The Battle of Tokyo and Dhaka Against Floods

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In Asia, two deltaic cities have to endure the constant threat of flooding: Tokyo, capital of Japan, and Dhaka, capital of Bangladesh. Bangladesh is one of the poorest countries of Asia and Japan is the wealthiest country of Asia. The question is how these cities handle the threat of flooding. Are there similarities between their approaches or do they follow different courses? This paper shows that both cities use similar flood protection structures, such as flood walls and embankments. This is remarkable because, in general, the type of structure depends on the available resources, the physical constraints and the degree of urgency. There are also differences in flood control. Aesthetics and an appealing waterfront are in Bangladesh of less importance than in the more developed Japan. In this paper it becomes clear that Japan and Bangladesh can learn from each other. Additionally, other deltaic countries, like in the European Rhine catchment, can also benefit from their knowledge. Exchange of knowledge between all deltaic and flood endangered countries all over the world remains important. It can induce innovative solutions which can lead to better protected cities and better protected hinterland.

Floods are one of the many disasters which happen throughout the world every year. However, the impact of flooding has changed greatly with increased urbanization. Less and less space is left for the river to discharge rain and melt water. Since industrialization road transport has become more important and many permeable surfaces have been replaced by impermeable surfaces such as concrete and asphalt. More water is collected by the rivers, increasing the problem of proper discharge. The result is an increasing flood threat.

Two Asian countries – Japan, one of the wealthiest countries in the world, and Bangladesh, one of the poorest – are among the many countries which have to endure the constant threat of floods. This paper focuses on these two countries, analysing their characteristics, their flood history and their flood measures.

Japanese Islands

Japan consists of 6,852 islands and has a surface area of about 377,900 km^2 (see table 1). More than 70 per cent of the country is steeply mountainous and not fit for habitation (Yoshimura, Omura *et al*., 2005). About 3.5 per cent of the surface area consists of water. Japan's rivers (see figure 1) are short (with a maximum stream length of approximately 367 kilometres), steep (with an average gradient of 0.44 per cent) (*Ibid*.) and flow rapidly down the mountains, across the plains and into the Pacific Ocean, the Sea of Japan or the Seto Inland Sea (Takahasi and Uitto, 2004). The Japanese rivers are fed by rain and melt water (see figure 2). The maximum discharge is about 100 times as much as the minimum discharge.

Japan is situated in the eastern monsoon

Table 1. Statistics of Japan and Bangladesh.

	Japan (Tokyo)	*Bangladesh (Dhaka)*
Total population in 2005 (*million)	127.8	138.6
Surface area (km^2)	377,900	147,000
Density (/km^2)	338	942
Gross Domestic Product (*billion) (US$)	4,600,000**	60.7***
GDP per head (USD$/-)	36,000	438
Metropolitan population in 2007 (*million)	12.8	13.5
Metropolitan density (-/km^2)	5,848	8,400

Notes: ** Figures from 2005; *** Figures from 2007.

Figure 1. Map of Japan.

region with a warm and humid climate (Yoshimura, Omura *et al*., 2005). The country has twice the world average precipitation (Infrastructure Development Institute, Japan and Japan River Association, undated) and mean annual precipitation is approximately 1,800 mm, while in some areas it can reach 3,000 mm (River Bureau, 1990). Large precipitation takes place during the rainy season in June and July, during the typhoon season with typhoons originating from the southern Pacific in September and October, and during winter snowfall in north-ern Japan (Yoshimura, Omura *et al*., 2005).

Today, Japan has, after the United States, the highest Gross Domestic Product (GDP) in the world and so is one of the wealthiest countries in the world. In 2005, its GDP (current prices) was about US$4.6 trillion, giving a GDP per head of US$36,000 (Statistics Bureau of Japan, 2006).

Figure 2. The Japanese landscape.

Bengali Delta

Bangladesh has a surface area of about 147,000 km^2 and borders with India in the west, north and east, Myanmar in the south-east and the Bay of Bengal in the south (Chowdhury, 2000; Bangladesh Bureau of Statistics, 2007). It is one of the largest deltaic countries in the world and is mainly formed by the Ganges, the Brahmaputra and the Meghna rivers (Mallick, Rahman *et al*., 2005) (see figure 3). These rivers create a complex network of 230 rivers of which fifty-seven are transboundary. When all three rivers simultaneously reach their peak discharge of 190,000 m^3/s during the monsoon season, the maximum drainage capacity of these rivers is exceeded. Flooding is the inevitable result (Ali, 2007). Eighty-two per cent of Bangladesh is low lying area (see figure 4), a combination of back swamps and old channels; only 8 per cent of the country (in the east and the north-east) is tertiary hills (Rumi, 2008).

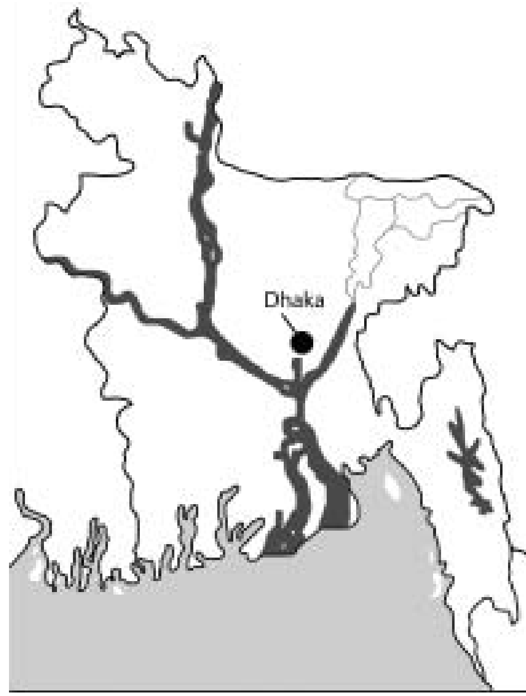

Figure 3. Map of Bangladesh.

The climate is classified as humid tropical with a monsoon season from July until October. The average annual rainfall is about 2,442 mm of which 1,733 mm falls in the monsoon season (Bangladesh Bureau of Statistics, 2007), thus it is no surprise that Bangladesh is very vulnerable to flooding.

Bangladesh is one of the poorest countries in the world. In mid 2007 the GDP (current prices) was about US$60.7 billion, giving a GDP per head of US$438, which is very significantly less than Japan's US$36,000 per head. Poverty is common, although the poverty headcount ratio, using the Direct Calorie Intake method, has decreased since the early 1980s (71 per cent), but at 41 per cent is still an impressive number. Therefore,

Figure 4. The Bengali landscape.

Bangladesh receives large amounts of foreign aid. In 2006, the country had an outstanding foreign debt of US$19 billion (Bangladesh Bureau of Statistics, 2007).

Objectives

This paper focuses on the deltaic cities of Dhaka, capital of Bangladesh, and Tokyo, capital of Japan. The question is how these metropolises handle the threat of floods. Are there similarities between the approaches of these cities or do they follow different courses? An interesting additional question is: do the geographical position, meteorological conditions and economic situation of these countries influence their approach to flood management? Furthermore, an interesting question is whether these two Asian countries can contribute to the knowledge of flood management in the European Rhine catchment.

Dhaka and Tokyo in Close-Up

What are the characteristics of these two cities? What is their geographical position? Are they influenced by river or sea? How many inhabitants do they have and what is the population density? These topics will be looked into in the following sections.

Tokyo: City Characteristics

Tokyo was founded in the Kanto region of Central Honsu, next to Tokyo Bay, where there was a little flat land between the low hills of the Musashino plain and the marshy shore of the bay (Hooimeijer, 2008). Today, Tokyo is located at the mouth of three large rivers: the Sumida river (figure 5, no. 1), the Ara river (figure 5, no. 2) and the Edo river (figure 5, no. 3). The Sumida river flows through the centre of the metropolitis and is integrated into the urban pattern of the city.

Figure 5. Map of Tokyo.

The Edo river and the Ara river are located in the outer districts of the city; each riverbank has a different type of building structure. Many urban rivers contribute to the city's drainage system against pluvial floods. They are the heritage of the historic low-lying city. One could say that they resemble Venice's system of canals, but the appearance is very different. Most of the urban canals in Tokyo are transformed into concrete drainage ditches which decrease the urban quality while Venice's canals are the main reason for that city's fame.

In Tokyo, the effect of industrialization is very noticeable (see figure 6). In 1940 the population of metropolitan Tokyo was about 7.4 million inhabitants; this had increased to approximately 12.8 million inhabitants by 2007 (Tokyo Metropolitan Government, 2008) and is about 10 per cent of Japan's total population. The population is still growing, but not significantly. The average population density for metropolitan Tokyo is about 5.848/km^2. Tokyo has very considerable assets and economic value and a highly developed infrastructure network. Psychologically, the population of Tokyo is on the highest level of the Maslow's hierarchy of needs, namely in the upper layer of self-actualization (Maslow, 1943).[1] This layer of Maslow's hierarchy of needs is very common in developed countries.

Geographically, large parts of Tokyo are below the flood level of its main rivers (River Bureau, 1990). These areas are former flat plains which were formed by sediment that was carried by rivers. By restricting the river course, no new sediment is carried into these regions, thus creating a height difference and a dike breach would give water free access to a large area. Also, Tokyo has a very large and dense subway system with a high concentration of underground shopping malls. Due to the immense increase in the population, the demand for water increased very considerably. Part of this need was met by the use of groundwater whose extraction began around the beginning of the twentieth century. However, this exploitation caused subsidence over a large area of the city. Today, subsidence has almost completely stopped thanks to the restriction on the use of groundwater (Arakawa-Karyu River Office and MLIT, 2006).

Dhaka: City Characteristics

Dhaka is located in the central alluvial area of the country, which is part of the Madhupur Jungle Terrace. The elevation of Greater Dhaka lies around 7–8 metres above mean sea level (Rumi, 2008), so storm surge is not a direct threat to Dhaka. Compared to the city of Tokyo, no river flows directly through the

Figure 6. Sumida riverfront in Tokyo.

city. It is, however, surrounded by four rivers: the Buriganga river to the south (figure 7, no. 1); the Turag river to the west and north (figure 7, no. 2) and the Balu river to the east (figure 7, no. 3) (Chowdhury, Rahman *et al*., 1998). The Buriganga river, see figure 8, is the largest of the four rivers and flows adjacent to the old city centre. Due to the deltaic character and the fact that the rivers are part of a big transboundary river system, there is a large threat of fluvial floods. Heavy rainfall in the river catchment in, for instance, India can endanger Dhaka.

Dhaka metropolitan area was about 1,600 km^2 in 2000 (Rumi, 2008). The population has grown rapidly since the independence of Bangladesh. In 1970, it was only 1.4 million, but had grown to 13.5 million by 2007 (United Nations, 2008) and was about one-third of Bangladesh's urban population (World, Bank Office, 2007) and 8.5 per cent of the total population (United Nations, 2008). In 2007, the population density in Dhaka metropolitan area was 8,400/km^2, which is tremendously dense. The population is still growing and is expected to reach 17 million by 2015. The overwhelming growth of the city's population is mainly due to the enormous number of rural migrants who came in search of jobs and other opportunities (Rumi, 2008).

Figure 7. Map of Dhaka.

This huge growth did, of course, have its impact on Dhaka. Suitable land became rare and many people were forced to build their houses in the low land and detention areas within the city borders. About 7,600 households in forty-four slums live within 50 metres of the river (World Bank Office, 2007). This resulted in the increased vulnerability of Dhaka to floods. Nearly 50 per cent of urban poor in Dhaka live in these slums (Rashid, 2000), which have inadequate water supplies, poor sewerage and hardly any paved streets. Psychologically, a large part of the population of Dhaka is still on the lowest level of Maslow's hierarchy of needs, namely in the layer of physiological needs (Maslow, 1943). Maslow states that if all needs are unsatisfied, and the organism is then dominated by physiological needs, all other needs may become simply non-existent or be pushed into the background. The poor in the slums are striving for basic needs such as food and water to survive. This state is very common for developing countries.

The Threat of Floods

In general, inundation in Tokyo and Dhaka can be the result of three types of floods. The first type are fluvial floods. Rivers can inundate the city, for instance due to overflow, dike failure or seepage. This was the case in 2000 in the Tokai district in Japan (see table 2). Heavy rainfall led to dike breaches on the Shinkawa river (Motoyoshi, Sato *et al*., 2004). The daily precipitation during this flood event was one-third of the average annual rainfall (Ikeda, Yoshitanu *et al*., 2005). More than 21,800 houses were damaged, of which ninety-eight totally collapsed. The second type of floods are pluvial floods. Inundation

Figure 8. Buriganga riverfront in Dhaka.

occurs from heavy downpours without sufficient runoff and drainage capacity within the city. This happened in Bangladesh during the 1987 flood. Several periods of heavy rainfall occurred in northern Bangladesh, with precipitation of 100–150 millimetres a day (Brammer, 1990*b*). A combination of fluvial floods and pluvial floods led to 39 per cent of the entire area of Bangladesh being inundated (see table 3). The third type of floods are typhoon floods. Both cities suffer from the threat of typhoons. Strong winds uproot trees, destroy power networks and cause chaos in cities. An example is typhoon Ise Bay in 1959 which affected all Japan except Kyushu (see table 2). More than 5,000 people were dead or missing and the typhoon damaged about 1.2 million houses (Arakawa-Karyu River Office and MLIT, 2006).

The Tokyo Flood of 1910

The flood of 1910 was the most severe flood during the Mejij Period (1868–1912).

Table 2. Major floods since 1910 in Japan.

Cause	*Date*	*Dead/Missing*	*Damaged houses*	*Affected area*
Heavy rainfall	Aug, 1910	369	270,000	Kyushu
Typhoon	Sept, 1917	500	800,000	Japan
Typhoon Makurazaki	Sept, 1945	1,700	361,321	Kyushu + North Honsu
Typhoon Kathleen	Sept, 1947	1,930	394,041	Central Honsu
Typhoon Jane	Sept, 1950	508	222,736	Shikoku
Typhoon Ruth	Oct, 1951	973	359,391	Japan
Rain storm	June, 1953	1,013	489,298	Kyushu + West Honsu
Nanki storm	July, 1953	1,124	97,368	Japan
Typhoon Toyamaru	Sept, 1954	1,761	311,075	Japan
Typhoon Kanogawa	Sept, 1958	1,269	538,458	West Honsu
Typhoon Ise Bay	Sept, 1959	5,098	1,197,576	Japan except Kyushu
Typhoon	1993	unknown	4,500	Kyushu
Heavy rainfall	2000	unknown	21,800	Central Honsu
Typhoons and rainfall	2004	230	26,000	North Honsu

Source: Arakawa-Karyu River Office and MLIT, 2006.

Table 3. Major floods since 1954 in Bangladesh.

Cause	*Date*	*Dead/Missing*	*Damaged houses*	*Affected area of Bangladesh*
Unknown	1954	unknown	unknown	36,000 km^2 (25 %)
Unknown	1955	unknown	unknown	38,000 km^2 (26 %)
Excessive rainfall	1974	1,987	1,165,000	55,000 km^2 (38%)
Monsoon rain	1987	1,657	2,536,000	57,000 km^2 (39 %)
Monsoon rain	1988	2,379	7,179,000	82,000 km^2 (57 %)
Monsoon rain	1998	918	1,000,000	101,000 km^2 (69 %)
Excessive rainfall	2004	unknown	unknown	31,000 km^2 (21 %)

Sources: Brammer, 1990*a*, *b*; Paul, 1997; Ali, 2007.

Accelerated urban growth during this period led to increased damage during flooding. At first, improvements were made at a local level, but these did not prevent floods along the Ara river. Local governments lobbied for better flood control, but it took the 1910 flood to get the national government to meet those demands. Large amounts of rain fell steadily in the monsoon season from the beginning of August 1910; total rainfall recorded in Naguri, Saitama prefecture was 1,216 mm (Arakawa-Karyu River Office and MLIT, 2006). The domestic river dimensions were too small for such an amount of precipitation resulting in overflow of the embankments all along the Ara river. Dikes failed in many places along several rivers. The entire area of river catchments was affected – not only the lowlands of the Tone river, Naka river and Ara river, but also the entire downtown area of Tokyo. The whole region turned into an enormous muddy area. The flood killed 369 people (including casualties in the Tone river area), destroyed or washed away 1,679 homes and flooded a further 270,000. The total cost of the damage was more than US$1 million, a figure equivalent to 4.2 per cent of the gross national income at that time.

The 1998 Flood in Dhaka

The flood of 1998 is considered as one of the longest and worst natural disasters experienced in Bangladesh. Over 67 per cent of Bangladesh was flooded. The flood was caused by extensive rainfall in the monsoon season in the entire catchment area of the transboundary Ganges-Brahmaputra-Meghna system. Monthly rainfall in July was 40 per cent higher than average and 35 per cent higher in August (Faisal, Kabir *et al.*, 2003). As a result, the discharges of the transboundary rivers increased and inundated about 45,000 km^2 by the end of July. Inundation happened again at the end of August, due to the Padma river, and in the first week of September, due to all main transboundary rivers. A total area of about 100,000 km^2 was flooded (Beck, 2005). More than 30 million people were affected and about one million homes; a total of 918 people died.

Focusing on the capital of Bangladesh, during the floods, the entire infrastructure of Dhaka came under severe pressure. About 1,000 km of road and about 262,000 houses were damaged (Faisal, Kabir *et al.*, 2003). People from all levels of society, from slum dwellers to the city's elite, were affected by the flood (Rashid 2000). Basic services, market places and transport were all disrupted. In the severely affected areas, boats became a common means of transportation. The flood started around 22 July and lasted for about 65 days (Chowdhury, Rahman *et al.*, 1998). This flood is the longest in the history of Dhaka (Faisal, Kabir *et al.*, 2003).

The Battle against Floods

For both Japan and Bangladesh floods are a constant threat. Focusing on Japan, the country was hit by severe floods in 1893 and 1896 which were the motivation for the enactment of the first River Law in 1896 (River Bureau, 1990). This law assigned the central government the responsibility for the flood control measures that required large funds, sophisticated technology and nationwide planning. Local government was held responsible for ordinary flood management (Takeuchi, 2002). During the Second World War flood control projects were neglected and maintenance of dikes and channels became poor. The combination of lack of flood control and a series of serious floods, such as the disastrous flood in 1947 caused by typhoon Kathleen, led to the enactment of the Flood Fighting Act in 1949 (see table 2) (River Bureau, 1990). This act brought about collaboration with meteorological sectors in order to develop systematic flood forecasting and early warn-ing. Furthermore, flood hazard maps were drawn up for specific rivers (Ikeda and Yoshitani, 2006).

The second River Law was adopted in 1964 as a result of a large number of floods over a relatively short time (see table 2) (River Bureau, 1990). This new law provided an institutional framework for flood control and water use (Infrastructure Development Institute-Japan and Japan River Association, undated). It introduced integrated management of river systems and at the same time developed regulations concerning water utilization. In 1977, the government adopted a policy of comprehensive flood management which combined conventional and innovative river basin measures and pluvial flood control measures, focusing on retardation and retention and damage mitigation (Takahasi and Uitto, 2004).

Ten years later, in 1987, the River Council proposed a policy for protection from extreme fluvial floods for specific urban areas. These urban areas have a variety of property and important business functions. Psychologically, the Japanese population had taken a large leap in Maslow's hierarchy of needs since the 1950s. People stood up for themselves and voiced their demands. From the 1980s they began demanding an ecologically sound environment, hence recovery of the river environment became an important issue in river management. It became clear that former river basin activities had damaged the ecological state of a huge number of rivers. The third River Law recognized that river projects were no longer only for flood control or water use functions, but ecology became important as well.

Looking at Bangladesh, there was little flood control activity before 1947. The severe floods of 1954 and 1955, see table 3, triggered the United Nations to draw up a report on water development problems in the country (Rumi, 2008). This led to the foundation of the Bangladesh Water Development Board (BWDB) in 1959. From then on different projects were executed for the construction of structural measures, like embankments and pumping stations, against flood problems in Bangladesh. However, non-structural measures are also important, such as education in different crop characteristics for improved agricultural production and disaster relief. Flood forecast activities started in 1972. Information is distributed through bulletins and maps. NGOs play an important role in disaster relief (Mallick, Rahman *et al*., 2005). Short-term relief includes emergency shelter, food and medical care; long-term relief consists of assistance with low-interest loans and re-construction of public facilities (Hossain, Baki *et al*., 2008). For instance, local communities need local context flood information in simple language before and during floods (Mallick, Rahman *et al*., 2005).

Flood Management in Tokyo

In Tokyo, three approaches are used for the prevention of floods. The first focuses on the prevention of fluvial floods and has two directions. The first direction implies giving more space to the rivers by constructing, for instance, diversion channels and detention areas. The Arakawa floodway, see figure 9, was a direct response to the huge flood of 1910 in the centre of Japan (see table 2). The floodway is a massive diversion channel which was dug next to the existing Sumida river. Its purpose was to lower Sumida river's water level during flood conditions. The floodway is 22 km long and its width varies between 445 m at the bifurcation point and 588 m at Tokyo Bay (Arakawa-Karyu River Office and MLIT, 2006). During flood conditions the floodgate at the bifurcation point is closed and flood water is diverted towards the Arakawa floodway. The project was started in 1911 and construction took a total of 20 years.

The second direction consists of using flood retaining structures along the rivers Sumida, Ara and Edo which flow through metropolitan Tokyo. Traditionally, quay walls and flood walls along urban rivers and dikes along major rivers were used (see figure 10). Today another concept has been added to this list. In areas where natural hazards like typhoons and earthquakes are part of everyday life, the consequences of a breach in a conventional dike can be catastrophic. The super levee is designed especially for extreme events in high-density urban areas. The main difference from a conventional dike is the width; a super levee has a mild slope of 1:30 (*Ibid*.). Super levees are resistant to earthquakes, which is one of the main reasons for their construction (Arakawa-Karyu River Office and MLIT, 2006). The concept, see figure 11, is based on incorporating both the need for flood control and the interests of the inhabitants (Takahasi and Uitto, 2004). The super levee provides usable land and space for dwellings (Arakawa-Karyu River Office and MLIT, 2006). This innovative structure underlines the statement that the population of Tokyo has climbed all the way up the Maslow pyramid. Super levees can be found along two rivers in Tokyo: the Ara and the Sumida.

The second approach focuses on the local prevention of pluvial flooding in Tokyo. In the city, the runoff coefficient increased from approximately 0.3 at the beginning of the twentieth century to 0.8 in 1994 (Fujita, 1994). Works to expand the rivers' capacity for the drainage of collected rainwater or adding new ponds to collect rainwater are, for the most part, impracticable in a highly urbanized area such as metropolitan Tokyo. Special measures, such as permeable pavements, were therefore developed to reduce runoff at a local scale. Such surfaces are an alternative to impermeable concrete or asphalt which would produce rapid storm water runoff (Pratt, 1999). Permeable pavements have either many voids through which storm water is filtrated directly or storm water can filter via the bodies and their

Figure 9. Arakawa floodway.

Figure 10. Flood wall along the Sumida river.

Figure 11. Super levee in Tokyo.

joints. Rainwater that filters into the subsoil does not have to be discharged via the rivers. By 1992, Tokyo Metropolitan Government had built some 494,000 m^2 of permeable pavements which is about 2.3 per cent of the total street area (Fujita, 1994). There is still a long way to go before this measure will have a significant effect, but the Japanese spirit and belief in continuing a project bit by bit until it is finished, is confident.

The third approach focuses on damage mitigation measures. Display panels throughout the city and in front of railway, bus and metro stations provide information to local residents about emergencies like floods and earthquakes. At home, people are informed through special television broadcasts and websites about the current state of the rivers. Also, people may receive information about flood conditions automatically through their cell phones if they register for the service in advance (Arakawa-Karyu River Office and MLIT, 2006).

Flood Management in Dhaka

In Dhaka, a combination of structural and non-structural measures are used for the prevention of both fluvial and pluvial floods. The flood of 1988, which was of similar severity to the flood of 1998, was a once in a 100 year flood that inundated 42–57 per cent of the country (Thompson and Sultana, 1996). Due to its massive impact, it received huge attention from the international community. The Flood Action Plan (FAP) was established rapidly after the flood (Brammer, 1990*a*, *b*). This consisted of twenty-six studies and pilot projects, supported by seventeen donor countries. The FAP plan also contained measures for the protection of Dhaka. Aim was to protect the city against a once in 500–1,000 year fluvial flood. One of the measures was the construction of embankments to protect Dhaka West (see figure 12). This work was completed in 1991. Furthermore, several roads were heightened to provide better protection in Dhaka West against river floods from the Balu river, which is located east of Dhaka. Pluvial flooding is tackled with urban lakes, city canals, water pipes. Unfortunately, during the flood of 1998 flooding still occurred in these areas due to blocked culverts and closed regulators (Chowdhury, Rahman *et al*., 1998). Heavy rainfall caused waterlogging within the city boundaries. Maintenance and cleaning of openings are therefore very important.

Unauthorized slum settlements on the embankments are a threat to the safety of the embankment and so increase the probability of a fluvial flood. Maintenance becomes difficult and the condition of the embankment can deteriorate at these locations (*Ibid.*). Local governments are forcing the inhabitants to move from the embankments to alternative locations. Similar problems occur at the lakes. In Dhaka West, four lakes are used for water storage during heavy rainfall, but because the water bodies are not always completely filled with water, they have been used for slum settlement (see figure 13). This is one of the causes of increased threat of pluvial floods in Dhaka. Additionally, poor sanitation in the slums creates an ecological hazard to these lakes. Discouragement of slum development is therefore needed. However, this is a difficult task, both socially and politically (*Ibid.*).

The city of Dhaka is divided into two halves: the urbanized city part, Dhaka West, and a more rural area, Dhaka East. Dhaka East is still less protected against floods than

Figure 12. Embankments with flood walls along the Buriganga river.

Figure 13. Unauthorized slum settlement in Dhaka.

Dhaka West. After the disastrous flood of 1998, the government decided to build a 60 km multipurpose embankment along the Balu river to protect Dhaka East as well, but the works have not been executed yet. Despite the delay, the area has been largely urbanized which causes a large flood threat to those living there. After the flood of 1988, many buildings in flood prone areas were built above a certain flood level (see figure 14). These houses benefited during the flood of 1998. Currently an act has been adopted to encourage more people to construct their houses above a certain flood level. If a dike fails or if a pump is out of order, the houses will be less affected during a flood event.

Comparison between Flood Control in Tokyo and Dhaka

Looking at structural measures against fluvial floods, both cities use dikes and flood walls. Along Dhaka's Buriganga river, flood walls are used in combination with the embankments. In Tokyo, dikes can be found along the Ara floodway and quay walls

Figure 14. Adjustments to houses in old Dhaka.

in combination with flood walls along the Sumida river. The motive behind the use of flood walls is the same for both cities. Both are highly urbanized and there is hardly any space for 'living', let alone for sufficient flood control. In Tokyo, many people live in high rises and many public services are located underground; in Dhaka, many people live in unauthorized slums. Both Tokyo and Dhaka feel the spatial pressure when improving the flood retaining structures according to government safety levels. In Dhaka, the old city is directly located along the Buriganga river. Heightening and thus widening of the original embankments is very difficult; hence flood walls are used to realize the required height. In Tokyo, dikes are not possible when preserving the high rises adjacent to the Sumida river. The quay wall is designed to accommodate the average discharge; the flood walls are designed to accommodate the peak discharge.

Besides the combined use of dikes and flood walls, different types of structural measures are also used against fluvial floods. The choice of structural measures is partly influenced by the rate of development of Japan and Bangladesh; Japan is a highly developed country while Bangladesh is a developing country and, as discussed above, there is a very considerable disparity between the economies of the two countries. The rivers in Dhaka are very important to the people, fulfilling mainly basic needs for living, such as transport, drinking water, fishing and washing. Good access to the rivers is realized by the construction of embankments in combination with stairs. As stated earlier, many people in Dhaka are still on the lowest level of the pyramid of Maslow. Hence the urban quality is, for the Bengali people, not important.

In Tokyo, it is a different story. Over recent decades, the visual and physical value of the waterfronts has become more and more important. Rivers have become an important component of the regional climate, landscape and culture (Infastructure Development Institute-Japan and Japan River Association, undated). Basic needs like fresh drinking water and washing are provided at everyone's home; rivers are mainly used for transportation of goods and people, and indirectly for tap water. Also, Tokyo offers tourist boat trips on the Sumida river and a promenade along the river gives inhabitants and tourists the opportunity to enjoy the river site. The development of the super levee also shows the importance of spatial quality to the Japanese. By transforming conventional dikes into super levees, the area can be protected against fluvial floods, current landowners do not have to move and the urban quality can be increased (Arakawa-Karyu River Office and MLIT, 2006). Added value is created through the restored accessibility and visibility of the river.

Another issue is how Asian countries deal with the ecological state of their rivers. In the 1980s, it became clear that the former river basin activities in Japan had damaged the ecology of a huge number of rivers. All rivers should provide a healthy atmosphere which creates a habitat for diverse plants and animals. In large contrast, the ecological condition of the rivers surrounding Dhaka is rather poor. River water is polluted due to uncontrolled use of the water and poor governmental supervision.

In addition to structural measures against fluvial floods, Japan is also using spatial measures. An example is the Ara floodway in Tokyo. The construction of the floodway preserved the urban quality of the Sumida river and created an additional riverfront along the floodway itself. At the time that the floodway was constructed, starting in 1911, the area was not yet highly urbanized, thus it was relatively easy to buy out land owners and to construct a floodway with dikes. Such spatial measures are not seen in Dhaka. One of the reasons is that Dhaka is surrounded by rivers; they do not divide the city in sections. The second reason is that the scale and magnitude of the rivers in Japan and Bangladesh differs. The surrounding transboundary rivers are much larger than the domestic rivers of Japan. Rivers like the Ganges produce such an amount of discharge that only large river works can help. The third reason is that it is questionable if the opportunity for creating extra value along the existing rivers and a newly dug channel is desired in developing Dhaka at the moment. Most people still strive to achieve their basic needs for survival.

Looking at measures against pluvial floods, both cities, except in the old city of Dhaka, use a sewage system. Furthermore, Tokyo and Dhaka use city canals for discharging rain water towards the main rivers. In Tokyo, these are mainly naturally formed urban rivers which have been transformed into efficient concrete drainage channels. The small urban rivers swell in a short period of time due to huge rainfall on a local scale. In Dhaka, mainly handmade canals are used to prevent pluvial floods. These canals are often less efficient than the ones in Tokyo. Most of the canals are only in operation during the monsoon season; the rest of the time they are hardly filled with water. Because Bangladesh is a developing country with an unstable governmental system, it is difficult to point out who is responsible for the maintenance of the canals. The result is that most of the time, the canals are filled with garbage leaving less storage capacity and drainage capacity. Also, the connections with the main rivers are often cluttered as well. Finally, the canals are often used as slums during the dry season. It is clear that although in theory both cities have a proper discharge system for rain water, in practice there is a large difference in their effectiveness.

A difference in approach in the prevention of pluvial floods is the use of innovative measures in Tokyo which were developed to handle excessive rain water. These measures were developed to reduce runoff on a local scale. An example is the permeable pavement. Compared to Tokyo, the percentage of im-permeable surfaces, such as asphalt, is much lower in Dhaka, thus the application of impermeable pavements is less urgent. There is also the question of whether permeable pavements are effective if they are not looked after properly. In Dhaka, excessive rain water is tackled by increasing the capacity for pumping water from city canals to larger rivers.

The difference in the economic positions of Bangladesh and Japan has an effect on the quality of their flood retaining structures. In Dhaka, the construction of flood retaining structures is often dependent on foreign aid, both financially and in kind. Many foreign engineering companies import knowledge and educate local people. The construction is mainly done by hand. Lack of money precludes the purchase of modern machines and manpower is cheap. Also, construction by hand gives more poor families work, which means money to purchase food. The negative aspect of hand labour is that the construction takes much longer than if done by machine, even if many workers are on site. The result is that the area remains insufficiently protected against fluvial floods for longer. Another concern is that local inhabitants might sabotage the work unintentionally by taking construction materials or by digging gaps in the structure so as to have access to the river.

In Bangladesh, dikes and flood walls are constructed out of local materials. Unfortunately, this often results in relatively weak dikes, made out of loose material. Additionally, the slopes of the dikes are often steeper than is advised by the foreign engineering companies. During high discharges dike breaches are likely due, for instance, to seepage or failure of the inner stability. In large contrast, Japan has sufficient finance and modern technology at its disposal. Although, hiring people is more expensive than in Bangladesh, the modern machines in combination with well trained workmen lead to an efficient and a relatively short construction period. Further, the Japanese culture of respecting rules prevents sabotage of the works in most cases. Also the flood retaining structures in Tokyo are well maintained. The government has formulated several flood laws which regulate who is responsible for which types of flood retaining structures in terms of maintenance, operation and improvement. These regulations are obeyed. In Dhaka, the flood retaining structures suffer from the poverty of the country and an unstable political system. After a structure is built, it is uncertain who will be in charge of the maintenance and what the local population will do. Due to lack of communication, structures may be damaged or even be demolished by the actions of the poor in pursuit of food and shelter. Access to fishing, thus staying alive, is more important than protection against floods of which the occurrence is uncertain. Also, unauthorized slums along the embankments are a huge point of concern. They endanger the hinterland by decreasing the strength and stability of the flood retaining structures.

Looking more closely at the differences in the river systems, the rivers in Bangladesh are large transboundary rivers whose water levels can be predicted days ahead whereas the rivers in Japan are short and steep domestic rivers which often cause flash floods that can only be predicted hours ahead. This indicates that, in theory, the people in Bangladesh can predict a flood discharge days ahead for which they can take proper measures. In practice, this is not the case. Due to tension with adjacent countries, the Bengali government only has access to data on precipitation, river discharge and water levels within Bangladesh. There is no exchange of data with adjacent countries. This makes prediction and proper action difficult. In Japan, heavy downpours which are common, can cause rivers to swell in a short period of time. Due to the Japanese drive for efficiency, these predictions can still be used to provide sufficient warnings to the public and to take operational measures such as closing flood gate defences.

It is interesting to see whether there is a difference in the applied design frequency in Tokyo and Dhaka. The aim of the FAP plan in Dhaka was to protect the city against a once in 500–1,000 year fluvial flood. This is a higher design frequency than mostly used in Tokyo. For instance, the Tsurumi multipurpose detention basin, which is located in the central part of Tokyo metropolitan area, is designed to ensure safety from a 150-year fluvial flood. The flood retaining structures along the Ara river are designed to protect Tokyo against a 200-year flood. This difference is remarkable because both cities are populated by millions of people. Additionally, the value of the economic properties in Tokyo is much higher than in Dhaka. An explanation could be that the threat of a flood in Dhaka is induced by multiple rivers. Also, when Bangladesh is hit by a flood, in most cases a large proportion of the entire country is flooded, including Dhaka. In Japan, most floods are regional due to the short length of the domestic rivers. If a flood is bound to happen along a specific river, that does not have to result in a flooded Tokyo. The choice of design frequency is also dependent on governmental policies which are often driven by flood disasters. The design frequency in Bangladesh was chosen by a network of foreign donor countries after the disastrous flood of 1998. In Tokyo, it has been several decades since a severe flood has happened; the need for a higher safety level became less urgent.

In addition to the use of structural measures against floods, both countries use non-structural measures. However, Dhaka focuses on preventing people from settling in flood endangered areas whereas Tokyo focuses on the evacuation of people. As stated earlier, in Dhaka, slums that are located in ponds and along embankments are decreasing the effectiveness of the flood retaining structures. Discouragement of slum development in those areas is therefore needed. Comparison with Tokyo shows that the homeless of Tokyo also seek the river, but that they do not endanger the safety of Tokyo. They camp on top of the promenade between the quay wall and the flood wall along the Sumida river, leaving the flood retaining structures untouched. The homeless are, however, not protected by the flood wall. Hence dissemination of information about the threats of living in flood endangered zones is important in both cities. The main non-structural measures in Japan are the damage mitigation measures that support the evacuation of people. The Japanese receive information through billboards, internet and cell phones about flood levels, flood discharges and escape routes. Due to other natural hazards like earthquakes, the Japanese have a lot of experience with such information systems. Bangladesh, however, does not use this type of non-structural measure for several reasons. Firstly, internet and cell phones in slums are rare. Face to face transfer of information can get the message across but that would take too long. Secondly, everyday life in Dhaka is not as well organized as in Tokyo. Evacuation is bound to be a chaotic process. And thirdly, more than 70 per cent of Japan is covered by steep mountains, but only 8 per cent of Bangladesh consists of tertiary hills. It is therefore difficult to find higher locations near Dhaka which are safe enough for evacuation. This shows that landscape features influence the type of measures that are used against floods.

Asian Lessons for the European Rhine Catchment

The analysis of Tokyo and Dhaka has shown that there are similarities and differences in their approach in flood management. It interesting to see how this relates to the approach in non-Asian countries, such as in the European Rhine catchment, and which Asian lessons can be learnt. The river Rhine has a length of 1,320 km, which is significantly larger than the average length of a Japanese river. Comparison with the transboundary Brahmaputra river, which flows partly in Bangladesh, shows that the Rhine is only a medium-sized river; the Brahmaputra is more than twice as long. The Rhine starts in the Swiss Alps and crosses Liechtenstein, Austria, France and Germany before flowing through the Netherlands and into the North Sea (see figure 15). The river is fed with rain water and melt water from different countries. In Europe, the meteorological situation differs greatly from Japan and Bangladesh. Europe does not experience any monsoon seasons or typhoons. The variations in discharge are therefore not as great as in Japan and Bangladesh.

Along the Rhine, many cities have been founded throughout the centuries; like Basel in Switzerland, Mainz and Cologne in Germany, and Nijmegen and Dordrecht in the Netherlands. These cities, like Tokyo and Dhaka, have to endure the threat of fluvial and pluvial floods and in some cases of storm surges. The use of quay walls, embankments and flood walls is widespread in the Rhine cities. The major difference is in the use of movable flood retaining structures in, for instance, the Dutch city of Nijmegen and the German city of Cologne. Stop logs are often used in combination with quay walls (see figure 16). This is due to conflicting demands from both the flood controllers and

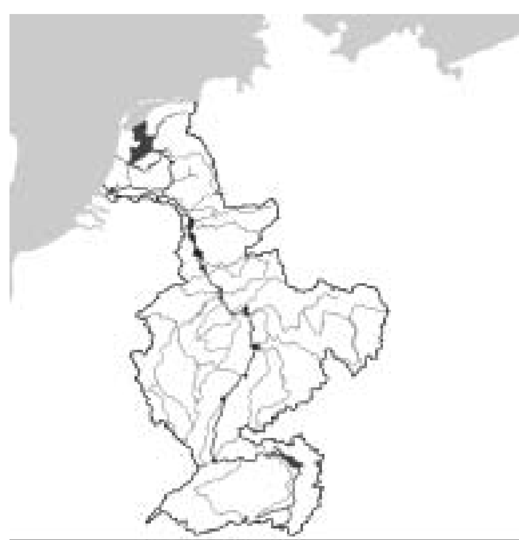

Figure 15. European Rhine catchment.

the municipality. The aesthetics and value of the waterfronts, as in Japan, have become more important in recent times. However, the question is whether the implementation of such movable structures is the answer. Human error becomes a point of concern. The Japanese concepts can contribute to the European situation. Innovative structural measures, such as the super levee and permeable pavements, have much potential. If these immovable structures against fluvial and pluvial floods are always in operation, human error is ruled out.

An important lesson from Bangladesh is that the population has to be aware of the dangers of living outside the flood defence system. In Dhaka, extensive slum settlements along the embankments are a serious problem. The authorities of Dhaka have the vital but difficult task of informing every inhabitant about the risk when living outside the flood defence system and to prevent them building their houses in such flood-prone areas. Communication on a regular basis is essential. The situation in European countries is very different; they do not have to deal with unauthorized construction of slums in flood-prone areas. However, in some regions along the rivers construction of buildings in flood-prone areas is permitted under restricted circumstances. The problem is that people tend to forget about the dangers. Furthermore, if people move, knowledge about the threat of flooding is lost. People should be periodically informed about the dangers by the authorities.

Another lesson from both Bangladesh and Japan is to encourage individual protection of people and assets via the construction of adaptive houses. This individual protection can have potential outside the flood defence system, in detention areas with fluctuating water levels or as back-up in case of failure of the main flood protection system. If a dike fails or if a pump is out of order, the houses become less affected during a flood event. In Dhaka, the entrance of the houses is slightly higher than ground level and can be reached by stairs. Also, slums can be seen as an example in this respect. Many shanties are built on bamboo stilts to keep free from floods. In Tokyo, houses are constructed in such a way that cars are parked on ground level and people live on the first floor. In countries like Germany and the Netherlands this type of flood protection is much

Figure 16. Stop logs are widely used in the Rhine cities.

discussed, but until now has been realized only in small-scale pilot projects.

Conclusions

This paper focused on the question how the deltaic cities of Dhaka and Tokyo handle the threat of floods. The outcome is that both countries are using several similar structural flood retaining measures for pluvial and fluvial flood control. Looking at the structural measures against fluvial floods, a combination of dikes and flood walls can be found in both cities. Additionally, both cities use city canals for discharging rain water into the main rivers. This might give the impression that differences in their economic situation do not affect the approach in flood protection. However, looking closely at the design and state of the structures, it becomes clear that the economic situation does have its impact on flood management. The structures in Dhaka are often dependent on foreign aid, both financially and in kind. There is a lack of money to buy modern equipment. In contrast, Japan has sufficient finances and modern technology at its disposal. Additionally, maintenance of the flood structures suffers from the poverty of Bangladesh. After the construction of a flood wall, for instance, it is uncertain who will be in charge of the maintenance and what the local population will do. Lack of communication and provision of information about the need for these structures, often leads to their damage by the poor. These difficulties are not known in Japan.

Flood defences in Tokyo, especially over recent decades, also have to contribute to the value of the waterfronts. Aesthetics and the ecological state of the river have become important. In Dhaka this is not yet the case. The riverfront is mainly used to fulfil basic needs, such as drinking water and washing. Here, the combination of accessibility and flood protection are the main issues. That is why innovative measures such as the super levee, integration of flood protection and urban functions, and permeable pavements are seen only in Tokyo.

The geographical location and meteorological conditions of Bangladesh and Japan have less effect on their differences in their structural flood measures than do their economies. Both countries endure river, flash and pluvial floods and are affected by typhoons. The difference in magnitude of the river system does not have a major effect on the flood management approaches in Tokyo and Dhaka. The only clear difference is that the measure of a floodway is only used in Tokyo and not in Dhaka. The geographical situation of both countries influences the choice of non-structural measures. One of the reasons why Dhaka does not use evacuation is that is difficult to find higher locations near the city.

In conclusion, Tokyo and Dhaka are both using similar and different flood structures. Bangladesh is still a developing country and can benefit from the knowledge and experience of Japan. Japan could also learn from Bangladesh. For instance, it remains important to communicate with the public. If plans are not understood, the population could undermine the authorities who construct the flood structures. Weaker structures are often the result, inducing a higher probability of a flood.

Japan and Bangladesh can not only learn from each other. Other deltaic countries can also benefit from their knowledge. For instance, the European countries in the Rhine basin can learn from the Japanese because of their quest to seek innovative solutions for flood management. Both the Japanese and the Bengali encouraged individual protection of people via the construction of adaptive houses outside the flood defence system, in detention areas with fluctuating water levels or as back-up in case of failure of the main system. The Bengali showed the importance of communication with the local residents. Exchange of knowledge between all deltaic and flood endangered countries over the world remains important; this can induce innovative solutions which lead to better protected cities and better protected hinterland.

NOTE

1. According to Maslow, there are five sets of goals (basic needs) which are related to each other and are arranged in a hierarchy of prepotency. When the most prepotent goal is realized, the next higher need emerges. Maslow states that even if all needs are satisfied, in the layer of self-actualization people often still expect that a new discontent will soon develop, unless the individual is doing what he is fitted for.

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