Meeting the Challenges of Climate-Proofing a Water System: How Surat Learned and Adapted

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Abstract

As climate change and associated risks have gained recognition on an international scale, planning processes within cities are beginning to evolve to take these risks into account. Water is fundamental to a city's economic and human life, and is a key service through which a city feels the new climate stresses—in the form of droughts, floods, contamination, and sea level rise. In this paper we examine the efforts of Surat City to secure its water system in the face of a history of endemic flooding. Surat has applied lessons learnt from past events, considered future conditions, and invested in the design of infrastructures and decision making processes to build resilience towards uncertainties and extreme events. In the short- to medium-term, this has led to a better water supply network and efficient water management practices. In the long term, Surat is insuring its economic stability and competitiveness by proactively managing its water supply in the face of future climate-related risks. Indeed, while, a flood-related public health catastrophe initially triggered reforms, over time, appreciation by the local population and businesses of the results of reform, as well as revenue-generation gains and efficiency enhancing benefits to the municipal agencies in-charge of water have created a much wider constituency that has helped sustain and indeed accelerate Surat's climate-aware reform.

Meeting the Challenges of Climate-Proofing a Water System: How Surat Learned and Adapted[1]

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1. Introduction

As climate change and associated risks have gained recognition on an international scale, planning processes within cities are beginning to evolve to take these risks into account. Among the many reasons for cities to be concerned with and try to address the consequences of climate change are compelling economic arguments. The consequences of climate change in the form of natural disasters such as floods, droughts, and sea level rise, create an economic drain on cities which must replace infrastructure ahead of schedule or invest in new technologies to deal with a rapidly changing environment. Disruptions caused by a changing climate change are potentially detrimental to a city's public and economic life, its agriculture and industries, and the well being of its citizens, all of which affect not only the creation of goods and services that drive the economy, but can exacerbate already existing urban inequalities by imposing the largest burdens on the city's most vulnerable communities.

As climate stresses enter into the dynamics of planning and public discourse, cities are having to build new vocabularies and planning methodologies that not only take account of future impacts of hazards and disasters, but also cultivate capacities to plan for incompletely understood problems and uncertainties and risks that climate change brings. Such future planning is also labeled by some as the 'climate proofing' of urban systems. 'Climate proofing does not reduce climate-based risks to zero, but allows cities to use infrastructure and social systems to reduce risks to a quantified level, accepted by the society or economy, and learn to live with them using local knowledge, iterative learning and experimentation, scientific projections as well social partnerships and relationships on the ground (Kabat et al. 2005). This risk can be further combated by "softer" measures, such as insurance schemes or, as a last resort, evacuation plans…"[2]

When it is applied to public or private infrastructure, The United Nations Development Program (UNDP) defines climate-proofing as "…actions that make infrastructure more resilient and resistant to anticipated scenarios of long-term climate change, as well as the

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1 This background paper was prepared as part of the Rockefeller funded ICRIER project on the Economic Resilience of Cities CAC 309 2014. We thank all the officials of the Surat Municipal Corporation who generously gave of their time to tell us about their water story. We also thank Mr. G.K. Bhat, and Mr. Kamlesh Yagnik and Mr. Jatin Shah for responding to our many queries. We thank Amanda Martin, Cara Wittekind, Sarah E. Wraight and Catherine McManus for their excellent feedback and suggestions on earlier versions of the paper. We are grateful to Sandeep Paul for excellent research assistance.
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2 Kabat, P., Van Vierssen, W., Veraart, J., Vellinga, P., Aerts, J., 2005. Climate proofing the Netherlands. Nature 438 (7066), 283–284.

risks associated with geological hazards and climate variability and extremes."[3] In other words, the process of climate-proofing explicitly takes into account climate change related risks and opportunities while designing, operating, and managing infrastructure.[4] Others question the presumed certainty that "hard" approaches to infrastructure adaptation imply, arguing instead for learning to accommodate the dynamics, ebbs and falls of natural systems (Mathur and Da Cunha 2014). In between these two approaches lie the many pragmatic experiments that cities around the world are engaged in as they learn to deal with, and live with, the pressures of a shifting climate.

Water is one of the key mediating variables through which a city feels the new climate stresses—in the form of droughts, floods, and sea level rise, all of which contribute to uncertainty in providing adequate and clean water to the population and can undermine economic systems. Water systems are also subjected to high stress as demand for water grows due to rapid urbanization (high natural growth rates, increase in migrant populations), increase in economic activities, and expansion of city boundaries among many other factors.[5] Water supply in most Indian cities is threatened by pressure on limited water resources close to the city, limited and aging infrastructure like water treatment and distribution facilities, and inadequate or crumbling distribution networks. Most local government bodies also lack the capital and institutional capacity to tackle the plethora of these pressing problems. In light of climate change risks, the problem is even graver.

The uncertainties and long timelines of climate change pressures create logistical, political, and economic barriers for cities to conceive and implement decisive action. Despite these challenges, some cities have forged innovative paths forward and taken decisive action to diminish risk to their water systems, which has, in turn, provided not just protection against climate change but also significant public health and economic benefits. The pathways through which cities have succeeded in upgrading water systems provide insight into the institutional structures and motivations that generate change.

Surat, in Gujarat, India, is one such city that has applied lessons learnt from its past events, considered future climatic conditions, and invested in the design of infrastructures and decision making processes to build resilience towards uncertainties and extreme events. In the short- to medium-term, this has led to a better water supply network and water management practices. In the long term, Surat is insuring its economic stability and competitiveness by proactively managing its water supply in the face of future climate-related risks.

In this paper we examine both the institutional drivers and the innovative strategies that Surat has used to climate-proof its water resources and enhance sustainability and the longevity of

[3] The UN Development Program (UNDP). 2011. Paving the Way for Climate-Resilient Infrastructure: Guidance for Practitioners and Planners. http://www.uncclearn.org/sites/www.uncclearn.org/files/inventory/undp_paving_the_way.pdf

[4] Ibid

[5] India's urban awakening: Building inclusive cities, sustaining economic growth, McKinsey Global Institute Report, 2010; http://www.mckinsey.com/insights/urbanization/urban_awakening_in_india

water supplies. In Surat, a determined and proactive bureaucracy, supported by a committed industrial elite, made highly strategic and successful use of state and central level funding as well as external support to make a series of changes to their infrastructure, including water, housing, and waste water that promoted water security, public health and economic competitiveness. This case study suggests that the "benign top-down" governance structure, built on a technocratic and meritocratic municipal bureaucracy with support from business leaders, provided the will and the strategic capacity to carry out these changes. The top-down structures can also be called the system's weakness. Nevertheless, through a series of administrative and collaborative efforts these actions have been sustained through a decentralized and distributed approach to delegating responsibility including in collaboration with community vigilance. While the risks are still many, and there are side effects and tensions within the system about the distribution of benefits, today Surat is considered to be on the frontlines of cities that have made serious progress toward "climate-proofing" many of their urban systems, particularly water.

The rest of the paper is organized as follows. We first examine Surat's history within a context of catastrophic water events that culminated in two key turning points in 1994 and 2006 that led the city to change course and embark on a more resilient strategy around water. In the four sections that follow next, we outline the specific measures that Surat took to innovate in four specific aspects of water: (i) water source security, (ii) disaster preparedness, (iii) water accountability, and (iv) sustainability in the context of a city resilience strategy. We then make an economic case for adaptation by providing an illustrative estimation of the costs the city bears when its water supplies are disrupted and how the city bureaucracy and especially the industrial elite understood the economic case for adaptation and why this mattered for Surat.

2. Surat's history and context within a climate-challenged world

Multiple climate risks threaten Surat. This rapidly growing industrial city of over 5 million people is located both on the banks of the Tapi River in Western Gujarat, which has a history of flooding, as well as on estuaries at the Arabian Ocean. Currently the city receives 950 to 1200 mm of annual rainfall, 90% of which falls during the monsoon season. Various climatic models predict an increase in annual rainfall in the range of 200 to 450mm by 2020.[6] This rainfall will occur in more intense precipitation events, as the overall number of rainy days is projected to fall. These models project a similar trend for the upper catchment areas of the Tapi River basin. Surat also expects to see its average maximum temperature rise. The average temperatures during winter months are projected to increase by 0.5^{0}C in each decade[7] (Bhat et al. 2013, and consistent with global projections under the business as usual scenario (Ahluwalia, nd). Rising temperatures, along with humidity present many public health risks, including an increase in vector-borne disease from higher concentration of pathogens in water. The risk of sea water flooding combined with high tides at the estuary threatens salt water inundation and contamination of the city's fresh water resources.

6 EPRE
7 The CSAG Weather Risk Attribution Forecast

Sourcing and transportation of potable water are also a concern. Surat is an industrial city known globally for its diamond trade and is a domestic textile hub. According to recent reports Surat is the fastest growing city in the world (Oxford Research 2018). Together with the rapid growth of an oil and gas and petrochemical hub on coastal Hazira, 20 km West of the city center, this has led to high, and growing, demand for water for both consumption and productive uses. The city however, has been and currently is mostly dependent on the Tapi River for its water supply. Since 1972 the flow of the river passing through the city has been restricted, as the Ukai dam (Vallabh Sagar Dam) was built 94 Km upstream from the city for irrigation, power generation, and flood control purposes (Bhat et al. 2013). The amount of water released from the dam is dependent on the amount of rainfall received in the Tapi's catchment area, most of which falls in other states. Around 76% of the catchment area falls in the state of Maharashtra, 17% in Madhya Pradesh, and only 7% lies in Gujarat[8]. In other words, Surat's drinking water supply is highly dependent on activity and decisions made in other states. Additionally, the operation of the dam is under the jurisdiction of the irrigation department, so the city has little say in determining the amount of water it receives for drinking purposes. Because of these circumstances, the function of supplying water to the citizens of Surat is under lot of pressure and uncertainty. Moreover, in the decades following the construction of the Ukai dam,[9] there was rapid and intensive development in the River Tapi's floodplain. This increased the risk of flooding and waterlogging (Bhat et al., 2013, p.4-5). When these, and other climate change risks (in the forms of heavy precipitation, salination due to the city's location on the estuary, and decrease in water quality due to high temperature) are factored in, the problem becomes acute.

Despite these serious climate change projections, it was not future predictions of risk, but direct experience with disaster that provided the primary motivation for adaptive action in Surat. Though the city has a long history of flooding,[10] two floods of 1994 and 2006 represented major turning points that transformed how the city dealt with water.

Devastating floods in 1994 and a resulting epidemic, struck fear in the city's economic and political leadership. The city faced a massive health crisis, including talk of incidents of plague following an episode of intense flooding. This shook up the city--its industrial elite, its governing elite and civil society. The municipality, known in the past for turf battles and lackluster performance, "took on the problem on a war footing," as one official noted, not only to save lives, but to retain investment and jobs. The event catalyzed civic leaders and institutions to collaborate and invest in both capital improvements and personnel training: the city built and improved infrastructure and put into place multiple time- and life-saving systems in case of future disasters. The primary innovations immediately following the 1994

8 Interview with Mr. Nilesh Patel (Executive Assistant) of Surat Municipal Corporation 18th July, 2013

9 1972, according to: http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Ukai_Dam_D01004

10 The city's experience with severe flooding dates back to the mid-19th century. Surat's relatively flat topography makes monsoon-led flooding endemic to the region. Between 1869 and 1884 the city routinely flooded every two and a half years, and about every four years between 1949 and 1979 (Bhat et al. 2013). In recent years, severe floods have occurred in 1990, 1994, 1998, 2006 and 2013, mainly due to the release of excess water from the Ukai dam. The floods of 1994 and 2006 were however key turning points for the city, and its perception of its own vulnerability.

floods were in the areas of water sourcing and shoring up its resilience, as well as dovetailing efforts around drinking water with attempts to overhaul the city's storm water drainage and sewer system particularly in its dense slums (as we discuss in subsequent sections).

The second turning point occurred in 2006 when one of the worst floods led to significant loss of life and property. In 1998 and 2006, repeat flooding events occurred, and the investments and innovations pursued over the intervening years demonstrated their effectiveness as well as revealed fresh weaknesses. Though floods after 1994 brought significant economic costs to the city and local industry, no health epidemic emerged. The 1994, 1998, and 2006 floods all served as learning events: If the 1994 flood was the "wake-up call" that climate-proofing the water supply system was necessary, the subsequent floods served as system tests and provided course correction to the city's evolving climate-conscious planning methods.

Along with the flood in 2006 a second major change took place: the nearly tripling of the City's territory (from 112 sq. km to ~326 sq. km) and a boom in the municipal population through annexation of surrounding land area. This increased the pressure on city officials to press forward on resilience and efficiency of the water system. Fortunately, this time period also featured new learning in the climate planning community as a whole, and new technologies that could be leveraged to solve problems. This has led to innovations in Surat in the areas of resilience, accountability within the water system, and efforts to build sustainability of the system. The city also made novel interventions to bring the water source closer to the city by investing seriously in recycling treated waste water for industrial uses and making efforts to conserve water (Ahluwalia n.d).

Later on, the city also overhauled the way it charged for water by introducing volumetric tariffs and started pilots to upgrade to continuous water supply. It adopted dedicated renewable energy sources (wind and solar) to reduce its dependence on electric power. It also adopted new standards, new informational technologies and community embedded strategies to upgrade water quality and stem leakages.

A third turning point came in 2010-11, when based on its past efforts, Surat was chosen as one of ACCCRN's 10 Resilient Asian cities. Building on the work it had done so far, this partnership and funding from the Rockefeller Foundation and technical assistance from expert groups such as TARU leading edge and local and national universities saw the city develop its first Climate Resilience Strategy, and efficient end-to-end early warning system to give city residents at least 4 days of advance notice before water released from the Ukai dam reached the city. This period also saw the introduction of networked technologies and sms-related surveillance systems that are now used to regulate water quality, water leakages, stagnation and disease.

Despite its troubling history with flooding, then, and a doubling of its area when municipal boundaries were enlarged in 2006, 95% of the city's households are connected to the city's piped water system. 86% to the city's sanitation system. The city has also famously never been in the red, covering its costs and strategically using external funding to expand, augment and upgrade its water infrastructure as well as water quality. These gains, we argue have a lot to do with how the city's endemic flooding, and the turning points of 1994 and 2006 pushed the city towards a more sustainable, focused and climate aware water policy. Better climate, better services, and a better economy can go hand in hand.

3. Meeting the Challenges of Climate-Proofing a Water System: How Surat Learned and Adapted

Turning Point 1: The Shock of 1994

In 1994, when the floods and plague hit the city, Surat was infamous as one of the dirtiest cities of India. Dominated by small and medium diamond and textile industries, the city was in the throes of growth. A magnet for migrant workers, Surat's population had approximately tripled over the previous 20 years, and the government had a long history of failing to provide adequate or efficient public services (Shah, 1994, p. 2671). In the years immediately preceding the 1994 floods, Surat had reached a crisis point. The issue of water shortage[11] had risen to prominence as population and industrial growth outpaced supply and industrial effluent discharges intensified (Shah, 1994, p. 2675). There was also a widespread perception among public and municipal officials that besides inadequate water, one of the main challenges facing the city was the lack of sanitation services (particularly drainage and solid waste disposal). The city was racked by 3-4 epidemics of vector borne diseases each year (Shah, 1994, p. 2675). Vector borne diseases are routine in a tropical environment, and despite concern, did not push city officials to sit up and act.

3.1 Organizational reforms in water were led by a drive to improve sanitation first

The flood of 1994 and the plague that arrived in its aftermath, shocked everyone into action. There were reports of riots, an exodus of the city's migrant workers, Surat was in the news for the wrong reasons, and the reputation of this rising industrial city was at stake, as was its workforce – more than half of Surat's industrial workers are migrants from other states and other parts of Gujarat. Pushed by the city's small-firm led business elite, local officials of the Surat Municipal Corporation (SMC) began to take immediate action. Government service provision systems began to be altered. The story of what was done has been widely told (Swamy et al. nd, Shah 1997, Chatterjee 2015), but in this paper we look at Surat's water story in the post-plague period to trace the steps and sequences that have made the city's water system an award-winning, economically efficient, climate-aware and sustainable system.

It is striking that the city's efforts to rescue its contaminated water in the post-1994 flood event was led by a drive to upgrade its storm water and sanitation system first. In 1991 the city had already begun building footpaths with Kota stones that facilitated garbage pickup

11 See Shah, 1994, p. 2675 for data on water supply in 1994: 71% of population had water service; water supply duration: at most a few hours each day. The SMC Website (SMC Website: Water Supply, 2015) reports that in 1995, gross average daily water supply was 180 MLD for a population of about 18 Lacs, and sea water ingress was contaminating the water supply. Other unsustainable water supply practices prior to 1995 included reliance on earthen dams were constructed on the Tapi and had to be rebuilt each year.

and street cleaning, and which acted as natural drains. After the 1994 floods, the SMC actively intensified Kota paving activity, not only on the main roads as they had begun doing in 1991-2, but also on smaller lanes and by-lanes and on slum roads. By 1996, 75% of the slums were paved (Shah, 1997, p. 609-610). Storm water drains were repaired, and the commissioner recruited local NGOs and communities to participate in street cleaning and

In 1992, national reforms on the decentralization of urban governance had granted cities more control in planning and financing their own development (Chu, 2015). In many cities these reforms have remained on the books, as they had in Surat. But post the 1994 floods and the chaos that followed, SMC began to seriously restructure and solidify these reforms, partly in response to the 1994 plague (Interview S. Mehta 2013, and also see Shah,1997). The city's 38 election wards were grouped into 7 administrative zones (Bhat et al., 2013), and two key SMC commissioners who followed each other after the 1994 episodes, S.R. Rao and S. Jagadeesan, began instituting a series of important organizational reforms. Key among these were the commissioner's "delegating his authorization power to the assistant commissioner, deputy commissioner and zonal chiefs" (S. Mehta, 2013) (reinforcing the decentralization of the municipal government), disciplining and firing staff who neglected their duties, eliminating the need for higher level approval of work orders (thereby streamlining work processes), and making each officer responsible for a different geographic area (thereby promoting accountability and diligence in carrying out duties) (See Swamy et al. nd, Shah, 1997). The commissioner also required all senior officers to spend more time in the field to supervise work and gain a better understanding of challenges facing city staff and city residents. The presence of these officers has bolstered the morale and motivation of lower-level field staff.

The delegation of responsibilities to zonal officers was accompanied by efforts to share information across city officials, elected officials and civic society. Informal, daily, information-sharing meetings were instituted between "the commissioner, deputy commissioner (general), director of planning and other divisional heads from the administrative wing and the leaders of the elected wing - the mayor, deputy mayor, and the chairperson of the standing committee" (Shah, 1997). SMC established a complaint filing and response system whereby members of the public could tell the SMC about water, sanitation, or drainage-related concerns. To aid in prioritization, concerns were classified as either sanitation related (24-hour response or 48-hour response) or engineering-related (Shah, 1997, p.612). SMC under Commissioner Rao dramatically increased staff numbers at all levels in the sanitation department so as to increase capacity to identify and address these problems. Together these practices created greater inclusion of street level staff in higher level decision making, while at the same time eliciting greater accountability by creating cross-sector knowledge and information flows that helped maintain transparency.

Indeed, to increase the city's capacity (in terms of numbers) to deliver on the intense clean-up that the post-plague situation required, SMC contracted out several services. The trash collection system was revamped and privatized following the 1994 floods (Small Focus Group 2013, 1,4.d.ii). Sweeping was privatized in 1996 and eventually SMC contracted with

31 private companies for street cleaning and trash collection (Trivedi 2009). SMC intensively cleaned sewers and septic tanks before the onset of the 1995 monsoons (Shah, 1997, p.609), and this policy has continued thereafter (Interviews, SMC 2013; also see Bhat et al., 2013, p.8). Similarly, surface drains that had been constructed in all the slums post-1994 to prevent waterlogging, were cleaned weekly. SMC meanwhile also intensified the construction of higher roads, bridges, and sewerage infrastructure after the floods (Interview, P.Dutta, 2013; also see Chu 2015. In 1995-1996, the Bhesan sewage treatment plant and sewage pumping stations at Rander, Adajan, and Adajan-Pal were completed (SMC 2015)

In our interviews in Surat city in 2013, municipal officials believed that the main lessons from the 1994 floods revolved around sanitation (ICRIER Workshop, 2013, Small Group 1,4.a). This would be in keeping with the broader public concerns about sanitation that existed in the lead-up to the crisis. It is interesting that the interviewees at the 2013 workshop also noted the willingness of city residents to pay their taxes on time in return for good city services (ICRIER Workshop, 2013, Small Group 3,4), suggesting a transformation of city residents' attitudes toward local government and toward taxation and user fees in particular.

In sum, then, Surat's adaptation sequences after the 1994 floods were led by sanitation, improved garbage collection, regular street cleaning, prevention of water-logging, drainage and sewer building especially in low-lying slums and organizational changes in municipal decision-making processes. As these reforms bore fruit and were appreciated by the public, revenues also increased, enabling the city to do more. Accompanying these more immediately visible reforms was an intensification of efforts by SMC to enhance and protect the city's water sources, to which we turn next.

3.2 Innovations in water source management

The history of municipal water supply in Surat goes back more than a century. The first water supply pipeline was laid in 1894 and the Varachha Water Works (WW), also known as Head WW, was inaugurated in 1898. Surat's first water treatment plant (WTP) was also commissioned in Varachha in 1952.[12] In 1985 20 new tube wells and two radial connecting wells, also called French wells, were constructed at Varachha and Sarthana to increase the Tapi river's water supply capacity. Three water distribution stations (WDS) were built during this period at Khatodara, Umarwada and Katargam.[13]

Before 1994, SMC drew water from the reservoirs created by earthen dams constructed on the Tapi River. However, these dams used to wash away and require rebuilding every year. This yearly activity was an expensive and unsustainable practice in the absence of any efficient and permanent way to harness the Tapi's water. The city started to take measures in the 1980s and early 1990s to increase its water harnessing capacity and efficiency. In 1985 two French wells with a total capacity of 90 MLD were constructed and in 1993 the capacity of Varachha WW was increased to 68 MLD. However, as this was outside the city, pumping

[12] SMC, Hydraulic Department, 2012, http://www.suratmunicipal.gov.in/Hydrolic/Hydraulic.aspx?SrNo=805005305406505404

[13] ibid

water to the urban core put financial burden on the city. Additionally, using all the available water resources, in the 1990s the city could still only supply 180 MLD of water to its 1.8 million citizens and thus faced severe shortages.[14]

The problem of water salinity due to high tides in the estuary also added to the overall concern. To resolve these issues of high water demand from the city's explosive population growth in the 1990s, and low water quality, the city decided to construct the Singanpur weir-cum-causeway on the Tapi's downstream section. The project was begun in 1992 but had stalled due a lack of funds. The completion of the weir was expedited post 1994, and was completed in 1995. The total cost to build the weir was Rs. 350 million which included financial help from the Hazira Area Industries Association (HAIA).[15] It increased the water store capacity to 31,000 trillion cubic meters. Building the weir was a landmark event for the city's water supply system as it increased the possibility to draw more water from the river.[16] It provides drinking water to the city and HAIA draws water from its reservoir for industrial purposes. Thus, it has been a boon for both the city's population and the industries in its vicinity. Besides this, it also helped to reduce flood risks. Other benefits include reduction of silting and pollution brought along with high tides, reduction in salinity of ground water, and control of erosion of riverbanks due to high tides.

After the weir was built, WWs and WTPs were commissioned at Katargam in 1997 (a capacity to supply 240 MLD). In subsequent years WW facilities were built at Sarthana and Rander, and intake wells in 2001 and 2003 respectively. All these efforts increased the water supply capacity from 440 MLD in 2001 to 580 MLD in 2006. The existing water supply facilities and their spatial location across the city can be seen in figure 1.[17]

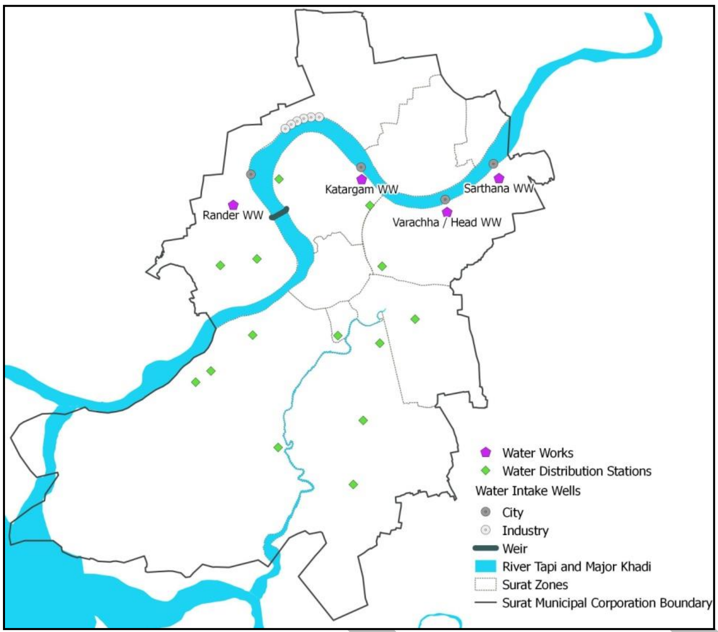
14 Interview with Mr. Jagadish Thadani (Assistant Engineer) of Surat Municipal Corporation 18th July, 2013

15 SMC, CE Special Cell, http://www.suratmunicipal.gov.in/CESpecial/CEspecial_pe.aspx?SrNo=005005305405005405005405

16 ibid

17 Alternative water sources: Climate change in the region will also bring uncertainty in the rainfall pattern, and thus will affect water availability generally. To address this issue, the city has proposed many projects that are still in the evaluation stage. One of the proposals is to build more check-dams on the Tapi River so that the storage capacity can be increased. Based on the 2012 water policy from the Central Government, Surat wants to request the Ukai Dam Authority to give top priority to drinking water and release water according to the needs of the city. It is also relying on the ambitious project of interlinking of the rivers in India. If implemented, the Tapi and Narmada will be able to share their respective excess water. This will be helpful during periods of low rainfall, droughts, or in case more dams are constructed upstream of Ukai. Another proposal that has received much support is the laying of direct water pipeline from the Ukai dam to the city. This project, if implemented, will help with water quantity and quality part as the cost for extensive treatment of raw water available downstream will be saved.

Figure 1: Water service facilities in Surat



Source: SMC

3.3 Financial adaptation

In the post 1994-flood period, the Surat Municipal government augmented its financial capacity to invest in capital works in five main ways. First, as we saw in the case of the Singanpur Weir, the city's industrial elite has contributed funds to aid source augmenting construction projects.

Second, the SMC had already shifted to an accrual based accounting system in the early 1990s. In 1992-1993, with external encouragement (which came through the World Bank), SMC had modernized its accounting system to accrual based, and SMC staff were trained by an external consultant in these new financial practices (Price Waterhouse). The conversion to accrual-based accounting included a shift to double-entry accounting. The benefits of these changes were several. They included more effective financial planning, transparency, and alignment with national and global standards. There were also benefits that were felt later on: the new accounting system played an important role in earning SMC a high credit rating (AA-) from CRISIL (2008[18]) that made it eligible to issue municipal bonds, though it has never done so. Moreover, the new accounting system made it easier to implement JNNURM-funded projects later on (Surat Municipal Corporation, Awards for Excellence p.19-26). A few years after the 1994 disaster, the SMC also revised its accounting system for valuation of fixed assets in 1996-7, which also helped augment revenues (Surat Municipal Corporation, Awards for Excellence, p.25). By 1998, all of the SMC's departments were computerized (Bhat et al., 2013, p.3), including the creation of a separate accounting system for water and the bringing online of the billing and payment of water supply.

18 http://www.crisil.com/ratings/company_fact_sheet.jsp# [Enter Surat in the search bar on the left side of the page]

Third, the SMC has been strategic about applying for and utilizing to the fullest external funding be it from the state, external foundations, or the national government. Thus in 2006, with the help of the capital investment from Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana (SJMMSVY) schemes, SMC carried out augmentation projects on various WWs to increase their capacity to treat more raw water and new storage structures were built. The city has been sanctioned Rs. 5091.3 million[19] under JNNURM to carry out water supply related projects. Under the SJMMSVY scheme, SMC has received Rs. 740 million for water supply projects in the newly annexed areas.[20] This timely utilization of funds to build necessary facilities and expansion of network has resulted in a steady increase in water supply, less stress on the existing infrastructure, and phased incorporation of the newly added areas in 2006.

Fourth, SMC began to look for energy savings in its water related expenditures. In 1997, India's national Ministry of Non-Conventional Energy Sources (MNES), which was working with UNDP and national Program on Energy Recovery from Urban and Industrial Waste, was looking for a city willing to do a biogas electricity generation pilot project, and put out a broad invitation. Surat responded and worked with MNES and Indian Institute of Science to prepare a feasibility study. In 1999, SMC decided to undertake a pilot project in biogas electricity generation at the Anjana Sewage Treatment Plant and began looking for a contractor (SMC website: Environment Cell, 2015). By 2001, SMC had established an Energy Efficiency Cell, led by the municipal commissioner to conduct energy audits aimed at cutting energy use in the water supply network leading to significant savings as we discuss in greater detail later in the paper. All of these efforts can be seen as forms of financial adaptation at the local level.

Finally, Surat is generating revenue by selling not just water but selling 'treated' waste water to industries. This latter strategy is novel for Indian cities. It not only provides the city with extra revenue, but by recycling treated waste-water, the city is augmenting its water sources in new ways.

Table: Water Works details

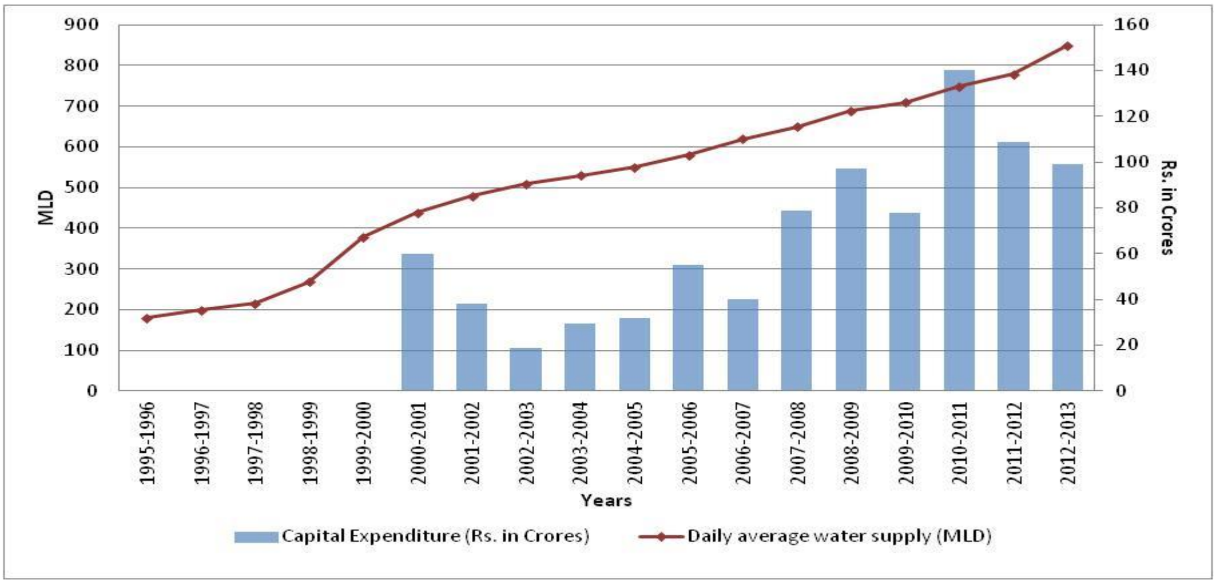
Name	Location (Zone)	Distance from the city (SMC HQ) in Kms.	Capacity		Year commissioned
			Treatment (in MLD)	Storage (ESR* + UGSR**) (in Lakh Liter)	
Sarthana Water Works	East	12.14	470	562.5	2001
Varachha/Head Water Works	East	8.5	68	445	1898
Katargam Water Works	North	7.1	390	675	1997
Rander Water Works	West	4.75	250	435	2003

*Source: SMC, Author; * Elevated service reservoir; ** Underground storage reservoir*

[19] Hydraulic Department, SMC, http://www.suratmunicipal.gov.in/Hydrolic/Jnnurmprojects.aspx?SrNo=905005305406705406

[20] ibid

Figure: Average Daily Water Supply and Capital Expenditure *



* Note: Capital expenditure data is not available from 1995-96 to 1999-00

Source: SMC

4. Turning Point 2: How the Floods of (1998, 2004 and) 2006 Forced deeper Lessons in Resilience

The innovations put in place after the 1994 flood were tested in floods that followed in 1998, 2004 and then a major flood in 2006. These flooding events were all associated with the a combination of natural factors and emergency discharge of water from the Ukai dam following intense rainfall in the upper catchment areas of the river in neighboring states. There was considerable damage and inundation during these floods, with 2006 being the landmark event where nearly 80% of the city was under water, power and electricity was disrupted for nearly three days with huge economic costs due to lost wages, production losses and property and infrastructure damage. Despite the devastation there was no plague or serious health catastrophe as in the aftermath of the 1994 floods.

In the immediate aftermath of the 2006 floods, SMC managed to restore water supply within 36 hours (in our interviews the figure ranged from 24 – 48 hours). In the immediate aftermath of the 2006 floods, SMC also managed to restore electricity within 36 hours (ICRIER Workshop in Surat, 2013, Small Group 3,9.b). There were also no reported cases of standing water that required pumping. This was attributed to the installation of a gravity-flow underground drainage system that had begun after 1994 where drains are constructed along every road, with manholes every 30 meters, and are cleaned on a regular basis. In the immediate aftermath of the 2006 floods, the cleanup was accomplished in 22 days, aided by coordination between private entities and NGOs, the city government, and the state government (ICRIER Workshop, 2013,Small Group 1,4.b-c; Parmar, 2013, 7), and in general NGOs became more active in the city after 2006 (J. Desai, 2013, 12). Yet, the extent of damage in 2006 drove home the many vulnerabilities that still remained, particularly around the need to build deeper resilience and systems of quality control, as we see next.

4.1 The GRID water distribution network, redundancy, and the role of engineers on the ground

Surat has taken many steps to make its water distribution system more hazard resilient. One of such innovative measures is the redundancy built into its water distribution network. This system is known as the GRID network/layout. In it, the water works and treatments plants are connected to water distribution stations with the interconnection such that water can be supplied to the distribution stations from any of the treatment plants[21] (see figure below). The pipelines in this GRID layout are also fitted with valves so that water can be stopped from entering the distribution stations from any specific treatment plant. This redundancy system was set up in the early 2000s and it proved critical in the quick restoration of the water supply system post 2006 flood.

During the 2006 flooding of the city, Rander experienced the most damage (electrical and mechanical) and water contamination. The then executive engineer (Mr. K.S. Khatwani) responsible for restoration of the water supply system was aware of all the machineries and the extent of damage at different WWs. Based on this knowledge, the department carried out the restoration process[22]. First Sarthana WW located in the north was restored and the distribution system was filled with clean water, using the GRID system. Subsequently, the WWs at Varachha, Katargam, and Rander were restored. The inbuilt redundancy in the water distribution system helped to restored water supply in Surat within 36 hours of flooding. At present, the hydraulic department is working to make the GRID system more efficient by fixing the loopholes, such as bypassing lines and installing valves.[23] This is one of the unique systems inbuilt in the distribution network that makes it climate proof and helps to bounce back after a disaster. This system is worth emulating for other cities that want to become more prepared and resilient against climate change risks.

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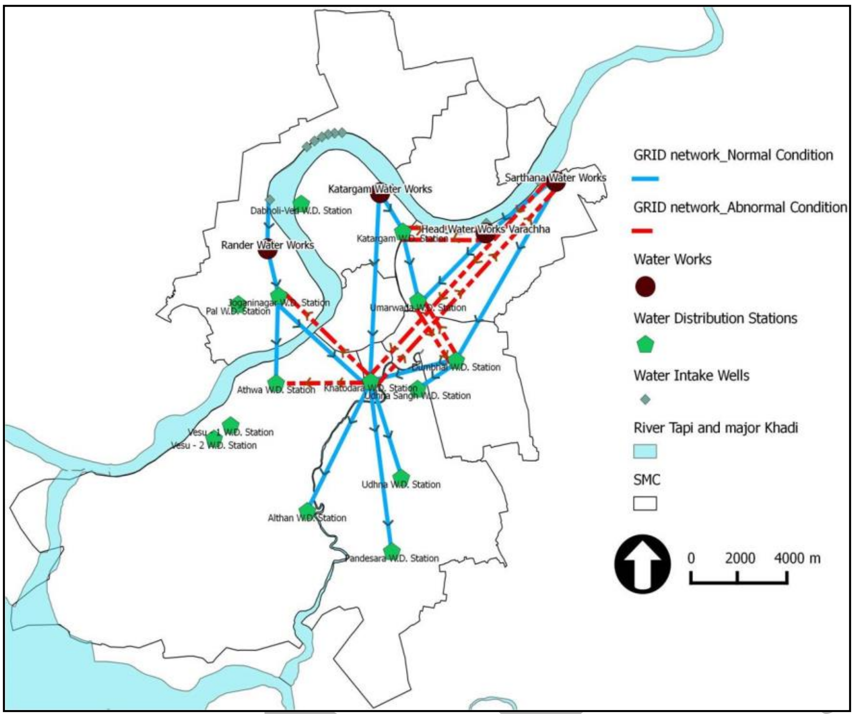
21 Hydraulic Department, SMC, http://www.suratmunicipal.gov.in/Hydrolic/Water_supply_initiatives_taken.aspx?SrNo=505005305406705406#lnk1

22 Interview with Mr. Nilesh Patel (Executive Assistant) of Surat Municipal Corporation 18th July, 2013

23 ibid

Figure: GRID water supply network system



Source: SMC, Author

4.2 Electrical and Mechanical Maintenance

Immediately following the 2006 flood, the electrical and mechanical machineries installed in the water facilities were in urgent need of restoration.[24] Some of the measures that the city had implemented earlier made this vital restoration work restoration easier. For example, the city had agreed to comply with ISO 9001 standards that were put in place in 2003, which set out the criteria for quality management system (QMS). QMS in turn lists out the organizational structure, procedures, processes, and resources needed to implement quality management. In other words, it standardizes all operations related to water supply. Part of the protocol requires formulation and execution of routine, breakdown, preventive and predictive maintenance schedules for electrical and mechanical machines.

The QMS requirements forced the city form two dedicated teams for electrical and mechanical maintenance. The electrical maintenance team consists of maintenance assistants, electrical supervisors, cable jointers, wiremen, and helpers. The electrical maintenance team is comprised of maintenance assistants, fitters, and helpers. Both the teams carry out routine maintenance, preventive maintenance, and predictive maintenance. To minimize breakdowns with regular maintenance, both the teams generate data related to breakdown.[25] These regular

[24] ibid

[25] Administrative Staff College of India, Submission for Best Practice for service delivery 2008, http://www.asci.org.in/ICT/Resources/CaseStudies/WSandSewerage/18Water%20Supply%20system%20Surat.PDF

preemptive steps not only help in maintaining high water supply standards, but also avoid and absorb the risks from a disaster.

4.3 Water quality control

The quality of water in rivers and streams is adversely impacted due to events like flooding and droughts. After a flood, water is contaminated with microorganisms such as bacteria, sewage, agriculture and industrial waste. Highly contaminated water needs more treatment to make it suitable for domestic use. Surat also faces the extra challenge of salinity of fresh water due to its proximity to the sea. Besides these factors, many of the water quality related incidents occur due to events in the water distribution network.[26] To address these water quality issues, the water department has taken many measures.[27]

After the Singanpur weir was built in 1995, many of the water quality issues were resolved. However, upstream pollution and water contamination due to climate change factors still remained a concern. An example for the latter is the 2001 case of red worms in water due to rise in water temperature. It contaminated the entire water network and once the problem was discovered, it was resolved in 2002 by rigorous screening at water treatment plants.[28] To resolve such water quality issues, various government agencies at the state, district, and city level along with numerous stakeholders came together and agreed to adopt drinking water standard IS 10500: 1991 in 2003.[29] Since then the city has followed high standards for water treatment and have complied with the standard of treating certain parameters of water to a set permissible level. In 2005, the water quality standard was upgraded to IS 10500: 2010. Under this, the city had to follow a detailed protocol to treat water at various stages (source to consumer) of the water distribution system. This protocol provides details of the parameters to be measured, the frequency at which they should be measured, and even the kind of instruments that should be used to measure them. The trained chemists in the labs set up at each WW follow these guidelines to measure and monitor water quality.[30] Besides this, to ensure better water quality of its source, the city has already built new sewage treatment plants upstream of the river.[31]

The Hydraulic department is also proactive in regularly improving their water quality monitoring and treatment setup.[32] The improvements are aimed at handling uncertainties

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26 Water Resource management, Smart Cities Council. Accessed on 25th February, 2015 from http://smartcitiescouncil.com/system/tdf/public_resources/Urban%20Water_%20Smart%20vs%20Traditional.pdf?file=1&type=node&id=1806

27 Interview with Mr. Nilesh Patel (Executive Assistant) of Surat Municipal Corporation 18th July, 2013

28 Interview with Mr. Rajesh Patel, Chief chemist at Katargam water works, 15th March, 2013.

29 Skoch Consultancy Services Private Limited, www.skoch.in, http://skoch.in/images/stories/knowledge_repository/urban/Surat%20Municipal%20Corporation.pdf

30 Interview with Mr. Nilesh Patel (Executive Assistant) of Surat Municipal Corporation 18th July, 2013

31 Interview with Mr. Jagadish Thadani (Assistant Engineer) of Surat Municipal Corporation 17th July, 2013

32 The technological part of the water supply system was also updated as many parts of monitoring are computer automated. These include, water quality from the intake wells to assess the amount of chemical needed to treat raw water and characteristics of raw water (pH, dissolved oxygen, turbidity etc.) for its subsequent treatment to specific standards. Water is again tested for some of the parameters after the treatment process to determine the efficiency of the treatment plant. Once water is supplied to consumers, samples from residential and commercial properties are collected and tested so that quality is ensured at the

related to climate change. Currently the WTPs have clarifier and sand filtration facilities for filtration. The city is looking into the feasibility of installing activated carbon filters to supply assured quality of water under any circumstances. If approved, it will be installed at the Rander WTP. The city is also looking into replacing chlorine (currently used to treat water) by chlorine oxide, as the former might not work in case the water pollution levels are too high.[33] These steps indicate SMC's willingness to invest in technologies that will make the city adaptive to extreme events and as a co-benefit; it will ensure quality service delivery to its citizens. By considering future scenarios and taking steps to augment the design of water facilities with latest technologies, Surat is indeed ahead of the curve among Indian cities to climate proof its water supply system.

4.4 Un-interrupted water supply

The Hydraulic department for Surat city learnt a great deal about emergency response during the flood of 2006. Though the staff members were trained, the circumstances they faced during the days of the flooding challenged them. Even though to the restoration of water supply was quick, the lessons that were learnt from the disaster have helped the city to take extra measures for the future. Since 2006, the department has taken many measures so that it is able to supply water during similar events.

Before restoration of water supply after an event like flood, it is more important to restore electricity in the water facilities. After 2006, all the power transformers located within the premise of water facilities have been kept over a physical structure and other electrical components like light-tension line and high-tension line panels are kept over HFL[34]. As a back-up measure to run the facilities, dual power system was also installed in each of the water pumping stations and booster stations. In case electric system cannot be restored, the city has planned to supply water to its citizens through water tankers. For this purpose, each WDS are provided with water tanker filling facility. To run pumps to fill the tankers, diesel generators have been set up in WDS[35]. Besides restoring electricity, treatment of the raw water is critical in the face of such events as the concentration of pathogens in water is high. To address this concern each WW stocks certain amount of chemicals in preparation for extreme events. The city also stockpiles portable chlorine kits for the field staff and chlorine tables to be distributed by the Health department.[36]

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consumer end. Thus, except the last phase, Surat's water quality monitoring is automated. It can further make its water network climate proof by incorporating technology that communicates real time data on water quality in all its water distribution phases.

33 ibid

34 Interview with Mr. Nilesh Patel (Executive Assistant) of Surat Municipal Corporation 18th July, 2013

35 ibid

36 Administrative Staff College of India, Workshop on ICT for Effective Urban Governance and Service Delivery in India, 2011, Bangalore http://www.asci.org.in/ICT/Resources/CaseStudies/WSandSewerage/18Water%20Supply%20system%20Surat.PDF

4.5 Administrative measures: Documentation as a Learning Tool

One of the key objectives of a city administration during and immediately after a sudden disaster is to restore basic services. To achieve that goal, effective coordination among officials and staff on the ground is crucial. The city officials in Surat learnt the importance of coordination after the 2006 floods. Since then many measures have been put in place to foster better disaster preparedness. A new emergency management system was created under which two emergency response centers were set up, one each for the waterworks and water distribution centers. Surat has also formulated teams for each of the WWs and WDSs. The members of these teams have been assigned responsibility for normal course and for emergency situations.[37] During any disaster, the nodal officers of these centers contact each other to coordinate among themselves. Besides these, every April (before the monsoon season) a booklet with the name and contact numbers for each of the pertinent officers is published. It also lists the stock of chemicals to be stored (discussed earlier) in each of the WWs along with the contact information of NGOs that distribute water and food pouches during disasters.

Besides preparing for the sudden onset of any calamity, the Hydraulic department has also used the documentation of past events to create teaching materials used to train its staff. Documentation of the 2006 floods, for example, explains the factors that caused the flood, the amount of damage incurred by the department, the various measures taken to restore the water supply system, and the lessons learnt. This document has proved helpful especially for new staff members who are unaware of the event and the subsequent response measures taken by the city administration. Thus, this documentation has evolved from a manuscript to a learning tool.[38]

The lessons from past flooding events also resulted in some important institutional measures to ensure preparedness in the event of future disasters. In addition to the dedicated response teams, each WW is stocked with chemicals used for water treatment to be used during times of emergency. Portable chlorine test kits for the field staffs and chlorine tables to be distributed by health department also stock pilled for such times. As one of the response measures, SMC have arrangements for de-watering pump sets for specified low lying areas and tankers to supply drinking water.

Smooth daily operation of the water supply system is a critical for a city's administration. A regular water supply system dependent on facilities like water works (WW), water distribution stations (WDS), and pumping stations to supply water from the source to the consumers. To provide water in an uninterrupted manner on a daily basis, SMC has contracted out the operational responsibility of these facilities to private parties. These private companies have installed dual power supply systems in these plants to ensure uninterrupted

[37] Administrative Staff College of India, Submission for Best Practice for service delivery 2008, http://www.asci.org.in/ICT/Resources/CaseStudies/WSandSewerage/18Water%20Supply%20system%20Surat.PDF

[38] Interview with Mr. Jagadish Thadani (Assistant Engineer) of Surat Municipal Corporation 17th July, 2013

power supply and in turn uninterrupted water supply. Other than running the stations, each of the facilities has diesel generator sets for lighting arrangements.

4.6 Resilient technology and management

The water supply network in a city includes technologies used to access water at the consumer end. During extreme events such as flooding, some of these technologies are more resilient than others. The World Health Organization has listed various water technologies and ranked them based on their vulnerability and adaptive capacity to climate change in their Vision 2030 document. Among the water supply technologies, utility-piped water supply and tube wells are considered potentially resilient to all expected climate change. However, under extreme circumstances such as heavy flooding these are vulnerable to water contamination'[39] The table below lists the water technologies and their level of resilience to the climate change risks.

Table: Raking of climate resilient water technologies

Water Technologies	Resilience to Climate Changes	Ranking
Utility piped water supply	Potentially resilient to all Climate Changes	1
Tube wells		
Protected springs	Potentially resilient to most Climate Changes	2
Small piped systems		
Dug wells	Potentially resilient to only restricted Climate Changes	3
Rainwater harvesting		
Unprotected dug wells	Non-improved drinking-water sources	4
Unprotected springs		
Carts with small tank or drum		
Surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels)		
Bottled water		

Source: WHO, Vision 2030 document

Given the list of resilient technologies discussed above, to assess the level of resilience at the city level it is important to look at the percentage of households with most resilient technology. The table below shows the same for Surat Municipal Corporation. The percentage of households with access to drinking water through tap water and tube well in 2001 and 2011 are shown below. The table indicates that Surat has improved in every category over the last decade. Given the city administrative boundary expanded during this period, this feat is even more remarkable. Part of this achievement can be contributed to the financial grants it has received from the Central and State governments through different schemes in the 2000s. The city has used these grants to build new infrastructure so as to expand its coverage of piped water supply.

[39] WHO, Vision 2030: The resilience of water supply and sanitation in the face of climate change 2009, http://www.who.int/water_sanitation_health/publications/9789241598422/en/

Table: Usage of water technology resilient climate change

Distribution of Resilient Water Supply Technology - Surat Municipal Corporation	2001	2011
Total number of Households (HH)	5.46 lakhs	9.49 lakhs
HH with Tap water & Tube well/Bore well (of all types of water supply connections)	91.00%	96.54%
HH with Tap water & Tube well/Bore well (of all with 'within premises' connections)	98.40%	99.44%
HH with Tap water & Tube well/Bore well (of all with 'near premises' connections)	75.97%	85.19%
HH with Tap water & Tube well/Bore well (of all with 'away' connections)	62.08%	53.57%

Source: Census of India, 2001 and 2011

4.7 Learning to promote accountability for Water: Monitoring Quality

One of the goals across all water departments is to reduce the amount of Non Revenue Water (NRW). The Ministry of Urban Development sets the benchmark level for non-revenue water (NRW)—or water that is supplied but which is not accounted for in revenues collected—at the city level at 15%.[40] But most of the Indian cities experience a much higher level of NRW, which leads to low cost recovery and higher financial burden on them. High NRW can occur due to inefficiencies of water facilities, leakages, and illegal connects among other reasons. Ways to reduce NRW include using appropriate technology to detect leakage, repairing old and leaking infrastructure, setting up water consumption meters at the consumer end and flow-meter at the water facilities. Flow-meters are devices that measure the amount of liquid that passes through them. If appropriate measures are taken by a city, it can reduce physical loss of water, ensure quality and pressure of water, earn revenue and recover the cost to treat and distribute water as well as can lead water conservation practices.[41] For Surat, with its climate-threatened water source, the ability to ensure optimal and efficient use of available freshwater is imperative.

In the pursuit of reducing the percentage of NRW, Surat has taken multiple steps in the last decade. Since 2001 Surat has committed itself to ISO 9001: 2000 for water QMS. To fulfill this commitment to deliver treated water, 20 flow-meters in four WWs (Sarthana, Varachha, Katargam, and Rander) were installed. These measure the quantity of raw water coming in and treated water going out of the water works. The water department also installed 15 flowmeters in its 12-water distribution system to keep record of the quantity of water dispatched to water distribution stations on a daily basis. Currently all the new facilities that are being built automatically have flowmeters installed. Such measure has been complemented by installing meters in flats and high-rise residential areas. These measures demonstrate that Surat is serious about reducing leakage of water at both bulk and retail

[40] Service level benchmarks, Ministry of Urban Development, Government of India http://moud.gov.in/sites/upload_files/moud/files/pdf/Indicators&Benchmarks.pdf

[41] The Issues and Challenges of Reducing Non-Revenue Water, Asian Development Bank http://www.adb.org/sites/default/files/reducing-nonrevenue-water.pdf

levels. Similarly all industrial units are metered and with their higher tariffs, generate among the largest percentage of revenue for the Hydraulic Department. When metering began in 2006-07, 125 industrial units were fitted with self-powered electro-magnetic flowmeters (replacing previous mechanical flowmeters). These measures resulted in almost 50% increase in the revenue generated from the industries per year (Rs. 240 million in 2008 and 500 million in 2013.).[42]

SMC has also installed pressure transmitters and pressure gauges at various WW and WDS. These efforts yielded in decline in NRW, which currently stands around 20%. Despite these efforts, it is acknowledged that with few residential meters installed, it is difficult to calculate the exact percentage of NRW.[43] Even though the assumed NRW in Surat is lower compared to some other cities like Kochi and Ludhiana, metering for each residential unit is necessary to increase water use accountability.

4.8 New Systems for Water Leakage Mapping

In the last two decades, Surat has been trying to cater to high water demand due to increase in population expansion of city limits in 2006. At present the gross daily water supply stand at 980 MLD. With the growing risk of climate change affecting its water source, the city has started multiple programs to address water leakage. These include water leakage mapping and water audit. The main object behind these programs was to achieve 15% non-revenue water benchmark set by Ministry of Urban Development. [44] In one of the initiatives, a new non-revenue water cell was formed to oversee a newly developed complaint redress system. The motivation came from the frequent complaints about pressure, leakage and breakage of the system and need to achieve service level benchmarks (SLB) set by urban development ministry at the central level (MoUD). The cell was planned as an institutional intervention departing from the previous piecemeal approaches to plan, monitor and implement the reforms in the water supply system. This helped the city to collect and map water leakage and water contamination data.

The zone-wise leakage data collection started in 2005, before the 2006 floods, while the leakage mapping started in 2007. Under the new setup, water leakage received due attention as the complaints are addressed with 24 hours. The complaints are reviewed a zonal and city level on a daily and weekly basis respectively. As the city officials understand the interrelations between water leakage, contamination, water-borne diseases, and the cost to transport and pump the valuable portable water, they are not only collecting leakage data but also using it to study leakage patterns and find frequent leakage point in the water supply system. This practice has yielded results as SMC has been able to pinpoint and address some of the reoccurring problems. The case of the Central zone is a good example as the data trend and mapping of frequent leakages and contamination indicated that most of the complaints originate from this zone and the reason was found to be the old and crumbling pipeline

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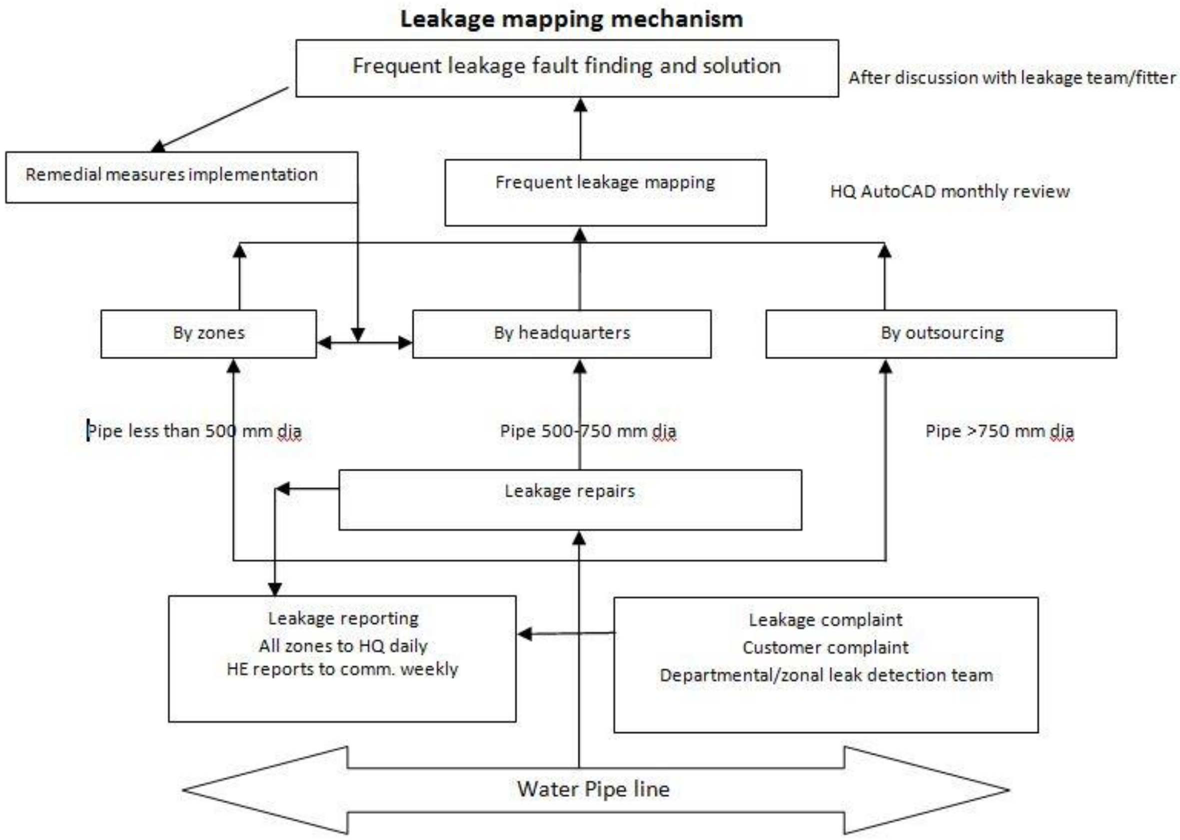
42 ibid

43 Interview with Mr. Jagadish Thadani (Assistant Engineer) of Surat Municipal Corporation 17th July, 2013

44 www.urbanindia.nic, http://urbanindia.nic.in/programme/uwss/uiww/PPT_7th_Meeting/NRW_Reduction_Mgmt_Surat.pdf

network. To resolve this issue a 25 km pipeline was laid out in this zone at a cost of Rs. 33.6 million. Since the laying of the new pipelines, the leakage complaints from this area have decreased by 50% of the original numbers. In 2005-06, the numbers of complaints were more than 1250 in a year; the figure fell to close to 300 by 2011-12 in the same zone. Similar trends have been noticed for the city as a whole as the numbers of complaints have dropped from 9,644 to 2,888 (for close to 3000 kms of water pipeline), a 70% decrease over a span of six years.[45] The combination of technological, capital, and resource interventions have not only helped in saving precious portable water and helped the city to get closer to minimum service level benchmark, but they also have resulted in lowering the chances of water borne diseases.



Source: NIUA Pearl Compendium of Good Practices

4.9 Innovative sustainability measures: Energy savings in water systems

For Surat and for many large Indian cities, a major part of annual cost incurred by water departments goes towards paying for electricity usage to operate water facilities. Historically the electricity consumption charges have been more than 50% of the annual water supply expenditure. Surat has taken steps to cut this cost as part of their broader water system improvement process. A dedicated Energy Efficiency Cell was set up in 2001. This cell is responsible for in-house energy audit, identify energy conservation projects and their

45 ibid

feasibility, check feasibility for own power generation, and monitoring usage of electricity. Under the leadership of the municipal commissioner, this cell is managed by trained staff members (certified by Bureau of Energy Efficiency, India).[46]

Since the inception the energy efficiency cell, the water department has created cost savings by installing efficient pumps and machineries with state-of-the-art technologies at various facilities, bypassing overhead tank to distribute water to Pandesara industries, and re-engineering of the water distribution routes from WW to WDS.[47] The last measure was implemented when it was found that transmission of treated water consumed 20% of the total electricity needed. The re-routing has been implemented at four facilities at a cost of Rs. 20.1 million. These projects save 8.174 million KWH per year, which in turn saves Rs. 32 million for SMC.[48] In the last decade between 2001-02 and 2012-13 close to Rs. 44 million was invested for energy saving measures. This has yielded an annual saving of around Rs. 59 million.[49] The gradual drop in total electricity cost for the Hydraulic department over the years is provided in the table below. The Hydraulic department has achieved low energy cost and increase in water supply efficiency.

Table: Impact of energy saving measures

Year	Average Daily Water Supply (MLD)	Percentage increase in Water Supply	Electricity Bill for Water Supply (Rs. Crores)	Percentage increase in Water Supply Electricity Bill	Electricity Bill of SMC (Rs. Crores)	Percentage increase in SMC Electricity Bill	Share of Water in SMC's Electricity Bill
1996-97	199	-	8.29	-	12.66	-	65.48%
2003-04	479	140.70%	26.4	218.46%	43.18	241.07%	61.14%
2012-13	850	77.45%	53.19	101.48%	93.23	115.91%	57.05%

Source: SMC

4.10 Water conservation practices, recycling and ground water recharge

In recent years Surat has not faced acute water shortages due to timely development of water facilities and infrastructure.[50] However, with rapid increases in population, industrial growth, and the expansion of the city limits, and with the overarching issue of climate uncertainly, water shortage remains a real possibility for the future. Under such circumstances it becomes important to create public awareness about water conservation.[51] SMC has taken some steps along these lines. It has conducted many seminars and workshops, designed and executed

46 SMC, Energy Efficiency Cell, http://www.suratmunicipal.gov.in/energyeff/050808_Re-engineering(Hyd).pdf
47 SMC, Energy Efficiency Cell, http://www.suratmunicipal.gov.in/energyeff/energy_benifits.aspx
48 SMC, Energy Efficiency Cell, http://www.suratmunicipal.gov.in/energyeff/050808_Re-engineering(Hyd).pdf
49 SMC, Energy Efficiency Cell, http://www.suratmunicipal.gov.in/energyeff/energy_benifits.aspx
50 Interview with Mr. Jagadish Thadani (Assistant Engineer) of Surat Municipal Corporation 17th July, 2013
51 ibid

campaigns to spread the awareness for water conservation, specifically reaching out to schoolchildren, colleges, and NGOs to increase the level of awareness in the population.[52]

Besides the awareness campaigns, SMC also mandates rainwater harvesting in all the new high-rise building projects with plot area more than 4000 sq. meters. Residential societies and industrial units also get rebates for installing this system. So far, 90 such projects have been completed and there are plans to install many more (around 500) in the next three years.[53] Such initiatives are extremely important to not only recharge the water tables, or help in diversifying the city's water sources, but also to empower and educate the community to conserve and use water with care. All these practices, in turn, build adaptive capacity in the face of everyday challenges as well as climate change.

Besides recycling, conservation and ground water recharge, the city is now careful about regulating development in the river's flood plain and in its post 2006 Master Plan that formally restricts development within a prescribed distance from the river. For example, the plan establishes a 150-meter no-construction buffer zone extending from the high flood level, and designates flood-prone areas as recreational zones (Basak, Interview, 2013, 2). This has also involved a long process of relocating slums and poor communities from the river's edge and away from low-lying areas to affordable flats on higher ground. This relocation, however has been controversial, and has been criticized as top-down and authoritarian by many (Chu 2015). In our interviews with workers who were thus relocated there was considerable dissatisfaction at being forced to move in ways that disrupted social networks and added miles to their access to work. City officials acknowledge that not everyone was satisfied, but said that there were few alternatives to relocation from unsafe ground. A lesson that city officials can take away from this experience is that while a more participatory and deliberative process would have taken more time, it would have secured greater buy-in, kept social ties intact in the relocation process, and resulted in perceptions among the residents that the process had been fair.

4.11 Reforms in water connection metering and restructured tariff plans

Water metering is an important step for a city to achieve many of its water management goals. Even though it involves initial investment and cost of continued maintenance, it can help in saving water, reduction of water leakage, more water accountability, and revenue generation. Despite these multiple benefits, most Indian cities have low water meter penetration. Surat is no exception to that as it had only around 1% of all domestic water connections are metered.[54] However, since JNNURM programs were launched in 2008, SMC has taken up metering more actively. SMC did this to comply with the conditions of recovering full operation and maintenance charges, pushed in part by benchmark norms and funding requirements of accessing national funding.

52 SMC, Hydraulic Department- Water Conservation Practices, http://www.suratmunicipal.gov.in/Hydrolic/Water_conservation_practices.aspx?SrNo=405005305406905405

53 SMC, Hydraulic Department

54 www.urbanindia.nic, http://urbanindia.nic.in/programme/uwss/uiww/PPT_7th_Meeting/NRW_Reduction_Mgmt_Surat.pdf

Recently, the city has also moved into 24x7 metered water connection schemes. The scheme covers about 19 % of the city. The 24x7 metered water connection scheme was first introduced in New North Zone where the scheme was introduced first in 2015. - Amroli, Kosad area. - This area is mostly inhabited by lower middle income groups. The scheme is expected to also cover other areas such as Jahangirpura, Jahangirabad, Vesu, Pal and Pal-Palanpur soon. Metering installation was carried out by a local technical institution (SVNIT). Readings are outsourced to an agency currently and will be taken over by SMC when 24x7 is fully implemented

The implementation of reforms saw Surat abandoning its previous tariff system and rate structure. Prior to 2008-09, water charges were embedded within the property tax and were collected in the form of flat rates or charges benchmarked to plot area and zone. E.g., for residential and non residential properties, a certain percentage of ratable value (with a fixed minimum amount) was charged as monthly water fees as part of the household's property taxes.

The reforms introduced a clearly defined volumetric tariff system at the consumer level. The reforms started with an amendment to the Bombay Provincial Municipal Corporations Act (BPMC) act that governs Surat in 2007 which allowed the SMC to restructure the tariff rates enabling it to levy user charges in consideration with O&M costs. This delinked the water charges from the property tax enabling the introduction of a volumetric tariff system at the consumer level through implementation of user charges and water meter installation policy. The amendment in the BPMC act allows the municipal commissioner to levy water and sewerage charges after the approval from the standing committee. The reforms in the tariff system and tariff rates were implemented by the hydraulic department that is charge of long-term planning, design & implementation & Monitoring of various water supply schemes according to the Master Plan. The water tariff is now based on the O&M expenditure of supplying water and the carpet area of the households for which connection is given. To meet the set goal of recovering cost, the rates for each slab have been redesigned. Tariff rates were revised for all types of properties. Tables 3 and 4 in Annexure A provide illustrative rate changes.[55] The existing low tariff for residential water connections is possible because of high rates levied on industries. In other words, cross-subsidized rates make the existing system work, but to reduce leakage and be financially sustainable in the long run, the city has to continue its water metering efforts more aggressively, as it is now doing.

5. Turning Point Three: Creating New Institutions to Plan Within a City Climate Resilience Strategy

Surat's efforts to secure its water and urban systems in the face of extreme events not only won awards, but also attracted the attention of global foundations, such as the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN) which selected Surat in 2010 as one of 10 Asian cities that it would invest in to develop urban resiliency strategies.

55 ibid

Over the next 3-5 years this ACCCRN partnered with SMC and TARU Leading Edge, a consulting company as well as with the city's leading industrial association, the South Gujarat Chamber of Commerce and Industry, local and national universities, NGOs and other civic actors to develop a number of innovative initiatives to help the city build greater resiliency (See Bhat et al. 2013, Karanth and Archer 2014, Chu 2015, Chatterjee 2015)

These included the creation of a new institution, the Surat Climate Change Trust (a city, business, community partnership) that became the site where the partners developed the City Resiliency Strategy (CRS) in 2011 through a process of cross sectoral and extensive civic engagement (929 households in 110 settlements were interviewed, Bhat et al. 2013). The most significant initiative under the CRS was the development of an end-to-end early warning system that used hydrological, meteorological and reservoir modeling to assess flood risks, and then helped develop protocols to coordinate multi-agency decision-making related to the Ukai dam water release process. The EEEWS would monitor conditions in real time on a daily basis during the monsoon season, and provide Surat's residents 48 hours advance notice in the event of water releases from the dam, as opposed ot barely 6 hours in the past (pre-2006 period). All citizens were connected to the city using SMS notifications to receive these alerts.

The Early Warning system, and the many other initiatives that the city had already taken as described in the rest of the paper, were tested during the floods of 2013. Relative to the devastation of the 2006 floods when over 120 lives were lost, there were no reported deaths, and although water entered most wards, there was no standing water in the city a day after the flood event. The early warning system, SMCs efforts to move people out of the flood plains, the practice of firms and homes elevating their plinths or leaving the ground floor for parking (SMC interviews, see also Chatterjee 2015) have all helped mitigate the city's traditional flood risks.

The Surat Climate Change Trust (SCCT), and the CRS encourages SMC and other agencies to work across sectors – water, housing, health. For example in 2011, ACCRN helped facilitate the establishment of the Urban Service Monitoring System (UrSMS). This digitized system enables city officials to monitor water quality and disease trends in near-real time, and receive and respond to complaints. UrSMS also generates automated alerts and reports (Rajasekar et al, 2011; Bhat et al., 2013, p.11; Chu, 2015, p.82). Water quality data are collected from around the distribution system; health data are collected from "major hospitals, urban health centres, selected private hospitals and private and government laboratories in Surat" to discern trends (Bhat et al., 2013, p.11). The Urban Health and Climate Resilience Centre, an ACCCRN initiative works with local authorities to analyze these patterns so that necessary action can be more effectively targeted. By replacing the manual (paper-based survey) data gathering system, the UrSMS standardized data collection, reduced duplication, and made it easier to process data (thereby improving work efficiency). It reduced government response time by more than 24 hours (Rajasekar et al, 2011; Bhat et al., 2013, p.11). Some claim that the the system's health monitoring component was directly related to an observed decrease in malarial cases in the monsoon season post-2012 (Rajasekar et al. 2011). Still, the existence of these efforts are commendable.

These public, non-profit institutions are important innovations and it remains to be seen if they sustain after ACCCRN funds phase out. Nonetheless, they have served to situate the language of climate change in the center of the daily operations of the municipality and helped frame the wider debate about the need to climate aware planning.

6. Making an Economic Case for Adaptation

Before concluding we presenting each turning point and detailing what the city did at each turn to adapt its water supply system to a climate challenged world, we provide some detail on the economic costs of not doing anything.

6.1 Estimating financial loss of disruptions to water systems during disasters

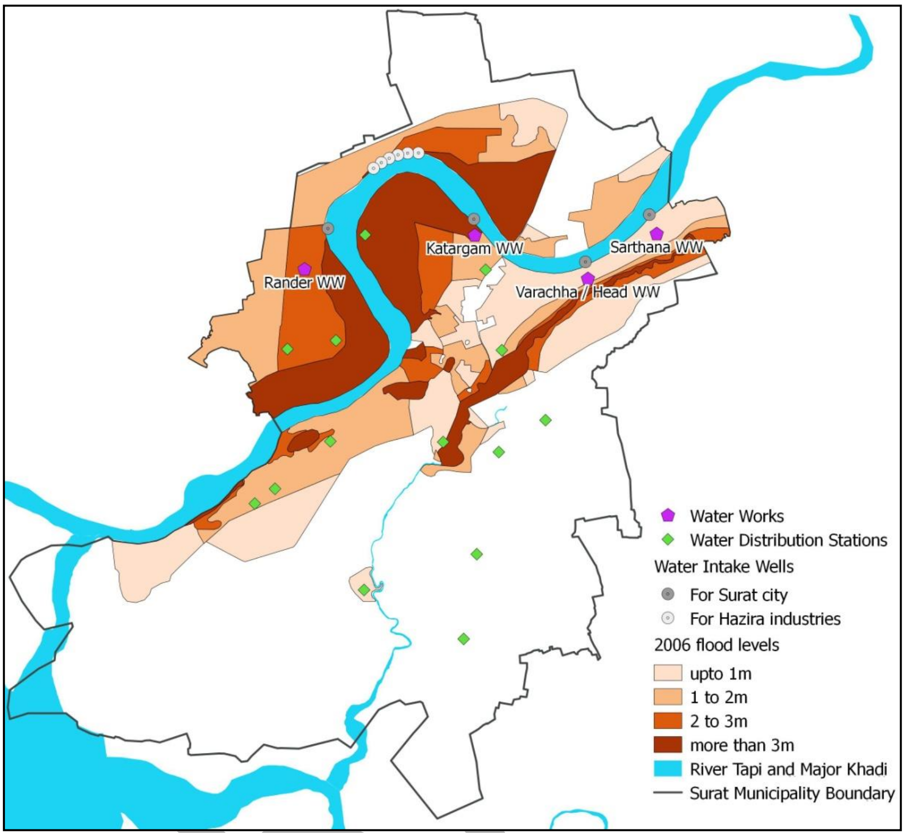
The costs cities bear when climate-related disasters strike can drain municipal budgets, make it difficult or impossible for the city to meet citizens' basic needs, and undermine current and future economic growth and development. As an illustration, this section offers a proxy estimation of the economic damage to the city in the form of revenue losses incurred in the case or another flood large enough to damage Surat's water supply network.

Surat sits on relatively flat terrain. It is less than 10 m above sea level, and the gradient of the city is mainly guided by the River Tapi. During the last major flood of 2006, the western parts of the city were damaged more than the southern and northern sections of Surat. The shape of the river within the city boundaries is also such that the northern bank on the western side of the river is lower lying and hence saw most of the flood impact. The effect was magnified by the building activity in the flood plains and the absence of adequate embankments. This resulted in damage to facilities including water supply infrastructure. The figure below shows the spatial location of the water supply facilities across the city and the flood levels from the 2006 floods. The Rander and Katargam water treatment facilities located on the western side were some of the worst hit public infrastructures. These facilities were shut down for more than a day before their premises were cleaned, electricity and machineries restored, and clean water was supplied from the other Water Treatment Plants (WTPs).

In the discussion below we provide an *illustrative* cost estimation of not acting in the face of climate pressures drawing loosely on past effects, which can be seen as a proxy for the magnitude of losses that can potentially be avoided through adaption. The costs estimated here are based on disaster events, which are discrete events that the public experiences in short periods of time, but it is vital to remember that they are the result of longer term changes and trajectories. To calculate costs for different impact scenarios, we examine two versions of past trends. In the first scenario we assume that the entire water supply network is affected (i.e., all four water treatment facilities are forced to shut down). In the second scenario only two water treatment facilities located in the western part of the city (Rander and

Katargam) are assumed to be affected. The financial loss calculated here only includes revenue loss and the cost borne to provide the same service through other means. It does not include cost incurred due to physical damage to the infrastructure network.

Figure 1: Water supply facilities with 2006 flood levels



Source: Mapped by authors using SMC data

After intake of raw water, water treatment is the first step in the water supply chain. So any damage or malfunctioning of the treatment facilities will affect the entire network leading water supply to stop. Thus our calculations are based on the volume of water supplied from the water treatment facilities for domestic and industry consumption, total annual revenue generated from these two consumer categories respectively, total cost for electricity consumption (largest share of annual cost), and depreciation cost (third largest share of annual cost after staff salary). The cost incurred by the city will include the revenue lost for the number of days the treatment facilities are not operational and the cost to provide equivalent amount of water using water tankers. During the days with non-functional water facilities, the savings gained by the city will include cost of electricity to run the facilities and depreciation cost as part of investment that won't be made. The net cost will be the total cost minus the savings, while also considering 20% revenue loss due to leakages and illegal connections. The net cost will be fully incurred by the municipality, the provider of water in Surat. To bring in private costs of acquiring drinking water during disasters, costs we consider the cost of private purchase of bottled water. Under this scenario, 4.2%[56] of the total water consumption for households and institutions is obtained from private agencies that sell bottled water. The cost per household to acquire drinking water through this channel is also calculated based on the current costs of vended water.

The figures for some of the parameters needed to estimate the above costs are provided below. These figures are approximate values. They come from various sources such as the Surat Municipal Corporation (SMC), interviews with city officials in the water department, staff members at water distribution centers, and bottled water vendors.

i. Total Water Supplied per day = 965 MLD

ii. Total water supplied to households and institutions per day = 885 MLD

iii. Total water supplied to the industries per day = 80 MLD

iv. Annual cost to operate the water supply system = Rs. 1010 million

v. Annual revenue generated from households and institutions = Rs. 800 million

vi. Annual revenue generated from industries = Rs. 500 million

vii. Annual electricity cost = Rs. 520 million

viii. Annual depreciation cost = Rs. 150 million

ix. Average cost of water from water tankers = Rs. 35/KL

x. Average cost of bottled water from private vendors = Rs. 2500/KL

Scenario 1: Table 1 in Annex A shows the daily net cost incurred by the city if all its water treatment facilities are shut down due to some calamity (scenario 1). The net revenue loss after incorporating the loss from non-revenue water is around Rs. 2.85 million (Rs. 28.5 lakhs). In this case it is assumed that 965 MLD of water will be supplied to the households, institutions, and industries through water tankers which on average costs around Rs. 35 per 1000 liters. The cost to supply water at this rate will be Rs. 33.7 million. The total saving for the city from electricity and depreciation cost for a day is close to Rs. 1.84 million (18.4 lakhs). So, a disaster that forces Surat to shut down its entire water treatment system will cost the city approximately Rs. 1.014 million (Rs. 10.14 lakhs) per day in operational cost (Net revenue – cost saved). But when the city takes the responsibility to supply water through water tankers, it will cost the city close to an additional Rs. 33.7 million adding up to a total cost of Rs. 34.7 million (Rs. 33.7 million + Rs. 1 million) per day.

[56] Shaban, A. and Sharma, R. N. (2007), Water Consumption Patterns in Domestic Households. Economic and Political Weekly, 42 (23), Mumbai.

Under similar circumstances but in another scenario, if it is assumed that households will buy bottled water for at least drinking purpose, the cost incurred by households can also be calculated. The average cost for bottled drinking water is Rs. 50 per 20 liters, which translates into Rs. 2500 per 1000 liters. Total quantity of water needed for drinking purpose is around 37.17 MLD (4.2% of 885 MLD). Households and institutions will spend close to Rs. 93 million to buy drinking water at the current price. If this cost is distributed to individual households based on the number of total households for Surat in 2011, which is close to 9.75 lakh households, the cost of buying drinking water comes to around Rs. 95 per day. Besides this private cost, the city will spend Rs. 34.7 million per day to supply the rest of the required water to households and the industries.

Scenario 2: Under scenario two, if we assume that floods will only partially impact Surat's water distribution system, as it did in 2006, when two water treatment facilities at Rander and Katargam were affected and until they were restored, water was distributed from the Varacha and Sarthana water works. The city might face a similar situation in the future. Under this scenario, the cost incurred by the city is calculated in the table below. The steps followed to calculate the cost are similar to scenario 1. The cost to distribute water through tankers and daily savings (from non consumption of electricity and no investment for depreciation) for the two damaged water works are based on the total treated water supplied from them. According to these proportions, the net operational cost incurred by the city per day will be around Rs. 0.60 million (6 lakhs). When the required water is distributed to the households and industries through tankers, it will cost the city an additional Rs. 18.9 million thus taking the net total cost to Rs. 19.5 million per day. In a different scenario when households buy 19.32 MLD (4.2% of 460MLD) of drinking water, they would spend Rs. 48 million. Based on benchmark supplies of 195 lpcd water supply, 460 MLD would reach 5.15 lakh households. These figures are based on information obtained from JNNURM[57] and the 2011 census. So, when the cost is distributed at per household level, it comes to Rs. 93 per day to buy drinking water. While not including the private cost, the net cost incurred by the city to distribute water for the rest of the city's needs will be close to Rs. 19.5 million per day. See Table 2 in Annex A.

The cost to acquire or deliver clean and safe drinking water, while severe, is only one among many economic blows a city (and thus, its citizens) must sustain when a climate-related weather event damages the water system. Repairing or replacing infrastructure and other investments, the loss of tax revenues from inoperable industry, income lost due to work-days lost, and intangibles such as perception as an unsafe or inefficient place to do business also threaten an area's economic security. This illustration shows one element among many which demonstrates the necessity of shifting towards climate-aware planning.

7. Conclusion

Surat has a long history of flooding that has placed at risk its water system, public health and economic competitiveness at many junctures. The floods of 1994, and the plague and public

[57] http://jnnurm.nic.in/wp-content/uploads/2010/12/Surat_USER_CHARGES.pdf

health catastrophe that followed, was a major turning point in the city's administrative and urban governance practices. Within a year of the floods, the city went from being one of the dirtiest in the India to its cleanest. The striking aspect of this change is that it is sustained, with great success for over 20 years. In this paper we trace the sequence of steps and actions that the city has taken to "climate-proof" in a matter of speaking, its urban systems. Our focus was on water, but we found that Surat's handling of it was inter-sectoral. Efforts made on water, sanitation, storm water and health all had resonant effects. Indeed, in the immediate aftermath of the 1994 floods, when water was contaminated, the city had to first fix sanitation, garbage collection and secure its drains before it could get to sustainably clean water.

A flood-related public health catastrophe initially triggered reforms, that were innovative, but relatively top down. Over time, however, appreciation by the local population and businesses of the results of reform, as well as revenue-generation gains and efficiency enhancing benefits to the municipal agencies in-charge of water have created its own constituency, a much wider one, that has helped sustain and indeed accelerate climate-aware reform. At the same time, annual recognition of good performance serves as incentives for city officers and technical staff to become more invested in reform and in responsiveness (J. Shah, 2013, 3).

Similarly, technology, information sharing, information collection, learning and public education were deeply intertwined in some of the city's most interesting initiatives. What seem like top-down often siloed reforms, then were inter-sectoral, and over time, especially after ACCCRN initiatives, became more embedded. Indeed, as some have noted, Surat's history of grappling with natural hazards spurred the local government to keep detailed records of each natural disaster (flood) and to undertake citywide data collection on an ongoing basis (Chu 2015). Documentation became a source of learning.

Economic arguments, tangible and concrete, often make greater headway in persuading burdened bureaucracies to consider (uncertain) future climate events, and intentionally incorporating them in their planning decisions. In this paper we make a simple assessment of the daily costs to the city of not acting to securing its water system. Taking only the water-works into account, we found that the city will need to spend over Rs. 34 million per day if none of its water works function, not counting private costs of up to an additional 93 million.

We thus show that even without taking the cost of physical damage into consideration, the city of Surat will incur heavy financial loss in a single day if its water supply system becomes dysfunctional due to the impact of a disaster. To avoid such economic loss and be better prepared for disasters, a city's water department can take many steps. According to WHO, while planning adaptation measures not much can be done with the location of the facilities but the city certainly can invest in design modifications to prepare for disasters. Based on Surat's experience, these measures can take the form of raising facilities in the low-lying areas, building protections or bunds around them; providing stand-by power generators;

stocking of repair equipment and chemicals to tackle contaminations; and training staff to handle emergency situations.[58]

This paper while covering various facets of Surat's water supply system demonstrated that the city administration has considered the possibility of extreme climate risk in their water planning process have identified the local vulnerabilities. Surat sees these vulnerabilities in the form of high water demand and low supply options, water contamination, financial strain due to low penetration of water metering, topographical constraints, climate related shocks and equitable distribution among others. The city has already applied many methods like reinstalling electrical wiring and machineries above the High Flood Line (HFL), providing back-up power supply option in each water treatment and distribution centers, using latest technology to monitor water quality for contamination and leakage detection, and building capacity among staff to manage disasters. Besides these the city has taken up water metering and has restructured tariff rates for financial prudency. Though challenges still remain, Surat has made progress towards living with water and minimizing the risks of extreme events, a step towards climate away planning through continuous learning, course correction at major events, and collaboration across sectors, governmental actors and community members.

58 http://www.who.int/water_sanitation_health/hygiene/emergencies/em2002chap7.pdf

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Annex A

Scenario 1: All 4 water treatment plants affected by flood

Water Treatment Facility / Water Works	Total water supplied per day (in MLD)	Proportion of total water supplied	Proportion of water for households and institutions	Proportion of water for Industries	Daily revenue from households and institutions (in Rs. Crore)	Daily revenue from industries (in Rs. Crore)	Water tanker cost @Rs.35/KL (in Rs. Crore)	Daily electricity charge (in Rs. Crore)	Daily depreciation cost (in Rs. Crore)
Rander	190	20%	21%	0%	0.047	0.000	3.378	0.142	0.041
Katargam	350	36%	31%	100%	0.067	0.137			
Varacha	50	5%	6%	0%	0.012	0.000			
Sarthana	375	39%	42%	0%	0.093	0.000			
Total daily revenue (in Rs. Crore)					0.356				
Total net daily revenue after 20% loss from NRW (in Rs. Crore)					0.285				
Total daily cost incurred to supply water (in Rs. Crore)					3.662				
Total net daily cost incurred to supply water (in Rs. Crore)					3.479				

Scenario 2: Water treatment plants at Rander and Katargam affected by flood

Water Treatment Facility / Water Works	Total water supplied per day in MLD	Proportion of total water supplied	Proportion of water for households and institutions	Proportion of water for Industries	Daily revenue from households and institutions (in Rs. Crore)	Daily revenue from industries (in Rs. Crore)	Water tanker cost @Rs.35/KL (in Rs. Crore)	Daily electricity charge (in Rs. Crore)	Daily depreciation cost (in Rs. Crore)
Rander	190	20%	21%	0%	0.047	0.000	0.665	0.028	0.008
Katargam	350	36%	31%	100%	0.067	0.137	1.225	0.052	0.015
Total daily revenue (in Rs. Crore)					0.204				
Total net daily revenue after 20% loss from NRW (in Rs. Crore)					0.163				
Total daily cost incurred to supply water (in Rs. Crore)					2.053				
Total net daily cost incurred to supply water (in Rs. Crore)					1.950				

Annexure B:

Table 3: Water tariff by carpet area

Annual Water & Sewerage charges for 0.5" connection (in Rs.)						
Carpet Area (in sq. meters)	2008		2012		2013-14	
	Residential	Non-residential*	Residential	Non-residential*	Residential	Non-residential*
0-15	180.00	270.00	210.00	300.00	348.00	600.00
16-25	270.00	405.00	360.00	540.00	600.00	1,080.00
26-50	360.00	540.00	480.00	720.00	960.00	1,440.00
51-100	540.00	810.00	720.00	1,200.00	1,440.00	2,400.00
101-200	720.00	1,080.00	1,050.00	1,800.00	2,100.00	3,600.00
201 & above	900.00	1,350.00	1,500.00	2,400.00	3,750.00	6,000.00
501 & above	-	-	3,000.00	4,500.00	7,500.00	11,250.00

*Source: SMC; * excluding industrial properties*

Table 4: Water tariff by connection size

User charges per 1000 liters per family (in Rs.)				
Connection size (in inches)	2008		2012	
	For monthly consumption upto 30,000 liters	For monthly consumption > 30,000 liters	For monthly consumption upto 30,000 liters	For monthly consumption > 30,000 liters
3/4"	1.50	6.00	3.00	12.00
1.0"	1.50	6.00	3.00	12.00
1.5"	1.50	6.00	3.00	12.00
2.0" & above	1.50	6.00	3.00	12.00

Source: SMC