# China and US Case Studies: Preparing for Climate Change

## Shanghai: Targeting Flood Management

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China-US Case Studies Project: This report is part of a series of six case studies (http://www.georgetownclimate.org/US-China-case-studies) that explore how subnational actors (municipalities, states, and special administrative regions) in the United States and China are building resilience to natural hazards, extreme weather, and climate change. These case studies examine efforts to adapt to impacts in three U.S. and three Chinese jurisdictions, including efforts to prepare for: (i) increasing coastal flooding due to more frequent and intense coastal storms and rising sea levels in coastal Louisiana and Shanghai; (ii) increasing water scarcity in Austin, TX, and Beijing; and (iii) increasing heat waves and urban heat islands in Washington, DC, and Hong Kong. These case studies are oriented toward building resilience to the weather and climate related impacts being experienced in each jurisdictions; these actions are not always explicitly linked to climate change, and we do not evaluate the effectiveness or appropriateness of the specific activities undertaken by each jurisdiction.

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## Introduction

The low-lying Yangtze River Delta is an important commercial and transportation center for China. At its center is the coastal city of Shanghai, the largest city in the world. An important global financial center and the busiest container port in the world, Shanghai consequently is China's most important economic center. Located on the estuary of the Yangtze River, Shanghai has long been vulnerable to flooding and sea level changes. Shanghai sits at an average of thirteen feet above the mean tide, making it particularly vulnerable as the climate warms and sea levels rise.[1] As the city continues to expand and formerly undeveloped land is paved over for roads and buildings, this construction boom has brought new challenges in the form of poor drainage, exacerbating flooding concerns.

## Background

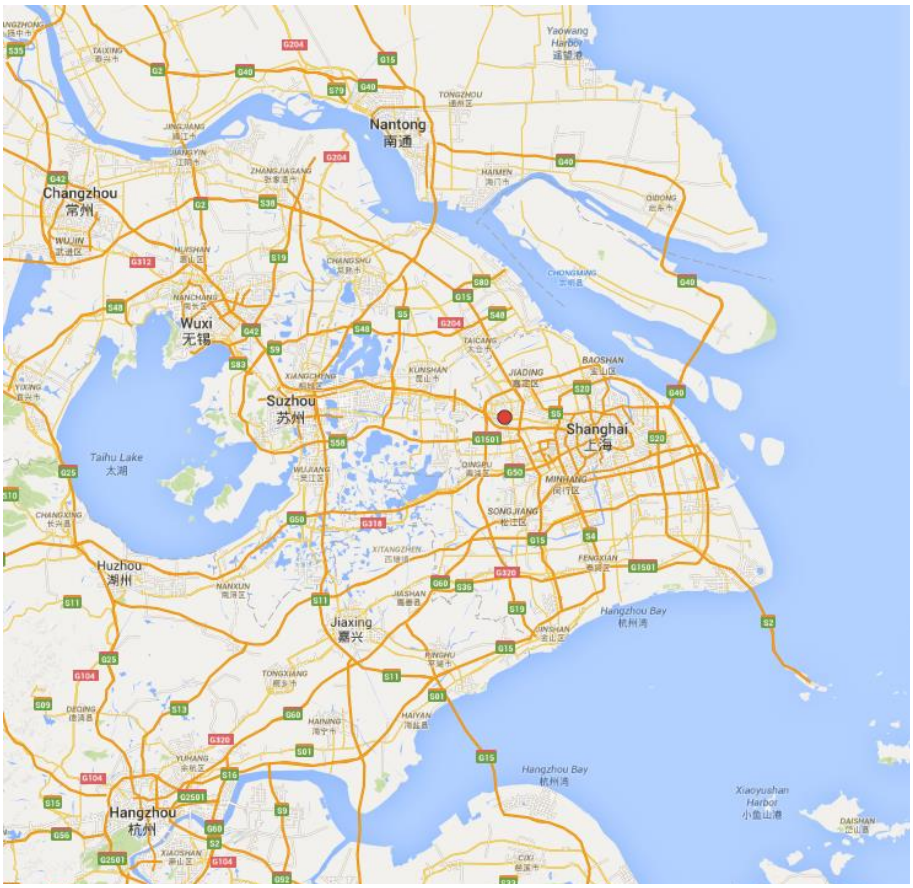
The municipality of Shanghai is surrounded by Provincial neighbors Jiangsu to the North and Zhejiang to the South, has a marine monsoon climate with hot and humid summer. The average temperature in Shanghai rose 2.35℃ (4.23°F) in past 50 years, which is twice as fast as the national average temperature

[1] Catherine Seavitt, *Scenario Journal*, 2013, http://scenariojournal.com/article/yangtze-river-delta-project/.

change and four times more than the average change globally.[2] Since 1990, the city's increasing "heat island" effect is thought to have increased the average temperature by 0.73℃ (1.3°F) per decade.[3]

Shanghai's geomorphic characteristics also make it one of the most vulnerable cities to flooding. Its geological foundations consist of alluvial mud deposited by the Yangtze River over hundreds of thousands of years making it susceptible to land subsidence. The Yantze delta region has thousands of linear canals for local irrigation and transportation increasing flooding risks. In addition, the region is extremely vulnerable to tropical cyclones or typhoons. [4]

The Yangtze Delta is also one of the most sensitive areas for witnessing sea level change in the world. In Shanghai, on average, sea level has risen 1.6 mm annually for the past 50 years (80 mm total or 0.26 feet), while it is expected to continue to rise 98 ~150 mm in total for the next 30 years (about 0.5 feet) .[5] In addition, the tides of the Huangpu River, flowing through downtown Shanghai, are affected by water levels of the Yangtze much further upstream, reaching Taihu Lake. High water levels during high tides, driven by storm surges and flooding events upstream, can result in tides of 2m-3m above sea level reaching Shanghai. During the decade of the 1990s, the water level exceeded 5 m only 5 times, but in the year 2001 this happened 4




*Map of Shanghai*
*Source: Google maps*

[2] Deshun Zhang, Xiangliang You, and Cheng Wang, "New and Excellent Tree Species Selection in Shanghai's Response to Climate Change上海应对气候变化的新优树种选择," *Chinese Landscape Architecture 中国园林*, no. 9 (2010): 72–77.

[3] Chaolin Gu et al., "Climate Change and Urbanization in the Yangtze River Delta," *Habitat International* 35, no. 4 (October 2011): 544–52, doi:10.1016/j.habitatint.2011.03.002.

[4] Seavitt.

[5] Zhang, You, and Wang, "New and Excellent Tree Species Selection in Shanghai's Response to Climate Change上海应对气候变化的新优树种选择."

times in one year.[6]

In addition to flooding and sea-level rise, Shanghai is also subject to extreme weather events such as typhoons and heat waves. Rainstorm frequency has increased from 6 times a year during the 1980s to 9 times per year by the 2000s.[7] The "nightmare" scenario for Shanghai would be a typhoon coming at the same time as high river levels, which could have devastating impacts on the city, and consequently on China's economy.

## Flood Control and Typhoon Adaptation

The Shanghai municipal government has taken various steps to address flood risks. Most notably they have built four levels of protection around the city to fight against floods, including (1) the Huangpu River Levee; (2) Seawalls;(3) Drainage Systems; and (4) an Advanced Flood Information Control System.

### The Huangpu River Levee

The Huangpu River is the primary water source for Shanghai and the last significant tributary of the Yangtze River before it flows into the East China Sea. The river comes from the Taihu Lake area in the South and at its North end runs into the Yangtze, dividing Shanghai into Pudong (meaning east of the Huangpu River) and Puxi (meaning west of the Huangpu River). The Huangpu River is the main source for Taihu Lake's drainage when the lake is at high tide. Thus, the Taihu Lake frequently causes flooding along the river, particularly during the summer rain season.

The Huangpu River Levee was initially built along both banks of the in 1956, and at that time the height of the levee was designed for a "100-year flood." However, the levee was overcome by several severe floods in following decades. In order to strengthen the protection of the levee, the municipal government started a heightening and reinforcement project in 1988. Upon completion in 1993, the total length of the levee reached 208 km, with a height of 2.5 m and a width of 14.4 m, estimated to be sufficient to withstand a "1000 years flood."[8] Furthermore, in 2002, the municipal government opted to add another 110 km to the levee along upstream of the river, stretching the wall protection further south.[9] The levee

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[6] Zhenyu Zhang, "Analysis of Flood Prevention and Countermeasures of Emergency Management in Shanghai上海防汛形势分析及应急管理对策措施," *Urban Roads Bridges and Flood Control城市道桥与防洪*, no. 6 (2006): 69–72.

[7] Fangfang He and Binke Zhao, "The Characteristics of Climate Change of Torrential Rains in Shanghai Region in Recent 30 Years近30年上海地区暴雨的气候变化特征," *Advances in Earth Science地球科学进展*, no. 11 (2009): 1260–67.

[8] Ministry of Water Resources of PRC, "Shanghai Flood Control Wall Reinforcement Project 上海防汛墙加固工程," accessed August 4, 2014, http://www.mwr.gov.cn/weiye/hehu/gongcheng8.html.

[9] Shanghai Investigation, Design and Research Institute上海勘测设计研究院, "The Special Report on Shanghai Flood Control Wall Reinforcement Project上海市区防汛墙除险加固防洪工程专项整治规划报告," September 2004.

project continues, and the municipal government re-evaluates the levee system as part of its five-year plan. By 2013, the levee had reached a length of 511 km (317.5 miles).[10]

## Sea Walls

Shanghai is just west of the East China Sea and North of Hangzhou Bay, making it close to the coast and vulnerable to typhoons, and the history of sea walls in the area dates back to ancient China. Most recently, a 1997 Shanghai municipal government policy, "the Shanghai Coastal Levees Regulation," called for heightening and reinforcing the seawalls. In addition, the municipal government also mandated beach nourishment projects in addition to reinforcement of the seawalls. Finished in 2002, the current seawalls are designed for level 12 typhoons (center wind speed >32.7m/s) with a 100 year return period. The current seawalls are 523 km (325 miles) long and protect the area of 2600 $km^2$ and 2.5 million people against the typhoons.[11] The walls were built along the south bank of the Yangtze River (106.8 km, 21 percent of the total length), the north bank of the Hangzhou Bay (95.5 km, 18.7 percent of the total) and around the Chongming Islands of Shanghai (307.7 km, 60.3 percent of the total).[12] The seawall project is called a "Great Green Wall," because it has been covered with trees, grass and playgrounds for public use and enjoyment.

*Photo of the Seawall at the East China Sea in Pudong, Shanghai*
*Source: Photo by Bo Shui, from http://scenariojournal.com/article/yangtze-river-delta-project/, 2010.*

[10] Yuandong Ma and Jiesheng Song, "Practices and Toughts about Urban Flood Control in Shanghai上海城市防汛工作的几点做法与思考," *China Water and Wastewater中国给水排水* 29, no. 2 (2013): 1–7.

[11] Shuangquan Xu, "History, Present Situation and Looking Ahead of Haitang Construction in Shanghai City上海海塘建设历史、现状和展望," *Urban Roads Bridges and Flood Control城市道桥与防洪*, no. 3 (2004): 54–56; Ma and Song, "Practices and Toughts about Urban Flood Control in Shanghai上海城市防汛工作的几点做法与思考."

[12] Feng Chen and Dingman Qi, "Study on the Present Defensive Capability of the Coastal Levees in Shanghai上海市海塘防护能力现状的调查及分析," *Journal of Marine Sciences海洋学研究* 28, no. 1 (2010): 72–79.

## Urban Drainage System

In 2012, in response to multiple flooding events in the area, the Shanghai Water Authority decided to spend 25 billion yuan ($3.96 billion) to upgrade the municipal drainage system with wider pipes in order to better withstand rainstorms and to prevent flooding caused by inadequate drainage and overflow of stormwater systems.[13] For example, in Hongkou District, 600 mm pipes were replaced with 800 mm ones. The Director of the Drainage Department of the Shanghai Water Bureau, Ma Yuandong, has said that another 13 such drainage improvement projects, including Jiaozhou Road in the Jing'an District and Julu Road in the Huangpu District, are also underway.[14] Another 28 drainage systems are planned by 2015.[15] Every year before the flood season, the authority pre-evacuates the pipes to make sure the system works at full capacity. In 2011, an estimated 14,000 km of pipes were maintained and 310,000 $m^3$ of mud was evacuated.[16]

## Advanced Information System

Shanghai has established a comprehensive Advanced Information System under the Shanghai Flood Control Information Center. The Center has responsibilities for collecting information, running a network for monitoring and supervision, and managing facilities. The information systems provide precise information, updated every five minutes, to the Shanghai Flood Control Headquarters. Information comes from 13 city-wide sea-level stations, 44 tide-level stations, 14 meteorological stations, 80 hydrometric stations, 36 water-logging-area monitors, 93 sluice-pump stations, and 160 city-center drainage monitors.[17] For example, the drainage monitors will alert relevant authorities once the water level has reached 20 cm in a specific location. When water levels reach 20-30 cm, the police will be alerted to implement road closures.[18]

In order to alert the public, the government has set up a warning system using social media and other forms of communication, such as Weibo and text messages. For example, on August 6, 2012, the day before Typhoon Haikui (Sea Anemone) landed in the area, the Shanghai Flood Control Information Center sent out 59.7 million text messages through the three major cell phone providers.[19] When natural disasters occur, rumors can cause panic, and can be difficult to control in large cities. As a result,

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[13] "China : Shanghai Water Authority to Build a Drainage System Worth $3.96 Billion to Withstand Heavy Rains," *MENA Report*, September 6, 2012, 1038168037, ProQuest Research Library, http://proxy.library.georgetown.edu/login?url=http://search.proquest.com/docview/1038168037?accountid=11091.

[14] "Shanghai Municipal Government: Road Drainage Improvements Under Way," *Hong Kong Government News*, July 1, 2012, 1022966487, International Newsstand, http://proxy.library.georgetown.edu/login?url=http://search.proquest.com/docview/1022966487?accountid=11091.

[15] "Shanghai's Drainage System Has Its Limits," *Shanghai Daily*, July 24, 2012, 1225539850, International Newsstand, http://proxy.library.georgetown.edu/login?url=http://search.proquest.com/docview/1225539850?accountid=11091.

[16] "Shanghai Municipal Government: Road Drainage Improvements Under Way."

[17] Shanghai Flood Control Information Center, "Shanghai Flood Control Conduction System上海市防汛指挥系统," accessed August 6, 2014, http://www.shanghaiwater.org/fxxxzx/jscg/cg1.jsp.

[18] "Shanghai's Drainage System Has Its Limits."

[19] Zhenyu Zhang, "Shanghai Utilized New Media to Adapt Typhoon 'Haikui'上海市利用新媒体防御台风'海葵'工作案例," *China Flood and Drought Managemenand 中国防汛抗旱*, no. 2 (2013): 28–29.

delivering information transparently and immediately can curb public concern and help prevent the spread of false information.

## Ecological Flood Control

Like many other cities in developed countries, Shanghai has also started to implement ecological flood control methods to harmonize the overall climate and to preserve the environment utilizing natural resources. Shanghai is increasing its natural resilience by using the absorption capacity of soil and plants to improve drainage. The city is also constructing green roofs to reduce rain runoff and heat island effects, and maintaining wetlands in the city. In the long run, it is a very effective way to decrease the impact of extreme weather events.

*Photo of Houtan Park on the Huangpu Waterfront: A Constructed Wetland for Ecological Flood Control. Source: Photo by Turenscape, http://www.archdaily.com/131747/shanghai-houtan-park-turenscape/*

## Lessons Learned

After experiencing levee and sea-wall breaches, the Shanghai government is actively pursuing measures to increase its resilience to future events. It instituted a process to continually to re-evaluate the efficacy of its infrastructure, particularly in light of increasing instances of extreme weather events and rising sea levels. The Shanghai Flood Control Wall Reinforcement Project is included in the municipal "Five Year Plan" to make sure the government pays attention to the issue consistently in a structured manner, and that the budget for such projects is appropriated several years in advance. The city also engages in annual maintenance as a resilience strategy. Every year before the flood season, the Shanghai Water Authority is responsible for pre-evacuation of the pipes to make sure the system is clear of mud and silt and working at full capacity is key to flood prevention as well.

It is also likely that extreme weather events that have affected other coastal cities around the world have inspired Shanghai to take its own resilience and protection measures seriously. For example, New Orleans is located at the estuary of the Mississippi River and on the north of the Gulf of Mexico, and therefore has a similar geography as Shanghai. Some Chinese scholars have examined how lessons learned during Hurricane Katrina could help to inform sea-wall management in Shanghai, in order to avoid a similarly huge loss of properties and lives.[20]

[20] Shuangquan Xu and Xianwei Zhu, "Inspirations from Hurricane 'Katrina' to Seawall Management of Shanghai'卡特里娜'飓风对上海市海塘管理的启示," *Urban Roads Bridges and Flood Control城市道桥与防洪*, no. 4 (2007): 33–37.

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