Liang Yang
Chunxiao Zhang
Grace W. Ngaruiya

Water Risks and Urban Responses under a Changing Climate: A Case Study of Hong Kong

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Water Risks and Urban Responses under a Changing Climate: A Case Study of Hong Kong*

Liang Yang[a,b], Chunxiao Zhang[c], Grace W. Ngaruiya[a,b]

[a] Research Group Climate Change and Security, Institute for Geography, University of Hamburg, KlimaCampus, Grindelberg 7, 20144 Hamburg, Germany
[b] School of Integrated Climate System Sciences, Grindelberg 5, 20144 Hamburg, Germany
[c] Institute of Space and Earth Information Science, The Chinese University of Hong Kong, Rm 210, Fok Ying Tung Remote Sensing Science Building, The Chinese University of Hong Kong, Shatin, Hong Kong

Correspondence to L. Yang:
Tel. +49 (40) 42838-7706
eMail: liang.yang@zmaw.de

Abstract

Hong Kong is often portrayed as a water abundant city because of its location in the subtropical zone. However, this is not accurate as Hong Kong has suffered from serious water shortages and occasionally floods for a long time. Recently, climate change is likely to add negative effects to the city and its people in water-related issues. Mitigating flood (or sea level rising) impacts and ensuring sufficient freshwater availability are emphasized as the major water resources management challenges for Hong Kong. Although several response measures play effectiveness, associated risks are brought in and would likely enlarge the threat degree, like the benefit conflicts in the Dongjiang-Shenzhen Water Supply Project (DSWS Project) and the surface contaminants threats when extend the water catchment area. This article discusses Hong Kong water issues based on data from field research in 2011, and seeks to draw attention to some of the associated risks and responses within the climate change context. First, the article describes the present water situation in Hong Kong. Second, the city's response measures in water management are discussed to give policy recommendations. Finally, the risk analysis and conclusion highlight that undertaking precautions is the best choice for Hong Kong to address potential water risks.
Keywords: Climate impact, flood, water shortage, risk & perspective, Hong Kong

1 Introduction

Hong Kong, located in the Pearl River Delta (PRD) in southern China, is portrayed quite often as a subtropical area with abundant water resource. However, this is only a part of the picture. Actually, water issues in Hong Kong are complex. On the one hand more than 70% of the water demand in Hong Kong is supplied by Dongjiang (East River) water from Guangdong Province, which is highly dependent and hardly adjustable. One the other hand, the city cannot do anything but see plenty of rainfall water (even flood) flow into the sea, because mostly the rainfall comes

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and goes quickly and the water is hard to be stored in this mountainous terrain. In addition, Hong Kong is suffering from tidal invasion in typhoon event and struggling with the costs of sea water desalination. Theoretically, Hong Kong has access to water resources as it is surrounded by the sea and the city receives high rainfall. However, risk of water shortage still exists, with the characteristics of seasonal-insufficient precipitation, lack of adequate fresh water, poor water storage condition, and water pollution as well as the expanding water demand of the expanding population. Global climate change adds another dimension to these problems. It is important to understand the effects of climate change on water issues in such a mega-city.

Since water system management is complex as well as politically difficult, decision makers responsible for the future of Hong Kong need the best expert knowledge available (Hunt et al. 2007). This paper, based on literature review and a half-month field trip to Hong Kong in December 2011, investigates the water issues and water management of Hong Kong to explore the key points, and then analyzes the potential risks under climate change and possible responses. Also, it discusses several priorities to address the water issue and to identify the added risks from climate change and rapid development.

2 Climate change in Hong Kong

While Hong Kong is already threatened by mentioned traditional water problems, additional threats posed by climate change are likely to increase the risk scale to the city and its people. Studies have shown that concentrated representation of human society development such as cities, are among the most vulnerable regions to climate change (Stern et al. 2006; IPCC 2007).

The average temperature per decade increased from 0.15°C between 1947 and 2011, to 0.23°C between 1982 and 2011 (Hu, et al., 2011). During the 65 years after the Word War II, the precipitation increased by 36mm per decade according to data from HKO (Hong Kong Observatory) (Fig.1). The interannual variability of precipitation is much more notable relative to the trend variability of precipitation, which means extreme precipitation events occur very frequently (Ginn, et al., 2010). Between 1954 and 2011, the average sea level showed an average increase of 2.8mm annually at the Victoria Harbor (Fig.1). Main effects of sea level rise on Hong Kong are exacerbating storm surge flood and the incursion to fresh water (Wong, et al., 2010).

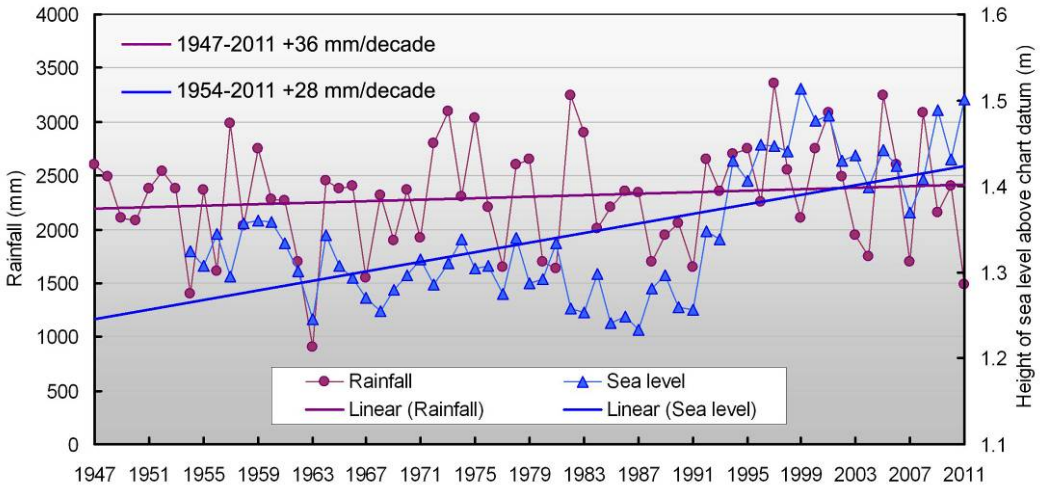


Fig. 1 Climate change indicators in Hong Kong (1947 - 2011)

Source: Hong Kong Observatory

Apart from the general trend of climate change in Hong Kong, extreme weather events (e.g. rainstorm/typhoon, drought, heat waves) affect water resources even more serious (Wong, et al., 2011). These disasters intensify water risks in Hong Kong and make water management more complicated. The Water Supplies Department of Hong Kong, as well as other water related departments, have taken measures to deal with water problems in the last few decades, but they focused more on current water problems instead of potential risks.

3 Water issues and current situation

Abundant rainfall: Hong Kong is in the subtropical monsoon zone with very rich annual rainfall. The average annual precipitation during 1981-2010 is 2398.5mm, which equals an average annual rainfall of 2648 million cubic meters in the whole Hong Kong area. Considering with the actual water consumption of 1228 million cubic meters between 2008 and 2009, Hong Kong could satisfy its water demands with rainwater. However, collecting 50% of the rainwater is hardly possible at the city scale. Despite the large average amount of rainfall in Hong Kong, the inner-annual distribution is very uneven. About 80% is received in storms between April and September while 20% is received in the dry season from October to March. In addition, high evaporation in the subtropical region contributes significantly to water losses (Liang, 1997).

Poor conditions for nature water storage: Hong Kong is made up of several peninsulas and a group of islands, of which about three quarters are covered by hills and another quarter by urban facilities (Fig.2). The islands are small and rivers are formed quickly. The rivers, such as the Shing-Mun River and Shek-Sheung River, are too short (less than 5 km), so runoff goes quickly into the sea and a considerable part of surface water can not be used at all. With the small size, short rivers and hilly landscape, Hong Kong has unfortunate conditions for the construction of large reservoirs. At the same time, Hong Kong geology is mainly composed of granite and volcanic rocks which have a poor water storage capacity (Su, et al., 2008).

Fig. 2 Poor conditions for water storage (mountainous terrain and highly developed urban areas)

*All the photos are taken by the authors, except those specified

High water demand: Even though Hong Kong is already considered overpopulated, the population is still growing and so is its water demand (Fig.3, Fig.4). Along with economic development, tourism has also developed very fast, increasing further the already high water

demand. In the year 2011, the number of visitors in Hong Kong reached 41.9 million, of which 22.3 million are overnight visitors and their average stay is 3.6 nights (Tourism Commission of the Government of Hong Kong Special Administration Region, 2011). This equals to 220 thousand people who stay in Hong Kong the whole year. Their water demands would increase the total demand with 3%, counting on the basis that one visitor consumes the same amount of water with one local citizen per day.

Fig. 3 High density of residential buildings in Tsuen Wan, Hong Kong

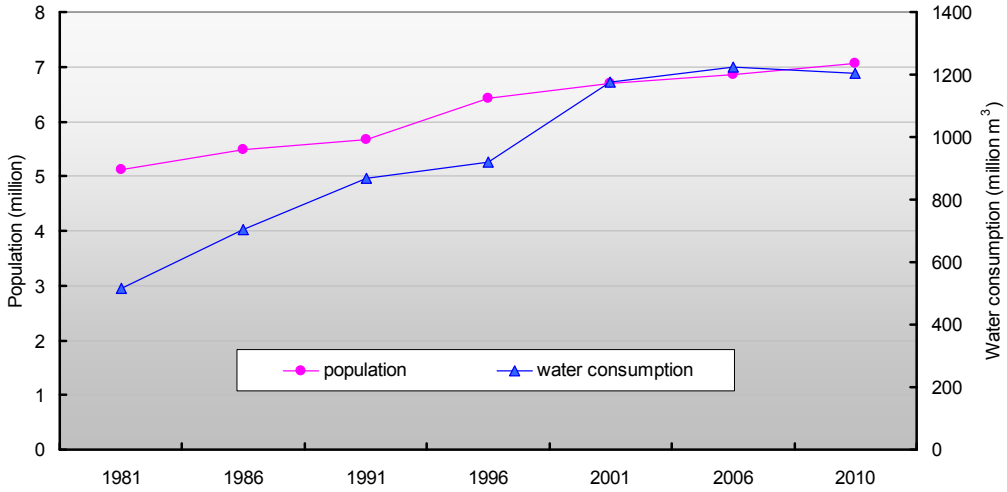


Fig. 4 Population and water consumption of Hong Kong

Source: Census and Statistics Department and Water Supplies Department, Government of the Hong Kong Special Administrative Region

Storm, flood and sea water intrusion: Heavy rainfall and storm come in May to June. The storms periodically cause large-scale flooding and landslides that result in major traffic disruptions. In some instances, it has even caused human injury and death (Chan, et al., 2010). According to HKO reports, the increasing frequency of extreme weather events could lead to increased flood probability. More so in cyclone weather, seawater goes up the rivers, invading freshwater systems or damaging engineering facilities. Some low-lying and poorly drained areas are frequently affected by flooding. For example, still some people live at low land near the river in northwest

Hong Kong, which is marked as flood-prone area (Fig.5).

Fig. 5 Riverside residences at Shan-Pui-Ho River, Hong Kong

4 Water management and planning

It's clear that Hong Kong is rich in water but poor in usable freshwater. The Hong Kong government implemented a series of measures to address the water predicament and achieved remarkable success.

Dongjiang–Shenzhen Water Supply Project (DSWS Project). Dongjiang (East River) is one of the three main rivers in the Pearl River system. It originates in the Xunwu County of Jiangxi Province, flows through Heyuan city, Huizhou city, Dongguan city of Guangdong Province and drains into the sea. Several branch streams flow from Shenzhen to the mainstream (Fig. 6). The Xinfengjiang Reservoir, in Heyuan, is a key to adjust the water level of the down stream.

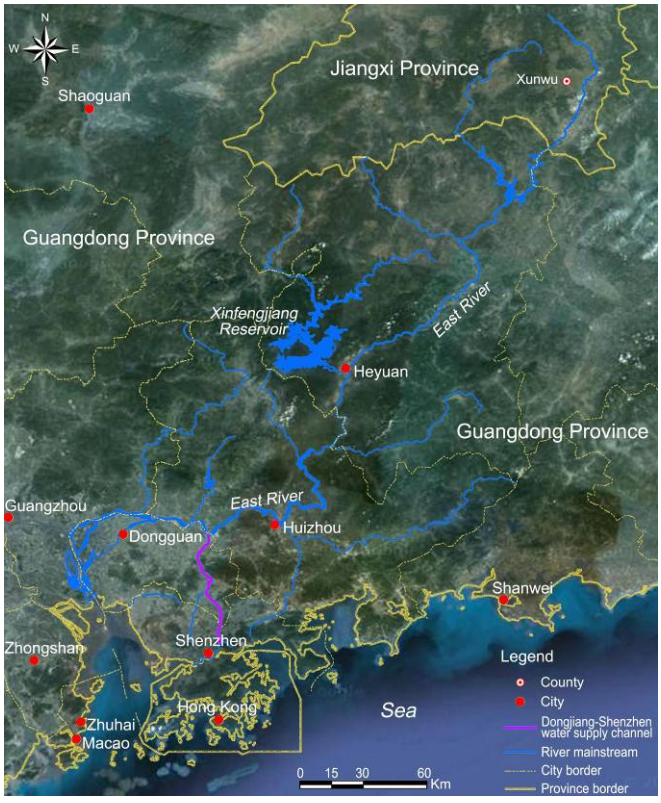


Fig. 6 Dongjiang river system and the DSWS project

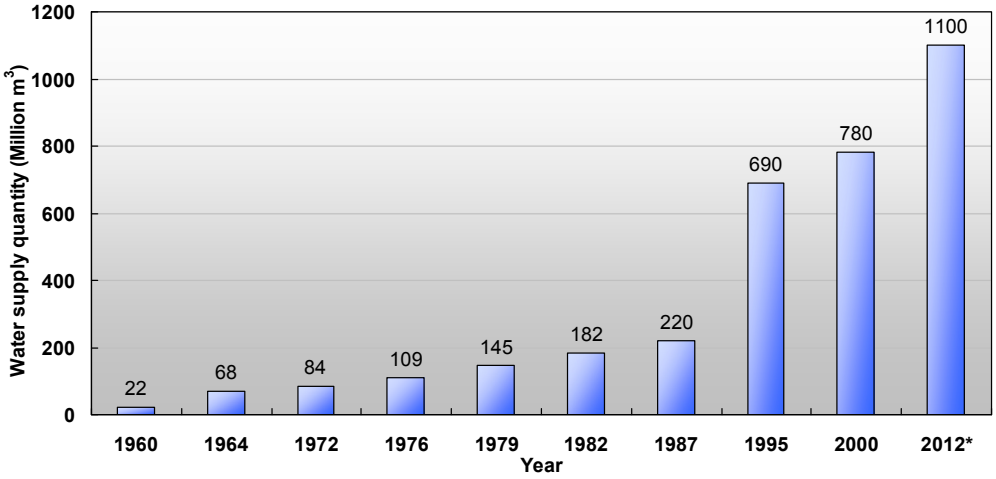
Source: Edited based on Google map (26.04.2012)

The DSWS Project starts from Qiaotou town of Dongguan. Water is pumped and pipelined 46m higher, backwards along the Shima River which is a branch of Dongjiang, to the Shenzhen Reservoir and then to Hong Kong (Fig.7). Although the project has initially been built with the main purpose of supplying water to Hong Kong, Shenzhen and Dongguan also benefit from it.

Fig. 7 Qiling aqueduct of Dongjiang–Shenzhen water supply project

Source: Guangdong Hydropower Planning & Design Institute

The water supply to Hong Kong has been increasing in the last 50 years. Several times the water supply agreement has been adjusted to the increased water demand. Currently, the actual water supply to Hong Kong is 800-900 million m^3. And the maximum capacity of the project is 1100 million m^3 per year (香港区全国人大代表对东江水源污染防治工作调研总结报告, 2011; Fig. 8).



* The value in 2012 is not the actual value, but the maximum capacity of the project.

Fig. 8 Amount of water supply to Hong Kong by DSWS Project

Source: 香港区全国人大代表对东江水源污染防治工作调研总结报告, 2011

There were many challenges when the project was initiated, and still many difficulties exist in the operation. There are big social and economic differences between the cities in the river basin. Economically, using indicators of urbanization and GDP per capita (which are concerned most by the local government) as examples to represent the local development level, the upper cities (Heyuan, Huizhou) have far smaller values in these indicators than the downstream cities. That means the upper cities are poor, underdeveloped, and have less economic power. Politically, the region is quite complicated. Normally there are four administrative levels of nation, province, city and county from top to down, but Hong Kong is the Special Administrative Region which is between the level of nation and province and Shenzhen is the Special Economic Zone which is between the level of province and city. Higher administrative level means stronger political power. Thus interestingly the Dongjiang water flows from Xunwu, Heyuan to Huizhou, Dongguan, and is then pumped to Shenzhen and Hong Kong, while the political-economical power goes down from

Hong Kong, Shenzhen to Dongguan, Huizhou, Heyuan and Xunwu. Water resource and political economical power decrease but in the opposite directions, meaning that water resources from the upper area are exchanged for money or other benefits in the downstream cities. This system of exchange appears to be balanced. But this balance depends highly on both sides' resource quantity and exchange intention. It could easily be broken by a drought, pollution, or a changes in social/economic field.

Rainwater collecting from natural catchment: Hong Kong has always been researching more effective uses of rainwater resources and reducing consumption of portable water for non-food uses (such as toilet flushing, irrigation and cooling systems, etc.). An ongoing project is the construction of the diversion channel on the hillside which is supposed to channel precipitation and mountain streams into reservoirs (Fig.9). There are 17 reservoirs (include 2 bay reservoirs) in Hong Kong, which play an important role in the water supply system. In a third of the Hong Kong area, rainwater is diverted by the winding hillside catchwaters and transported to the reservoirs. Almost all reservoirs are artificially built based on certain natural conditions, for example, the High Island Reservoir, the largest in storage capacity and Plover Cove Reservoir - the largest in area (Fig.10). These two large surrounded-bay reservoirs account for 87% of total reservoir capacity (5.86×10^8 m^3) in Hong Kong. In addition to saving collected rainwater, the reservoirs also play a role of regulating and storing the water from DSWS Project.

Fig. 9 Rainwater collecting channel at hillside

Fig. 10 Plover Cove Reservoir

For reducing dependence on Dongjiang water, it has been proposed to expand the rainwater catchment area and to increase the storage capacity of reservoirs in Hong Kong. This proposal is not favorable to the city since land development in the catchment area would be restricted. Actually, one-third of the land has been protected as rainwater catchment area in Hong Kong. This proportion is quite high already. In addition, larger water catchment area means more surface contaminants could flow into reservoirs with rain water.

At present, Hong Kong identifies a number of parks and public buildings to recycle rainwater for flushing and irrigation by a rainwater harvesting system. The preliminary effects will be referenced subsequently in the setting of rainwater harvesting system standards. In addition, the Water Supplies Department commissioned a consultancy study to formulate a set of design guidelines and water quality standards for rainwater harvesting systems. The work is expected to be completed in 2012.

Seawater utilization: In 1971, Hong Kong established a desalination plan, which was developed by a Japanese company. Six groups of desalination equipments were built with the respective production of 30.3 thousand m^3 fresh water per day. Due to high running cost, the plant only operated from 1976 to 1982. And, it was deconstructed in 1992 since cheaper and constant water supply was available from DSWS Project to meet the total water demand.

Hong Kong began to use seawater for toilet flushing from 1950 because of the lack of natural fresh water resources. Whereby sea water is pumped in the seawater pumping station and goes through the grid to remove the larger impurities. Then the water is disinfected and transported to households when it meets the standard quality requirements. The use of seawater for flushing is a major feature of the urban water supply in Hong Kong. The system has a separate water distribution pipes, pumping stations and service reservoirs. Currently the annual consumption of seawater in Hong Kong has reached over 200 million m^3, which helps saving the same amount of fresh water and accounts to about 18% of the total water consumption. About 80% of the residents use seawater for flushing, and the proportion is expected to grow up to 90% in future. In addition to utilization of flushing, in some areas of Hong Kong the seawater has also been used as municipal fire water.

Water treatment and reuse: The Hong Kong Environmental Protection Department has

issued “Water Quality Indicators of Wastewater Treatment for Landscape Irrigation” in 1994. However, few projects about treated water reuse are launched in Hong Kong at present, since the pressure on fresh water supply is lessened greatly by the DSWS Project and seawater flushing. According to a technical staff of WSD (Water Supply Department), part of the drainage is treated and reused for green land in the project of Hong Kong’s new airport on Lantau Island.

Multi-level water charging system: This system is an effective measure to promote water conservation. The system divides household water consumption (within a certain time, e.g. one month) into several levels and charges different rates for each level.

Furthermore, the Hong Kong WSD has also developed a number of other water-saving provisions, such as changing water from swimming pools once a year, using inductance or delay self-closing faucets at public places and so on, which all have played a certain role in water conservation.

5 Risk and perspective

Drought risk of the water source area: Despite water supply assurances to Hong Kong, water shortage due to drought in the source area is likely lead to conflicts between upper stream areas and the down stream cities. The DSWS Project supplies more than 70% of the water demand in Hong Kong thus should there be a disastrous drought in the Dongjiang River basin (like the draught in 1963) the effects would be severe. Although a moderate drought may not affect the household water availability, drought would intensify water pollution and make water pumping harder (low water level, more electricity consumed) and therefore increase water treatment costs and terminal water prices.

Threats of sea level rise and flood: Hong Kong is a highly urbanized city characterized by significant artificial land reclamation, which together with natural riverbed siltation and effects of climate change contributes to an observable sea level rising. This threatens water-related infrastructures, especially the two largest freshwater reservoirs. Meanwhile, offshore pollutants along with salty sea water intrusion in freshwater would destroy the water supply and piping system. For a long term perspective, coastal projects must be constructed with higher flood-control standard and desalination plants need to continue working.

Pollution risk of source water: To control water pollution at the source, the upstream cities are restricted in using pesticides and emitting sewage. But they ask for economic compensation due to reduced industry development. In addition, Shenzhen and Dongguan also demand more and more water from the DSWS Project, even through the two cities discharge sewage to the Dongjiang River. How much can they share in the project and how much should they contribute to the project? In such a complicated situation, any small scale event (like pollution) could cause conflict or social unrest.

Social and cultural conflicts: Although Hong Kong returned to mainland China 15 years ago, social and cultural conflicts between the two still exist although at low intensity. Hong Kong depends highly on fresh water, electricity and food from the mainland, but it used to complain the air pollutions from the Pearl River Delta cities (Lu, 2007). Also, many mainland people go to Hong Kong for high quality medical care, education or shopping, thus using much of Hong Kong’s public resources. Hong Kong citizens view this as scourge and resist the inrush of mainland people, which is then retorted by the mainland as discrimination. These trivial matters in the social field could be a signal of large scale resources conflicts in the future over certain

situations.

Policy risk: Presently, domestic climate security consciousness is still in its infancy in Hong Kong. Economic development and climate protection are still seen as contradictions. The public is not sure about the necessity for improving urban adaptation, and is lacking awareness of possible future risks. So far, there has not been an integrated "climate response" strategy that integrates the urban society, water and conflicts. Thus a government policy based on population unawareness and myopic planning could be a serious potential risk for the city that needs to be highlighted and sorted.

Basically, Hong Kong is facing water risks from both the climate impacts and the social activities(Fig.11). Previously taking response measures and improving resilience capacity are the key points. Due to natural river siltation and artificial reclamation as well as sea level rise in the context of climate change, water levels of tides and floods keep increasing. Thus, more work needs to be done to improve the anti-flood capacity of buildings and other infrastructures. The public should be prepared to actively save water in daily life and the government should build more water storage projects so that the city could cope with the uncertainties of abrupt climate change or extremely low rainfall. Researchers suggest that the main goal of all adaptation strategies should be to improve local resilience, or the ability of a community to bounce back quickly from climate impacts (CCAP. 2009). Also with this aspiration in mind, aggressive public awareness on climate change impacts and response strategies need to be undertaken so that people in Hong Kong can prepare for climate change impacts. Finally, strengthening studies on urban response to climate impacts must continue to be supported to mitigate potential water risks.

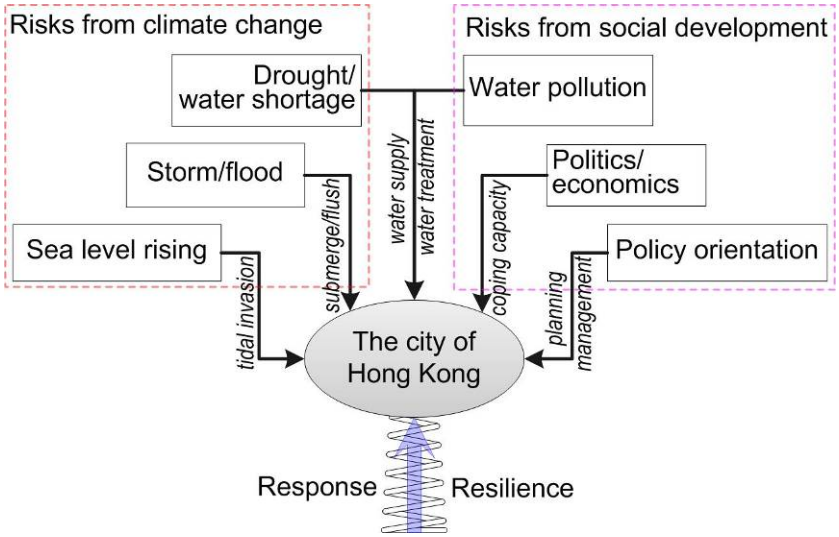


Fig. 11 Framework of water risk in Hong Kong

6 Conclusions

Hong Kong is a city with sufficient average precipitation, but it still suffers from water shortage. Thus, most of the drinking water is transferred by DSWS Project, sustained by political and economic power in a water supply agreement. However, should conditions change, like a severe drought or pollution in the Dongjiang River basin, it could become a potential security problem. In addition, although urban development and water supply-drainage systems are well designed and planned in Hong Kong, flood disasters and seawater invasion could still happen, even worse, in the context of climate change. Lack of awareness of the local population on climate

impacts has also made the government take few measures to deal potential climate risks. So far the focus has been on current visible problems. So mitigating flood (or sea level rising) impacts and ensuring sufficient freshwater availability are the major water resources management challenges for Hong Kong. For reducing risks in the future, taking precautions is always the best choice.

Acknowledgements

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