Introduction

Vietnam can most simply be described as having mountains and hills in the west (accounting for approximately two-thirds of its territorial mainland) with steep slopes down to the low flatlands of Red River Delta in north the Mekong River Delta in the south and a long stretch of coast in between. The tropical monsoon climate of Vietnam results in a complicated hydraulic regime that has a different quantity and quality of rainfall in the wet and dry seasons and differently affects on the nation’s various topography. The Red River Delta, the focus of this paper, is smaller than the Mekong Delta, but has a significantly higher density of population (averaging over 1000 people per square kilometer) [Le 1997: 340]. It hosts the oldest wet-rice agricultural civilization in the nation across a territory that has a range of 0.1-1.5 km/km$^2$ of naturally flowing rivers and 0.67-1.6 km/km$^2$ of irrigated land [Tran 2006: 2].

As the most ancient human settlement area in Vietnam, the Red River Delta has 2000 years of evidence of reclamation activities for paddy farming [Fontenelle 2001: 6]. Besides receiving the privileges of nature, this area also suffers from natural disasters. The most dangerous natural calamities are related to water such as annual typhoons, seasonal floods and droughts. For over 1000 years, man has developed water management techniques in order to harmonize with and tame the forces of nature. The delta’s complex system of water management has been built both for protection and irrigation since the 8th century. It includes an intricate and dense network of permanent and semi dykes, pumps and sluices.

As with most large rivers in monsoon Asia, the water regime of Red River is quite varied. The water level fluctuates from 1.41 to 14.3 meters in different time per year with an average of flow of 2,640 m$^3$/second and total is about 83.5 million m$^3$/year [NHPI 2010: 4] where the velocity of water can reach to 3.45 meters per second. [NHPI 2010: 39] This makes the Red River one of the world’s largest rivers with high flow. In general, the water level of the Red River rises relatively slowly, except after typhoons (up to four in two months) where the water level can very quickly rise from 1.0 to 4.0 meters within 24 hours [ALMEC 2007: C-2-12]. The river also carries a great deal of alluvial sediment, especially during floods (hence the name of the red in the Red River). On average, the water of the Red River carries 1000g of silt per 1 cubic meter and about 114-115 million tons per year [NHPI 2010: 58]. The quantity of water and silt are different throughout the year, where there is 80-85% of water [NHPI 2010: 2] and 90% of silt [NHPI 2010: 59] in the rainy season (from May to September).

Water management in Vietnam and the Red River Delta

Vietnamese culture, particularly in the north, is quite diverse the result of many thousands years of innovation. Vietnamese customs and habits are strongly tied to both

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1 Northern Hydraulic Planning Institute

2 The Cooperation of ALMEC Corporation, Nippon Koei Co., Ltd., and YACHIYO Engineering co., Ltd.
water management and agricultural traditions. The delicate man/ nature relationship structures not only the physical environment, but also the cultural landscape as is evident in legends and literature of the nation.\(^3\)

Vietnam’s water management, which includes extensive dyke and canal construction, has been an inseparable component of settlement practices in the Red River Delta for more than 1000 years. In the north of Vietnam, engineering water works were implemented to reduce the impact of natural calamities, while in south of Vietnam there was more a tradition of living with the ebb and flow of water regimes. North Vietnam’s regional dyke system was first mentioned in ancient Chinese documents [Phan 1995: 205]. However, after some centuries of development, the regional dyke system became an obstacle for flood water discharge. It was then that river dyke systems were developed, and which were particularly well suited to address seasonal flooding. As early as the end of 19\(^{th}\) century, the Red River banks, from its course into the delta and downstream to the East Sea, were completely protected by a range of different dykes. They protected the Vietnamese population from Red River floods during the monsoon season. River gates through dykes supplied water to a network of canals which, in turn, provided water to paddy fields during summer droughts and dry seasons in the winter.

Due to both the characteristics of the Red River Delta and the climate, inhabitants have continually faced natural disasters from the resulting forceful water regimes – consequently, the delta suffers from both flood and drought. And, since traditional Vietnamese economy was primarily based on mono-wet-rice, water management was the most important issue at stake. The construction of dyke (including river and sea dykes) and irrigation networks by digging canals were primary concerns. The canal network was not only for irrigation in the rice fields as well as for drainage, but also for communication by waterways. As a result, there is an extensive dyke system and dense water network that has been constructed from generation to generation. The dyke system within the Red River Delta was 3,000 kilometers long in 1945; it increased to 8,000 kilometers by 1996 including 5,000 kilometers of river dykes (which 2,400 kilometers are along main rivers including 1,580 kilometers along the Red River and 750 kilometers along the Thai Binh River) and 3,000 kilometers of sea dykes. These became the most important means for protecting land and controlling the water in the agricultural fields. Without the dyke system, two-thirds of the Red River Delta world be inundated in the summer [Gliedman 1972: 6]. [Fig. 01] The development of such hydraulic works led to a strongly organized and hierarchical structure of Vietnamese society that had to cooperate to construct systems for agricultural production, facile communication and protection from both enemies and nature.

Moreover, Vietnam’s hydraulic works have been improved as a seasonally complex system to regulate water through the dyke to both protect fields and settlement and to supply water for irrigation. During the rainy summer monsoon season, the intakes under the dykes are closed to prevent high river flows into the fields, while the main canal network acts as ditches which collect the surface runoff water from the fields. The main canal network excess flow is drained by gravity through the outlet or by drainage pumping stations built downstream along the dyke. Apart from rainy season, during the winter and spring, water for irrigation is provided from the rivers by gravity through the intake or pumping station (in case of a low water level in the rivers). The main canal network acts as a reservoir in addition to its primary purpose to convey

\[^3\] Hung King 18\(^{th}\) (the last Hung Kings) had a beautiful daughter. When she of the age to marry, both Son Tinh (the mountain genie) and Thuy Tinh (the water genie) came to seek her hand. The King asked them special things as the wedding gifts and promised that his daughter could marry the first who returned with the required wedding gifts. The following day, Son Tinh came first, was married to the Princess and took her to the mountains to live with him. Thuy Tinh was very angry and decided to control his soldiers [aquatic monsters] to fight Son Tinh. He failed because when he ordered the waters to rise above the mountains, Son Tinh raised the mountains higher than water level. The two men battled it out year after year, the result being the nation’s strong geography of low-lands that are yearly inundated and high, rugged mountains.
Imperial Water Management

According to ancient annals, numerous dykes and hydraulic works were constructed in the delta. Hanoi’s first citadel and dyke were erected in swampy lands in 767 AD. In the earliest times, more general hydraulic works were built and maintained at the local level of hamlets and villages. According to historical documents, the first dyke of the Red River Delta built at the level of State was in 1077 along the Cau River (which was the Nhu Nguyet River in the past). In 1103, the first royal proclamation stated that dykes were under the direct control of State the directly and affected the interests and stability of the State. In case of Hanoi, the first dyke along the river, the Co Xa Dyke, was built in 1108. In 1248, a low soil-dyke system along the main rivers of the whole Red River Delta was built under the Tran Dynasty. This network of dykes protected the paddy fields from water surges and controlled the monsoon waters’ flow into the fields, which was necessary to deposit nutrient alluvial into the delta. At this time, King Tran Thai Tong ordered his mandarins to inspect the dyke system, thus setting their role in the affairs of the State [Le 1997: 299; Logan 2000: 246; Tran, Nguyen 2004: 28]. The soil-dyke system along the tributaries of the main river began to be constructed from 1503 under the Le Dynasty [Phan 1995: 30]. Tied to these dykes were a system of gravity-based culverts which opened to allow water to flow into the paddy fields in dry season and closed to protect the fields excess water in times of floods [Phan 1995: 68]. A sea dyke built along the coast not only provided protection, but also reclaimed.
land by accumulating silt at the mouth of rivers. Already in the 11th century, a number of large canals were dug for the irrigation network, including the Dan Nai Canal in 1029, Lam Canal in 1050 and Lanh Kinh Canal in 1089 [Nguyen 2007: 45],

The dyke system and hydraulic works were repaired yearly by compulsory participation in public works, whereby the population, including students and soldiers, was mobilized to move volumes of earth and make bamboo embankments to reinforce the dykes. In each hamlet, a man was appointed to supervise dyke protection in the rainy season. [Fig. 02] The activity related to the responsibility of individuals was quite important to develop the hydraulic system and to maintain the quantity of water for human life agricultural production [Nguyen 1984: 76; Nguyen 2007: 75; Vu 1993: 240; Phan 1995: 27]. Following the yearly harvest, the mandarins inspected the dykes and directed maintenance and repair work. The king himself even did such work:

“In August 1315, when the waters rose to a dangerous level, King Tran Minh Tong personally directed the work. A mandarin advised him against such work, saying, “It becomes virtue, not to devote himself to small things”. Another dignitary, supporting the king’s actions, retorted by saying, “when the country is threatened by a major flood or severe drought, it is a king’s duty to take part directly in carrying out the necessary measures. This is the best way to show great virtue”.” [Nguyen 2007: 45].

Since the feudal period, water management was a village responsibility. Rules and regulations of individual water accesses and maintenance of collective reservoirs were stipulated in the village customary law [Fontenelle 2001: 6]. At that time, there was a complex and complete system of water management, which had been upgraded to new conditions as history proceeded. In general, local people themselves initiated small projects in their dwelling environments while larger, territorial-scale projects were implemented under the guidance of the State and financed by taxes [Nguyen 1984: 75-6; Phan 1995: 34]. Dyke-building and hydraulic works were amongst the most important issues at the level of State, evidenced in the decrees within in the Royal Proclamation of 1103 [Phan 1995: 22]. The mandarins were very concerned with the water management problematic and over the course of the imperial era, debated a number of manners to control floods – including the cutting off a number of smaller rivers, canals and tributaries of the Red River by dams and sluices, the widening of small rivers which connected to Red River and even the destroying the dyke system in Red River Delta [Nguyen 2009: 49-65].
Vietnam’s first complete policy of water management was published by the Nguyen Dynasty in 1809 which regulated a hierarchical dyke system based on the rivers sizes: for large rivers, the dyke was 8 meters wide on the top, 28 meters wide at the foot and 4.8 meters high; for medium-sized rivers, the dyke was 4.8 meters wide on the top, 16 meters wide at the foot and 4 meters high; for small rivers, the dyke was 3.6 meter wide on the top, 12 meters wide at the foot and 3.6 meters high. The document revealed the indigenous dyke construction which combined wood, bamboo and soil that was excavated at least 2 meters away from the dyke itself (for soil stabilization purposes). Elephants were utilized to compact the soil and thereafter the dykes were covered with grass. The system of culverts that controlled the water flowing in-out of the paddy fields was constructed from wood or brick, which had the problem that they could be easily damaged [Phan 1995: 86]. The culverts were important, as they affected the stability of dyke system and the aqua-agricultural production. By 1839, ceramic culverts became commonly used [Phan 1995: 59]. Otherwise, the proclamation was quite generic, without specifying the characteristics of different rivers and their different water levels. Only in the 1838 annex was the highest water level in various rivers mentioned in relation to a classification of rivers in three regions (the mountain area, midlands and lowlands): the dykes along the larger rivers in mountain areas and the midlands were to be higher than the highest water level (0.6 meter) and in the lowlands higher than 0.4 meter [Phan 1995: 55-6].

However, after centuries of flood control, the Vietnamese people understood that the heightening of the dyke system was limited and that this process needed to be paralleled with the lowering flood water level. Therefore, the digging of new rivers to discharge flood waters was begun in 1729 [Phan 1995: 141] combined with the creation of dams, reservoirs and the dredging existing rivers – which were measures previously mentioned in a report made by Mandarin Nguyen Tu Gian in 1857 [Phan 1995: 92].

French Water Management

After occupying Vietnam, the French colonial administration was more concerned with building roads and railways of strategic importance which served colonial exploitation policies than with constructing hydraulic works for protecting agriculture from natural disasters. Initially, there were only a few projects to create new spillways and the dyke system mainly was repaired where it had broken or had heightened where it was too low. As a result, flood, drought and constant food shortage severely affected the Vietnamese peasantry and greatly impacted the colonial enterprise. It was only after a number of serious natural calamities that hydraulic works finally became one of the main objects of colonial attention.

The French made a number modern hydraulic works, repaired and expanded the dyke system with modern techniques which created a paradigm shift in Vietnamese water management. [Fig. 03; 04] The dyke system had become a central concern of been both Vietnamese and French researchers with regards to flood control and management of the high water level of Red River in the rainy season. Amongst the solutions debated were various degrees of upstream afforestation, the creation of new reservoirs, the divergence to other tributaries, the complete canalization of the Red River [Nguyen map, date unknown] [Fig. 06] and even the destruction the dyke system [Phan 1995: 98-129] (the latter which had also been discussed often in the feudal era, with the notion to use the silt to fill the low-lying land of the delta). Between 1918 and 1935, there were a great number of projects to strengthen and heighten dyke system. [Fig. 05] In subsequent years, from 1937 to 1944, there was not any breach of the dyke system, evidence of the previous decades’ public works and of a strong hydraulic system along the Red River [Phan 1995: 133]. The French rationalized and intensified the entire infrastructural system in Red River Delta in the first half of the 20th century. From the late 1940s, 377,000 hectares (the total area of Red River Delta
is 1.5 million hectares) and were made newly irrigable and all of the Red River Delta's rivers were embedded within a complete network of earth dykes and equipped with gates which allowed water transit. This network of dykes created 30 primary hydraulic units, each autonomous with regards to water control [Phan 1995: 7].

The French also created a regulation to make a new profile for dykes along the Red River. The new dyke profile was designed as step dyke, with the dyke being at least 5 meters higher than the land. The dyke was 6 meters wide at the top, a slope of 2:1 on the river side and 3:1 on the land side with the width of each step was 5 meters and the distance of 1.5 meters high in between. From 1918 to 1924, 8 million cubic meters of soil had been used to improve the dyke system along the Red River by people living in the delta. The dyke building increased in 1924-26, when 4.5 million cubic meters of soil were used with the help of three steam rollers. For the first time, mechanical techniques were implemented in Vietnam, which when combined with the Vietnamese labor force, added significantly to the quantity and quality of the dyke system. Meanwhile, techniques in dyke construction were regularly improving and in 1926, a new profile was again introduced. The dyke profile was widened to 7 meters.
at the top and strengthened by creating a 3 meters thick layer of clay-mixed-with-sand on the river-side to prevent water penetration under the dyke and to improve the dyke slope on the land-side in order to combat erosion. [Fig. 07] The dykes along the Red River were classified in two levels: level 1 for the 4-8 meters high dykes, level 2 for the 2.5-4 meters high dykes [Phan 1995: 129-33]. As well, for the first time, modern sluices and dams were constructed with new materials such as concrete. Waterworks such as the Vinh Yen Dam (in 1896), Day Dam (in 1932), and Lien Mac Sluice (in 1937) were built to control water along tributaries of Red River and to strategically control water that flowed into the delta. [Fig. 08] Nonetheless, at the end of the French colonial era and following decades of dyke enforcement, the dyke system in Hanoi could not sustain more than 12 meters of flood waters – whereas in 1926 the engineering had been designed to confront 13.30 meters of flood waters. Maintenance had not kept pace and the network was in urgent need of up-grading.

[Fig. 05] French dyke reinforcement in 1924
Between 1924-26, the French developed a large dyke reinforcement program for the whole of the Red River Delta to protect the important cities in the delta and areas where French had economic interests

[Travaux Publics au Tonkin 125/1729- Archival Center n°1 in Hanoi]

[Fig. 06] Canalization of the Red River
In the 1920s, the Nguyen Court engineer (Nguyen Canh) proposed a radical engineering project to canalize the Red River in order to improve the water discharge in the rainy season and to let water flow as fast as possible to the East Sea.

[Tuan Pham Anh 2010, redrawn from Canh Nguyen, L’Hydraulique Fluviale et Le Fleuve Rouge]
In the Vietnamese struggle for independence with the French, there was massive destruction to the dyke system in the Red River Delta. Therefore, from the end of 1945 until early 1946, there was exceptional mobilization of social labor by the State for dyke repair; more than 1,200 kilometers of dykes were repaired, which involved 11 million workdays and the moving of 2 million cubic meters of earth [Nguyen 2007: 220-1]. In later years, an additional 13,880,000 and 17,735,000 cubic meters of earth were moved in 1955 and 1956 respectively to create protective and irrigation dykes [Phan 1995: 158-60]. From the beginning of the 1960s to the end of the 1970s, a huge amount of work was undertaken. In comparison with 1959 where there were recorded 2.3 million man-days, 9.8 million man-days were recorded in 1962. More than 80% of State direct investments were dedicated to water management improvements. Large drainage and irrigation schemes were created with a canal network from primary to tertiary levels. Channels giving access to rivers were excavated and large-scale irrigation and drainage pumping stations were built. Between 1961 and 1965, more than 2,500 pumping stations were built in the Red River Delta. [Vo, Nhan Tri, 1967]
The dyke system in Red River Delta was strong enough to confront up to 13.30 meters of flood water level in Hanoi and 6.5 meters in Pha Lai [Phan 1995: 172]. However, the momentum gained in the development of the hydraulic works was gravely interrupted during the time of First Indochina War.

The method of water management in the Red River Delta changed once again under the political framework of agriculture collectivization and cooperative settlement with the formation of the independent North Vietnamese State in 1954. From 1958, after establishing a Ministry of Hydraulics, water management became a high priority of the State, particularly with regards to flood control in the Red River. During this period, with the assistance of Russian and Chinese experts, there were a number of studies made for the development of hydroelectric plants for industrial purposes and for flood control in the Red River. As well, in this period, the dyke system (including the river and sea dykes) was significantly upgraded. In 1958, the largest hydraulic system in the Red River Delta, made by series of canals, dams, pumping stations and dykes, was implemented and which can supply water to an area of 2002 km² which is delimited by the Red River, Duong River, Thai Binh River and Luoc River. [Fig. 09] From 1958 to 1960, 33,238,600 cubic meters of earth, 528,600 cubic meters of stone and 9,780 cubic meters of concrete were mobilized for dyke reinforcement. In Hanoi, the dyke system in that period could completely resist flood waters up to 13.30 meters in the Red River. For twenty years, from 1954-1974, a further amount of over 168 million cubic meters of earth and 2.137 million cubic meters of stone was mobilized. Until this date (1974), Red River Delta counted 2,838 kilometers of dykes along its main rivers which were managed by the government [1266 kilometers along the Red River, 763 kilometers along the Thai Binh River, 420 kilometers along other main rivers, and 388 kilometers along the coast]. In addition, there were 2034 kilometers of dykes along small rivers and semi-dykes controlled by local governments [Phan 1995: 165-79]. However, the hydraulic works were again severely interrupted and destroyed during the time of the Second Indochina War. Destruction of the dyke system was a strategic component of the American military as it significantly affected the fledgling North Vietnamese State. Such military action also underscores the vital importance of the Red River Delta dyke system in Vietnamese economics and polity.

The priority after the war was rebuilding infrastructure, settlement and livelihoods. As part of the Socialist State and agricultural collectivization, development of the countryside took on a renewed importance. In addition to attention the main dyke system along the rivers, the government directed villagers who lived inside the dyke system (where the primary production areas for collective programmes were located) to create a system of earthen semi-dykes to protect themselves and agricultural production from river floods in rainy season. These semi-dykes were erected to the level of annual flood waters. Over time, there developed and entire network of semi-dykes dispersed across the Red River Delta which continues to facilitate agricultural production and new urbanization.

[Fig. 09] Post-independence agricultural hydraulics:
The Bac Hung Hai pump station is a part of the 200km long agro-hydraulic system, the largest hydraulic system in the Red River Delta, made by series of canals, dams, pumping stations and dykes which was implemented in 1958 which can support water for 2002.3 km². It is delimited by the Red River, Duong River, Thai Binh River and Luoc River.

[Tuan Pham Anh photo, 28 March 2010]
For the main dyke system, after the 1971 devastating Hanoi flood in Hanoi, the government decided to construct a new concrete wall in the city center and earth dykes in the rural area on both sides of Red River in order to complement the existing dyke system. Thereafter, the dyke system in Red River Delta reached what was considered a maximum height level in 1975, following centuries of progressive heightening. Therefore, flood management for the delta had to be rethought. At the time, large-scale engineering solutions were highly regarded and hydroelectric plants were planned [Phan 1995: 180]. The largest hydroelectric project in Vietnam and the first important one on Red River Delta, the Hoa Binh Hydroelectric Plant, was began construction in 1979. It was only completed in 1994, but significantly contributed to flood management of the Red River, since its reservoir has a capacity of 9.45 billion cubic meters. Of course, every year, dyke building proceeds and 2 – 3 million cubic meters of earth and ten thousands cubic meters of stone are mobilized to fight the force of the waters and dynamics of the Red River Delta [Phan 1995: 191]. At the same time, a number of reservoirs constructed on upstream of the Red River outside of Vietnam reveal the troubles of watershed management which work irrespective of national boundaries and politics. Vietnam suffers the consequences (flood and drought, pollution, etc.) of being the outlet of the Red River and the river fluctuations are no longer only decided by the vagaries of nature but also by the politics and economics of its neighbors.

**Water Management after “Doi Moi”**

By recognizing the failure of the “great socialist agriculture” experiment, the Vietnamese government decided to change its economic policy as set forth in the so-called economic liberalization (called “doi moi”) that was defined in 1986 at the Sixth Party Congress. There were significant consequences for the nation’s water management system as the territorial ordering was inseparable from the logics of production and settlement structure. Once Vietnam entered the “Doi Moi” period, water management, like all else in the country, became part of the interests of the larger international (donor and investment) community. A great deal of experts given the opportunity to abroad study and many international experts began to advise Vietnam. As well, Vietnam has received substantial investment from international organizations for dyke improvement and education, including from organization such as Save the Children Fund - United Kingdom (SCF/UK), and the World Food Programme (WFP) and as well participated in a number of international programs related to national disaster reduction such as international decade for National Disaster Reduction in 1991 [Phan 1995: 194-5]. Vietnamese knowledge on the dyke construction and flood control was much improved and updated with help of the international community. Meanwhile, a set of legal documents and hierarchical organization from the central State to local communes for coordinated dyke management and storm/ flood prevention was completed in 1990. At the moment, everything related to the Vietnam’s dyke network is based on two legal documents: (i) “Ordinance on Dyke and Dyke Maintenance”, No. 26/2000/PL-UBTVQH10 issued on 07/9/2000, and (ii) “Law of Dyke Management”, 79/2006/QH11 issued on 19/11/ 2006. Article 23 of the latter is particularly relevant for the detailed regulation on the protected areas of dykes.

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4 Based on an interview with Mr. Tran Van Dien, 80 years old, who has lived his whole life in Yen My village, Thanh Tri, Hanoi on 03 April 2010 during fieldwork.
5 In December 1988, Vietnam received financial assistance from Save the Children Fund – United Kingdom for opening the first training course about storm control in Vietnam.
6 In 1986, Vietnam received financial assistance from World Food Programme for constructing a number of sea-dyke along the coast in Ha Nam Ninh, Nghe Tinh and Binh Tri Thien Provinces.
7 According to the “Law of Dyke Management”: In urban, residential and tourist areas, the protected area of the dyke is 5 meters from the existing dyke foot on both the riverside and the field side, in the other areas it is 25 meters wide on the field side and 20 meters on the riverside regulated for the dyke in levels I, II and III of river dyke and 200 meters on the seaside for the sea dyke. The protected area of an embankment which directly protects a river and sea dyke is 50 meters wide from the outer edge of the dyke foundation on both sides. Considering digging activities carried out outside the dyke protection area: For boring 1m deep in the natural ground, the boring must be located 10 meters more from the dyke foot in normal geological foundation, and 200 meters from the dyke foot in bad geological foundation where sand boils can occur in the flood season, except in special cases permitted by State authorities.
Due to increased urbanization in the larger cities of the Red River Delta, the dyke system is under extreme pressure. This is particularly evident in the capital city of Hanoi. Due to ill-maintenance, some parts of dyke system have disappeared completely, so the defense system is weakened. At the same time, as rapid urbanization proceeds, the natural surface for flood-water discharge has been significantly diminished as impermeable areas replace formerly permeable natural areas – as illegal settlement encroaches the flood plain of the dyke system. After a few decades of urbanization combined with the predicted consequences of climate change, the dyke system has once again become a more important and serious issue which is (again) getting renewed attention from both the Vietnamese government and as well from international organizations. In the areas along the dyke system where there are margins of open space, the Vietnamese government has directed the population and local governments to plant bamboo trees or to improve the slopes of the dyke systems by concrete embankments to prevent erosion. In order to address the (urban) appropriation of land along the dyke and threatening its efficiency and even stability, the Vietnamese government is systemically attempting to created security corridors of the way of new local roads at the foot of dyke system. [Fig. 10]

From 1996 to 2001, there was a project, supported by Asian Development Bank (ADB), to create a special dyke on the Hanoi’s right bank of the Red River. The existing dyke was upgraded by widening the top (to a width between 10-16 meters) and including an asphalt vehicular road, strengthening the slopes of dyke by wave-preventive methods upstream and with technical grass in downstream with slopes from 1/3 to 1/2 on both sides of the dyke [NHPI 2010: 78].

Furthermore, there is a new flood control project by the Northern Hydraulic Planning Institute for Hanoi’s entire river system and which is beginning implementation in 2010. This project ambitions to upgrade the entire whole dyke system according to a new classification for river dykes. The dyke system along Red River will be widened to 15 meters wide for right bank dyke and 12 meters wide for left bank dyke on the top with slope is 1/2 on the riverside and 1/3 on the field side. A wall of 1.5 meters height and 1 meter wide is to be erected on the top of dykes on both sides of the Red River [NHPI 2010: 230-32]. For the other rivers, step dykes will be constructed which combine roads on the top of them and which are widened to 5 meters wide on the top of dyke on both sides of rivers The dykes along the Day and Cau Rivers will be widened to 9 meters on the top on both sides of rivers with slopes if1/2 on the riverside and 1/3 on the field side. A wall which has 0.9 meters high and 0.7 meters wide will be

[Fig. 10] Dyke protection, landscape and urbanization
In the “doi moi” era of water management, systems of local roads are constructed at the foot of dykes to both protect the integrity of the dyke (protect it from encroachment) and to deal with the pressure of urbanization. The landscape along the dyke system will inevitably change following the initiation of infrastructure.

[Tuan Pham Anh photo, 28 April 2010]
erected on the top of dykes on both sides of the Cau River. There are to be 2.5 meters high steps on the riverside and 2.5 to 3.5 meters high on the field side all of which shall be 5 meters wide [NHPI 2010: 240-6]. Moreover, a series of stone embankments will be constructed and improved where there is the most vulnerability due to flood-waters both sides of the Red River. As well, new landmarks of flood-water discharge points and a new position of the dyke system for the Red River and Duong River to control water in rainy season and to protect the areas where are dense settlement are proposed. [Fig. 11]

In addition to the obsession with the dyke system itself, there is also a great deal of attention being paid to the points that plug into the network – the dams/reservoirs, pumps, sluices and even purification systems. Hanoi’s largest and newest pumping station and water purification plant has been constructed next to the right bank dyke along the Red River in Yen So. Yen So is the lowest area in Hanoi center, and thus a strategic location for such a facility to address the flood and polluted water issues for the larger Hanoi area. The project consist of two phases and phase 1 was completed in 2005 with the capacity of water discharge is 45 cubic meters per second. After finishing phase 2 (expected in October 2010) the capacity of water discharge in the Yen So Pumping station will be increased to 90 cubic meters per second and thus be able to manage the rainfall of 310 millimeters per two days [Hanoi People’s Committee 2005: I-7]. The purification plant is being constructed by Gamuda Company (Malaysia’s Leading Infrastructure Group) with a capacity of 200,000 m$^3$/day and can support 2 million inhabitants living in the areas of the Lu, Kim Ngu and Set River Basins.8

In addition to the Vietnamese studies and projects to address the new challenges for water management of the Red River Delta in the face of new pressures of urbanization, Hanoi has also received significant inputs various Japanese and Korean organizations.

Japan’s ‘second dyke’ for the Red River

“The Comprehensive Urban Development Programme in Hanoi Capital City of the Socialist Republic of Vietnam (HAIDEP)” was a cooperation project between Hanoi

8 Based on interview with Mr. Minh Chau, who is a technical management of Yen So Park Project – a part of purification project in Yen So, Hanoi on 29 April 2010 during fieldwork.
People’s Committee and Japan International Cooperation Agency (JICA) from 2004 to 2007. Pilot Project C: The Improvement Plan and Strategy for The Outside-of-dyke area studied the vast 40km long flood plain area along the banks of the Red River that has been illegally appropriated by housing development in the past decades. The project proposed new development orientation for the area via a series of alternative scenarios that were developed spatially, technically and financially.

Clearly the area is of strategic value – as a flood plain for the swelling river in the monsoon season but also as a landscape for the city of Hanoi. Until a year ago, the urban expansion of Hanoi was envisioned to cross the Red River and develop northwards, putting the river (once again) at the heart of Hanoi's development. Real estate speculation would have put incredible pressure on the fragile and strategic environment. As expansion is now planed westwards, water management can once again be developed comprehensively. In the HAIDEP project land use is proposed to be controlled to meet the demand and capacity of the area, and rampant urban development activities would be restrained. Overall space management would be integrated between urban development and natural environment control.

The HAIDEP project recognized that the area outside the Red River dyke is a precious asset for the entire city because of its historical value, landscape and disaster prevention capacity. Arguably they also value it for its urban development potential – which it could be argued goes against the environmental principles and the notion of giving more space to the water to deal with floods and the predicted consequences of climate change (more water). However, as their more (economically-driven) argumentation goes, to enhance the development potential of the area outside of the dyke, as well as to secure people’s quality of life, there should be built a second dyke closer to the river. This structure would be at the height of flooding for the 5-year return period, which would allow for limited development projects within the newly protected area. In addition, they suggest the development of a clear policy with due consideration of the following [Fig. 12]:

(i) Areas lower than the water level of a 5-year return period must be free from any kind of development, except temporary public facilities;

(ii) In the proposed special areas, which shall be preserved as cultural assets of the city or be developed as urban spaces, construction of a secondary dyke (with a height of 12m) along the water level line of a 5-year return period to protect the area between the existing dyke where non-residential developments, such as markets, parking, recreation facilities, commerce/business, etc., can be located.

[Fig. 12] Development outside the dyke area of the Red River

HAIDEP has proposed a double dyke system in complex integration of open space and urban development which severely compromises the natural ecologies and dynamics of the water flows in lieu of economic and urban development.

[HAIDEP, 2007]
To confront the process of urbanization outside of the dyke, the HAIDEP research suggests that in the future, only areas immediately adjacent to the existing urban core of Hanoi would be allowed to have "controlled development" behind a second dyke. Other land would be preserved as open space and agricultural lands [Fig. 13]. Therefore, the prioritized areas for resettlement would be the areas which violate the current Dyke Ordinance (many housing and industrial areas). Security is given a high priority in their plan and residential areas along the river terraces, around bridges, nearby the dyke roads are to be relocated for safety concerns in times of flooding. As well, their plan recognizes areas of high cultural values, the traditional Bat Trang ceramic village, for example. To preserve and protect such cultural areas, it is proposed to construct a second dyke around. This would also be a solution for urban communes such as Phuc Xa, Yen Phu, Chuong Duong Do, that have traditionally flourished and have long history as rural villages linked to the Red River [HAIDEP 2007: C-3-5 to C-3-8].

Korea’s ‘super infrastructure’ for new riverfront development

From 2006-7, a cooperation research between the capital cities of Hanoi and Seoul worked to develop lessons learned for the Red River from the Han River. The project sought to marry flood control with new urbanization, economic drive, river-based recreation and identity. The development of an infrastructural system and dyke system became the backbone of the entire project, upon which was grafted and entire new high-rise city, new landscape system and waterfront area along the entire length of Hanoi’s Red River. [Fig. 14]
As in the Japanese project, a second dyke was also proposed, but here the dyke was much more extensive and the flood plain of the Red River is radically reduced in width. [Fig. 15] As compensation, the banks of the river are in some places excavated, but overall the space for the water is lost and space for urbanization prevails. Inevitably, the flooding risks will be exacerbated by filling that occurs on the inside of the existing dyke. Large arterial roads are developed alongside the dykes and give access to a new high-rise city [Red River Project Team 2007: 9-6 to 9-8]. [Fig. 16] The dykes themselves are free of cars and all developments and the new and re-profiled existing dyke form part of the waterfront park system. Pedestrian access from the city to the river is made via a series of landscape bridges over the arterial roads (effectively making the roads then in tunnels at every 550 meter intervals) [Red River Project Team 2007: 7-52 to 7-53]. [Fig. 17]
The dyke building tradition in the Red River Delta has a long and distinguished history. The feudal system of Mandarin control and maintenance by the local peasantry revealed an intimate understanding of the logics of the landscape and the dynamics of the delta. Man tamed the water regimes with quite low-tech means and massive human effort and ingenuity. Over time, trial-and-error, gained knowledge – both indigenous and imported – and new techniques, water management became more sophisticated and more refined.

The speed and scope of today’s urbanization, in addition to the predicted consequences of climate change and the uncontrollable up-stream river constructions by neighboring countries has brought the tradition into a new era that needs radical rethinking. It is clear that contemporary projects discussed in this paper by the Vietnamese, Japanese and Korean are all struggling to reconcile the demands of urbanization and economic growth with the struggles to and even responsibilities of protecting the environment. It is well known the economy and ecology are not often developed in tandem – but, in fact, there can be strategies developed where this can be the case. The contemporary challenges demand a new paradigm of water management creatively marries infrastructure, urban development and public space into a hybrid entity and innovatively and economically solves a number of problems at once – while using the best of indigenous knowledge and contemporary international practices.
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Fieldwork interviews

03 April 2010: Mr. Tran Van Dien, 80 years old, who has lived his whole life in Yen My village, Thanh Tri, Hanoi

29 April 2010: Mr. Minh Chau who is a technical management of Yen So Park Project– a part of purification project in Yen So, Hanoi