promotes balancing the needs and goals of all users. However, in heavily urbanized basins, a significant or even dominant proportion of water uses are for urban uses and water-related challenges are different (e.g. important water quality challenges, such as contamination from solid waste and domestic and industrial wastewater, reductions in aquifer recharge due to soil sealing, tensions between users). For IWRM/IRBM institutions and instruments to have an impact on these challenges they must address the relevant drivers and actors. This is even more complex in metropolitan regions, due to the larger number of actors involved and their sometimes conflicting political and administrative interests.

5. THE IMPLEMENTATION OF IWRM/IRBM IN SÃO PAULO

5.1 INTRODUCTION

This chapter examines how different drivers and institutions at multiple levels of the river basin governance regime shape water-related challenges experienced in the Metropolitan Region of São Paulo (MRSP). It uncovers the causal chains behind these water challenges and the effectiveness of existing policy instruments. It reviews the relevant historical and geographical context of Brazilian river basin governance and the driving forces on the river basin from the local to the global level (see 5.2); explores how IWRM actors and institutions at multiple levels address water challenges at the basin scale (see 5.3); analyses the related instruments according to their stated mandates, their effect on actors' behaviour and their impacts on inclusive and sustainable water governance (see 5.4) and draws conclusions on how more appropriate instruments could be (re)designed for the São Paulo (see 5.5).

5.2 CONTEXT AND DRIVERS OF SÃO PAULO'S RIVER BASIN CHALLENGES

5.2.1 CONTEXT IN RELATION TO THE RIVER BASIN

Although Brazil is water abundant in absolute terms, with about 12% of the world's surface water resources[23], water is unevenly distributed (Formiga Johnsson and Kemper, 2005). Most of these resources are concentrated in the humid and sparsely populated Amazon rainforest, while most Brazilians live within 300 km of the coast. The country also has extremely dry regions such as the Northeast.

São Paulo is located near the Tietê River's springs, in the Alto-Tietê Basin (ATB)[24], a sub-basin of the Tietê River. Despite being only 22 km from the Atlantic Ocean, the coastal escarpment forces the river to flow inwards (see Map ***2.1***). The river crosses the MRSP and flows 1136 km until it joins the Paraná River.[25] The ATB is a heavily urbanized sub-basin that virtually overlaps with the MRSP. Due to the MRSP's population size, water is relatively scarce (Interviews-B4/B5/B28). Water availability per capita here is just above 130 m^3 per year[26] (SABESP, 2017) and is aggravated by the severe contamination.

5.2.2 MAIN DRIVERS OF SÃO PAULO'S RIVER BASIN CHALLENGES

Many driving forces at multiple levels directly or indirectly shape water-related challenges in the MRSP and its river basin (see Table ***5.1*** for overview).

23 Per capita water availability reaches 40,000 m3/inhab./year

24 Alto-Tietê means Upper-Tietê

25 The waters of the Tietê River discharge into the Atlantic Ocean in the Paraná Delta north of Buenos Aires.

26 Regions face absolute water scarcity if renewable water resources are below 500m^3/inhab./year (FAO 2012).

Table 5.1 Multi-level drivers of water-related challenges on the river basin

	Direct		Indirect	
	Local	Regional / global	Local	Regional / Global
Land use change	Urbanization (especially informal)	Urbanization		
		Agriculture		
Demographic	Population growth in urban periphery	Growing water demand for public supply	Rapid population growth during 20th century	Rural/urban migration
	Growing water demand for public supply			Population growth in nearby regions
Economic development	Industrial (water use and contamination)			
	Mining (contamination)			
	Water demand for hydropower			
Climate			Heat island effect	Climate variability and change
			Drought of 2013-2015	

Source: Author

Climate

São Paulo has a humid sub-tropical climate. Heavy summer precipitation causes frequent floods. However, winters are dry, and the city regularly experiences longer dry spells. Forest fires in São Paulo State have reportedly increased in recent years (Interview-B14). Between 2013 and 2015, Brazil's Southeast, including São Paulo, experienced a record-breaking drought. Unusually high temperatures and low precipitation levels contributed to an almost complete exhaustion of the metropolis' water reservoirs (Nobre *et al.*, 2016).

Although it is difficult to establish clear causality between extreme weather events, such as the recent drought, and global anthropogenic climate change, scientists expect these events to become more frequent as a result of the latter. Since the early 20th century, the country is warming on average (Nobre, 2001; Marengo *et al.*, 2007). Several climate change scenarios indicate warming trends up to 4-6^{o}C in parts of the country, particularly in the Amazon region, by the end of the century (Nobre, 2001; Gosling *et al.*, 2011). Precipitation in the Southeast (where São Paulo is located), is projected to decrease overall (up to 5%) but with more intense and irregular rains (São Paulo Legislative Assembly, 2009; Gosling *et al.*, 2011; Angelo and Feitosa, 2015). A rise in extreme weather events could both aggravate water scarcity and lead to more floods and mudslides. In addition, São Paulo State's Participatory Adaptation Plan claims that there are insufficient studies on Brazil's (and consequently São Paulo State's) vulnerability to climate change (São Paulo Legislative Assembly, 2009). Although climate change is acknowledged as a risk multiplier, public managers remain sceptical (Interviews-B5/B8/B24/B33).

Scientific models estimate that deforestation in the Amazon rainforest contributes to higher temperatures and decreases in precipitation (São Paulo Legislative Assembly, 2009; Nobre, 2014). Nonetheless, São Paulo's State Secretary for Sanitation and Water Resources dismissed this link citing the heavy rains and floods of 2016 and blaming natural variability (Watts, 2017).

Demographics

São Paulo experienced explosive population growth during the 20th century (see 2.2.2), a process that has slowed down. The Municipality of São Paulo currently grows 0.55% a year, and the metropolis as a whole, 0.73% (Seade, 2019). Moreover, the population has also grown beyond the MRSP, leading to the definition of the Macro-metropolitan region of São Paulo. In 2009, São Paulo State was 94% urban (São Paulo Legislative Assembly, 2009).

During the second half of the 20th century, the Brazilian population increased exponentially from 51.9 million inhabitants in 1950 to 190.8 million in 2010 (IBGE, 2010). National population growth has slowed down to 0.8% a year, and projections indicate that this trend will continue in the coming decades (IBGE, 2018). Parallel to this, Brazil's urban population rose from 31.24% in 1940 to 84.36% in 2010, pushed by rural to urban migration (IBGE, 2010). By 2005, 42.8% of Brazilians lived in metropolitan regions (Braule Pinto, 2007).

Land use changes

Before the region was transformed by Portuguese settlers, it was an ecotone – a transition area between several biomes – composed of Atlantic rainforest, wooded grasslands, wetlands, and vegetation typical of the South, the coastal area and the central West region of Brazil (Cardim, 2018). This led to a rich variety of native flora and fauna. It is estimated that 80 km of wetlands extended along the rivers that crossed what is today the MRSP (Del-Rio *et al.*, 2015). Not only has most of this original landscape disappeared, but within the small pockets of vegetation that are left, 90% of the plants are non-native (Cardim, 2018). São Paulo's accelerated pace of urbanization during the 20th century, has been characterized by a lack of planning.[27] Expansion at the margins of the metropolis and irregular occupation of the green belt and areas of springs led to water contamination (Interviews-B4/B5/B14/B19/B33).

While rapid, unplanned urban growth significantly deteriorated the river basin's water quality and decreased water availability for public supply, the demand for water grew exponentially (Jacobi *et al.*, 2015). The relative scarcity of water further drove water use conflicts between public/urban use, industrial use, agriculture and energy production within the MRSP and with neighbouring regions.

27 São Paulo's first master plan dates from 1972, when the MRSP had over 8 million inhabitants (São Paulo City, no date; Saconi and Entini, 2013).

In addition, land use changes within the broader region, such as deforestation, agricultural expansion or intensification and unplanned urbanization (in particular inadequate drainage and sewage discharge[28]) can cause or contribute to erosion, which deteriorates soils and leads to siltation, ultimately aggravating risks of mudslides and floods (Jacobi *et al.*, 2015; FABHAT, 2016) (Interviews-B17/B19). The lack of adequate soil conservation in rural areas further aggravates these risks (Interview-B17).

Urban growth across Brazil has been characterized by a lack of planning, which led to increased inequalities in Brazilian cities, including in the distribution of risks derived from precarious construction (Jacobi and Sulaiman, 2017). Throughout the 20th century, there was a legal and policy vacuum regarding urban planning, with no general guidelines.

Economic development

In colonial times, the Tietê River was strategic for exploration and served as an integrating element within the state (Paganini, 2008). The need for water resources for the population and industry, as well as the need for space for urban expansion, led to a transformation of the regional hydrology, as rivers were channelled, rectified, diverted and/or buried. Many of the Tietê's tributaries were buried (e.g., Tamanduateí and Anhangabaú Rivers), becoming invisible and forgotten (Gouveia and Moroz-Caccia, 2016).

Although the public-urban and industrial sectors dominate water use in the ATB, irrigation accounts for 65% of water use at state level (DAEE, 2009). However, WRM in the region first developed for energy generation. The Tietê River's hydropower potential was first explored in the late 19th century through dam construction (Paganini, 2008). The Serra do Mar (Sea Mountains) project, an ambitious project which began in 1927, transformed the natural flow of the Pinheiros River, a tributary of the Tietê River and the second most important river in São Paulo (see Figure ***5.1***). This transformed the Pinheiros River into a canal diverting water to the newly built Billings dam. From there, water flows towards the coastal cliffs, generating power through a 750m drop (Braga *et al.*, 2006) (Interview-B19). This increased the region's energy capacity from 16MW to 480MW in the early 1950s, supporting the MRSP's rapid urbanization and industrialization (Braga *et al.*, 2006; Paganini, 2008).

28 Erosion can be caused by large volumes of effluents that are concentrated and discharged in one location, in a stream that is not channelled (Interview-B17).

Figure 5.1 Pinheiros River in São Paulo and the Traição pumping station in central São Paulo

Source: Author

5.3 The institutional framework for IWRM/IRBM in São Paulo

This section examines which formal institutions and organizations at multiple levels shape river basin governance in the MRSP.

5.3.1 Global level

International institutions finance mega-projects. The World Bank (partially) funded the 'Programa Mananciais' (Headwaters Program), which aims to preserve water sources and surroundings ecosystems.[29] The Inter-American Development Bank (IDB) funded the 'Tietê project', together with SABESP, which aims to clean the Tietê River by expanding sewage treatment services in the MRSP (see Box 6.1).

5.3.2 Transboundary level

The MRSP is not located within a transboundary river basin or aquifer. However, the Guaraní aquifer, measuring over one million km^2, reaches approximately 200 km from the city of São Paulo (DAEE, no date). Municipalities in the Western part of São Paulo State heavily rely on the aquifer. It is the world's largest aquifer and is shared by Brazil, Argentina, Paraguay and

29 Although this programme being on hold for lack of funding, it received USD$ 10 million in 2016 and 5 million in 2017 (SABESP, 2016, 2017).

Uruguay. While an integrated management agreement was signed in 2010 by the four nations, it did not include institutional arrangements for its implementation (Silva and Barbosa Pereira, 2018).

5.3.3 NATIONAL LEVEL

During the military dictatorship that started in 1964, Brazil experienced a process of centralization that eliminated elections at state and municipal levels, and reduced their fiscal autonomy (Abers and Keck, 2004). Water management was fragmented between national line ministries and between government departments at state level, while also centralized, technocratic and top-down (Abers and Jorge, 2005; Kellas, 2010; OECD, 2015c).

The democratic shift of the 1980's promoted political and financial decentralization and civil society participation, which became important characteristics of new Brazilian federalism (Eghrari, 2012). The 1988 Constitution engendered widespread reforms across sectors and substantial revenues were transferred from federal to state and local governments (Abers and Keck, 2004). The Constitution states that all waters within the national territory are public, belonging to the nation if they cross state borders, and to a specific state if they are contained within its borders (Arts. 20 and 26, Federal Constitution). The Federal government is responsible for instituting a national system for WRM and defining criteria for water allocation (Art. 21). This only concerns surface water as all groundwater resources are under the exclusive domain of the states (Art. 26).

Enacted in 1997, the National Water Law (NWL) (Federal Law no 9.433) instituted the National Water Resources Management System (SINGRH). This was based on São Paulo State's Water Law, adopted in 1991 (see 5.3.4). It moved towards IWRM, as it considered the multiple uses of water and suggested a multilevel governance system, including integration, decentralization to the basin level and stakeholder participation (see Table ***5.2***). River basin committees are responsible for managing each basin through inclusive arrangements for stakeholder participation (equal representation of state government, municipalities and organized civil society) (Brazil, 1997: Art. 1) (see 5.3.5).[30] The Law recognizes water as a public good with economic value, and a limited natural resource –contrary to Brazil's traditional vision of water's inexhaustibility (Benjamin *et al.*, 2005). This framework therefore promoted a shift in the national discourse on water and introduced new instruments (see 5.4).

The SINGRH sets national water management objectives, which it pursues through several key entities (for a detailed overview see ANNEX E - MAIN ACTORS IN SÃO PAULO'S METROPOLITAN WATER GOVERNANCE). The National Council on Water Resources (CNRH) is a multi-stakeholder platform for river basins of Federal domain. The National Water Agency (ANA) regulates bulk water use and water use permits for water bodies under federal jurisdiction.

Although this model of WRM is over two decades old, power asymmetries remain and

30 Federal basin committees are created for river basins of federal domain, and state basin committees for basins of state domain.

maintain a centralized power structure in practice at the state level (Porto and Porto, 2017). Environmental politics more broadly have suffered from the deterioration of the relationship between the State and civil society organizations (CSOs) and a focus on mega-infrastructure projects and expanding natural resources extraction (de Castro and Motta, 2015).

Table 5.2 Main aspects of the National Water Law of 1997

Approach to water	Public good
	Limited natural resource with economic value
	WRM provides for the multiple uses of water
	Water for human and animal consumption have priority in times of scarcity
	River basin as the territorial unit for policy implementation
	Decentralization of WRM and participation of the Public Authority, users and communities
Goals	Ensure current and future generations the necessary water availability in quality standards appropriate to their uses
	Rational and integrated use of water resources, including waterway transport, aiming for sustainable development
	The prevention and defence against critical hydrological events of natural origin or arising from inappropriate uses of natural resources
Key actors	The National Council of Water Resources (CNRH)
	The National Water Agency (ANA)
	The River Basin Committees for national rivers
	The State and Federal District Councils on Water Resources
	The federal government, state, municipal and federal district bodies whose responsibilities relate to WRM

Source: Federal Law no 9.433, 1997

5.3.4 State level

In 1991, São Paulo State adopted IWRM through State Law 7.633 (São Paulo State Water Resources Policy), inspiring the 1997 NWL. This policy includes principles of decentralization, participation and integration. Integration concerns surface and groundwater, quantity and quality, and stakeholders (users, the Public authority and Civil Society).[31] The State Water Law created the State Council on Water Resources, which defines the water resources policy for water bodies under State domain and is responsible for its supervision and regulation. Other key state entities are the DAEE, SABESP, CETESB, EMAE and the Public Prosecutor's office:

The DAEE (Department of Water and Hydropower), a parastatal agency of the State Department of Sanitation and Water Resources (SSRH), implements the State's WRM policy. Created in 1951, it is an autonomous agency that oversees quantitative aspects of water management (i.e. dams for water supply, water use permits, macro-drainage and flood control)

31 Unlike the principles of decentralization and participation, the principle of integration does not have clearly defined mechanisms.

(DAEE, 2018). It allocates water by defining criteria for water use, issuing water use permits and regulating water uses (see 5.4.2). It is seen as technocratic, focusing on hard engineering and large works to control water, dominated by aging engineers and lacking in renewal and innovation (Interview-B6).

SABESP is the state Wat&San (Water and Sanitation) company, providing services to most MRSP municipalities and around half of those in São Paulo State (see 6.3.3). Due to its size and dominance within the MRSP, it also plays a key role in WRM. It has built multiple reservoirs that constitute the 'Integrated Metropolitan System' (see 5.4.1).

Another State agency, the Environment Department (SMA) is responsible for environmental policy. It addresses issues of water quality and, to a lesser extent, climate change mitigation and adaptation. CETESB (São Paulo State Environment Agency), an autonomous branch of the SMA, monitors and licenses activities that could cause pollution. More specifically, its activities include the 'green agenda' (suppression of forests, vegetation), 'grey agenda' (pollution sources, sewage and water treatment plants, landfills) and 'blue agenda' (areas of springs). CETESB works with municipalities, as this cooperation facilitates licensing and pollution control (CETESB, no date). It focuses exclusively on contamination but ignores issues such as climate change (Interview-B8).

The State office of the Public Prosecutor aims to defend the rights of citizens and the public's interest (MPSP, no date). Through special groups it acts on issues such as environmental crime and irregular land parcelling. It has been particular active on the issue of untreated wastewater discharge (Interviews-B22/B23).

Finally, the EMAE (Metropolitan Company for Water and Hydropower) is a state company created in 1998 that operates several hydropower plants (EMAE, no date).[32] It operates in close collaboration with the DAEE and SABESP (Interview-B19).

5.3.5 RIVER BASIN LEVEL

The 1991 State Water Resources Policy promoted the creation of basin committees across São Paulo State. The ATB committee was established in 1994 (SIGRH, no date) (see ANNEX E - MAIN ACTORS IN SÃO PAULO'S METROPOLITAN WATER GOVERNANCE).[33] This basin overlaps almost entirely with the MRSP's boundaries, leading many to refer to it as the 'metropolitan committee' (Brandeler, 2013). The area's complexity justified the formation of six sub-committees to manage the ATB's sub-basins (Campos, 2009).[34]

The basin committee has no direct influence on water allocation, which is the DAEE's responsibility. However, it sets the fees for bulk water use and can therefore impact water demand (see 5.4.3). It also has limited say on the planning and construction of large-scale

32 The EMAE originated in 1899 in the creation of the São Paulo Railway, Light and Power Company, a Canadian company that provided public transportation services and lighting São Paulo City (Custódio, 2012).

33 The first was the Piracicaba-Capivari-Jundiaí basin committee, a region with a history of strong participation regarding WRM.

34 Only the Alto-Tietê basin has this division.

infrastructure for WRM. The river basin committee emphasizes the role of municipalities in containing urban expansion in areas that are still undeveloped, particular those that contain springs (FABHAT, 2016). The committee's role in this is to support local actors in appropriating knowledge, information and actions developed at regional level (Interview-B6). Its own powers are limited as its decisions are not binding.

The basin agency (FABHAT) leads the elaboration of the basin plan, which establishes priorities for actions and projects (see Box 5.1), the water resources situation report, which monitors water quantity and quality indicators in the basin, and provides grants according to the criteria established by the committee (SIGRH, no date) (Interview-B20). These grants are available through the FEHIDRO fund (State Fund for Water Resources) (see 5.4.3).

Box 5.1 Alto-Tietê basin plan

The basin plan must have a 12-year planning timeframe, with short, medium and long-term goals (Deliberation 146, CBH-AT, 2012). The plan in place at the time of fieldwork (2017) was for 2009-2012, and was widely criticized for being outdated, and disproportionally focused on flood risks and piece-meal environmental education programmes (Interviews-B6/B7/B17/B24). Water quality was not granted significant attention (Interview-B7).

The basin plan was under revision at the time of fieldwork through a more inclusive and multi-disciplinary process. This included developing the plan 'in-house' so that committee members would be familiar with it and 'own' it (Interview-B7). It was discussed with a wider group, including through public hearings (Interviews-B6/B7/B20).

Finally approved in 2018, the new plan includes a wider range of concerns, including climate change, adaptation, water demand reduction, water losses, wastewater recycling, (a much greater emphasis on) water quality, land use and development matters and lessons from the water crisis (although no contingency plan thus far) (FABHAT, 2016) (Interviews B6/B19/B20). It considers Wat&San services and supports municipalities in developing their own (Interview-B11/B12). The plan aims to go beyond diagnostics and provide concrete planning and actions, including for the protection of areas of springs (see 5.4.4) and for flood risk management (see 6.4.2) (Interviews-B6/B7). The new plan identifies the interconnection of water supply systems within and beyond the basin as a potential, though short-term, solution to water shortages, and it supports further research on the potentiality of aquifers (FABHAT, 2016). The sub-basin committees develop plans separately, and these were not necessarily coherent with the main basin plan.

5.4 Instrument analysis

5.4.1 Inter-basin water transfers

Design

The MRSP mostly uses surface water sources. As water availability within the ATB became insufficient (or too contaminated), SABESP's unofficial strategy for 'water security' shifted to importing water. Construction began in 1966 of an inter-basin water scheme (the Cantareira System) from the neighbouring PCJ (Piracicaba-Capivari-Jundiaí) river basin (Braga *et al.*, 2006). Of the 81m3/s of water used in the MRSP, 33m3/s were imported from the Cantareira System (see Table *5.3*) (FABHAT, 2016; SABESP, 2019). A small section of the PCJ basin is within neighbouring Minas Gerais State, but the springs in that area produce close to half of the basin's water (ANA, no date).

The São Lourenço system, inaugurated in 2018, has contributed another 6.4m3/s to the MRSP from a river basin Southwest of the ATB. In 2018, SABESP also inaugurated an inter-connection between the Cantareira system and the Jaguarí dam in the Paraíba do Sul river basin, located Northeast of the MRSP (SABESP, 2017). This allows for diverting up to 8.5 m3/s towards the Cantareira system or 12.2 m3/s to the Paraiba do Sul system, depending on which is in greater need.

Table 5.3 SABESP Water production systems within and outside the Alto-Tietê Basin

System	Approximate production (m3/s)	Percentage of total production	Population supplied (in millions)	River basin
Cantareira System	33.0*	40.62%	7.5	Piracicaba-Capivari-Jundiaí
Alto-Tietê	15.0	18.46%	4.20	Alto-Tietê
Guarapiranga	15.0	18.46%	3.70	Alto-Tietê
Rio Grande / Billings	5.5	6.77%	1.20	Alto-Tietê
Rio Claro	4.0	4.92%	2.06	Alto-Tietê
Alto Cotia	1.2	1.48%	0.36	Alto-Tietê
Baixo Cotia	1.05	1.29%	0.42	Alto-Tietê
Ribeirão da Estiva	0.1	0.12%	0.04	Alto-Tietê
São Lourenço	6.4	7.88%	1.4	Ribeira de Iguape e Litoral Sul
Total	**81.25**	**100.00%**	**20.9**	

Source: Adapted from SABESP, 2019.

*Approximately 8 m3/s are used within the PCJ basin.

Inter-basin transfers require water use permits (see 5.4.2). The water transfers from the PCJ and the Paraíba do Sul basin spread across multiple states[35], and their permits involve agreements at federal level (SABESP, 2015) (Interviews-B2/B4). Water imports are contingent on sufficient water availability within water supply reservoirs and are compensated through water use fees (see 5.4.3).

35 The Paraíba do Sul basin spreads across the states of São Paulo, Rio de Janeiro and Minas Gerais.

Effectiveness on actors in terms of mandated goals

As of 2018, the MRSP received water from nine different water supply systems that interlinked to form SABESP's Integrated Metropolitan System. Different parts of the MRSP can be supplied by two or more systems, depending on the reservoirs' water availability (Interview-B4). Reliance on inter-basin transfers and the interconnection of water systems accelerated after the 2013-2015 water crisis, and according to SABESP representatives, this increased water security through increased reservoir capacity, but also by adding redundancy and flexibility to the system (Interviews-B4/B5/B33).

However, many non-state actors have argued that these large-scale works are only a temporary fix and that insufficient emphasis has been given to reducing water use, contamination and losses, or prioritizing certain uses (São Paulo (Estado), 2017, p. 178) (Interviews-B12/B14/B30/B31/ B32/B33/B34). The Alto-Tietê basin plan was not coordinated or made coherent with the basin plans from donor basins, limiting knowledge sharing and potential synergies (Interview-B20). SABESP's strategy also ignores drivers of climate change and population growth. As the MRSP expands, so will water demand and the need to search for more distant water sources at increasing costs. Climate variability and change, meanwhile, can both lead to increased water demand due to rising temperatures, and decreased availability with higher evaporation in dams and more frequent droughts. In the longer-term, exclusive reliance on this strategy is unsustainable.

Impact on inclusiveness and sustainability

Inter-basin transfers increased water supply in the short-term, but also caused environmental degradation while affecting aquatic species from changes in water flows. News reports from July 2018 claimed that after beginning operations, the Jaguarí dam dropped by 4m in 20 days (Lira, 2018). Land use changes around the dams, such as deforestation, can affect the springs that recharge them. The construction and maintenance of basin transfers was also expensive, but no cost-benefit analysis about this approach versus alternatives was publicly available.

Moreover, since the Cantareira System was built, the demand for water for public/urban use and irrigation within the PCJ basin increased significantly, causing tensions between the two basins over water allocation (Braga *et al.* 2006). It also represented a challenge for maintaining minimum environmental flows in drier periods (Ibid).

The MRSP's economic weight for Brazil and its dependence on water imports led the DAEE and the ANA to prioritize it in inter-basin transfer negotiations to guarantee continued supply, often at the expense of other urban areas (Interviews-B4/B34). Interference by agencies at higher levels may also be inevitable due to the contrasting interests of the two basins, which make decentralized management of such transfers unrealistic (Interviews-B2/B4/B5/B11/B12/ B22/B23). Such interference may also lead to the centralization of power and the side-lining of the basin committee and local governments (Interviews-B22/B23/B32). An example of how the imbalance in power relations impacts water allocation is that the Cantareira water use permit – which guarantees the transfer of 30m^3/s of water to the ATB – was renewed in the middle of the 2013-2015 water crisis in a top-down manner with little transparency or consideration for environmental impacts (Interview-B32/B33). The water use fees (see 5.4.3) that the PCJ basin received in exchange for the transfer were insufficient to compensate for the lost economic opportunities and environmental costs (Demajorovic *et al.*, no date).

SABESP's scale and resources have enabled its own plans to effectively become the State's Wat&San policy and to consolidate its conceptualization of water security as a supply-side problem (Interviews-B6/B11/B14/B22/B23/B31/B32/B33/B34). The basin committee considers SABESP's plans for its basin plan, but not vice versa, and there is no other WRM plan at any level that is utilized by the basin committee, municipalities, utilities and state actors (Interview-B16).

5.4.2 WATER USE PERMITS

Description

The 1997 NWL aimed to ensure quantitative and qualitative control over water resources by introducing water use permits and wastewater discharge permits (for the latter, see ANNEX G – ADDITIONAL INSTRUMENTS). Water use permits concern derivations or abstractions from surface or groundwater for various uses. Permits were granted if the volume in question could sustainably be abstracted from a certain water body.[36] This process required data on water availability in terms of quantity and quality, as well as on users upstream and downstream of the abstraction point (Braga *et al.*, 2008).

Permits were granted by the DAEE or ANA, depending on whether the water resources were of state or federal domain (Brazil, 1997 Art. 14). They were registered to a specific holder, abstraction point and type of use, and were subjected to inspections. Permits could be transferred to other holders for an administrative fee (DAEE, 2017). They were valid for a maximum of 35 years but could be renewed, and they were subject to the water use priorities' ranking established in the state water resources plan. Each state defined its own criteria for issuing water use permits. São Paulo State applied the 'Q7,10' method to define the minimum environmental flow: the drought flow over a period of seven consecutive days that occurs approximately once every 10 years (São Paulo State Legislative Assembly, 1994). Holding a permit is a prerequisite for obtaining an environmental license from CETESB for activities or enterprises that affect waterways (either through abstraction or discharge). The environmental licensing process involves an environmental impact assessment (EIA). The basin committee and agency had no role in granting water use permits (Interview-B20).

Effectiveness on actors in terms of mandated goals

Water permits allowed the State to control water use, and improved on the existing situation of private appropriation of water resources with no accountability (Menezes Da Costa and Tybusch, 2015). Permits had to be compatible with the state's water resources plan, which

36 Sustainable abstraction depends on the effect on the water stock or flow.

ensured that it was consistent with water use priorities defined by participants. Moreover, as permits were a prerequisite for obtaining an environmental license, WRM could be coordinated with environmental management.

Nevertheless, despite relative water scarcity, there were no quantitative restrictions to obtain a permit beyond the ‘Q7,10’ method standard in the ATB.[37] São Paulo State holds areas with restrictions on extractions due to quantity or quality concerns, generally where groundwater extraction is more widespread. Nonetheless, there were zones with restrictions on extractions due to quantity or quality concerns, but there were no restrictions in the ATB (Interviews-B16/B20). Agricultural users do not have water metres, encouraging wasteful irrigation practices, and the DAEE lacks capacity to adequately monitor users and ensure compliance with allocated volumes (Interviews-B5/B6/B8/B16).

There were also no substantial qualitative or environmental criteria for granting water use permits (Interviews-B5/B6/B29).[38] The CETESB was not involved in this process (Interview-B10). Although the new river basin plan also aimed to reduce water demand, this topic was still marginal within the basin committee’s discussions (Interview-B14). In certain circumstances, such as environmental degradation, a permit could be suspended (Brazil, 1997 Art. 15). However, the DAEE eased regulation by only requiring users to have the necessary paperwork required for a permit and not necessarily verifying it (Interview-B16).

Impact on inclusiveness and sustainability

Although the water permit system gave the DAEE greater control over who had access to water, it did not reduce overall water allocation. In the MRSP and surroundings, the majority of water permits were for surface water resources, and groundwater use was often dismissed as irrelevant by respondents (Interview-B19).[39] However, it was estimated that around 11m^3/s of groundwater were extracted across the MRSP, and clandestine groundwater use was estimated to be significantly above registered use (FABHAT, 2016; OECD, 2017) (Interviews-B4/B5/B20/B28).[40] Registered and unregistered wells increased significantly during the water crisis, particularly by residential and commercial buildings in the (wealthier) centre of the city, with often no quality regulation, exposing users to potential public health risks (Interview-B6/B7/B19).

Municipal utilities could obtain permits for water resources beyond their borders, but this required agreements with the state government and the municipalities where water would be abstracted, as well as large infrastructure investments to transport this water (Interviews-

37 However, the issuing of new permits was temporarily suspended during the 2013-2015 water crisis.

38 A SABESP official specified that users will not receive permits for water of low quality, but criteria around this are not formally defined (Interview-B5). Further, there were no criteria that restrict groundwater use near potential pollutant sources such as gas stations.

39 The Guaraní Aquifer is too far from the MRSP to be used (with current infrastructure and technologies), while the aquifer below the MRSP had limited capacity and is susceptible to contamination.

40 A SABESP official claimed that there were around 5000 registered groundwater use permits out of an estimated 12,000 total wells (Interview-B5). Unregulated wells could be located in areas at risk of contamination (e.g. near gas stations) (Interview-B10).

B22/B23). As a result, if they needed to import water, they bought it from SABESP. According to some respondents this created a dependency on the state and pushed municipalities to delegate water services to SABESP (Interview-B36).

5.4.3 Water use and wastewater discharge fees

Description

River basin committees can choose to charge bulk water use fees to users holding water use permits within the basin (i.e. user-payer policy), except those of the energy sector (CEDE, 2015).[41] Water use fees aim to: (a) recognize water as an economic good and give users an indication of its value; (b) incentivize rational water use; and (c) obtain financial resources to fund programmes and interventions defined in the basin plan (Brazil, 1997 Art. 19). The fees should not significantly increase costs but be sufficient to promote behavioural changes inducing rational water use and constitute a financial reserve for rehabilitation actions within the basin (CEDE, 2015).

After years of debate, this system was implemented in the ATB in 2013/2014.[42] The fees include an abstraction, consumption and discharge component[43] and reflect the relationship between availability and demand (MMA, 2010). Their value is discussed and agreed on within the basin committee, and the collected fees go to the State Fund for Water Resources (FEHIDRO) (Interview-B20). This fund must be used within the river basin in which it was collected, to finance studies, programmes, projects and works and to pay administrative expenses (Brazil, 1997 Art. 22). The river basin committee members decide how the funds are used, based on the goals and actions outlined by the basin plan, reviews by the technical boards and voting in plenary sessions (Interview-B20). All committee members can propose projects, which are then reviewed by the technical boards of the committee.

The PCJ Committee charges an additional fee (0.02 Real/m^3) if water is not returned to the basin – as is the case with inter-basin transfers. However, SABESP negotiated a 50% discount on this fee for imports from the Cantareira System to the MRSP in a 2006 agreement (when the PCJ implemented water use fees) (Consórcio PCJ, 2018). SABESP's aim was to limit the impact of the transfer fee on water tariffs in the MRSP.

Effectiveness on actors in terms of mandated goals

The implementation of water use fees has led to a slightly greater awareness of the value of water but limited increase in rational water use. However, collecting the fees is difficult. When

41 The energy sector pays a "financial compensation for water use for electricity generation", which aims to indemnify states, the Federal District and municipalities for liabilities caused by this activity.

42 The PCJ basin, where the Cantareira system is located, was the first to implement it, and many basins are yet to follow suit (Interviews-B5/B29).

43 The abstraction fee is 0.01 Real/m^3, the consumption fee is 0.02 Real/m^3 and the discharge fee is 0.10 Real per kg of Organic Water Pollutant (Interview-B20).

first implemented, it was estimated that the total collected fees would sum up to USD 10 million per year, but in 2015 the collected total amounted to just over half of that (FABHAT, 2016). Users must send proof of their water meter reading and, if they fail to comply, they are charged the full amount they are authorized to use according to their permit (FABHAT, 2017). They therefore lack incentive to declare uses above their permitted use. Water utilities and industries pay the same fees. If utilities have a 'Water Losses Master Plan", and industries a rational water use programme, they pay 20% less (São Paulo State, 2010). However, agricultural users do not pay any water use fees (Interview-B6). As agricultural use is relatively low in the ATB, as most of the land is either urbanized or protected, urban and industrial users were the main contributors (Interviews-B1/B6/B10).[44] Moreover, due to high levels of urban and industrial use, the ATB collected higher fees than most basins, and therefore had a more substantial budget (Interview-B25).

The value charged was too low to lead to substantial reductions in water use (e.g. for large industrial users it was often not even 1% of their advertising costs) (Interviews-B7/B11/B25/B29/B32). Estimates indicate that, in 2017, SABESP paid around USD 19 million in bulk water fees within São Paulo State out of its USD 3.6 billion revenue (Interviews-B11/B29). Moreover, the rate per cubic metre decreases as the volume used increases, which incentivizes wasteful practices (Interview-B29). In recent years, the PCJ Committee has attempted to renegotiate the discount fee for inter-basin transfers and strengthen the shared management of the Cantareira System (Consórcio PCJ, 2018). Additional funds would be destined to the economic sustainability of municipalities upstream of the Cantareira system, and the protection of springs.

Another challenge concerns uncertainty around the cost of treating wastewater discharge to the quality standards required (see 0). With better knowledge of these costs, a more adequate system of fees can be designed that could decrease water use or increase wastewater treatment (Da Silva and Rios Ribeiro, 2006). Some industries were reported to have reduced their permit's allocated volume of water, reduced their water use and adopted measures such as wastewater reuse, although these cases still seemed marginal (Interviews-B7/B20/B34).

Impact on inclusiveness and sustainability

The implementation of these fees has increased the committee's budget tenfold and revived participants' interest in the basin committee (Interview-B16). While the fees charged were not large for SABESP, they can strengthen the committee and allow for capacity-building and investments in protecting water resources (Interviews-B4/B6). However, the FEHIDRO fund cannot be used to address land use and housing-related issues in areas of protected springs that significantly contribute to water-related challenges. This falls under the mandate of other actors, who are not integrated with the basin committee (Interview-B15).

44 A member of the committee and civil society representative estimated that SABESP and large industrial users contributed approximately 60% to the budget (Interview-B35).

Furthermore, at the time of fieldwork, the basin plan, which determines the priorities for actions financed by the FEHIDRO fund, was outdated and widely criticized for being inadequate (Interview-B29)[45]. Potential recipients (e.g. municipal departments) often lack the technical capacity to elaborate projects that comply with the criteria (CEDE, 2015). There was also disagreement within the basin committee on whether to spend FEHIDRO funds on investments in sanitation. While progress is urgently needed on the latter, this is the mandate of Wat&San utilities and not the basin committee.

Tensions have risen between the ATB and PCJ committees, as the latter claims greater compensation for the use and transfer of its water resources. The importance of the MRSP at national level has contributed to top-down intervention by SABESP, the DAEE and the ANA to ensure its access to subsidized bulk water.

5.4.4 Areas of Protection and Rehabilitation

Description

In 1975-76, São Paulo State adopted legislation for the protection of areas surrounding springs, streams, reservoirs and other water bodies of interest in the MRSP, with the aim to protect these areas' water production services by regulating land use and land occupation, Wat&San services[46], and natural resources management (São Paulo State, 1997) (Interview-B10). However, as the city grew, real estate and political interests in developing these areas were high, and these laws were not adequately enforced, resulting in informal occupations (FABHAT, 2016) (Interviews-B5/B7/B14/B17/B19/B33/B36). There was no public policy to address regional inequalities and unequal urbanization (Interview-B33), nor metropolitan-level planning for these areas.

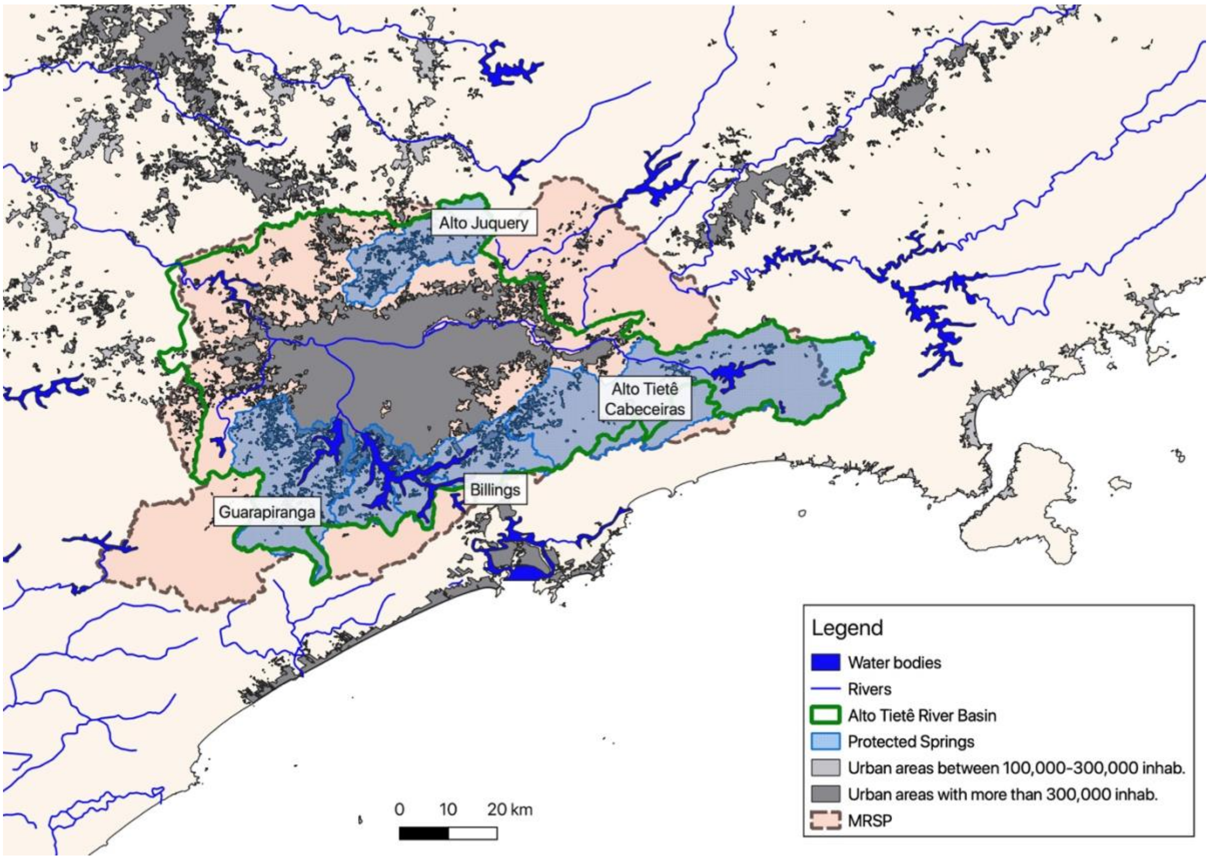
Hence, in 1997, a new State Law (n$_o$ 9.866) was adopted setting guidelines and norms for the protection but also the recovery of areas of springs of regional interest in São Paulo State (São Paulo State, 1997). This led to the creation of four Areas of Protection and Recovery of Springs (APRMs), located within the ATB and corresponding to 55% of its territory (FABHAT, 2016) (see Map **5.1**). APRMs aim to 1) preserve and rehabilitate springs of regional interest for public supply; 2) harmonize these actions and environmental protection more broadly with land use and socio-economic development; 3) promote participatory management; 4) decentralize the springs' planning and management; and 5) integrate housing policy with environmental protection (São Paulo State, 1997). Sub-basin committees are responsible for developing specific plans for each APRM, aligned with the basin plan (Interview-B6). These plans must establish policy guidelines on housing, transportation, environmental management and infrastructure that interferes with the springs' water quality.

45 A large proportion of funds were spent on small-scale, scattered environmental education projects or other local projects, with insufficient transparency on project selection, spending and impact assessment (Interviews-B5/B17/B29).

46 This concerns water treatment, stormwater drainage, flood control, solid waste management, sewage management and the transmission and distribution of electric energy.

Within the APRMs, there are three categories of 'Intervention Areas': 'Areas of Restriction to Occupation', which have the highest level of protection; 'Areas of Directed Occupation', which may be developed for urban or rural uses if these comply with a number of criteria for environmental preservation, and; 'Areas of Environmental Rehabilitation', which compromise the areas of springs and require corrective intervention (São Paulo State, 1997). Each of these areas have guidelines and norms.

Map 5.1 Expansion of urbanization towards areas of protected springs in the MRSP



Source: Author

Effectiveness on actors in terms of mandated goals

This focus on areas of springs is a more pragmatic approach that allows for regularization and slum upgrading in some cases. It differentiates between areas that are more and less important to the protections of the springs and reservoirs. The installation of sewage infrastructure is possible even in the most restrictive 'Intervention Areas, but must be approved by CETESB, and the discharged effluents must be compatible with the classification of the receiving water body (São Paulo State, 1997). The CETESB is focused on environmental issues and land occupation is not its priority, which limits the integration between the two policy areas (Interview-B15). The lack of integration between different mandates and goals favours the maintenance of the status quo in practice, with environmental actors reluctant to regularize settlements or approve basin infrastructure (Interview-B5/B15/B20).

As with the previous legislation, the APRMs require constant monitoring and interventions, and municipalities lack such capacity (FABHAT, 2016) (Interview-B14). They were often blamed for their lack of planning and control over developments within their borders, while utilities were criticized for their lack of sewage treatment (Interviews-B5/B10/B22/B23). Even if they can install sewage collection infrastructure, connecting households to sewage treatment plants remains a challenge (Interview-B10).

An important hurdle is the incompatibility between municipal master plans and the APRM's specific laws. Comparing zoning maps of APRMs with municipal zoning maps reveals different delimitations and land uses for the same areas (Nascimento, 2019). In many cases, municipalities did not update and harmonize their master plans with the APRM legislation (Interview B30). This confusion facilitates and obscures inadequate land use.

In addition, neighbouring municipalities within APRMs often did not coordinate preservation adequately as land use management is a municipal responsibility (Interview-B20; B30). This made common policies difficult to agree on.

Impact on inclusiveness and sustainability

Some municipalities of the MRSP have large portions of their territory within APRMs[47], which restricts their ability to obtain environmental licenses from CETESB for development, condemning them to poverty and informality (Interview-B7). The new legislation is more permissive and has allowed for regularization in some areas and thereby the installation of basic urban infrastructure and sanitation services. Between 2008 and 2015, over 1000 km of sewage pipes were installed in the APRMs (FABHAT, 2018). Despite this, the effects on slum upgrading and the reservoirs' water quality have been subpar (e.g. phosphorus levels in effluents remain significantly above targets). In 2013/2014 studies reported cases of water-borne diseases within the Guarapiranga and Billings APRMs and showed that contamination levels remained significantly above the target levels (FABHAT, 2016). In 2015, the CETESB registered high mortality rates in fish and other aquatic fauna (FABHAT, 2016). Moreover, urbanization growth is higher within the APRMs than in the rest of the basin (FABHAT, 2016), indicating that not enough is done to prevent new informal settlements from developing in these areas. However, as the plans for the APRMs were implemented only in 2006 and later, it may be too early to conclude about their success.

5.5 Instrument assessment and redesign

The instruments employed in river basin governance in the MRSP show mixed results, both in terms of their ability to change actors' behaviour and to foster more sustainable and inclusive water governance (see Table ***5.4***).

47 17 municipalities of the MRSP have at least 50% of their territory inserted in an APRM, and 6 are entirely contained within one (FIA, no date).

Table 5.4 Assessment of IWRM/IRBM policy instruments in the MRSP

	Instrument design	Effect on actors in relation to mandate	Impact on sustainability and inclusiveness
Inter-basin transfer	[+] Aims to increase water supply and redundancy through integration Donor basin is compensated	[+] Increases supply and integrates supply systems Disincentivizes water demand measures Not a long-term solution considering drivers of CC and urban growth	Ecol: [--] Externalities are transferred to donor basin Soc: [+] Access to drinking water is high Econ: [-] Positive for MRSP but negative for donor basin, and costs are transferred to future generations Rel: [--] Donor basin has little voice in the process and its own development is affected
Water permits	[+] Dependent on water availability, considering minimum environmental flow and priorities ranking	[-] As a prerequisite, environmental licenses encouraged users to obtain water permits However, criteria to obtain one are too lax. Enforcement is weak, especially for agricultural users	Ecol: [-] Greater quantitative control of water resources, but no reduction of overall water allocation. Irregular (groundwater) use is high Soc: [-] Lack of qualitative control, with health risks Eco: [-] Irregular uses have short-term costs (i.e. loss of fees) and long-term costs (i.e. depletion) Rel: [-] The MRSP exports its water scarcity
Water use and wastewater discharge fees	[++] Reflect availability, promote rational use and are redistributed within basin	[+] Effects were limited by the fees' low value (stronger effect for industrial users) The general trend gives ground for optimism, as fees will be increased progressively	Ecol: [+] Limited impact, but as the fees' value rises it is expected that users will reduce use (assuming improved enforcement) Soc: [++] Utilities are charged lower fees than industries. The funds from the fee can also be used to support poorer municipalities Econ: [++] The basin committee's funds have increased, allowing it to invest more Rel: [++] As funds increased, interest in the basin committee rose and gave it more influence at regional level
APRMs	[+] Pragmatic approach to preservation and rehabilitation and more inclusive of marginalized residents	[0] Has enabled basic services provision to certain areas, although differences in plans and mandates between sectors and levels of government limit progress	Ecol: [+] Legalizing areas, allowing for sanitation infrastructure, may improve water quality more than full protection (with no compliance) Soc: [+] If implemented adequately, residents in these areas will have greater access to services Econ: [+] Legalisation adds paying water services consumers. If contamination is reduced, local water bodies become usable, reducing reliance on imports Rel: [+] It has potential for better integrating marginalized areas within the MRSP

Relative assessment scores: ++ Very positive; + Positive; 0 Neutral; - Negative; -- Very negative (See Section 2.4)

Redesign

Based on the evaluation of the above instruments, the following redesign options are recommended.

No additional inter-basin transfers: The conceptualization of water security must integrate demand-side measures and the preservation of ecosystems in order to be sustainable. As SABESP depends on water sales for its revenue, it lacks incentive to reduce these. If bulk water in other basins becomes more expensive, through higher bulk water use and inter-basin transfer fees, users may have an incentive to reduce imports and improve the quality of nearer water sources. The cancellation of SABESP's discounted inter-basin fee – potentially over the course of several years to allow it to adjust – could incentivize water conservation and investments in alternative strategies (e.g. wastewater reuse, rehabilitation of the ATB's water bodies by expanding wastewater collection and treatment), while increasing revenue for the PCJ basin committee preserving the Cantareira System and sustainable economic activities around it. The PCJ Committee and other stakeholders from donor basins require a greater voice in decision-making processes that involve water transfers, to negotiate outcomes that benefit both donor and receiving basins.

If the aim is to achieve sustainable and inclusive development, alternative measures to additional inter-basin transfers can be explored. Those that are in place will be in use for a long time (lock-in effect), but as water demand is expected to increase with urban growth and climate change, this allows for a slow transition while other measures such as wastewater treatment and reuse and water saving equipment are progressively scaled up.

More scrutiny on the issuing of water permits: Although more water is allocated to public supply than other uses, the allocation of permits to intensive industries, a use of lower priority than drinking water consumption, could undergo more rigorous scrutiny of costs and benefits. Incentives can be put in place to nudge industries towards water reuse. For instance, flexibility can be introduced in permits so that users could still receive part of their water through the public supply, subsidies could be granted for investments in the necessary technology, and reuse could be incorporated into certifications or labelling schemes recognizing greener industries. Industries could also establish partnerships with sewage treatment plants, if located nearby (e.g. receiving treated wastewater at a discounted price, or for free in exchange for their water use permit). These measures require adequate risk assessments.

In addition, water abstractions without permits must be addressed. A starting point can be industries and commercial or large residential buildings, as they are more likely to use groundwater. More reliable and easily accessible quantitative and qualitative data is also necessary to prevent over-abstraction, as it would enable more effective monitoring of users. Groundwater use is practically ignored by key actors despite estimates of significant (unregulated) use, and this could receive greater attention if groundwater management was effectively included within water resources management. Furthermore, despite the need for inter-basin transfers, water use permits continue to be granted to new users. The DAEE could introduce a restriction zone within the ATB, increasing requirements for obtaining a permit (e.g. through environmental and social impact assessments, compensation mechanisms), and potentially creating a moratorium on new permits, where users can still transfer existing permits.

Expand water use fees (progressively): The return of water use fees to the basin committee, to be spent on projects within the basin, according to priorities that were set in a collaborative manner, has strengthened participatory basin management. The fees are still too low to have a significant effect and nudge users towards conservation or reuse. A sudden increase in rates would mainly create difficulties for smaller users. However, a progressive, annual increase (as was done in other cases, such as in French basin agencies) would allow users time to adjust, for instance by adopting water saving technologies or switching to water reuse. To prioritize water for public supply, an increase in water use fees can be part of a differentiation between types of users. Large, lucrative industrial and commercial water users could be charged a higher fee. Agricultural users could be charged a fee, albeit significantly lower, to discourage wastewater irrigation practices. Efforts could also be made to increase the proportion of water users that pay these fees, which is linked with enforcing water permits.

Integrating APRMs in regional, inter-sectoral planning: The APRMs represent a more pragmatic approach to preserving BESS within and around the mega-city. Although concrete results are still limited, with proper implementation this instrument has potential to keep uncontrolled urban growth in check. One obstacle is the incoherence of plans and mandates at different levels of governance and across sectors. Municipal actors must reconcile state-level environmental policies with their constituents' demands for housing and basic infrastructure and services, with often limited human and financial capacity. The new basin plan aims to support municipalities to make their municipal Wat&San plans and drainage plans compatible with the basin plan, and thereby with the APRMs. As an incentive, municipalities that do so could receive points within the point system for applying for FEHIDRO funds, which would increase their qualification for receiving funds. If municipal Wat&San plans are coordinated with land use management and urban planning, they could identify parts of informal settlements that can be legalized, that can be upgraded with certain services or that must be relocated (e.g. areas at risk or where no form of sanitation can be installed).

Moreover, regional planning could identify areas to direct urban growth and densification, with shared efforts towards the protection of environmentally valuable areas so that it does not fall disproportionally on the shoulders of peripheral municipalities with limited budgets. Such regional spatial planning has greater potential if it is linked to the granting of environmental licenses, and thereby to water use and discharge permits. The Integrated Urban Development Plan for the Macro-metropolis (see 6.3.4), under development at the time of research, aims for regional planning on land use, Wat&San, environmental matters, water resources, housing and more. It remains to be seen whether it will develop instruments promoting a shared regional vision and a fairer distribution of the costs of preserving crucial ecosystem services.

Missing instruments

In addition to the changes above, the suggestions below could be incorporated into the instrument mix.

The research found that no significant suasive instruments were in place. The basin committee and other organizations had supported environmental education initiatives and awareness campaigns, but these tended to be small-scale and piece-meal, and they had not been assessed to examine results. On the other hand, during the water crisis, media reports, documentaries and other sources were effective in spreading awareness about the need to drastically reduce water use. In Spain, campaigns to promote awareness on the need for rational water use and the use of water-saving technologies have had major impact on reducing water consumption (Tortajada *et al.*, 2019). The challenge in São Paulo is the state government's own reluctance to discuss water scarcity. The basin committee could partner with multiple NGOs (and even the private sector) to develop a more comprehensive, large-scale awareness campaign.

PES programmes have been implemented in some parts of Brazil, but not in the ATB. Their effective implementation presented several challenges, such as continuity if they depended on donations. However, with stable funding, they could be used to help preserve areas of springs. They can link users to the ecosystems that they rely on and help make this relationship more visible and valued. If FEHIDRO funds increase, through the collection of water use fees, a portion could be allocated in this way and be linked to the APRMs.

The NWL originally included financial compensation to municipalities (for land use and development restrictions due to environmental and zoning regulations) as one of its instruments, but this was ultimately vetoed. Several respondents mentioned that a financial compensation instrument would not only be fair, considering the disproportionate negative externalities put on peripheral, poorer municipalities for benefits in the urban core. This could be linked to wastewater discharge fees or to taxes on real estate developments and industries. This could also make polluting more costly and incentivize polluters to invest in sewage treatment, reuse and other measures.

6. THE IMPLEMENTATION OF UWM IN SÃO PAULO

6.1 INTRODUCTION

This chapter examines how different drivers and institutions at multiple levels of the urban water governance regime shape water-related challenges in the Metropolitan Region of São Paulo (MRSP). It uncovers the causal chains behind these water challenges and the effectiveness of existing policy instruments. It reviews the relevant context of Brazilian urban water governance and its main drivers (see 6.2); analyses the driving forces according to their scalar level; explores which formal actors and institutions shape Urban Water Management (UWM) (see 6.3); analyses the instruments of UWM according to their stated mandates, their effect on actors' behaviour and their impacts on inclusive and sustainable water governance (see 6.4). Finally, the chapter summarizes the main empirical findings and considers how more appropriate instruments could be (re)designed for São Paulo in relation to UWM (see 6.5).

6.2 CONTEXT AND DRIVERS OF SÃO PAULO'S URBAN WATER CHALLENGES

6.2.1 CONTEXT IN RELATION TO THE METROPOLITAN REGION

São Paulo was founded in 1554, but remained a small and relatively unimportant settlement until the 19th century, when the country attained independence and the Southeast developed the coffee industry (Bógus and Véras, 2000).[48] Since the 1930's, São Paulo has transitioned into a new period of industrialization and the city has experienced exponential urban growth (see 2.2.2). With few natural barriers, the city expanded horizontally, absorbing surrounding towns and transforming into one of the world's largest metropolises. The MRSP is composed of 39 municipalities, occupying an area of 8,050 km^2 (Kellas, 2010).

6.2.2 MAIN DRIVERS OF SÃO PAULO'S URBAN WATER CHALLENGES

Table ***6.1*** provides an overview of the main direct and indirect drivers at multiple levels of urban water challenges in the MRSP.

Urbanization

Unplanned urbanization in the MRSP has contributed to soil-sealing[49] and the occupation of hillsides, aggravating the risk of floods and mudslides (Jacobi *et al.*, 2015; FABHAT, 2016; Bis, 2017) (Interviews-B14/B17/B19). These risks are compounded by inadequate sanitation and solid waste management, and poor citizen awareness, causing the accumulation of waste in streams and rivers that consequently clog drains and stormwater channels (Jacobi *et al.*, 2015; Bis, 2017) (Interviews-B16/B17/B19).

48 São Paulo's population was 30,000 in 1872 when the first census was conducted (São Paulo, no date).
49 It is estimated that 37% of the land within the ATB is impermeable (Jacobi *et al.*, 2015).

The lack of spatial planning has facilitated the multiplication of informal settlements, while real estate speculation and a lack of affordable housing policies have facilitated vacant plots and inner-city buildings, and the inadequate enforcement of land use regulations has allowed for the construction of luxury developments on the edge of the Pinheiros River (Monteiro *et al.*, 2017) (Interview-B15/B19).

Rapid urban growth, mainly through rural to urban migration due to the modernization of agriculture and the expansion of industrialization, has meant that cities could not meet the growing need for housing, which stimulated the occupation of abandoned buildings in inner cities and the expansion of informal settlements within and around cities (Jacobi, 2004; Monteiro *et al.,* 2017) (Interview-B15). Local governments and utilities could also not meet the growing need for Wat&San services (FABHAT, 2016). Informal settlements spread to the margins of the MRSP, and especially to the East and South, around springs and water supply reservoirs, as these were vacant being Protected Areas relatively near the urban core (see 5.4.4) (Alvim and Kato, 2011; Rolnik and et al., 2015). This has reinforced marginalization processes, as low-income residents were living increasingly far from the urban core, in precarious housing, and without access to land tenure and access to adequate infrastructure and services (Denizo, 2009; Monteiro *et al.*, 2017). Rivers and streams became progressively more polluted, with downstream municipalities particularly affected.

From the 1970's, housing programmes were designed by all levels of government in response to the growing low-income housing crisis.[50] These were mainly designed to fulfil the primary need for shelter with less consideration for urban planning and basic infrastructure and services (e.g. drainage, sanitation, lighting, and other public services) or environmental impacts (Interview-B30). Housing projects were mainly developed in the MRSP's periphery (Rolnik and et al., 2015). Housing programmes were also not linked to other policies promoting social inclusion, such as access to education and jobs, nor did they consider factors such as the target population's limited ability to pay taxes and maintenance and utility costs, their proximity to jobs, or the loss of social fabric that can come from uprooting communities (Denizo, 2009). These programmes also soon stopped targeting the poorest section of the population, due to the high default rate on subsidized loans offered for the acquisition of a home (Monteiro *et al.*, 2017). Federal government action has focused on promoting housing programmes rather than developing a housing policy that considers slum upgrading and linkages with land use management and with urban planning (Marguti, 2018) (Interview-B30).

Economic development

Municipalities lack the financial and human capacity to contribute adequately to investments in Wat&San services. This motivates many to delegate the responsibility of service provision to the state water company, SABESP, or (more rarely) to a private company. Municipalities, especially small ones, often rely significantly on financial support from the federal government.

50 The State is responsible for the housing needs of those that cannot access the formal housing market (Denizo, 2007). It operates through the State Housing Department and the Housing and Urban Development Company of São Paulo State (CDHU). The CDHU attends families that earn between one and 10 minimum wages (CDHU, no date).

The economic crisis that hit Brazil in 2012 further reduced budgets at all levels of government for sanitation and risk prevention.

Heat island effect

Furthermore, large-scale urbanization has triggered the heat island effect. This, combined with water shortages, is believed to have caused a severe dengue epidemic during the 2013-2015 water crisis (Clorosur, 2015) (Interview-B33). The heat island effect also leads to a decrease in atmospheric pressure causing heavier precipitation (Goldenstein, 2017).

Table 6.1 Multi-level drivers of water-related challenges in the city

	Direct		**Indirect**	
	Local	Regional / global	Local	Regional / Global
Land use change	Urbanization (especially unplanned, informal)	Urbanization		
Demographic	Population growth in urban periphery	Growing water demand for public supply	Rapid population growth during 20th century	Rural/urban migration
	Growing water demand for public supply			Population growth in nearby regions
Economic development	Insufficient investments in sanitation and solid waste management		Economic centre of Brazil	Economic crisis in Brazil (2012-ongoing)
Environmental awareness			Lack of environmental awareness	
Climate			Heat island effect	Climate variability and change
			Drought of 2013-2015	

Source: Author

6.3 Institutional framework

Actors and institutions of UWM at multiple levels shape metropolitan water-related challenges and responses to these in the MRSP (see Figure ***6.1***).

6.3.1 Global level

Global level actors have played a crucial role in UWM through the financing of infrastructure for Wat&San in the MRSP. The World Bank has granted loans to SABESP, for programmes aimed at reducing leaks and connecting areas using irregular connections to the public network (SABESP, 2018).

6.3.2 National level

During the 1970's, Brazil went through a period of important investments in Wat&San infrastructure, with the implementation of the PLANASA in 1971 (National Sanitation Plan). This centralized, top-down process, led by the military regime, focused on expanding water supply infrastructure through the creation of powerful state water companies (Saiani and Toneto Júnior, 2010; Jacobi *et al.*, 2015). The Federal government established policy guidelines for state companies, and municipalities were given a merely passive role in the sector (Sousa and Costa, 2016). Investments dropped sharply in the late 1970's, and the plan was abandoned in 1992, after the democratic transition. As the centralized state remains associated with the military dictatorship to this day, there is widespread support for decentralization as a mechanism for empowering disadvantaged groups (Abers and Keck, 2004). Although the Constitution gave municipalities the responsibility for Wat&San provision, a policy vacuum remained at national level until 2007 (Saiani and Toneto Júnior, 2010) (Interview-B36).

In 2007, the Federal Law No. 11.445 for basic sanitation established a legal framework for Wat&San services (Brazil, 2007). The definition of these services was expanded to include drinking water for public supply, the collection, treatment and discharge of wastewater, urban drainage, stormwater management and solid waste management.[51] This legal framework led to the National Basic Sanitation Plan (PLANSAB), which aims for the universalization and improvement of Wat&San services nation-wide (see Table **6.2**). It is based on the principles of universality, equity, integration (i.e. Wat&San services should be provided together), sectoral integration, economic efficiency and sustainability, and alignment with public health and environmental concerns. Although this is a distinctive shift away from the sectoral approach to Wat&San services, investments may be too low to reach the goal of universalization by 2033 (Almeida, 2017). The Law also explicitly stipulates that it does not address water resources management (Brazil, 2007, Art. 4). This reinforces a separation in Wat&San and WRM policies, as federal and state water resources laws focus on users and the municipality is not given a role (dos Santos *et al.*, 2019) (Interviews-B12/B15/B16/B32/B36).

The National Secretariat for Sanitation is responsible for implementing the PLANSAB in municipalities of more than 50,000 inhabitants (SNS, 2019). The Ministry of Health has this responsibility for municipalities below 50,000 inhabitants (Ibid). The Environmental Ministry is involved in urban water policy, such as flood control, areas of springs, and river parks.

Although housing policy is not directly linked to urban water governance, it indirectly plays a significant role, as access to water-related services and protection from water-related risks is significantly influenced by where and how people live. The 1988 Federal Constitution

[51] The Law defines national parameters such as minimum standards for drinking water and the promotion of incentives for conscientious water consumption (Paganine, 2015).

represented a turning point for housing policy, as it defined access to housing as a right and devolved greater responsibilities for social housing to states and municipalities (Souza *et al.*, 2009; Santos and Duarte, 2010). However, this was not combined with adequate financial mechanisms, which especially hampered municipalities' capacity to adequately respond to the housing demand (Santos and Duarte, 2010).

Table 6.2 Main aspects of the PLANSAB

	PLANSAB
Approach to Wat&San services	A citizen's right, fundamental to the improvement of their quality of life
Goals	Universalization, combined with fair prices and tariffs for: -access to drinking water -wastewater management (collection, treatment and disposal) -urban solid waste management (collection, treatment and disposal) -adequate urban stormwater management (and thereby flood control)
Key actors	Ministry of the Cities, through the National Secretariat for Environmental Sanitation (SNSA)

Source: Adapted from (Federal Law n_o 11.445, 2007)

In 2015, the 'Metropolitan Statute', a Federal Law, established an institutional framework for metropolitan governance and created norms and guidelines for "public functions of common interest" (Casa Civil, 2015). The enactment of this Law derived from a 2013 Supreme Court decision that stated that services of 'common interest' in metropolitan regions should be managed jointly by the state and local governments (Costa and Góes, 2013). As Wat&San services fall under this category, it has important implications for UWM in the MRSP. In fact, the debate behind this decision was prompted by ambiguity surrounding the mandates of Wat&San services in metropolitan regions (see 6.3.4). The Metropolitan Statute requires all metropolitan regions in Brazil to develop Integrated Urban Development Plans (IUDPs) that harmonize municipal master plans.

6.3.3 State level

There is no state-level legal framework for Wat&San, and state actors follow the PLANSAB's guidelines. Municipal governments are responsible for Wat&San planning and must guide the service provider's actions (see 6.3.5) (Brazil, 2007). Before the PLANSAB's adoption, state water companies often developed Wat&San plans, *de facto* shaping the sector's policies (e.g. defining priorities, tariffs) (Interviews-B4/B29/B30/B32/B34/B36). Key actors at state level are SABESP, ARSESP, the DAEE, EMAE and the Public Prosecutor's office.

The main actor for drinking water and sewerage services in São Paulo State is SABESP, the State Wat&San company, which operates in around half of the state's municipalities. The largest in South America, it serves approximately 27.7 million consumers, including in informal settlements (Tortajada and Biswas, 2018).[52] It is a Government-sponsored, publicly-traded company (51% owned by the State and 49% owned by stockholders) and is listed on the stock exchanges of São Paulo and New York (Brandeler, 2013). SABESP is autonomous but linked to the SSRH (State Department of Sanitation and Water Resources) (see 5.3.4), and was founded during the military dictatorship, when the federal government pushed for the establishment of powerful state companies. The company has been consistently profitable (Tortajada, 2008). The MRSP corresponds to approximately 60% of the SABESP's net revenue (Interview-B36). At the time of research, SABESP operated in 34 of 39 municipalities of the MRSP, although discussions were under way for its takeover of the operations in some remaining municipalities.

ARSESP (São Paulo State Regulatory Agency of Sanitation and Energy) is an independent regulatory agency, bound to the SSRH and created by the 2007 Federal Law on Wat&San. ARSESP regulates stated-owned sanitation services (i.e. SABESP's services), and some municipal and private companies' services. It promotes the expansion of these services at an affordable price, while meeting commercial (e.g. billing, tariffs) and operational (e.g. water quality) targets (Interviews-B11/B13). It also monitors whether utilities are meeting the targets established in municipal Wat&San plans, such as reducing leakages. It can punish the company or establish a Conduct Adjustment Commitment through which it converts a fine into an investment in the service. As the regulating agency was created long after SABESP and many private providers, it has had to negotiate its position and there are still some ambiguities regarding the limits of its role (Interviews-B5/B11). Overall, its powers are dwarfed by those of SABESP.

The DAEE is involved in UWM as it is responsible for macro-drainage and flood control around major rivers (i.e. those that cross municipal boundaries) (see 6.4.2). This means it must prevent flooding of the Tietê and Pinheiros Rivers within the MRSP. The EMAE also has mandates related to urban flood management within the MRSP, as it is responsible for controlling the volume of water in the canalized Pinheiros River to mitigate flood risks after heavy rains (EMAE, no date).[53]

The State office of the Public Prosecutor monitors, pressures and prosecutes polluting activities, and sets targets for municipalities towards the universalization of sewage collection and treatment services. This has incentivized municipalities to regularize informal settlements to allow for sewerage infrastructure to be installed, as removing populations is often practically impossible (Interviews-B22/B23). The Public Prosecutor's office was criticized for lacking technical knowledge and putting disproportionate blame on Wat&San utilities and local governments (Interviews-B5/B22/B23).

52 Initiatives such as the 'Legal Water' programme, initiated in 2016, aim to bring drinking water services to informal settlements (SABESP, 2018). This contributes to universalizing water supply services and reduces water losses from irregular connections. It represents a shift in urban policy towards proactively addressing the challenges of informal urbanization, through coordination between the utility and local government (Pasternark and D'Ottaviano, 2018). However, without land tenure, these interventions remain in a legal grey zone. Moreover, the physical layout can make the installation of sanitation infrastructure practically impossible.

53 The EMAE and DAEE can use the Pinheiros River as a reservoir when too much water accumulates in the Tietê River. A movable dam was built in the 1990's between the two rivers for this purpose (Interview-B19).

6.3.4 *Metropolitan level*

The MRSP was created in 1973 by Federal law (Brasil, 1973), as part of the technocratic and centralized planning apparatus of the military regime. The Federal Constitution of 1988 (Art. 25) delegated power to the states to institute metropolitan regions, urban agglomerations and micro-regions to bring municipalities together in the planning and implementation of public functions of common interest, such as Wat&San (Casa Civil, 2015). The MRSP almost entirely overlaps with the ATB (Alto-Tietê Basin), which indicates a significant opportunity for collective action and harmonized policies.[54] Nevertheless, metropolitan and basin institutions largely act separately (Interviews-B4/B15).

In São Paulo State, the EMPLASA (São Paulo State Metropolitan Planning Company) is responsible for regional and metropolitan planning, including the development of the Integrated Urban Development Plans (IUDPs) required by the 2015 Metropolitan Statute (EMPLASA, no date). It formulates policies at macro-metropolitan level on land occupation issues and compatibility with the region's sustainable development.[55] However, it lacks implementation power.

Inter-municipal consortia may also play a role in water governance at metropolitan level. They are legal entities with an autonomous governance structure and their own budget. They unite different municipalities in joint actions that, if produced individually by these municipalities, would not reach the same results or would require more resources (Vaz, 1997). Possible joint actions include public services (e.g. basic sanitation provision) and environmental protection. Some municipalities have formed consortia within the MRSP, with their success significantly dependent on coordination between local politicians and actors, as well as on available funding (Interviews-B8/B28/B22/B34/B36).

6.3.5 *Local level*

The Brazilian Constitution of 1988 required that services of 'local interest' must be managed by municipal governments (Constitution of Brazil, 1988). This decentralized power and enhanced the role of local governments in a wide range of policy decisions, although limited resources sometimes stretched their ability to design effective policies. Municipalities in charge of Wat&San services (including drainage and solid waste management) were generally understood as being services of local interest. Some municipal attributions relevant to water governance also include land use management, urban planning, basic health care centres, drainage systems and local environmental issues (Formiga Johnsson and Kemper, 2005, p. 24). They are also responsible for the areas of springs in their territory. Municipalities can therefore significantly influence local and regional water resources in terms of quantity and quality.

54 Only five municipalities of the MRSP are not part of the basin.

55 The São Paulo macro-metropolis encompasses four institutionalized metropolitan regions: São Paulo, Campinas, the Baixada Santista and the Vale do Paraíba, and the Northern Littoral, and several urban agglomerates and micro-regions. In 2010, this region had over 30 million inhabitants (EMPLASA, no date).

Municipalities are also in charge of drainage and flood control, although the State is involved in macro-level aspects. Municipal civil defence authorities must cope with the immediate consequences of flood risks, which especially affect informal settlements in floodplains and unstable hillsides (Interviews-B8/B17). Municipalities must develop master plans that combine these various functions. However, these often overlook the basin plan (Interview-B16). Integration between the basin and city plans has been hindered by a lack of funding to facilitate their coordination, and political will by local officials (Interview-B36).

Municipalities choose whether to provide Wat&San services through a municipal company, to contract a private company or to delegate the responsibility to a state company– in the case of São Paulo State, to SABESP.[56] Most municipalities within the MRSP have delegated these services to SABESP, but those that have not still bought at least part (and usually most) of their bulk water supply from SABESP, *de facto* connecting them to the Integrated Metropolitan System for bulk water management (Interview-B4). As groundwater was generally not considered a reliable or sufficient source, and many surface water bodies in the MRSP were contaminated, the reliance on water resources beyond municipal borders reduced local utilities' autonomy. Their sewage was sometimes also treated in a regional rather than municipal treatment plant (Interview-B4). Regardless of the service provider, the municipality remains responsible for planning and for ensuring a minimum volume of water per person per day (Interview-B32). Although municipal Wat&San plans are mandatory, lack of human and financial capacity has often led to low quality plans or plans copied from those of neighbouring municipalities plans (Interviews-B4/B7/B12/B30/B32/ B35).[57] These should be updated every four years, which is rarely done[58], and often do not match their context's reality (i.e. population growth, priority projects and investments), leading water companies to carry out their own planning in practice (Interviews-B11/B22).

After the approval of the 2007 Federal Wat&San policy, debate arose on the ambiguity surrounding *who* had the mandate for operating Wat&San services. The Law delegates the services to 'titleholders', but does not clarify who they are (Brazil, 2007). The issue of the mandate is controversial, as the military regime had pressured municipalities to delegate these services to state companies that were not regulated and received federal funds (De Sousa and Costa, 2016). In 2013, the Supreme Court ruled that municipal governments were indeed responsible for Wat&San services but that, within metropolitan regions, Wat&San services must be provided through shared management between municipalities and the State (Costa and Góes, 2013). This decision was largely based on the principle that such services were of common interest within metropolitan regions, rather than of local interest (Costa and Góes, 2013). This ruling led to uncertainty and significant debates on how to implement it in practice. The PLANSAB (see 5.3.3) has not yet been adjusted to include considerations for the Supreme Court decision.

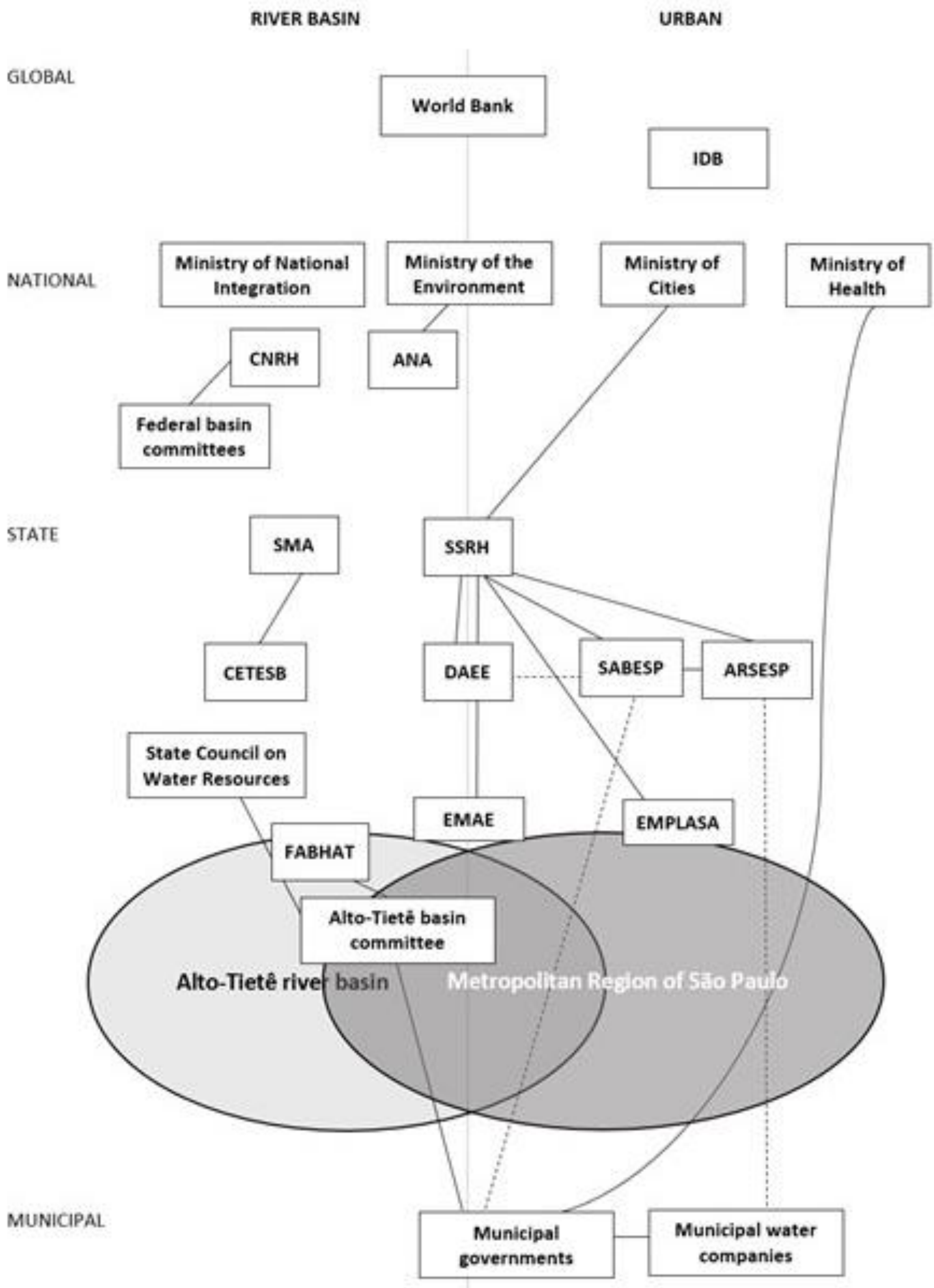
56 Solid waste management is typically partially or entirely outsourced, whereas drainage services are mostly carried out by municipal authorities as these have not found a way to monetize these services (Tucci 2009).

57 An official from a municipality of the MRSP (Interview-B21) was unable to find the municipality's plan after significant searching during an interview. An ARSESP respondent claimed that mayors are sometimes convinced that their municipality does not have a Wat&San plan (Interview-B11).

58 Even the municipality of São Paulo has not renewed its plan since 2009 (Interview-B12).

As can be seen, a mesh of actors is responsible for managing water in the MRSP, sketched by Figure ***6.1*** below.

Figure 6.1 Basin and urban water stakeholders in the MRSP



Source: Author

6.4 Instrument analysis

The performance of policy instruments is examined in relation to water quantity, water quality, and adaptation to unpredictable and extreme water-related weather events, and their consistency across multiple levels of governance.

6.4.1 Water and sanitation tariffs

Design

The 2007 Federal Law for basic sanitation, stipulates that utilities should ensure the financial sustainability of Wat&San services provision while striving for universalization of services and maintaining reasonable rates for consumers (Brazil, 2007). Contracts for water and sanitation services between a utility and a municipal government must also include targets for rational water use (Art. 11 (§2)(II)). The regulatory agency is responsible for defining economic criteria for these tariffs and potential subsidies (Ibid) (Interview-28). The basin committee is not involved in decisions, although ARSESP holds public hearings in which members can participate. SABESP applies the same tariffs in all the municipalities it operates in by using cross-subsidies, through which smaller, poorer municipalities are subsidized by more profitable regions such as the MRSP (Interviews-B5/B11/B28). In municipalities with other water utilities, tariff rates vary.

SABESP charges 'increasing block tariffs'. For water consumption between 0 and 10 m^3, SABESP consumers pay a fixed rate (ARSESP n.d.). The rate increases for each additional cubic metre and rises sharply above 20m^3 to incentivize rational water consumption (Interview-B4). Most utilities charge one tariff for water supply and another for sewage collection and treatment, regardless of whether a household's wastewater is treated (Interview-B28). As collecting and treating sewage is costlier than providing drinking water, there are cross-subsidies between these (Interview-B29). A higher tariff is applied to large consumers, such as industrial and commercial consumers (ARSESP, no date). However, their rates per cubic metre decrease as consumption increases above the volume negotiated through a contract agreement, and they are fined if consuming less (IDS and Aliança pela Água, 2017) (Interviews-B28/B29)[59].

SABESP separates domestic consumers into three tariff categories: 'regular', 'social' and 'favela' (the latter is only implemented in the MRSP) (Interview-B4). In 2019, in the MRSP, the social tariff was USD 2.40 and the favela tariff was USD 1.82 for water consumption up to 10m^3, compared to USD 7.04 for regular residential consumers (see Annex H – Water tariffs). Consumers qualify for the social or favela tariff under certain conditions, although these are only valid for the first 10m^3 of water (Interviews-B4/B11/B28). The social tariff involves a complex calculation to determine eligibility of consumers that meet at least one of the following criteria: A combined household income lower than three times the minimum

59 Between 500-1000 m^3, large consumers pay USD 3.8 per cubic metre. Above 40,000 m^3 they pay USD 2.5 (IDS and Aliança pela Água, 2017).

wage, energy consumption below 170 Kwh/month, a dwelling with up to $60m^2$ of surface area and employment status (unemployed consumers have priority) (ARSESP, 2009) (Interviews-B28/B29). Consumers paying social tariffs must reapply each year to prove their eligibility (ARSESP, 2009). Some municipal utilities also apply such a tariff (Brandeler, 2013) (Interview-B22).

Effectiveness on actors in terms of mandated goals

Drinking water provision is almost universalized within the MRSP (FABHAT, 2016). Around 99% of the population in the municipality of São Paulo has access to drinking water through the piped network and this reaches 100% in some wealthy metropolitan municipalities. However, access falls heavily in smaller, poorer municipalities of the MRSP (e.g. 63% of the population in Salesópolis, where the Tietê River has its springs, has access to drinking water) (SNIS, 2016). In many cases, residents in informal settlements access drinking water through clandestine means (by connecting their home to the official network themselves, thus not paying for their consumption), and this population is included within data on access to drinking water, thereby masking inequalities in terms of quantity and quality.[60] Nonetheless, special programmes to install water supply infrastructure that require authorizations of the municipality have been implemented in recent years[61]. The average daily per capita consumption in the MRSP is around 130 litres, but this number blurs inequalities between rich and poor areas (SABESP, 2017)[62]. However, sewage collection rates are above 90% in only seven municipalities of the MRSP (including São Paulo), whereas ten have rates below 50% (FABHAT, 2016). Sewage treatment coverage varies from 0 to 100% across the MRSP. Consumers nevertheless pay for these services if they have access to drinking water (Interview-B19). While lack of land tenure in informal settlements is part of the explanation for the backlog in sewage collection and treatment, many formal neighbourhoods are not yet connected either.

Designing a water tariff system that is affordable to all consumers is challenging in a context of severe inequalities, where consumers have vastly different abilities to pay. The inclusion of 'social' and 'favela' tariff rates leads to more affordable services for many consumers, although fewer households receive this tariff than those who qualify for it (Interview-B29). The fixed tariff rate for consumption between 0 and $10m^3$, with rates increasing exponentially above that, encourages rational water use, but unfairly penalizes larger households for higher consumption even if their consumption per capita is reasonable (Interview-B11). The minimum bill for water consumption of 10m3 even for lower actual consumption also hampers affordability and reduces incentives to further conserve water (dos Santos *et al.*, 2019) (Interview-B29).

60 In Guarulhos, a municipality of approximately 1.3 million inhabitants neighbouring São Paulo, many residents have access to water every other day or less frequently (Brandeler, 2013) (Interview-B23).

61 Through its Legal Water Programme, SABESP aimed to install official water connections in 160,000 buildings, for 600,000 residents, in 2018. This corresponds to around 2.7% of the MRSP's population (SABESP, 2017).

62 In comparison, in Spain the average person consumes around 140 litres a day, and this number is around 200 in the Netherlands and 60 in Slovakia (EurEau, 2017).

Some local water utilities charged higher tariffs than SABESP (e.g. Guarulhos, East of São Paulo), even though many residents received water only every other day (Brandeler, 2013) (Interview-B22). Higher tariffs could be due to reliance on SABESP for bulk water as they had insufficient water resources within the municipality's borders (Interview-B12/B23). Some municipalities applied lower tariffs than SABESP, or did not even charge tariffs, due to widespread clientelism (interviews-B4/B5/B28/B30). This was criticized as 'tariff populism' by a SABESP representative, as local utilities – often closely connected to the municipal government – could strengthen local support by highlighting that their tariffs were lower than those of SABESP (Interview-B4). These local utilities largely rely on SABESP for bulk water, but some do not pay for this service, which means that SABESP's own consumers ultimately subsidize water consumption in these municipalities (many of which are in relatively wealthier areas of the MRSP) (Interview-B4).

Finally, concerning the goal of financial sustainability, SABESP has been constantly profitable, although some local utilities have not been so. In 2018, SABESP's net profits were USD 760 million. Between 2003 and 2014, the company redistributed between 26 to 60% of its net profits to shareholders (Schapiro *et al.*, 2018). Economies of scale allowed for cross-subsidies across the state, which has helped expand access to services in rural and lower-income areas (Interviews-B4/B5). SABESP's tariffs were relatively low compared to rates across Brazil, and SABESP executives argued that higher rates on regular consumers would accelerate investments towards the universalization of services and lower consumption (Interviews-B4/B28/B29/B33). However, SABESP's profits could also indicate room for greater investments (e.g. in reducing leaks, increasing sanitation services) or for expanding social tariffs, rather than focusing on paying dividends to shareholders (Interviews-B4/B16/B13/B22/ B29/B32/B36).

Impact on inclusiveness and sustainability

The tariff structure designed does not incentivize rational water use and investments in wastewater management (Interviews-B4/B6/B13/B22/B29/B32/B36). Water tariffs are subsidized for large parts of the population (Interviews-B4/B30/B34). For industrial and commercial consumers, the rate per cubic metre not only decreases as consumption increases, but this category of consumers must consume a minimum volume of water or pay a fine, which commodifies water and encourages wasteful practices (IDS and Aliança pela Água, 2017) (Interview-B29). This perpetuates the reliance on inter-basin transfers to meet demand, instead of investments in reducing water use or expanding the use alternative water sources (e.g. rainwater harvesting, wastewater recycling and reuse[63]) (Interviews-B6/B29). Water losses (from leaks and clandestine connections) were estimated to be around 35% (Interview-B20/B28/B33). ARSESP did not introduce measures to verify the stability of water resources or the quality of wastewater treatment, further reinforcing the disconnect between the tariff

63 Aquapolo, a large industrial wastewater reuse plant near the MRSP, produces 650L/s of reusable water for a petrochemical complex, a volume equivalent to the water supply of a city of 500,000 inhabitants (Aquapolo, no date). Although this shows significant potential demand for greywater, laws and norms needed to be adjusted, and these practices needed to gain public acceptance (Interviews-B4/B34).

structure and sustainable WRM (Interviews-B4/B29).

Another highlighted problem was that the tariff calculation was complex, and the tariff-setting process lacked transparency. Tariffs are mainly developed by SABESP, and ARSESP was described as a rubber-stamper (Interviews-B12/B29/B36). Although there are public hearings on tariff-setting, these are difficult to follow for regular citizens and CSOs, due to the topic's complexity (Interview-B36). In addition, although the tariffs are the main contribution to investments in Wat&San, it is not clear who is involved in decisions regarding how revenue from these tariffs is reinvested (Interview-B29).

The lack of rational water use was brought to light during the 2013-2015 water crisis, partly due to SABESP's and the state government's slow reaction (Interview-B28). ARSESP does not have mandates over WRM (Interviews-B11/B29/B36). Nevertheless, during the water crisis, SABESP, with the approval of ARSESP, eventually implemented a system of bonuses and fines to incentivize consumers to reduce their consumption. Fines were applied to monthly water bills that were more than 20% above of the consumer's average water bill of the past year, and bonuses for bills 20% below. Water consumption in the MRSP decreased from 169 l/day per person to 120 litres in 2015 (SABESP, 2017). By late 2017, consumption had rebounded to 130l/day per person (SABESP, 2017), but still remained below pre-crisis levels, leading some to believe the population had become more aware of the need for rational water use and had changed habits (Interviews-B4/B6/B7). Others claimed that water consumption will rise again as no permanent demand management measures were implemented and the focus remained on increasing supply (Interviews-B4/B29/B30).

However, during the water crisis, the MRSP's periphery was reported by the media to be significantly more affected by water shortages, especially neighbourhoods uphill and far from water supply dams (Leite, 2014; Schmidt and Dezem, 2014; Lobel *et al.*, 2015) (Interview-B38). The State government claimed that there was no water rationing and that shortages were connected to reductions in the systems pressure (i.e. to reduce leaks, which lowered water flow to the extremities of the system) (Schmidt and Dezem, 2014; Martin, 2015). Protests were organized by social movements that termed this situation 'selective water rationing' (Martin, 2015).

While ARSESP focused on affordable tariffs and financial sustainability, it did not establish clear social or quality standards for services (e.g. water quality) (Interviews-B4/B29). Many households in informal settlements still obtained water through clandestine means (Interviews-B19/B32/B33). Although special tariffs helped some residents in low-income households or informal settlements, land tenure and slum upgrading were not addressed.

The fact that some local utilities did not pay for bulk water could have contributed to higher tariffs, as SABESP had to compensate its financial losses (Interviews-B4/B5/B28). Moreover, some municipal utilities receiving bulk water from SABESP were reported to sell it to industrial users (Interviews-B5/B30). The local utilities claim that SABESP's bulk water fees are excessive. The situation has led to conflicts and lawsuits, creating additional pressure for these municipalities to transfer the services to SABESP (Interviews-B5/B11/B20/B36).

6.4.2 MACRO-DRAINAGE

Design

Macro-drainage is defined as drainage and flood control measures for inter-municipal rivers and is the responsibility of the State government. The Macro-drainage Master Plan of the Alto-Tietê Basin (MMP-ATB) is focused on the ATB as a whole and led by the DAEE, which brings together the State, municipalities and the basin committee. It aims to foster integrated stormwater and flood management by coordinating actors and linking public policies through both structural (i.e. reservoirs) and non-structural measures (i.e. flood insurance, risk mapping, zoning, monitoring and warning systems, emergency plans) (DAEE, 2012; FABHAT, 2016). Structural measures include mainly grey but also green infrastructure, such as the development of linear parks along floodplains and the expansion of permeable areas (DAEE, 2012). The plan's guiding principles are: An interdisciplinary approach in diagnosing and solving floods; The basin as the planning unit; Engineering solutions based on the valuing and rehabilitation of the environment; Economically viable solutions; Containment of excess surface runoff upstream; Control of impacts from new developments on the drainage system; Priority towards the control of soil-sealing; a 20-year planning timeframe (DAEE, 2012).

The first version of this plan, elaborated in 1998, was based on the principle of restricting flows and storing water rather than increasing canals (Abril, 2016). The MMP-ATB, now in its third version, has been incorporated into the new basin plan (Interview-B6). It promotes a regional view of water-related risks and is implemented within 12 Drainage Districts, based on sub-basins divisions (FABHAT, 2016). The main funds come from municipal and state budgets (DAEE, 2012). The MMP therefore functions mainly to guide municipal governments to adjust their local drainage plans, and for state investments. In 2010, the Supreme Court established that the adoption of a 'drainage tax' as a financial mechanism was constitutional, and it has been implemented in at least one municipality (STF, 2010; DAEE, 2012). The ATB committee also funds certain projects through the FEHIDRO (FABHAT, 2016). Other sources of funding that the State and local governments can try to obtain include international funding (e.g. World Bank, IDB), federal funding (e.g. the National Bank for Economic and Social Development) and state funding (e.g. FEHIDRO, public-private partnerships) (DAEE, 2012).

The plan emphasizes that urbanization and soil-sealing aggravate flood risks and shows the importance of coordinating municipal drainage plans with the macro-drainage plan. It also involves partnerships between the DAEE and municipalities for infrastructure works, and with the EMAE for flood control and information-sharing (Interviews-B4/B19). By integrating both urban and basin considerations, it thereby links to both IRBM and UWM.

Effectiveness on actors in terms of mandated goals

In practice, the DAEE takes on a dominating role. There seems to be more coordination between the DAEE and individual municipalities than between neighbouring municipalities (Interview-B8/B17). For instance, the DAEE sets flow quotas for municipalities and these are generally respected (Interview-B24/B30). The lack of horizontal coordination is a challenge because municipalities, through their civil defence departments, are still largely responsible for dealing with water-related risks, and they act in an isolated and reactive manner. They must develop a drainage plan, but many municipalities still lack one (FABHAT, 2016). They often have limited financial resources and are reluctant to spend these outside their own borders through regional-level measures, despite sharing rivers and streams with neighbouring municipalities (Interview B17). Between municipalities of different political parties, cooperation is even more limited, and tensions can be high (Interviews-B17/B23/B24)[64].

The Macro-drainage plan is not integrated with Wat&San planning, even though large volumes of wastewater are diverted into stormwater drains and streams (Travassos and Momm-Schult, 2013) (Interviews-B4/B5/B22/B24/B30/B32). Solid waste also aggravates flood risks, by blocking drains and channels, but this is not addressed in the Macro-drainage plan (DAEE, 2012). Local governments are also responsible for land use management and urban planning. However, they have often been unable to prevent the informal occupation of areas at risk, and as a result, there is increasing support for regularizing and re-urbanizing informal settlements (Interviews-B4/B17). While the Macro-drainage plan devises technical, economic and environmental solutions surrounding larger rivers, it cannot directly act on land use management and urban planning. Local-level and basin planning identify vulnerable areas and potential responses, but ultimately only have limited powers to guide municipal urbanization and development (Travassos and Momm-Schult, 2013).

While the third version of the MMP-ATB aims to contain deforestation, preserve riverbeds and retain waters upstream, most actions of the first and second version of this plan have focused on storing and diverting excess rainwater, dredging and other engineering works such as river channelling (FABHAT, 2016) (Interview-B8). This reflects the plan's conventional, linear approach to UWM. One of the main infrastructural measures are the concrete reservoirs knows as 'large pools' (*piscinões*), which receive and hold excess water runoff and prevent flooding during heavy rains (FABHAT, 2016). The idea of storing excess water to mitigate flood risks was a departure from the previous approach focused on rapidly discharging water downstream (Travassos and Momm-Schult, 2013). The *piscinões* have been criticized, as they tend to accumulate sediments and require extensive maintenance, they ignore the roots of the problem (e.g. erosion from land use changes upstream[65], soil-sealing), and the ecosystem functions of floods in certain environments, such as aquifer recharge and the transportation of sediments (Travassos and Momm-Schult, 2013) (Interviews-B17/B30). In addition, while they may address small and medium-sized flood events, they may not be sufficient for larger events (Travassos and Momm-Schult, 2013).

Nature-based solutions for stormwater infiltration and water treatment measures are not given emphasis or have been implemented sporadically by various municipal departments, without a basin logic, inter-sectoral coordination and maintenance (Machado, 2017; Cavalcanti, 2018). São Paulo City has expanded green infrastructure measures through its

64 The municipality of São Paulo developed dykes, drainage systems and green areas in an area along the Tietê River. The municipality of Guarulhos, on the other side of the river, was not informed or involved in these works, leaving it more vulnerable as river flows could only spill to one side (Interview-B24).

65 As erosion and siltation are cumulative problems that are not immediately apparent, they do not receive adequate attention (Interview-B17).

Municipal Master Plan for Drainage and Stormwater Management, launched in 2010, which envisioned “another relationship between the city and its rivers”, combining the river basin, land use and green infrastructure (Bis, 2017) (Interview-B24). However, most municipalities of the MRSP do not have such a plan at municipal level. A basin-wide project of the Macro-drainage plan is the Tietê linear park, which would extend along 75 km, from São Paulo to the springs of the Tietê River and is under development (DAEE, 2012).

Impact on inclusiveness and sustainability

Almost two decades after the implementation of the first Macro-drainage plan, flooding remains a recurrent challenge in the MRSP. According to the new basin plan, 50% of municipalities in São Paulo State and most of the ATB’s municipalities were affected by floods (FABHAT, 2016) (Interviews-B5/B17). Flooding events in the municipality of São Paulo increased from 736 to 1191 between 2007 and 2016 (Bis, 2017).

Residents in informal settlements located in floodplains or steep hillslopes are the most exposed to water-related risks (Interviews-B8/B24). These areas often lack adequate infrastructure for sanitation, drainage and solid waste collection, which increase the risks, through contamination and clogged drains (Hordijk *et al.*, 2016) (Interview-B24).

Many of the measures in place to address flood risks, such as dredging, are costly and address only the symptoms of the problems (Interviews-B17/B19). The total dredging of the Pinheiros river would require removing around two million cubic metres of accumulated sediment and other materials (Interview-B19). Due to contamination, the transportation and disposal of these sediments is an added challenge (Interview-B17). As opposed to services such as drinking water provision and sewage collection and treatment, stormwater management does not generate any revenue and often relies on federal and state funds (Interviews-B18/B24). In low-income and informal settlements, residents are often left to their own devices to prevent flooding, and improvise walls and other measures to cope (Brandeler, 2013; Hordijk *et al.*, 2016).

6.4.3 Integrated Sewage System

Design

As with water supply, SABESP developed an integrated system for sewage collection and treatment at the metropolitan scale as part of the Tietê Project, now in its fourth phase (see Box 6.1). This was based on the premise that integrating sewage mains across the metropolis and building fewer, larger sewage treatment plants would enhance efficiency through economies of scale (Interviews-B5/B11). This system reflects the interconnections between metropolitan municipalities, as pollution flows downstream (Interview-B5). SABESP divides the basin into sewage discharge basins that follow hydrological boundaries and guide the spatial planning of sewage collection and treatment (FABHAT, 2016). Six large treatment plants spread across the MRSP’s core and roughly three times as many smaller plants were part of ‘isolated systems’ in the periphery, where the more distant location, low-density of population and other physical factors made this more cost-effective (FABHAT, 2016). The number and the capacity of individual treatment plants is in constant expansion, as SABESP pursues the goal of universalizing these services, and some municipalities of the periphery still discharged their sewage *in natura*. Some of the municipalities with local utilities, particularly those more centrally located within the MRSP, transported part of their sewage to SABESP's treatment plants (FABHAT, 2016).

Box 6.1 The Tietê Project

> In the early 1990's, SABESP introduced the Tietê Project after growing public outrage with the Tietê's contamination, a successful petition by the NGO SOS Mata Atlántica (SOS Atlantic Rainforest), and the added media attention from the Rio 1992 Conference (Interviews-B3/B31). The project aimed to expand sewage collection and treatment across the MRSP to prevent effluents from reaching the Tietê River or its tributaries. Critics argued that progress had been slow despite around USD 2.7 billion invested over the last 25 years (Mori, 2017). The 2013-2015 water crisis was a further setback as investments were divested towards water supply, and the pollution of the river expanded from 65 km to 130 km (Interview-B31).

One of the largest wastewater treatment plants in Latin America is located in Barueri, a municipality of the MRSP downstream of São Paulo. It treats a large proportion of the MRSP's sewage, and the municipality of São Paulo is involved in investments and decision-making regarding the plant (Interviews-B11/B12).

Effectiveness on actors in terms of mandated goals

In 2010, 87.3% of households in the MRSP were connected to the sewage network, up from 81.4% in 2000 (FABHAT, 2016). Peripheral municipalities had lower sewage collection levels, even though many are located in sub-basins with important springs (FABHAT, 2016). However, not all sewage collection pipes are connected to treatment plants and much of the collected sewage is discharged in waterways without treatment (FABHAT, 2016; Goldenstein, 2017) (Interviews-B4/B7). Some local utilities have high rates of collection and treatment, mainly those in relatively wealthy municipalities, and others do not. The municipality of Guarulhos, with approximately 1.3 million inhabitants, had a municipal utility and only treated around 5 to 8% of its wastewater, although it collected around 89% of it (Interviews-B22/B28). Most of the collected wastewater was directed towards stormwater drains and into streams, even though SABESP had a sewage treatment plant nearby (Interviews-B5/B22). This may be due to inter-municipal rivalries and Guarulhos avoiding the loss of future revenue opportunities (SOS Mata Atlântica, 2017). The Barueri treatment plant is surrounded by municipalities with some of the lowest rates of collection and treatment in the MRSP (FABHAT, 2016). In part this is because connecting such a large region requires installing an extensive network of pipes and large sewage mains. However, in many cases the sewage interceptors and treatment plants in the central areas of the MRSP are in place, but there is only a low flow of wastewater towards the treatment plants due to the difficulty of installing sewer mains in riverbeds of the tributaries, due to their informal occupation (FABHAT, 2016). This also concerns SABESP's isolated systems and those operated by municipal utilities in some metropolitan municipalities (FABHAT, 2016).

Part of the population in areas not covered by the public network have self-built and unregulated sceptic tanks (D'agostino, 2013) (Interview-B21). Alternative solutions, such as adequately built and regulated sceptic tanks or small-scale decentralized treatment plants could support an expansion of sewage collection and treatment in marginalized areas, but such options are not mainstreamed. Resistance from governments at different levels and SABESP towards such solutions, even for informal settlements, are likely due to the need for a significant cultural change among water sector professionals, politicians' fondness of large and visible public works (believed to bring more votes) and the practical challenges of maintaining and regulating multiple, dispersed plants (Interviews-B30/B32).

As mentioned before (see 6.3.5), municipalities with lower financial and human capacity, had non-existent, outdated or inadequate Wat&San plans. Municipalities require such plans to qualify for federal funds to invest in sanitation. For ARSESP, inadequate plans are also problematic as the agency relies on them to evaluate whether utilities are fulfilling their responsibilities (Interview-B11). Despite interconnections through water flows and large-scale infrastructure, municipal Wat&San plans are developed in an isolated manner (Interviews-B12/B36). They are neither coordinated with the Wat&San plans of neighbouring municipalities, nor with other sectoral plans within their own borders, leading to contradictions between the identified needs and goals of different sectors (Interviews-B6/B23).

The lack of local level planning leads SABESP to develop its own, informal plans (see 6.3.3). Although cross-subsidies between municipalities allows SABESP to expand services while charging the same tariff, poorer and smaller municipalities tend to be left behind. One of the MRSP's municipalities with the lowest rates of sewage collection and treatment, Mairiporã, had not had new investments in sanitation since the 1970's (Correio Juquery, 2017). There is little transparency on how SABESP makes investment decisions in different municipalities. In addition, tensions may arise from the fact that municipalities within metropolitan regions generally subsidize others due to their relatively lower costs, and this can contribute to arguments in favour of re-municipalisation (Cruz *et al.*, 2016).

Furthermore, unplanned urbanization hinders utilities' ability to install sewage infrastructure (Interviews-B22/B32). This is especially challenging for municipalities that are largely or entirely contained within an APRM due to restrictions on development (see 5.4.4), although even some wealthy areas of the MRSP are not connected to sewage treatment plants (Interview-B31). The goals and mandates of the Wat&San utilities, the environmental sector and municipal governments are set at different levels: Protected Areas and water contamination are regulated at state level (by CETESB), the responsibility for providing Wat&San and managing land use is municipal, but infrastructure that prevents sewage contamination is mainly managed by a state-level entity (SABESP) (Interviews-B4/B5/B15/B22/ B32). The urban and environmental agendas are at odds, with some actors pushing for better protection of areas of springs and others supporting land tenure and upgrading of informal settlements in these areas so that they can receive sanitation services (Interviews-B4/B5/B25). This has led to a deadlock, where informal settlements are neither relocated nor regularized or upgraded, and residents continue to have inadequate sanitation that contaminates water bodies (Interviews-B4/B5/B6/B7/B15/B19/B32/B33). This reflects a lack of a common vision of the urban/metropolitan water cycle (Interviews-B4/B25).

Impact on inclusiveness and sustainability

The lack of sewage collection and treatment across the MRSP has caused the contamination of waterways and of the Tietê River far downstream, decreasing water availability (Interviews-B7/B16/B17/B20/ B36). The cost of the contamination of the Tietê River by the ATB is estimated at more than USD 19 million per year, based on the volume of Organic Water Pollutant in the yearly discharge of sewage within the basin and the fees charged for wastewater discharge (SOS Mata Atlântica, 2017). Sewage contamination causes visual pollution and discomfort from its smell, threatens public health (e.g. dengue, leptospirosis, and diarrhoea) and water systems, substantially reduces potential water uses and leads to the loss of commercial value of riverside areas (Brandeler, 2013; Goldenstein, 2017) apart from the damage to the ecosystems that are affected (see Figure ***6.2***).

Figure 6.2 View of the Billings Dam where the Pinheiros River flows in

Source: Author

Industrial contamination has decreased through stricter regulations and the move of industries to neighbouring basins such as the PCJ basin, but it has remained a challenge within the MRSP (SOS Mata Atlântica, 2017) (Interviews-B7/B31). Data from 2008 on over 26,000 industries linked to SABESP's sewage system showed that only 43% were connected to a treatment plant (FABHAT, 2016). A 2014 study estimated that 28% of industrial wastewater in the MRSP was discharged untreated into rivers and streams (Oliveira *et al.*, 2014). Monitoring illegal discharges remains a challenge (Interview-B31). Inadequate solid waste management, particularly in informal settlements, and insufficient environmental awareness and education has also affected water quality (Interviews-B19/B20/B36). The EMAE removes around 10,000 tons of solid waste (and a few corpses) from the Pinheiros River each year, which accumulate in their dams (Interview-B19).

Water contamination and increased water demand have led to conflicts between users. Moreover, the extreme contamination of the Pinheiros River, and thereby of the Billings Dam, has threatened the reservoir's water supply potential. As a result, since 1992, water from the Pinheiros River is only released into the dam after heavy rains, as a flood control measure, and the dam's hydropower potential has been reduced (Interview-B19).

6.5 Instrument assessment and redesign

Although Wat&San, stormwater and flood risks are mainly local responsibilities, state-level actors played important roles in the MRSP's UWM. Informal urbanization and inadequate urban planning are a major obstacle for all three of the analysed instruments (see Table ***6.3***).

Table 6.3 Assessment of UWM policy instruments in the MRSP

	Instrument design	Effect on actors	Impact
Water tariffs	[+] Differences between utilities, but most of the MRSP has tariffs designed to be affordable and financially sustainable	[++] Drinking water access has increased, but millions have no access or highly precarious access in terms of service quality. Sanitation is lacking despite a sewage fee. Tariffs are mostly affordable and include low rates for low-income households, but, not all qualifying households receive these tariffs, and large households are penalized by the fixed rate for consumption between 0-10m^3 Cross-subsidies facilitate access in smaller, poorer towns Clandestine connections lead to losses but operating in informal areas is a challenge. SABESP is financially sustainable	Ecol: [--] Tariff structure does not incentivize rational water use, nor link to water availability. Bonuses and fines during the water crisis helped reduce consumption but were discontinued Soc: [++] Overall affordable, but many households that qualify for social/favela tariffs do not receive these, even though SABESP has significant profits Econ: [-] SABESP's recurrent profits suggests to some that it could invest more heavily in sanitation and reducing losses. Ignoring this will lead to higher costs in the future Rel: [-] Lack of transparency in tariff calculation. The regulator is much weaker than SABESP
Macro-drainage plan	[++] Multi-stakeholder planning with structural and non-structural measures, managed at sub-basin level	[0/+] Effective coordination between DAEE and municipalities, but less so between municipalities Emphasis on structural, reactive measures over non-structural and preventive ones It does not address the main driver of floods: informal urbanization. Urban policy does not adequately consider water-related risks It is not integrated with Wat&San and solid waste management	Ecol: [-] Hard engineering focus that ignores ecological functions. Upstream erosion and solid waste are not addressed Soc: [-] Floods and mudslides have a heavy toll, disproportionately affecting poorer, marginalized inhabitants Econ: [-] Flood costs are high, enhanced by the focus on measures that address the symptoms rather than the causes Rel: [0] Significant responsibility remains at municipal level, so poorer municipalities are less prepared. However, this basin approach provides them more support
Integrated Sewage system	[+] Planning within sewage discharge basins. Focus on centralized infrastructure and small systems in peri-urban and rural areas	[0/+] Combining a central, integrated system, with surrounding isolated systems is an efficient approach. Remote and informal areas are under-serviced and local alternatives might be more suitable. The lack of Wat&San planning hampers efforts	Ecol: [-] Environmental damage from sewage contamination Soc: [-] Waterborne diseases, smell and visual pollution Econ: [--] Contamination remains high despite large investments in sanitation. Water has to be imported Rel: [-] Marginalized residents are more exposed to contaminated water. Peri-urban municipalities receive less attention from SABESP

Relative assessment scores: *++ Very positive; + Positive; 0 Neutral; - Negative; -- Very negative* (See 2.4)

Redesign

Based on the evaluation of the above instruments, the following redesign options are recommended.

Water tariffs: Currently, utilities are incentivized to increase water sales, leading to more water imports. Incentives for rational water use need to be better integrated into the tariff system. For instance, eliminating the decreasing volumetric rates of water consumption for industrial and commercial consumers (i.e. currently, the more they consume, the lower the cost of an individual cubic metre) could reduce the consumption of large water users. Water saving measures, such as fines for excessive consumption (based on average consumption) implemented during the water crisis, could immediately go into effect during water shortages (e.g. when water supply reservoirs drop below a specified level), as is done in the energy sector. Incentives for installing/ retrofitting water saving equipment and appliances, such as subsidies or faster water use permit approvals, could further promote behavioural changes.

A significant obstacle is the disconnect between the tariff structure and water availability in the basin (with the exception of bonuses and fines applied during the water crisis). This is not only the case for SABESP's tariff, which benefits from a discounted fee for water imports from the Cantareira System (see 5.4.3), but also for municipal utilities that receive bulk water from SABESP and do not always pay the latter for this service. These local utilities are then more likely to disregard water availability when setting their tariffs. To achieve greater environmental sustainability, ARSESP may include water availability considerations in tariff regulations and hold SABESP and other utilities in the MRSP accountable to higher standards (i.e. increasing rational use, reducing water losses), in addition to the narrow focus it has now. Furthermore, by increasing transparency, utilities could show the connection between the sewage tariff and investments in sanitation. This involves making information on investment spending more transparent and accessible, and discussing these decisions in public hearings. This could lead to greater social control, as consumers currently pay this tariff even if they do not receive sewage collection and treatment services.

In addition, a greater share of SABESP's (significant) profits could be diverted towards subsidies for households that qualify but currently do not benefit from these. They could also be invested in programmes for expanding water supply services in informal settlements (when appropriate), which would benefit shareholders as well by increasing the number of paying consumers. If sanitation services are expanded to informal settlements, the reduced contamination in water bodies would reduce costs of treating and using this water.

Macro-drainage plan: To be effective, the Macro-drainage plan must be coordinated with municipal stormwater plans and other sectoral plans at local and state levels (Interview-B36). Local governments could attempt to harmonize their stormwater, Wat&San and solid waste management plans with the Macro-drainage plan to ensure synergies and coherence, with support from the basin committee and FEHIDRO funds. Although municipal governments generally coordinated their drainage-related policies and actions with the DAEE, they did not always cooperate with each other. Updating local stormwater plans in line with the macro-drainage can help ensure that local decisions do not cause externalities on neighbours.

In addition, expanding green infrastructure (e.g. bioswales, floodplain rehabilitation, community gardens, green roofs) could provide relatively low-cost alternatives to stormwater reservoirs, dredging works and other standard measures, while providing various ecosystem services. Cost-benefit analyses at regional level can estimate when such options are preferable. Areas further from the urban core are more likely to benefit, whereas the urban core generally lack the necessary space. The experience of existing green infrastructure projects indicates the need for both regional and inter-sectoral coordination, in particular the environmental, planning and housing sectors.

Climate change considerations are not incorporated into the Macro-drainage plan. This may be due to a lack of studies on expected local impacts. Such studies are crucial to develop resilient infrastructure and identify areas that could become more exposed to risks from extreme weather events.

Integrated sewage system: In comparison to water supply, where local authorities depend on water resources beyond their borders, requiring centralized management, wastewater can often be more effectively managed at smaller or intermediary scales (Interview-B30). Large sewage plants can foster economies of scale and are sometimes the most effective approach, but the MRSP's largest treatment plant operates under capacity as many of the surrounding areas consist of informal settlements with no sewage connections. Other areas also fail to connect to this plant due to the lack of large sewage mains. Peripheral areas of the MRSP and other areas with specific characteristics may be better served by local treatment options. In particular, small-scale, local sewage treatment has greater potential in informal areas, including those in the APRMs and where building or biophysical characteristics make it almost impossible to connect households to the sewage network. In such cases, local governments and utilities can collaborate on alternative solutions. Local governments can lead by indicating in their Wat&San plans where such alternatives would be viable. However, local governments also need greater support in enforcing land use restrictions and in upgrading informal settlements. Within the APRMs this could be through technical and financial support (i.e. FEHIDRO funds) from the basin committee. Access to these funds should also be conditional on the updating and harmonizing of Wat&San plans with the APRM's plans.

Although there are smaller wastewater treatment plants across the basin, SABESP has a mega-plant downstream of the MRSP, along the Tietê River. The downstream location also prevents retaining and reusing treated effluents within the basin (for human uses or for ecosystems), thereby maintaining dependence on external water sources. Decentralized wastewater management, at sub-basin level, with larger or smaller treatment plants according to populations density would lead to plants operating at higher capacity and the repurposing of treated effluents within the basin.

There have been suggestions for compensating the basin downstream of the ATB for the contamination of the Tietê River that it receives by redirecting (part of) the revenue from wastewater discharge fees to the neighbouring basin committee. This would be fair, but as the ATB committee currently receives these fees it is not clear whether it would incentivize greater investments in sanitation by SABESP and other utilities in the MRSP. However, it would negatively impact the ATB committee's project funding, including those related to increasing sanitation coverage.

Missing instruments

Regional policies: In the absence of an official state policy for Wat&San and the weakness of municipal Wat&San planning, SABESP has taken a dominant role in shaping both (Interviews-B4/B29/B30/B32/ B34/B36). This has led to a regional and infrastructure-oriented approach to Wat&San for the MRSP, with the development of Integrated Metropolitan Systems for water supply and for sanitation. SABESP's approach is top-down, and local governments, the basin committee and other state actors have little influence. The SSRH or DAEE could be the appropriate actor to develop a state-level Wat&San policy that oversees regional sanitation planning and harmonizes utilities' plans. Water services could then also be better coordinated with the state water resources policy, as the DAEE has significant attributions in both areas (Interview-B36).

The development of the Integrated Urban Development Plan (IUDP) by the EMPLASA, (see 6.3.4), could potentially strengthen integrated planning, including for Wat&San, at the metropolitan and macro-metropolitan level. The advantage is that the macro-metropolitan scale allows for considering interlinkages between basins for bulk water supply. The ARSESP could oversee the implementation of the IUDP's Wat&San plans, as this complements its evaluation of municipal plans. Knowledge and data-sharing between municipalities and compensation mechanisms (e.g. for downstream municipalities that receive contaminated waters) within the IUDP's regional planning for Wat&San and water-related risks could further enable coherent regional planning. Local level knowledge tends to remain where it is produced and a participatory approach in regional planning is required to ensure knowledge sharing (Hordijk and Baud, 2006). Furthermore, coordinating a regional Wat&San plan with regional plans for environmental preservation, land use, urban planning and housing could lead to a more sustainable and inclusive strategy for informal urbanization (i.e. which informal settlements can be regularized, which must be relocated, which can be upgraded), as this represents the greatest challenge for expanding Wat&San services and addressing water-related risks.

Climate change approach: The local climate change impacts and adaptation were not high on the agenda for most municipal or state actors, despite frequent floods and the recent record-breaking drought, and the heat island effect was generally seen as a greater preoccupation (Interviews-B7/B8/B24/B32). A State Policy for Climate Change was adopted in 2009, establishing the State's commitment towards climate change mitigation and adaptation, emphasising sustainable development, the polluter-payer principle, civil society participation and multi-level cooperation, among its main principles. It consolidates existing policies relevant for climate change mitigation and adaptation across departments (São Paulo Legislative Assembly, 2009). These focus mostly on mitigation measures, and even then, these are more about keeping inventories on emissions and disseminating information than about proactive measures (Interview-B7/B8/B9). While some activities in state departments such as CETESB have synergies with adaptation goals, there are few projects specifically aiming for this (Interview-B8).

Efforts can be made to mainstream climate change adaptation into sectoral plans and the river basin plan. Although climate proofing development involves costs, current strategies focused on increasing water supply through inter-basin transfers and mitigating floods through stormwater reservoirs will become increasingly expensive and prone to fail, as climate change is forecasted to lead to a decrease in precipitation but spread over fewer, more intense rainfalls. Measures involving water demand management, floodplain rehabilitation and environmental preservation would enhance climate change adaptation, thereby reducing future costs. As adaptation strategies need to be regional, in order to consider interlinkages between areas (e.g. areas that provide crucial ecosystem services, large-scale infrastructure that crosses the region, upstream/downstream effects), a key obstacle is coordination between actors and political will. Climate change adaptation should be a cross-cutting objective of the various sectoral plans of the IUDP. In addition, task forces could be set up between agencies at state and municipal levels to build on common challenges and goals and identify synergies. For instance, developing a network of linear parks along waterways and green areas in flood-prone areas brings together agencies for stormwater management, risk management, sanitation, recreation, urban planning, and housing, where their diverse interests converge around one project.

Integrating urban and water policies: Addressing the MRSP's water-related challenges requires greater coordination between water and urban policies to jointly discuss how to address the challenge of informal settlements. They could identify areas to legalize and urbanize, facilitating the provision of basic infrastructure and services and thereby also reducing wastewater contamination in nearby water bodies. This concerns long-established settlements where eviction and relocation are not socially acceptable or financially viable options, but it cannot include occupations within floodplains, areas at risk and other areas where sanitation infrastructure cannot be installed (e.g. characteristics of housing construction) (Interviews-B4/B6/B22). Such occupations must be relocated to social housing projects, ideally nearby to be less disruptive.[66] A regional strategy must identify areas available for these housing projects across the MRSP, including by revitalizing inner-cities and through densification policies. Municipal master plans must be harmonized with Wat&San plans and with the IUDP (Interviews-B4/B5). A regional strategy requires developing policies and plans that address regional inequalities across the MRSP and its rural hinterlands, as these put disproportionate pressure on peripheral municipalities with little capacity and that must preserve APRMs (Interviews-B4/B14/B15/B33). A regional strategy should develop financial instruments to support access to social housing for those who need to be relocated, such as cross-subsidies between high-end developments and low-income/social housing[67], and compensation mechanisms for municipalities that face restrictions on their development in order to preserve areas with crucial ecosystems.[68]

66 A former SABESP employee estimated that around 2.3 million people in the ATB live in areas of springs. He calculated their need for housing at 50,000 housing units, for some 200,000 people: "That is for those who would need to be removed, and the housing of another 300,000 or 400,000 would need to be upgraded, which would require land use regularization" (Interview-B6).

67 Suggestion by a respondent from the State housing department (Interview-B15).

68 As was included in the original NWL.

7. THE IMPLEMENTATION OF IWRM/IRBM IN MEXICO CITY

7.1 INTRODUCTION

This chapter examines how drivers and institutions at multiple levels of the river basin governance regime shape water-related challenges in the Metropolitan Valley of Mexico City (MVMC). It uncovers the causal chains behind these water challenges and the effectiveness of existing policy instruments. It reviews the relevant historical and geographical context of Mexican river basin governance and its main drivers, analyses the driving forces on the river basin from local to global level (see 7.2), explores how Integrated Water Resources Management (IWRM) actors and institutions at multiple levels address water challenges at the basin scale (see 7.3), analyses the instruments of IWRM/IRBM according to their stated mandates, their effect on actors' behaviour given the drivers and their impacts on inclusive and sustainable water governance (see 7.4). Finally, the chapter summarizes the main empirical findings and considers how more appropriate instruments could be (re)designed for the Mexico City case study in relation to IWRM/IRBM (see 7.5).

7.2 CONTEXT AND DRIVERS OF MEXICO CITY'S RIVER BASIN CHALLENGES

7.2.1 CONTEXT IN RELATION TO THE RIVER BASIN

Mexico is a water-stressed country with uneven water distribution. Average annual precipitation ranges from below 500mm in the North, to more than 2,000mm in the Southeast, and around 650mm in the central region where Mexico City is located (CONAGUA, 2015). When population distribution is considered, these contrasts become even starker. More than three-quarters of the population live in regions with little water (OECD, 2013). In addition, rainfall is unequally distributed throughout the year: 67% of rainfall occurs between June and September and droughts are frequent (OECD, 2013).

Most of the MVMC lies within the lower part of the Valley of Mexico Basin (VMB), around 2,200 metres above sea level (masl). This is an endorheic basin, enclosed by mountains and volcanoes reaching 5500 masl (Martínez and Enciso, 2015). Surface and groundwater resources originate from the springs in these mountains. 65.5% of the VMB's surface area is urban, while 34.5% is rural, with agricultural, livestock, forest and conservation uses (World Bank, 2013). Urban growth has reduced water availability in the VMB to around 144m^3/inhabitant/year[69].

[69] A region faces absolute water scarcity if renewable water resources are below 500m^3/inhab./year (FAO, 2012).

7.2.2 MAIN DRIVERS OF MEXICO CITY'S RIVER BASIN CHALLENGES

Climate

Recent research on climate change forecasts increases between 1.5 and 5ºC from 2050 to 2100 for Mexico (Guido Aldana, 2017). Precipitation is likely to be concentrated in fewer but more intense rainfalls, and to decrease on average by 5.8% in the 2020s, and by 10.4% in the 2070s (Sosa-Rodriguez, 2014; Guido Aldana, 2017). This may contribute to an intensification of mid-Summer droughts and impact water demand and alter water quality in surface water bodies (IMTA, 2007). However, vulnerability to climate change varies significantly per region. Areas in the dry North, the Centre-West, and the VMB are considered highly vulnerable (Guido Aldana, 2017).

Average annual precipitation varies between 1,200mm in the South of the VMB and 600mm in the North, and is mostly concentrated between May and September (Romero Lankao, 2010). Heavy summer rains increase flood risks. The basin tends to alternate between wet years and drought episodes, some of which last longer than ten years (Romero Lankao, 2010).

Glaciers and eternal snows in the surrounding mountains, crucial for groundwater recharge, may disappear before 2025 (Burns, 2009). With the depletion of local aquifers, longer and more intense droughts risk increasing the basin's dependency on external water sources (Sosa-Rodriguez, 2014). Overall, Mexico City is likely to experience more intense droughts and heat waves, aggravating water shortages, and more frequent floods and increased risks from waterborne diseases (Sosa-Rodriguez, 2014).

Demographics

Mexico's population grew from 35 million inhabitants in 1960 to approximately 120 million in 2015 (INEGI, 2015).

The VMB's temperate climate and fertile soil attracted settlements long before the Spaniards arrived (Escamilla and Santos, 2012). Around the Aztec city of Tenochtitlán, which would become Mexico City, peri-urban and rural communities developed highly productive floating farms (Escamilla and Santos, 2012). These supplied urban areas and allowed for Tenochtitlán's growth. By the 17th century, the Spaniards first population census registered a total of 144,760 inhabitants (Escamilla and Santos, 2012). In 2010, the basin had 20.6 million inhabitants across 85 municipalities, though mostly concentrated within the MVMC (Rodríguez Tapia and Morales Novelo, 2013).

Economic development

The 1910 revolution centralized power and led to large-scale economic development projects (Aguilar *et al.*, 2010). In addition, technological innovations brought dams, canals, inter-basin transfers, and the electric pump (Aguilar *et al.*, 2010). As a result, the ability to abstract and transport water resources over large distances increased significantly, and water consumption rose sharply after 1950. By the late 1980's, water infrastructure was decaying and the government, struggling to handle a severe economic crisis, was unable to address the sector's extensive needs (Wilder, 2010).

The GDP of the VMB is 23.8% of the national GDP. Besides hosting the financial capital of the country, the basin has important agricultural and industrial sectors.

Land use changes

The natural hydrology of the VMB has been radically altered since the Spanish conquest of the Aztec empire, when lakes still covered large parts of the basin (see Map 7.1). The Aztecs developed a sophisticated system of terraces, reservoirs, canals, irrigation ditches, dikes and aqueducts to both use the hydrological conditions to their advantage and cope with its risks. From the 16th century onwards, the lake-bed was progressively drained by the Spaniards (Wilder, 2010; Mazari-Hiriart *et al.*, 2014). As urbanization accelerated, the remaining water bodies were polluted by open sewage canals, spreading waterborne diseases and increasing reliance on groundwater (Romero Lankao, 2010). Today, only one river system, the Magdalena-Eslava, still provides surface water to the city, albeit heavily contaminated and with a diminishing flow, while other rivers have been piped to avoid flooding and unsanitary conditions (Mazari-Hiriart *et al.*, 2014).

Map 7.1 Lakes in the Valley of Mexico around 1519

The lakes have been reduced to two small water bodies and a few canals – a fraction of their original size. The rest of the lake waters were drained and today the MVMC expands across the vast expanse of the dried lakebed.

Source: Madman2001 / CC BY-SA 3.0

The surface area of the VMB's urban sprawl increased over 5 times between 1950 and 2000, and its population multiplied by 5.65 times between 1950 and 2005 (World Bank, 2013). As urbanization spread to the mountainous areas of the basin, the capacity of these areas to infiltrate water and recharge aquifers was drastically diminished, reducing water availability and increasing flood risks through soil-sealing (Romero Lankao, 2010; World Bank, 2013). The growth of informal settlements without access to basic infrastructure and services in the green belt also degraded the quality of local springs and aquifers.

Moreover, primary activities, such as logging and agriculture, have led to environmental degradation and land surface erosion, accelerating the desiccation of lagoons and siltation of drainage systems (Romero Lankao, 2010; Pina, 2011). Land use changes in neighbouring basins also affect the MVMC as these areas supply water through inter-basin transfers (see 7.4.1). Between 1980 and 2011, the population in the sub-basins of the Cutzamala System, the main inter-basin transfer, increased by almost 150%, occupying mainly informal settlements deprived of sewage collection and treatment (World Bank, 2015). Moreover, agricultural activities and deforestation also increased around these reservoirs (Martínez, 2018).

The direct and indirect drivers of water-related challenges at multiple levels are summarized in Table ***7.1*** below.

Table 7.1 Multi-level drivers of water-related challenges on the river basin

	Direct		**Indirect**	
	Local	**Regional/global**	**Local**	**Regional/global**
Land use	Urbanization, expansion into green belt	Logging and deforestation for agriculture	Transformation of original lake basin	
		Agricultural intensification		
Demography		Rapid population growth in the basin		Rapid national population growth
Climate	Heavy summer rains, frequent dry spells			Climate variability and change

Source: Author

7.3 THE INSTITUTIONAL SET UP FOR IWRM/IRBM IN MEXICO CITY

7.3.1 GLOBAL LEVEL

The World Bank and IDB have provided loans to Mexican authorities for climate change adaptation, and more specifically for drought forecasting, for the protection of water reserves and for supporting the development of IWRM in the VMB (CONAGUA, 2012b). The federal government and users finance the bulk of the Mexican water sector, and international actors represent only a minuscule fraction of total investments in water resources management (OECD, 2013). The presence of international cooperation is stronger within UWM (see 8.3.1).

7.3.2 TRANSBOUNDARY LEVEL

The MVMC is contained within one river basin, the VMB, although water shortages lead it to depend on several other basins for water supply. The VMB spreads across the entire federal entity of Mexico City, and parts of the states of Mexico, Hidalgo and Tlaxcala (CONAGUA, 2012a). This has important implications for WRM as the governments of these four federal entities must negotiate and agree on decisions related to the river basin.

7.3.3 National level

The Federal Constitution defines all waters within Mexican territory as national property to be administered and managed by the federal government (Mexican Constitution, 1917, Art. 27). Until the 1980's, water policy remained highly centralized within a limited authoritarian political system ruled by a powerful presidency and top-down regulation (Wilder, 2010). It was conducted in a top-down fashion without social participation.

The emergence of political pluralism in the late 1980s, including democratic power sharing between different political parties and levels of government, led to the reform of Mexico's water management institutions (Hearne, 2004). The federal government introduced decentralized water management policies and adopted three WRM goals: (1) develop large infrastructure projects with combined public and private funds, (2) increase water use efficiency, and (3) control water pollution (Hearne, 2004). In 1989, the National Water Commission (CONAGUA) was established to develop a new water policy to carry out these goals (Hearne, 2004). This led to the 1992 National Water Law (NWL), which defines the principles and mechanisms for managing water resources, including the use of national waters, their distribution and control, as well as the preservation of their quantity and quality for 'integrated sustainable development' (NWL, 2004; OECD, 2013). Its set of reforms are centred around decentralization and marketization, and the river basin or aquifer as the unit of water management (Wilder, 2010). River basin councils were created in 1996, with the aim of promoting citizen participation and coordinating water management across three levels of government within watershed boundaries (Hearne, 2004). The NWL thus indicated the possibility of a new state-citizen relationship but also increased private sector involvement in water supply and sanitation services.

In 2004, after heated discussion among intellectuals and water sector professionals, the NWL was significantly rewritten, with greater emphasis on decentralization and sustainability (Wilder, 2010). It led to the creation of thirteen regional Basin Agencies that operate as CONAGUA's implementing agencies (Hearne, 2004; OECD, 2013). These agencies are based on hydrological boundaries, often grouping together multiple river basins.

CONAGUA is an autonomous agency of the SEMARNAT (Ministry for the Environment and Natural Resources). The SEMARNAT, together with CONAGUA, and state and municipal authorities, establishes official norms in relation to water management and supervises their enforcement (OECD, 2013). CONAGUA receives 70% of its budget from the SEMARNAT, though it maintains significant autonomy, and is responsible for water policy, water planning, financing and strategy-setting (Spring, 2011; OECD, 2013). It grants water use permits, maintains the national water user registry (REPDA), constructs and operates federal water infrastructure and provides bulk water to Wat&San utilities, large industries, and irrigation districts. In addition, CONAGUA contributes to developing and managing irrigation and flood control systems (Hearne, 2004).

Other federal-level actors include the National Commission for Protected Areas (CONANP) and the National Forestry Commission (CONAFOR) through their efforts to preserve ecosystems (for a detailed overview see Annex F - Main actors in Mexico City's metropolitan governance). In addition, the Federal Attorney's Office for Environmental Protection (PROFEPA), a deconcentrated branch of the SEMARNAT, is responsible for supervising the compliance with environmental regulations.

The Ministry of Agriculture is responsible for addressing agricultural pollution (i.e. regulation of the use of fertilizers), whereas CONAGUA oversees water quality norms and standards issued by the Health Ministry. CONAGUA is thus limited to localized discharges from industries and water utilities (Spring, 2014). Overall, national legislation on water quality was considered weak due to institutional fragmentation, a lack of enforcement and political will, and the PROFEPA's ineffectiveness (Interviews-M40/M42/M58).

7.3.4 STATE LEVEL

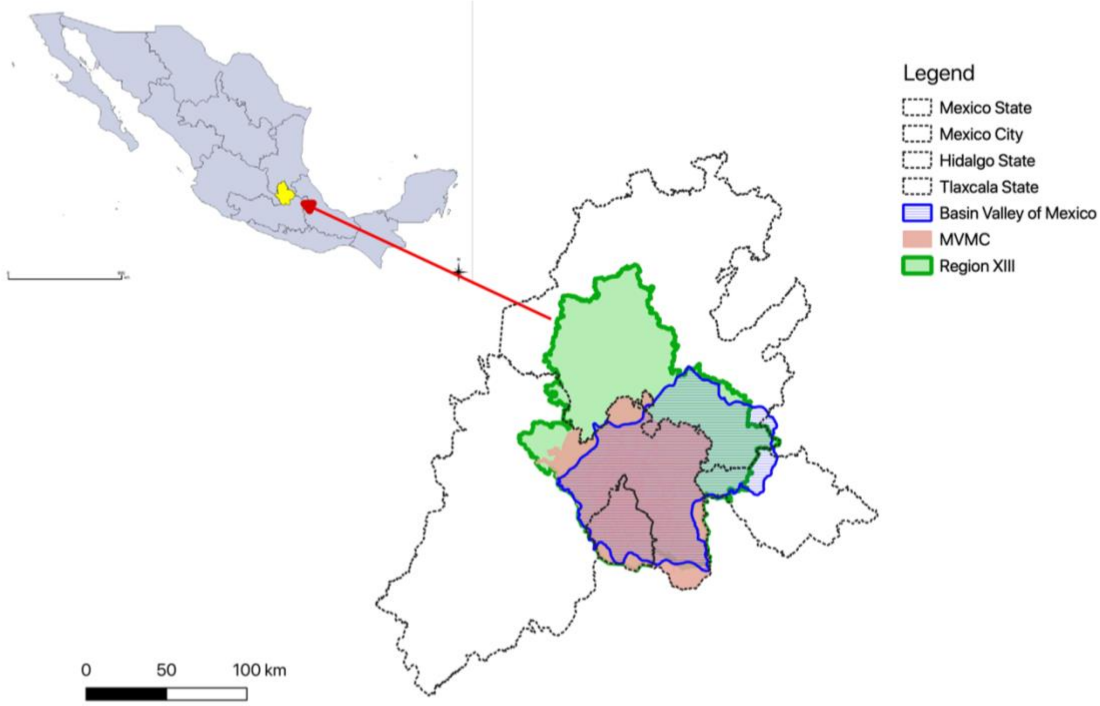
At state level, the main institutions are the State Water Commissions. These autonomous entities, usually under the authority of the State Ministry of Public Works, foster coordination between the federal government and municipalities (OECD, 2013). Their attributions vary per states and can include WRM, irrigation, technical assistance to municipalities and the provision of Wat&San services (when municipalities choose to delegate these) (OECD, 2013). States also have environmental departments that are responsible for carrying out the state environmental policy, but their capacity varies significantly. For Mexico City, this is the SEDEMA (Environmental Secretariat of Mexico City) and its branch the CORENA (Mexico City's Commission for Natural Resources).

7.3.5 RIVER BASIN LEVEL

The 2004 revision of the NWL introduced IRBM into Mexican water policy and key water management functions were transferred to the river basin. The MVMC is located within the hydrological-administrative region managed by the Basin Agency 'Waters of the Valley of Mexico – Region XIII', which is responsible for formulating regional water policy, planning and maintaining water use registries (see Map ***7.2***). Region XIII has two river basins: The Basin of the Valley of Mexico and the Basin of the Tula River, each with its own basin council (CONAGUA, 2012a). The borders of the basins do not overlap perfectly with those of Region XIII as the former are based on hydrological boundaries and the latter uses municipal borders as delimitations of its territory. Basin councils are multi-stakeholder platforms established as consultative bodies that bring together government representatives, civil society representatives and users. Other water management entities include the basin commissions, the basin committees and the groundwater technical committees (see Table ***7.2***). These are voluntary and meant to provide support to the Basin Councils (Interview-M55).

While the creation of these multi-stakeholder entities was an important step towards implementing IWRM/IRBM, they were seen as ineffective, leading many participants to retreat from the process (Interviews-M5/M17/M38)[70]. The VMB's size and complexity, and the numerous interests and actors involved, made negotiations virtually impossible (Interviews-M17/M55). In addition, as 'consultative entities', basin councils lacked the necessary planning, regulatory, financing and enforcement power to implement decisions (OECD, 2013) (Interviews-M17/M31/M33/M38/M54).

Map 7.2 Map of Region XIII and the metropolitan region of the Valley of Mexico



Source: Author

Moreover, basin commission plans were not considered by basin councils, resulting in incoherencies between sub-basin and basin management (Interview-M40). The groundwater committees lacked information and decision-making power, and they depended on funds from CONAGUA, which restricted their autonomy (Interview-M40). The basin agency had decision-making power and funds, and ultimately implemented CONAGUA's agenda at regional level. Other spaces seemed to serve to give legitimacy to decisions already taken by CONAGUA (Interviews-M15/M40/M58).

The Basin Agency implements the 'Regional Water Programme 2030', which promotes integrated and sustainable basin and aquifer management (CONAGUA, 2012a). This includes strategies focused on increasing supply and reducing demand, improving water quality, attaining universal coverage of water services and reducing risks from weather events. Climate change does not have a strong presence within the programme, and the NWL (Art. 13) only

70 Basin council meetings are also infrequent: during six months of fieldwork, the only meeting that I could hear of took place in Cancún during a parallel event. Civil society was mainly represented by (large) users, whereas representatives from CSOs and basin commissions were not given a voice or informed on how to participate (Interviews-M28/M38/M40/M48/M54/M55).

mentions that basin agencies should "evaluate the effects of climate change on the hydrological cycle".

Table 7.2 IWRM/IRBM entities

IWRM/IRBM entities	Description	Mandates
Basin agencies	13 deconcentrated agencies of CONAGUA, based on hydrographic boundaries. The MVMC is in Basin Agency Region XIII	Formulate and implement regional policy; recommend rates for water user fees and collect them; program, build, operate and maintain federal water works
Basin councils	2 basin councils in Region XIII Composed of government representatives, civil society representatives and users	Guide the work of the Basin Agencies through coordination, concertation, support, consultation and advice
Basin commissions	4 in the VMB Same composition as basin councils. Independent from CONAGUA	Provide support to basin council at sub-basin level or on a specific issue
Basin committees	2 in the VMB Micro-basin level	Address issues relevant to a specific area by bringing together residents and stakeholders
Groundwater technical committees	1 in the VMB Multi-stakeholder platform at aquifer level, independent from CONAGUA	Technical work and discussions relating to groundwater management

Source: Mexico, 2004; CONAGUA, 2018

7.4 INSTRUMENT ANALYSIS

7.4.1 INTER-BASIN TRANSFERS

Design

The MVMC has long relied on its aquifers to respond to rising water demand. As these became increasingly over-exploited, the region developed a complex system of large engineering works spanning multiple federal entities and basins to provide bulk water services to the VMB, mainly for public/urban use. These aimed to reduce the pressure on local aquifers while sustaining the MVMC's growing population and economic development. Table ***7.3*** shows the multiple water supply sources to this basin.

The first of these inter-basin water transfers was the Lerma System, inaugurated in 1951 and managed by the SACMEX, Mexico City's water utility (see 8.3.3) (CONAGUA, 2018). It extracts and transfers groundwater from the Lerma River aquifer to Mexico City and parts of Mexico State. It measures 60 km in length, provides 5% of the VMB's water supply and has a capacity of 14 m^3/s, although actual supply is around 5 m^3/s due to the over-exploitation of the Lerma aquifers (CONAGUA, 2018).

The Cutzamala System supplies water to 11 districts of Mexico City and 11 municipalities of Mexico State (CONAGUA, 2018). It corresponds to 17% of the volume of water used within the VMB annually (~15 m^3/s of 88 m^3/s) (CONAGUA, 2018). Besides supplying water from 160 km away (one of the largest water supply systems in the world), it also pumps water up 1100 m, making it energy-intensive and expensive, representing around 0.6% of Mexico's total electrical energy demand (Tortajada, 2008; Engel *et al.*, 2011)[71]. The Cutzamala System alone costs around USD 240 million a year (World Bank, 2015). 48% of this cost is financed by water use fees, and the rest is paid with federal government resources (World Bank, 2015).

Table 7.3 Overview of water supply in the Valley of Mexico Basin (VMB)

Source	Volume (in %)
Groundwater	**73**
Local aquifers	68
Lerma System (inter-basin transfer)	5
Surface water	**20**
Local rivers and springs	3
Cutzamala System (inter-basin transfer)	17
Water reuse	**7**

Source: Adapted from Aneas (2015)

Effectiveness on actors in terms of mandated goals

The MVMC's aquifers and nearby aquifers in Mexico State continue to be over-exploited and this has worsened in the last decades. Nevertheless, as external sources contribute roughly 22% to the VMB's water use, the pressure on the MVMC's aquifers would be much more drastic and water shortages more severe without centralized control of water resources (Interview-M32). The MVMC's aquifers may run dry by 2060, so relying on external sources seems unavoidable (EFE, 2019). CONAGUA announced that the Cutzamala System's water supply capacity would increase by two additional cubic metres per second in 2020 through investments in water treatment efficiency (López, 2019).

However, a first issue regarding inter-basin transfers concerns allocation rules, which are still largely based on a federal decree of 1972 (DOF, 1972). Mexico City was granted around five times more water than Mexico State, under the unstated rationale that it had a much larger population. Since then, the MVMC expanded largely into Mexico State. Although the volumes apportioned to both entities increased over time, the decree was never adjusted and Mexico City continues to be entitled to a much larger volume of water (Mendoza, 2016). This may have contributed to the sharp rise in groundwater extraction in metropolitan municipalities of Mexico State since at least the 1990's (Neri-Ramírez *et al.*, 2013).

71 The energy use of the Cutzamala System corresponds to Puebla's, a Mexican city of 8.3 million inhabitants (Escolero *et al.*, 2016).

Moreover, the decree does not specify where imported water comes from, nor the capacity of the Cutzamala System (Mendoza, 2016). This opened the door to the possibility of constant expansion of water transfers and encouraged CONAGUA and other actors to expand water imports rather than reduce water use (Spring, 2015).

Furthermore, the Federal government partially subsidizes the inter-basin transfers, so users are not sufficiently incentivized to increase their water use efficiency, leading to high levels of physical and commercial water losses (i.e. leaks and theft), and excessive water consumption. Moreover, the water fees for private uses (i.e. uses other than public supply) and basin transfer fees paid to the Basin Agency are collected by the Federal Treasury, while bulk water supply fees (from water utilities) go to the Fideicomiso 1928 budget (a regional trust fund for water infrastructure). The latter is mostly spent on drainage and sanitation works in the VMB (World Bank, 2015). These fees therefore do not return to the donor basins to be reinvested in preserving regional ecosystems, managing urban and rural development or treating wastewater.

Despite the dependence on external basins, the Region XIII agency does not interact with the basin agencies where the Lerma and Cutzamala systems have their production areas, and there is no policy at that larger scale (Interviews-M28/M33). These water transfers are coordinated in a top-down manner by the central CONAGUA office (Interview-M33):

> *"These agencies do not meet, do not dialogue. There is no policy at that scale. […] The federal government should guide coordination processes, create spaces for debate and joint decision-making, not tell them what to do. […] These administrative borders are a straitjacket as our new socio-hydrological realities no longer fit these moulds. We need to create a new entity; rethinking the scale we need to use as the policy of inter-basin transfers is unlikely to change in the short and even medium term".*

The relevant basin councils, state and municipal governments, and other regional entities (e.g. metropolitan commissions (see 8.3.4)) also do not coordinate regarding water transfers despite the many inter-connections between them (OECD, 2013) (Interviews-M17/M28/M48). Overall, the inter-basin transfers are not part of a sustainable and integrated basin management vision (Interviews-M13/M28).

Impacts on inclusiveness and sustainability

Large infrastructure works mitigate water shortages for the MVMC in the short-term and reduce pressure on the MVMC's aquifers but in the longer-term they are inadequate in themselves to address water scarcity in the VMB, as demand will continue to rise and water would need to be imported from constantly further at increasing costs (e.g. infrastructure, energy, environmental degradation, on displaced local communities) (M6/M7/M9/M28/M40/M48/M49/M50). Moreover, climate change forecasts project an overall decrease in precipitation, which will put additional stress on the region's water systems, and this is not considered in current water supply planning (Interview-M55). The emphasis on importing water comes at the expense of efforts such as conservation in areas crucial for aquifer recharge, reusing water or reducing leaks, which are part of an integrated and long-term vision of the basin (M9/M15/M40/M44).

Large engineering works have altered the original hydrological balance of the basin of the VMB and surrounding regions by artificially unifying not only the urban areas but also the regions beyond the city (Interview-M32). Consequently, the water system has been configured into a sort of mega-basin (Perló and González, 2005; Romero Lankao, 2010). Around the dams, forest cover has decreased, while unsustainable farming practices and human settlements with inadequate sanitation have increased (World Bank, 2015) (Interview-M51). Erosion has caused severe siltation; algae blooms have resulted from the disposal of organic matter and agrochemicals (Martínez, 2018) (Interview-M48). Toxicity levels in the dams have reached such high levels in 2014 that the CONAGUA considered suspending water imports. This was ultimately avoided by adding an additional treatment step (Martínez, 2018). The degradation of the dams' water quality thus contributes to higher water treatment costs. In addition, uncertainty remains around the effects of climate change on surface water systems, and basin transfers rely on diesel pumps and hence emit greenhouse gas emissions (Interviews-M14/M40).

The power structures in place favour the city, where water is heavily subsidized by the central government, at the expense of water producing areas, where locals often lack access to basic water services while *their* water is piped and exported (Interviews-M12/M28/M32/M33/M51). However, urban dwellers do not benefit equally from this system. Poorer, peri-urban areas in the East of Mexico City and the MVMC do not receive these waters (Interviews-M28/M32/M48/M50/M52). Top-down management of basin transfers has contributed to rising political opposition and socioenvironmental conflicts with communities in the donor basin (Tortajada, 2008; Engel *et al.*, 2011; Pina, 2011; Spring, 2015). For instance, in 2004, indigenous women from the Mazahua group shut down the megacity's water supply by peacefully occupying a water treatment plant in Mexico State, after CONAGUA flooded their fields (Spring, 2011). Tensions date back to the 1970's, when federal authorities started to exploit the communities' water resources without consultation or compensation. Plans for additional inter-basin transfers have stalled in part because of opposition by local communities, but tensions could escalate if a drought arises (Interview-M12).

Finally, the cost of inter-basin transfers is high, and it is not only borne by users but also by the general population, due to large subsidies. As the systems expand and new sources further away are connected, the costs will increase (Interviews-M15/M48). Cost-benefit analyses are not transparent, and it is not clear whether investments in alternative solutions (i.e. reducing leaks, water reuse) have been adequately considered (Interviews-M40/M48).

7.4.2 Water use permits

Design

Water use permits aim to control water use and provide users with rights and obligations (NWL, 2004, sec. Art. 20). Due to (relative) water scarcity, the water allocation regime is crucial to control water use, as it establishes water abstraction restrictions in certain zones through water use permits and fees (see 7.4.3). CONAGUA grants water use permits through its basin agencies or directly when appropriate (NWL, 2004, sec. Art. 20). Permits specify the maximum amount of water a user can abstract, the use's purpose (e.g. domestic, industrial, agricultural), the abstraction's location and the duration of the right (OECD, 2013). They must be registered in the Public Registry of Water Rights (REPDA), which was created in 2004 to regulate water use and provide information on water uses and legal security to users (Art. 9, NWL). The CONAGUA also grants water discharge permits (see ANNEX G – ADDITIONAL INSTRUMENTS).

Permits are the NWL's main instrument to achieve hydrological balance, and the CONAGUA is responsible for verifying water availability in the relevant watersheds and aquifers to cover all registered water use permits (CONAGUA, 2015). Mexico is divided in several water availability zones that determine the volume of water that users can request to be granted via a permit.[72] There is no official limit to the total amount of water a user can be granted. However, new concessions cannot be emitted in restriction zones, such as most of Region XIII, which aims to create a ceiling for the level of abstraction within the region (OECD, 2013). In addition, an environmental and economic impact assessment must be presented when requesting a water use permit (CONAGUA, 2018). Water use can be temporarily restricted when it affects the minimum environmental flow[73] and during droughts, and the NWL guarantees priority for public supply in times of scarcity. CONAGUA has the power to sanction those who violate their water extraction agreements, as well as users who grossly abuse or misuse urban water resources (Acevedo *et al.*, 2013).

Domestic and public-urban uses represent about 75% of the total volume of water granted in concessions in the VMB, 18% is allocated to agricultural use and around 5% to industrial use (World Bank, 2013).

Permits are somewhat flexible. SACMEX can relocate its extractions points to new areas within the same aquifer and dig new, sometimes deeper, wells if it does not extract more water (and receives CONAGUA's authorization). Moreover, water users can transfer their permits to other users within a same basin or aquifer (Federal Constitution, Art. 27). CONAGUA can approve, reject or apply conditions to such transfer request, depending on whether the hydrological or environmental conditions of the concerned basins or aquifers are altered in the process (Art. 34, NWL). CONAGUA charges a small administrative fee for reviewing and authorizing the transfer and registering changes in the REPDA.

72 Surface water use permits are required if abstraction significantly alters water quality or flow (NWL 2004, Art. 17). Groundwater can be abstracted without a permit, except when the Federal Executive establishes regulatory means to limit extraction and use (NWL 2004, Art. 18). The following zoning restrictions apply: 1) In 'regulated zones' aquifers have sufficient mean annual water availability, and addition volumes can be allocated without jeopardizing the aquifer balance; 2) In 'prohibition zones' more water is leaving the aquifer (e.g. extractions, natural discharge) than entering it. No new water use permits can be issued. This concerns a large part of Region XIII; 3) 'Reserve zones' limit water use for conservation or specific uses.

73 The term 'environmental use' or 'ecological conservation use' is used to refer to the minimum flow or volume of water needed in receiving bodies or the minimum natural discharge flow of an aquifer, which must be preserved to maintain environmental conditions and the system's ecological balance (Art. 3, LIV, NWL)

Effectiveness on actors in terms of mandated goals

Water use permits are designed to meet sustainability and inclusion criteria (i.e. preserving minimum environmental flow, guaranteeing priority for human consumption, charging fees to encourage rational use), but they are not adequately enforced. CONAGUA lacks the capacity to continuously monitor all users and rarely sanctions misuse (Acevedo *et al.*, 2013; OECD, 2013) (Interviews-M5/M6/M9/M32/M50). Moreover, bulk water use metres are often absent. As a result, clandestine extractions (without water permits) have persisted despite restrictions in place since the 1950's (prohibition zones) (Interviews-M6/M7/M9/M32). Inspections are often conducted following 'citizen complaints' that inform about irregular activities.

During the last few decades, users have had several opportunities to regularize irregular wells (Interviews-M9/M32). The legalization of irregular uses after the 1992 reforms led to a significant reduction in irregular wells, although not a reduction in extractions, as irregular wells became legal wells (Interview-M32). This sudden legalization meant that the groundwater allocated was greater than the rate of aquifer recharge (Interviews-M32/M48/M52). Worse, actual extraction rates were often much higher still – problems that persist due to strong resistance by permit holders to decrease consumption (see Table ***7.4***). 864 hm^3 are over-extracted each year from the VMB's aquifers, as shown by calculations based on government data. This corresponds to 27.3m^3/s – slightly higher than the volume imported from the Cutzamala System.

Permit transfers are in theory efficient; they allow for new uses without increasing extraction. However, the difficulty of obtaining a permit and the lack of monitoring have encouraged irregular water uses. In addition, permit transfers have spurred a black market where sellers and buyers agree on a (sometimes exorbitant) price (Interviews-M9/M31). Through this black market, permits are often bought for a different purpose than the one they serve on paper: Many wells in the MVMC's periphery were used for industrial or public-urban purposes but were registered for agricultural use (Interview-M9). As the city grew, and the demand for both water and land increased, real estate companies and industries bought lands from farmers in the periphery to build housing developments, and they also often bought the farmers' water permits without CONAGUA's approval and only legalized this permit transfer afterwards (Interviews-M6/M7/M9/M32). Permit transfers are not supposed to involve a financial transaction between users – just an administrative fee to CONAGUA – and require CONAGUA's approval before the transfer is carried out, yet developers suffered no consequences (Interview-M9/M51/M58). Developers also often infringed rules and regulations regarding land acquisition and building norms, and the local governments either turned a blind eye or eventually legalized the land (Interviews-M22/M23/M50/M51). Permit-holders who no longer need to extract water, should cancel their permit, but this has rarely happened (Interviews-M6/M7). Groundwater permit-holders often consider themselves 'owners' of this water and feel entitled to sell it as their property (Interview-M31). In addition, building regulations (i.e. number of floors, percentage of surface area free from construction) are often violated, with no serious consequences (Interview-M51).

Table 7.4 Water availability in the Valley of Mexico Basin's aquifers (in hm^3 per year)

Aquifers	**Aquifer recharge**	**Natural discharge**	**Groundwater volume allocated**	**Groundwater volume extracted**	**Over-allocation***	**Over-extraction****
Cuautitlán-Pachuca	357	0	415	751	-58	**-394**
Metropolitan Zone of Mexico City	513	0	1104	624	**-591**	-111
Tecocomulco	28	1	1	13	26	15
Apan	30	0	19	15	11	15
Chalco-Amecameca	80	0	90	128	-10	-48
Texcoco	49	0	93	465	-44	-416
Soltepec	93	42	16	18	77	75

* = Aquifer recharge - Natural discharge - Volume allocated to users

** = Aquifer recharge - Natural discharge - Volume extracted

Source: Adapted from SEGOB (2016a, 2016b, 2016c, 2016d, 2016e, 2016f)

Furthermore, the ability of water utilities to open new, deeper wells if old ones run dry, does not incentivize water use efficiency or efforts to reduce water demand (Interviews-M6/M7/M9/M19/M52). Moreover, permits are issued for a certain amount of time and their renewal should involve an evaluation, which rarely happens due to a lack of capacity and will on behalf of CONAGUA (Interview-M31). Many users even had permits that had long expired without suffering any consequences, although in 2014-2016 CONAGUA carried out a nationwide process to renew such permits without sanctions for a period of three years, after which they would need to apply for a regular renewal (De Regil, 2014; Valadez, 2016).

The basin councils are considered ineffective to address problems related to water use and permits. In part, this is due to inadequate knowledge-sharing mechanisms (Interviews-M31). The COTAS within the VMB do not interact with the basin councils and other entities, impeding integration between surface water and groundwater management (Interview-M32). In fact, significant uncertainty remains regarding surface and groundwater interactions, and about aquifers themselves, due to limited available data on the location of aquifers' recharge and discharge areas, their depth, flows and more (Interviews-M31/M32). Aquifer and (sub)basin boundaries also do not (necessarily) coincide, but this is often ignored as basin boundaries are taken as management units (Interview-M32). This means that quantitative or qualitative alterations of aquifers may affect a neighbouring basin more than the one directly above it. Moreover, water allocation is mainly calculated on the basis of the average annual availability and the preservation of the minimum environmental flow (or minimum natural discharge in aquifers), but it does not consider the impacts of climate change (OECD, 2013).

Impacts on sustainability and inclusiveness

Aquifers, the main source of water, are recharged through summer rains and natural springs in the surrounding mountains, but extraction rates exceed recharge rates – estimates point out that 45% of water supplied to the MVMC comes from over-exploited aquifers (Tortajada, 2008; Pina, 2011; Martínez and Enciso, 2015) (Interviews-M6/M7/M9). This has led the groundwater table to fall by about one metre per year which, in turn, causes soil subsidence (5-40 cm per year) (Tortajada, 2008; Engel *et al.*, 2011; Pina, 2011). Over-extracting groundwater can lead to the disappearance of ecosystems, wetlands and lakes, and reduced river flow, and the link is not always identified due to delayed effects (groundwater flows are slow) appearing far from their cause (Interviews-M32). Experts warn that Mexico City will run out of water within the next decades if it does not urgently develop sustainable water management (Spring, 2015) (Interview-M9). A business-as-usual scenario for 2030 estimates that renewable water sources will only cover 53.8% of demand, with 21.1 m^3/s supplied through over-exploiting current sources and a remaining deficit of 25.1 m^3/s (World Bank, 2013). Over-exploiting aquifers will contribute 23% (if they are not pumped dry first)[74], while for the remaining 27% new sources are yet to be determined (World Bank, 2013).

Some of the aquifers with higher levels of extractions than registered use, such as Cuautitlán-Pachuca and Texcoco, export water to Mexico City (Escolero *et al.*, 2016). The groundwater table of the Cuautitlán-Pachuca aquifer, just north of Mexico City, was reported to decline by two metres per year (Ramírez, 2015; Escolero *et al.*, 2016) (see Table ***7.4***). The inauguration of a soda drink plant that would extract large volumes of water annually – despite the aquifer's classification as a 'prohibition zone' and the low priority of this use—caused conflicts between civil society, CONAGUA and the soda drink company in 2017, as experts warned this threatened public water supply (Olvera, 2017). Illegal abstractions are also estimated to be among the highest nationwide (Galindo, E. *et al.*, 2011; Ramírez, 2015). The pressure on aquifers surrounding Mexico City highlights that this is a metropolitan problem requiring a regional solution with coordination between actors from the jurisdictions involved. Considering that the Cuautitlán-Pachuca and Texcoco aquifers are home to large, low-income peri-urban populations, questions of unequal access and power relations arise: Of every 100 residents of the VMB, only 6 do not suffer from water scarcity (Burns, 2009). Of these 6, two residents consume on average 567 l a day, and four 399 l. As many as 77% of residents consume less than 150 l a day, but often for a higher cost as water is frequently transported through trucks (Burns, 2009).

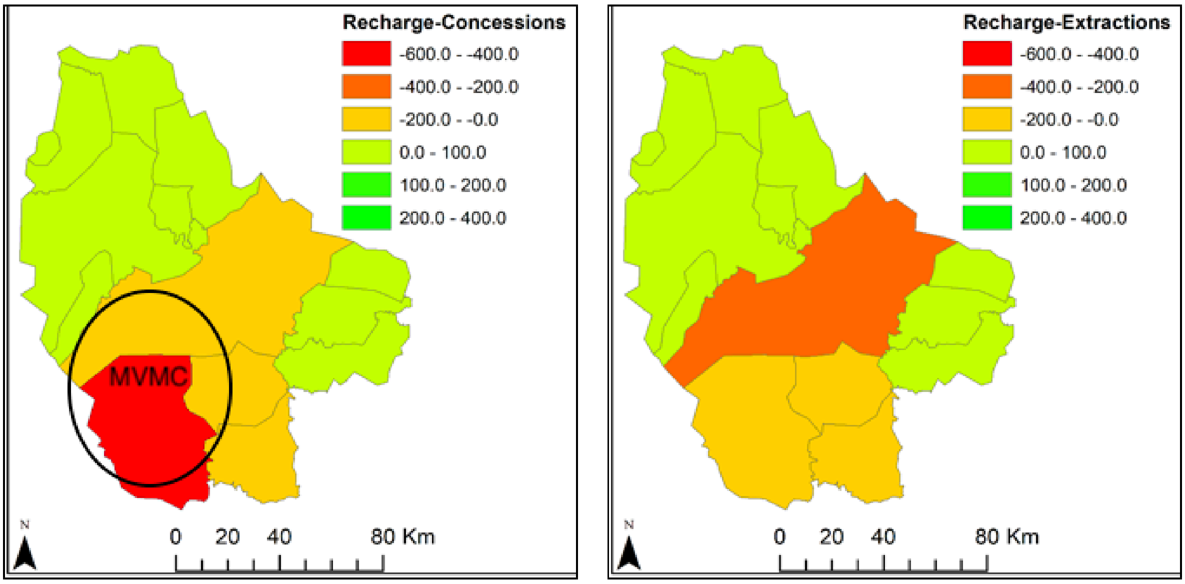
The maps in Figure ***7.1*** build on Table ***7.4*** and highlight the water availability based on calculations derived from CONAGUA's data on water allocation (official calculation to determine water availability) and water extraction[75]. The MVMC spreads mainly across the Mexico City aquifer in its South and the Cuautitilán-Pachuca aquifer in its North. Comparing the two maps reveals that CONAGUA's current water availability calculations may be

74 The current knowledge on the exact volume and flows of groundwater in the MVMC are still limited, making it difficult to develop accurate forecasts (Interview-M32).

75 CONAGUA calculation of water availability = Aquifer recharge – natural discharge – water allocated. Alternative calculation of water availability = Aquifer recharge – natural discharge – water extracted

misleading, as water extractions can be significantly below or above the volumes allocated to users within an area. In fact, tensions between Mexico City and Mexico State (where the Cuautitilán-Pachuca aquifer, in dark orange on the right-hand map, is located) are rising. This indicates that while Mexico City's aquifer may be more over-exploited, surrounding aquifers are rapidly depleting.

Figure 7.1 Water balance per aquifer based on allocated water (left) and extracted water (right)



Source: Author

Water allocation remains a top-down process. The lack of data transparency creates confusion about real water abstraction and the areas that require greater support in addressing unsustainable water use practices. Ineffectiveness and corruption favour wealthy users willing and able to pay high prices for water permits, as CONAGUA lacks capacity to pursue irregular permit holders. In addition, this black market for permits is most likely facilitated by insiders. One groundwater expert claimed that CONAGUA employees attempted to sabotage the COTAS as monitoring and accountability-holding activities threatened entrenched (and corrupt) interests (Interview-M32). In April 2019, a fire broke out in a CONAGUA building over the weekend, and amidst rumours of an upcoming audit, within an area that held important documentation relating to water use permits (Martínez, 2019).

7.4.3 Water use fees

Design

CONAGUA employs a 'user-pays' principle, meaning users must pay a fee for the abstraction and use of water resources (NWL, 2004). These bulk water fees aim to incentivize water utilities to invest in reducing per capita consumption, while representing the main mechanism for water users' contribution to financing WRM (OECD, 2013). They were introduced in Mexico in 1982 and their rates vary according to the type of use (e.g. industry, urban, hydropower, aquaculture and recreation) and geographical location. Water use for agriculture, for domestic use related to agricultural activities and for rural settlements of less than 2500 inhabitants are exempt from paying water use fees (DOF, 1981). Mexico's basins and aquifers are classified in one of four different 'availability zones' that reflect water scarcity, and typically the cost of the cubic metre is higher in low availability zones (CONAGUA, 2018). The bulk water rate is determined by an algorithm published in the Federal Law of Rights (DOF, 1981) and adjusted annually by CONAGUA (CONAGUA, 2018).

The Federal Treasury, collects fees from users other than water utilities and from inter-basin transfers through the Basin Agency (World Bank, 2015). These fees fund the bulk of CONAGUA's budget and programmes such as the federal payment for ecosystem services programme (PSAH) (see 7.4.4) (World Bank, 2013). Since 2004, water utilities pay bulk water fees to the regional Fideicomiso 1928 trust fund, which invests in large-scale drainage and sanitation works in the VMB (World Bank, 2015). The governments of Mexico State and Mexico City are the fund's settlors and CONAGUA acts as president and technical coordinator (World Bank, 2015). The SACMEX also includes this trust fund as part of its financing plan (OECD, 2013).

Users also pay a fee for wastewater discharge, based on the 'polluter-pays' principle (NWL, 2004). These fees are set at Federal level. However, this fee is only charged if the discharge does not meet minimum quality standards (Interviews-M5/M6/M7). The fee aims to cover investments in wastewater treatment (DOF, 1981).

Effectiveness on actors in terms of mandated goals

The delimitation of availability zones and the identification of the VMB as a water scarce region means that water use fees should ideally reflect the gap between water availability and water demand (Interview-M32). Indeed, as water availability decreased in the VMB, bulk water use fees charged increased significantly (World Bank, 2013), even if they remain generally low and were restricted mostly to industrial uses (Interviews-M5/M32). Agricultural users were exempted if they remained within their licensed quotas and the rate for water use exceeding their licensed quota was only between 0.7% and 8% of the general rate (depending on the availability zone) (OECD, 2013) (Interviews-M32/M50).

Most fees collected reflect users' self-reported volume of water use. Users have some incentives to regularize their water usage and pay some fees. In particular, energy costs for pumping groundwater are subsidized but to apply for these subsidies, users must show their water use permit. Audits of industries also often start with a request to see water use permits and bills from water use fees (Interview-M32). Nonetheless, Basin Agencies cannot afford to inspect most users, so these self-reported values were rarely verified (Interview-M58). The lack of macro-metering also encourages under-reporting (Interview-M19). Lack of monitoring, enforcement and exemptions also impacts wastewater discharge fees (Interview-M40). The total value of the collected water use fees (for public supply and other uses) in Mexico has increased slightly between 2008 and 2017, reaching just over USD 860 million in 2017, and Region XIII contributes over a third of this amount (CONAGUA, 2018). In 2017, the value of the wastewater discharge fees collected in Mexico was only USD 80 million. In 2009, the collected wastewater discharge fees represented 0.4% of the amount needed per year for 2011-2015 to clean water bodies according to CONAGUA (CONAGUA, 2012a). The fees go to the Federal Treasury and are reinvested in Federal level programmes, which are unlikely to be related to preventing contamination (Interview-M58). As a result, all users lacked incentives to reduce water use, invest in water saving technologies or prevent water contamination (Interviews-M5/M9).

Impacts on sustainability and inclusiveness

The limited effectiveness of bulk water use and wastewater discharge fees aggravates that of water use and wastewater discharge permits, reinforcing the same impacts (see Impacts – Section 7.4.2). Nevertheless, the fees paid by water utilities in the VMB are partly reinvested in water supply and sanitation infrastructure through the Fideicomiso 1928 trust fund (see 7.4.1), which has supported the cash-strapped utilities (OECD, 2013) (Interview-M19). However, a large volume of water used by utilities in the MVMC comes from other basins, but their fees benefit infrastructure within the VMB. This does not compensate donor basins for infrastructure maintenance or ecosystem preservation. Fees from other users are absorbed at national level and do not benefit the MVMC or its donor basins.

7.4.4 Payment for ecosystem services (PES)

Design

Several water-related PES programmes have been implemented in Mexico. At federal level, the CONAFOR (National Forestry Commission) manages the Payments for Hydrological Ecosystem Services Programme (PSAH) – the main PES programme focused on hydrological services. It was implemented in 2003 to protect and restore ecosystems, and preserve their services through direct economic compensation to the providers of environmental services (OECD, 2013; Perevochtchikova and Torruco Colorado, 2014). It is one of the world's largest PES programmes focused specifically on watershed services and was mainly funded by revenues from bulk water use fees, ensuring it stable, long-term funding (OECD, 2013). Landowners were eligible for different payment levels depending on the type of ecosystem in combination with their score on a deforestation risk index, and payments were issued yearly after verification of the forest cover (through satellite image analysis or ground visits) (OECD, 2013). Areas that lost forest cover were removed from the programme and payments were reduced proportionally (OECD, 2013).

In Mexico City, the CORENA (Natural Resources Commission of Mexico City) manages the PROFACE (Support Funds for the Conservation and Restauration of Ecosystems Program) programme, which covers 13,000 hectares. It financially compensates landowners or designated groups for conservation efforts in important sites, including through fire prevention, productive reconversion, the preservation of agroforestry systems and silvopastoral systems. Brigades are trained for each participating area for environmental monitoring, including through GIS (Interview-M30). These payments are generally focused within the Conservation Land (see 8.4.4). Mexico State also has a PES programme, similar to the PSAH, financed by a percentage of the Wat&San tariff.

Effectiveness on actors in terms of mandated goals

Results appear to be mixed. To be effective, PES programmes must compensate for the opportunity cost of preserving rather than developing land. This opportunity cost varies greatly across the country, being higher close to Mexico City and lower in isolated, distant areas (Interview-M48). The financial compensation of the PSAH is much lower than the opportunity cost of refraining from exploiting or selling the land, as payments only average USD 15-20 per hectare per year (Interviews-M2/M9/M26/M48/M50/M54). Landowners often worry about informal occupations of their land and illegal loggers and choose to develop or sell their land (Interview-M10/M26/M48). As a result, CONAFOR encourages alternative activities compatible with environmental protection, such as honey and essential oils production, or ecotourism (Interview-M10). Those involved with the programme compared the payments to seed money supporting local projects in their initial stages (Interview-M55).

There have been virtually no studies on the impact of PROFACE, although respondents familiar with the programme claimed it had modest yet positive results, despite a low budget (Interviews-M15/M17/M29/M37). Supporters argue that it is more permissive but also more pragmatic than the PSAH. To expand, the SEDEMA would need to be convinced that the programme was effective, but without evaluations this was difficult (Interview-M30). The PES programme in Mexico State ensures a stable, reliable inflow of funds, although these remain low due to subsidized tariffs and consumers who did not pay their water bills (Interview-M15). Nevertheless, this financial stability gave recipients security.

Despite the existence of multiple PES programmes, there were no coordination mechanisms between these or with similar policy instruments. In addition, PES programmes focused on water were not always designed based on basin or aquifer boundaries, which hindered the ability to measure changes in ecosystem services (Interview-M55).

Impacts on sustainability and inclusiveness

PES programmes have potential to preserve areas important for springs and aquifer recharge. This is crucial for the MVMC to continue using groundwater in the coming decades. However, near large urban centres the opportunity cost of protecting land rather than selling it to real estate developers or others is too high for many landowners (Interview-M46/M48). Recent studies show that areas of Mexico City included in the PSAH programme sometimes had higher deforestation indices than other areas (Saavedra Díaz *et al.*, 2017). As those areas were under pressure from real estate and agricultural interests, it was difficult to evaluate whether deforestation would have been worse without the programme. Although there has been no formal assessment of the PROFACE programme, respondents claim that biodiversity and reforestation increased in the areas involved in recent years (Interview-M30).

However, critics argue that PES programmes put an arbitrary value on water resources and reinforce their commodification (Interview-M58). It is also politically difficult to charge fees or taxes in one jurisdiction, in order to reinvest these funds elsewhere for results that would only be apparent in the medium to long term (Interview-M28). This would likely be the case with a PES programme for the Cutzamala System financed by the MVMC. However, supplying water is increasingly expensive (e.g. groundwater pumped from deeper depths and inter-basin transfers from more distant regions), and these costs will rise much more sharply if no urgent measures are implemented to preserve ESSs.

7.5 Instrument assessment and redesign

The instruments employed in the MVMC's river basin governance were sometimes promising on paper, but generally failed to effectively change actors' behaviour and foster more sustainable and inclusive water governance. The linear approach still dominated key institutions and policy frameworks. Water resources from multiple states were transported into the MVMC and out (as wastewater) through a complex infrastructural network of inter-basin transfers, deep drainage tunnels and canals. This artificially connects four basins and multiple jurisdictions, leading some to use terms such as 'City-basin' (Peña-Ramírez, 2012) or the 'Hydropolitan Region' (Perló and González, 2005). This multi-basin structure has lowered incentives for rational water use, reducing contamination and preserving vital ecosystems (see Table ***7.5***).

Table 7.5 Assessment of IWRM/IRBM policy instruments in the MVMC

	Instrument design	Effects on actors	Impact
Inter-basin transfers	[0] Necessary to respond to growing demand and reduce pressure on aquifers Costly and energy intensive	[0/+] Ability to respond to rising water demand (for now), though water supply is unequal across the MVMC Subsidies reduce incentives to decrease water use and losses	Env: [--] Reduced pressure on aquifers, but externalities are transferred to donor basins Soc: [--] Peri-urban and rural dwellers receive less water Econ: [--] Subsidies hide real costs Rel: [--] Conflicts with donor basin. Decisions are centralized and lack transparency
Water use permits	[++] Based on water availability and type of use Requires environmental impact assessment, preservation of minimum flow. Can be transferred	[-] Lack of capacity and political will to enforce regulations. Transfer system enabled users to bypass rules. No coordination on regional water use, despite interlinked systems	Env: [--] Groundwater table has fallen, and local sources may dry up in next decades Soc: [--] Peri-urban poor lack adequate access to drinking water Econ: [-] Industrial and real estate actors obtain permits, but they are hardly enforced, leading to (unsustainable) economic and urban growth Rel: [--] Industrial users receive permits despite scarcity. Lack of transparency
Water use & wastewater discharge fees	[+] Rates vary per use and area Reinvested in drainage and sanitation works in the VMB or go to Federal Treasury	[-] Prohibition zone and other strict regulations exist, but lack of metres, cost of monitoring and impunity hindered enforcement. Low fees and energy subsidies promote high use. Only part of the fees was reinvested regionally	Env: [--] Same as water use and wastewater discharge permits Soc: [--] Same as water use and wastewater discharge permits Econ: [--] Fees were not all reinvested locally or even in water management Rel: [--] Donor basins are not compensated for their ESSs
Payments for Ecosystem Services programmes	[+] Aim to compensate ESS providers Federal programme funded by water use fees, Mexico State by water tariffs, Mexico City by city budget	[0] Does not always compensate for opportunity cost, but demand grew, and funds are insufficient. Stable funds are important	Env: [-] Deforestation and degradation continue on urban fringe. Difficult to link programmes to local impact Soc: [0] Restricting urbanization does not address the affordable housing deficit Econ: [+] Programmes are costly, but degradation is much more so in long-term Rel: [+] Alternative for landowners. Recognition of the value of ESSs

<u>Relative assessment scores</u>: ++ Very positive; + Positive; 0 Neutral; - Negative; -- Very negative (See 2.4)

Redesign

Based on the evaluation of the above instruments, the following redesign options look promising.

Inter-basin transfers: As aquifers are increasingly over-exploited, it is unrealistic to support the dismantling of inter-basin transfers in the short or medium-term, despite the many negative externalities they cause. In the longer-term, a combination of measures could alleviate the need for external resources, but in the meantime decision-making on water imports could be more transparent and inclusive of marginalized interests, as current decisions regarding the expansion of inter-basin transfers are centralized and made behind closed doors. Involving basin councils in discussions would allow for different interests to be voiced and greater social inclusion. While they may not have mandates to influence infrastructure decisions, members should at least have access to financial information to ensure accountability. Investing more resources in land use management and environmental conservation in the donor basins, as well as basic infrastructure for communities living near water supply dams, would reduce water losses, increase the productivity of water systems and include currently marginalized groups. This could be through federal funds, PES programmes or revenues from bulk water fees. This will sustain supply dams by ensuring that springs continue to replenish them, reducing the need for searching for new sources further away at increasing costs. Indeed, the strategy of supplying the MVMC with inter-basin transfers is reaching the limits of economic viability. Investments in donor basins could also come from the water use fees for uses other than public supply and from basin transfer fees. These fees are now collected by the Federal Treasury but at least part of them (e.g. those coming from basin transfers) could be reinvested in donor basins. Changes to water tariffs for domestic consumption (see 8.4.1) could also increase water conservation within the MVMC and reduce the need for water imports.

Water use permits: To increase their effectiveness, water use permits do not need to be redesigned but to be better enforced. Addressing irregular water use requires monitoring, which is costly as much of it involves groundwater extraction, which is less visible. However, monitoring teams do not need to inspect all users constantly. The current impunity for violations must be addressed by applying adequate fines that reflect the severity of the transgression (Interview-M9). This will make non-compliance more costly, reduce irregularities and reduce water use, while fines would help fund monitoring costs. These efforts can be focused on large water users, such as big industries, as their use significantly impacts other (potential) users and their development and investments plans are generally less affected by the payment of water use fees. Smaller users require technical assistance through CONAGUA, as the process of obtaining a permit can be burdensome and expensive (Sanz, 2015).

A significant challenge relates to permit transfers, as these are not adequately regulated. Combined with a lack of land use and building regulations and environmental regulations, users such as real estate developers and industries can obtain water use permits, thereby allowing for unsustainable urban expansion and economic activities. This could be prevented by requiring environmental impact assessments that address consequences on over-exploited aquifers and access to water for nearby residents and how these would be compensated. Strengthening the basin councils and the COTAS could also better include diverse, local interests into decision on water allocation.

Moreover, more transparency is needed regarding data collection and calculations of water availability and extractions. CONAGUA calculates water availability based on how much water is already allocated rather than how much is extracted, seemingly assuming these values are the same. If the system to calculate water availability is not adjusted, at least relational inclusiveness can be enhanced by making its methods more transparent.

In addition, if CONAGUA aims for environmental sustainability and social and relational inclusiveness then the enforcement of priority uses is crucial. Water-intensive industries could undergo environmental impact assessments with a significant emphasis on their potential impacts on water availability for other users. If it is determined that these industries would jeopardize surrounding communities' drinking water access and the sustainability of the aquifer, licensors could withhold approvals, in particular when these communities oppose the presence of such industries.

Water use fees: Expanding mandatory and tamper free metering and water use fees could promote more rational water use (Interviews-M13/M15/M46). This requires transgressions to be subjected to sanctions. While it may be difficult to implement water use fees for agricultural users, incentives can be put in place for farmers to transition to less wasteful irrigation techniques. This could involve a combination of subsidies for irrigation technologies and the strengthening of irrigation districts to seek collaborative solutions to growing water scarcity.

Another issue is that water use fees are not necessarily returned to the basin where they were charged, as is the case in the MRSP. This creates a disconnect between water users and the areas that produce water resources. By applying a system similar to that of the MRSP, the willingness to pay of users may increase and it could strengthen participatory basin management by creating a source of revenue for basin councils.

Payment for Ecosystem Services: As most land in Mexico is privately owned, implementing strict land use restrictions with no compensation would amount to expropriation and lead to time-consuming and costly litigation and uncertainty. Considering this context, PES programmes have potential in areas under pressure from urban and agricultural expansion. However, funding sources for PES programmes remain scarce. Integrating a small fee within water and sewage tariffs for such programmes, as is the case of Mexico State, is viable as Wat&San tariffs are currently very low (see 8.4.1). Low-income households could be exempted from paying this additional fee. The fee could increase proportionally with consumption. This would not only ensure stable funding and incentivize rational water use, but it could also raise awareness among consumers by emphasizing the link between water sources outside the city and their taps.

Furthermore, returning the collected fees proportionally to the areas where water came from can enhance sustainability and inclusiveness. More environmentally sustainable management of the river basins that drain into the Cutzamala system could reduce water imports. However, while there is some recognition (with still limited action) of the ecosystem services provided by areas within the metropolitan area, there is virtually none for the ecosystem services provided in these other basins. This requires integrating PES programmes with basin and aquifer management and could strengthen the link between IWRM/IRBM and urban water services. It could also capacitate basin councils and increase their weight in negotiations (Interviews-M40/M55). PES programmes would then account for interconnections and spillovers across different basins. Ultimately, a mix of regulatory and economic instruments are necessary to preserve environmentally significant areas and landowners require greater support to contribute to these measures.

Coordinating PES programmes and environmental agencies with authorities responsible for urban planning and land use could also help address the challenge of environmental preservation at its root, by finding solutions for affordable housing in other areas or by promoting densification rather than sprawl.

Missing instruments

Water use should be compatible with the needs of current and future consumers but also with those of the basin(s) from which water is supplied. Reinvesting bulk water use fees and water tariffs in programmes to preserve ecosystem services are potential mechanisms for this purpose. For reinvestments of water tariffs, this requires Wat&San planning that looks beyond the boundaries of the utility's jurisdiction, at a larger regional, scale.

Some alternative approaches have been gaining support, including facilitating groundwater recharge in the city through green infrastructure and artificial aquifer injections (where rainwater or treated wastewater is injected into the ground), or environmental protection in areas of aquifer recharge (particularly in the mountains surrounding the basin). These both mitigate excess surface water runoff and replenish water supply sources. The effectiveness of these measures is difficult to determine due to the many unknowns surrounding groundwater flows (e.g. velocity, impact on water quality from contaminants). Understanding groundwater flow dynamics is important for prioritizing preservation efforts and for installing water injection technology in optimal locations (Interview-M32). More groundwater studies are needed to evaluate the potential impacts and costs of such measures, and thereby the extent to which it could reduce the dependence on external water resources.

8. THE IMPLEMENTATION OF UWM IN MEXICO CITY

8.1 INTRODUCTION

This chapter examines how different drivers and institutions at multiple levels of the urban water governance regime shape water-related challenges in the Metropolitan Valley of Mexico City (MVMC). It uncovers the causal chains behind these water challenges and the effectiveness of existing policy instruments. It reviews the relevant historical and geographical context of Mexican urban water governance and its main drivers (see 8.2). It analyses the driving forces on the city from local to global level. Section 8.3 then explores which formal actors and institutions shape Urban Water Management (UWM) in the MVMC. Section 8.4 analyses the instruments of UWM according to their stated mandates, their effect on actors' behaviour and their impacts on inclusive and sustainable water governance. Finally, the chapter summarizes the main empirical findings and considers how more appropriate instruments could be (re)designed for the Mexico City case study in relation to UWM (see 8.5).

8.2 CONTEXT AND DRIVERS OF MEXICO CITY'S URBAN WATER CHALLENGES

8.2.1 CONTEXT IN RELATION TO THE METROPOLITAN REGION

Mexico City was founded by the Spaniards in 1521 on top of the ruins of Tenochtitlán, which had approximately 70,000 inhabitants at the time of the Spanish conquest (Escamilla and Santos, 2012)[76]. As the capital expanded, it formed the Metropolitan Valley of Mexico City (MVMC), which includes Mexico City and 60 municipalities located primarily in Mexico State, but also in the states of Hidalgo and Tlaxcala (Spring, 2011). Mexico City itself is a federal entity, composed of 16 districts that are similar to municipalities.

8.2.2 MAIN DRIVERS OF MEXICO CITY'S URBAN WATER CHALLENGES

Urbanization

The MVMC grew rapidly during the 20th century, especially after 1950, through urban-rural migration. By 2010 it contained a fifth of Mexico's population, with 20 million inhabitants (INEGI, 2014). While Mexico City's growth rate has declined since 1990, it increased in the surrounding municipalities, intensifying pressure on water resources through increased water use (Spring, 2011; Escamilla and Santos, 2012). Moreover, the city could no longer absorb all the newcomers into the labour market, leading to high levels of unemployment and underemployment, and the spread of informal settlements in peri-urban localities (Romero Lankao, 2010; Spring, 2015)[77]. The speed of urbanization, the lack of planning and local

76 Population estimates for Tenochtitlán vary from 50,000 to 175,000 and even 300,000 inhabitants (Evans, 2013; Matos Moctezuma, 1988; Hardoy, 1964; Vaillant, 1941). Recent estimates are more conservative.

77 The MVMC has one of the world's largest informal settlements, Neza-Chalco-Itza, with around 4 million inhabitants.

governments' weak financial and institutional capacities led to neighbourhoods constructed without basic infrastructure (World Bank, 2013).

Climate

The MVMC is likely to experience the greatest impacts of climate change in Mexico due to ecological degradation and population density (Sosa-Rodriguez, 2014). Temperatures have increased by almost 4°C due to the heat-island effect and climate variability and change (Sosa-Rodriguez, 2014). Current models predict an increase in the mean temperature by 2 to 4C$_{o}$ and a decrease in mean precipitation of up to 20% by 2080, which could further disrupt Mexico City's aquifers (Sosa-Rodriguez, 2014). The metropolis is highly vulnerable to floods due to soil subsidence and its location within an endorheic basin (Spring, 2011)[78].

Economic development

National economic policies since the 1980's have transformed Mexico City into a hub of financial and service activities, stimulating, along with the increasing lack of economic prospects in rural areas, population flows to the capital (Romero Lankao, 2010). The Mexican capital has the largest concentration of wealth in Mexico, generating a third of the national GDP (Romero Lankao, 2010). Poverty and socio-economic inequalities across the country continues to foster migration to the MVMC.

Table 8.1 Multi-level drivers of water-related challenges on the city

	Direct		**Indirect**	
	Local	**Regional/global**	**Local**	**Regional/global**
Urbanization	Urban growth	Urban growth in surrounding regions	Soil subsidence	
	Informal expansion at MVMC's margins			
Economic			Economic centre of the country	Poverty and inequality across Mexico
Climate	Heavy Summer rains		Heat island effect	Climate variability and change

Source: Author

[78] Soil subsidence has inverted the land slope, so expelling wastewater requires more engineering and energy and represents a greater flood risk (Martínez and Enciso, 2015).

8.3 The institutional framework for UWM in Mexico City

8.3.1 Global level

International institutions in the MVMC influence UWM by setting standards and providing financing. For instance, in 2010, the World Bank approved a USD 450 million loan to support the development of climate change adaptation policies for the Mexican water sector (Score, 2010). The IDB also provides funding to the water sector, for instance by supporting water operators (IDB website). However, as Mexico continues to develop, the role of development partners in financing the Mexican water sector is expected to diminish (OECD, 2013).

Furthermore, the Millennium Development Goals (MDGs) (UN, 2000) targets for Wat&San have influenced water policies in Mexico. By 2010, the supply of previously disinfected piped drinkable water in Mexico reached 90.9% of the population, slightly above the 2015 target of 89.2% set by the MDGs (UN, 2013). Access to sewerage reached 87.7% in 2010, above the 79.3% target defined for 2015. However, data about access to piped water also includes households that have a tap but do not receive water every day (Martínez and Enciso, 2015).

8.3.2 National level

During the 20th century, Wat&San functions were gradually transferred to states and municipalities. However, Wat&San has no overarching legal framework at national level, which has hindered efforts to expand these services (OECD, 2013). This vacuum was brought to light in 2012, when Wat&San services were recognized as a human right within the Constitution (OECD, 2013)[79]. This Constitutional reform required the publication of a new NWL that guaranteed this right across the three levels of government. However, as of May 2019 no new bill had been approved. In March 2014, CONAGUA sent a bill to Congress but the text was met with strong rebuttal and was removed from the parliamentary agenda by March 2015 (Godoy, 2015)[80].

Despite the transfer of UWM responsibilities to lower levels, CONAGUA intervenes within the MVMC through its management of deep drainage infrastructure and the canal that discharges wastewater to the Tula Basin (Spring, 2011) (see 8.4.3). The SEMARNAT, CONAGUA, the Ministry of Health and the Ministry of Economy have issued standards relevant to UWM, such as permissible limits of pollutants in wastewater discharges, guidance on how to evaluate tariffs for water services and quality standards for drinking water (CONAGUA, 2018).

79 Article 4 states that: “Every person has the right to water access, disposal and sanitation for personal and domestic consumption in a sufficient, clean, acceptable and affordable manner”.

80 A coalition of CSOs and academics argued that the bill commodified water resources, banned water quality research and favoured the diversion of river flows and dam construction (Godoy, 2015). Members of the ruling coalition retorted that public investment was insufficient to respond to water demand and only the private sector could fill this gap (Adler, 2015).

The General Law for Climate Change was adopted in 2012 and led to the creation of the National System for Climate Change (Mexico (Cámara de Diputados), 2012). CONAGUA states that water-related climate change adaptation and prevention measures that diminish the vulnerability of the population are a priority (CONAGUA 2016a). This is exemplified by the inclusion of these concerns and measures in various federal programmes, including the Special Programme for Climate Change (2014-2018). These programmes focus on mitigation, and adaptation-related measures at national level are mostly limited to monitoring and forecasting of extreme weather events (Interviews-M6/M7/M12). In addition, although a number of laws have been established, implementation in practice has been slower, especially at lower levels of government, in part due to a lack of stable funding sources (Interviews-M6/M7/M15/M46).

8.3.3 State level

The lack of an overarching framework for Wat&San services means that the role of state governments varies significantly. State governments are responsible for planning, regulating and developing infrastructure for water resources. State congresses approve tariffs and are involved in approving state water plans and allocating financial resources for water infrastructure (OECD, 2013). Municipalities can choose to delegate Wat&San services to the State Water Commissions. Besides sometimes acting as Wat&San operators, the latter may be responsible for standard setting, monitoring service provision, improving efficiency and promoting public participation, but they often lack capacity to adequate regulate Wat&San services (OECD, 2013). Within the MVMC, the state water commissions also coordinate with the basin agency and the civil defence and firefighters in case of flood risks (Interview-M19). However, information sharing between these commissions, basin institutions and academics could be improved through the integration of water information systems (OECD, 2013). Overall, state governments have few mandates in relation to water, creating a gap between the federal government and the almost 2500 municipalities (Interviews-M4/M15).

Mexico City's water commission is the SACMEX (Water System of Mexico City) and operates as a water utility. It also operates several large wells within the city and the Lerma System (see 7.4.1). It is a deconcentrated entity of the SEDEMA and has limited technical, budgetary and decision-making autonomy (Interview-M20). Mexico State's Water Commission (CAEM) manages large volumes of water (e.g. water abstraction from the Lerma-Cutzamala systems)[81], treats wastewater and provides Wat&San services in some municipalities. The limited mandates of states and state water commissions in UWM leads to fragmentation in the MVMC as the metropolis spreads over several states.

8.3.4 Metropolitan level

The Federal Constitution states that municipalities within a metropolitan area must coordinate their actions (Mexican Constitution, 1917, sec. Art. 122). It establishes a normative framework that enables the creation of metropolitan committees with representatives from municipalities,

81 It provides bulk water to 16 municipalities of the MVMC.

the Mexico City and Mexico State governments, and sectoral entities. Several committees have been created in the MVMC, such as the Metropolitan Committee for Water and Drainage (CADAM) (1994), Metropolitan Committee for Human Settlements (1995) and Metropolitan Committee for Civil Defence (2000). The Environmental Commission of the Megalopolis, created in 2013 to replace the Metropolitan Environmental Committee (1996), focuses on air pollution in the MVMC (Interviews-M14/M15/M16/M17/M48/M57). There is no policy for conservation at metropolitan or regional scale.

Nevertheless, most metropolitan commissions did not coordinate in terms of shared planning and decision-making (Interviews-M9/M14/M46). Metropolitan-level coordination was mainly limited to day-to-day technical operation of large-scale infrastructure, as the hydraulic systems were completely interconnected (Interview-M14). This type of coordination was more effective when governments at multiple levels are from the same political party (Interview-M6/M7). The financing of metropolitan-scale infrastructure is carried out through the Metropolitan Fund, formed from federal funds to finance not only hydraulic infrastructure but also roads and transportation in Mexico's metropolitan regions (SAF, 2019) (Interview-M15). Municipalities are not directly involved, and there is no long-term, strategic regional vision for water supply management (Interview-M14).

Metropolitan coordination was a divisive topic, with respondents defending decentralization to local levels, while others argued that metropolitan management was necessary to address shared water-related challenges (Interviews-M9/M17/M19/M40/M52). Coordination is also particularly challenging in the MVMC, as it involves three different federal entities (Mexico City, Mexico State and Hidalgo State). Party politics reinforced the fragmentation as they created tensions between levels of government and between state, municipalities and districts across the MVMC (Interviews-M5/M9/M14/M15/M17/M33/M47/M49/M54). Metropolitan entities did not coordinate with basin entities (Interview-M48).

8.3.5 Local level

Democratization reforms allocated numerous UWM responsibilities to local governments. The Constitution gives municipalities the mandate to provide water services (Mexican Constitution, 1917, sec. 115). This includes drinking water supply, drainage, sewage collection, treatment and disposal. Drainage, stormwater and solid waste management are also municipal responsibilities (SEMARNAT, 2003). State laws specify the form in which these services will be provided. Municipalities are responsible for developing a municipal water policy.

Across Mexico, the provision of these services is highly heterogeneous due to the lack of an overarching regulatory framework and the lack of financial and human capacity in most municipalities, which depend on federal and state funds (OECD, 2013) (Interviews-M4/M6/M7/M15/M17/M33). Municipalities can delegate Wat&San services to the state or a private company. Within the MVMC, Mexico City has one public water utility, the SACMEX, for its sixteen districts (although it outsources many activities to third parties), some municipalities of Mexico and Hidalgo States delegate this service to their respective state water commissions and others have their own utility, causing a coordination challenge at regional level (Interviews-M2/M6/M7/M28). Some regions created inter-municipal Wat&San utilities[82].

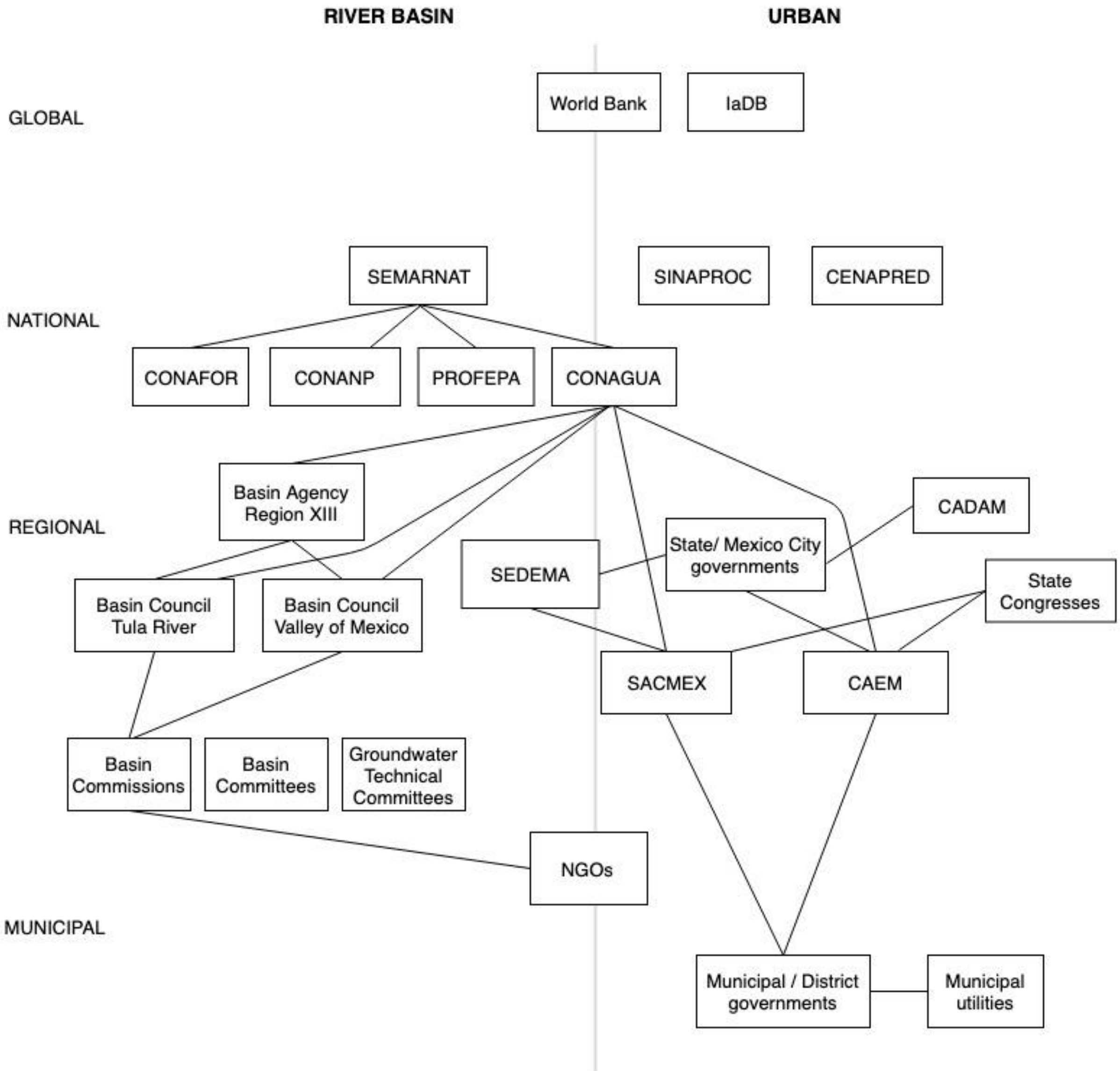
Water utilities cannot provide regular services in informal settlements, as their legal status prohibits the installation of basic infrastructure. Consequently, these areas are supplied through water trucks or alternative systems (e.g. rainwater harvesting) (Interviews-M24/M26/M49). NGOs and companies fill this gap by developing rainwater harvesting and wastewater recycling initiatives and selling water filtering or water saving equipment. However, despite the deficit in Wat&San services across the metropolis, these organizations claimed to receive little support from local or higher-level authorities (Interviews-M41/M42/49).

The municipal civil defence addresses water-related risks through monitoring, implementing security measures and elaborating civil defence programmes (SEGOB, 2014). The Municipal Civil Protection Programme outlines goals, strategies and actions, and the necessary resources to implement this, and is based on a risk diagnosis (SEGOB, 2014). It requires municipalities to develop a Risk Atlas that identifies the type and severity of local risks (SEGOB, 2014). Municipalities are also expected to develop, implement and evaluate a municipal climate change policy framework and instruments in accordance with the national and state climate change frameworks (Mexico, 2012).

Municipalities are also responsible for land use management and zoning, and can create ecological reserves within their territory (Mexico, 2009). However, due to its special status as the nation's capital, Mexico City's central government is responsible for the planning of the whole territory, delegating certain implementation tasks to its districts (Connolly and Wigle, 2017). Mexico City's districts coordinate certain actions (e.g. on environmentally protected areas, through the SEDEMA), but coordination is absent between districts and the surrounding municipalities (Interview-M26). Water and other urban policies also lack continuity as municipal and district administrations change every three years (Interviews-M14/M17/M21/M55). Moreover, officials are often political appointees rather than professionals, as there is no professionalization of the careers within these departments (Interviews-M17/M55/M57).

82 One challenge for this form of water provision is that, when municipalities have wells, they often consider themselves owners of the water resources and are reluctant to share these (Interview-M4).

Figure 8.1 Basin and urban water stakeholders in the MVMC



Source: Author

8.4 Instrument analysis

8.4.1 Water tariffs

Design

With no overarching legal or policy framework for Wat&San, utilities largely defined their own objectives. However, the Constitution defined Wat&San as a human right, implying that all utilities should universalize these services within their jurisdiction. Broadly, utilities in the MVMC, such as SACMEX, CAEM and municipal utilities, established goals such as the provision of clean and accessible drinking water, including to marginalized communities that comply with land tenure laws, and tariff systems that allow for autonomy and financial selfsufficiency, and that incentivize rational water use (CAEM, no date; SEDEMA, 2012; ODAPAS, 2016). Residents in informal settlements are therefore excluded from such services.

Multiple factors fostered wide inter-municipal disparities in Wat&San tariffs: The absence of a national framework, highly unequal distribution of water resources across Mexico, different levels of costs, and differences in cost-recovery efforts (OECD, 2013; CONAGUA, 2018). However, even within regions there were stark disparities. In Region XIII, water tariffs, set by different utilities, range from USD 0.95/m3 (in Pachuca de Soto, Hidalgo State) to USD 0.28/m3 in several municipalities of Mexico State (Hernández, 2014). A price variability analysis revealed that municipalities with similar water availability sometimes had significant disparities in tariffs (Hernández, 2014). While the State Congress generally approved tariffs, this was sometimes done by the board of directors of municipal operators, and municipal councils have the option to grant subsidies, surcharges or cancel fines (OECD, 2013).

Tariffs were typically composed of a fixed charge, a volumetric charge (sometimes divided in increasing blocks) and a surcharge for wastewater treatment (OECD, 2013). The latter was not applied by all utilities. For instance, the SACMEX charged a water tariff with a fixed rate up to 15m3 with increasing block rates above this volume, but no separate sewage tariff (Mexico City Government, 2018). Tariffs depended on the quantity of water consumed, with rates increasing steeply for higher consumption (Interview-M9). The SACMEX applied a development index to subsidized rates based on socio-territorial characteristics, including social marginalisation, property values and income, allowing for cross-subsidies between consumers paying the full rate and those receiving subsidies. Each street block had a specific tariff based on these characteristics (Mexico City Government, 2018) (Interview-M24). As a result, tariff rates varied across the city (Interview-M2). Comparing water tariffs across the MVMC is difficult due to differences such as the inclusion of fixed rates or sewage fees, but overall Mexico City proper's tariffs were much lower than other metropolitan municipalities (OECD, 2015a).

Effectiveness on actors in terms of mandated goals

SACMEX's tariff structure aimed for equity, by charging increasing block rates and lower tariffs for low-income households, and other utilities in the MVMC applied similar policies. In fact, water tariffs were heavily subsidized in many municipalities, including in Mexico City (Interviews-M6/M19/M28/M38/M42/M46/M50/M56). Subsidized tariffs were often a tool used by local politicians in their campaigns (Interviews-M4/M19/M38). Mexico City residents without subsidies paid a flat rate of approximately USD 13 per month for water consumption up to 15m3 (see ANNEX H – WATER TARIFFS). However, it was estimated that at least 75% of consumers in Mexico City received subsidies of up to 91% (Roa, 2018). There are four categories of subsidies for domestic consumers: Popular, Low, Middle and High. Their respective water tariffs for consumption up to 15m3 were USD 1.14, 1.29, 4.27 and 5.12 per month. Therefore, large parts of the population with the financial means to pay higher tariffs are charged subsidized water tariffs. In addition, many residents paid fixed tariffs, regardless of their consumption, because they lacked water metres (World Bank, 2013; Mexico City Government, 2018) (Interviews-M6/M7/M15). However, residents purchasing water from water trucks spent around 14 times more than residents with access to the piped network, for water of much lower quality (Mendoza, 2016). Subsidized tariffs therefore do not reach the most marginalized citizens. Only 43% of CAEM's consumers, in Mexico State, had water metres and the rest paid fixed rates, which also varied according to subsidies (Hidalgo, 2018). Although Mexico City has the same tariffs across its 16 districts, tariff rates in the rest of the MVMC vary per municipality, including those serviced by the CAEM.

Wastewater treatment services were increasingly included into tariffs (OECD, 2013). More households had water metres (OECD, 2013) (Interview-M50). However, most utilities still struggled with cost-recovery. Tariffs collected within the MVMC barely covered 51% of the costs of service provision (World Bank, 2013). In Mexico City proper, the annual revenue collected from water tariffs is USD 116 million, whereas service provision costs reach USD 405 million (Ciencias, 2018). SACMEX was therefore in complete deficit and is subsidized by the federal and Mexico City governments (OECD, 2015a) (Interviews-M7/M9/M46/M51/M56). Mexican water utilities were almost always in financial deficit, not only due to subsidized tariffs, but also because many consumers did not pay their water bills (Interviews-M5/M50/M56). In 2018, it was estimated that 45% of SACMEX's consumers did not pay their water bills regularly (Navarro and Gómez, 2018). SACMEX can cut off the water to households that recurrently do not pay as a last resort, but usually attempts to seek agreements with consumers and it sometimes reduces the water pressure in the network as a deterrent (Interview-M19).

Tariffs are largely determined by congressmen, who are reluctant to increase rates due to the political cost (IMCO, 2014; Flores *et al.*, 2016) (Interviews-M4/M6/M15/M32/M46)[83]. Water tariffs increased above inflation rates in many cities, but remained far from allowing for cost-recovery (OECD, 2013) (Interview-M6). For many municipal utilities in the MVMC, their small scale was an obstacle for cost-recovery (IMCO, 2014).

Impacts on sustainability and inclusiveness

Approximately 97% of the MVMC's population had access to piped water infrastructure (Romero Lankao, 2010). However, access – in both quantitative and qualitative terms – was not equally distributed across the city (Romero Lankao, 2010; Hackett and Eakins, 2015; Spring, 2015). Drinking water services were irregular and unreliable in certain areas, particularly for peri-urban residents (Romero Lankao, 2010; Acevedo *et al.*, 2013). While Mexico City's districts received on average 300 l/per person/per day, the Eastern districts of Tláhuac, Xochimilco and Iztapalapa received 177 l, 214 l and 238 l respectively (Rodea, 2016). Even these numbers hide the heterogeneity of water supply distribution, as wealthy neighbourhoods of Mexico City consume up to 800 l/per person/per day, while certain marginalized areas receive only 14 l/per person/per day (Spring, 2015; Rodea, 2016). Some marginalized areas are not connected to the public supply network, leading to precarious access to drinking water. Survey evidence across the MVMC indicates that drinking water access is

83 CONAGUA had recently started to help municipalities set tariffs through more technical approaches based on cost-recovery (Interview-M4).

even more precarious outside Mexico City (OECD, 2015a). In many parts of the MVMC, residents had water a few hours a day every other day, or less frequently, but at a higher cost as water was frequently brought by trucks (Burns, 2009) (Interviews-M14/M24;M46). Water delivered by trucks was generally free in regularized neighbourhoods, but in informal settlements residents organized this delivery and paid for it themselves[84]. Subsidized water tariffs therefore did not benefit those who most needed these.

Residents sometimes resorted to clandestine connections, which caused water losses as well as health risks from contamination. In one informal settlement visited in July 2016 in the Xochimilco District, in the South of Mexico City, flimsy drinking water hoses criss-crossed the polluted canals that were the vestiges of the ancient lake city (see Figure ***8.2***). Data on contaminants is not provided, and although data on water quality in the Cutzamala is available, there is no information on water quality after water enters local delivery networks (OECD, 2015a). The South and Southeast of Mexico City were among the most affected by poor drinking water quality (Sosa-Rodriguez, 2010). Although the CONAGUA stated that 88% of water in the MVMC was chlorinated, independent studies showed that only 60% of tap water was suitable for human consumption (Spring, 2011). Sources of contamination included deteriorated pipes, insufficient treatment processes and high levels of dissolved minerals in groundwater (Spring, 2011). Although the SACMEX frequently states that the piped water meets official quality standards, there is no transparency around this data (Durán and Gómez, 2018).

Unequal access to water services reflects and reinforces broader patterns of inequality and power imbalances between residents across the MVMC (Interviews-M47/M50), with impoverished communities in the East suffering much more than rich inhabitants in the West (Interviews-M14). Women carry the burden of ensuring that their families have water and they are vulnerable to harassment by water truck delivers (Interviews-M27/M59/M60).

Furthermore, the lack of effective communication to the population about drinking water reliability has resulted in a general distrust of tap water (Interviws-M47/M50). In combination with inconstant supply, this has led Mexicans to become the world's largest consumers of bottled water per capita, at 234 l/per person/per year in 2015 (Martínez and Enciso, 2015).

Although residents are wary about drinking water from public supply, highly subsidized tariffs encourage high water consumption for other purposes – e.g. washing, cleaning, filling swimming pools (Interviews-M6/M15/M46). This is compounded by the many households without metres or with fixed tariffs (Interviews-M9/M15/M19/M56). Consumers with access to the (subsidized) piped network have few incentives to switch to alternative systems, such as rainwater harvesting or water reuse (Interviews-M32/M46/M49). In addition, up to 40% of water was lost in leakages due to decaying infrastructure and soil subsidence (Martinez *et al.*, 2015; Ciencias, 2018) (Interview-M46). Besides contributing to water shortages, leaks lead to revenue losses and reduced investment capacity (Interview-M51). Under current conditions,

84 Land tenure was the main obstacle, but the physical layout and topography also prevented access to the piped water network.

the deficit between demand and supply may reach between 25 and 46 m^3/s by 2030 (World Bank, 2013).

Figure 8.2 Improvised water supply in Amalacachico, Mexico City

Source: Author

Furthermore, as utilities are unable to recover costs, they depend significantly on federal state and municipal funds (IMCO 2014). As a result, taxpayers across Mexico subsidized utilities by paying an annual economic cost of around USD 1.5 billion, or almost a triple of the amount paid in tariffs (World Bank, 2013). With access to external funds, cheap bulk water and relatively little revenue from tariffs, utilities lack incentives to improve services (Interviews-M19/M32).

8.4.2 Metropolitan drainage system

Design

Managing drainage and stormwater is challenging in the MVMC due to its location within a closed basin and much of the soil's impermeability. While the region has always been flood-prone, soil subsidence has aggravated this risk as parts of the city have sunk by more than 12m. The macro-drainage system aims to mitigate flood risks by rapidly removing excess water from the basin and depositing it in the Tula basin. Four artificial exits (canals and large tunnels) interconnected within the metropolis have been built over the years to discharge stormwater, with the first inaugurated in 1789 and the last in 1975 (SACMEX, 2013). CONAGUA began construction of an additional mega-tunnel that can evacuate up to 150 m^3/s from the basin in 2008 (CONAGUA, 2012a). It had not started operations as of August 2019.

CONAGUA, Mexico City and Mexico State jointly manage this infrastructure through the CADAM and shared operation protocols (e.g. infrastructure maintenance, warning systems, emergency strategies. The Fideicomiso 1928 funds the approximately USD 160 million per year in costs (Burns, 2009) (Interviews-M15/M19). The Valley of Mexico Metropolitan Fund also finances drainage infrastructure in the MVMC. However, the latter has been used mainly for transportation and urbanism investments, and just USD 1.3 million were spent between 2014 and 2017 on stormwater management. It is managed by the governments of Mexico City, Mexico State and Hidalgo State, to reduce vulnerability to extreme weather events through studies, plans, evaluations, projects and hydraulic infrastructure (DOF, 2011). The 2019 budget was around USD 170 million.

Effectiveness on actors in terms of mandated goals

There is a recognition that managing stormwater and floods requires a metropolitan approach between the federal government, states and sectoral entities, as the metropolitan drainage infrastructure is entirely interconnected (Interviews-M14/M19). This coordination is relatively efficient in daily operations to control large infrastructure works, with the three governments in constant communication (Interviews-M7/M14/M19).

While respondents recognize the impressive engineering feats of managing stormwater and drainage systems in a highly challenging location, many also criticized the lack of an integrated, strategic, long-term vision of water management and metropolitan planning (Interviews-M9/M14/M15/M46). SACMEX was "in the day-to-day, in constant battle", focusing exclusively on flushing water out of the city with pumps and pipes (Interview-M14). The CADAM, which should plan stormwater management at metropolitan scale, only addressed hydraulic infrastructure (SACMEX 2013) (Interview-M46).

Furthermore, the metropolitan scale was not always considered ideal to address drainage and stormwater challenges. Municipalities were responsible for drainage networks within their borders, but these were often clogged from inadequate solid waste management, which aggravated flooding (SACMEX 2013) (Interviews-M5/M19). There are arguments for focusing efforts at local or sub-basin levels rather than exporting these problems. This would still require metropolitan coordination, but to a lesser degree. Supporters of such an approach argue for capturing surface runoff, treating it, reusing it when possible and returning it to the sub-basin or aquifer, thereby reducing dependence on external sources and limiting negative externalities (Interviews-M40/M52).

Impacts on sustainability and inclusiveness

Rapidly expelling water from the city has prevented catastrophic floods in recent decades. However, as stormwater mixes with sewage and diffused pollution, it also allows for ignoring worsening water contamination in the metropolis and exporting this problem to the neighbouring basin (Interview-M52). While many industries moved out of the MVMC, domestic wastewater is still mostly discharged untreated (Interview-M40). These waters are then reused for irrigation in the Tula basin, contaminating surface and groundwater (Interview-M58).

In addition, this infrastructure presents risks for human settlements within the MVMC during heavy storms (Hackett and Eakins, 2015). When infrastructure fails, surrounding settlements are flooded with contaminated waters, and these risks increase with soil subsidence (Interviews-M50/M57). This often affects informal settlements in the East of the MVMC, disadvantaged by their peripheral location and historical power relations (Interviews-M27/M57). Clientelism is widespread in such areas, as residents and politicians trade votes for promises of better water services and land tenure (Interviews-M17/M20/M26/M46).

Moreover, soil subsidence inverts the slope of canals that discharged water out of the basin. Consequently, diesel pumps force these waters out, which contributes to significant costs and emissions (Interview-M40). Siltation in the drainage infrastructure adds additional risks and costs. Meanwhile, due to their limited financial resources, many municipalities in Mexico struggle to do their share of the drainage responsibilities (Interviews-M6/M15).

Although the system was meant to foster a regional approach, in practice the governors and finance departments of each federal entity determine the destination of the funds, and these often end up in projects of local and personal interest, rather than projects of metropolitan scale (Interviews-M15/M17/M33/M57). Negotiations and agreements on metropolitan-scale measures between governments at state and federal level are even more complicated when they were from different political parties (Interview-M7). While the CADAM supposedly manages this coordination, it is not transparent and does not involve other regional entities (e.g. basin councils, other metropolitan commissions) or public participation (Interviews-M15/M17/M28/M46/M48/M52).

8.4.3 Metropolitan wastewater infrastructure

Design

In 2017, only 10% of wastewater in Mexico City proper was treated, despite dozens of treatment plants spread across the MVMC (Ambiental, 2017). To address the lack of sewage treatment in the MVMC, the Atotonilco wastewater treatment plant was inaugurated in 2017 at the junction of the enormous drainage infrastructure and the Tula River (Ambiental, 2017). This strategic location allowed for easily capturing wastewater from the metropolitan drainage system. This treatment plant was part of CONAGUA’s planning for the VMB and received funding from the Fideicomiso 1928 (SACMEX, 2013). The plant aims to discharge treated waters into the Tula basin’s irrigation canals. Its treatment capacity of 35 m^3/s make it the largest in Latin America and the treated discharge can more safely be reused by farmers to irrigate 80,000ha than the previously untreated flows (SACMEX, 2013; Tamargo, 2016; Ambiental, 2017). The biogas produced in the process is used for energy, covering approximately 60% of the plant’s energy requirements.

Effectiveness on actors in terms of mandated goals

Most treatment plants in the MVMC are significantly underused or even abandoned, mostly because they reached the end of their lifecycle or funds for their rehabilitation were never invested. The effluents from these plants are partially reused in the irrigation districts in the South of Mexico City, and therefore the plants do not operate during the rainy season (Ambiental, 2017).

The Atotonilco plant has significantly increased the volume of wastewater that is treated before being discharged *in natura*. Respondents claimed that building large sewage treatment plants is more attractive to local politicians than rehabilitating existing ones, as they often bring in substantial federal funds (Interviews-M4/M15/M40/ M42). Federal funds do not cover operational costs and time will tell if this plant can meet its high expectations.

Furthermore, critics argue that this mega-plant reproduces the linear approach of taking, using and expelling water. It reduces the viability of decreasing the dependence on water imports, as the huge investments made have to be recovered, which requires large volumes of sewage and stormwater to leave the VMB. These critics argue that sewage treatment capacity should have been distributed across the VMB to allow for wastewater recycling and reuse and groundwater infiltration (Enciso, 2018) (Interviews-M9/M32M40/M52). Recycled wastewater is mainly used to irrigate parks and fill the Xochimilco canals, although it could be used more extensively (e.g. in industrial processes, to infiltrate into aquifers or for toilet flushing) (Interview-M40). A demand for treated wastewater must be created for wastewater reuse initiatives and policies to be successful (Interviews-M27/M44). However, the authorities seem hesitant to support such initiatives (Interviews-M6/M40/M44).

Moreover, despite the Atotonilco plant's direct effect on basin management, decision-making on sanitation is not discussed within nor between basin councils, nor between basin councils and state and municipal governments, and the metropolitan commissions (Interviews-M17/M28/M48).

Impacts on sustainability and inclusiveness

In 2017, Mexico City treated only around 3 m^3/s, or 15% of total wastewater, significantly below the national average of 57.7% for municipal wastewater and 38.3% for industrial and other wastewater (CONAGUA, 2018). It is not yet clear how much the Atotonilco plant has increased sewage treatment rates in Mexico City and the VMB, but this increase will likely be significant, with positive effects on the Tula basin's water quality, including its groundwater. This is crucial, as earlier studies revealed that irrigated lands in the Tula Basin received 44,000 tons of nitrogen and 17,000 tonnes of phosphorus yearly, causing severe risks of waterborne diseases and contaminated crops (Burns, 2009)[85].

[85] Children in the parts of the Tula Basin exposed to contaminated irrigation waters were 16 times more likely to suffer from gastrointestinal diseases than those in areas where clean water was used (Peña *et al.*, 2013).

Building the Atotonilco plant was expensive, at approximately USD 630 million, several times the initially projected amount (*Acciona Agua*, 2018). Maintaining operations is estimated to cost around USD 5.5 million per month (Interview-M9). These numbers do not include the additional costs of building sewage pipes within the city and pumping this sewage out. The construction of the plant is also clouded by corruption allegations (Interview-M9).

Finally, many farmers in the Tula basin are unhappy, as untreated sewage was better for their crops' productivity (González, 2018). In addition, residents living near the treatment plant complained about a rise in skin diseases (González, 2018).

8.4.4 The Conservation Land

Design

Within Mexico City proper, an area known as the 'Conservation Land' occupies 59% of the surface area of the city, spread across nine southern districts (Escamilla and Santos, 2012). The Conservation Land holds high ecological value and its preservation is considered crucial for the city's sustainable development (SEDEMA, 2013). This area was defined in 1976 through a Federal District law, modified in 1982, which classified the territory in either urban or conservation land (Federal District Legislative Assembly, 1982). This special zoning category established strict restrictions through a zero-growth land use policy (Aguilar and Santos, 2011). Its preservation requires collaboration between sectoral entities and districts and a common land use management vision. This is implemented through conservation measures, such as monitoring activities, forest fire prevention, land use planning and PROFACE (see 7.4.4). Across the MVMC, Environmentally Protected Areas have also been established at smaller scales – including within the Conservation Land – and are created by the state or federal government (SEDEMA, 2016). These areas have particular value in terms of biological diversity and have individual plans and strategies.

Around half of the Conservation Land is covered in forests, a third by agricultural lands, 12% by grasslands and 11% by urban uses (Escamilla and Santos, 2012). About 30% of the Conservation Land is within environmentally protected areas, which have their own advisory councils (SEDEMA, 2013). The Conservation Land hosts over 1,800 flora and fauna species and provides important ecosystem services for the MVMC, including climate regulation, water provision[86], soil and water retention and contamination reduction (Escamilla and Santos, 2012; SEDEMA, 2013). The Conservation Land is part of a larger green belt that surrounds the MVMC and extends across state borders.

Effectiveness on actors in terms of mandated goals

This instrument recognizes the high value of the territory's ecosystem services. However, as the only undeveloped land, this region is under heavy pressure from continued urban growth. The district governments are largely responsible for enforcing zoning regulations, but often

86 57% of the water consumed by the city came from aquifers recharged in this area.

lack capacity and political will (Connolly and Wigle, 2017) (Interview-M17). Residents pressure local politicians to legalize informal settlements, further contributing to corruption and clientelism (Interviews-M17/M26). For instance, district authorities changed zoning regulations without informing the Mexico City government (Interviews-M6/M7). This prevented the development of alternative solutions that addressed the affordable housing gap while preserving the Conservation Land, such as housing programmes with higher densities and better access to basic infrastructure and services in less ecologically valuable areas and meant that official land use maps are often inaccurate (Escamilla and Santos, 2012).

Disjointed environmental and urban policies within Mexico City lead to incoherent planning, as sectoral departments for conservation, housing and agriculture have conflicting interests (Interview-M15). This ultimately hinders the city's ability to contain urban sprawl in the Conservation Land. Moreover, there is also no regional or metropolitan land use planning, and basin entities and metropolitan commissions are not involved, even though the green belt extends beyond Mexico City and the VMB (Interviews-M9/M17). This coordination is the role of the Environmental Commission of the Megalopolis. Additionally, 70% of the Conservation Land is communally held by traditional agrarian communities. Any intervention in these areas involves negotiations with (all) the landowners (Interview-M48).

Impacts on sustainability and inclusiveness

Despite land use restrictions and multiple conservation measures, informal settlements have expanded, causing environmental degradation with severe impacts for the city, including in terms of aquifer recharge (Escamilla and Santos, 2012) (Interviews-M15/M46). Informal urbanization of 2700 hectares in the Conservation Land may have prevented the infiltration of around seven billion litres of water per year (Macdonald, 2016). The current trend indicates that the Conservation Land would continue to urbanize significantly in the next years, and forest cover could entirely disappear by 2030, further jeopardizing the city's groundwater resources (Hernández, 2016) (Interview-M29).

Moreover, weak land use regulation and monitoring have facilitated the expansion of illegal logging and intensive agriculture that causes groundwater contamination from pesticide use (Interview-M48/M50). In some cases, conflicts erupt between communities in the Conservation Land and local authorities (Interview-M33). Although multiple sectors at Mexico City and district levels are involved, non-governmental voices are not included in planning.

8.5 Instrument assessment and redesign

UWM in the MVMC was disconnected from environmental management and the real cost of water services (see Table ***8.2***). Although the basin agency, Mexico City and Mexico State closely coordinated mega-infrastructure that expelled stormwater and wastewater from the basin, they maintained a mainly technical, top-down and linear approach (Interviews-M6/M7/M19/M40).

Table 8.2 Assessment of UWM policy instruments in the MVMC

	Instrument design	**Effects on actors**	**Impact**
Water tariffs	[0] No overarching framework leads to large disparities Many utilities use subsidies for low-income residents	[0] Tariff design promoted equity and inclusion of low-income residents through block rates and subsidies. Lack of metres and cost-recovery reduced investments. Informal settlements were excluded	Env: [--] Excessive consumption and high leaks Soc: [0] High access to drinking water except in informal settlements. Quality was lacking Econ: [-] Utilities rely on external funds, transferring costs to taxpayers Rel: [-] The most marginalized rely on water trucks at higher prices
Metropolitan drainage system	[-] Coordination between state governments for infrastructure funding and operation	[-] Metropolitan management is necessary as infrastructure is interlinked. Coordination does not involve regional planning. Disconnect with local level hindered overall efforts	Env: [-] Combined sewers contaminated potentially reusable rainwater Soc: [-] Residents exposed to flood risks are also at risk from contaminated waters Econ: [--] Pumping water out is costly Rel: [-] Investments depend on political negotiations
Metropolitan sewage infrastructure	[0] Mega-sewage plant built downstream of MVMC, centrally managed Treated water can be reused for irrigation	[0] Sewage treatment increased with new mega-plant, but its location prevented reuse of treated wastewater within the basin	Env: [+] Positive effects were expected on environmental quality in Tula basin. Soc: [0] Farmers and local residents are negatively affected Econ: [-] Expensive and unclear if operation costs are sustainable. Potentially more efficient alternatives exist Rel: [-] Top-down management with no voice for farmers, residents
Conservation Land	[+] 60% of Mexico City under special zoning and land use restrictions Cross-sectoral planning Does not extend beyond Mexico City proper	[0] Weak enforcement of regulations due to lack of capacity and political will. Fragmented policies further weaken efforts	Env: [-] Degradation from urbanization, deforestation and agriculture continued. Soc: [0] Lack of tenure of (sometimes long-term) residents led to precarious living conditions Econ: [-] Local politicians and landowners saw opportunities in developing land, but degradation had severe costs in longer-term Rel: [0] Cross-sectoral planning limited to government agencies

Relative assessment scores: ++ Very positive; + Positive; 0 Neutral; - Negative; -- Very negative (See 2.4)

Redesign

Water tariffs: Subsidies for low-income households are crucial to ensure affordability, as the population has large disparities in their capacity to pay. However, such subsidies do not benefit the most marginalized residents of the MVMC, as utilities are not allowed to provide services in informal settlements. Special programmes to provide drinking water, and when possible sanitation, have been successful in expanding access to established informal settlements in the MRSP, through cooperation between utilities and local governments, and could be considered for the MVMC. Besides benefits to residents, this can reduce commercial water losses (i.e. clandestine connections). Furthermore, as subsidies were extended to around 75% of the population of Mexico City proper, a review of subsidies' qualifying criteria is necessary, as many households may have the capacity to pay. This process requires the creation of an independent regulatory agency to set criteria and approve tariff rates, transferring this mandate from the State Congress. The design of an overarching national policy framework for Wat&San could establish minimum standards and general goals.

In addition, the tariff system should reflect the social, economic, relational and environmental impacts of importing water from other basins and over-exploiting aquifers (see 7.5). Criteria for designing tariffs are based on local socio-economic characteristics to ensure affordability (in formal settlements) but do not consider water availability within the basin and the effect of tariffs on water demand. A more independent process of setting tariffs could ensure rates that would improve cost-recovery for utilities and reduce excessive consumption. This could incentivize repairs of leaks and the installation of water metres where there are none and water saving equipment. The reduction or elimination of subsidies for households with the capacity to pay could lead to internal investments by the utility. A portion of the added revenue could also fund PES programmes or conservation measures in donor basins, as is done in Mexico State.

Macro-drainage: It is necessary to shift from linear to more circular stormwater management, while remaining realistic about the basin's propensity to flood. Efforts could be made to retain surface runoff within the Conservation Land through preservation, and in the rest of the MVMC through green areas and a combination of decentralized grey and green infrastructure (e.g. bioswales, green roofs) adapted to the local context (i.e. available space, permeability of soil, uphill/downhill). Small-scale initiatives to capture, filter and inject surface runoff into the ground have increased in recent years to simultaneously address groundwater over-exploitation, soil subsidence and recurrent floods. Retaining water within the basin could also reduce the costs of pumping stormwater and wastewater out of the basin. These could be scaled up within a regulatory framework with strict norms for the infiltrated water quality. This decentralized infrastructure could be managed locally or at sub-basin level to adjust to local needs and to be treated and reused or returned to streams or aquifers rather than to be funnelled downstream. Decentralized stormwater management should be part of a regional plan that considers basin and aquifer dynamics, with coordination between the MVMC's municipalities and state governments and shared financing. Nevertheless, centrally managed artificial drainage exits will continue to play an important role because of infrastructure lock-in. In addition, the concentration of rainfall in a short timeframe makes it more difficult to store water (Interview-M28).

Mega-sewage: Sewage and stormwater are currently combined and expelled together, and as with stormwater, efforts are needed to retain, treat and reuse wastewater within the MVMC. Separate sewer and stormwater systems could be installed in new developments or when replacing old pipes, but the total replacement of combined systems is prohibitively costly and unrealistic in the short-term. Initiatives for decentralized stormwater and wastewater treatment, recycling and reuse already exist, and have great potential for non-drinking uses such as school toilets and industrial processes (CCRAC 2011) (Interviews-M4/M52). Similarly, such measures require a clear normative framework. Users, such as industries, were often reluctant to shift to water reuse because this meant giving up their water extraction permits and thereby the security of stable access to water. Introducing flexibility within water use permits could facilitate transitions to water reuse while maintaining a water allocation guarantee, thereby enhancing environmental sustainability and avoiding the alienation of large users.

A mega-sewage plant was recently built downstream of the MVMC, although most sewage treatment plants within the metropolis operated significantly under capacity or were abandoned. Investing in these plants rather than the mega-plant would have reduced the need for transporting sewage across the entire MVMC. The mega-plant disincentivizes measures to retain and treat stormwater and wastewater within the basin. Nevertheless, smaller plants within the basin could still play a role as not all wastewater is currently collected and treated. Expanding the network has to do with the financial capacity of utilities, but also issues of land tenure, as many unconnected households are in informal settlements. This justifies a greater involvement of local governments within regional wastewater planning.

Conservation Land: Efforts are fragmented as the Conservation Land is limited to Mexico City, and there was no regional approach for preserving the MVMC's green belt. However, coordinated actions between Mexico City and surrounding states are crucial for preserving ecosystem services. More effective coordination could be achieved by harmonizing the states' land use management plans and conservation policies. Funding for a regional approach could be linked with PES programmes or compensation mechanisms. Such an idea has emerged from civil society actors, through the Water Forest Conservation Strategy, which promotes a regional approach to conservation and sustainable land use management. Part of this strategy is to raise awareness about the interdependencies between the ecosystems surrounding the megacity and the water used by the latter. Whether through local or regional efforts, conservation of the MVMC's ecosystems would require engaging local rural dwellers, including indigenous communities, whose livelihoods are threatened by urban encroachment. As land is largely privately owned, expropriating and compensating landowners may be necessary in areas identified as significant in terms of ecosystem services and at risk of development (Intervew-M9/M15). In most cases, cooperation with landowners to ensure sustainable land use practices is the more pragmatic approach.

Ultimately, political leadership and political will are necessary. In 2018, the newly elected governor of Mexico City committed to a fivefold increase in the Conservation Land's budget and to double resources for PES and compensation programmes. This presents a window of opportunity for Mexico City's leaders to engage surrounding regions for regional conservation efforts.

Missing instruments

UWM is currently excluded from urban policy and planning. If the aim is to achieve greater social inclusion, assessments could be conducted to identify informal settlements that can be legalized based on criteria such as the age of the settlement, viability of installing basic infrastructure and environmental impacts. Residents in areas considered at risk or highly valuable in terms of ecological functions should be relocated as part of a regional housing strategy. Slum upgrading programmes coordinated between the water utility, relevant sectoral departments and local authorities could lead to joint efforts to expand sewage collection.

In addition, in upgraded and newly built neighbourhoods, sewage and drainage systems could be separated. As climate change will bring more intense precipitation, this can mitigate floods of contaminated waters. Funds could partially come from construction companies.

Moreover, rainwater harvesting initiatives have multiplied and were used to complement water supply for non-drinking uses or for aquifer recharge. It was increasingly common in marginalized peri-urban areas without piped water but with space for rainwater tanks and filtering systems. This could significantly reduce dependence on water trucks, at least during the rainy season, and lower household expenses. While there were legitimate concerns about water quality, rainwater could be used for less noble uses such as toilets and watering gardens. The popularity and success of such initiatives indicated they had potential to be scaled up. Although it is estimated that the volume of rainwater that enters the MVMC's drainage systems is greater than the volume of water imported from the Cutzamala System, only a fraction of rainwater could realistically be captured by rainwater harvesting systems (Sosa-Rodriguez, 2010) (Interview-M40). This is due to the surface area needed to capture rain and the irregularity of rainfall. While rainwater harvesting systems may make only a dent in reducing groundwater over-exploitation and water imports, it could be significant for households and users with precarious access to water, in particular those currently depending on water trucks.

9. COMPARING SÃO PAULO AND MEXICO CITY: EVIDENCE OF SCALAR MISMATCHES

9.1 INTRODUCTION

This chapter compares the case studies of São Paulo and Mexico City to provide insights on how to best respond to water-related challenges in terms of quantity, quality and climate change, and through which policy instruments. First, it examines the two cases in terms of the drivers that shape their water challenges (see 9.2). It then analyses the organizational set up of the institutions that respond to these challenges in each case (see 9.3). Subsequently, it describes the policy instruments employed in the two case studies (see 9.4), and compares their effects on actors (see 9.5). This is followed by an evaluation of the instruments' effectiveness in achieving their stated mandates (see 9.6). It then compares recommendations for redesign in the two case studies and considers lessons that can be learned from each (see 9.7). Finally, the chapter summarizes the conclusions and introduces the concept of 'Scalar Mismatches', which, if unaddressed, impede sustainable and inclusive water governance in large metropolises (see 9.8).

9.2 COMPARING DRIVERS OF METROPOLITAN WATER CHALLENGES

Overall, similar drivers shaped water-related challenges in both São Paulo and Mexico City: Urbanization (associated with population growth), economic development and climate change.

Urbanization was the most influential driver for both case studies. Urbanization was characterized by nation-wide rapid although slowing rural to urban migration accompanying population growth especially concentrated in a few cities, and by the inability of cities to account for the daily influx of migrants. Unplanned urbanization has exacerbated inequalities, as informal, precarious settlements have mushroomed in peri-urban areas, leaving local authorities unable to cope with the high demand for affordable housing and related services. At regional level, urban expansion encroached on surrounding areas of springs or aquifer recharge. Repercussions include erosion and increased floods and mudslides, water degradation and increased water demand. At local levels, soil-sealing and the occupation of floodplains and steep hill sides, as well as inadequate sanitation and solid waste management (i.e. clogged drains, water-borne diseases), exacerbate flood risks. The type of housing and land tenure also affect residents' access to water services and exposure to risks. Moreover, water use was often unsustainable and inefficient, particularly in the MVMC, with heavy losses and excessive consumption in wealthier parts of the city.

Economic development is an important driver for both Mexico City and São Paulo as they are their respective countries' economic centres. At national and regional levels, policies have prioritized economic growth over environmental preservation, leading industrial, mining and agricultural development at local and regional levels. These sectors are important water users, thereby driving tensions around the allocation of limited water resources. Contamination remains a challenge and diffused pollution is particularly hard to address.

Climate variability and change, including global and regional processes (e.g. deforestation of the Amazon, El Niño) may have significant influence on extreme weather events experienced in Mexico City and São Paulo. Both cases record increases in extreme weather events and in temperatures in line with climate change forecasts. The size of the two megacities also contribute to strong heat island effects.

The combination of rapid, unplanned urbanization and a focus on spurring economic development have led Mexico City and São Paulo to grow into wealthy mega-cities with rampant inequalities – including in access to safe drinking water, safety from contaminated water, and protection from water-related risks. Climate change could act as a risk multiplier to the existing challenges.

9.3 Comparing actors and institutions

9.3.1 Institutional changes in UWM and IWRM/IRBM

Both Mexico and Brazil have made efforts to develop IWRM/IRBM over the last three decades, implementing water laws inspired by the Dublin principles. These legal frameworks recognize the multiple uses of water, introduce a multilevel governance system and create new policy instruments. IWRM is more advanced in São Paulo, where basin committees have broad representation, meet regularly, develop basin plans in a participatory manner and have budgets for projects within the basin. Even then, the ATB (Alto-Tietê Basin) Committee is often bypassed in decision-making processes, as happened during the 2013-2015 water crisis. In Mexico, basin agencies oversee WRM at regional level, but these are deconcentrated offices of CONAGUA and are thus government agencies that implement decisions in a top-down manner. Participatory basin councils exist on paper but represent a limited range of interests and lack resources and influence.

Regarding UWM, Wat&San responsibilities have been decentralized in both cases. Municipalities have been granted a wide range of mandates after Brazil and Mexico's democratic transitions, with a focus on land use, local environmental issues, drainage, urban planning and civil defence. At higher levels, however there is often a vacuum. In Mexico, there is no national level framework for Wat&San policy, which means states and municipal governments implement vastly different standards and goals. Brazil introduced a national Wat&San Law in 2007, but the role of states remains limited in the legislation, although the state water companies play a crucial role in the sector. Existing frameworks in both cases also do not specifically address metropolitan regions. A 2013 Supreme Court decision in Brazil has stated that, within metropolitan regions, functions of common interest, including Wat&San services, should be a shared responsibility between municipalities and the State. However, the decision does not clearly outline how this will take place and municipalities have since been struggling to turn this command into action. In the MVMC, stormwater and flood management are, to some extent, coordinated at metropolitan level by national and state-level actors.

9.3.2 The influence of federalist structures

Both case studies are in federal regimes. Mexico has more power concentrated at federal level, and Brazil at state level. Despite formal decentralization, local governments often lack financial and human capacity to implement adequate measures. Decisions at higher levels often bypass metropolitan/basin platforms and local actors, while local level decisions are often not coordinated between municipalities. This results in fragmented policies at regional level. In the MRSP, municipalities develop Wat&San plans separately despite interlinkages with neighbouring municipalities. This fragmentation has led state-level actors to take the lead. For instance, SABESP has developed its own planning and investment priorities as there was no Wat&San state policy and it operates in a majority of São Paulo State's municipalities. The dependence on external water resources strengthens higher levels of government in both cases. As the MVMC spreads across three states and imports water resources from even further, the involvement of federal actors is inevitable. State level actors are more prominent in the MRSP, as most water resources are contained within the state, but dependence on other states has increased as water supply systems have expanded following the 2013-2015 water crisis.

Furthermore, the three-layered structure of these federal regimes (i.e. federal, state and municipal) makes it more difficult to legitimize any intermediary governance level (e.g. metropolitan, basin) (see 6.3.4 and 8.3.4). As a result, institutions at such levels are mainly voluntary and rely on political will, consensus and alternative funding sources. Moreover, the MRSP is composed of 39 municipalities, and the MVMC of 60 municipalities and 16 districts in three federal entities, with vast differences in financial and human capacity. Differences in political party affiliations further aggravate fragmentation across the metropolitan region, as governments often take decisions based on political priorities and the interests of their jurisdiction rather than regional needs. Party politics may hinder horizontal coordination (i.e. between municipal governments), and vertically (i.e. between a local government and the state government).

Nevertheless, the two megacities have attempted to develop metropolitan initiatives related to water and other issues. In the MVMC, this takes a highly top-down form (e.g. metropolitan funds for mega-infrastructure), whereas initiatives in the MRSP are voluntary and often failed to materialize. Either way, developing a shared, metropolitan vision is challenging both in terms of structural design (how to create decision-making bodies) and in terms of resources to implement projects.

9.4 Comparing instruments

9.4.1 Instruments per country and level of governance

Table ***9.1*** lists the policy instruments selected in each case and the levels at which they are implemented. Brazil and Mexico have designed similar instruments, but sometimes at different levels. Unlike the MVMC, the MRSP has no (substantial) PES programmes. Suasive instruments, such as awareness campaigns for rational water use, exist in both cases but are considered of minor influence as they are generally implemented at a small scale and in a piece-meal manner. Electricity subsidies for irrigation pumping exist in Mexico but have not been analysed as they are beyond the urban/metropolitan scope of this research. Relevant instruments that are absent from both cases include environmental taxes[87] and flood insurance[88].

Table 9.1 Instruments at multiple levels of governance in Brazil and Mexico

	Brazil	**Mexico**
National	Water use permits Wastewater discharge permits*	Water use permits Water use and wastewater discharge fees Wastewater discharge permits* Classification of water bodies* Metropolitan water supply system Metropolitan sewage and drainage system
State	Water use permits Wastewater discharge permits* Areas of Protection and Rehabilitation Macro-drainage plan Integrated Metropolitan System	Climate change plan and fund* Conservation Land
River basin	Water use and wastewater discharge fees Classification of water bodies*	Water use permits
Municipal	Water tariffs: Local governments are involved if the Wat&San services are provided by a municipal utility	Water tariffs
Other:	Water tariffs: Determined by the utility and the State regulatory agency	PES programmes: Multiple: Federal and State

Source: Author

*See Annex G – Additional instruments

9.4.2 EVALUATING AND COMPARING INSTRUMENTS IN TERMS OF DESIGN

Water use permits

In both countries, water belongs to the nation or state, which grants access to users under similar specific conditions. In the VMB (Valley of Mexico Basin), permits are issued by the national government, through the CONAGUA. In the ATB they are issued by the state government, through the DAEE, except for permits for water imports from basins that cross state borders (e.g. permit for imports from the Cantareira System) that are issued by the ANA.

87 Brazil's National Water Law originally included compensation for environmental damage as an instrument, but this was later vetoed. In 2018, a federal law created a fund for compensation from environmentally damaging activities (MMA, 2018). This fund aims to support the management of Protected Areas.

88 Flood insurance exists in both cases although it was not widely used. This research did not examine measures adopted at individual or household level.

Brazilian and Mexican water permits both aim to control water resources use. There were restrictions in the VMB on the granting of new permits because the Basin is in a low 'water availability zone', meaning that a user can only obtain a permit through a permit transfer. Such restrictions are not implemented in the ATB. On paper, the MVMC's water use permits system is therefore more adequate for water use management in a water scarce basin.

Water use fees

In both cases, water use fees aim to incentivise rational water use while financing WRM. In Mexico, fees are set at national level and differ according to the basin or aquifer's 'water availability zone', increasing as availability decreases; the MVMC's basin has the highest level of fees. In principle, this may encourage certain water users, such as industries, to move to areas where water is more affordable. In São Paulo, water use fees are set by the river basin committee through a participatory and deliberative process, and in consultation with its technical boards.

In each case, the fees are reinvested in different ways. In the MVMC, only fees from water utilities are collected and reinvested in drainage and sanitation infrastructure within the VMB. Investments are not returned to the donor basins to compensate users or invest in ecosystem preservation. Fees from other uses are collected by the Federal Treasury and are reinvested nationwide in the water sector as well as other programmes. Within the ATB, all collected water use fees are reinvested in projects within the basin that were defined in the basin plan.

Water tariffs

In Brazil, a national policy framework defines that water tariffs should support the universalisation of water services while allowing for financial sustainability. There is no overarching framework for water and sanitation in Mexico, but water operators in the MVMC share comparable goals. In São Paulo, water tariffs are approved by an independent regulator at state level[89], unlike the MVMC, where this is generally done by the State congress, making tariff-setting a political as well as a technical decision. In both cases, subsidies are provided to low-income households and different rates are charged for commercial and industrial consumers connected to the water utility. Tariffs rise exponentially as consumption increases, except for industrial and commercial users in the case of São Paulo. While some metropolitan municipalities had local utilities, most were serviced by a state-level utility.

Inter-basin transfers/Metropolitan water supply systems

Inter-basin transfers have been created to respond to the water demand in the MRSP and the MVMC as local water supply sources became insufficient or inadequate. For both cases, these supply-oriented approaches are core strategies for responding to water demand. The CONAGUA builds and manages these systems for the MVMC, with SACMEX's help. Both

89 The design of tariff rates is nevertheless complex and lacks transparency.

national and state entities are involved in the ATB, depending on whether the imported water comes from a basin that is at least partly located in another state. In Brazil, basin committees are also involved in negotiations regarding these transfers, but ultimately limited with influence. In the MRSP, water is mainly supplied from surface water sources in large reservoirs within the ATB and beyond, through an inter-basin transfer. These systems are interconnected, forming the Integrated Metropolitan System, to create redundancy so that, if one system is dry, the area supplied by it can receive water from another system. Mexico City also relies heavily on inter-basin transfers, which import both surface and groundwater from other basins.

Metropolitan wastewater infrastructure

In both cases, metropolitan wastewater infrastructure centralizes the efforts to collect, treat and discharge wastewater, based on the premise of greater efficiency through economies of scale. It represents a conventional approach to UWM. Again, CONAGUA (national level) is directly involved in decisions and operations, whereas SABESP (State level) oversees this infrastructure in the MRSP. SABESP has developed an integrated system for sewage collection and treatment at the metropolitan scale, based on a few treatment plants, including one mega-plant. It takes an integrated view of the river basin and the metropolitan sanitation infrastructure and relies on cooperation from municipalities and industries to connect to the sewage network. In the MVMC, a giant sewage treatment plant was opened in 2017, thereby responding to the significant backlog in sewage treatment. It pumps sewage water out of the VMB, and discharges treated wastewater into the neighbouring Tula basin.

Macro-drainage plan of Alto-Tietê

The Alto-Tietê Macro-drainage plan, led by the DAEE, aims to mitigate flood risks through an IRBM approach and coordination with multiple actors. It is integrated with basin planning and the basin committee funds certain projects. As the Alto-Tietê Basin and MRSP almost overlap, this scale facilitates a regional approach to urban/metropolitan macro-drainage and flood management. Drainage districts are further delimited according to sub-basin boundaries. The plan combines cost-effective solutions that integrate hard and soft measures, including environmental rehabilitation. In addition, the plan emphasizes that flood risk management requires coordinating the urban drainage plans of all the municipalities in the river basin, acknowledging upstream/downstream interlinkages. Although the CONAGUA in the MVMC coordinates metropolitan-scale drainage infrastructure, this is not based on basin management principles or a regional plan but focuses on rapidly expelling excess surface water.

Environmental protection measures

In the MRSP, state legislation for APRMs regulates land use and development in areas crucial for water supply. The areas are delimited by sub-basin and aim to protect the springs while improving the living conditions in the area. Municipal governments are expected to control land use within their borders and therefore shoulder a large portion of the responsibility regarding these laws. Within the MVMC, part of Mexico City proper, including the mountainous South that recharges the city's aquifers, is in 'Conservation Land', which restricts land use and development. The Mexico City government played a predominant role but depended on cooperation from district authorities. A limitation is that the ecologically valuable green region extends beyond the borders of Mexico City, but there is no regional or metropolitan land use planning for environmental conservation. While there are Protected Areas within Mexico City and surrounding states, these do not foster a regional approach to preserving water-relevant ecosystems. Environmental and urban policies within Mexico City are also not coordinated, leading to inconsistencies between sectoral plans.

PES programmes

Multiple PES programmes have been implemented in the MVMC, by different levels of government (e.g. federal government, Federal District, Mexico State) and with different strategies (e.g. strict rules on land use change or ability to develop sustainable activities, technical assistance, different payment frequency). They aim to protect ecosystem services, especially hydrological services, by supporting or compensating the providers of these services. As much of the land is communal, authorities must collaborate with and obtain consensus from a large number of individuals. No PES programmes are implemented within the MRSP. The PCJ basin applies some of the resources from water use fees in a PES programme that seeks to reforest areas around the Cantareira System.

9.4.3 INFERENCES

Most instruments were evaluated positively or as neutral in terms of their objectives. They emphasize environmental sustainability (e.g. preservation of minimum environmental flows, protection of green areas around urban areas) and social equity (e.g. subsidized tariffs for low-income households, compensation to landowners in the green belt). Although many instruments could be linked to climate change adaptation, this was generally not their primary goal. Moreover, the infrastructural and planning instruments are mainly implemented at the spatial scale of metropolitan region and/or basin, although they are managed at higher levels of government. Instruments focused on ecosystem protection are implemented at multiple levels, including through funding mechanisms, although their scope is local or regional.

Overall, responsibilities are often spread across multiple levels (e.g. legislation or policy framework at national or state level, land use management is a local responsibility, implementation and coordination takes place at regional level) and between actors with different interests. This has implications for how policy instruments are coordinated. Although the goals of UWM and IWRM/IRBM significantly overlap in both cases, they are managed separately. This is clearly illustrated by the absence of linkages between water use or discharge instruments (i.e. permits, fees) and water services instruments (i.e. tariffs), as IWRM/IRBM and UWM mandates and goals are designed at different spatial scales. Interactions between IRBM and UWM entities mainly focus on the management of large-scale infrastructure for water supply (e.g. the inter-basin transfers from the Cutzamala and Lerma systems and from the Cantareira and São Lourenço systems) and drainage/flood control (e.g. deep drainage, canals and pumps to evacuate water from the VMB, and coordination between ATB municipalities that manage drainage systems and the DAEE that manages larger rivers).

9.5 Comparing the effect of instruments on actors' behaviour

This step involved evaluating how effective the instruments were in achieving their stated mandates.

9.5.1 Regulatory instruments

Water use permits

In both cases, water allocation through water use permits is based on water availability within basins and aquifers but decisions are made at state or national levels with little transparency. The possibility of transferring permits between users in Mexico has meant that these have changed hands over time from farmers to industries and real estate companies, as the city expanded. The value of these permits has spurred a black market that favours the highest bidders. These permit transfers, combined with weak enforcement of regulations regarding abstractions, have failed to reduce or even stabilize water use levels in the region. In fact, they enable unsustainable urban and industrial growth.

In the ATB, there are no restrictions for allocating additional water volumes, despite low water availability, and permits are granted through lax criteria, even though large volumes are imported from other basins. In both cases, no effective measures are in place to limit who can obtain permits, interlinkages with surrounding basins are ignored, and reliable groundwater extraction data is lacking. Moreover, the import of water from other basins corresponds to a reallocation of water resources from rural to urban areas. Through water use permits, these cities gain legal control over water resources and thereby over areas far from their borders.

Environmental protection measures

The enforcement of Protected Areas, with restrictions on land use and land occupation, has been ineffective due to a lack of monitoring and relies disproportionately on local governments in the periphery of the metropolises. The latter tend to be poor and lack capacity for monitoring and are under pressure from the local population to provide housing and urban infrastructure and services. In fact, informal settlements have multiplied around these areas, with reports of clientelism by local politicians, severely contaminating the springs that are crucial to the entire metropolitan region.

9.5.2 ECONOMIC INSTRUMENTS

Water use fees

Water use fees for bulk water are low and lacking in both cases (e.g. they excluded agricultural users, despite their heavy water use), discouraging actors from internalizing the real cost of bulk water supply – as discussed in the water tariffs section below. Low fees impact the effectiveness of the fees in both cases. However, water use fees in the MRSP have been reinvested within the basin where water was extracted, and according to the priorities defined by basin committee members. This gave users a sense of shared ownership and better acceptance of fees, meaning that a progressive rise in the fees' value and the inclusion of agricultural users was more likely to be accepted than in the MVMC. Industrial users in both cases are more likely to reduce use, due to the cost and the possibility of switching to recycled water and other water saving practices.

Water tariffs

Water tariffs for water supply services were considered relatively affordable in both cases, with subsidized rates for low-income households, and even for most residents in the case of Mexico City. However, the lack of an independent regulator in the MVMC politicized the design of water tariffs. Heavily subsidized water tariffs and fixed tariffs due to a lack of water metres have led to very high consumption rates. As a result, cost-recovery is low, and Mexican utilities depended on external funds. This hinders their ability to invest in the sector, including for reducing non-revenue water, such as leaks and water theft. This mainly affected low-income peri-urban residents who received subpar services or none at all. Informal settlements in the MVMC did not benefit from subsidized tariffs as they were not connected to the public network, and they often depended on water trucks that charged very high prices. In the MRSP, utilities such as SABESP had special programmes to provide drinking water services in informal settlements, although not all such neighbourhoods were included.

In the MRSP, significant funds are invested in expanding water supply infrastructure, and profits are also redistributed to shareholders. Critics argue that these profits are insufficiently reinvested in expanding wastewater services or reducing leaks. Nevertheless, SABESP's state-wide cross-subsidies have allowed it to expand access to peri-urban and rural areas, while applying the same tariff (including subsidized rates for low-income households) regardless of the cost of service provision. All in all, the lack of transparency prevents an in-depth evaluation, but this indirect evidence, when combined with high levels of water losses and the constant need to increase water supply, indicates that there is significant room for improvement in balancing the water use fee/water tariffs within SABESP.

Payment for Ecosystem Services

The value of the PES programmes in the MVMC is low compared to the opportunity cost for landowners to develop their land or log the wood. Nevertheless, at least around 2.5 million hectares of forests have benefitted from the federal PES programme across Mexico. The Mexico State PES programme has stable funds as it receives part of the revenue from water tariffs, and this has also created a direct link between water consumption and WRM.

Although there is no PES programme in the ATB, the neighbouring PCJ basin has led to the reforestation of over 500ha out of 35,000ha needed. A challenge in both cases is cooperation with private landowners, as the economic benefits are minimal. As the pressure on landowners near springs in the MRSP is high, PES programmes or other economic instruments could incentivise adequate land use and environmental protection in these areas.

9.5.3 Infrastructural instruments

Inter-basin transfers

Inter-basin transfers and the interconnection of supply systems have ensured relatively stable water flow to both metropolitan regions, although marginalized communities still have precarious access, especially in the MVMC. The integration of systems may lead to greater resilience in the face of droughts. However, in both the MRSP and MVMC, inter-basin transfers are managed by higher-level actors in a top-down manner. The lack of transparency is more pronounced in the MVMC, as basin and local actors are not involved in discussions.

The focus on increasing water supply through inter-basin transfers (rather than reducing demand, rehabilitating local water sources or investing in alternative water supplies[90]) has increased dependence on bulk water suppliers, thereby further empowering these actors. Overall, residents have high levels of water access in both metropolitan regions.

Metropolitan wastewater infrastructure

Despite investments in large-scale sewage infrastructure in both megacities, sewage treatment remains low. Informal settlements are an obstacle for utilities to obtain and treat sewage (pipes cannot be installed due to lack of land tenure, and physical layout is a further obstacle for areas that are regularized).

In São Paulo, wastewater treatment plants are often running under capacity, due to the cost and practical challenge of transporting sewage through extensive piping networks. With fewer but larger plants, the networks need to travel longer distances and have a wider diameter to allow for a greater flow. Municipal treatment plants often perform worse in both cities, generally because they lack financial resources, cannot enjoy natural economies of scope and scale usually associated with these services and sewage treatment is not their priority. Neither

90 In both cases, industrial users seemed more likely to invest in wastewater reuse technologies if there were sufficient incentives to do so. While cost through fees and environmental norms can push them in this direction, they also need security in knowing they will continue to have stable access to water. They can be reluctant to give up a permit for water use otherwise. In Mexico, respondents mentioned cases of industries or buildings switching to reuse/rainwater harvesting, but still being charged fees as they still had a water permit, and this can dissuade them from making these switches.

very large nor very small sewage treatment plants are optimal in the more urbanized areas, but local solutions were effective in sparsely populated peripheral municipalities of the MRSP.

However, the downstream location of both mega-plants prevents the reuse of treated wastewater within the metropolitan region or the replenishment of local waterways and aquifers. While it represents an effort to expand sewage treatment and reduce water contamination, this linear approach justifies the need to continue importing water from other basins and is not an ecologically sustainable path.

Macro-drainage plan (São Paulo)

Although this plan aims for a basin approach, the interactions between municipalities and the State (DAEE) are stronger than horizontal interactions (between municipalities). Tensions still occur between municipalities, especially those with rival political parties (e.g. construction of dykes that aggravate flooding for neighbouring municipality). Local mandates to address stormwater and flood challenges and different levels of financial and human capacity further prevent inter-municipal coordination. The plan mainly reinforces the DAEE's power and its vision of flood prevention through large, hard infrastructure, and does not substantially help foster changes in urbanization or land use. Nevertheless, it fosters a common vision of flood risks and priority areas in the basin. While the MVMC coordinates the discharge of sewage and stormwater between CONAGUA and the three state governments, this is limited to financial decisions and the operation of infrastructure and does not involve a multi-stakeholder basin-oriented planning process.

9.5.4 INFERENCES

Investing in large-scale infrastructure remains the preferred choice for state and national governments to address water quantity, water quality and climate change adaptation-related challenges. While this allows actors to (partly) fulfil their main goals (e.g. supplying drinking water, treating sewage), it also consolidates their monopolistic power and reproduces their linear approach of taking, using and expelling water, and provides little incentive for sustainable water use in the long-term.

Although regulatory instruments are crucial for better oversight of water resources and crucial ecosystems in and around the two metropolises, their enforcement is limited. In particular, they do not address the drivers of urban and economic growth.

In terms of economic instruments, water use fees are overall too low to incentivise users to reduce their use. When implemented, they seem more effective when the collected funds are reapplied in the region where they are collected, through an inclusive decision-making process. Even if the funds are dwarfed by those of other entities, it helps foster a basin-oriented approach. Regarding water tariffs, subsidized rates are not necessarily correlated with greater access to services for marginalized residents. With no cost-recovery, the quality of services of utilities tend to worsen due to the inability to invest. Funds such as the Fideicomiso 1928 and the Metropolitan Fund only invest within the MVMC as the actors in charge of these do not have mandates to act outside its borders.

Suasive instruments play a minimal role. Since the 2013-2015 water crisis in São Paulo, there is greater awareness of the region's relative water scarcity and consumption levels are still below pre-crisis levels. The experience of the crisis and the application of bonuses and fines for reductions or increases in water consumption were more effective than awareness campaigns for water saving.

9.6 Comparing the impact on sustainable and inclusive water governance

In this step, I assessed the impact of instruments in terms of the four dimensions of sustainable and inclusive development, in the context of existing driving forces.

9.6.1 Ecological impacts

Environmental criteria are often unambitious or applied weakly. For instance, water use permits in São Paulo mainly rely on quantitative standards for surface water (i.e. the Q7,10), disregarding that large volumes of water within the basin are unavailable due to contamination and that significant groundwater is extracted. In Mexico City's case, there are restrictions on granting new water use permits but water has been over-allocated, and monitoring is lacking. Water use fees and water tariffs are disconnected from water availability levels in both cases, but especially in the MVMC, where drinking water tariffs are highly subsidized despite regional water shortages. Industrial plants continue to obtain permits, through permit transfers, to extract large volumes of water, for low fees, from over-exploited aquifers. Furthermore, utilities were often not allowed or able to provide Wat&San services in informal settlements. WRM and UWM actors have limited to no influence on land use management and land tenure. In addition, industrial contamination has decreased as industries have moved to nearby regions in both cases, but this transfers contamination to other basins, some of which supply the megacities through inter-basin transfers.

The current instruments focus on the symptoms of metropolitan water challenges, but fail to address their drivers, in particular uncontrolled urbanization and a constant push for economic growth at the expense of environmental sustainability. Both cases studies revealed that WRM is often disconnected from land use management, environmental protection and urban planning, in part because these are the mandates of actors at different governance levels. Ultimately, the instruments reflected a mismatch between where ecosystem services originate and where they are used, which promotes importing water from increasingly further away, and ignores high water losses, contamination and encroachment on surrounding green belts.

9.6.2 Social impacts

Water for human consumption is officially prioritized over other uses in both cases. Water tariffs are subsidized (significantly in the MVMC) for low-income households. Cross-subsidies in the MRSP favour poorer, peri-urban municipalities. Nevertheless, marginalized residents in informal settlements lack access to sufficient drinking water, as the lack of land tenure sometimes leads to total exclusion from water services. During the water crisis in São Paulo, poorer households in the periphery experienced severe water shortages, while residents in central areas more rarely experience dry taps. This issue is more severe in Mexico City, where residents in peri-urban areas continuously struggle to access water and rely on water trucks, often paying much higher prices. Further from the metropolitan area, indigenous communities have seen their water sources become fenced off and inaccessible as these have been incorporated into the inter-basin transfers. Meanwhile, permits for other uses, such as industry, have still been granted in recent years, despite protests from surrounding communities whose drinking water comes from the same aquifer.

Similarly, instruments addressing water-related risks are mainly focused on technical and infrastructural fixes and do not address the greater socio-economic vulnerability of certain residents or uncontrolled urbanization that lead to the occupation of floodplains and hillsides.

9.6.3 Economic impacts

Water use permits grant users security and enable economic development. However, unsustainable water allocation harms the economic prospects of future generations and of the areas where more water is imported from. In Mexico City, land subsidence from over-drafted aquifers is also causing damages to buildings and infrastructure. Water availability and the risk of water depletion have not been effectively incorporated within a regional, long-term economic strategy.

Water use fees can redistribute gains across the basins and recognize the value of ecosystem services. In São Paulo, fees are reinvested within the basin where water is abstracted, in projects negotiated within the basin committees. In Mexico City, these fees disappear within a federal budget or are invested in large-scale infrastructure in the MVMC through a top-down process. The ineffectiveness of wastewater discharge fees has led to heavy economic costs due to reduced water availability and the potential waterborne diseases it can cause.

Regarding water tariffs, certain respondents in São Paulo argue that profits are redistributed to shareholders or invested in increasing water supply, rather than invested in reducing water losses or water contamination. In Mexico City, tariffs are too low for cost-recovery. The cost of mega-infrastructure for water supply is borne by taxpayers nationwide, while utilities cannot afford or do not prioritize measures such as reducing non-revenue water. The MRSP, on the other hand, de facto subsidizes many of the municipalities in the rest of São Paulo State.

Large infrastructure (e.g. mega-sewage plants, inter-basin transfers, flood management works) was often very costly. No comparative analyses are carried out (or disseminated publicly) to evaluate if these measures are the most economically efficient.

9.6.4 *Relational impacts*

Decision-making on UWM and WRM lacks transparency, prioritizes short-term political and economic interests and reproduces the exclusion of marginalized communities through policies and actions focused on importing water, exporting storm and wastewater and ignore issues of environmental preservation or land tenure. It has led to conflicts with indigenous communities and users in donor basins, who have neither voice nor vote in the process. Besides water tariffs, most instruments do not aim to put the needs of the most vulnerable first, but even subsidized tariffs often fail to benefit marginalized residents. Clientelism is common between local politicians and residents in the case of Mexico City and between municipal utilities and residents in the MRSP. In Mexico City, CONAGUA's control over water use and wastewater discharge permits and fees hindered involvement of more local level actors and bottom-up knowledge integration. Participatory river basin planning is virtually absent. In São Paulo, basin and local actors have more influence, although ultimately, state-level actors dominate decision-making processes. Partly, more advanced implementation of IWRM/IRBM may be due to the near overlap of the ATB and MRSP's territories and being contained within one state, creating fewer coordination challenges. In addition, water use fees increased the ATB committee's budget and thereby its potential for effective IRBM.

Mega-infrastructure for water supply, sanitation and stormwater play prominent roles in both cases and reinforce the power of state and national actors, legitimized by the concept of water security. Some respondents argue that mandates and funds should be transferred to local level actors, but besides the lack of technical capacity, it is not clear how the collective water-related challenges highlighted in this thesis can be addressed in that manner.

9.6.5 *Inferences*

Overall, instruments applied in the MRSP performed better in terms of design, effect on actors given their mandates and impacts on inclusive and sustainable development than in the MVMC, although there is room for improvement in both cases. Social inclusiveness is greater in the case of the MRSP, which has high levels of access to the piped water network and cross-subsidies that support poorer municipalities. However, in both cases, the patterns of economic growth that reproduce socio-economic inequality and unequal exposure to water-related risks remain unaddressed. Negative ecological impacts are clear in the MRSP through the contamination of local water sources, and in the MVMC through land subsidence from groundwater over-exploitation. Even instruments specifically designed to address this, such as PES programmes or environmental protection areas are mostly ineffective. In particular, such instruments do not address the root causes of environmental degradation, namely informal urban growth that leads to encroachment on green areas and a lack of basic infrastructure and services such as sewage and solid waste collection. In terms of economic impacts, many instruments favour short-term outcomes and supply-focused approaches disregarding the (not-so-distant) future economic consequences. They are often economically inefficient, preventing cost-recovery, or with a budget too low compared to the needs (i.e. PES programmes). The financial gains benefit a small number of private sector actors and, sometimes, corrupt politicians, excluding marginalized peri-urban and rural communities. Finally, power largely remains in the hands of state or national level actors. Table ***9.2*** provides scores based on the evaluation of Mexico City and São Paulo's instruments in terms of their design (see 9.4), their effect on actors' behaviour (see 9.5) and their impacts in terms of sustainability and inclusiveness (see 9.6).

Table 9.2 Evaluation of the effectiveness of instruments in the MRSP and MVMC

	Brazil			**Mexico**		
	Design	Effect on actors	Impact on Sust&Incl	Design	Effect on actors	Impact on Sust&Incl
Water use permits	+	-	Ecol: - Soc: - Econ: - Rel: -	+ +	-	Ecol: - - Soc: - - Econ: - Rel: - -
Water use and wastewater discharge fees	+ +	+	Ecol: + Soc: + + Econ: + Rel: + +	0 / +	-	Ecol: - - Soc: - - Econ: - - Rel: - -
Water tariffs	+	+ +	Ecol: - - Soc: + + Econ: - Rel: -	0	0	Ecol: - - Soc: 0 Econ: - Rel: -
Metropolitan water supply	0	+	Ecol: - - Soc: + Econ: - Rel: - -	0	0 / +	Ecol: - - Soc: - - Econ: - - Rel: - -
Metropolitan wastewater infrastructure	+	0/+	Ecol: - Soc: - Econ: - Rel: -	0 / -	0	Ecol: - Soc: - Econ: - - Rel: -
Macro-drainage	+ +	0 / +	Ecol: - Soc: - Econ: - - Rel: -	-	-	Ecol: - Soc: - Econ: - - Rel: -
Environmental protection areas	+	0	Ecol: + Soc: + Econ: + Rel: +	+	0	Ecol: - Soc: 0 Econ: - Rel: 0
PES programmes				+ / + +	0 / +	Ecol: - Soc: 0 Econ: + Rel: +

Relative assessment scores: ++ Very positive; + Positive; 0 Neutral; - Negative; -- Very negative (See 2.4)

9.7 Comparing redesign

Finally, based on the instruments' effects on actors and impacts in terms of sustainability and inclusiveness, I conclude about the lessons that each city can learn from the other in terms the (re)design of policy instruments within urban water and river basin governance regimes.

9.7.1 Macro-drainage

A participatory, basin-scale plan such as the MRSP's Macro-drainage Plan, which has strengthened metropolitan-wide collaboration and more context-appropriate responses in the MRSP, could benefit the MVMC as the current focus on expelling storm and wastewater ignores basin considerations and local interests. However, the MRSP's plan mainly focuses on hard infrastructure, and more emphasis could be shifted to drivers of vulnerability such as land use, land tenure, affordable housing and climate change. Green infrastructure is rare despite its potential for flood mitigation and other co-benefits (e.g. leisure, climate regulation, groundwater recharge). Its relatively low-cost warrants further consideration. In the MVMC, small-scale infrastructure to infiltrate or harvest rainwater is more common. These measures mitigate flood risks and help retain water within the basin for reuse or aquifer recharge, alleviating the pressure on over-drafted aquifers and external water resources. While aquifers are not under similar pressure in the MRSP, retaining stormwater through green infrastructure would alleviate over-burdened grey stormwater infrastructure during heavy rains and reduce diffused pollution in waterways. Scaling up these measures, in both cities, could involve incentives and the revision of norms, combined with risk assessments.

Moreover, the MRSP's Macro-drainage Plan has not increased coordination between municipalities. This could be addressed if local governments adjust their stormwater plans to be coherent with the macro-drainage plan. As an incentive, this can be a pre-requisite for local governments to apply for funding from the basin committee for stormwater and flood management-related projects. In the MVMC, three state governments and the federal government coordinate infrastructure across the metropolis, but as in the MRSP, municipalities did not coordinate among each other. Regional, long-term strategic planning that includes local authorities, metropolitan infrastructure and basin hydrology could better integrate underlying and localized vulnerabilities. As was learned from the Brazilian experience, this is more effective if local governments are incentivized or required to make local stormwater and flood mitigation plans coherent with regional planning. Measures can be implemented at sub-basin level (as in MRSP) to adjust to local needs and return surface runoff to streams rather than funnelling it downstream.

9.7.2 Metropolitan wastewater systems

Despite relative water scarcity within the ATB, there are few efforts to promote recycling and wastewater reuse. Treated wastewater is reused more extensively in the MVMC, for urban and rural agriculture, industrial use and the replenishment of canals. This can reduce pressure on (blue) water systems. However, the downstream locations of mega-sewage plants in both cities disincentivizes measures to retain treated wastewater within the basin for reuse or replenishing streams (or aquifers through artificial groundwater infiltration), thereby reducing dependence on external water sources. Promoting (treated) wastewater reuse in the MRSP may be easier as wastewater treatment plants are more decentralized than in the MVMC, with large and small treatment plants are distributed according to population density and managed at sub-basin level. This reduces wastewater transportation – and thus overall – costs. Many smaller wastewater treatment plants in the MVMC operate under capacity or are abandoned. As sewage collection and treatment does not reach all households, especially those in informal settlements, these smaller plants could support wastewater recycling and reuse.

Many sewage plants in the MRSP also operated under capacity due to legal and physical limitations to connect households in informal settlements to the sewage network. This was particularly true for the mega-sewage plant, surrounded by informal settlements. Expanding sewage treatment services is now less an issue of treatment capacity but of connecting households in informal settlements and installing sewage mains. This requires utilities to coordinate with local governments, responsible for land use and housing. The latter need greater support in enforcing land use restrictions and in upgrading informal settlements. Within the APRMs, municipalities could receive technical and financial support for the upgrading of settlements from the basin committee, conditional on their harmonization of local plans with the basin or regional Wat&San plans. Expanding decentralized wastewater treatment – and therefore reuse – in the MVMC is also more likely to succeed if utilities and local governments are coordinated within a regional wastewater management plan.

In addition, water users in the MVMC were often reluctant to take the risk of switching their water supply system to treated wastewater. Large users such as industries could receive incentives, such as lower water use fees, easier access to water use permits or a water allocation guarantee (e.g. if the alternative system was inadequate for a user's needs, they can reclaim their permit for bulk water supply within a set deadline).

9.7.3 WATER TARIFFS

In both cities, water tariffs are overall affordable and promote equity and the inclusion of low-income residents through block rates and subsidized tariffs. In the MRSP, water tariffs still allow for cost-recovery. However, subsidized tariff rates in the MVMC were granted to most households, including those with the capacity to pay full rates, which crippled utilities' revenues and ability to invest in the services. It has also led utilities to depend on federal funding, meaning taxpayers subsidize water services in the country's wealthiest region. Adjusting eligibility criteria for such tariffs will allow utilities to better recover costs and encourage more rational water use and the installation of water metres. Additional revenue could further support leak repairs or service expansion to areas currently relying on water trucks. The MVMC could learn from the MRSP, which has legal frameworks at national and state levels to promote minimum standards and goals for access to drinking water and an independent regulator. In addition, programmes for informal settlements in the MRSP have expanded access to drinking water and reduced commercial water losses. This could also be implemented in the MVMC through collaboration between local authorities and utilities. In addition, coordination between utilities and local governments regarding land use and land tenure could facilitate the identification of settlements to be legalized, upgraded or serviced through alternative means.

Furthermore, SABESP applies the same tariff rates and subsidies in all the municipalities it operates in through cross-subsidies, enabling service provision in unprofitable areas. However, the tariff structure does not consider water availability within the basin or aquifer. The exception was when bonuses and fines were applied during the water crisis of 2013-2015 to incentivize water saving. In addition, local water utilities that obtain bulk water from SABESP do not always pay for this and are likely to disregard water availability in the broader basin when setting their tariffs. This disconnect by SABESP and local utilities from the water resources that they depend on could be addressed by incorporating environmental impact criteria and compensation mechanisms into tariff-setting.

The tariff design in the MVMC also ignores water availability within the basin, the cost of importing water and the effect of low tariffs on water demand. The State Congress is not accountable to the basin and is incentivized to apply widespread subsidies as a political tool. A more independent process of setting tariffs (e.g. through a regulator) could improve cost-recovery for utilities and increase investments, but also incentivize rational water use and better match the reality of the basin.

9.7.4 Water permits

Water permits in both metropolises prioritize water for domestic consumption and preserve minimum environmental flows. In the MRSP they are a pre-requisite for obtaining an environmental license and in the MVMC they require an environmental impact assessment. In the MVMC, there are stricter regulations than in the MRSP for obtaining a water permit as a restriction zone across the basin imposes a moratorium on the granting of new permits. Nevertheless, permits in the MVMC can be transferred between users. The introduction of a moratorium on new water permits could be considered for the MRSP, but the case of the MVMC highlights the importance of an accountable regulatory system. Unregulated permit transfers and weak land use and building regulations allow for continued urban expansion in peri-urban areas, increasing water demand. This shows a disconnect between WRM at basin or aquifer level and urban planning at local level. In some cases of over-allocation, it may be preferable for the relevant authority to terminate a permit rather than to allow its transfer to another user. If a transfer is allowed in a water scarce area, guaranteeing priority uses is necessary – although not always sufficient – to achieve sustainability and inclusiveness.

In addition, water-centric Strategic Environmental Assessments could help decision-makers identify where new projects are viable without causing environmental or social impacts. This would go beyond current Environmental Impact Assessments as it would allow region-wide impacts in a continuous manner and support sustainable planning processes. Such regional planning that includes stakeholders from the multiple basins inter-connected in metropolitan water use, the water allocation authority, users and local governments could lead to concerted action to ensure that urban and economic growth considers resource limitations and benefits local residents. More groundwater data and knowledge and the integration of groundwater into participatory basin management could also ensure more adequate responses to current groundwater use.

9.7.5 Water use and wastewater discharge fees

Although they promote rational water use and consider water availability, the value of water use and wastewater discharge fees in the MRSP remains low. In part this is because they were only introduced in 2013 and the basin committee plans to raise them progressively. Increasing these fees, at least for certain larger users, will help reduce water demand and increase the basin committee's budget for basin-wide projects. In Mexico, these fees are set at national level and vary per 'availability zone'. The value of fees in the MVMC is also relatively low, despite its location in a low availability zone. Requiring the use of water metres for bulk water users could increase rational water use and the revenue collected. Applying sanctions to users who lack metres or use water illegally would also incentivize compliance (as non-compliance is now met with virtual impunity) and finance intermittent inspections. Although water for public supply is the largest use, incentives for farmers to switch to more efficient irrigation systems could reduce water use in the MVMC's rural hinterlands and reduce pressure on aquifers.

In the MRSP, bulk water use and wastewater discharge fees are returned to the committee of the basin where they were charged. With the implementation of these fees, the ATB committee's budget increase. This has led to renewed stakeholder interest and involvement due to a greater capacity to invest in projects of basin relevance. This system of keeping fees within the river basin and involving users and other stakeholders has potential for the MVMC. Currently water use fees for water resources used within the MVMC are either reinvested in stormwater and sanitation works in the metropolis, even when these water resources were imported from other basins, or they are absorbed by the Federal Treasury. The MRSP's system increases willingness to pay of users and stakeholder engagement, leading to more sustainable and inclusive outcomes at basin level.

9.7.6 Inter-basin transfers

For both the MRSP and the MVMC, inter-basin transfers have been key to responding to rapidly growing water demand, and due to the heavy reliance on donor basins it is unrealistic that either city could stop importing water in the short to medium term. Nevertheless, the focus on inter-basin transfers as the main strategy to achieving water security has disincentivized water demand management in both cases. As both cities are reaching the limits of the economic viability of importing water and as climate change forecasts indicate an overall decrease in precipitation, cost-benefit analyses could reveal the economic advantages of investing in water demand management.

In both cases, water imports have transferred externalities to donor basins. In the MRSP, this has led to tensions with the PCJ committee and its reluctance to renew transfer agreements. In the MVMC, there have been conflicts with indigenous communities who lost access to nearby water resources without prior consultation or any form of compensation. Basins exporting water to the MRSP receive compensation through water use fees. However, these fees do not fully compensate for externalities. Cancelling the discount on inter-basin transfer fees from the Cantareira System to the MRSP would more fairly reflect the costs transferred onto the donor basin. This could be done progressively to allow time for users to adjust (e.g. by investing in water saving technology). The additional funds could be reinvested in preserving the Cantareira System and sustainable activities around it, thereby economically supporting the donor basin and ensuring the preservation of ecosystem services that benefit the MRSP. In addition, actors within the PCJ basin, or other basins that export water to the MRSP, could be given a greater role in basin transfer negotiations through a platform at a larger spatial scale, such as the Integrated Urban Development Plan.

In the MVMC, bulk water use fees are not returned to donor basins and subsidized drinking water tariffs reduce incentives to reduce water consumption at household level. Returning water use fees to donor basins, eliminating subsidized water tariffs for those who have the capacity to pay, improving billing by installing water metres where they are absent and incentivizing investments into water saving and recycling technologies at local levels could reduce water demand and the pressure on donor basins. Returning water use fees to basins could also strengthen basin councils and give stakeholders in donor basins a stronger voice in negotiations.

9.7.7 Environmental protection measures

In both cases, environmental protection measures have been characterized by sectoral fragmentation and a lack of coordination between local governments and across levels of governments. APRMs in the MRSP require coordination between local, basin and state-level authorities. They involve participatory planning and basin considerations. Although APRMs are managed by sub-basin committees, their main struggle is informal urbanization; and land use management and housing are primarily municipal mandates. It is therefore essential that the sub-basin committee, municipalities, state entities and Wat&San utilities coordinate their actions and goals and develop coherent planning. Municipalities that update their Wat&San plans to align with the basin plan could receive points in the FEHIDRO system, increasing their qualification for funds from the basin committee. Coherent plans would facilitate coordination between utilities and local governments regarding land use limitations for service provision to find solutions, when possible, for service provision in informal settlements.

As in the MRSP, the preservation of Mexico City's Conservation Land involves multiple local governments (i.e. districts), but the green belt expands far beyond the Conservation Land

and there is no inter-state cooperation. A regional vision and plan that englobes the MVMC's green belt has been designed by NGOs but has failed to attain broad government support. However, such a plan could guide investments for PES programmes and from revenue generated by water use fees, as well as facilitate coordination between state conservation programmes. As in the MRSP, managing funds and coordination activities could be the responsibility of a regional body (e.g. a basin organization or an inter-state conservation body). Although PES Programmes still have relatively small budgets, they can support over-burdened local governments and strengthen collaboration across administrative boundaries.

9.8 Inferences

In both case studies, rapid and unplanned urbanization, economic development prioritizing the interests of industry and the economic elite and extreme weather events aggravated by climate change are the major drivers of metropolitan water challenges. Developing coherent UWM and IWRM/IRBM that leads to changes in actors' behaviour and that impacts inclusive and sustainable development is challenging in both the MRSP and MVMC. In part this is due to the multitude of jurisdictions involved and the need to align mandates at different levels, spatial scales and sectors (e.g. preservation involves land use management at local level, environmental policies at state level, basin management, etc.). Instruments are sometimes disconnected from the water cycle (e.g. water tariffs focusing on affordability but ignoring water availability) or fail to include already marginalized communities within or outside the metropolis. Many suggestions for redesign therefore relate to the spatial scale of instruments and the challenge of overcoming mismatches between the scale of their design and the scale of their impacts. Harmonizing plans at different levels and between sectors is crucial in that regard. Importing water from other basins remains necessary in the short and medium term but externalities could be accounted for through regional planning that incorporates inter-linked basins and gives a voice to all stakeholders, and through compensation mechanisms, which would also incentivize implementing more water demand measures. Drainage and wastewater management require a metropolitan plan for interlinked infrastructure, but stormwater and wastewater can often be managed at sub-basin level, retaining water closer to its source. Although the MRSP's river basin and urban water governance regimes are overall more effective in terms of inclusiveness and sustainability, policy redesigns are recommended for both cases and each has relevant lessons for the other.

10. TOWARDS A THEORY OF METROPOLITAN WATER GOVERNANCE

10.1 INTRODUCTION

Large metropolitan regions are quickly multiplying and increasingly facing challenges in terms of water quantity, quality and adaptation to risk from extreme weather events. Although they generally have greater access to resources to address these challenges, their complexity increases exponentially with their size, as the number of actors and institutions involved directly or indirectly in metropolitan water governance also multiplies. The failure to reconcile metropolitan water governance across urban and river basin scales can translate into water policies that lead to a 'scalar mismatch'. In some cases, this can create redundancies that enhance resilience within overall water governance, as different actors and instruments work towards similar goals through different means. This is very necessary to cope with the impacts of climate variability and change. However, overlapping and disconnected policies and a lack of coherence and coordination between different levels of government and between urban and basin scales can also render measures ineffective or lead to externalities and conflicts over limited resources.

This thesis investigates river basin and urban water governance in relation to metropolitan water challenges through the following overarching question: **How do interactions between drivers and institutions at different spatial and institutional scales levels shape metropolitan water challenges, and how can policy instruments from river basin and urban water governance frameworks be (re)designed to foster more sustainable and inclusive metropolitan water governance?**

Section 10.2 reviews the lessons learned from the case studies in terms of the scalar mismatches that influence sustainable and inclusive metropolitan water governance. Section 10.3 highlights important considerations for metropolitan regions in federal states around the world. Following this, 10.4 identifies five elements that need to be considered individually and jointly to address scalar mismatches in metropolitan water governance. Section 10.5 then assesses the implications of this research for global policy and the SDGs.

10.2 TAKING STOCK FROM THE EXPERIENCES OF SÃO PAULO AND MEXICO CITY: SCALAR MISMATCHES IN METROPOLITAN WATER GOVERNANCE

The case studies illustrate the challenge of developing sustainable and inclusive metropolitan water governance as multiple levels of government and spatial scales are involved. This challenge translates into mismatches across scales.

10.2.1 MANAGING BULK WATER SUPPLY AND WATER CONTAMINATION AT THE MULTI-BASIN SCALE

Applying the spatial unit of the river basin to managing bulk water supply and water contamination does not internalize the two megacities' externalities on neighbouring

basins. Both the MVMC and MRSP are contained within one river basin (although the VMB is much larger than the MVMC, whereas the MRSP and ATB roughly overlap). However, the impacts of the two metropolitan regions in terms of water use and water contamination extend far beyond their basins and artificially interlink several basins. Water availability is insufficient: Between 39.4 and 47.9m^3/s are imported into the ATB from other basins out of the 81.25m^3/s that are used[91]; 20m^3/s are imported to the VMB out of 88m^3/s used and over 27m^3/s are estimated to be over-extracted within the VMB's aquifers (see 5.4.1 and 7.4.1). In both cases, higher levels of government intervene to ensure stable water supply to the megacities from other basins, thereby transferring the cities' water scarcity to donor basins, with impacts on the latter's communities, economies and ecosystems. Similarly, contamination from the MRSP flows down the Tietê River far beyond the borders of the ATB[92], while contaminated waters were reused in irrigation in the VMB's neighbouring basin until a large treatment plant was inaugurated in 2017. In fact, the impact of large cities extends much further as they tend to rely on 'virtual water' through the import of food and other goods, and local changes in the hydrological cycle can have repercussions far away. This regional approach may not fully account for these impacts.

A regional scale that includes all concerned basins can better account for these externalities. It is unrealistic for cities such as Mexico City and São Paulo to reduce their demands and impacts on surrounding basins in the short or medium-term. Centralized management of large-scale infrastructure for water supply (e.g. inter-basin transfers, metropolitan-scale integration of supply systems) at the multi-basin scale will remain in the short- and medium-term due to infrastructure lock-in, but is also more appropriate for cities of this size as it allows for economies of scale and integrates water scarce areas and areas without the means (or scale) to develop local infrastructure. The MRSP can learn from Mexico's restrictions on issuing new permits in low water availability zones. This does not address challenges of irregular water use and requires significant enforcement efforts, but it represents an effort to stabilize overall water use. The MVMC could adopt a water use fees system similar to the MRSP's, where funds are collected by the relevant basin entity and reinvested in projects that benefit the population and ecosystems within that basin. Wastewater discharge fees could also partly be used to compensate areas downstream of the metropolitan regions that receive contaminated water.

Nevertheless, the two cases show that **measures that reduce water demand, increase water use efficiency, integrate alternative sources of water and treat wastewater closer to the source can wean metropolises from their dependency on distant water resources and reduce contamination far beyond their borders.** Although they require long-term planning and regional coordination, they can often be managed locally. Decentralized management generally ensures more context-relevant responses and better user compliance (Xiao 2018). These initiatives exist but generally receive little support from governments or water utilities (e.g. rainwater harvesting for non-drinking water purposes, bioswales or artificial injections to

91 When needed, an inter-connection with the Paraíba do Sul basin allows to divert up to 8.5m3/s towards the Cantareira System (see 5.4.1).

92 The river was contaminated 130 km downstream of the MRSP in 2015.

infiltrate surface runoff). While certain initiatives had clear benefits, utilities lack incentives to reduce the volume of water they supply or of wastewater they treat, as this affects their revenue. It also requires long-established actors to radically change their approach and is therefore met with scepticism.

In the longer-term, if these measures are effective, the spatial scale of managing bulk and water supply and water contamination can be reduced. However, parts of these metropolises may never become self-sufficient in terms of water supply, and some degree of intervention through inter-basin transfers might remain necessary in the long-term (see 7.4.1). The MVMC is expected to face a deficit of 25.1 m^3/s of water by 2030, even after importing water from the Cutzamala and Lerma systems and over-drafting the local aquifers (World Bank, 2013). These calculations do not account for the effects of climate change on precipitation, evaporation and water use. The over-exploitation of aquifers and the deficit would correspond to 51% of the water demand (of approximately 90m^3/s). Reducing the pressure on local aquifers and addressing the remaining gap of 25m^3/s could partially be done through reducing leaks (projected to be 28.1m^3/s in 2030 in a business-as-usual scenario) and commercial losses (projected at 6.8m^3/s in 2030) and other measures mentioned above. Nevertheless, these require significant investments by the government and households. Halting water imports from other basins would require supplying another 20m^3/s through water demand management and alternative sources, which is unrealistic to be achieved by 2030 and even beyond.

10.2.2 Coordinating surface and groundwater management

The river basin scale is also too restrictive to think about bulk water management and water contamination as it mainly focuses on surface water dynamics. The MVMC and MRSP cases highlight that **groundwater, that is not part of a basin system, is not adequately integrated with basin management**. Significant uncertainty remains around groundwater dynamics. In the MVMC, groundwater use is very high, but little is understood about recharge rates, groundwater flows and quality levels. In the MRSP, it is not clear how much groundwater is used, but it is estimated to be significantly higher than official rates. There may be potential for expanding groundwater use in certain areas, thereby decreasing the need for water imports, but this would require more studies. This translates into an absence of groundwater management in the MRSP and the absence of effective groundwater management within basin management in the MVMC. Although rules and restrictions are in place in the MVMC to reduce groundwater over-exploitation, the relevant authorities lack capacity and incentives to enforce these (see 7.4.2).

The invisibility of the aquifer hinders the sense of a shared resource among users across a larger spatial scale. It is harder to monitor, and users tend to feel more strongly that the water beneath their feet belongs to them. Water use permits and fees do not consider interlinkages between surface and groundwater. However, the consequences of inadequate groundwater management can spread far beyond water extraction wells. It can lead to land subsidence and dried up springs and wetlands. In the MVMC, efforts to recharge local aquifers exist (e.g.

artificial groundwater recharge, retention reservoirs in the mountains surrounding the city). Their effects on the groundwater table are uncertain and depend partly on the speed of groundwater flows. However, as they also mitigate flood risks it is worthwhile to further assess such options and scale them up.

10.2.3 Retaining and reusing greywater: Semi-decentralized stormwater and wastewater management

The approach to stormwater and wastewater has focused on metropolitan-scale infrastructure to rapidly evacuate these effluents, ignoring downstream effects. This centrally managed linear approach is disconnected from local mandates and basin dynamics. Local responsibilities are not made coherent with a basin vision and plan. This has led to flood control infrastructure in one municipality that aggravates flood risks for a neighbouring municipality. Erosion or inadequate sewage treatment upstream affects downstream municipalities. In addition, this linear approach **consolidates a dependence on water imports.**

The ATB's macro-drainage plan defines a shared vision with **differentiated measures implemented at sub-basin levels** according to local characteristics, and vertical coordination between the state and municipalities to ensure that local stormwater measures are coherent with the regional plan. This combines local and metropolitan-scale measures that address soil-sealing, sewers and the occupation of floodplains, as well as basin-scale measures to reduce erosion and siltation upstream and maintain or rehabilitate wetlands and floodplains and retain stormwater upstream. Smaller-scale measures (e.g. warning systems, civil defence emergency measures, green infrastructure) can be more effectively implemented locally within a regional plan. To avoid a lack of coordination between municipalities – resulting, for instance, in stormwater being pushed to neighbours – it is crucial that local stormwater plans are made coherent with the ATB's plan. Meanwhile, government agencies at state or national levels can more efficiently coordinate large-scale infrastructure, such as deep drainage systems, and monitor large rivers.

While CONAGUA and state actors in the MVMC also coordinate large drainage infrastructure, this is not part of a regional plan that includes local governments or basin management principles. Groundwater depletion has caused severe land subsidence in certain areas, making these more vulnerable to flood risks. Existing measures, such as artificial groundwater infiltration that address flood risks and recharge aquifers, can be implemented in densely urbanized areas, while green infrastructure measures to retain stormwater in the MVMC's surrounding mountains naturally recharge aquifers and reduce urban floods. Scaling up rainwater harvesting can also contribute to reducing surface runoff and provide a source of water for non-drinking uses. The MVMC could therefore benefit from a regional plan such as the ATB's macro-drainage plan, which considers local needs, implements measures within sub-basin or aquifer units and promotes regional collaboration.

Wastewater management can also be better addressed through a multilevel framework. Decentralized wastewater management allows for discharging treated wastewater closer to the source, recharging aquifers or replenishing local wetlands, or it can supply industries and other users, according to local needs. Designing wastewater treatment measures at sub-basin level can allow for better consideration of local characteristics (e.g. population density, local hydrology, potential demand for recycled wastewater, lack of land tenure and physical obstacles that prevent the connection of informal settlements to the sewage network) to design context-appropriate measures. Meanwhile, regional coordination remains necessary as mega-treatment plants and large sewage mains will remain in place for decades, and the failure to treat sewage has a regional impact.

In the longer-term, retaining stormwater and (treated) wastewater within the cities' sub-basins can restore ecosystems and reduce the need for external water resources. As climate change will bring more irregular but more intense rains, such measures will enhance urban resilience.

10.2.4 WATER SERVICES ARE FRAGMENTED ACROSS THE METROPOLIS AND DISCONNECTED FROM WATER RESOURCES AND ENVIRONMENTAL MANAGEMENT

Whether the services are provided by a local or a state utility, metropolitan municipalities generally depend on shared water resources and inter-linked infrastructure. However, different utilities do not coordinate in terms of planning, which leads to fragmented infrastructure and inefficiencies and downstream impacts from inadequate sewage treatment. In the MRSP, municipal governments remain responsible for developing Wat&San plans, even when they have delegated this service to SABESP. However, these plans are often not (adequately) designed and/or implemented and SABESP *de facto* elaborates state planning for water services. In addition, there is no requirement for neighbouring municipalities to harmonize their plans or seek synergies. On the other hand, as SABESP has control of planning it could – in theory – ensure greater coherence across municipalities. In the MVMC, the total vacuum in terms of Wat&San policy at national level meant there are no shared standards and goals between local and state governments. This hinders the ability of local actors to coordinate actions on shared challenges.

While municipal provision may enable greater proximity to consumers and knowledge of the local context, **some degree of regional planning and or management can better address the dependence on shared water resources and infrastructure and the regional impact** from a lack of wastewater collection and treatment. This would allow for economies of scale (e.g. water purification and wastewater treatment plants can often be shared between multiple municipalities), greater technical capacity (local utilities often struggle to hire and retain skilled professionals, especially in poorer municipalities) and cross-subsidies between municipalities. Moreover, in Brazil, the Supreme Court decided in 2013 that services of common interest (such as Wat&San services) should be managed by both the state and local governments within metropolitan areas. This represents a recognition of the need for regional cooperation in the management of Wat&San services, due to shared benefits and externalities. However, this ruling fails to address the reliance of Wat&San services on distant water resources and the externalities transferred beyond the metropolis.

Even with regional planning, utilities cannot control local factors such as land use and land tenure, which often restrict the areas where they can provide Wat&San services. Utilities face great obstacles to expanding drinking water provision and sewage collection services to informal settlements, and the consequences are felt at a regional level (e.g. leaks from clandestine connections, sewage discharge into local streams and reservoirs). This was even more problematic in Protected Areas, but environmental actors rarely collaborated with utilities and local governments to find common ground. Overcoming this requires inter-sectoral coordination, sometimes between government agencies at different levels.

Furthermore, **water tariffs can be a tool for facilitating more equal access to Wat&San services at a regional level.** Affordable tariffs in metropolitan regions are crucial to ensure social inclusion, but still need to enable cost-recovery on average – where some consumers pay more to compensate for the lower costs to others – and reflect regional water availability. Cross-subsidies across São Paulo State enable SABESP to apply the same tariffs (including subsidized rates) to all its consumers. In the MVMC, tariffs are highly subsidized for all consumers, despite water shortages, which leads to irrational water use and transfers costs to future generation and donor basins, as well as to taxpayers nation-wide. The poorest did not benefit as they live in informal settlements and spend much more buying water from water trucks. The spatial scale for designing water tariffs therefore involves a solidarity component that considers who benefits and who pays within the utility's jurisdiction but also beyond it. The adequate scale for water tariffs also has a water availability component (i.e. how is water consumption affected, where is water taken from, at what cost). People and water resources beyond a utility's jurisdiction are often affected by its water tariffs but not considered in their design. The presence of an independent regulator at regional or higher level was therefore found to be crucial for sustainable and inclusive tariffs (see 9.7.3).

10.2.5 Linking water management, ecosystem services and land use/spatial planning

A great challenge is the **disconnect between both UWM and IWRM/IRBM and land use and spatial planning**. While WRM responsibilities are at basin, state and national levels, the mandates for land use and spatial planning are mainly at municipal level, despite some attempts at regional planning. However, the effectiveness of WRM instruments is determined significantly by local factors. In particular, land use and building regulations and commercial or industrial developments – generally overseen at local levels – drive increases in water demand. Corruption, clientelism and weak human and financial capacity at local level facilitate unsustainable economic activities and irregular urbanization, including into Protected Areas. Harm to ecosystem services is directly linked to such land use changes, yet there is no regional planning that adequately addresses it. Strategic Environmental Assessments are not conducted at river basin or aquifer scale, even when impacts on water resources were significant. Some respondents argued for the creation of a regional planning body with actual influence over land use and zoning.

Both the MVMC and MRSP have Protected Areas that are crucial for producing ecosystem services and protecting nature's contributions. For municipalities (or districts in the case of Mexico City) that have a significant part of their territory under such status, this represents significant restrictions on their urbanization potential, economic development and tax revenue. **The metropolis (usually) relies on peri-urban or rural municipalities to monitor and prevent irregular occupations and preserve vital ecosystem services – even when these municipalities lack financial and administrative resources and economic incentives to do so.** Measures that acknowledge the dependency of the metropolis on ecosystem services from its rural hinterlands and align incentives (e.g. laws and zoning regulations, PES programmes) are limited, unenforced or absent.

Land ownership further complicates land use and spatial planning. In Mexico, most land is privately owned, making government interventions very difficult. The land of indigenous communities and communal landowners is established and protected by the National Agrarian Law, requiring municipalities to deal with federal institutions for any land and water-related matters in these areas. Moreover, many residents of metropolitan municipalities work in the urban core, consuming water, producing waste and wastewater, and being exposed to flood risks. Despite this, they have no influence on decisions relating to these challenges and do not pay for the costs they create, as they live and vote in the neighbouring municipalities (and even neighbouring states in the case of the MVMC).

10.3 IMPLICATIONS FOR METROPOLITAN SYSTEMS IN FEDERAL STATES AROUND THE WORLD

Urbanization in Mexico and Brazil is expected to continue in the next decades but at a much slower rate than experienced during the second half of the 20th century. Other countries, especially in Asia and Africa are still in earlier stages of this radical transformation of their societies, and many of their cities are expected to mushroom in the coming decades. For those in federal states, in particular, the cases of Mexico City and São Paulo can provide a number of lessons for addressing metropolitan water challenges. The particularities of metropolitan regions in federal regimes have implications for the provision of urban water services, for water resources management, the link between the two and the role of land use management.

10.3.1 METROPOLITAN AREAS IN FEDERAL STATES

Metropolitan 'government' is usually not an option

Federal regimes have more than one level of government, each with specific responsibilities defined within the Constitution. Arrangements at intermediary levels (e.g. metropolitan, basin) generally cannot have administrations with executive power. Unitary states can more easily redefine territorial boundaries for different purposes (e.g. creation of Grand Paris as a metropolitan area). Therefore, metropolitan regions in federal states usually cannot form a metropolitan government with powers that compete with or exceed those of other levels of governments.

The Federal Constitution of both Mexico and Brazil define metropolitan regions and highlight the importance of regional action on issues of common interest. In 2013, the Supreme

Court in Brazil stated that, in metropolitan regions, the state government and municipalities concerned must jointly address functions of common interest. In Mexico City, a Law for Metropolitan Coordination aims to establish guidelines for a metropolitan planning strategy. In both cases, these efforts are met with resistance by those who see it as a threat to the federalist regime or to the decentralization of power to municipalities, which followed democratization.

Metropolitan water challenges are better addressed at different spatial scales and through different levels of government or non-state actors depending on the nature of the challenge (e.g. bulk water at multi-basin scale). Metropolitan entities are therefore not necessarily an adequate response, and metropolitan regions can better address water-related challenges through a range of arrangements across multiple scales.

Multi-scalar water governance in metropolitan regions

The Constitution in a federalist regime determines to a large extent the balance of power between levels of government. In Mexico more power is concentrated at central level, whereas states have significant power in Brazil and many responsibilities have been decentralized to the municipal level. This contributes to shaping water governance regimes in metropolitan regions and determining the levels at which policy instruments are designed. The types of jurisdictions included within a metropolitan region also play a role. As the MVMC includes multiple states, the national government is involved, controlling major infrastructure that crosses state borders and supplies several states. In addition, through inter-basin transfers both metropolises include multiple states and therefore also the federal government. The complexity of their water governance regimes is therefore much greater than the jurisdictional composition of the metropolitan regions themselves.

To address metropolitan water challenges, it is essential that the Federal government and Constitution define the 'metropolitan region', its boundaries and expectations regarding what functions can be carried out at that territorial scale and by whom. Nevertheless, the metropolitan region is not necessarily the ideal spatial scale to address all metropolitan water-related challenges. Depending on the nature of these challenges, different spatial scales may be relevant for designing policies and policy instruments.

10.3.2 Implications for Urban Water Management

Water services are often considered of local interest and carried out by local actors. The research shows that while some challenges and solutions within metropolitan water governance are local, many are shared, as externalities spread beyond jurisdictions. Three factors suggest that (partially) managing UWM functions at a higher level in metropolitan regions can promote more inclusive and sustainable development:

- First, many metropolitan regions have severe inequalities, including in access to adequate drinking water. Peri-urban municipalities tend to have less capacity for providing these services independently, and their form of urbanization may make it more costly (and therefore less attractive) to utilities. Fragmented service provision is also linked to clientelism at local levels. If managed at a larger spatial scale, Wat&San services can benefit from cross-subsidies that allow for more affordable water tariffs and enable provision in marginalized areas.

- Second, metropolitan regions tend to be densely urbanized and share water resources used in water provision. There can be potential gains from combining financial and human resources from multiple municipalities and scaling up the provision of certain services (e.g. shared water and wastewater treatment plants). Coordinating water supply also enables municipalities with insufficient water resources within their borders to respond to local water demand. As water resources are often imported from beyond metropolitan boundaries, managing at least certain aspects of Wat&San services (e.g. regulation, housing) at a higher level can better address potential externalities.
- Third, surface water runoff is not restricted by administrative boundaries within metropolitan regions. Actions in one municipality may aggravate flood-related risks in a neighbouring jurisdiction. Implementing basin principles and harmonizing local stormwater plans involve a certain amount of coordination at higher levels.

The autonomy of local governments, as well as competition and tensions between them, can hinder the formation of this type of collaboration. For example, the fact that **opposing political parties control the State and Municipal governments in the MRSP is a hurdle to integrate Wat&San policies in the area.** Scaling up services is also often associated with centralized, top-down decision-making. Arrangements where metropolitan municipalities must share responsibilities with the State government, as was pushed by the Supreme Court in Brazil, can allow for a balance between local autonomy and regional interest. The State (through a regulatory agency, for instance) can define criteria for municipal Wat&San plans and verify their compatibility and overall coherence at regional level. Instruments such as cross-subsidies and redistributive policies benefit from economies of scale and can reduce inequalities across the metropolis (and beyond, depending on the reach of the provider). Meanwhile, many actions can be decentralized and may be more effective at local level, such as billing, pipe repairs, monitoring of small-scale stormwater and flood infrastructure, or flood evacuation strategies. The Subsidiarity Principle supports governance at the lowest adequate level, but in large metropolitan areas the adequate level for certain water governance functions may not be the local level.

10.3.3 Implications for Water Resources Management

In federal regimes, authority over water resources is generally shared (to different degrees) between central and state governments. Local governments may be responsible for streams, small rivers and other water bodies contained within their borders. WRM therefore requires vertical coordination between government agencies at different levels. It also involves horizontal coordination between states, and between municipalities. Furthermore, where IWRM has been adopted, river basin organizations (RBOs) must also navigate this complex web of interactions. RBOs have been relatively successful in Brazil, but, in both cases, they have struggled to counter the weight of state institutions as they lack executive power. In metropolitan regions, WRM can therefore involve the three levels of government, the basin level and the metropolitan level. In fact, this research highlighted that metropolitan regions often involve multiple river basins and sometimes more than one state through the supply of bulk water and, in some cases, the discharge of contaminated waters.

Metropolitan regions often have large-scale water infrastructure managed by the state or central government. If water bodies belong to the state or federal domain, the involvement of higher levels of government is inevitable. To include the interests of communities and protect ecosystems in donor basins, it is crucial to involve all jurisdictions concerned with the transfer of water resources and the discharge of wastewater and stormwater management within and beyond the metropolitan area. Mechanisms are key, however, to ensure accountability and transparency, as higher levels of government may have interests and favour certain jurisdictions, both within the metropolitan regions and in relation to its rural hinterlands.

For sustainable and inclusive water governance, actors in a metropolitan region must assess which water resources and respective ecosystems are used, affected or implicated one way or another. Metropolitan regions can then develop plans and instruments that consider these interdependencies and the spatial scale(s) for their design. For instance, returning funds from water use fees to the basins (or even sub-basins) where they originated from strengthens the ties between the metropolis and basin(s) it relies on. A sense of a shared regional identity with awareness about the importance of surrounding ecosystems for the metropolis can help increase public pressure for regionally coordinated action.

Due to the interconnections between metropolitan regions and water systems beyond their borders, utilities and other UWM actors should be involved in WRM and held accountable if the aim is to achieve sustainable and inclusive development. While water for human consumption is a priority within WRM, mechanisms can ensure that utilities strive for efficient water use. Flat rates, impunity for consumers who lack metres and highly subsidized water tariffs encourage excessive use. As the case studies in this thesis demonstrates, this may ultimately hurt the poorest within the metropolis and in its rural hinterlands, who remain excluded from formal services and pay much higher prices. Involving a regulator or third party that can link the services to their water resources would facilitate relational and social inclusiveness.

10.4 UNDERSTANDING AND OVERCOMING SCALAR MISMATCHES IN METROPOLITAN WATER GOVERNANCE

Addressing scalar mismatches in metropolitan water governance is necessary, although not sufficient, in order to increase sustainable and inclusive development. This research concluded that considering five key elements in institutional and policy design can enhance policy effectiveness.

10.4.1 Defining metropolitan water governance

Due to their concentration of people and economic activities, metropolitan regions have a water footprint and impact on people and ecosystems that expands far beyond their own borders. Identifying the demands and impacts of the metropolis locally and on the surrounding (or relatively distant) rural hinterlands may foster a shared conceptualization of the metropolis and its interlinkages with water systems. The concepts of 'metropolitan water' and 'metropolitan water challenges' are not static, but rather moving targets, as cities continue to expand and increase their demands and impacts. Over time, institutional frameworks and instruments can become irrelevant or ineffective. This is the case of water allocation quotas for Mexico City and Mexico State based on the MVMC's characteristics in the 1970s (see 7.4.1). In addition, 'metropolitan water' can involve different spatial scales, and therefore different stakeholders, institutions and policy instruments, according to which challenges are addressed. Both IWRM/IRBM and UWM embrace the principle of subsidiarity, albeit to different spatial scales (i.e. basin and municipal) and bringing these actors together within a metropolitan water governance framework therefore enhances complexity. These different IWRM/IRBM and UWM actors have different approaches to water related challenges and their policy responses, different types of knowledge and unequal power. This complexity is further enhanced by party politics across the metropolis and its rural hinterlands and between levels of government. Reluctance or inability to act at different levels can lead to problems of 'fit' between legal and policy frameworks for cities and basins. The experience of RBOs, for instance, has demonstrated that municipal representatives typically maintain localist stances and require incentives to act towards the interest of the river basin. In metropolitan regions, this is further complicated by the tensions between regional interest and political-administrative fragmentation. In this complex scenario, there are no one-size-fits-all solutions.

Metropolitan water governance actors are generally understood as those within the metropolitan region or at higher levels of government that act on the metropolis. However, it also includes actors of neighbouring areas that are interlinked in water governance – for instance, because they influence water resources exported to the metropolis, or shape land use management in areas that produce these water resources.

To address scalar mismatches, metropolitan water governance requires:

- Identifying the relevant spatial scale to address various metropolitan water challenges;
- A sense of a common interest and a shared commitment to its challenges;
- A recognition of the importance of knowledge- and data-sharing at the relevant scale;
- Clear mandates and guidelines for joint action, when this is beyond an actor's traditional attributes. Due to institutional inertia, actors do not easily change behaviour;
- Developing planning mechanisms at the relevant spatial scales (i.e. municipal, metropolitan, macro-metropolitan, (sub-)basin, multi-basin) with synergies between local concerns and interests and those at larger scales, such as ecosystem protection. These plans are not an amalgamation of local plans but are coherent with these while

taking the regional interest as a basis. This can be facilitated by creating a set of common standards at local levels.

Scalar mismatches within metropolitan water governance are reflected within four key elements. First, scalar mismatches concern the water resources that are currently used or impacted in the metropolitan region, or that could be in the future (see 10.4.2). Besides blue water (i.e. surface and groundwater), this also involves green water and grey water. Second, metropolitan water management involves infrastructure at different spatial scales, from small-scale infrastructure catering to the local level, to metropolitan-wide and beyond (see 10.4.3). Even small-scale infrastructure may be interconnected with other infrastructure at a larger scale rather than operate in isolation. It is important to consider these interconnections and how infrastructure in one area may impact another area of the metropolis. Third, it is necessary to connect water resources (of different types) to the ecosystems and ecosystem services that sustain them (see 10.4.4). Often, little is understood about these ecosystems and the crucial role that they play in metropolitan water governance. Finally, although municipalities have clear borders, there is more ambiguity about metropolitan regions' boundaries, especially as they are constantly evolving, and this has implications for how they manage land use and contain sprawl (see 10.4.5).

10.4.2 Considering different types of water

Large metropolitan areas have heavy footprints on different types of water, including blue, green and grey water. Sustainable and inclusive metropolitan water governance must aim to increase efficiency of use of different types of water and to diversify among them.

Blue: Towards multi-basin coordination and conjunctive use

Bulk water supply is based on surface and groundwater resources from within and beyond metropolitan boundaries. Regions exporting (surface or ground) water to the metropolitan region are often side-stepped in decision-making processes, as state and national-level actors make top-down decisions. Inclusive and sustainable bulk water management therefore requires a framework with fair rules and a shared responsibility for water allocation that incorporates the multiple basins and aquifers concerned, and the interests of local stakeholders. In addition, it is necessary to address differences in cost structures and subsidies that lead to water uses inconsistent with overall water resources optimization (e.g. subsidies on inter-basin transfers that make water imports cheaper than more sustainable alternatives) and disincentivize water saving (e.g. utilities' revenue depends on maximizing water sales). Efforts could be made to reduce megacities' impact on other basins through demand management measures. These include: (i) consistent use of water metres (for bulk use and for retail services) that must be installed within a set deadline to avoid a fine; (ii) leakage detection and repair programmes; (iii) incentives for installation or retrofitting of water saving equipment and the use of more efficient irrigation systems in cities' rural hinterlands; and (iv) the use of alternative sources such as recycled wastewater and rainwater harvesting (for non-drinking water purposes, including artificial groundwater infiltration). This last one is particularly important to help "close the loop" sub-basin and basin levels and reduce the spatial scale of bulk water use. This implies strengthening coordination with Wat&San utilities, the industrial sector and rural water users.

Although IWRM/IRBM promotes the integration between surface and groundwater sources, many large metropolitan areas that rely on both do not address these together. Reliable knowledge on groundwater resources (including recharge rates, actual extractions and contamination risks) is limited, preventing adequate planning of groundwater use. Groundwater extraction infrastructure is also often privately owned, as opposed to infrastructure for surface water abstraction, and monitoring groundwater extraction is resource-intensive, which further prevents it from being effectively integrated in a regional strategy. Consistent application of fines for water use infractions – instead of tacit acceptance and impunity – could support more widespread monitoring and enforcement.

Moreover, the boundaries of aquifers and river basins do not necessarily overlap. Aquifers may spread over more than one basin and vice versa. However, IWRM/IRBM promotes river basins as the unit for analysis and management, adding to the uncertainty regarding how to manage groundwater resources. The consequence can be unregulated groundwater use, with conflicts arising once the wells run dry.

Overcoming the mismatch between ground and surface water management requires switching to conjunctive use that integrates all river basins and aquifers used and affected by the metropolitan region. This can increase climate change adaptation, as diversifying water resources will provide reserves during droughts or relieve pressure on over-exploited aquifers (Pincetl *et al.*, 2019). With conjunctive management, an allocation framework can be implemented that sets limits on water use permits to sustainable abstraction levels. In times of heavy precipitation, measures such as green infrastructure and artificial aquifer recharge can store groundwater and complement water reserves in dams (which have drawbacks such as evaporation, sedimentation, and the use of valuable land) (Porse *et al.*, 2015). The effectiveness of this measure depends on aquifers' storage capacity and their potential discharge. In periods of water scarcity, users could trade their surface water permits for groundwater permits. Conjunctive management may require a single institutional framework for both types of resources, with structures at multiple spatial scales.

Grey/black: Switching blue water for grey water

As metropolitan water demand rises and the accessibility of affordable and sustainable blue water decreases, another alternative is to recycle and reuse (the increasing volume of) grey (and sometimes black) water for uses that do not require high water quality. Many industries that require water for industrial processes (e.g. cooling) can use grey water with no effect on the quality of their output. Win-win arrangements are possible if they transfer their (blue) water use permits to users requiring higher-quality water. Public water utilities, for instance, can sell treated wastewater to these industries at a much lower cost than the original bulk water fees they are paying or for free in exchange for their water use permit. A challenge is that blue water and the cost of abstracting and distributing it is often subsidized or even not paid for by the user, which makes a switch to grey water – and its related costs – significantly less attractive. To increase grey water recycling and reuse it is therefore important that blue water is priced adequately and fairly.

Many grey water use measures are small-scale (e.g. grey water in toilets, rebates on water saving technology) and can be implemented in (new) houses, hotels, office buildings, schools and factories; retrofitting is more expensive and may need to be subsidized. They often rely on private initiative but are much more likely to spread if there are incentives or regulatory measures that promote this shift (see 9.7.2).

Green: Towards understanding the links between land use, green water and blue water

As cities expand, agricultural land, forests and other ecosystems are converted into urban land. This impacts blue water (e.g. disappearance of springs) and green water flows (soil moisture). The role of green water, including its links to blue water, is still often misunderstood or ignored by water managers, and it is generally not integrated within IWRM/IRBM strategies in practice. A better understanding of green water could reduce the need for irrigation or increase its efficiency and free up blue water for other uses. It would also highlight the link to land use management and the protection of crucial ecosystems. Although IWRM/IRBM promotes the integration of water and land, water managers typically have no influence on land use management.

10.4.3 Metropolitan water infrastructure

Thinking small (when possible): Incremental shift towards a new approach to water use

To a large extent, the modernist paradigm that promotes society's control of nature through hard engineering and a linear approach to water remains in place. The financial model of water management institutions also often favours a linear approach to water supply. Their revenues are mainly based on water sales and they therefore have a structural disincentive to reduce water supply. Larger, consolidated utilities are more capable of revising revenue strategies. Incentives and regulations could be designed at regional level with a medium to long-term perspective.

Shifting towards a more socially inclusive, ecologically sustainable approach that attempts to 'close the loop' of the urban water cycle is essential. Reducing pressure on donor basins can decrease regional inequalities and environmental stress. This requires the adoption of small-scale (sometimes disruptive) solutions at local level that can be scaled up (e.g. water metres, artificial recharge, reuse of treated wastewater, and rainwater harvesting), that empower local actors and strengthen a multi-scalar water governance approach. However, this is generally thwarted by institutional inertia, path-dependency, transitioning costs and stranded assets, and it is therefore not always realistic in the short-term. An incremental shift that combines large and small-scale infrastructure can allow for slowly phasing out or reducing mega-works that are neither sustainable nor inclusive. Both large and small-scale infrastructure must be integrated in regional planning, as small-scale measures may impact the effectiveness of large-scale measures if they are scaled up. Although some large infrastructure will remain indispensable in established metropolitan regions, there is an opportunity to avoid mistakes in rapidly growing cities, especially in the Global South. In cities of the Global North, there is a window of opportunity with aging infrastructure to switch to a new system.

Avoiding white elephants: Wastewater treatment

The linear approach to wastewater management affects the replenishment of waterways and aquifers within urban areas. Large wastewater treatment plants allow for economies of scale and mean that fewer plants are needed, at least in theory. However, they can also become white elephants, operating far below capacity as sewage from distant neighbourhoods does not reach these plants due to topography, the extensive piping needed and the inability (for practical or legal reasons) to connect informal settlements. Localized sewage treatment can be a solution for certain housing complexes and industries (especially as these are privately financed), but not across the city as they occupy extensive space. However, large metropolitan areas offer sufficient scale for several medium to large-sized treatment plants. It can make sense to distribute these by sub-basin or sub-region within a large city, so that treated wastewater is discharged closer to the source – reducing the length of pipes needed – and recharges local stream flows. With sewage treatment plants spread out across the metropolitan region, opportunities also arise for wastewater recycling and reuse as treatment facilities are located closer to the demand. In addition, it can lead to savings in the transportation of both untreated (plants are closer to wastewater producers) and treated wastewater (plants are closer to potential users of treated wastewater). It also means that treatment involves smaller quantities and can more easily be adjusted to the level of treatment necessary for different uses. In the city it can be reused in industrial processes and large buildings (e.g. toilet water) and in peri-urban/rural areas it can be reused for agricultural irrigation.

Combining local and regional-scale approaches: Adaptation (in particular to flood risks)

As the proportion of urban land in high-frequency flood zones is increasing and climate change is making extreme weather events more frequent and intense, inadequate urban stormwater and flood management will have severe consequences (Güneralp *et al.*, 2015). Adopting measures that allow for redundancy and fast responses increases adaptation to climate-related risks, such as floods and mudslides is critical. This is the case of small-scale measures such as green infrastructure, warning systems, or civil defence departments and community networks, which can be context-relevant and managed locally. Green infrastructure (e.g. parks, bioswales, green roofs) can complement conventional stormwater systems, and provide additional ecosystem services (e.g. aesthetic, climate regulation, water quality regulation).

However, in metropolitan regions, actions in one area can cause or exacerbate flood risks in other areas (e.g. dykes that redirect flood waters to neighbours, erosion upstream causing siltation downstream, regional and global processes such as climate change). Local adaptation measures must therefore be supported by a metropolitan- or basin-scale plan that identifies and addresses externalities and shared risks across the urban space. Such a plan can tailor strategies to different areas of the metropolis. For instance, grey infrastructure is more cost-effective in densely urbanized centres, whereas infiltration is viable in peri-urban areas. Municipal governments or private actors can implement small-scale measures, while larger-scale measures may require involvement from higher levels of government.

Municipalities tend to be reluctant to spend resources for results felt outside their borders but may be encouraged if funds are made available for actions of larger-scale impact identified within a metropolitan or basin plan. Funding could be based on the user-payer or polluter-pays principles (e.g. a risk creator-payer mechanism), where developers that remove vegetation, increase soil-sealing or enhance flood risks in any other way must pay proportional compensation. The use of water fees for basin projects, including flood-related projects, in the case of São Paulo shows that this has potential to mobilize stakeholders around common-interest actions. Adding stormwater charges to the water bills could also be an option, even if only during the rainy season, although this represents an additional financial burden for poorer households. Construction permit approvals can require developers to plan for on-site stormwater retention. In Washington D.C., stormwater retention credit trading enables developers to meet their on-site requirements or buy ‘credits’ for stormwater retention from other developers who voluntarily retrofit their properties through a stormwater credit-trading programme (DOEE, no date; Cardona, 2019). This creates flexibility for developers according to available space and relative cost of foregoing development for stormwater retention, and this can provide incentives for preserving green areas in poorer parts of the metropolis. These credits can only be sold within the (sub-)basin where they are generated. This project is now expanding to other cities, such as Chicago, which is also dealing with stormwater flooding and a lack of financial resources (DOEE, no date; Cardona, 2019).

Without a regional approach, municipalities have no incentives to adopt stricter building and zoning regulations in a unilateral manner, as developers can simply move to the neighbouring municipality. Therefore, regulations pushing for adaptation in urban and housing development must be enforced at metropolitan or regional level.

10.4.4 Sharing and compensating for Ecosystem Services/Nature’s Contributions

Ecosystem services produced within and around metropolitan regions are highly valuable as they support large populations and major economic centres. Ecosystem approaches can be integrated in both water services and risk management and WRM. This can foster a system of sharing and compensating the use of ecosystem services.

Upstream effects

Surface and groundwater bodies that depend on healthy and productive ecosystems sustain water supply to metropolitan regions. The role of these ecosystem services is often misunderstood and undervalued. Even in contexts of (relative) water scarcity, bulk water supply is often wasteful (e.g. heavy water losses, inefficient irrigation practices, high industrial water use for non-essential products). This is linked to the linear approach to WRM that assumes water’s inexhaustibility and ignores ecosystems’ limitations. Even when water allocation systems recognize the discrepancy between supply and demand and impose restrictions, these are rarely associated with environmental preservation measures.

Sustainable bulk water management requires defining the relevant ecosystems' boundaries of all the aquifers and the multiple basins that supply water to the metropolis. Identifying and mapping these areas allows for assigning legal protections and responsibilities to enforce these. Although local actors can enforce these measures, recipients of these ecosystem services (metropolitan water users and others) can fund these through water use fees, compensation mechanisms, Payments for Ecosystem Services and other mechanisms.

In addition, to ensure sustainable water supply, water allocation should not exceed what these systems can provide sustainably. Preserving minimum environmental flows and recharge rates within water allocation regimes is therefore crucial.

Downstream effects

Ecosystems upstream of the metropolis are crucial for metropolitan water provision, but those downstream are negatively affected by untreated wastewater, contaminated stormwater and other diffuse pollution. The spatial scale of this contamination may extend beyond the immediate river basin and stakeholders downstream. Pollution reduction mechanisms such as wastewater discharge fees often fail as they are weakly enforced or because they are cheaper than reducing contamination. Wastewater use discharge fees are often reinvested in wastewater treatment within the metropolis or even in other areas and downstream jurisdictions do not necessarily receive any type of compensation. In some cases, compensation is obtained through courts. Provisions can also be implemented to redirect (part of) the revenue from wastewater discharge fees to affected jurisdictions.

Water and sanitation services

Wat&San providers lack incentives to consider the sustainability management of the water resources they rely on or to address externalities from service provision onto other jurisdictions (e.g. lack of sewage treatment contaminating rivers). This disregard for the value of ecosystem services is reflected in the pricing of Wat&San services, such as highly subsidized tariffs for all consumers. Often subsidized tariffs are given to the poor, but the poorest remain entirely excluded from access. In rural areas this is because their water is taken away, while in urban areas it is because they are in marginalized settlements. Measures that ensure access for all enhance social inclusion, but water tariffs should also relate to water availability and the cost of bulk water supply to consider environmental and economic sustainability. This will incentivize water savings by both consumers and utilities.

10.4.5 Addressing urban sprawl as a regional phenomenon

Land use

Urban growth drives land use and ecosystem changes in the periphery and rural hinterlands. The city exercises significant influence over rural areas, through its economic and political power, to obtain and monopolize water resources and export wastewater downstream. The challenge is that urban policies (i.e. land use, zoning, housing, infrastructure) are disconnected from environmental and water-related policies. As cities expand, farmland and green areas are converted into urban land and farmland respectively. While urban demand for water resources and agricultural products rises, the land available for food production either shrinks or shifts to more distant areas, expanding the spatial scale on which the metropolis depends. This threatens both food and water security for metropolitan areas. In addition, urban expansion is a less conspicuous form of reallocating water from rural to urban areas, as water allocated to agricultural use is then (formally or informally) reconverted into water for urban uses.

Although IWRM/IRBM acknowledges the need to integrate water resources and land, it does not provide concrete tools for spatial planning. These are the mandates of municipalities and states, or even of the federal government, and RBOs do not have any say on land use, zoning, or spatial planning. Land ownership also affects what measures can be implemented to control sprawl (e.g. difficulty from preventing private landowners to sell land to developers). Meanwhile, ineffective water allocation mechanisms can facilitate urban expansion despite (relative) water scarcity if water use permits originally issued for agricultural use are adopted for urban use. At metropolitan or regional level, the policies of one municipality may be incoherent with those of a neighbouring municipality, or even negatively impact them. A regional land use policy is necessary to curb unregulated sprawl, push for densification and offset negative impacts. This is supported by the push for ‘Compact Cities’, promoted by the United Nations’ Habitat III report, with the aim to prevent the spread of suburbs and preserve crucial ecosystem services (United Nations, 2016a).

Environmental protection

Although certain areas valuable for their ecosystem services are protected on paper, this can be difficult to enforce near large urban areas. If land is privately-owned, landowners face an opportunity cost by preserving the area rather than selling it or developing it themselves. Expropriating this land for environmental protection involves significant compensation payments. Very restrictive legislation to protect areas can backfire without constant monitoring (which is also costly) and lead to informal occupations. Local governments are often responsible for land use, including preventing the occupation of protected areas, but municipalities in the periphery – where the pressure on land is highest – generally lack capacity to enforce these measures. As Wat&San companies are often not allowed to provide services in informal settlements, residents install clandestine water connections and discharge their wastewater *in natura*.

Nature-based solutions need greater support, but basing these on a regional strategy rather than exclusively piece-meal initiatives by local governments is more effective. This can involve protecting green belts that provide ESS such as water recharge and water production, and linear parks that cross the metropolis. In addition, compensation mechanisms designed at regional level may reduce the disproportionate burden on municipalities in the periphery that must protect green areas on limited budgets. Although IWRM/IRBM actors have limited influence on land use and spatial planning, they may have indirect influence through other instruments, such as the classification of water bodies (see ANNEX G – ADDITIONAL INSTRUMENTS). By influencing the degree of protection granted to water bodies, RBOs can restrict the type of activities and land uses that can (legally) be developed near them.

Housing

As metropolitan regions expand, the demand for housing leads to the occupation of floodplains and areas of springs and aquifer recharge through both formal processes (i.e. real estate developments) and informal processes (i.e. informal settlements). Besides threatening crucial ecosystems, this often leads to inadequate housing for residents (e.g. exposure to flood risks). Low-density sprawl causes environmental degradation and increases inequality between periphery and core, as low-income residents are increasingly far-removed from employment opportunities. It also impacts water and wastewater infrastructure as pipes must cross greater distances.

In response to these challenges, a regional plan can identify areas adequate for development and aim for densification rather than sprawl. This may involve adjusting zoning regulations and building codes, addressing real estate speculation and regenerating or upgrading inner cities and informal settlements. Where legalization is unlikely to ever happen (e.g. settlements in areas at risk of floods or mudslides or crucial for ecosystem services), relocating residents through inclusive and participatory processes are necessary. Besides reducing the negative impacts from sprawl, densification reduces water consumption (e.g. smaller/no gardens needing watering, fewer appliances) and the unit costs for water utilities. Compact cities can host growing populations while minimizing impacts on the habitats that provides them with ecosystem services.

10.5 THE SUSTAINABLE DEVELOPMENT GOALS: INCLUDING A REGIONAL APPROACH INTO IWRM

The 2015 Sustainable Development Goals (SDGs) are likely to play an important role in shaping future metropolitan water governance regimes. Metropolitan water challenges relate directly to three of the 17 SDGs (see 1.2.2): SDG 6 on water and sanitation, SDG 11 on cities and human settlements and SDG 13 on climate change.[93] Therefore, even if metropolitan water governance regimes do not explicitly adopt sustainable and inclusive development as a normative framework, shifts in related policy areas may influence how actors and institutions

93 And indirectly to many more (e.g. SDG 15 ‘Life on Land’, SDG 10 ‘Reduce Inequality’).

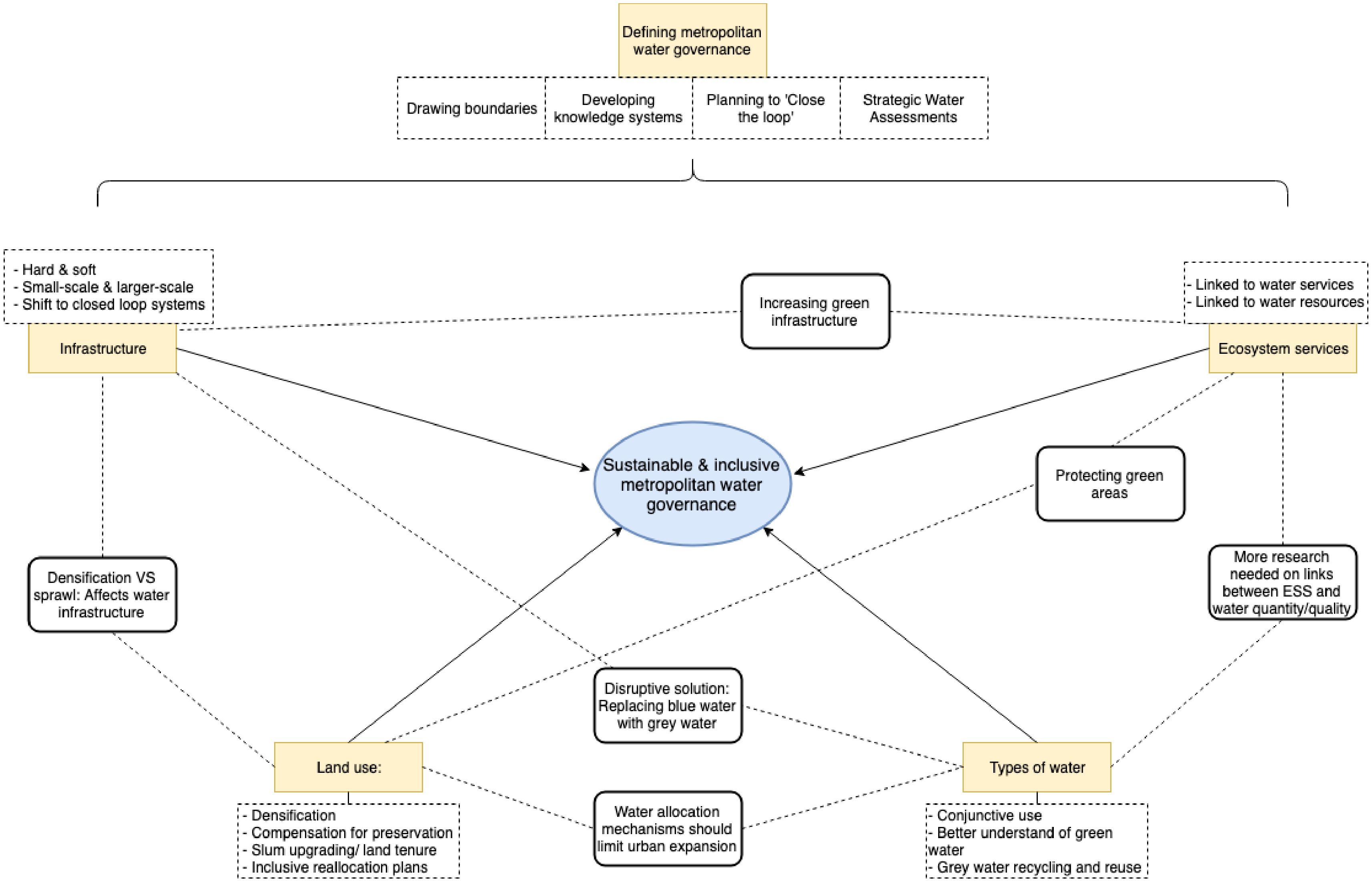
respond to metropolitan water challenges. This study's aim in relation to policy was to consider how interlinkages between SDGs impact these challenges and how synergies can be harnessed for win-win strategies.

Metropolitan water governance requires a multi-level approach with coordination across levels of government, but this thesis emphasized the need for regional spatial planning. Many of the challenges concern land use changes (i.e. urbanization, agriculture) and involve multiple municipalities, as well as trade-offs and externalities between municipalities within the metropolitan region or between the urban and rural areas. It is essential that the spatial scale of implementation and effects of instruments are coherent with the scale of the issues they address. Otherwise, the costs (economic, social, environmental or relational) are likely exported elsewhere. A regional approach for addressing metropolitan water challenges should involve the following steps:

- *Drawing boundaries*: Defining the urban area; Identifying at least the blue, grey and black water systems that are used or impacted by the urban area; Delimitating the areas that provide ecosystem services crucial to the city's water systems; Mapping the relevant macro-infrastructure for water management.
- *Developing knowledge systems*: Collecting and sharing urban data across megacities and their rural hinterlands. Data is typically kept within organizations, sectoral silos and municipal or state governments.
- *Elaborating a regional plan* to 'close the loop' of the urban water cycle. Coordinating river basin plans (including groundwater management) with city plans and providing guidelines for local governments. Outlining measures to reduce sprawl, create buffer zones around water bodies to reduce contamination and protect ecosystems, and promote a shift towards decentralized grey and green infrastructure.
- *Developing Strategic Water Assessments* for plans and programmes centred around water and related ecosystems. This could integrate metropolitan water and spatial planning through a focus on the changes necessary within the planning processes.

SDG 6 combines water services and IWRM, which is an important step forward in overcoming mismatches between urban and river basin scales. To support the integration of UWM and IWRM/IRBM, this thesis proposes an additional indicator under 6.5 ("Implement IWRM at all levels") that promotes developing regional water plans for cities with more than one million inhabitants. Such a plan would be based on the four steps above. This regional planning framework for integrating urban and basin concerns in large cities can then be used to design, implement and evaluate policies and policy instruments related to different types of water, infrastructure, ecosystems and urbanization (see Figure ***10.1***). Such an approach recognizes and addresses the multiple spatial scales involved in water-related challenges in metropolitan regions, thereby facilitating more inclusive and sustainable responses.

Figure 10.1 Regional approach for integrating urban and basin concerns



10.6 FINAL REFLECTIONS

This research explored the ways in which spatial scales in policy design play a role within metropolitan water governance and either hinder or support inclusive and sustainable responses to water-related challenges. Over the past decades, the complexity of water resources in major metropolises has been addressed through two main governance approaches – river basin governance and urban water governance. Although these approaches have promoted greater inclusiveness and sustainability, they focus on river basin and urban systems separately, which prevents each governance regime from addressing all relevant drivers and policy effects. This thesis proposes the concept of 'scalar mismatches' and develops the framework of 'metropolitan water governance' to bridge this gap.

By selecting the case studies of Mexico City and São Paulo, two megacities that grew rapidly during the 20th century, I was able to examine what each could learn from the other, but also what lessons could serve cities in the Global South more broadly. As cities multiply and expand in the coming decades, and climate change puts additional stress on urban water systems, governance regimes must carefully consider where they draw boundaries and what as well as who these include. With adequate resources, political will and public support, policy (re)designs in metropolitan water governance can overcome potential 'scalar mismatches' and support sustainable and inclusive development. These new concepts are open to further contributions from researchers and policymakers.

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ANNEXES

ANNEX A – LITERATURE REVIEW

Search term(s)	Period	Fields	Numbers of results
Integrated Water Resources Management	1970-2015	Title – Abstract – Keywords	1275 (271 with quotation marks)
Integrated River Basin Management	1970-2015	Title – Abstract – Keywords	487 (44 with quotation marks)
Integrated Urban Water Management	1970-2015	Title – Abstract – Keywords	349 (23 with quotation marks)
Sustainable Urban Water Management	1970-2015	Title – Abstract – Keywords	314 (17 with quotation marks)
Metropolitan Water Management	1970-2015	Title – Abstract – Keywords	113 (0 with quotation marks)

Source: Generated from ScienceDirect

Annex B – Comprehensive list of policy instruments

	Regulatory	Economic	Infrastructure	Suasive
Water quantity	Water use permits Environmental flow standard (Mexico) Water abstraction restriction zones Transfer of water use permits between users Environmentally protected areas relevant for water resources Classification of water bodies	Water use fees (bulk use) Water tariffs (consumers) Electricity subsidies for irrigation pumping (Mexico) Sanctions for over-abstraction of bulk water Cross-subsidies in water tariffs at state level (Brazil) Metropolitan funds (FUMEFI in Brazil and Fideicomiso 1928 in Mexico)	Rainwater harvesting systems Water-saving technology Inter-connected regional water supply system Water metres Inter-basin transfers Artificial groundwater infiltration	Collection and publication of data on water availability within a basin or aquifer (Mexico) Registry of water use permits (Mexico) Water resources information system (Brazil)
Water quality	Wastewater discharge permits Quality standards for drinking water Quality standards for wastewater treatment Environmentally protected areas relevant for water resources Environmental licensing Classification of water bodies	Pollution fees/fines Payment for Ecosystem Services linked to water resources Financing of protected areas through various funding sources Environmental compensation mechanisms (Brazil)	Water recycling Treatment plants Water filters	Awareness campaign of pollution in the Tietê River (Brazil)
				Flood alert systems

Climate change adaptation	Environmentally protected areas relevant for water resources	Adaptation fund at city level (Mexico)	Basin-wide or regional cooperation on flood management	National climate change assessments
	Classification of water bodies	Adaptation fund at national level (Brazil)	Municipal, regional and national adaptation plans	
	Environmental flow standard (Mexico)	Fund for Natural Disaster Prevention (Mexico)		
	Water abstraction restriction zones (Mexico)	Payment for Ecosystem Services linked to water resources	River basin organizations	National Risk Atlas (Mexico)
		Financing of protected areas through various funding sources	National water resources plan	

ANNEX C – POLICY INSTRUMENTS SELECTED FOR ANALYSIS

Instrument	Selection criteria	Brazil	Mexico
Water use permits	Scope	Allocation of bulk water in and around the metropolis is a source of tension	
	Focus	Main focus on water quantity, but may link to water quality and climate change adaptation	
	Instrument goal	Inclusiveness and sustainability: Ecological → equitable access to/ownership of water resources and ecosystems' protection; Social → Guarantees water for small-scale farmers and preserves ecosystems for people's well-being; Economic → Crucial for industry, agriculture and energy generation; Relational → Criteria for granting permits that prevents power imbalances	
	Type of instrument	Regulatory instrument	
	Levels of implementation	State or federal level	
Bulk water use fees	Scope	(Differentiated) cost of water can lead to tensions between users	
	Focus	Water quantity focus	
	Instrument goal	Inclusiveness and sustainability: Ecological → May incentivize rational use; Economic → Rational use and reinvestment of funds; Relational → A regulated system prevents the richest and most powerful actors to grab all water resources	
	Type of instrument	Economic instrument	
	Levels of implementation	Basin level	Basin or aquifer level through regional organization
Water tariffs	Scope	Differentiated tariffs between and within municipalities and unpaid tariffs lead to tensions	Subsidized rates for public/urban use lead to problems with other users
	Focus	Water quantity focus	Water quantity focus with impacts on water quality
	Instrument goal	Inclusiveness and sustainability: Social → Subsidized tariffs for low-income households and cross-subsidies for state water company; Ecological → Scaled rates aim for rational use; Economic → Some tariffs are too low or not paid; Relational → Low-income and informal settlement residents have lower tariffs, but often sub-par access	

	Type of instrument	Economic instrument	
	Levels of implementation	Municipal or state level	Municipal level
Wastewater discharge permits	Scope	Contamination of water bodies affects communities and ecosystems downstream, causing tensions	
	Focus	Water quality focus	
	Instrument goal	Inclusiveness and sustainability: Ecological → Reduces contamination by discouraging wastewater discharge without treatment; Social → Low-income communities often most affected by contamination (e.g. waterborne diseases); Economic → Preventing contamination is cheaper than fixing it or having to import water from further; Relational → All polluters are held to these standards	
	Type of instrument	Regulatory instrument	
	Levels of implementation	State or federal	Basin or aquifer level through regional organization
Payment for Ecosystem Services	Scope	Preserving ecosystems and water resources for the city has an opportunity cost for landowners and municipalities in the rural hinterlands upstream	
	Focus	Water quality focus, but also relevant for water quantity and climate change adaptation	
	Instrument goal	Inclusiveness and sustainability: Ecological → Incentivizes restoration/maintenance of crucial ecosystems. It also leads to climate regulation and protects habitats for biodiversity; Social → Inclusion of rural communities and compensation for conservation efforts, possibly leading to poverty alleviation; Economic → Loss of economic value in short-term but long-term benefits and cost savings; Relational → Empowers rural landowners	
	Type of instrument	Economic instrument	
	Levels of implementation	Multiple possible levels, but mainly municipal	Federal or state level
Classification of water bodies	Scope	Defines restrictions on activities near water bodies and thus impacts economic development and environmental preservation	
	Focus	Water quality focus	
	Instrument goal	Inclusiveness and sustainability: Ecological → Determines where more restrictive policies can be implemented to preserve water resources; Economic → Restrictions affect economic activities;	

		Relational → All actors must comply to same standards	
	Type of instrument	Regulatory instrument	
	Levels of implementation	State or federal	Federal
Metropolitan-scale water management system (water supply)	Scope	Tensions on water sharing across metropolitan region and between basins	
	Focus	Water quantity focus, but also relevant for climate change adaptation	
	Instrument goal	Inclusiveness and sustainability:	
		Ecological → Rational use and conservation may be included	
		Social → May help overcome relative scarcity that affects marginalized communities	
		Economic → Guarantees supply for various users	
		Relational → Less powerful actors must have equal decision-making power	
	Type of instrument	Coordination instrument	
	Levels of implementation	State level	Federal level
Macro-drainage	Scope	Floods and related issues affect the whole basin and municipalities can aggravate effects downstream	Large volumes of wastewater, low levels of treatment and topography create risks for population and ecosystems. Floods affect all lower lying areas of the metropolis, but especially lower-income neighbourhoods in periphery
	Focus	Climate change adaptation focus	Water quality focus
	Instrument goal	Inclusiveness and sustainability:	
		Ecological → Ecosystem approaches, green infrastructure	
		Social → Marginalized communities should be main target	
		Economic → Cost must be compared to cost of inaction	
		Relational → Less powerful actors must have equal decision-making power	
	Type of instrument	Coordination instrument	
	Levels of implementation	Basin level (but municipal and state levels may also be involved)	Federal and state levels
Climate change	Scope		Climate change risks affect the MVMC as a whole, but poorer areas are more vulnerable

adaptation fund	Focus	Climate change adaptation focus (but also relevant for water quantity and quality)
	Instrument goal	Inclusiveness and sustainability: Ecological → Green areas, water saving, resilience Social → Reduce citizens' vulnerability, increase adaptive capacity and risk awareness. Economic → Economic benefits estimated to slightly outweigh costs in 6-year period Relational → Inclusive decision making
	Type of instrument	Economic instrument
	Levels of implementation	Federal District level

ANNEX D – INTERVIEW LIST

Code	Type	Level	Professional background	Country
Interview-M1	Government agency for environment and climate change	National	Climate change adaptation	Mexico
Interview-M2		National	Water management	Mexico
Interview-M3		National	Water management	Mexico
Interview-M4	National water agency	National	Water services policy	Mexico
Interview-M5		National	Water management/ basin entities	Mexico
Interview-M6		National	Hydrologist	Mexico
Interview-M7		National	Hydrologist	Mexico
Interview-M8		National	Executive advisor	Mexico
Interview-M9		National	Former high-level official	Mexico
Interview-M10	National Forestry Agency	National	PES programmes	Mexico
Interview-M11	National housing agency	National	High level officials	Mexico
Interview-M12	National Centre for Disaster Prevention	National	Extreme weather events expert	Mexico
Interview-M13	Basin management entity	Regional	Water supply infrastructure	Mexico
Interview-M14	Mexico City environmental department	Provincial	Climate change adaptation	Mexico
Interview-M15		Provincial	Environmental management, metropolitan planning	Mexico
Interview-M16		Provincial	Climate change adaptation	Mexico
Interview-M17	Mexico City conservation agency	Provincial	Environmental conservation	Mexico
Interview-M18	Mexico City Department of urban and land development	Provincial	Human right to water, urban water	Mexico
Interview-M19	Mexico City water and sanitation	Provincial	High level official	Mexico
Interview-M20	Mexico City government	Provincial	Metropolitan planning	Mexico
Interview-M21	Environmental regulator	Provincial	Environmental law	Mexico
Interview-M22	Environmental regulator	Provincial	Environmental law	Mexico
Interview-M23	CSO	Local	Political activist / Local leader	Mexico

Interview-M24	District level hydraulic department	Local	Hydraulic engineer	Mexico
Interview-M25	District level hydraulic department	Local	Geophysical engineer	Mexico
Interview-M26	District level urban development department	Local	Urban planner	Mexico
Interview-M27	Local water and sanitation utility	Local	Hydraulic engineer	Mexico
Interview-M28	University/ Research institute		Water governance	Mexico
Interview-M29	University		Ecosystem management	Mexico
Interview-M30	University		Ecosystem management	Mexico
Interview-M31	University		Basin management, agronomist	Mexico
Interview-M32	University		Hydrogeologist	Mexico
Interview-M33	University		Political scientist / water policy	Mexico
Interview-M34	University		Climate change adaptation	Mexico
Interview-M35	University		Water justice / climate change adaptation	Mexico
Interview-M36	University		Human right to water	Mexico
Interview-M37	University		Urban and environmental management	Mexico
Interview-M38	University		Water governance / social justice	Mexico
Interview-M39	University		Water management	Mexico
Interview-M40	University		Wastewater management	Mexico
Interview-M41	Private sector		Engineer	Mexico
Interview-M42	Private sector		Entrepreneur	Mexico
Interview-M43	Private sector		Commercial	Mexico
Interview-M44	Private sector		Commercial	Mexico
Interview-M45	International NGO		Soil and water conservation	Mexico
Interview-M46	International NGO		Environmental and urban policy	Mexico
Interview-M47	International - NGO		Environmental and social policy	Mexico
Interview-M48	International NGO		Environmental conservation	Mexico
Interview-M49	National - NGO		Executive / hydraulic engineering	Mexico
Interview-M50	NGO		Conservation biologist	Mexico

Interview-M51	NGO		Economist	Mexico
Interview-M52	NGO		Basin management / activist	Mexico
Interview-M53	NGO		Water as a human right activist	Mexico
Interview-M54	NGO		Environmental policy	Mexico
Interview-M55	National - NGO		Basin conservation / Forest conservation	Mexico
Interview-M56	NGO		Engineer / water saving technology	Mexico
Interview-M57	Independent		Climate change adaptation / urban water	Mexico
Interview-M58	Independent		Engineering / water policy	Mexico
Interview-M59	Independent		Drinking water access activist	Mexico
Interview-M60	Independent		Drinking water access activist	Mexico
Interview-B1	National Water Agency	National	Water resources management / financial instruments	Brazil
Interview-B2	SABESP	State	Urban water and ecosystem conservation	Brazil
Interview-B3		State	Former high-level official of Tietê River Project	Brazil
Interview-B4		State	High level official	Brazil
Interview-B5		State	High level official	Brazil
Interview-B6	State Secretariat for Sanitation and Water Resources	State	Coordinator, bulk water supply / Representative in basin committee	Brazil
Interview-B7	State Environmental Department	State	Environmental Planning / Involved in basin committee	Brazil
Interview-B8	CETESB	State	Climate change division, Adaptation and vulnerability officer	Brazil
Interview-B9		State	Climate change Division, Mitigation officer	Brazil
Interview-B10	State Environmental Agency	State	Environmental management of metropolitan areas / Representative in basin committee	Brazil
Interview-B11	State Regulatory Agency for Water and Sanitation	State	Regulation specialist, Water and Sanitation Directorate	Brazil
Interview-B12		State	Regulation specialist, Water and Sanitation Directorate	Brazil
Interview-B13		State	Regulation specialist, Economic-financial Directorate	Brazil

Interview-B14	State Agency for forest conservation	State	Manager of conservation units in the MRSP	Brazil
Interview-B15	State Housing Agency	State	Architect / Representative in basin committee	Brazil
Interview-B16	Research institute (state-affiliated)	State	Researcher, hydrogeologist	Brazil
Interview-B17		State	Researcher on erosion, flood risks	Brazil
Interview-B18		State	Technical agent of FEHIDRO	Brazil
Interview-B19	EMAE	State / metropolitan	Environmental department / Representative in basin committee	Brazil
Interview-B20	Basin Agency	Basin	High level official	Brazil
Interview-B21	Municipal environmental department	Municipal	Official of environmental department	Brazil
Interview-B22	Municipal water and sanitation company	Municipal	Director of the Department of Planning and Projects	Brazil
Interview-B23		Municipal	Commercial / manager	Brazil
Interview-B24	Municipal department	Municipal	Drainage specialist	Brazil
Interview-B25	International - NGO		National Water Manager/ water activist	Brazil
Interview-B26	International - NGO		Activist, climate and energy	Brazil
Interview-B27	International - NGO		Water activist	Brazil
Interview-B28	NGO		Water services / Communications	Brazil
Interview-B29	NGO		Researcher focusing on water	Brazil
Interview-B30	NGO focused on river rehabilitation		Geographer, water and urban policy, public administration	Brazil
Interview-B31	NGO		Water quality and conservation, coordinator	Brazil
Interview-B32	NGO		Water resources and water services, urban environmental management	Brazil
Interview-B33	University		Water governance	Brazil
Interview-B34	Consultancy		Water services consultant	Brazil
Interview-B35	Lobby group		Industrial water policy	Brazil
Interview-B36	Water and sanitation workers union		Sanitation advisor	Brazil
Interview-B37	Low-income housing construction company		New real estate developments analyst	Brazil
Interview-B38	University		Spatial planning, environmental governance	Brazil

ANNEX E - MAIN ACTORS IN SÃO PAULO'S METROPOLITAN WATER GOVERNANCE

Scale level	Actor	Responsibilities
Global	World Bank	Grants loans and provides for projects and infrastructure in the water and sanitation sector.
	Inter-American Development Bank	Provides technical and financial assistance in the water and sanitation sector.
National	National Water Agency (ANA)	Regulates and issues permits for the use of national water resources.
		Carries out scientific studies and establishes an Information System.
		Acts as a conflict mediator (increased demand for water for diverse uses has increased conflicts (ANA n.d.).
	National Council on Water Resources (CNRH)	Highest organ of the SINGRH, and by nature normative, deliberative and participatory.
		Promotes the integration of the national and state government, users and civil society stakeholders in water management. However, it overwhelmingly represents government interests.
		Elaborates the National Water Resources Plan and deliberated on major issues and disputes.
		Determines the creation of river basin committees for rivers pertaining to the Federal Union
	Ministry of the Environment (MMA)	Promotes the integration of sustainable development in public policies, in a participatory and democratic manner at all levels of government and society.
		The Ministry of Environment coordinates policies related to fresh water, river basins (e.g. river revitalization programmes), aquatic biodiversity, water resources and coastal zones and oceans (OECD, 2015c, 64). It formulates policies in relation to climate change adaptation and the national policy on climate change (OECD, 2015c).
	Ministry of Cities	Develops urban development policy and coordinates with other government bodies on environmental sanitation (including water and sanitation).
	The River Basin Committees for rivers of federal domain (CBHs)	Approve the basin plan, arbitrate conflicts over water use, establish the values of bulk water use fees and more. They count on the participation of representatives of the States, municipalities, users, civil society and the Federal government.
Sub-national	DAEE	Manages water resources at state level. Grants water permits. Controls water use. Analyses proposed projects. Provides technical and administrative support to the CBHs.
	CETESB	Manages environmental concerns at state level. Issues environmental permits. Monitors pollution. Analyses proposed projects. Provides technical and administrative support to the CBHs.
	Basic Sanitation Company of São Paulo State (SABESP)	Responsible for water supply, and sewage collection and treatment in many municipalities of São Paulo State.

	State Council on Water Resources (CRH)	Multi-stakeholder council that oversees and regulates IWRM in the state (i.e. Discusses and approves laws related to the State Water Resources Plan, mediates conflicts between CBHs, classifies water bodies, etc). It is composed of 33 members, with equal representation from the state, municipalities and civil society (FABHAT, 2016).
	Secretary of Energy, Water Resources and Sanitation (SERH)	Formulates and implements the state policies on water resources and sanitation and integrates these with the state policies on the environment, health, urban development and more. DAEE and SABESP are subordinated to SERH.
	State Environmental Secretariat (SMA)	Establishes the State Environment Policy. The CETESB is subordinated to the SMA.
Basin	River basin committees	Approve and update Water Resource Plans. Deliberate on water-related decisions within the basin. Reduce conflicts among stakeholders. Define water bulk prices. The committee's creation is preceded by the elaboration of a basin Status Report that diagnoses its main challenges. The Alto Tietê basin committee is composed of state, municipal and organized Civil Society representatives, each with 18 seats[94]. As there are 36 municipalities in the basin, there is a representative and a substitute of each sector for each municipality. Representatives are elected, and each municipality is either directly represented or through a substitute, except the municipality of São Paulo, which always has a seat (Brandeler, 2013). The civil society bloc is composed of broad interests (e.g. industry and environmental preservation). The executive board is composed of a president, a vice-president and an executive secretary[95]. Meetings occur monthly and are open to the public, although the population is mostly unaware of the committees' existence (Interview-B31).
Metropolitan	Metropolitan regions	Regional units instituted by the States, formed by the grouping of neighbouring municipalities for integrating the organization, the planning and the implementation of "public functions of common interest" (Casa Civil, 2015). São Paulo State's definition of 'metropolitan region' is "a grouping of neighbouring municipalities of national prominence, due to high population density, significant conurbation, highly diverse urban and regional functions, socio-economic specialization and integration, requiring permanent integrated planning and joint action by the involved public entities" (State, 1994).

94 Civil society representatives embody organizations such as NGOs, user associations, neighbourhood associations, and business or industry associations. While SABESP is 51% state-owned, it represents the State's interests in the committee and not that of consumers (i.e. civil society) (Interview B35).

95 The president is always a mayor, the vice-president is a Civil Society representative and the executive secretary is a State representative (from the DAEE or the CETESB). State representatives are technical experts and their leadership position in the execution of the committee's activities is based on the premise that they have more technical knowledge (Alvim, 2006, p. 163).

	EMAE (Metropolitan Company for Water and Hydropower)	Produces hydropower for the metropolitan region, through reservoirs and major engineering works that involved rectifying and reversing the Pinheiros River.
	EMPLASA (Metropolitan Planning Company of the State of São Paulo)	It is bound to the State Secretariat for Metropolitan Development. Formulates policies at the macro-metropolitan level on land occupation issues and compatibility with the region's sustainable development. EMPLASA aims to integrate sectoral, spatial and institutional projects and actions, and is focused on issues of mobility and logistics, environmental sanitation and housing. It has developed metropolitan plans for housing and urban development in the past, but they are not enforced (Interview B15).
Municipal	Municipal governments	Responsible for land use and soil occupation, water services, urban drainage, civil defence, micro-basins and areas of springs in their territory, and local environmental issues. The municipality of São Paulo's department of Works, which is responsible for drainage and flood control within the municipality, has the Emergency Management Centre that focuses on flood forecasts and triggers different alert levels. This centre is in close communication with the Civil Defence (Interview B24).

Source: Author

ANNEX F - MAIN ACTORS IN MEXICO CITY'S METROPOLITAN GOVERNANCE

Scale levels	Actors	Responsibilities
Global level	United Nations	Promoting global norms, standards and targets (Human right to water, MDGs targets for water and sanitation)
	World Bank and other IFIs	Providing financing to the water sector
National level	Federal government	Regulating the use of water resources Contributing to the financing of investments
	SEMARNAT	Establishes official norms in relation to water management Supervises enforcement of norms
	CONAGUA	Responsible for water resources management in Mexico, including: Granting of water abstraction and wastewater discharge permits Supplying bulk water to the Federal District and to parts of Mexico state through the Cutzamala and Lerma systems Water policy, planning, irrigation and drainage development, water supply and sanitation, and emergency and disaster management (with an emphasis on flooding).
	Inter-ministerial Commission on Climate Change (CICC)	Supporting collaboration among federal and regional agencies, minimizing conflicts among sectors, and maximizing the benefits of synergies for the integration of a climate change policy.
	SINAPROC (National Civil Protection Service System)	Informing authorities and society of imminent extreme events and risks, well as carrying out prevention signals, early warnings, evacuation procedures, providing provisional dwellings for affected people, damage control measures, thoroughly surveying damages and possible solutions for affected areas and helping the re-establishment of former living conditions (CONAGUA, 2011).
	CENAPRED (National Disaster Prevention Centre)	Develop risk reduction policies and coordinate information and warning systems.
State level / Federal District level	SACMEX	Providing residents of the Federal District with drinking water, drainage and sewerage services, as well as the treatment and reuse of wastewater, in adequate quantity and quality Operating, maintaining and building water infrastructure
	Mexico State Government	Planning, regulating and developing infrastructure for water resources Providing bulk water Treating wastewater Assisting municipalities in providing water and sanitation services

	Mexico State Water Commission	Buying bulk water from CONAGUA, transmitting it through its own bulk water infrastructure and selling it on to 57 municipalities (4.1million inhabitants) Monitoring water quality Providing technical assistance to municipalities in water disinfection and sewer cleaning Operating wastewater pumping stations and five wastewater treatment plants, emptying septic tanks Providing water in tankers in emergency situations Providing training and assisting municipalities in the establishment of municipal utilities
Basin level	Basin agencies (decentralized office of CONAGUA)	Formulating regional policy Designing programmes to implement such policies Conducting studies to estimate the value of the financial resources generated within their boundaries (water user fees and service fees) Recommending specific rates for water user fees and collecting them.
	Basin councils	Guiding, together with CONAGUA, the Basin Agencies' work. Coordinating government institutions Negotiating with water users and social organizations, with as main objectives the formulation and execution of programmes and actions to improve regional water management, support of hydraulic works development and related services, and preservation river basin resources.
City level	Municipalities	59 municipal governments in Mexico State, one municipality in Hidalgo State and 16 districts in Mexico City are responsible for the provision of drinking water, drainage, wastewater collection, treatment and disposal for their constituents, as well as the management of solid waste and the creation of environmental protection zones.
	Municipal utilities	Municipalities can delegate the provision of water and sanitation services to a municipal utility or to the state water commission.
Other	Irrigation districts	In Hidalgo state these oversee irrigation with wastewater from Greater Mexico City.
	NGOs	Focusing on social and environmental issues linked to water (Guardianes de los volcanes; UN Habitat, Isla Urbana, Agua Para Todxs Agua Para la Vida and more)

Source: Author

ANNEX G – ADDITIONAL INSTRUMENTS

CLASSIFICATION OF WATER BODIES IN THE MRSP

Description

According to the State Water Law (no 7.633 of 1991), the State is responsible for the protection of aquatic flora and fauna and of the environment. This involves establishing priority uses for water and classifying water bodies in different categories according to their purpose for water users and the water quality levels required for these (Brazil, 1997). These are then submitted as proposals to the basin committees for discussion and approval (CEDE 2015). The aim is to ensure water quality compatible with the more demanding uses and to lower the costs of combatting water pollution through permanent, preventive actions (Brazil, 1997). There are five categories for surface freshwater resources and six categories for groundwater resources. Each category determines the level of protection by regulating the discharge of effluents and the licenses for activities with environmental impacts (PERH 2017). Water bodies that are deemed important for uses that require clean water or that are still well preserved, are typically classified within a category that involves more restrictions (CEDE, 2015). This instrument links with the granting of water use permits, the charging for bulk water use and environmental licensing (CEDE, 2015). This instrument can be considered a planning tool, as it not only looks at the current state of a water body but at the water quality it requires to respond to society's needs.

Effectiveness on actors in terms of mandated goals

All the waters of São Paulo state have been classified, which is not always the case in other states (CEDE 2015). The main challenges for the effectiveness of this instrument is the lack of adequate monitoring of water bodies and the need to calibrate cost estimates for the adoption of the measures to attend to the classifications (CEDE 2015). Nevertheless, in some basins, particularly those where the charging for the use of water is implemented, there are registration systems and monitoring networks (MMA 2010).

This classification significantly depends on the political will of a state or basin committee, as a more restrictive class means more restrictions on potential activities (CEDE 2015). The focus is on making water bodies meet the standards of their classification, which are sometimes very low, rather than promoting their preservation and restoration for purposes such as supporting aquatic life or improving the quality of life of riverside inhabitants.

Impact on inclusiveness and sustainability

Indirectly, besides a water quality instrument, this also represents a land use control mechanism as it restricts the installation of activities that would affect the quality of the water that a water body should maintain according to its classification (MMA, 2010). As many sources of water contamination are related to land use factors, such as informal urbanization, the implementation of the regulations associated with this instrument has the potential to influence drivers of contamination.

The challenge is that contaminated water bodies often already have a lower classification, and therefore have weak regulations in place. Environmentalists criticize the category 4 class as so weak that it encourages the contamination of water bodies. In addition, the existence of the more permissive categories is at odds with the Law of Environmental Crimes that prohibits “pollution that results in damages to human health or that cause the mortality of animals or the destruction of significant flora” (Federal Law 9.605, 1998). This leads to legal ambiguity “where everyone does what they think is the right interpretation, or the most convenient”. In the Alto-Tietê river basin, rivers in the urbanized areas fall under Class 4, the most permissive category, even when they are in still relatively good state, which reduces the incentive to reduce pollution.

Instruments	**Effect on actors**	**Impact**
Classification of water bodies	It has been implemented, although monitoring costs make it difficult to verify compliance.	Ecol: 0 Class 4 leads to tacit acceptance of “dead rivers” and does not encourage improvement. However, classifying rivers allows for differentiated and more realistic standards.

Redesign

This has the potential to influence land use management, as higher classifications restrict polluting activities near the water body in question. This instrument should be integrated with other planning instruments, so that discussions around it may include a broader range of actors, including the community to deliberate on what kind of river they want and what kind of river they can get. Informal settlements where sanitation cannot be installed remains a challenge and the solution must be negotiated with the housing and urban planning sectors, and with municipalities.

Some have argued that the most permissive class should not exist as it informally condemns the water body to remain in its contaminated state. However, eliminating it should be done within a longer-term planning horizon, so that current “polluters” have time to adjust.

Comparison in terms of design

In the case of São Paulo, the granting of a wastewater discharge permit depends on the classification of a certain water body. This classification ranks water bodies and waterways in terms of the level of restrictions and protections they require, and this depends on their condition and the type of use that is made from their water resources. Higher ranked water bodies, which may be well-preserved and used for water supply, therefore face more restrictions. While this protects these water bodies, it does not create incentives to reduce contamination in already polluted water bodies.

In the case of Mexico City, obtaining a wastewater discharge permit is also linked to the classification of the water body in question. The classification determines the water body's capacity to assimilate and dilute contaminants, the levels of contaminants that can be contained in discharged effluents and quality targets to be attained within specific timeframes. It is based on three quality parameters, which ignores other contaminants that can have harmful impacts and international recommendations on the number and types of parameters. Lack of compliance results (in theory) in a fee to be paid and that is (in theory) invested into the improvement of the appropriate infrastructure.

Comparison in terms of effect on actors

The classification of water bodies has meant that clean water bodies, sometimes used for water supply, had a higher ranking and thus level of protection. However, the responsibility to maintain these water bodies at those levels falls largely on local governments, which must enforce zoning laws and control land use around these water bodies. They typically lack the human and financial capacity to fulfil these expectations. Moreover, water bodies that are given low rankings – due to their current state of contamination – are condemned to remain as such, as the classification does not create incentives for improving the ranking. In addition, critics have claimed that water bodies have been downgraded in their classification in order to allow more (polluting) activities near them. In the case of Mexico, although included in the National Water Law, the classification of water bodies had not been implemented everywhere. Overall, the responses were that regulatory measures had not remedied the problem of sewage contamination in the country.

A stricter application of wastewater discharge fees and more restrictive classification of waterways would incentivize polluters to treat their sewage. This requires a basin view, more difficult to achieve with highly fragmented sewage management, and a regional approach to land use and the challenge of informal settlements.

WASTEWATER DISCHARGE PERMITS IN SÃO PAULO

Description

Wastewater discharge permits are the main instrument for water preservation (Brazil, 1997). They allow water users to discharge effluents into water bodies for dilution, transport or final disposal, and hydropower use. Together with water use permits, discharge permits are a prerequisite for obtaining an environmental license and a key step to realizing any activity that can pollute or cause environmental degradation (Brazil, 1981)[96]. Although environmental licenses are granted by the CETESB, wastewater discharge permits are emitted by the DAEE or ANA (depending on whether the water body is of state or federal domain) (Brazil, 1997 Art. 14). CETESB monitors the discharge of effluents at their source by collecting and analysing samples, and by verifying monitoring devices installed for this purpose (Interview-B7). The

96 Licenses are renewed periodically, and measurements are taken to verify compliance (Interview-B10).

DAEE shares its database of water uses and permit-holders with CETESB, which then defines which use needs a license (Interview-B7).

Wastewater discharge permits are granted if the effluents meet qualitative requirements, or if the receiving water body has the necessary flow or volume to dilute the effluents so that it meets these requirements, thereby not compromising the water body's classification (CEDE, 2015). This classification determines different standards for different water bodies according to their current condition and the quality requirements of users that rely on it. Polluting effluents must therefore undergo adequate treatment prior to discharge (Conama, 2005). As with water use permits, a fee is charged for the discharge of effluents.

Effectiveness on actors in terms of mandated goals

Improvements in water quality may be attributed to water discharge permits, but the Tietê Project likely contributed by injecting large investments into SABESP's sanitation programmes. The difficulty of obtaining environmental licenses due to strict regulations may have curtailed the effect of discharge permits (Interview-B5/B37). The intended result (i.e. compliance with high standards and adjustment through stricter wastewater treatment processes) backfired and led to non-compliance (Interview-B5). The CETESB lacked the capacity to monitor potentially polluting activities, and although fines could be applied, in practice there was still a lot of impunity for polluters (Interview-B5). Meanwhile, the State Office of the Public Prosecutor operated in an isolated manner and presented polluters, such as SABESP, with billionaire fines rather than seeking comprehensive plans towards increasing sewage treatment (Interviews-B5/B22/B23).

Moreover, these permits are granted when pollutants can be absorbed without causing the downgrading of the water body's classification, but there are no requirements or incentives in place to improve the effluents' quality further (Interview-B5). This becomes a vicious cycle as polluted rivers are tacitly encouraged to remain so.

The effect of this instrument on industrial pollution is seen more positively than that on domestic sewage, which is partly explained by utilities' lack of financial capacity for their operations: In the largest wastewater treatment plant of the MRSP, "the pumping systems do not work and there are no interceptors, there is no maintenance" (Interview-B7). While the pressure is on sewage treatment plants and industries, diffused pollution from both urban and rural sources is left largely unaddressed.

Impact on inclusiveness and sustainability

Between 1990 and 2014, the length of the pollution slick in the Tietê River shrunk from 380 km to 70 km, although it returned to 130 km after the water crisis, as investments in sanitation were diverted to increase water supply (SOS Mata Atlântica, 2017). In addition, formal housing and commercial developments in areas that required higher levels of protection stopped, but irregular developments multiplied. This is particularly problematic in areas of springs, such as the Guarapiranga dam[97]. By focusing exclusively on quantitative and qualitative impacts on water bodies, the licensing process ignores the factors leading to the pollution (i.e. lack of affordable housing, informal urbanization) (Interview-B5).

There is a disconnect between wastewater discharge permits, which are emitted at state or federal level (depending on the domain of the water body), and sanitation planning, which is a municipal responsibility and does not (necessarily) integrate basin considerations. This leads to tensions between zoning, and the developments sponsored at local level, and the protection of water bodies by basin and state entities. State-level respondents particularly emphasized the municipalities' inability (or unwillingness) to prevent occupations by new informal settlements.

Instruments	**Effect on actors**	**Impact**
Wastewater discharge permit	The lack of enforcement encourages non-compliance. Fines have been applied sporadically and without attempts at remediation. Sewage treatment plants lack resources, and fines will not help.	Ecol: - Discharge of untreated effluents remains high and cause water contamination. Soc: - Marginalized populations are more likely to lack sanitation and live near contaminated water. Econ: -- As local water resources are polluted, water imports become necessary. Costs are transferred from polluters to the State and donor basins. Rel: - Lack of coordination between sectors and levels of government has contributed to informal growth, but permits do not apply in these areas.

Redesign

First, compliance must be addressed. Environmental licenses should only be granted or renewed if it is verified that a wastewater treatment system is accounted for. Although constant monitoring is prohibitively expensive, sporadic inspections to a small number of permit-holders and the application of increasing fines (i.e. first-time offenders vs recidivists) can encourage compliance. Part of the value collected by the permits should also be allocated to monitoring and compliance schemes, creating a possible snowball effect.

To address the main challenge (i.e. informal settlements), it is necessary to increase coordination between local and state actors. Approval of water and wastewater discharge permits should be connected to the municipal master plan and Wat&San plan, and if sewage treatment facilities cannot comply (e.g. large investments still needed, informal settlements that are not connected to the network), they must work with local authorities towards a solution (e.g. regularization and upgrading of areas or relocation, alternative treatment options).

97 Regulations in areas of springs aim to prevent housing densification by requiring a minimum surface area of 250m^2 per housing unit (Interview-B37).

Comparison in terms of design

In Mexico they are obtained together with water use permits. The classification of a water body determines the quality standards that the effluent must meet before discharge so that the water body concerned is deemed capable of assimilating and diluting the contaminants. In theory, a lack of compliance with these standards means that the polluter must pay a fee that is reinvested in the necessary sanitation infrastructure.

In Brazil, wastewater discharge permits are granted if the relevant authority (ANA or DAEE) estimate that the receiving water body has a volume or flow of water sufficient so that the discharge – together with the already existing discharges – do not affect water quality such that it would alter the water body's classification. Wastewater discharge permits are also necessary to obtain environmental licenses (for any type of potentially polluting activity). Similarly to Mexico, discharge permits require effluents to meet qualitative standards according to the classification of the water body.

In both cases, qualitative requirements tend to be stricter in areas further from the city, where water resources are better preserved. This instrument relies significantly on the classification of water bodies, and consequently so does its effectiveness.

Comparison in terms of effect on actors

In both cases, wastewater is still often discharged without treatment, due to a lack of treatment capacity or – more often – a lack of piping infrastructure connecting to a treatment plant. This also concerns "polluters" with wastewater discharge permits and leads authorities to turn a blind eye in many cases. Even when "polluters" could be connected to the wastewater infrastructure, the lack of monitoring did not incentivize them to do so. In the MRSP, utilities that do not treat sewage could face significant fines, and SABESP faced legal woes for its slow progress in sewage management.

Overall, in both cases, industrial users are more likely to comply (as they are easier to monitor and fine). For some, this has contributed to an incentive to treat and recycle wastewater, although this is still a minority.

WASTEWATER DISCHARGE PERMITS IN MEXICO CITY

Design

Wastewater discharge into national waters requires a CONAGUA permit (NWL, 2004). This permit is obtained simultaneously with the water use permit and is also registered in the REPDA. In issuing this permit, CONAGUA considers the capacity of the concerned water body to assimilate and dilute the effluents' contaminants. Depending on the water body's classification, the effluents must meet more or less strict quality standards (CONAGUA, 2015). More specifically, the effluents must comply with a series of indicators concerning water contaminating, the volume of wastewater and the pollutant load of the discharge (CNA-01-

001). CONAGUA may charge fees for lack of compliance investing the money into infrastructure improvement projects.

Effectiveness on actors in terms of mandated goals

Wastewater discharge permits are ineffective due to insufficient enforcement. There was little monitoring, the few discovered infractions rarely led to fines and, when they did, polluters may ask to commute the fine into reinvestments into a poorly monitored water pollution reduction initiative (Interviews-M5/M9/M40/M52/M58).

Most importantly, effective water preservations policies require a shared, long-term vision of the river basin, with consideration of upstream and downstream linkages, communication between municipalities and other stakeholders of the river basin (Interviews-M2/M9). This vision does not exist. For example, although a mega-sewage treatment plant has been built recently, there is no regional policy to prevent water contamination (see 8.4.3).

Impacts on sustainability and inclusiveness

Despite the emphasis on wastewater discharge on paper, in practice the large majority of wastewater effluents are discharged untreated and contaminated water bodies and agricultural fields beyond the VMB, affecting the health of locals and crops (Interview-M4/M9/M40/M50). Diffuse pollution and a lack of adequate solid waste management further degraded water quality and increased flood risks by clogging pipes and drains (Interviews-M5/M19/M50/M46). This was aggravated by informal urbanization as waste management services are not provided in these areas (Interviews-M5/M51).

The lack of domestic wastewater treatment and contamination from industrial activities, as well as soil subsidence – and the subsequent damage to piping – also threatened groundwater quality (Tortajada, 2008; Pina, 2011; Spring, 2015).

Instruments	**Effect on actors**	**Impact**
Wastewater discharge permits	No enforcement and no regional view of water contamination challenges	Env: -- Untreated sewage discharges pose risks to public health and food crops Soc: - Informal settlements are most affected

Redesign See the redesign of water use permits, as similar recommendations are valid.

CLIMATE CHANGE ADAPTATION PLAN AND FUND OF MEXICO CITY

Design

The SEDEMA coordinates a climate change adaptation plan, the Climate Change Action Programme of Mexico City (PACCM). The plan, first introduced in 2008, had a timeframe for 2014-2020. Its main objective was to increase quality of life and sustainable development with low carbon intensity (SEDEMA, 2014). The Environmental Fund for Climate Change (FACC), managed by the SEDEMA, was created in 2015 to implement the plan (Interview-M16). It received contributions from the national and local governments, and from external sources such as international foundations (Interview-M16). The PACCM had three main axes: Mitigation, adaptation and communication/education. The adaptation axis, with a budget of approximately USD$ 160 million, consisted of 12 actions, including actions on sustainable housing, water saving systems, greywater reuse and energy saving systems (Interview-M14). Issues such as food security and water availability in adequate quantity and quality are emerging in discussions but not yet integrated into the plans (Interview-M14).

Effects on actors

Mexico City detailed climate change programme reflected a recognition within the administration of the need to address the climate crisis and its local effects. This was supported by a broader legal framework, including the National Law on Climate Change. However, the plan put much greater emphasis on mitigation than adaptation (Interview-M57). This could be explained by the synergies of mitigation actions with addressing the city's severe air pollution. Nevertheless, the plan adopted ambitious targets for both mitigation and adaptation. Despite the FACC, funding remained limited in comparison to the plan's scope (INECC, 2017).

Although all states and municipalities were supposed to prepare similar plans, many had limited or non-existent plans (OECD, 2013) (Interview-M16)[98]. Despite the shared challenges, adaptation measures were not coordinated with the MVMC's municipalities in Mexico State, beyond the coordination of macro-drainage (Interview-M14). Mexico City's districts were supposed to develop local plans, but differences in resources and political will led to important differences between them (Interview-M15). Some districts still lacked plans (SEDEMA, 2017).

Moreover, there are no clear coordination mechanisms between levels of government to ensure a coherent adaptation policy (Interview-M15). The Federal Climate Change Fund could strengthen institutional capacity for adaptation at state and municipal levels, but funds often remained at federal level (Interview-M15). Ultimately, state and municipal governments designed and implemented separate climate change programmes. The result was fragmented policies due to different budgets and political will, with the further marginalization of peri-urban areas. Political will was low in most jurisdictions as there was little pressure from civil society and government administrations (Interview-M15).

Impacts on sustainability and inclusiveness

There are no clear evaluation measures in place to verify progress on the PACCM. In fact, it may be almost impossible to isolate the effect of the plan and its fund, as they supported many

98 As of early 2015, only 2.84% of municipal governments had a climate action plan (Delgado Ramos *et al.*, 2015).

existing initiatives managed by other actors. This further limited the ability to effectively communicate results to the public (INECC, 2017).

Instruments	Effect on actors	Impact
Climate change adaptation plan and fund	Ambitious targets despite focus on mitigation over adaptation. Disconnect between levels of government and across MVMC hindered coherence	Impacts are difficult to link to the plan, which mainly supported pre-existing initiatives. It raised awareness of the need for adaptation and strengthened capacity in sectoral departments

Redesign

It is necessary to design clearer evaluation methods, that can highlight which actions are effective. As many actions are implemented by sectoral departments or districts, this would require closer communication between entities.

All state had to develop such plans, but in the case of the MVMC this led to fragmented strategies and a loss of potential synergies and economies of scale. Mexico City, Mexico State and Hidalgo State should collaborate on a regional climate change plan (for mitigation and adaptation). This should be compatibilized with their individual plans and should not aim to centralize all efforts. Rather, this could help identify shared challenges and opportunities. This could include a regional approach to conservation and the preservation of ecosystem services that feed the basin's aquifers.

Comparison in terms of design

This plan represents a political recognition of the threat of climate change and a comprehensive strategy to address it in Mexico City. Multiple actions and a sizeable budget are dedicated specifically to adaptation, although mitigation is the plan's main focus. The actions are diverse, including actions related to housing, water saving systems, wastewater reuse, and more. The cost-benefit analysis suggests that water-related measures will bring more benefits than costs. The plan includes attempts to better integrate urban and environmental policies, in particular in the Conservation Land, which is crucial for climate regulation and aquifer recharge. In terms of extreme weather events, it only addressed risks from heavy precipitation (as opposed to droughts, forest fires, and other risks). In addition, while the plan recognizes that vulnerability aggravates risks, it does not specifically attempt to address or reduce drivers of vulnerability.

Another drawback is that, as the plan is developed by the Federal District, it does not include the rest of the metropolitan region. Many of the poorest areas, and those most vulnerable to the effects of climate change, are thereby excluded, and urbanization of the green belt is also an important factor aggravating risks for the entire MVMC. Neighbouring states, such as the State of Mexico, have climate action plans, as the General Law on Climate Change specifies that federal entities must develop their own actions. However, the State of Mexico's plan is focused on general guidelines rather than concrete actions, with timeframes and cost estimates.

	Brazil	Mexico
Wastewater discharge permits	0	0
Classification of water bodies	+	+
Climate change plan and fund		+

Comparison in terms of effect on actors

While all federal entities must design a climate change action plan and fund, according to the Federal Climate Change Law, these have been slow to comply. In the case of the Federal District, there is a climate change mitigation and adaptation Law, which makes the implementation of the Plan and Fund mandatory. The higher level of human and financial capacity may further explain its greater progress. However, an effective climate change adaptation strategy was hindered by several elements. The plan lacked data and information to develop a baseline and specific indicators for adaptation, which led to mainly generic guidelines. The plan significantly depended on international funding, and resources are limited in comparison to the ambition of the plan. Many of the actions are the responsibility of different departments and the plan served more to put these existing actions under one umbrella, which did not give additional support to these existing actions. In addition, the plan only concerned the Federal District, and neighbouring municipalities of the MVMC did not have similar plans. Moreover, there was also no vertical coordination mechanism with the Federal government, to ensure coherence of measures. For some actions, isolated, local actions work well, as each district can focus on those that are most relevant. Addressing issues such as air pollution and water-related risks would benefit from a more regional approach as causes and effects spread across borders.

In the case of the MRSP, there is little official recognition of climate change risks and there is no specific strategy at city, metropolitan or basin levels. Climate change concerns could be incorporated into the basin plan and serve to reinforce existing measures that constitute win-win strategies (e.g. drought or flood prevention measures). Overall, climate change was still a taboo subject and many respondents argued that it is not clear whether the water crisis was linked to climate change or climate variability.

ANNEX H – WATER TARIFFS

- *MRSP: SABESP'S TARIFFS*

Normal residential tariff		**Water**	**Sewage**
0 to 10	Reais/per month	26.18	26.18
11 to 20	Reais/ m3	4.1	4.1
21 to 50	Reais/ m3	10.23	10.23
above 50	Reais/ m3	11.27	11.27

Social tariff		**Water**	**Sewage**
0 to 10	Reais/per month	8.88	8.88
11 to 20	Reais/ m3	1.53	1.53
21 to 30	Reais/ m3	5.43	5.43
31 to 50	Reais/ m3	7.74	7.74
above 50	Reais/ m3	8.55	8.55

Favela tariff		**Water**	**Sewage**
0 to 10	Reais/per month	6.77	6.77
11 to 20	Reais/ m3	0.77	0.77
21 to 30	Reais/ m3	2.56	2.56
31 to 50	Reais/ m3	7.74	7.74
above 50	Reais/ m3	8.55	8.55

Source: (ARSESP, 2019)

- *Mexico City: SACMEX's tariffs*

Normal residential tariff		**Minimum rate**	**Additional fee per m3**
0 to 15	Pesos	497.17	0
<15 to 20	Pesos	497.17	33.15
<20 to 30	Pesos	662.89	33.15
<30 to 40	Pesos	994.31	33.15
<40 to 50	Pesos	1325.76	33.15
<50 to 70	Pesos	1657.19	40.34
<70 to 90	Pesos	2464.18	43.95
<90 to 120	Pesos	3343.23	58.36
< 120	Pesos	5094.06	90.79

Middle residential tariff		**Minimum rate**	**Additional fee per m3**
0 to 15	Pesos	162.13	0
<15 to 20	Pesos	162.13	20.9
<20 to 30	Pesos	266.59	22.87
<30 to 40	Pesos	495.29	27.08
<40 to 50	Pesos	766.02	29.18
<50 to 70	Pesos	1057.76	32.26
<70 to 90	Pesos	1703.07	43.23
<90 to 120	Pesos	2567.67	57.66
< 120	Pesos	4297.36	90.79

Popular residential tariff		**Minimum rate**	**Additional fee per m3**
0 to 15	Pesos	43.23	
<15 to 20	Pesos	43.23	
<20 to 30	Pesos	61.96	
<30 to 40	Pesos	121.3	
<40 to 50	Pesos	242.45	
<50 to 70	Pesos	419.22	
<70 to 90	Pesos	945.85	33.38
<90 to 120	Pesos	1613.4	57.66
< 120	Pesos	3343.1	90.79

High residential tariff		**Minimum rate**	**Additional fee per m3**
0 to 15	Pesos	194.54	0
<15 to 20	Pesos	194.54	21.9
<20 to 30	Pesos	304.01	24.48
<30 to 40	Pesos	548.78	29.06
<40 to 50	Pesos	839.29	31.04
<50 to 70	Pesos	1149.58	33.25
<70 to 90	Pesos	1814.66	43.23
<90 to 120	Pesos	2679.26	57.66
< 120	Pesos	4408.95	90.79

Low residential tariff		**Minimum rate**	**Additional fee per m3**
0 to 15	Pesos	49	0
<15 to 20	Pesos	49	8.36
<20 to 30	Pesos	90.79	11.25
<30 to 40	Pesos	203.28	15.95
<40 to 50	Pesos	362.75	22.38
<50 to 70	Pesos	586.51	28.3
<70 to 90	Pesos	1152.69	34.62
<90 to 120	Pesos	1844.97	57.66
< 120	Pesos	3574.66	90.79

Source: (Mexico City Government, 2018)