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The bigger a city is, the more complex its relationship with the hinterlands that surround it. To obtain the resources that it lacks, a city must either impose its demands upon these hinterlands or negotiate a sharing arrangement with them. Water is a noteworthy example because the invention of water purification added a qualitative dimension to the quantitative issue. Since the Industrial Revolution, three main urban water supply strategies have developed, each relying upon a combination of government, technology and economics. Following a phase where technical solutions – water treatment – dominated, there is now a return to cooperating with rural areas to prevent pollution of upstream drinking-water sources.

**THE CITY RETURNS TO ITS HINTERLANDS FOR NATURAL RESOURCES**

Since Antiquity, empires and kingdoms have sought to supply water to their capitals, and sometimes to other cities, by other means than increasing the number of wells in their own territories. The first example that comes to mind is the Roman aqueducts. They still serve as reminders that the Mediterranean climate, more than that of other areas, required water from distant sources. Similar means were used elsewhere around the world. For example, at the beginning of the first century A.D., China diverted waterways to irrigate plains and to supply centres of government. At the time, this supply was used indiscriminately for agriculture, households (public fountains) and craft-production purposes. These conditions persisted until the nineteenth century, except during the Classical period in Europe, when urban development grew out of a proto-industry based on decomposition and putrefaction of organic matter, such as flax maceration. Neo-Hippocratic physicians then found a new reason to bring water to the city: to wash it clean and flush out the “miasma.”

This could be accomplished either by pumping water from a nearby river, or by building new aqueducts to carry in water assumed to be clean. Increasingly-polluted wells in urban territories no longer supplied enough water. Cities needed concessions to extract water from distant regions, often at the expense of local users, and this required government intervention. With state support, the capitals and large cities brought in water from over 100 kilometres away, whilst other cities continued to draw their water from rivers and alluvial groundwater.

The situation changed with the discoveries of chemists and biologists such as Ebert, Koch and Pasteur: microbial threats required treating water, first by filtration,
followed by chemical treatment. Since water now had to be treated regardless of its source, water purification plants had an advantage over collecting local surface water. The technology reduced cities’ dependence on their surrounding environment and on the government. Later, the development of wastewater purification techniques would further increase cities’ independence and draw the line between city water – the water supplied (and discharged) by public utilities – and water as a natural resource.

By the end of the twentieth century, advances in scientific knowledge made treatment solutions increasingly expensive. This now induces cities to return to the hinterlands in their quest for cleaner water resources. These efforts require negotiated solutions, such as cooperative arrangements with farmers and payments for ecosystem services. These experiments are still a long way from water markets. Yet we will close this chapter with the case of San Diego – a city that buys water from an irrigation district in Southern California – illustrating the new city-hinterland paradigm.

**MORE WATER FROM FARTHER AFIELD**

In Europe at the end of the eighteenth century, urban growth and industrialization created an unprecedented problem: water – clean water, if possible – needed to be imported to cities. The rising population density exacerbated the risk of epidemics, particularly given the levels of waste allowed to fester in the streets. In addition, there was the risk of fire, primarily in cities where buildings were made of wood, as in Northern Europe and the United States. The obvious solution was to pump nearby surface water. Fortunately, most cities were built along a waterway. They already used the flow’s energy to pump water to a higher elevation than its source – for example, with a hydraulic ram or impulse pump. However, during low-flow periods, there was little or no water left to draw, and until the steam engine was invented, no adequate pumping technology. One alternative was to collect water from sources or streams at higher elevations outside the city, so that the water would flow downhill by gravity. While this water was usually cleaner, it was not as plentiful as water drawn from the river. To remedy this situation, many new catchments needed to be built, and growing concerns over public health prompted the cities to choose this alternative.

This raised various legal and financial issues. A city needs special authorisation to withdraw water from outside its own territory, because in the end, this will infringe on the water rights of local users, especially if it creates a shortage. Moreover, water supply systems of this kind are capital-intensive, and most cities did not have the financial wherewithal to pay for them. As a result, they turned to the state to help implement their projects. The lack of funding meant that many of the first private-sector water supply companies merely pumped water from the river and delivered it in its untreated state. Because many people could not afford to pay for service, the water companies served only affluent areas or business districts. By contrast,
Aqueducts from outside the city supplied public buildings and fountains. Water was free and there was no tradition of paying for it except among the affluent, who early on had water piped into their homes and paid a flat rate for the service.

In Switzerland, where mountain streams abound, water was harnessed as a source of power to run factories in cities. It was also available to provide a good quality supply to city dwellers. As a result, locally administered public water and energy utilities developed fairly rapidly through the creation of municipal companies. Germany focused more on pumping groundwater or naturally filtered surface water through the riverbanks (Uferfiltrazion). This was feasible because surface water was abundant, and the practice continues to this day.

England began to set the pace of innovation at the beginning of the nineteenth century. Industrialization and urbanization had come early to the country, and clever, practical-minded “mechanics” (engineers) would invent public utility network technologies just as the central government was devolving infrastructure management to municipalities. This is how England came to invent “municipalism,” or municipal involvement in the local economy. This system spread to the rest of Europe within a few decades. While private companies did initially deliver water services, in many cases local authorities took over management of the networks to universalize the service, even before the discovery of bacteria demonstrated the importance of extending services. Furthermore, because England lacks high mountains and abundant aquifers, it had to turn to surface water, which accounted for three-quarters of the total water supply. In addition, British law on water diversion and pollution was (and remains) highly restrictive (Barraqué 2001). Water had to be pumped from rather polluted rivers, which empirically led to the invention of purification by filtration. The English experience would then strengthen local water management across Europe, as will be shown below.

The situation was somewhat different in Scotland, where water is abundant; Glasgow was able to obtain water from a Highlands lake 55 kilometres away, with government assistance, and concurrently terminated a contract with the private company that had provided poor public service (Maver 2000). In France – a large country with a varied climate and a plethora of small communes, left as a legacy from the Revolution – different kinds of arrangements evolved. These ranged from building aqueducts that conveyed water from distant sources to Paris and Marseille, to pumping water out of the ground and from rivers, as in Lyon.1

Ito sum up, in the initial stages of urbanisation, water supply was regarded as a matter of hydraulics and civil engineering, and no one foresaw that this approach

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1. In Paris under Napoleon III, owing to the efforts of public works engineers such as Eugène Belgrand and his successors, the city obtained water from sources some 100 kilometres away. The catchments stood at a higher elevation than the city and water flowed down under the force of gravity via a system of siphons and aqueducts, thereby requiring little energy. Today, Paris still gets over half of the water it uses from this faraway source. By contrast, its suburbs draw nearly all of their water by pumping water from the Seine, Marne and Oise rivers.
would eventually test financial and technical limits. The insidious outcome that prevailed with this “more water from farther afield” policy was the discharge of untreated effluent into the rivers, gradually turning them into sewers (Tarr 1996). This technical option was also bound to reach its limits. Over time, urban growth and the increasing variety of water uses inevitably led to rivalries, ultimately bringing the local water authorities under the stewardship of higher levels of government. Moreover, distant aqueducts did not supply adequate water as a rule, or only did so at prohibitive cost. This happened in Lisbon, where the Águas Livres Aqueduct – a source of local pride built in the eighteenth century – would elicit nothing but derision from foreign engineers a century later.

During the first half of the twentieth century, water conveyance over large distances experienced new developments, as nation-states grew more involved in economic development and financing of large, multi-functional hydraulics projects. Dams and reservoirs regulated water flows and would generate electricity, develop irrigated agriculture, and supply more water to cities, while helping to prevent floods and extending the waterway navigation season. This model found its strongest expression in the United States, in the form of the Tennessee Valley Authority and the California water transfer arrangements. Low population density made it easier to implement the model: rivalries would not emerge until later. The model also spread across Europe, particularly in countries under authoritarian rule and in certain
colonies. The dictatorships in Italy, Portugal and Spain used the Mediterranean climate as an excuse to push through the major hydraulics projects that were part of their nation-building plans. They quelled any controversy over water resources versus improved public services. In Brazil, for example, the United States provided aid during the military regime of 1965-1985 that supported the expansion of hydroelectric projects, under a plan (the Planasa) to modernize public water utilities (Barraqué et al. 2008). By contrast, in wealthy, industrialized Europe, the cities would take advantage of the invention of water purification to overcome rivalries and dependency.

CLEANER AND CLOSER

Following the discovery of germs, water quality analyses evolved appreciably and a specialized branch of chemical engineering known as sanitary engineering focused on preventing the contamination of cities. Prevention, in the form of a universal water supply first filtered then purified, appeared preferable to treating people after they became ill. After all, an epidemic could kill the wealthy living in comfort as well as the underclass in slums. (Today, in large Third World cities where modern medicine protects those who can afford it, public utilities do not operate in the same spirit of solidarity as their European counterparts did a century ago.) With the advent of sanitary engineering, drinking water criteria multiplied and became more scientific, so the effects of water treatment could be measured. By the early twentieth century, the main chemical processes had been invented for purifying drinking water and for wastewater treatment.

From that point on, cities would rapidly achieve greater independence from water resources and other water uses. Because surface water could be purified to make it drinkable, waterworks could be built close to the city, and treatment costs offset by savings on transportation costs. Similarly, pollution from wastewater discharged by the city into the aquatic environment downstream could be reduced through wastewater treatment. Sewage treatment plants began to proliferate in England, Germany and the United States before World War II, and in the rest of continental Europe during the 1960s, with the backing of central governments. Water supply became a public service that was local and financed by the consumer rather than through taxes.

In Paris, the technical shift to drinking water purification occurred at the beginning of the twentieth century. At the time, it was thought that water was in short supply and that sources needed to be found farther and farther afield. Even the possibility of bringing water from the Loire was considered – an idea dating back to Louis XIV’s plan for supplying the fountains at Versailles. However, the Loire’s summer flow dwindles at the very time when additional water is most needed. In 1890, the French engineer Duvillard drafted a technically feasible project to
bring water to Paris from Lake Geneva, 440 kilometres away. Advocates developed comprehensive arguments to gain support for his project – it would do away with shortages forever, bring in high-quality water, and extend the navigation season, while the constant additional flows would further dilute effluent releases: the City of Light required enormous quantities of water. The Council of Paris held serious debates over the project and the engineers fine-tuned their calculations. But then a typhoid epidemic broke out, and its origins were traced to a distant supply source, the Loing River. This showed that even remote sources could be contaminated and that water required purification regardless of its origin.

In 1902, Paul Brousse, a Council of Paris member known for his “Possibilist” positions for “municipal socialism,” inaugurated a waterworks in the upstream suburb of Ivry. It was a model slow filtration plant – a showcase for this process in its heyday, and in fact one that has recently undergone renovation. Paris, like other European cities, then turned to a sustainable alternative: draw and treat water locally, and stop transporting more high-quality water over long distances. The Council of Paris finally shelved the Lake Geneva project in 1919, for technical reasons and strategic considerations: it was feared that if war broke out, Germany would attack the aqueduct and shut it down, thereby forcing France to capitulate.

As water treatment plants proliferated, a new system came about: economies of scale became an inducement to concentrate water management units, and joint boards developed in many countries. Although the initial infrastructure would be funded primarily through government subsidies (i.e. taxes), in continental Europe water treatment was generally viewed as a consumer convenience. This reinforced the notion that the consumer should pay for the water piped into his or her home on a volume-consumed basis. This shift towards commercialized public service gradually spread across the continent, but not to England and Ireland, where consumers still usually pay for water through a local tax assessed on the rental value of their residence. The shift made the utilities more financially independent; they could add costs for infrastructure depreciation and replacement provisions onto the consumer’s water bill. This is why many cities created joint public-private companies and, in some cases, private companies that they own. These have the combined advantage of government legitimacy and private-sector flexibility. In France, government-mandated restrictions on creating municipal corporations led joint boards to grant lease and management contracts to ever-larger and more consolidated private operators.

Another advantage to billing for water was that once all or most city dwellers were connected to public supply, a small increase in water price could generate enough money to pay for new connections, primarily in rural areas. In France, FNDAE, – a national water supply development fund – was created in the 1950s to help connect small towns and villages for whom bearing the full cost would have been prohibitive. Major cities in developing countries – which often lack this kind of social
solidarity – currently face a similar problem when expanding public utility services. Most European countries eventually found it most convenient to add sewer service charges to the water bill, as a way to help finance expansion of sewer systems and sewage treatment plants.

Ultimately, the most widespread system now in use is what is known as urban water, i.e. “city water” and sewage, plus storm water management where applicable. Treatment technology allows for the sanitary engineer’s fantasy: the water treatment plant and sewage works form a boundary between the city water and the water resource. On each side of this boundary, there are two different legal and financial systems. The right to city water is clearly distinct from water rights and resource-sharing. The cities are not dependent on the hinterland water, because they can produce drinking water from even highly polluted sources. Wastewater can also be recycled and the effects of wastewater discharge drastically reduced. In this fantasy, technology can do anything; the only issue is money. But new factors have emerged, making this fantasy unattainable and requiring cities to return to the hinterland for water. But what does “return” mean in this context?

ENVIRONMENTAL ENGINEERING AND A RETURN TO THE HINTERLAND

A number of signs have pointed to a new crisis in public water and sewer services. First, the inclusion of sewer charges in water bills has caused water prices to more than double, particularly when subsidies dry up for capital expenditure on sewer systems. It has become apparent that in the long term, maintenance and replacement of the massive infrastructure developed over time will prove extremely costly, because after the initial investment, government revenues and taxes have no longer funded or subsidized these systems. They have been paid for through water bills, especially once neoclassical economists advocated that the full cost be passed on to the consumer. Water prices have spiralled upward everywhere, raising public opposition in countries where the private sector plays an important role in public services, such as in England and Wales, France, and Latin America.

Because of these price increases – coupled with a growing awareness of the threat of water scarcity – some customers have turned away from the utility or cut back their use. This raises an issue previously obscured by decades of expansion in consumer-financed water supply. The supply system does not sell a product; it provides what is known as a “club good.” In fact, infrastructure depreciation accounts for the bulk of the utility’s costs, while operating expenses represent a much smaller fraction. An investment in a water supply system generates about one-third of the revenues derived from investing in a power supply network. As a result, if demand falls, the cost of “membership” in the “club” needs to be increased for the remaining customers. It becomes risky to rely exclusively on consumption-based billing to cover the full costs of water and sanitation services. Indeed, what will happen to the poorest people? Will they be deprived of water if they can no longer afford it? Can we figure out a new system of territorial governance, thus reducing the need for costly technology?
Lastly, the quality of tap water adds another crisis factor. Advances in water quality monitoring have not only raised drinking water standards; they have uncovered growing numbers of substances than can prove hazardous to public health. As a result, water treatment costs have increased while public trust has eroded.

Throughout the history of public utilities, governments and engineers essentially reasoned on the supply side, during both the infrastructure development and water purification phases. The idea was to provide increasing supplies of water of the highest possible quality to be used for growing numbers of public and private purposes, with economies of scale as the key. And while investing in technology has given the cities a great deal of independence from water resources and those who are in charge of allocating them, the technology race now appears to be too expensive. As a result, new approaches are emerging, together with new engineering disciplines, including urban and environmental engineering.

Contrary to what economists may claim, demand-side management does more than simply find the price that will achieve optimum supply/demand equilibrium. Rather, the issue is to develop technical and regional water service arrangements, using a controlled, dynamic approach to assess the effect of demand on supply and vice-versa. If demand increases and the technical system reaches full capacity, it becomes essential to save water, since the cheapest water is that which has not yet been used. One possibility is to encourage owners of large gardens and swimming pools to look to sources other than tap water for these less critical uses. Conversely, if demand for drinking water falls – a trend that began in the 1990s in many European cities and even earlier in the United States and Switzerland – the infrastructure should be re-sized, reflecting a change in demand that still needs to be -further assessed.

NEW POLICIES AND STRATEGIES
In sanitation, similar questions require new answers: how big an area can a centralized system serve before reaching the point where decentralized solutions or semi-central systems may be preferable? Can cities shrink storm-water drainage systems by managing rainwater runoff and by retaining storm water on residential parcels? Public water utilities can also cut costs by adopting new regional strategies within their environment. This brings to mind water pollution in drinking water catchment areas resulting from intensive farming nearby.

In response to this problem, cities can either find new, more protected sources, buy the required land and plant trees to create “water sanctuaries,” or treat the water to remove nitrates and pesticides. There is a fourth solution, often applied in Germany and the Netherlands: “cooperative arrangements” with farmers who raise crops in the catchment runoff area. Under these arrangements, farmers receive compensation and support for switching to practices that ensure that raw water meets or will
meet the standards for water that is to be turned into drinking water. In Germany, a study found more than four hundred cases of these local arrangements, providing support to farmers for an average period of fifteen years. The cost of these arrangements is charged back to consumers. This strategy is a way to obtain a supply of water that does not need to be treated for pollution from agricultural runoff, and reduces costs of treatment technology by one-half to two-thirds. Similar arrangements exist in France; for example, the city of Paris uses distant “abstraction points” or remote ponds and small reservoirs. However, the development of agricultural corporatism and the very large number of small water management units have delayed adoption of such arrangements – thereby favouring development of water sanctuaries and utilities’ consolidation.

In the United States, these new policies are called “Payments for Ecosystem Services” and cover measures to reduce erosion, protect bio-diversity or conserve water resources, *inter alia*. New York is a well-known case in point: during the past century, the metropolitan area has drawn its water from a relatively undeveloped area, the Catskill Mountains. Protection of reservoir land has provided an abundant water supply (per capita consumption is two-and-a-half times higher than in Europe) without the need for filtration. However, advanced analysis techniques have found a risk of contamination by parasites such as *cryptosporidium*, so the Environmental Protection Agency has asked the city to filter its water. New York managed to obtain an exemption through extensive negotiations with the Catskills Region and agreeing to further reduce pollutant releases.

There are many more examples of how land-based solutions have partially replaced technological solutions, primarily in the areas of flood risk mitigation (which protects cities by creating flood containment areas elsewhere, even by compensating rural residents if necessary) and water shortage prevention. These approaches require a new type of governance geared to negotiating issues related to water and sharing in terms of its quality and quantity. Cities can no longer merely collect water and purify it. They must get involved in new, integrated watershed management policies.

Paris is a clear illustration of this recent development: it has increased protection of its remaining distant collection points, and helps manage water resources during low-flow periods (Figure 1). As early as the 1930s, it had become clear that the city would run out of water in the event of summer drought. After World War II, the low-water problem was finally solved by building major dams and reservoirs upstream on the Seine, Marne and Aube rivers – projects “sold” to the public in part for their role in flood mitigation. In the 1980s, a project to build a fourth dam with a direct water pipeline to Paris (colloquially called the “Chirac Pipe”) was shelved because public and private water producers had foreseen the political difficulties it would entail; they installed alarm systems to shut off the water intake in the plants in case of accidental river pollution, and made sophisticated improvements to the plants themselves. Moreover, for the first time, demand for drinking
water in Paris, as in many European cities, has levelled or declined. Over the last fifteen years, demand has dropped by 25% in the city of Paris proper, and has also contracted in the inner suburbs. Eventually, the Ivry waterworks mentioned above will become redundant and be closed down. Similarly, a highly complex institutional arrangement has developed for wastewater and storm water treatment, to coordinate the efforts of different tiers of government: municipalities for sewer systems; the inner suburbs’ counties for collectors and rainwater management; the SIAAP, an inter-county sanitation board managing the largest collectors and waste water treatment plants; along with the region and the Seine Normandie water agency as planning and funding institutions. All these organizations must work together, which is no small accomplishment. The case of Paris is one example among many. It shows that attaining an economically, environmentally and socially sustainable system requires good multi-level governance.

**WATER TRANSFER ARRANGEMENTS IN THE WESTERN UNITED STATES**

In Europe, cooperative arrangements aim mainly to restore the quality of raw water. In the United States, the best-known high-volume water transfer arrangement concerns Southern California and the “water market” between San Diego and the Imperial Irrigation District. Southern California has perhaps created the biggest and boldest example of water transfer arrangements in the world today, outside of China. In the early twentieth century, the Federal government embarked upon a major programme to realize Thomas Jefferson’s agrarian ideal by populating the country with small farmers. Congress passed appropriations for ambitious irrigation projects that were also designed to supply electricity. In California, these projects included a transfer of water from north to south to irrigate the Central Valley, which stretches over six hundred kilometres, followed by the California Aqueduct that spans the valley’s entire length. Dams were also built on the Colorado River to generate electricity, provide water for irrigation and control the rivers untamed flows. To supply more water to the urbanizing southern part of the state, the Metropolitan Water District was formed in 1927, as a Colorado water wholesaler to other water agencies (Erie 2006).

Agricultural water development and deliveries, devised in the early twentieth century with federal funding, de facto assured the supply for Southern California cities (Figure 2). The 1922 Colorado River Compact allocates water flowing from the Colorado among the seven states that share a watershed covering more than 600,000 square kilometres. The allocation was based on mean annual flow, and demographic and land use data available at the time. Even then, California was the most populous state – and thus obtained the largest share of water – just over

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2. Syndicat interdépartemental pour l’assainissement de l’agglomération parisienne
one-quarter of the total. Mexico, through which the Colorado flows before spilling into the Sea of Cortez, was left with 1.5 million acre-feet of the (more than) estimated 16.5 (maf).

At the time of the 1922 allocation, Imperial County’s Imperial Irrigation District (IID) received three-quarters of California’s allotment. The remainder went to other farm irrigation districts. As urban growth spread along the coast, the urban water supply proved insufficient. This was particularly true for San Diego County – the second largest metropolitan area in the state, and an MWD member agency. For some twenty years, the San Diego County Water Authority chaffed at its dependence on the MWD for its water supply and worked hard to get access to its own supply of water, independent of the MWD – something it obtained in 2003 through a complex water transfer arrangement (Figure 3). This opened a new chapter in the long history of controversies among the operators drawing their water from the Colorado River (Pincetl and Katz 2007). The agreement results from the Federal government’s cuts in California’s water allotment: under the 1922 compact, the state was entitled to 4.4 maf, but it drew 5.5 maf on a regular basis because the other states did not use their quotas and the flow of the Colorado remained high. However, at the end of the twentieth century, as Las Vegas and Phoenix grew at a dizzying pace, Nevada and Arizona claimed their due share.

The transfer arrangement provides sufficient water to meet San Diego’s projected urban demand based on annual population growth estimates and minimum per capita consumption of 200 gallons per day (gpd) and up to 280 gpd in the summer (local resources supplying only 20% of the water). But the San Diego County Water Authority, which sets the price of raw water and wholesales it, is not directly involved in demand-side management: the more water it sells, the more money it makes. Consequently, the allocation agreement does not include any water conservation measures. Yet estimates indicate that the potential for water conservation and efficiency improvements in California exceeds what has been currently achieved. In a report on the potential for urban water
conservation in California, the Pacific Institute showed that water use could be reduced by 33%. Even with current technologies and policies, residential water use could be as low as 60-65 gpd without any change in the services actually provided (Gleick et al. 2003). Building more apartment complexes would increase efficiency, but San Diego has separate decision-making authorities for urban development and water supply management, preventing effective action in this area.

Moreover, the San Diego County Water Authority is the water wholesaler. It does not directly sell water to users and does not have the authority to require water conservation. Further, any conservation of water would reduce water sales, impinging on its profits. There has been no attempt to decouple water sales volume from revenue, thus maintaining a need to sell increasing volumes of water to grow. Finally, government institutions and purviews are notoriously fragmented at the local level in the United States, with little coordination or integration of planning and service delivery. Each service is provided independently of the other, and land use planning occurs separately as well. In contrast, the most striking aspect of the new urban water policies in Europe is their attempt to reduce the scale of future investment (and therefore of water bills) through demand-side management and by replacing sophisticated technology with new, integrated land management approaches.


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