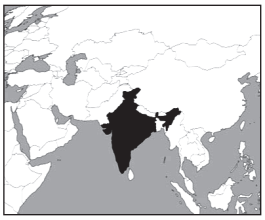

Addressing flooding in the city of Surat beyond its boundaries

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1. This paper draws heavily on TARU Leading Edge (2010), "City vulnerability analysis report: Indore and Surat", TARU Leading Edge, Gurgaon and Gandhinagar, 116 pages plus annexes; also TARU Leading Edge (2011), "Surat city resilience strategy", TARU, ACCCRN, Surat Municipal Corporation and the Southern Gujarat Chamber of Commerce and Industry, Surat, 48 pages.

ABSTRACT This paper describes the flood risks faced by Surat, one of India's most successful and also most flood-prone cities. The city is located on the Tapi River and faces flood risks not only from heavy precipitation in and around the city but also from heavy precipitation upstream and from high tides downstream. Reducing the risks from upstream depends on better water management in a water catchment area and dam reservoir located far outside the city authority's jurisdiction and in another state. The paper also reviews measures being taken to reduce flood risks – and how climate change is likely to affect such risks. It suggests that part of the city's response needs to be a greater ability to live with floods, while minimizing the costs these usually bring in terms of loss of life, damage to homes and disruption to businesses.

KEYWORDS climate change / early warning / flood risks / livelihoods / slums / urban infrastructure

I. INTRODUCTION

The city of Surat is a large and successful city in south Gujarat, India, with a population estimated at around 4.5 million in 2009.(1) It has a tropical monsoon climate with summer temperatures ranging from 37°C to 44°C. Annual rainfall ranges from 1,000 to 1,200 millimetres, with around 90 per cent of this falling between June and September and with very little rainfall between December and May.

Surat is located on the banks of the Tapi River, which flows into the Arabian Sea 16 kilometres from the city centre. As Surat is located near the mouth of the river, high tides reach the western part of the city, with a tidal range of five to six metres, and during the rainy season, high tides often inundate settlements located along several tidal creeks.

Surat is a major industrial and commercial centre and port, and in recent years it has experienced one of the most rapid economic growth rates among cities in India. Its long history dates back to 300 BC and by the sixteenth century it was an important sea port; during the seventeenth century it was one of India's most important commercial centres. Measures were taken at that time to protect the city against flooding. For instance, in 1664, the construction of a wall around the city was begun, with gates that could be closed when there was a risk of flooding.

The main industries are diamond cutting and polishing (representing 42 per cent of the world's total output), textiles, machinery and chemical,

petrochemical and natural gas-based industries. Located between Ahmedabad (the state capital) and Mumbai (India's financial capital), it is well-connected to railway and highway networks, which also connect it to Delhi. Many leading industrial companies and corporations have invested in Hazira, which is also a deep-water port, located some 20 kilometres southwest of the city on the Arabian Sea.

The city's population has grown more than ten-fold since 1951 to reach 4.5 million inhabitants, while the municipal boundary area has expanded from 8.2 square kilometres in 1951 to 327 square kilometres today. The expansion of the city boundaries to include the Dumas coastal area has also made Surat a coastal city.

In 2005, 490,305 persons lived in 307 slums[2] within the then 116 square kilometre boundary; with the expansion of the boundaries in 2006, the number of slums increased to 406. Many of these are located on tidal creeks and along the river and other drainage channels. The rapid growth in the slum population has been halted and reversed since the 1990s, with large investments in housing for low-income groups (what are termed "economically weaker sections") and the relocation of slum dwellers to housing in peripheral areas. In addition, the proportion of the slum population with safe drinking water, connections to sewers and provision for storm drains has increased.

The city draws on surface and groundwater for its water supply, with 90 per cent of the gross daily water supply coming from the Tapi River, which also provides the drinking and industrial water for the Hazira industrial area. To prevent seawater ingress, a weir was constructed in 1995. The piped water system reaches around 95 per cent of the municipality's population.

Regarding sanitation, 86 per cent of the population is connected to sewers. Within the previous municipal boundaries that encompass 112 square kilometres, 92 per cent of the habitable area and 97 per cent of the population is served by sewers. This is much expanded from 1997 when the sewer system only reached 29 per cent of the habitable area. There has also been substantial investment in sewage pumping stations and sewage treatment plants. At present, the peripheral areas outside the previous boundaries of the municipal corporation are not served by sewers although there are plans to extend piped water and sewer systems to some of these. For the settlements outside the municipal corporation boundaries, there is no centralized water supply or sewer system.

There are three main government bodies – the Surat Municipal Corporation (with 334 square kilometres under its jurisdiction), the Surat Urban Development Authority (SUDA) with 722 square kilometres (which includes the municipal corporation area) and the Hazira Development Authority, which governs the port and industrial hub located downriver from Surat city. SUDA is responsible for preparing the area development plan and for controlling unauthorized developments within the 722 square kilometres that includes (in 2004) 552 square kilometres of non-urbanized area (Table 1). The municipal corporation is responsible for town planning schemes within its jurisdiction.

The South Gujarat Chamber of Commerce and Industry is important in terms of influencing city and state government and in taking the lead on several city development initiatives. It has 4,000 direct members and around 67 affiliated associations accounting for 65,000–70,000 members.

2. The term "slum" usually has derogatory connotations and can suggest that a settlement needs replacement or can legitimate the eviction of its residents. However, it is a difficult term to avoid for at least three reasons. First, some networks of neighbourhood organizations choose to identify themselves with a positive use of the term, partly to neutralize these negative connotations; one of the most successful is the National Slum Dwellers Federation in India. Second, the only global estimates for housing deficiencies, collected by the United Nations, are for what they term "slums". And third, in some nations, there are advantages for residents of informal settlements if their settlement is recognized officially as a "slum"; indeed, the residents may lobby to get their settlement classified as a "notified slum". Where the term is used in this journal, it refers to settlements characterized by at least some of the following features: a lack of formal recognition on the part of local government of the settlement and its residents; the absence of secure tenure for residents; inadequacies in provision for infrastructure and services; overcrowded and sub-standard dwellings; and location on land less than suitable for occupation. For a discussion of more precise ways to classify the range of housing sub-markets through which those with limited incomes buy, rent or build accommodation, see *Environment and Urbanization* Vol 1, No 2, October (1989), available at http://eau.sagepub.com/content/1/2.toc.

TABLE 1
Land use in SUDA planning area 1978–2004

Land use	Area (1978) (km^2)	%	Area (1995) (km^2)	%	Area (2004) (km^2)	%
Residential	27.0	40.0	61.9	46.8	98.1	57.5
Commercial	1.4	2.1	2.6	1.9	4.2	2.4
Industrial	10.1	14.9	27.8	21.0	30.2	17.7
Educational public purpose	5.4	8.0	7.4	5.6	5.8	3.4
Recreation, gardens and public space	0.2	0.3	0.6	0.4	1.1	0.6
Transport and communications	7.9	11.7	16.6	12.6	15.6	9.2
Agriculture	15.5	23.0	15.5	11.7	15.5	9.1
Total urbanized area	67.5	100.0	132.4	100.0	170.5	100.0
Non-urbanized area	654.5	–	589.6	–	551.5	–
Total	**722.0**	**–**	**722.0**	**–**	**722.0**	**–**

SOURCE: Surat Municipal Council (2006), *Surat City Development Plan*, page 17.

It has also taken a lead in providing relief after disasters, in partnership with civil society organizations and the municipal council.

The city is highly regarded for its urban management, which includes a strong revenue base – the municipal corporation has an average annual gross income of around three billion rupees (around US$ 70 million). The city was also recognized as among the cleanest in India. It was also the first municipal corporation in India to develop an information technology policy and all departments were computerized in 1998. Part of the motivation behind the improvements in urban management was the plague epidemic that hit Surat in 1994 and that threatened its economic success. Partly in response to the epidemic, the municipal corporation's structure was amended from a vertical hierarchy to a more decentralized structure within its 38 election wards and their grouping into seven administrative zones.

II. FLOOD RISKS

It is estimated that around 90 per cent of Surat's geographical area is affected by some type of climate hazard, whether flooding, coastal storms and cyclones or inundation associated with high tides and sea level rise. Much of the city and its surrounds are less than 10 metres above mean sea level. These hazards have not all been experienced with the same intensity. Only two cyclones, for instance, have been reported passing

through the Gulf of Khambhat in the last 140 years, the most recent in 1976. The highest tide, recorded in 2007, inundated some coastal areas that had never previously been submerged by tides.

Flooding has been a recurrent event, however. The city has records of floods going back to 1869, and on average the city flooded every two and a half years between 1869 and 1884. Flood frequency fell between 1949 and 1979, when the average natural flood occurrence was once every four years. Since 1979, there have been five major floods (1979, 1990, 1994, 1998 and 2006), and the floods of 2006 inundated 75 per cent of the city area with a very high cost to the population, the city economy and the municipal corporation (running to several hundred billion rupees). Around 150 people are officially estimated to have lost their lives; unofficial estimates suggest that the death toll may have been more than 500.

Many of the most serious floods have resulted from heavy rainfall in the Tapi River's catchment area, which covers 65,145 square kilometres, only six per cent of which is in Gujarat; 79 per cent is in the neighbouring state of Maharashtra and 15 per cent is in Madhya Pradesh (where the river originates). The monsoon generally starts in this area during the third week of June and there are occasional heavy rainstorms from the beginning of August to the end of September. The catchment area receives around 90 per cent of its annual rainfall between June and October and most floods occur in August.

The Ukai multi-purpose dam, built 94 kilometres upstream of Surat and completed in 1972, was intended to include flood control along with its primary tasks of providing water to irrigate the coastal plains of Gujarat and generating electricity. Heavy rainfall in the dam's catchment area (especially in Maharashtra) leads to heavy inflow into the dam's reservoir and often heavy discharges, which then flood Surat. One of the major constraints for flood prevention is the inability to manage the Ukai dam around competing demands. For purposes of irrigation, for example, the reservoir ideally should be full by the end of the monsoon rains; it can be difficult to coordinate this need with measures to prevent flooding in Surat.

Since the construction of the dam, Surat's growth has expanded dramatically along both sides of the river, which has meant major modifications in the hydrology in Surat and Hazira. Increases in the built-up area, construction in the floodplains, filling in of the riverbed and floodplains at Hazira, silting up of the riverbed due to tides and to the construction of embankments, new bridges and the Singanpore weir (which prevents the ingress of tidal water and so protects the quality of the water from which city supplies are drawn) have all contributed to reducing both the capacity of the river and the open space that allows floodwaters to spread out. In addition, the Hazira industrial complex downstream of Surat has grown by reclaiming sections of the floodplain, thereby narrowing the mouth of the Tapi River where it meets the sea. Raising the ground level by more than three metres in Hazira, and the closure of tidal creeks that could potentially drain the water, further reduced the size of the floodplain, and sea level rise is likely to further aggravate the free flow of floodwaters. The large-scale industrial development at the mouth of the river also causes a rise in the water level immediately upstream.

The floods of 1998, 2004 and 2006 occurred following emergency discharges of the Ukai dam. While the river, within its embankments, can

safely discharge around 0.3 million cusecs (cubic feet per second), inflows of up to 1.3 million cusecs over three to five days have to be managed in order to control flooding, often at the end of the rainy season. The largest peak flow was in 1968, at 1.5 million cusecs; the flood in 1970 had a peak flow of 1.3 cusecs.

In addition to the Tapi floods, Surat also faces local flooding (called Khadi floods) from two streams that pass through the southern part of the city. These streams flood during heavy local rains and can cause serious damage to settlements located near their banks. This happened in 2004, 2005 and 2007. In the 2004 floods, nearly 400,000 people were affected; there was also a power failure lasting two days, water supply lines were disrupted for a week and many city neighbourhoods were inaccessible for two days.[3] There are also new areas that have experienced unexpected flooding and waterlogging – perhaps because of the blocking of natural water flow patterns by infrastructure and new developments.[4]

The 2006 floods brought major disruption to the city's economy, and industry took nearly a month to return to production. Some of the industries located on the eastern edge of the city were not inundated – but they were affected by the absence of workers. Around 77 per cent of the working population lost between 15 and 30 days' work. Industrial losses totalled 160 billion rupees (around U$$ 3.5 billion), with around three-fifths of this being direct losses and the rest from loss of production. Loss to public infrastructure, including the dam, flood embankments, electricity and telephone lines totalled 25 billion rupees (US$ 544 million).

3. Sekhsaria, Peeyush (2010), "Even this height will not suffice; coping mechanisms of Surat to its recurrent floods", Taru Leading Edge, 19 pages.

4. See reference 3.

III. SURAT'S VULNERABILITY TO CLIMATE CHANGE

a. Climate change scenarios

Climate change scenarios for Surat all indicate an increase in rainfall, with monsoons dominated by heavy spells of rain interspersed with longer dry spells. This could potentially increase the frequency of floods. Surat's climate change risk profile also includes sea level rise, water scarcity and temperature rise. Future precipitation trends may increase flood frequency and peak discharges from the Ukai dam. With the floodplains becoming narrower because of new developments and sea level rise, inundation levels are likely to increase. Sea level rise is likely to impact coastal aquifers and erode parts of Dumas beach, a popular tourist area, some parts of which have already reported coastal erosion.

In most of the climate models under the A2 and B2 scenarios, total annual precipitation is expected to increase in Gujarat and the adjoining western India plateau by 250–500 millimetres.[5] This has a significant bearing on the Khadi floods. Two models also indicate higher precipitation over the Tapi basin. The number of days with more than 200 millimetres of rainfall is expected to increase and precipitation of more than 350 millimetres will also probably be more frequent. This would lead to the need for a greater number of emergency releases from the dam reservoir and increase the frequency and intensity of floods in Surat. The increased peak discharges under various climate change scenarios are likely to place further stress on the reservoir management operations, with its conflicting objectives of irrigation and power generation versus flood control. All models predict a likely increase in minimum and maximum

5. IPCC scenarios, available at http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf.

temperatures, with a variation of one to five degrees; the monthly average maximum temperatures are likely to increase by around 0.5°C per decade. With Surat's high humidity levels, rises in temperature may increase levels of discomfort for much of the year.

Most stakeholders in the city are unaware of future risks arising from rapid urbanization and climate change. For example, the city has expanded in the coastal zone and there are no land use rules in place to prevent urban growth (especially high-value real estate) in current and future high-risk zones. The coastal area may, in fact, become some of the most sought-after real estate.

b. City vulnerability assessment

A citywide vulnerability assessment has highlighted the vulnerability of households in Surat, but in particular that of slum dwellers and low-income populations residing in riverine areas in homes that are not usually able to withstand floodwaters. This vulnerability assessment was carried out as part of the process initiated by the Asian Cities Climate Change Resilience Network (ACCCRN), where Surat is one of the 10 core cities (Box 1).

The assessment involved interviews with 929 households in 110 settlements and looked at the level of education, social networks and access to lifeline services, income stability (and use of loans or insurance), physical infrastructure (water supply, sewers, roads) and water scarcity. It also drew on Google Earth maps to delineate homogeneous areas (based on factors such as building densities, roof types and road network distribution), thus allowing the definition of areas or neighbourhoods that are likely to be populated by fairly homogeneous socioeconomic groups, namely slum, lower income, middle income, mixed (residential and commercial) and upper income. Small area surveys of buildings and household questionnaires provided detailed on-the-ground data.

Of all those surveyed and across all socioeconomic categories, 22 per cent were unskilled, (for example, hawkers and vendors or workers who

BOX 1
The Asian Cities Climate Change Resilience Network (ACCCRN)

ACCCRN is an initiative launched by the Rockefeller Foundation in late 2007, which focused initially on 10 cities across four countries (Thailand, Vietnam, Indonesia and India) and is now expanding to include cities in Bangladesh and the Philippines. In India, the three core ACCCRN cities were Surat, Indore and Gorakhpur, with activities now being scaled up to other cities through a network of partner organizations. In Surat and Indore, city level processes have been implemented with the support of TARU, a consultancy firm that has worked with city actors during the ACCCRN process.

The aims of ACCCRN are to build the capacity of cities to plan, finance, coordinate and implement climate change resilience strategies, while building a network of knowledge around urban climate change resilience and scaling up action to a wider range of cities and actors. In the 10 core cities, a process of vulnerability assessment was carried out, leading to the development of city-specific resilience strategies from which interventions to build resilience could be prioritized and implemented. In Surat, ACCCRN support is facilitating the development of the end-to-end early warning system and the Surat Urban Health and Research Centre, which opened in March 2013.

support the construction and transport sectors) and 12 per cent were semi-skilled. Seventy-five per cent of the slum population figured in these categories. Unskilled workers are often more vulnerable to floods because they are paid daily. Generally, the lower socioeconomic groups and new migrants face greater difficulties with income insecurity and have the most trouble coping with any disruption to their income during the time it takes for industries to resume production after flooding. Migrants may face particular difficulties because of their lack of social contacts – and there is a high proportion of migrants from distant states among the Surat population, especially among the slum population, more than half of whom came from further afield than Gujarat (and 10 or 11 per cent were from Uttar Pradesh and Orissa, among the poorest states).

The interviews confirmed that the city has an efficient solid waste collection system, which was put in place after an outbreak of the plague in 1994; 65 per cent of slum households had house-to-house collections and all other socioeconomic categories had an even higher proportion served, with, for example, 99 per cent of households served among high-income groups.

With regard to flood risks, households were classified according to an index based on damage from floods, depth of inundation and flood duration. The GIS-based analysis suggested that around 71,000 households are subject to Khadi flooding (around half live within 50 metres of the streams) and around 450,000 households are vulnerable to flooding from emergency releases from the Ukai dam. Most of the slums and low-income settlements are near or within the flood risk zones and had higher flood vulnerability indices, although many higher-income households were also at risk, especially those living on the ground or first floors of housing.

Direct risk from sea level rise affects around 5,000 households located along tidal creeks. The zone most at risk from sea level rise is not yet heavily populated, comprising a few thousand houses near Dumas beach. But this problem is expected to grow unless real estate development can be controlled in the areas at risk.

c. The city resilience strategy

The modelling, sector studies and vulnerability assessment together informed the development of the city's resilience strategy (2011), and highlighted the short-term, mid-term and long-term strategies for addressing the various issues. With regard to flood management, the short-term strategies included developing an end-to-end early warning system and improved information and data management. Mid-term strategies identified mapping of flood-risk areas and the regulation of construction in floodplains, while long-term strategies included the diversion of floodwaters from the Tapi River and the construction of a balloon barrage system. These flood-specific measures were identified alongside other sector-specific strategies that would also build resilience to flood risks, such as improving wastewater and sanitation systems to reduce health risks from flooding, as well as improving the health surveillance system. This city resilience strategy now forms part of the city's plans for preparing for climate change impacts.

IV. ADDRESSING FLOOD RISKS

a. Coping

Among the most common coping measures taken by businesses and households is to raise the plinth height and this is evident in many buildings in areas that often flood; some modern buildings even use the ground floor only for parking. Many houses have raised shelves and small attics or lofts where valuable goods can be stored. In the households interviewed for the vulnerability assessment, 60 per cent of respondents had no coping mechanisms, although the figure was lower for the slum population (47 per cent).[6] But this also reflects responses from those who are at less risk of flooding – for instance, the highest proportion of respondents who reported no coping measures were from wealthier groups. In another study, 184 of the 400 respondents surveyed reported relocating to a dry place during the 2006 floods – 27 per cent moved to the upper floors or terraces of their homes, while the remainder stayed with friends or relatives, or in schools, temples and hospitals.[7]

Some coping measures are not relevant to middle- and upper-income groups, who suffer less from waterlogging. The vulnerability assessment reported on how slum dwellers have developed a system of storing their valuable documents in a plastic pouch, which is carried by members who move to a temporary shelter. It is common for some adult men to stay in their homes when these flood, in order to guard valuable assets such as televisions, furniture, bicycles, motorbikes and productive assets such as sewing machines.

b. Measures taken to reduce flood risks

The municipality aims to harden power supplies and communication and other essential services as part of the city's resilience strategy. Integrated planning to make it possible to live with floods will be topmost on the adaptation agenda for the city. Reducing disruptions to water and electricity supplies is important for the whole city. The electricity supply to industry is generally good for most of the year, with virtually no scheduled power cuts and few unscheduled ones being reported. During the summer months, weekly 12-hour cuts were reported by 72 per cent of industries, most of which are located on the outskirts of the city. Regarding water supply, there may be falling demand from the textiles industry (as it shifts to high-value products) but demand from other sectors and from Hazira is expected to rise.

The municipality has taken measures to mitigate flood risks during the monsoon. This includes clearing the drainage and sewer systems and undertaking preparedness for emergency evacuation, including regular evacuation drills. Water levels in the reservoir behind the Ukai dam are monitored and there are many LED hoardings in Surat displaying these levels, in order to warn people. Advance warnings are provided by megaphones and through the short messaging system (SMS) for mobile phones. These have helped to greatly reduce the loss of life. A household survey of 400 households assessed what proportion of the population received early warning messages before the 2006 floods:[8] 43 per cent received no warning and the proportion did not differ much between the various socioeconomic groups; 20 per cent had less than

6. See reference 1, TARU Leading Edge (2010).

7. Centre for Social Studies (2010), "Learning to live with floods in Surat", Sector Study Report prepared for ACCCRN, Veer Narmad South Gujarat University Campus, 43 pages.

8. See reference 7.

three hours warning and again this did not differ much by income group; the percentage receiving longer warning periods did not differ much by income category either except for those being warned 12–24 hours in advance, which reached 16 per cent of the upper-income group and 28 per cent of the mixed-income group but much lower levels for other socioeconomic categories. With regard to the source of the warning, television was the most important for all groups except for the slum population, for whom loudspeakers were the most important, followed by television.

The municipal corporation is planning to set up a GIS-assisted two-way information system, which includes geo-tagging of all residential buildings, pre-monsoon updates of people requiring special medical care during emergencies (elderly, infirm, babies, pregnant women) and also a volunteer and mobile SMS-based two-way information system. Mobile phone coverage is now high, with 70 per cent of the population having one or more mobile phones; however, 40 per cent of the slum population, 35 per cent of the lower-income and 21 per cent of the mixed- and middle-income groups have no cell phone, so alternative warning systems are still required.[9]

9. See reference 1, TARU Leading Edge (2010).

c. The end-to-end early warning system

An integrated meteorological, hydrological and reservoir modelling system has been developed to forecast reservoir levels and improve reservoir operations for flood risk mitigation. An end-to-end early warning system has been set up to warn the city administration to take action in the event of extreme precipitation; this project is being implemented under the ACCCRN programme in order to build upon, expand and strengthen existing early warning systems (Figure 1). Community disaster response capacity is also being built. This addresses the issue of flooding in a multi-scalar and multi-institutional manner, looking at upstream causes of flooding beyond the administrative boundary of the city, while building the capacity of the city administration, institutions, businesses and civil society for planning, preparedness and management before and during flood emergencies, including tidal creek floods (Ukai floods).

Key activities include the establishment of the Surat Climate Change Trust with a range of stakeholders (including government, business representatives, academics and NGOs) to facilitate the design of the flood management system and direct agencies to set up a data collection system and suggest studies to identify and act on vulnerability. The establishment of this trust will help to ensure the city's continued capacity to implement and manage other climate change adaptation interventions in the long term, in an integrated manner. With regard to the end-to-end early warning system, having an institutional coordination system is necessary in order to organize the multiple actors involved, including city officials, disaster management authorities, the national dam management agency, the irrigation department, the meteorological department and the universities involved in modelling.

Climate change-informed modelling is being developed, with existing hydrological models integrated with rainfall prediction and real-time rainfall, stream gauge and reservoir data collection systems. Simulations of climate change-induced changes will be carried out to assess future

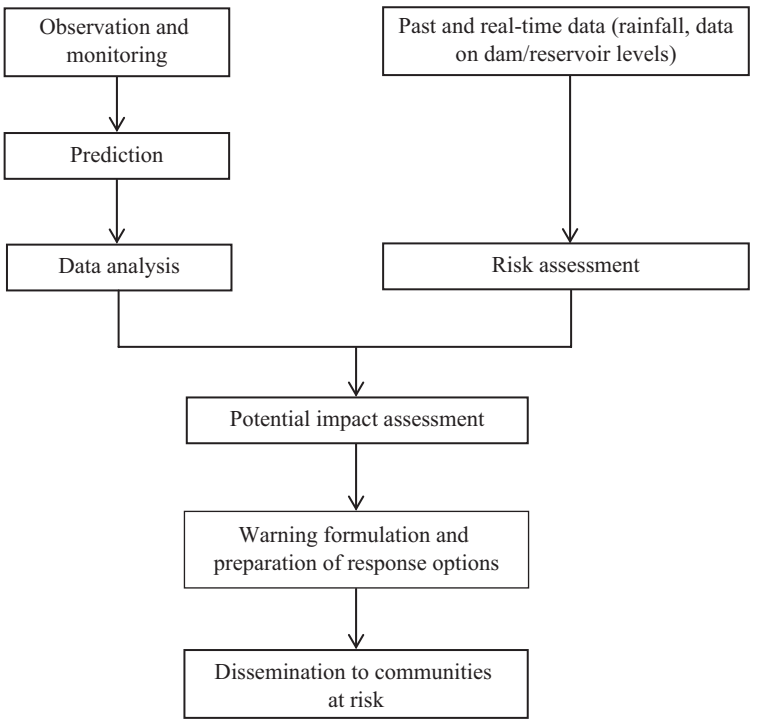

FIGURE 1
The end-to-end early warning system

SOURCE: http://www.acccrn.org/resources/documents-and-tools/2011/02/01/end-end-early-warning-system-ukai-and-local-floods-surat--0.

scenarios. Using the model's results from past climate and reservoir data and projected climate variability over the next 30 years, flood risk maps will be generated that can provide a better basis for land use policies and building regulations. Thus, the end-to-end early warning system combines "soft" institutional coordination mechanisms with technical tools to ensure improved decision-making processes and the ability to warn of impending floods up to four days in advance.

In addition to early-warning mechanisms, Surat has just seen the opening of an Urban Health and Climate Resilience Centre, as another ACCCRN-supported initiative. This centre will work with local authorities to study the impacts of climate change on health, with a particular focus on poor and vulnerable city residents. The centre will also carry out disease surveillance alongside education and training, to better improve the city's resilience to outbreaks of disease that may be exacerbated by climate change impacts such as floods.

The end-to-end early warning system gives city authorities, businesses and residents more time to take action ahead of floods, and supports better disaster management with particular attention to reaching and

supporting those who are most vulnerable, including facilitating their evacuation if necessary. The warning system should provide at least four days respite before floodwaters enter the city and will support the ward level disaster management plans. It also gives the dam managers an improved information base for controlling releases in order to minimize flooding in Surat. It allows more time to warn residents of flood risks and a more accurate and detailed forecast of where flooding is likely to occur; this will benefit the households living in more flood-prone areas.

Floods generally hit the poor and vulnerable groups hardest because their houses are located in the more flood-prone areas with low land values. They often lose their assets as a result of flooding and may also lose their income sources for possibly up to a month as the city economy comes to a standstill. The measures outlined above will provide them with more time to act before the floodwaters arrive and will reduce flood damage; different modes of communication will also be used to reach them.

Feasibility studies are looking at the possibility of setting up a database of vulnerable people and also a community-managed asset bank where households at risk of flooding can place their assets. Building by-laws will also be adapted to better reflect the needs of low-income households.

As the city is located on nearly flat terrain waterlogging is common during the monsoon, and Surat suffers from endemic malaria and filariasis; leptospirosis-related morbidity is also common during the rainy season. A mobile phone-based disease surveillance system to track diseases and to enable early action has been implemented in the city (Box 2). This system has reduced both the response time, by more than 24 hours, and also the drudgery of having to first collect data on paper and then take it to the municipal offices for re-entry into the computer, followed by analysis and report preparation.

BOX 2
The Urban Service Monitoring System

The Urban Service Monitoring System (UrSMS) was developed under the Asian Cities Climate Change Resilience Network (ACCCRN) to improve monitoring and grievance redressal for health, water supply, sewerage and solid waste services. The system has two main interfaces: the mobile phone interface for sending and receiving structured data via SMS; and the PC interface with Internet Mapping Service for visualizing the information as charts, reports and maps.

Surat Municipal Corporation (SMC) has been using this system for health and water monitoring for the past two years. Major advantages of the UrSMS are standard data collection, improved work efficiency or reduced person-hours, and improved water quality and disease surveillance.

The UrSMS collects data (near-real time) from major hospitals, urban health centres, selected private hospitals and private and government laboratories in Surat. SMC officials can view the city's daily, weekly and monthly disease trend/pattern at different levels of aggregation (e.g. administrative zone, ward and also by disease type) for early action on any epidemic situation. The SMS alert system generates an automated SMS to the concerned authority when the incidence of disease crosses a certain threshold. The UrSMS also provides auto-generated reports, graphs and statistics to SMC officials and decision makers.

The earlier manual data collection system required data to be fed into computers for it to be analyzed, which used to cause more than a day's delay. The UrSMS has reduced the duplication of work (data entry at several levels) and also improved the disease surveillance system through near-real time data-gathering and analysis. The system can be upgraded for use during emergencies such as floods and is being developed by TARU in active partnership with SMC.

The end-to-end early warning project will also help residents to build safer houses, based on scientific information on the extent of risk. The results will be integrated with the existing ward level disaster management plans and monsoon preparation exercises. By zoning risk areas and ensuring alternate land use in these current and future high-risk areas, low-income groups can make better choices regarding their investments in housing.

The early warning system will provide direct benefits to around three-quarters of the city's population, to businesses and to the municipal council. More than 20 per cent of the city's low-income households who live alongside creeks and rivers and nearly 50 per cent of all households will benefit from reduced risks due to more controlled releases and sufficient time to shift to safer locations with their moveable assets.

Almost all households will benefit from shorter periods of livelihood disruption, in particular migrants and other workers who lack the savings or assets to help them cope when their incomes are disrupted. Industry will greatly benefit from less disruption to their business, their workforce and other businesses they rely on, and also from reduced damage to equipment and workplaces.

The project contributes to building multiple resilience characteristics in Surat. Improved management of the Ukai dam allows it to function normally within a wider range of rainfall patterns and creates "safe failure" through the controlled release of water if capacity is exceeded. The flood-modelling database and vulnerable people's database enable appropriate planning mechanisms to identify and prioritize problems and mobilize resources. The establishment of the multi-stakeholder Surat Climate Change Trust increases the capacity to manage various systems to help protect against potential threats. The shared flood-modelling database and the establishment of the trust allow internal agents to understand flood risk and climate change impacts on their city and incorporate learning into appropriate urban management strategies.

V. CONCLUSIONS

Surat remains at high risk from floods, and thus far urban expansion has not been managed to address these risks. Climate change is likely to exacerbate flood risks, with increases in precipitation within and around the city and in the Tapi basin. The actual increase in flood frequency and intensity will depend on a number of factors, including the management of the Ukai dam under competing demands of water versus flood control, how and where the city expands (especially onto floodplains), landfill in the Hariza industrial complex to reduce risk to high-value industries from sea level rise/flood, and sea level rise.

The city has the capacity to address flood risks – and has greatly improved the quality and reach of conventional infrastructure and services since the outbreak of plague in 1994. This includes hardening infrastructure and essential services against floods. The municipal corporation has recognized the need for improved preparedness for floods. The performance of the early warning system is good but it would be much improved by a shift towards using IT, satellite-based weather monitoring reinforced with telemetered ground weather stations, and advanced real-time flood models. The city may have to prepare to live

with floods rather than flood-proofing the whole city. This would mean understanding future risks under increased urbanization and responding to changing risks. Land use planning and the enforcement of development rules based on risk categorization, as well as upgrading housing and other private infrastructure to withstand floods is important for this. Detailed, publicly available data on risks can help discourage growth in high-risk zones such as tidal creeks and beaches. It can also provide insurance companies with information on such zones and help them reach lower-income households. There is a need to explore group insurance or city level insurance that could be financed by a surcharge on house tax.

The expansion of the city boundaries to include the Dumas coastal area has made Surat a coastal city and any expansion of the city in this area is likely to increase flood risks from sea level rise.

Early warning needs to be improved to increase respite time, also better-informed community level response contingency planning to minimize damage and loss. Hence the initiation of the end-to-end early warning system, as a soft measure that can have immediate benefits for the city's residents and industry. To live with floods, city dwellers need to be trained to take effective individual and collective action to manage life with minimal disruption. Monsoon preparations need to include updating the database of the elderly, infirm and persons requiring special care, and provision for effective two-way communication.

As highlighted in the city resilience strategy, short-term measures need to be combined with longer-term strategies that may require more investment and preparation, such as a balloon barrage to better control the release of water from the Ukai dam. Slum rehabilitation programmes should incorporate features to enable living with floods, such as improved sanitation and waste management systems. Detailed flood risk assessment followed by the designing of suitable structures that incorporate flood protection features may be included during the planning stages. The urban community development department of Surat's municipal council should have a strong role in enabling the slum communities to adapt to the floods.

REFERENCES

Centre for Social Studies (2010), "Learning to live with floods in Surat", Sector Study Report prepared for ACCCRN, Veer Narmad South Gujarat University Campus, 43 pages.

Environment and Urbanization Vol 1, No 2, October (1989), available at http://eau.sagepub.com/content/1/2.toc.

http://www.acccrn.org/resources/documents-and-tools/2011/02/01/end-end-early-warning-system-ukai-and-local-floods-surat--0.

http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf.

Sekhsaria, Peeyush (2010), "Even this height will not suffice; coping mechanisms of Surat to its recurrent floods", Taru Leading Edge, 19 pages.

Surat Municipal Council (2006), *Surat City Development Plan*, 180 pages.

TARU Leading Edge (2010), "City vulnerability analysis report: Indore and Surat", TARU Leading Edge, Gurgaon and Gandhinagar, 116 pages plus annexes.

TARU Leading Edge (2011), "Surat city resilience strategy", TARU, ACCCRN, Surat Municipal Corporation and the Southern Gujarat Chamber of Commerce and Industry, Surat, 48 pages.