Chapter 14 Natural Conditions in the Red River Delta

14.1 River basin and tributaries of the Red River Delta

14.1.1 Geographical conditions

The main stream of the Red River, or Song Hong in Vietnamese, originates at Yunan Province in China. The total catchment area is 169,000 km^2, of which about a half lies within Vietnam. It runs into the territory of Vietnam, named the Thao River, through Lao Cai Province in between the Mountain Ranges of Hoan Lien Son and Con Voi, elevation of which are higher than 1,000 meters. The portion of Thao River has irregular riverbed.

As shown in **Figure 14.1.1** the Red River has four major upstream tributaries, i.e. the Da River on the right side, and the Chay River, the Lo River, and Gam River on the left side. They merge near at Viet Tri as a nodal point, which constitutes the border of the upstream and downstream portions of the Red River and the apex of the *Red River Delta*. The Delta has an area of about 17,000 km^2.

The lower Red River System is characterized by many branches and their complicated alignment with silty-sand bottom on the flat plain. The Day River is the first bifurcation to the right from downstream of Son Tay to the Gulf of Back Bo, passing by Ninh Binh. After flowing for about 60 km, the Red River is separated by the Duong River in Hanoi City from the left bank to the east.

The main Red River continues to flow down to the southeast. After passing Hung Yen, the river has the third branch on the left, the Luoc River, which connect another major river in the basin, the Thai Binh River, on the east. The Red River has the next bifurcation at Pham Lo to the east, the Tra Ly River, which passes Thai Binh and runs into the sea at the Tra Ly Estuary. The fifth branch is located at Hung Long, the Dao Nam Dinh River, which connects the Red River and the Day River on the southwest side, and has the role of an access to Ninh Binh. The last branch is the Ninh Co River, which runs to the south and into the Gulf at the Lach Giang Estuary. The main river ends up at the Ba Lat Estuary on the coast of the Gulf.

Returning to the Duong River, it joins the Thai Binh River at downstream of Pha Lai. The Thai Binh River flows by Hai Duong into the Gulf, forming the Thai Binh Estuary. Just below the confluence of the Thai Binh River and Duong River, the Kinh Thay River starts to run further to the east at My Loc.

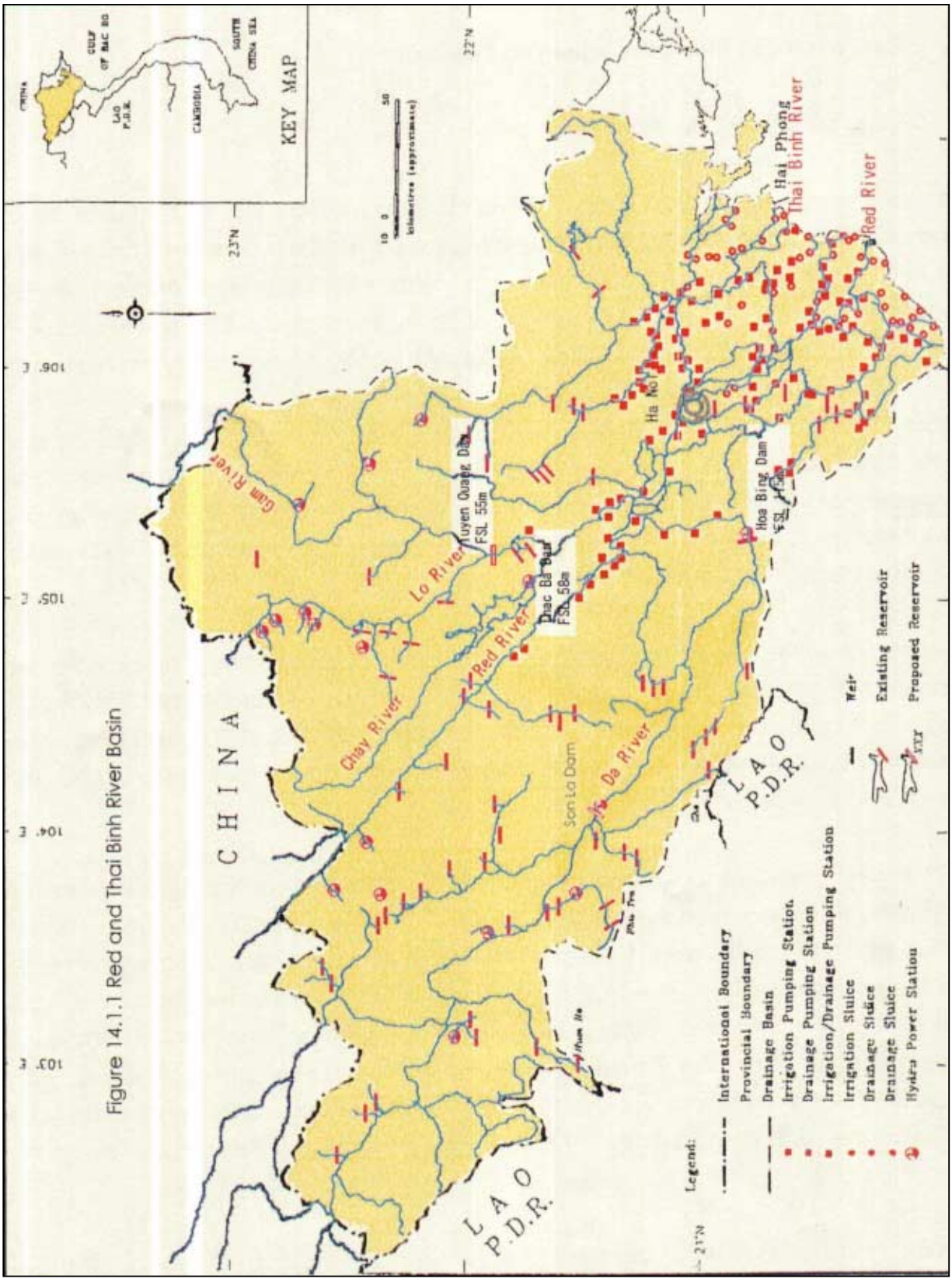


Figure 14.1.1 Red and Thai Binh River Basin

Source) Vietnam-Water Resource Sector Review; World Bank, ADB, FAO, UNDP & NGO, May 1996

The Kinh Thay River separates again into the Mao khe River, the Kinh Mon River and the Rong Binh River. The Kinh Thai River changes the name at the downstream to the Cam River. The Mao Khe River reaches the Gulf as the Bach Dang River and the Nam Trieu Estuary. The Cam River passes Hai Phong and reaches the Lach Tray Estyary. The Rong Binh River is separated into its main stream and the Lach Tray River. The Lac Tray River has a branch channel connected to the Cam River. The main stream of the Rong Binh River changes the name to the Van Uc River and reaches the sea as the Van Uc Estuary.

14.1.2 Administrative conditions

The Red River Delta, following the traditional administrative definition, consists of two designated cities, i.e. Hanoi and Hai Phong, and nine provinces, i.e., from the northwest to the southeast, Vinh Phuc, Ha Tay, Bac Ninh, Hung Yen, Hai Duong, Ha Nam, Thai Binh, Nam Dinh, and Ninh Binh. Taking account of the inland waterway network related to this Study, three more provinces bordering the area are considered to be included in the Delta, i.e. Bac Gian and Quang Ninh to the northeast, and Hoa Binh to the southwest of the area. The total population in this area is 20,133 thousand persons in 1999, which is equivalent to 26.2 % of the overall population of Vietnam.

14.2 Meteorology

14.2.1 Climate

The climate of the Red River Basin is tropical and sub-tropical. It is dominated by the monsoon winds of the Southeast Asia, i.e. the southwest wind during summer time and the northeast wind in winter.

Besides the seasonal variations of the monsoons, which are significant everywhere in the Basin, tropical depressions (TD) and typhoons sometimes attack the coastal areas in north Vietnam from May to August, which bring strong wind and heavy rain.

For more detailed information on wind and TD, please refer to **Appendix A14.2**.

14.2.2 Temperature and rainfall

The records of monthly average temperature and monthly rainfall are shown in **Figure 14.2.1** for Lao Cai and Hanoi Meteorological Stations in 1999. In Hanoi, the

hottest month was July and the coldest month was December in this year.

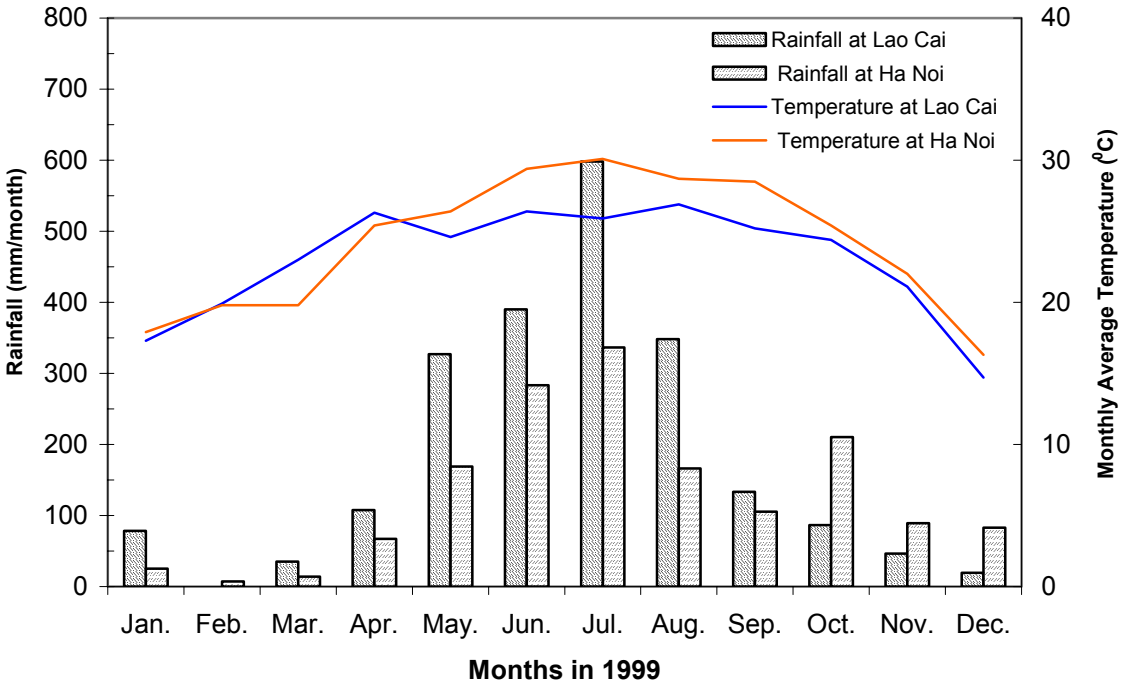


Figure 14.2.1 Temperature and Rainfall in Lao Cai and Hanoi (1999)

Source) Statistical Yearbook 2000

The rainy season is commonly defined from May to October, and the dry season prevails from November to April. The total annual rainfall in the Basin is higher in Vietnam side than in China side. It amounts to more than 2,000 mm in the mountain area in Vietnam, as is the case of Lao Cai in 1999, or 2,170mm. The rainfall in the flat lower delta is about 1,500 mm as the case of Hanoi in 1999, or 1,556 mm. During the rainy season, the amount of rainfall reaches to about 80 % of the annual rainfall.

14.3 Water and flood levels, and flood protection

14.3.1 Water levels

(1) Water levels in the Red River Delta

There are 40 Hydro-meteorological Stations in the Red River Delta from Viet Tri to the sea as shown in **Figure 14.3.1**. Among them 17 stations are selected, and water level data are collected, which are summarized in **Table A.14.2.12**.

The distribution of water levels at representative stations from Viet Tri to the river

mouths is illustrated in **Figure 14.3.2** for the highest water level on 22 August 1971. The water level difference between Viet Tri and Ba Lat is 16.5m, or the average gradient is about 1/ 10,000.

The distribution of 1) Average Water Level during Flood Season, 2) Mean Water Level, and 3) Average Water Level during Dry Season are illustrated in **Figure A.14.2.3 (1)** to **(3)**.

Figure 14.3.1 Locations of Hydro-Meteorological Stations in the Red River Delta

Source) JICA Study Team

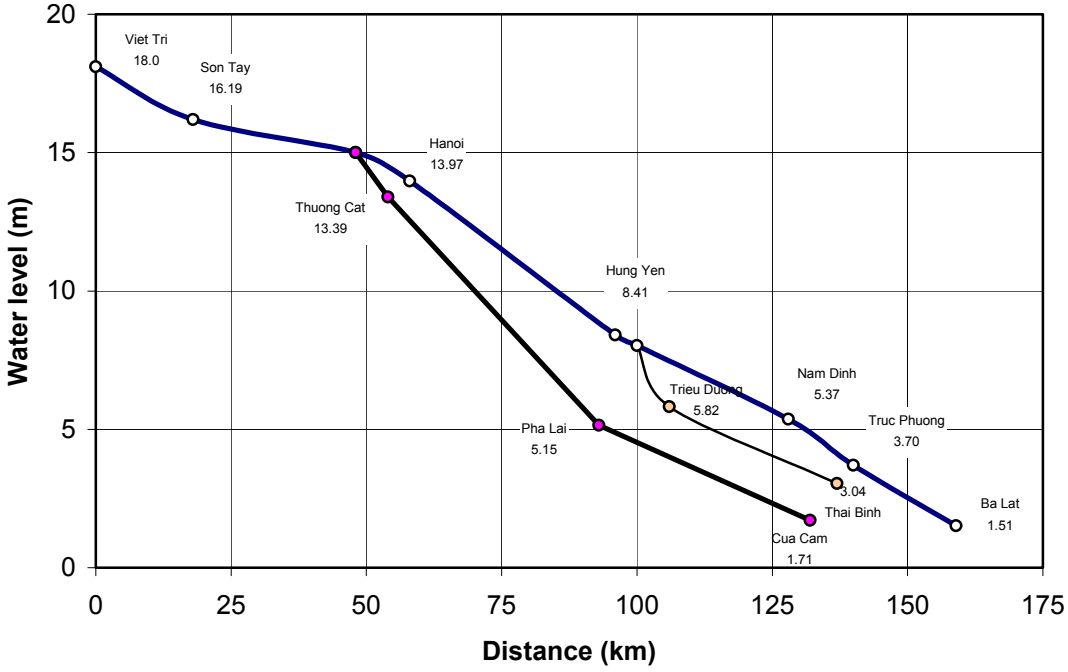


Figure 14.3.2 Distribution of Water Levels in the Red River Delta (1971Flood)

Source) JICA Study Team

(2) Water level in Hanoi city

There are two gauging stations in Hanoi City, i.e. Hanoi Station in the Red River and Thuong Cat Station in the Duong River.

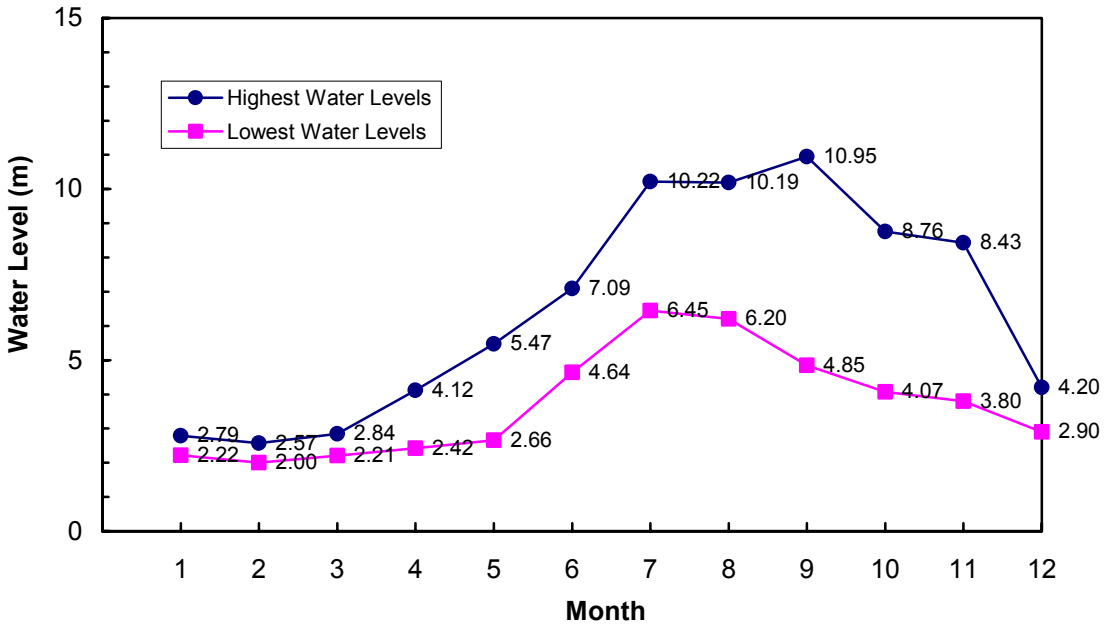
In addition to these two permanent stations, eight temporary gauging stations was set up along the Red River in Hanoi City for the site surveys of the Study Team, i.e. from upstream to downstream, Giay Agriculture Pump Station (right bank), Chem Temple (right bank), Phu Thuong (right bank), Duong River Mouth (left bank), Hanoi Port (right bank), Hanoi Shipyard (right bank), Thanh Tri (right bank), and Khuyen Luong Port (right Bank). The Study Team carried out measurement of water level, current velocity and suspended sediment, which is summarized in **Appendix 14.2**.

The maximum and minimum water levels recorded at Hanoi Station are presented in **Table 14.3.1** for the past 16 years. The maximum water level occurred from June to September. While the minimum water level occurred from December to April, mostly in February. The change of monthly highest and lowest water levels at Hanoi Station is shown in **Figure 14.3.3**.

Table 14.3.1 Maximum and Minimum Water Levels recorded in Hanoi Station (1986-2001)

Year	Max Water Level		Minimum Water Level	
	Level (m)	Date occurred	Level (m)	Date occurred
1986	12.19	29-7	2.01	26-3
1987	10.02	25-8	2.03	21-3
1988	9.99	10-9	**1.91**	5-4
1989	10.07	14-6	1.96	23-2
1990	11.78	31-7	2.44	13-2
1991	11.33	16-8	2.70	4-5
1992	11.30	27-7	2.62	28-4
1993	9.46	26-8	2.82	4-1
1994	10.47	19-7	2.68	16-3
1995	11.57	19-8	2.82	31-12
1996	**12.43**	21-8	2.40	22-3
1997	11.09	24-9	2.86	3-2
1998	11.00	13-7	2.22	31-2
1999	10.95	4-9	2.00	20-2
2000	11.29	26-7	2.55	29-2
2001	11.21		2.38	

Source) Hydro-meteorological General Department – National Elevation System



Note) The above water level are shown in national elevation system

Figure 14.3.3 Monthly Highest and Lowest Water Levels observed at Hanoi Station (1999)

Source) Hydro-meteorological General Department – National Elevation System

The extreme maximum and minimum water levels are shown in **Table 14.3.2** along with the volume of water and sediment discharges. The statistical maximum and minimum water levels at Hanoi Station are summarized in **Table 14.3.3**. Various water levels at Hanoi Station to be used for design purposes are summarized in **Table 14.3.4**.

14.3.2 Floods

The high volume of water flows, the monsoon climate, and frequent Tropical Depressions (TDs) make the Red River Basin vulnerable to severe flooding. The high bank of the riverside land in the Red River in Hanoi has elevations of Land Survey Datum (LSD) +10.0m to +13.0m. Water levels over this elevation cause flooding for the houses on the floodplain.

The flood warning water levels, which is divided into three classes I, II, and III are defined for each river in the Basin as shown in **Table 14.3.5**. In the Red River, the warning water levels are 9.5m, 10.5m, and 11.5m for Class I, II, and III, respectively.

The following is general feature of historical or typical floods.

(1) Flood in 1971

The highest flood level recorded in the 20th Century was that in August 1971. Huge areas in the Delta were inundated, including Hanoi, and there were numerous causalities.

The highest high water levels at representative gauging stations in the Red River Delta have already shown in **Figure 14.3.2**. The gradient of the water level is gentler at the upper segment from Viet Tri to Hanoi than the lower stream from Hanoi to Ba Lat.

The record of change in the water level, as an example, at Thuong Cat Station is shown in **Figure 14.3.4 (1)**. The peak water level was LSD +13.39m at the Station. The water level higher than LSD +12.0m lasted for about 5 days, and water level above LSD +10m continued for more than 30 days. At Hanoi Station the peak water level was LSD +13.97m, or 58 cm higher than that at Thung Cat Station. The peak discharge at Son Tay reached 34,200 m^3 that has a return period of 150 years. The 8-day flood volume is estimated to have a return period of 200-250 years.

Table 14.3.2 Maximum and Minimum Water Levels and Discharges recorded in the Past

Water Levels	Unit	Son Tai St.	Hanoi St.	Thuong Cat St.
Maximum water level	m	16.19 (21/08/71)	13.97 (22/08/71)	13.39 (22/08/71)
Average water level	m	7.75	4.86	5.00
Minimum water level	m	3.47 (07/05/60)	1.55 (09/05/60)	1.46 (26/04/58)
Maximum sandy mud volume	m^3s	34,200 (21/8/71)	22,200 (20/8/71)	9,000 (22/8/71)
Average sandy mud volume	m^3s	3,560	2,710	880
Minimum discharge	m^3s	368 (7/5/60)	359 (9/5/60)	28.8 (28/4/58)
Maximum sandy mud volume	Kg/s	135,000	65,400	25,100
Average sandy mud volume	Kg/s	3,610	2,280	829
Minimum sandy mud volume	Kg/s	104	269	0.346
Maximum suspended mud degree	g/m^3	7,930	6,530	5,770
Average suspended mud degree	g/m^3	1,010	847	932

Source) Pre-feasibility Study Report, TEDI, 2001, partly revised by the JICA Study Team

Table 14.3.3 Statistical Maximum and Minimum Water Levels at Hanoi Station (1956-2001)

No.	Return Period (Years)	Max Water Level (m above LSD)	Min Water Level (m above LSD)
1	100	14.40	1.41
2	50	13.87	1.50
3	30	13.55	1.55
4	20	13.13	1.64
5	10	12.53	1.76
6	5	11.87	1.90
7	1	8.38	3.54

Source) TEDI-port

Table 14.3.4 Water Levels at Hanoi Station for Design Purposes (1956-2001)

Name of Water Level	Water level (m above LSD)
Highest Water Level (1971)	+13.97*
Water Level for Design of Hanoi Dyke (Special Class)**	+13.4
Mean Annual Highest Water Level	+10.96
5% Occurrence Water Level (1995-2001)	+9.52
Mean Water Level in the Flood Season (May to October)	+7.34
Mean Water Level	+5.04
Mean Water Level in the Dry Season (November to April)	+3.47
95% Occurrence Level (1995-2001)	+2.58
Mean Annual Lowest Water Level	+2.20
Lowest Water Level (1960)	+1.55

Note) LSD = Land Survey Datum (equal to the National Elevation System)
= CDL (Chart Datum Level at Hon Dau) +1.86m;
* By Hanoi HM Station ** Defined by MARD in July 2002

Source) TEDI-port and JICA JICA Study Team

Table 14.3.5 Warning Water Levels in the Red River Basin

River	Gauging station	Warning Water Level			Remarks
		I	II	III	
Cau River	Dap Cau	3.8	4.8	5.8	
Da River	Hoa Binh	21.0	22.0	23.0	
Dao River	Nam Dinh	3.2	3.9	4.4	
Duong River	Thuong Cat	9.5	10.5	11.5	
Hoang Long River	Ben De	3.0	3.5	4.0	
Kinh Thay River	Ben Binh	2.8	3.8	4.6	
Lo River	Tuyen Quang	22.0	24.0	26.0	
Luc Nam River	Luc Nam	3.8	4.8	5.8	
Luoc River	Trieu Duong	4.7	5.4	6.1	
Red River	Hanoi	9.5	10.5	11.5	
Thai Bin River	Pha Lai	3.5	4.5	5.5	
Thao River	Phu Tho	17.5	18.2	19.9	
Tuong River	Lang Thuong	3.8	4.8	5.8	

Source) VIWA

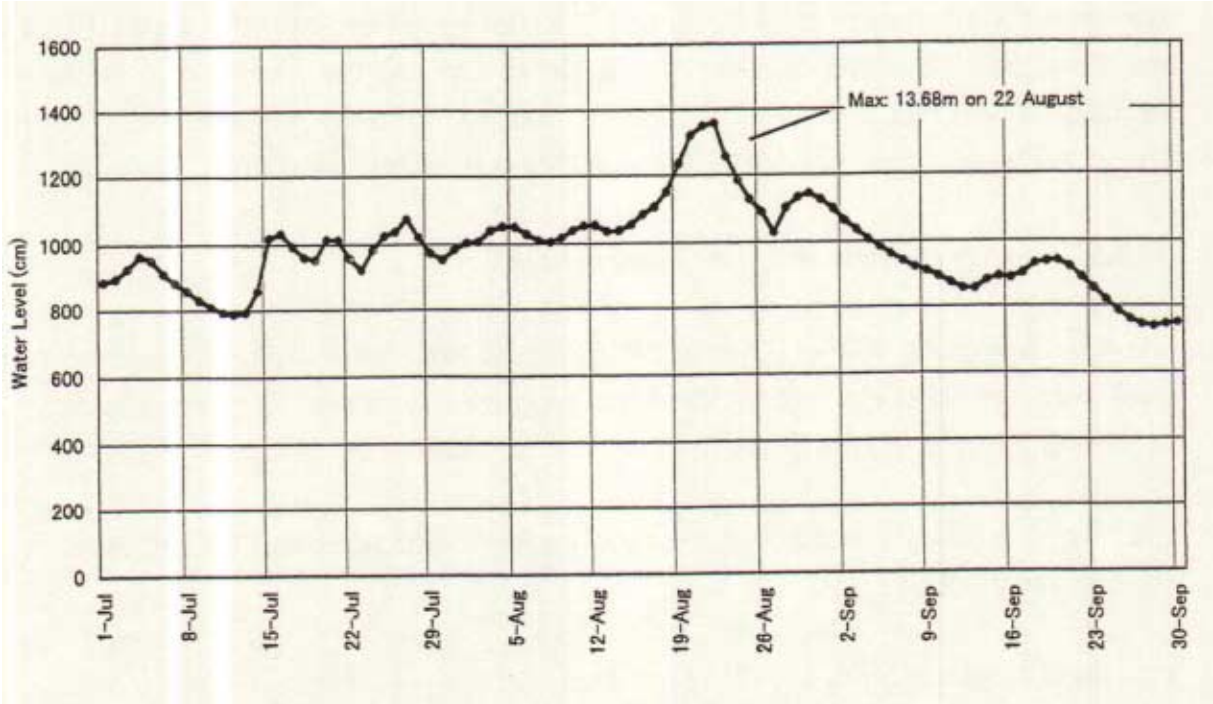


Figure 14.3.4 (1) Variation of Daily Average Water Level at Thuong Cat Station in 1971

Source) Thuong Cat Gauging Station

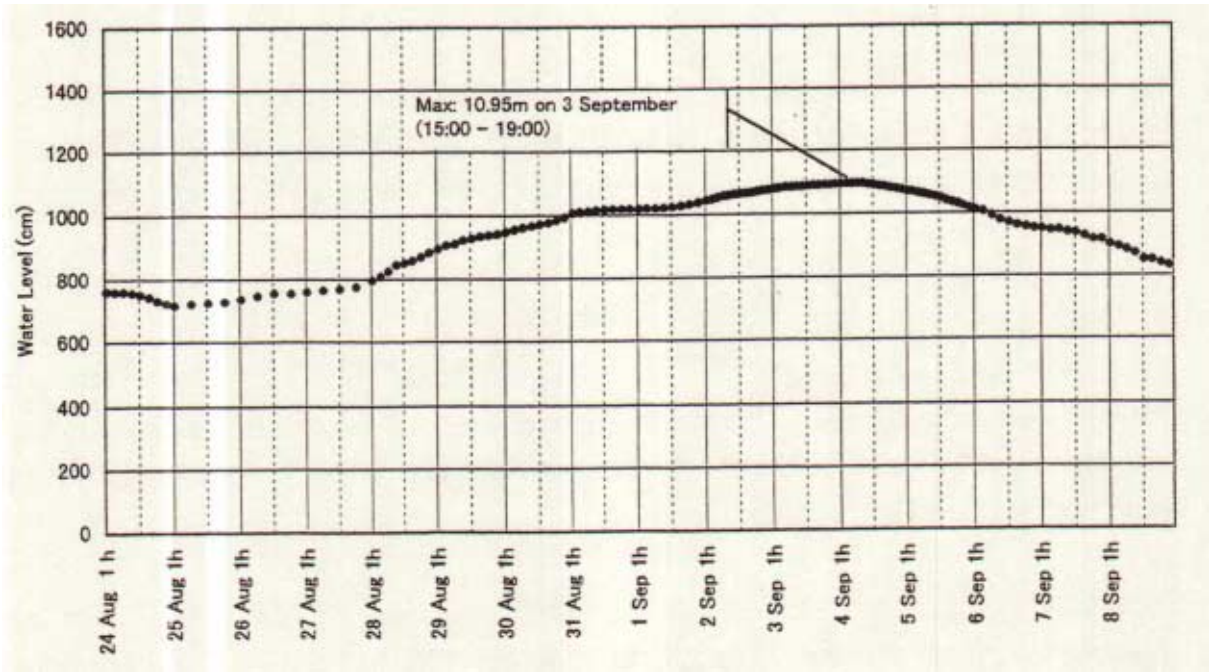


Figure 14.3.4 (2) Variation of Hourly Water Level at Hanoi Station in 1999

Source) Hanoi Gauging Station

(2) High Water in recent years

A recent common example of variation of water level is presented in **Figure 14.3.4 (2)** for the flood in 1999. This is a record at Hanoi Station. The variation is rather smooth compared with that in 1971. The highest monthly highest water level was LSD +10.95m. The water level higher than LSD +10m was maintained for seven days.

In 2002, flood of which water level exceeded 10m occurred twice, i.e. from 5 am on August 2 to 7 pm on August 7, and from 1 pm on August 12 to 1 am on August 23. The highest water level recorded in Hanoi Station is SDL +12.01 m from 4 pm to 8 pm on August 18. The damages suffered are summarized in **Table 14.3.6** for the Red River and the Duong River.

Table 14.3.6 Damages by Floods in the Red River and the Duong River (in August 2002)

River	Location	District	Water level when damaged	Damage	Date
Red River	Hai Boi	Dong Anh	+ 8 ~ 9 m at Hanoi Station	Erosion of river bank	N.I.
	Yen So	Thanh Tri			
	Trung Ha	Hoan Kiem		Erosion of sand bar	
Duong River	Le Chi	Gia Lam	+12m at Thuong Cat Sation	Secondary dike broken	August19
	Phu Dong	Gia Lam	+6 ~ 7 m at Thuong Cat Station	Erosion of river bank	N.I.

Note) "N.I." stands for "The exact date cannot be identified."
Source) TEDI port

(3) Water level for dyke design

The Minister of Agriculture and Rural Development issued guidelines on the flood water level for dyke design along the Red River and Thai Binh River Systems by Decisions Nos. 59 and 60/2002/QD-BNNPTNT in July 2002 and No. 609/Qd-PCLB in August 2002 define that Hanoi Dyke (Special Class) should prevent the flood at the water level of 13.4m, and Dyke (Class Nos. I, II and III) should prevent the flood at the level of 13.1m as shown in **Table 14.3.7**. The original Decisions are

attached in **Appendix 14.2-2, 3, 4** and **5**.

The flood preventing criteria is that, at present time, the return period is 125 years to prevent flood in August 1971 both at inner Hanoi and other areas (Branch Criteria No. 14 TCN122-2002).

Table 14.3.7 Water Level for Dyke Design defined by MARD

(Unit： m)

No.	Location	River	Km	Dyke class I to III (m)	Special class dyke
1	Son Tay Station	Red	K31+600 (Right bank)	16.30	
2	Long Bien Station	Red	K66+400 (Left bank)	13.10	13.40
3	An Canh Station	Red	K96+500 (Right bank)	10.60	
4	Thuong Cat Station	Duong	K1+995 (Right bank)	12.90	
5	Ben Ho Station	Duong	K32+500 (Left bank)	10.00	
6	Manh Tan Station	Ca Lo	K6+700 (Right bank)	9.50	
7	Ba Xa Station (Phuc Loc Phuong)	Cau	K28+800 (Right bank)	9.20	
8	Dap Cau Station	Cau	K59+350 (Right bank)	8.20	

Source) MARD, Decision No. 609/Qd-PCLB

14.3.3 Flood protection and river training facilities

The river dikes along the Red River and its tributaries have been built in a piecemeal fashion over centuries. The height of the dikes has progressively increased after major floods, also reflecting the gradual rise of the riverbed and settlement of the dikes.

The MARD has the "Training Plan for the Improvement of Flood Drainage Capacity and Riverbed Stabilization in Hanoi," which has a close relationship with planning of channel stabilization facilities under this Study.

The following is major features of the flood protection facilities and training works in Hanoi segment of the Red River.

(1) River dikes

The present river dikes at both sides of the Red River and the Duong River in Hanoi City was constructed in 1980's and 1990's by MARD. It has an earth-fill structure and trapezoidal profiles. Most of the inner surface is not armored by concrete. The top of the dikes on the right- hand side of the Red River is used by paved road of two lanes with a side step behind the parapet.

The arrangement of the dikes and their crown heights is sketched in **Figure 14.3.5**. The crown height is higher at upper and right-hand parts of the river. The highest crown height is LSD +15.9m at the upper right portion, and the lowest is +13.9m at both sides of the lower river portion.

The new "Dike Law" was effectuated in January 2001, which is attached in **Appendix A14.2-6**. The principle of construction of new river structures shall be no change in existing situation. The Article 12 of the Dike Law stipulates the procedures how to apply for approval of new construction of river facilities from MARD.

(2) Groins

Groins were constructed to control the flow of the Red River and to protect Hanoi City from the late 1920's to throughout 1930's as seen in **Figure A.14.3.1**. All of them have been destroyed or buried in the banks.

Construction of groins restarted at Tu Lien Bank in 1986 to 1987 by VIWA. Then, a series of groins were constructed at Thach Cau Bank from 1988 to 1991, Phu Gia Bank from 1992 to 1998, and Tam Xa Bank from 1994 to 1996, the detailed arrangements of which are shown in **Figure A.14.8.1**.

The aims of the groins are to stabilize and secure the channel for inland waterways. It eventually relates to fixing of the Talweg of the flow, and to protect the sand bars and river banks. Some of their structures, however, were not complete because of luck of funds.

(3) Slope protection

In the Hanoi segment of the Red River, the side slopes of the riverbanks are mostly not covered by artificial protection works such as revetments made of concrete pats or natural stones except for the portions in Hanoi Port, Khuyen Luong Port,

and others. The portions where the bank slope is protected are shown in **Figure A14.8.1**. All the bank cliffs are left untouched, being dependent on natural failure or accretion due to the effect of currents.

HNPC has a plan of so-called "Rigid Embankment Project". The alignment of embankment, as shown in **Figure 14.3.5**, is extensive, covering the major portion of the Red River in Hanoi, and has a planned crown height of 11 m to 11.5 m. The Plan was sent to the Prime Minister's Office for approval and not yet authorized as of December 2002.

On the other hand, HNPC started the works to protect the high banks on the right hand side of the downstream area of the Thang Long Bridge, and planning to start slope protection works at the area of downstream Chuong Duong Bridge.

14.3.4 Dams

There are many weirs in the tributaries of the Red River as already shown in **Figure 14.1.1**. The important in view of the effect on flood control is large-scale water reservoirs accompanied by dams for hydroelectric power stations at the Red River Tributaries.

(1) Hoa Binh Dam

The Hoa Binh Dam with a storage capacity of 9.5 billion m^3 (live storage of 5.6 billion m^3) on the Da tributary was constructed from 1979 to 1988. The dam run in full power after 1994.

It is a hydroelectric plant to produce energy of 7.8 billion kWh. The dam has rock-fill type structure with a height of 215m.

It is expected that the dam will reduce the peak flood level, for example the peak flood level of the 1971 magnitude by 1.5 m at Hanoi, or from 14.0 m to 13.5 m. On the other hand, the dam will also lengthen the time of flood during which the river dikes must hold high water levels. It has an effect to reduce sediment transport from the Da River to the Red River.

(2) Thac Ba Dam

The Thac Ba Dam on the Chay River was constructed from 1962 to 1972. It has a live storage volume of 1.2 billion m^3 with energy production at 0.4 billion kWh. The

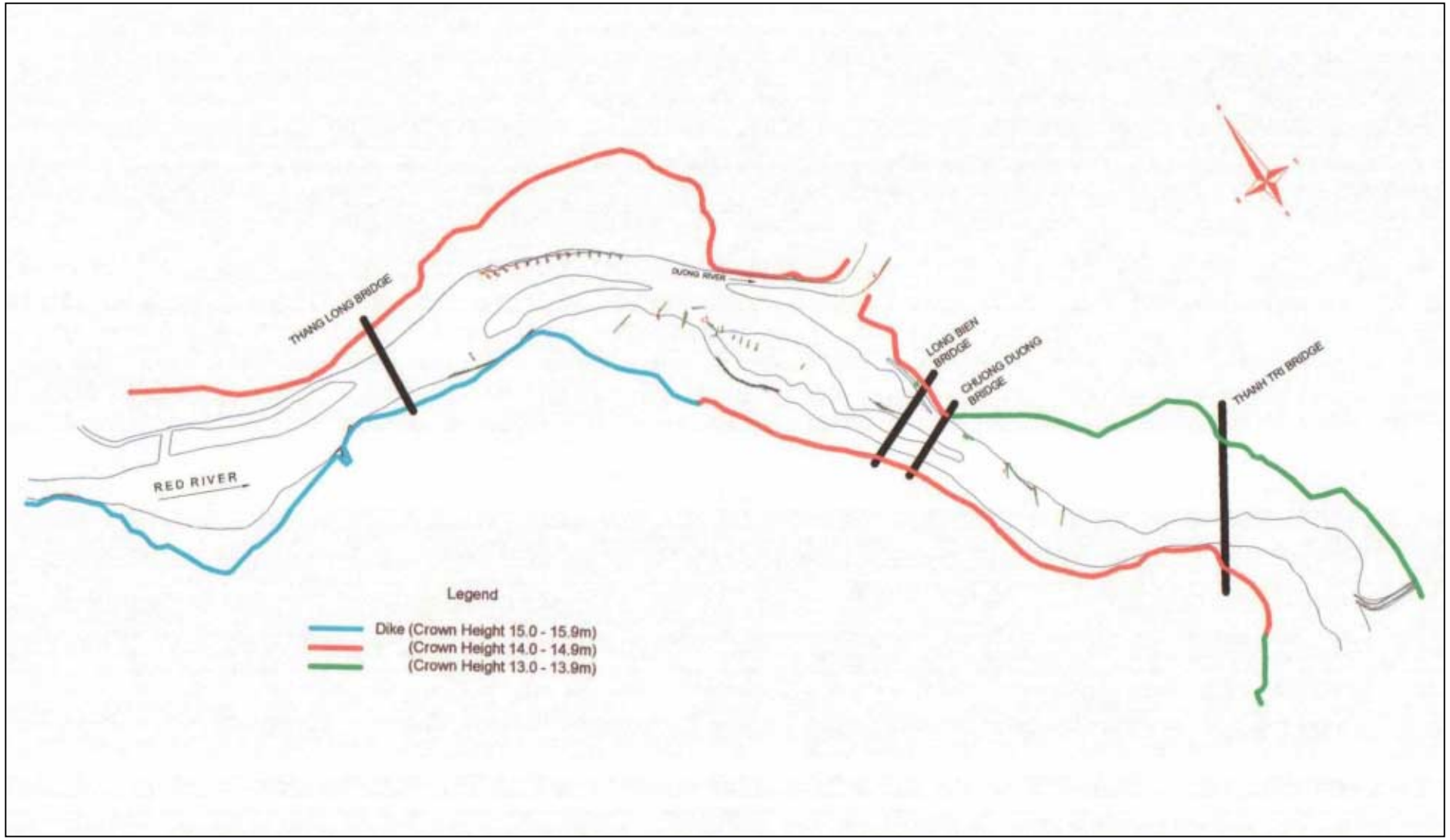


Figure 14.3.5 Arrangements of Flood Protection Facilities in the Red River

Source) VIWA and JICA Study Team

dam has the same effects on the Red River of peak-cut of flood level and stoppage of sediments.

The above two dams have nearly 7 billion m^3 storage capacity, but hold 6 % of the mean annual flow of the river, or less than one month of mean flows.

(4) Son La Dam

The Son La Hydro-electric Plant is planned to generate electricity, to provide water for low land farming in the dry season, and to prevent flooding in the rainy season. It is the largest dam in Vietnam with the height of 215 m now planned, the location of which is at the upstream of the Hoa Binh Dam in the Da River. It has a planned storage capacity of 4.5 billion m^3. It will provide energy of 9 billion kWh. The project is expected to complete in 2015.

Once constructed, the dam will also have a certain effect to reduce the peak flood level in the Red River and the supply of sediments through operations of the Hoa Binh Dam.

(5) Na Hang Dam

The Na Hang Dam in the Gam River is another hydroelectric plant, which is going to be constructed. It is sometimes called Tuyen Quang Dam. It started construction in December 2002 and planned to be completed in 2006. The planned water levels of maximum, mean, before flood season, and minimum for hydropower generation are 124m, 120m, 105m, and 90m, respectively. Water reserving volume is 1 billion m^3 for flood prevention, and 2.2 billion m^3 for the whole capacity.

The Na Hang Dam is the first reservoir in Tuyen Quang Province, and will have the similar effects as the other dams have on hydraulic conditions in the Red River.

14.4 Change of river configuration and depth in Hanoi Segment

14.4.1 Available topographic/bathymetric Information

(1) Old maps

The configuration of the Red River has changed drastically in the past. It is said that the records of old maps have been kept since 1885, as far as the portions

from Son Tay and Hanoi concern. A list of available topographic/bathymetric maps in the Hanoi segment is summarized in **Table A.14.3.1**.

Reliable and usable maps are limited in terms of horizontal and vertical reference systems. In this context the data after 1975 are valuable to be taken into account. The older maps before 1958 lack in information of water level. They are useful to acquire rough images of the change in configuration and fluctuations of the river flows.

(2) Aero-photographs

Besides the above maps, there are three sets of vertical aero-photographs taken in 1952, 1977-79, and 1992-93. They are useful to confirm the water boundaries as well as conditions of land use at each time. The analysis of these photos is presented in **Appendix 14.3**.

(3) Newest maps

There are recently surveyed two topographic and bathymetric maps at the Hanoi segment:

- Survey by Pre-feasibility Study in December,1999 with a scale of 1/10,000, and

- Survey by this Study in January, 2002 with the same scale.

They have the same accuracy of survey, and are very suitable to compare each other to know the changes occurred during the two years.

14.4.2 Change in the configuration from 1901 to 1958 on maps

The maps presented in **Figure A.14.3.1** show change in the shape of riverbanks and sand bars from 1901 to 1958 (copied from the Pre-feasibility Report) for the section between the present Thang Long Bridge (constructed from 1974 to 1984) and Chuong Duong Bridge (built from 1983 to 1985). The Long Bien Bridge (built from 1889 to 1902), always appears on these maps.

Significant characteristics of the change are as follows:

- The sand bars between the mouth of Duong River and the Long Bien Bridge changed the shape almost every year,

- The present Trung Ha Bank was merged with the present Phu Xa High Bank in 1952 and 1958,

- The stream became single at the immediate upstream of the Long Bien Bridge in 1952. The rest of the period had the axial stream and a minor stream,

- The large sand bar at the present Tam Xa Flood Plain and Nhat Tan Bank was maintained from 1901 to 1952.

- It is noticed that the change in around 1952 was drastic, and

- Other changes.

In consideration of the above facts, it is considered in the Pre-Feasibility report that there are following three alternative river alignments of the main stream as shown in **Figure 14.4.1**.

- Alternative A: Similar to the present alignment, passing in front of Tam Xa High bank, the mouth of Duong River, and Hanoi Port,

- Alternative B: Modified Alternative A with much a larger meandering at Tam Xa , but almost same at downstream portion, and

- Alternative C: Smoother alignment passing Hanoi side all around the segment of this portion.

From the Inland Waterway navigation point of view and from the point of view of irrigation water intake and overall hydrology, the following **6 functionalities** should be maintained/preserved by all means:

- The culvert water intake for irrigation at the following sites :
  - Liem Mac (on the Red River right bank upstream Thang Long Bridge)
  - Xuan Quan (on the Red River left bank between Hanoi Port and Khuyen Luong Port) ;
- The water intake at the Duong River affluent on the Red River left bank (and the associated culverts) ;
- The stability of the soil around the piles of the Long Bien Bridge and the Chuong Duong Bridge;
- The nautical depth in front of the ports of :

- Hanoi ;
- Khuyen Luong.

Hence, it appears that it yet can be stated that only **Alternative A** is compliant to the above-mentioned hydraulic requirements and that this alternative will be further investigated in this study.

The basic sinuosity of the Red River is shown in **Figure 14.4.2.**

14.4.3 Changes confirmed on the aerial photographs

An example of comparison of the aero-photographs at the mouth of the Duong River is presented in **Figure 14.4.3**. The photos in the three eras, or 1952, 1977, and 1992 are compared by mapping and superimposing each other, along with the configuration of topographic map made in 2002. The result of the comparison is shown in **Figure A14.3.3**.

There are following morphological changes during the periods:

1) The shape of sand bars in the River changed drastically by era.

2) One of the most significant changes took place at Tam Sa sand bank. In 1952 the main stream run to the left of the bank, which made the bank an isle. In 1977 it is connected to the land and the main stream flew to the right of the bank.

3) The configuration of the entrance of the Duong River, or the area of the present Bac Cau 1 and 2 communes, has been maintained almost same throughout the times, except the tip of the commune where small erosion has been occurring. This can be judged to be owing to the stiff foundation consisting of hardened silty sand layers. It is noted that the other side of the Duong River is protected by the river dike,

4) Tu Lien and Trung Ha sand bars changed their shapes era by era,

5) Thach Cau bank in front of Hanoi Port expanded and shrunken,

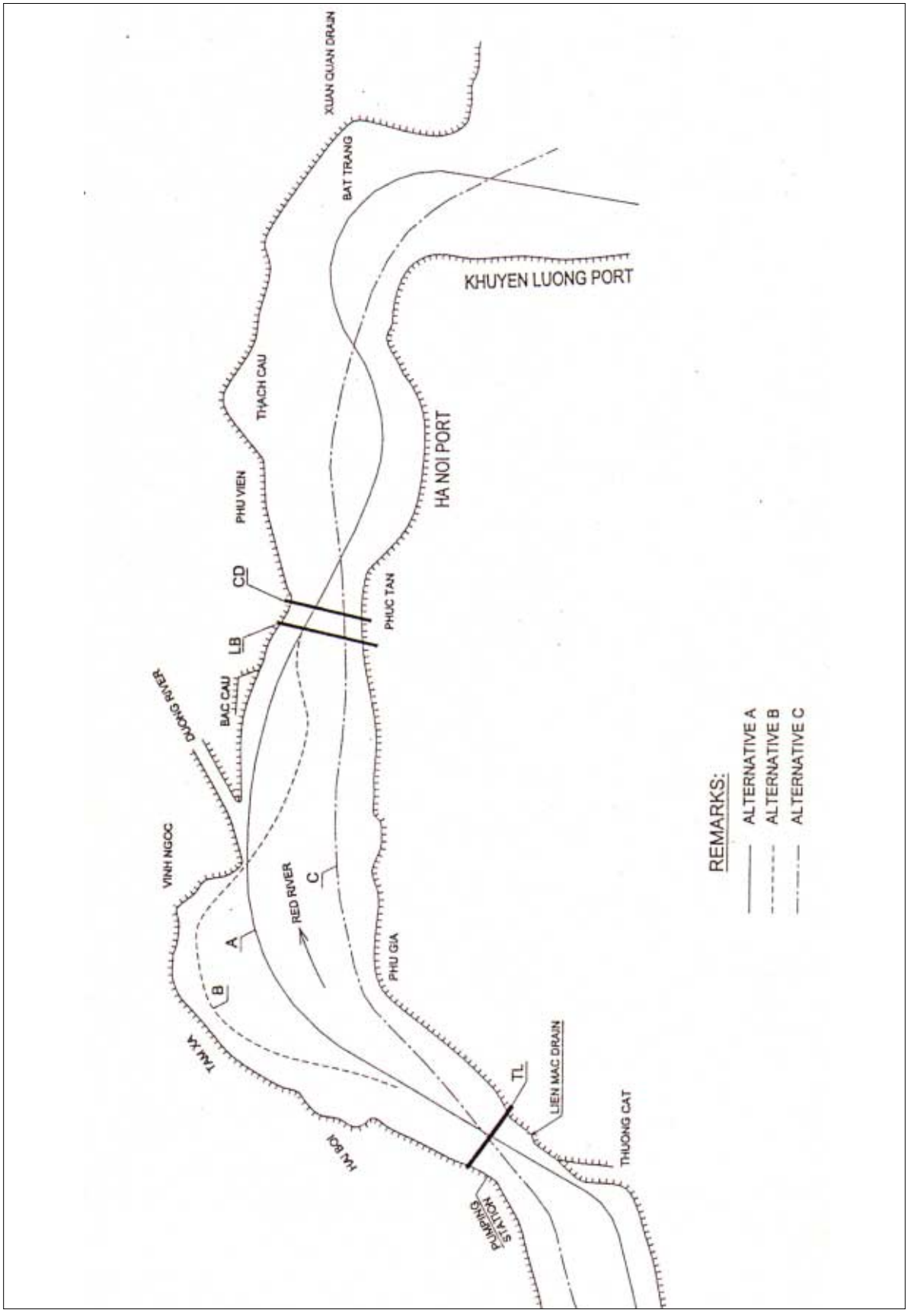
6) Thanh Tri bank forwarded from1952 to1977,

7) The meandering at the corner of down stream Khuyen Luong Port has developed between 1952 to 2002, and

8) Others.

It also can be expected that, after a drastic change in around 1952, the situation of the main stream tracks changed again in between 1979 and 1992.

The quantitative areas of sand bars and banks at each era are summarized in **Table A14.3.2**.



Source) Red River Pre-feasibility Study Report, TEDI

Figure 14.4.1 Three River Alignment Alternatives in Hanoi

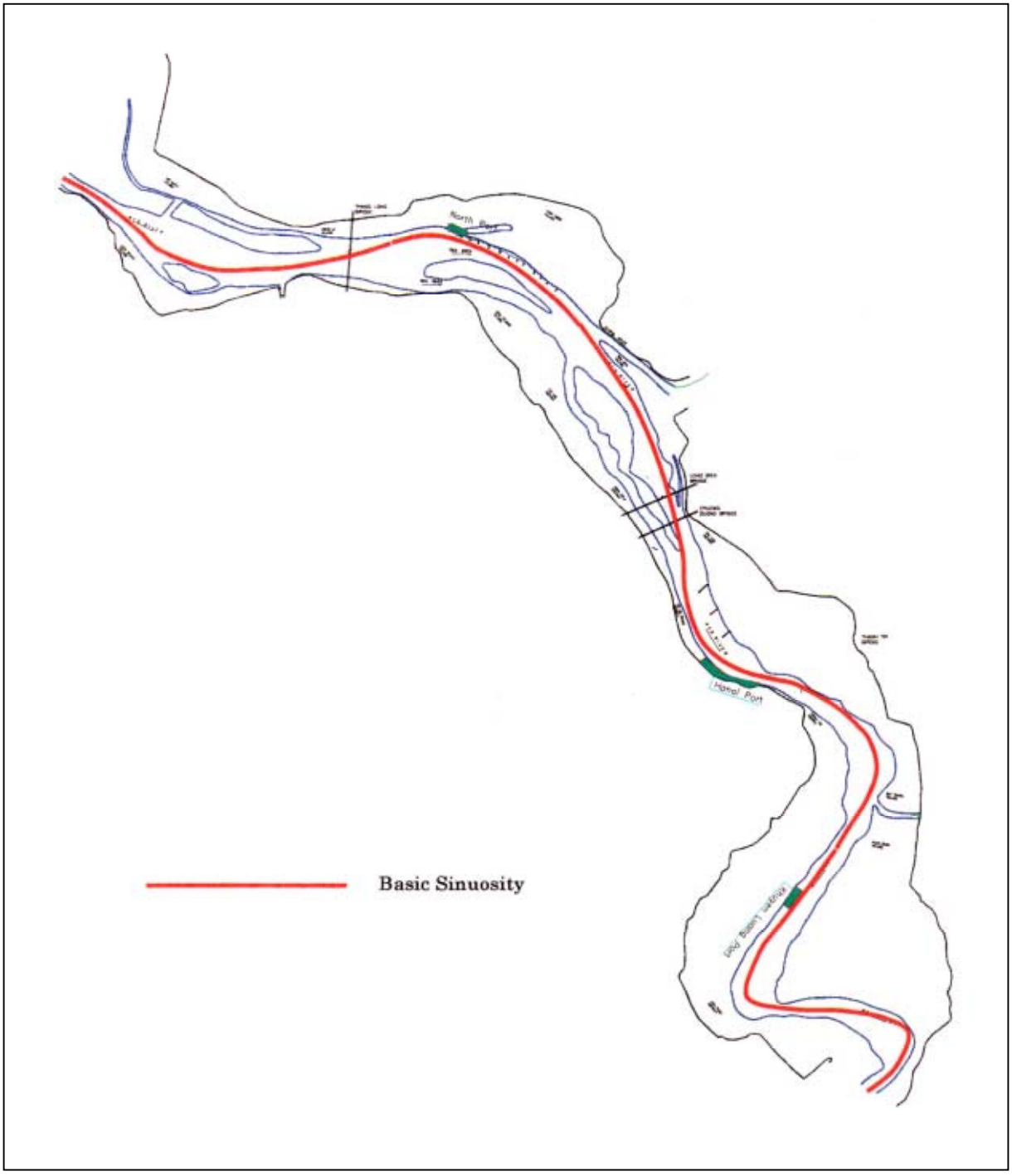


Figure 14.4.2 Basic Sinuosity of the Red River

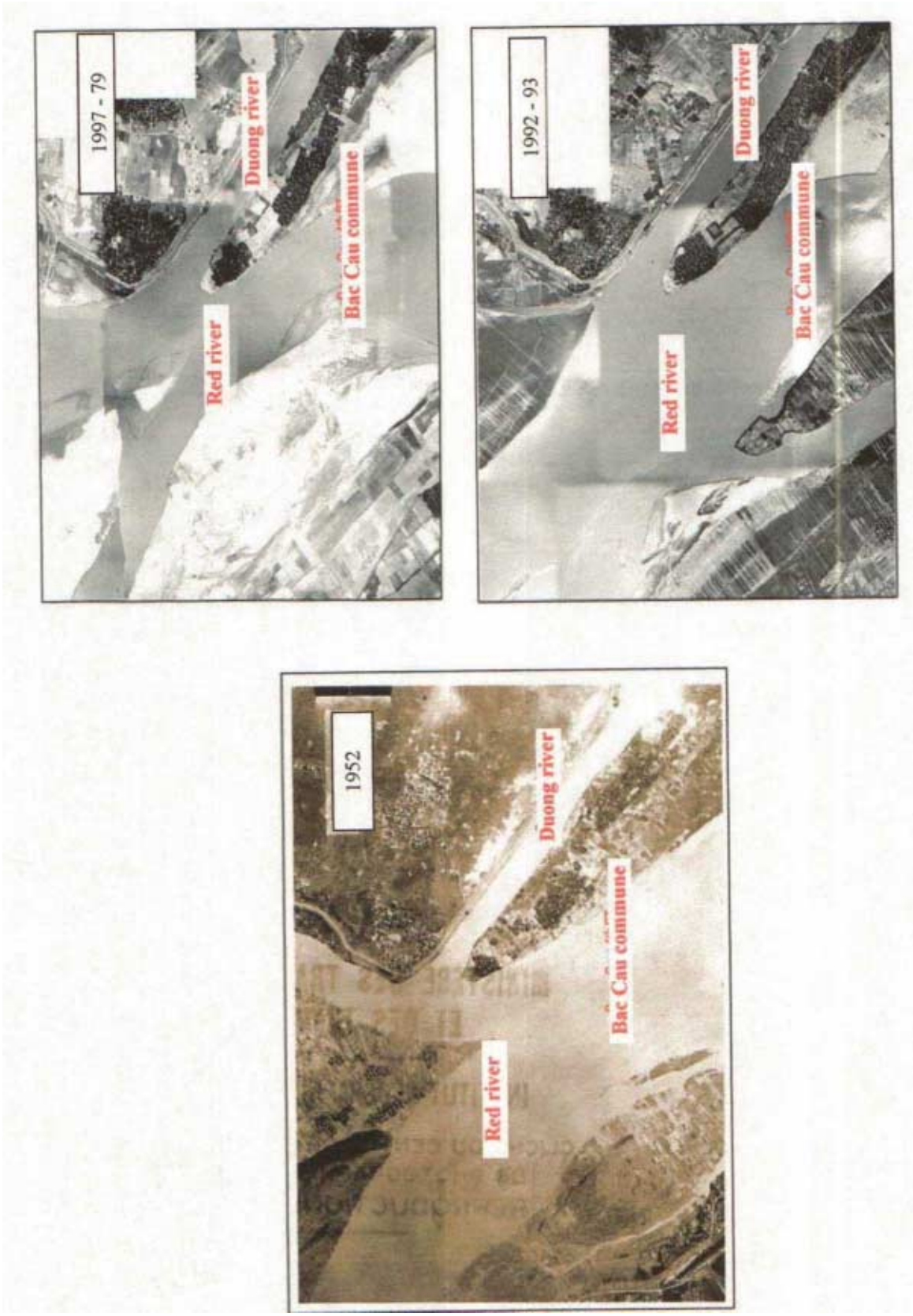


Figure 14.4.3 Comparison of Aerial Photographs

Source) Service Center of Land Administration

14.4.4 Changes occurred in the past two years

(1) Changes in plane alignment

The contour lines of the two bathymetric maps in December, 1999 and January 2002 are superimposed, and shown in **Figure 14.4.4**. The major changes occurred are summarized, from the upstream to the downstream, as follows:

- The Dong Lai Bank is widened significantly,
- The sand bars in front of Thuong Cat suffered erosion on the main stream side,
- The Phu Thuong Bank moved northward, or the main stream in the north had accumulation and bank slope on the secondary stream in the south had erosion,
- Cross section in front of the Duong River does not have significant change. There is a large movement of Talweg toward the north east, or to Tam Xaq side,
- The Tu Lien Bank and the Trung Ha Bank has been connected. The width of the bank became narrower, and the width of the connecting bank decreased significantly,
- The tail of the Trung Ha Bank has prolonged considerably,
- The cross section at Hanoi Port has not changed significantly except advancement of the Thach Cau Bank,
- The downstream portion from the Thanh Tri Bridge site does not changed much, or proved relatively stable profile under the past and the present upstream conditions, and
- At the narrow corner of Van Phuc, however, considerable accumulation occurred.

The most vulnerable portion of the segment, i.e. the central Hanoi portion between the Phu Thuong Bank to the Chuong Duong Bridge, is shown with an enlarged map in **Figure 14.4.5**.

(2) Changes in cross sections

In total 12 cross sections in December, 1999 and January 2002 are prepared to confirm the above changes at places shown in **Figure 14.4.6**. The comparisons are shown in **Figure 14.4.7 (1)** to **(5)**. The characteristics described above can be verified by these cross sections. The following are noted :

- The Locations of Hanoi Port and Khuyen Luong Port are among the most

stable in the segment for the past two years, and

- The main stream under the Thang Long Bridge, which is a nodal point of the flow, had an accumulation of about 1m under the conditions in the past two years.

During the flood season in August 2002, the latest cross-sectional survey was carried out at 16 sections. Detailed comparison of the cross sections is made between those in the dry season (January 2002) and the flood season (August 2002). The result of comparison is summarized at 12 sections and shown in **Figure A14.3.3**.

- At Vong La – Chem section (Section No.1), sedimentation dominated on the right side of the river, which amount to about 2m on average.
- At Thang Long Bridge(Section No.2), erosion occurred throughout the cross section. Increase in water depth is about 2m at the deepest point.
- At Hai Boi bank – Nhat Tan Sand Bar (Section No. 3), accretion occurred in the main channel and erosion occurred in the secondary channel. As the result, the depth became deeper in the secondary channel, or SDL +0.5m, than in the main channel, or about SDL +3m.
- In front of Tam Xa bank (Section Nos. 4 and 5), the deepest portion in the dry season in the main channel is further deepened by about 1m to 3m. In the secondary channel considerable erosion occurred at the slope of Nhat Tan Sand Bar without change in water depth.
- At the mouth of the Duong River (Section No. 6), there is not significant change except at the shallow point at the center where erosion made the riverbed flattened. At Section No. 7, there is not significant change.
- At Bac Cau – Tu Lien Sand Bar (Section Nos. 8 and 9), erosion of the left bank and accumulation along the left slope of the sand bar are significant. Deepening of the secondary channel, or Lach Quit, is significant.
- In between Long Bien and Chuong Duong Bridges (Section No.10), the main channel is eroded throughout the channel, including the left slope of Trung Ha Sand Bar. There is not significant change at the secondary channel.
- At Thach Cau – Hoan Kiem section (Section No.11), erosion of the right bank occurred and the cross section shifted to the right.
- In front of Hanoi Port (Section No.12), the deepest depth is LSD –10m in the flood season, or increased by about 2m from the dry season.

In October 2002 there observed a sign that the main channel beside Nhat Tan Sand Bar has shifted from left to right, which is very important for planning of channel alignment.

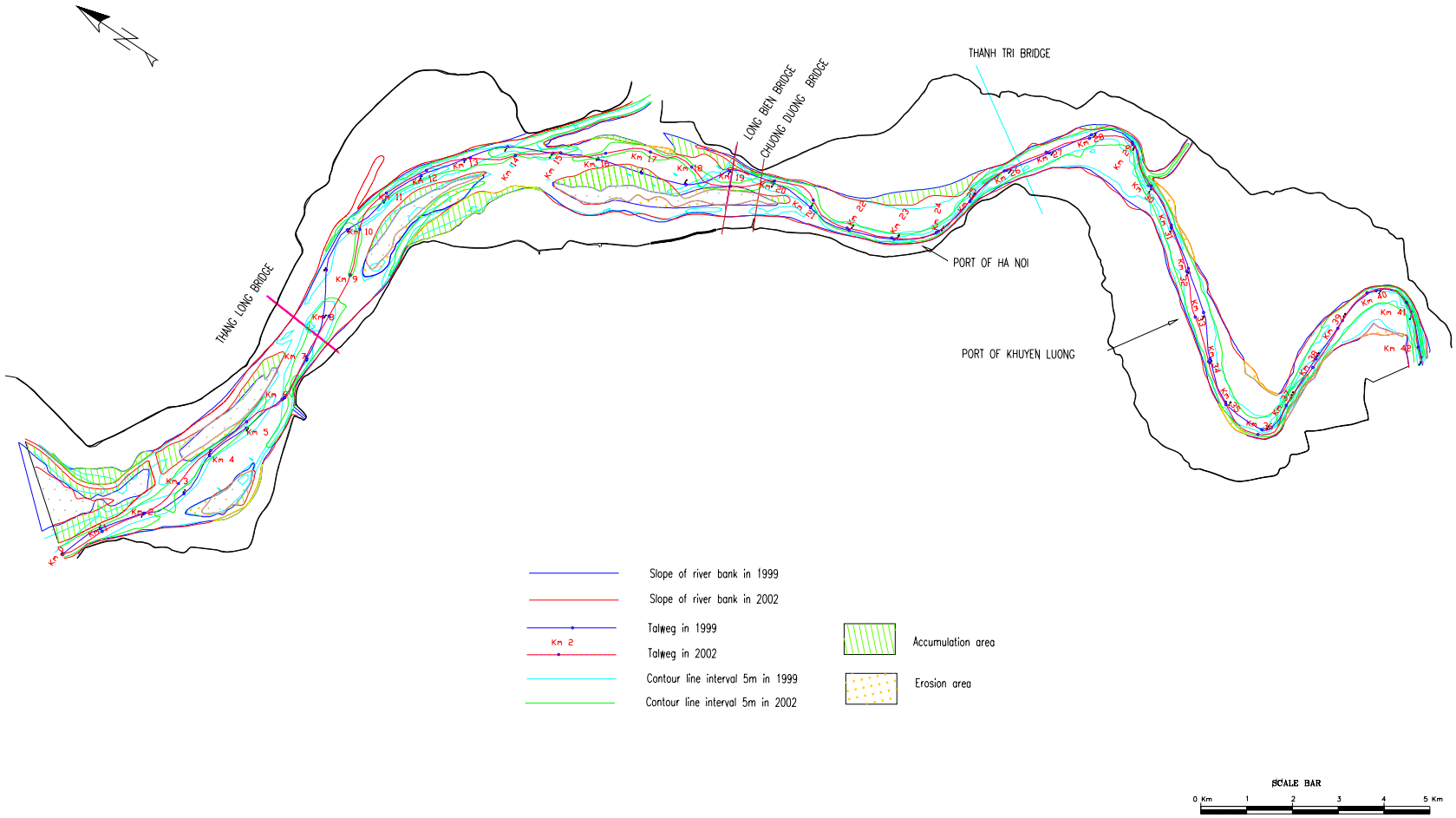


Figure 14.4.4 Comparison of River Bed Contour Lines in 1999 and 2002 (5m interval)

Source) JICA Study Team

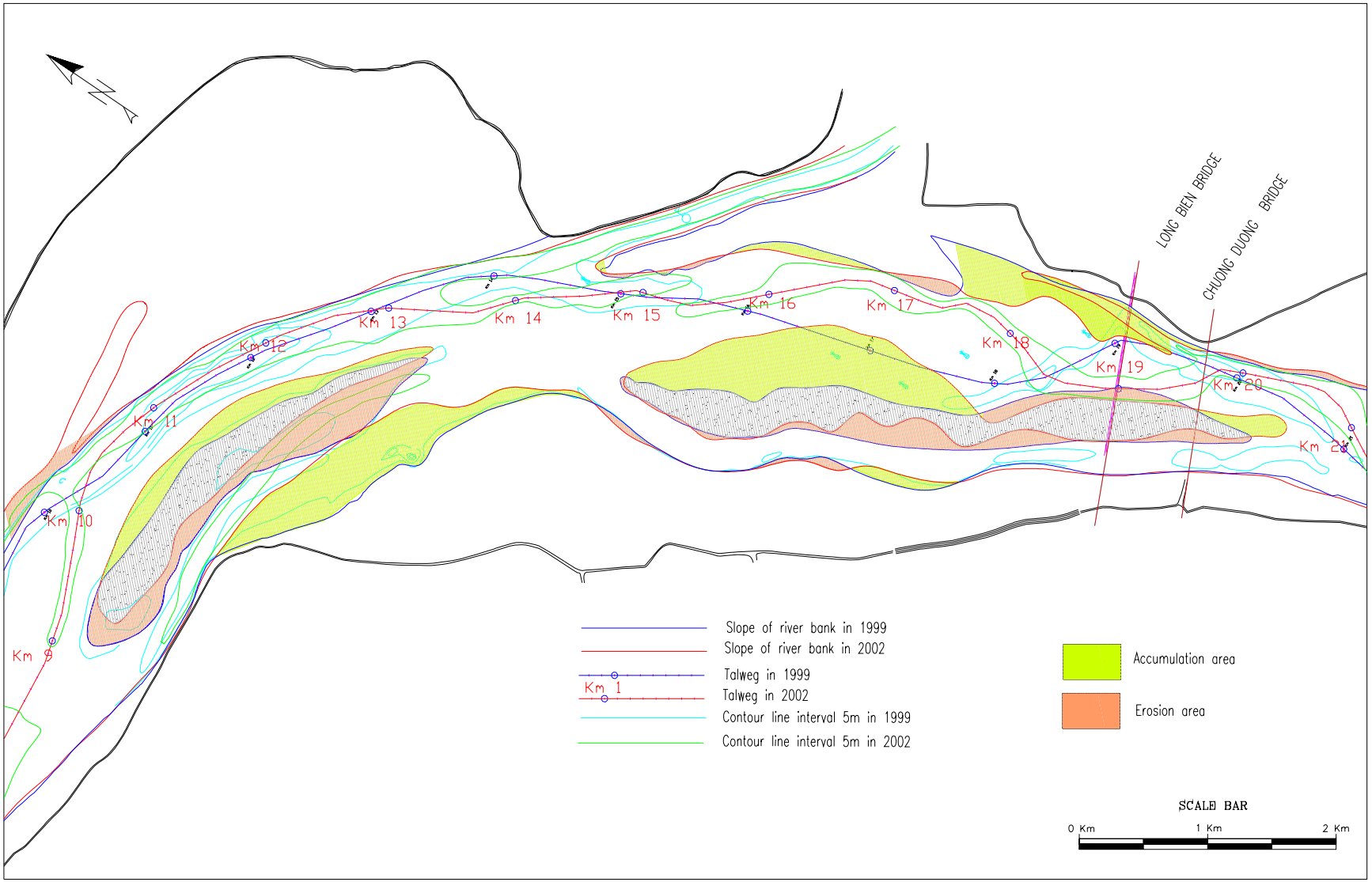


Figure 14.4.5 Changes in Riverbed at the Central Hanoi Portion from 1999 to 2002

Source) JICA Study Team

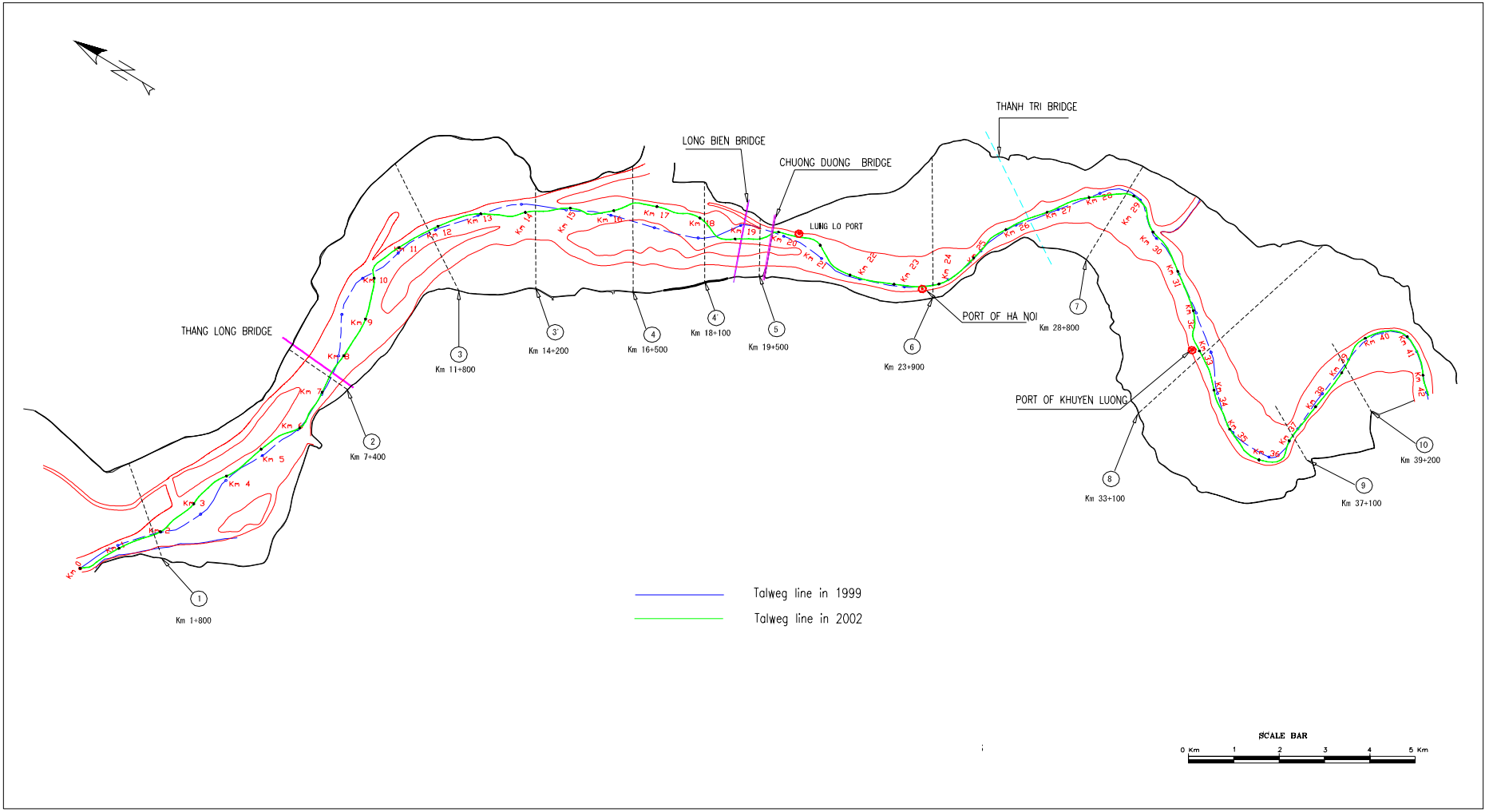


Figure 14.4.6 Locations of Cross Sectional Analysis

Source) JICA Study Team

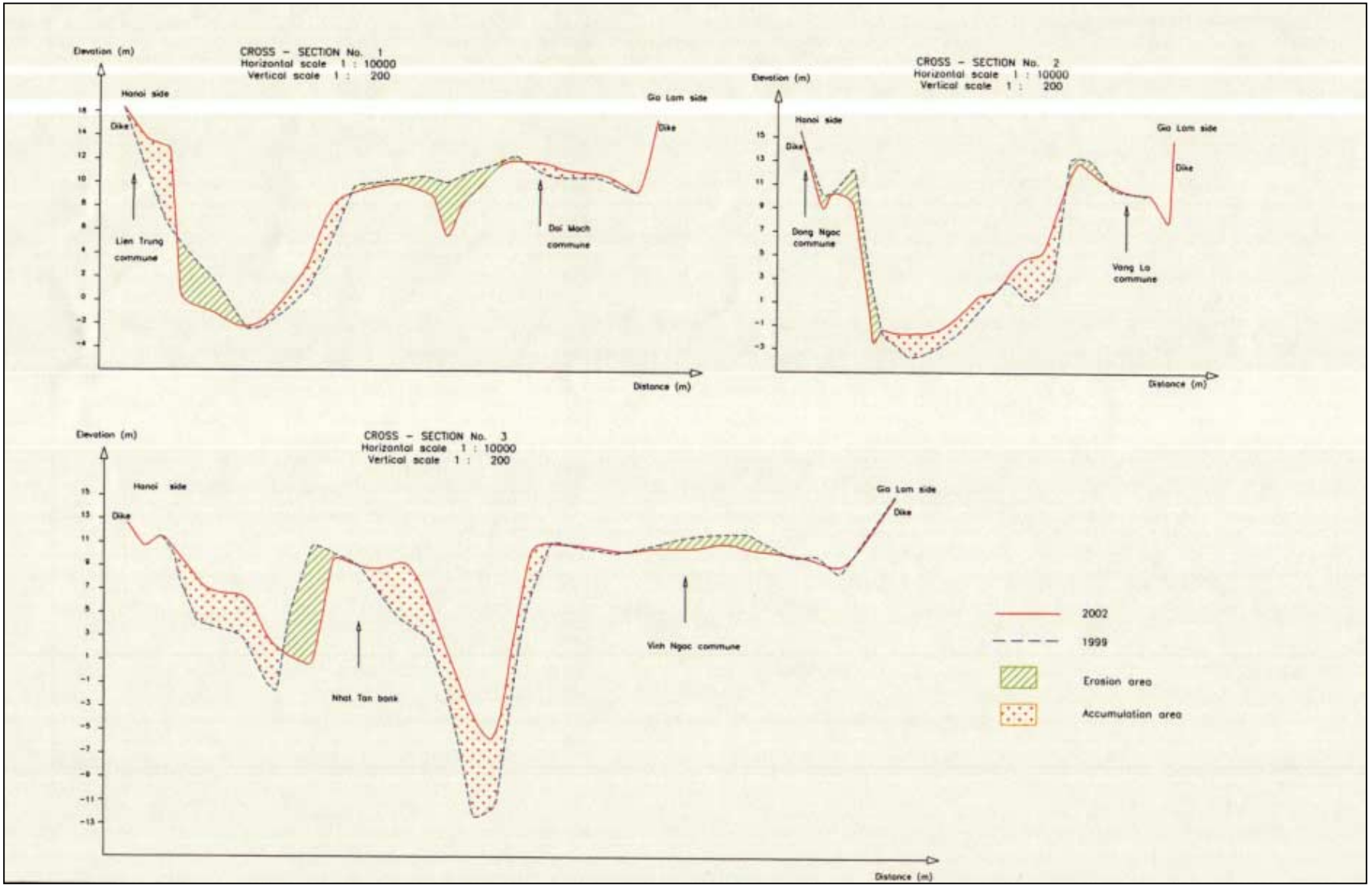


Figure 14.4.7 (1) Cross Sectional Comparison of Riverbed between 1999 and 2002

Source) JICA Study Team

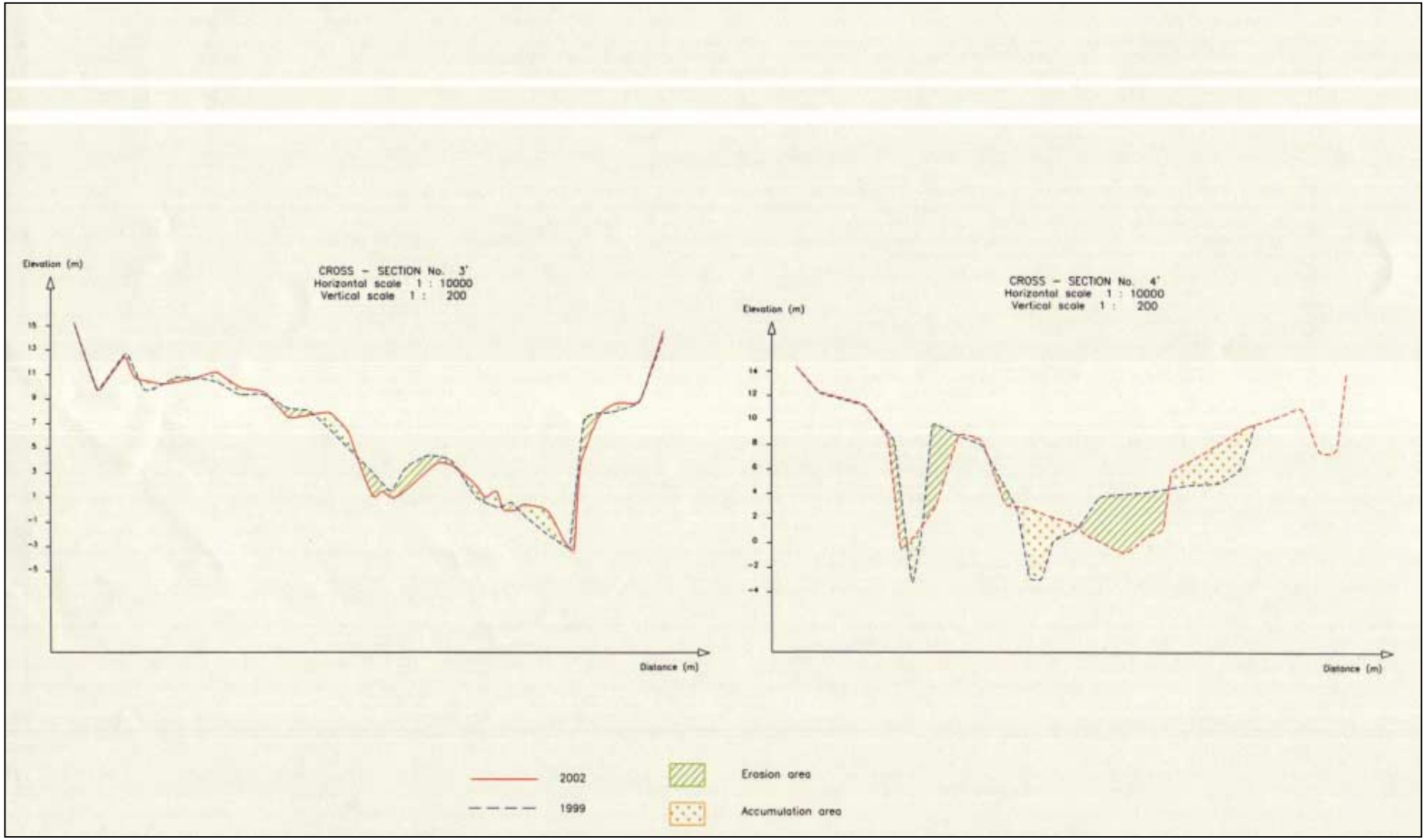


Figure 14.4.7 (2) Cross Sectional Comparison of Riverbed between 1999 and 2002

Source) JICA Study Team

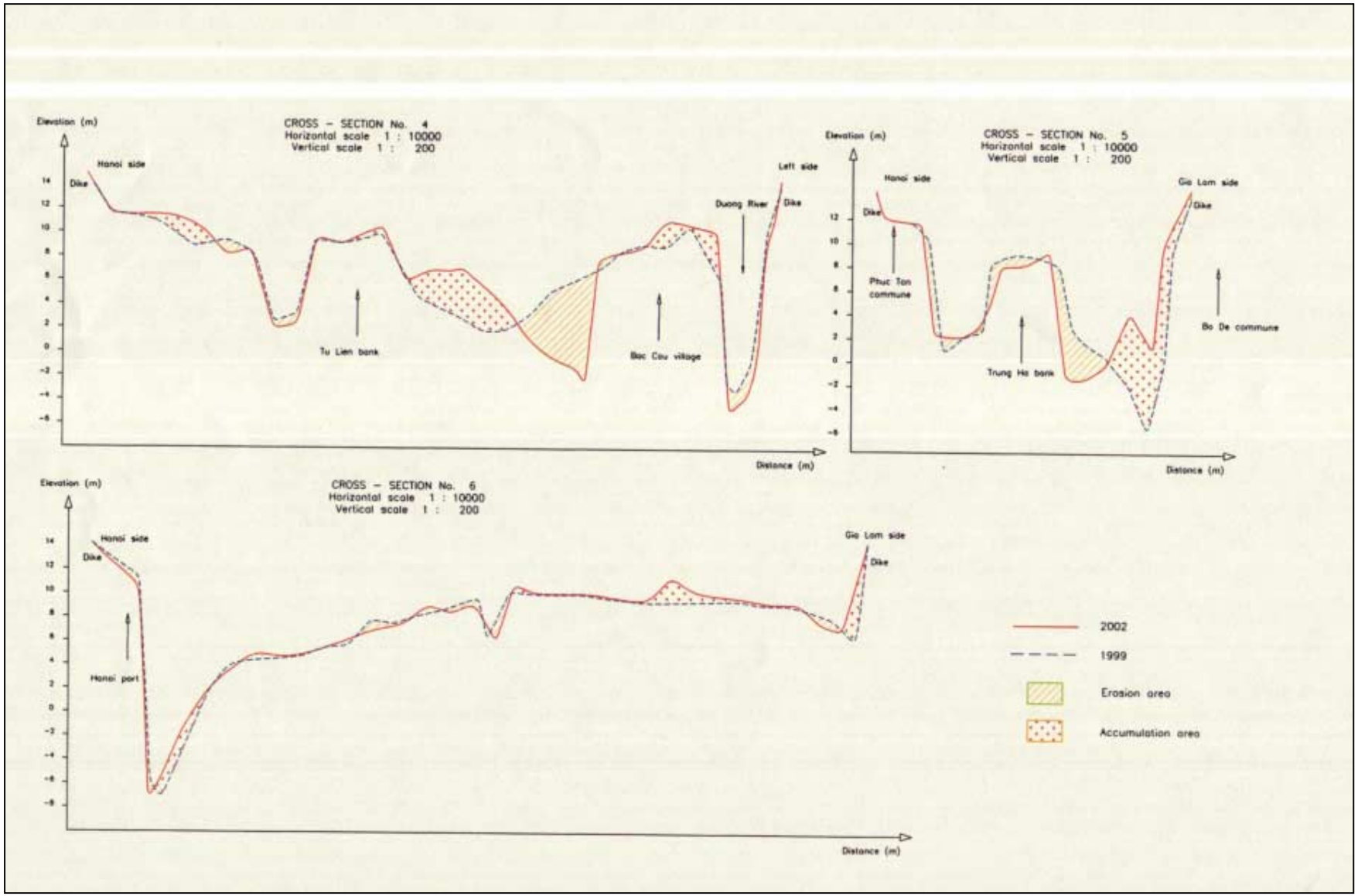


Figure 14.4.7 (3) Cross Sectional Comparison of Riverbed between 1999 and 2002

Source) JICA Study Team

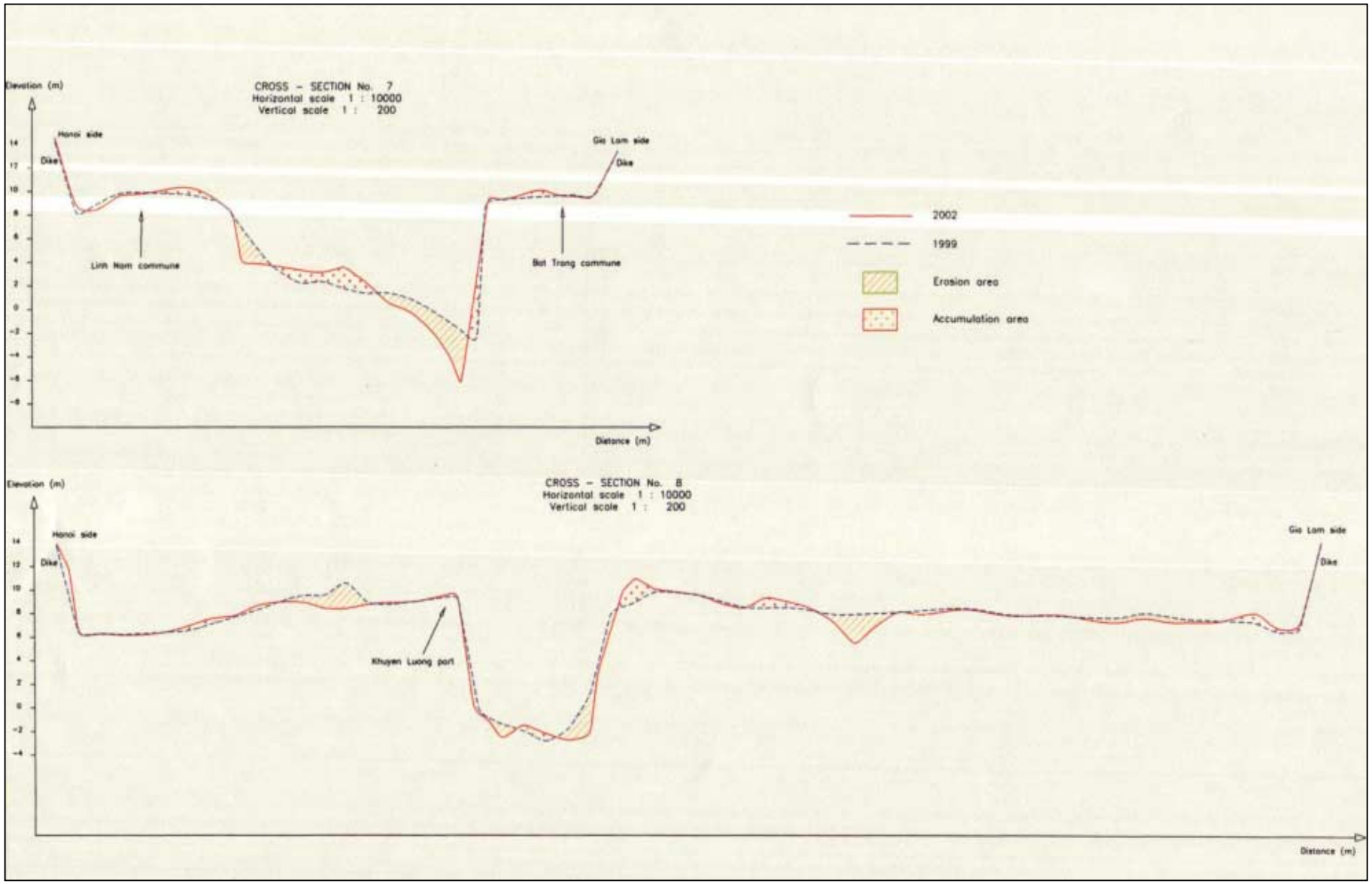


Figure 14.4.7 (4) Cross Sectional Comparison of Riverbed between 1999 and 2002

Source) JICA Study Team

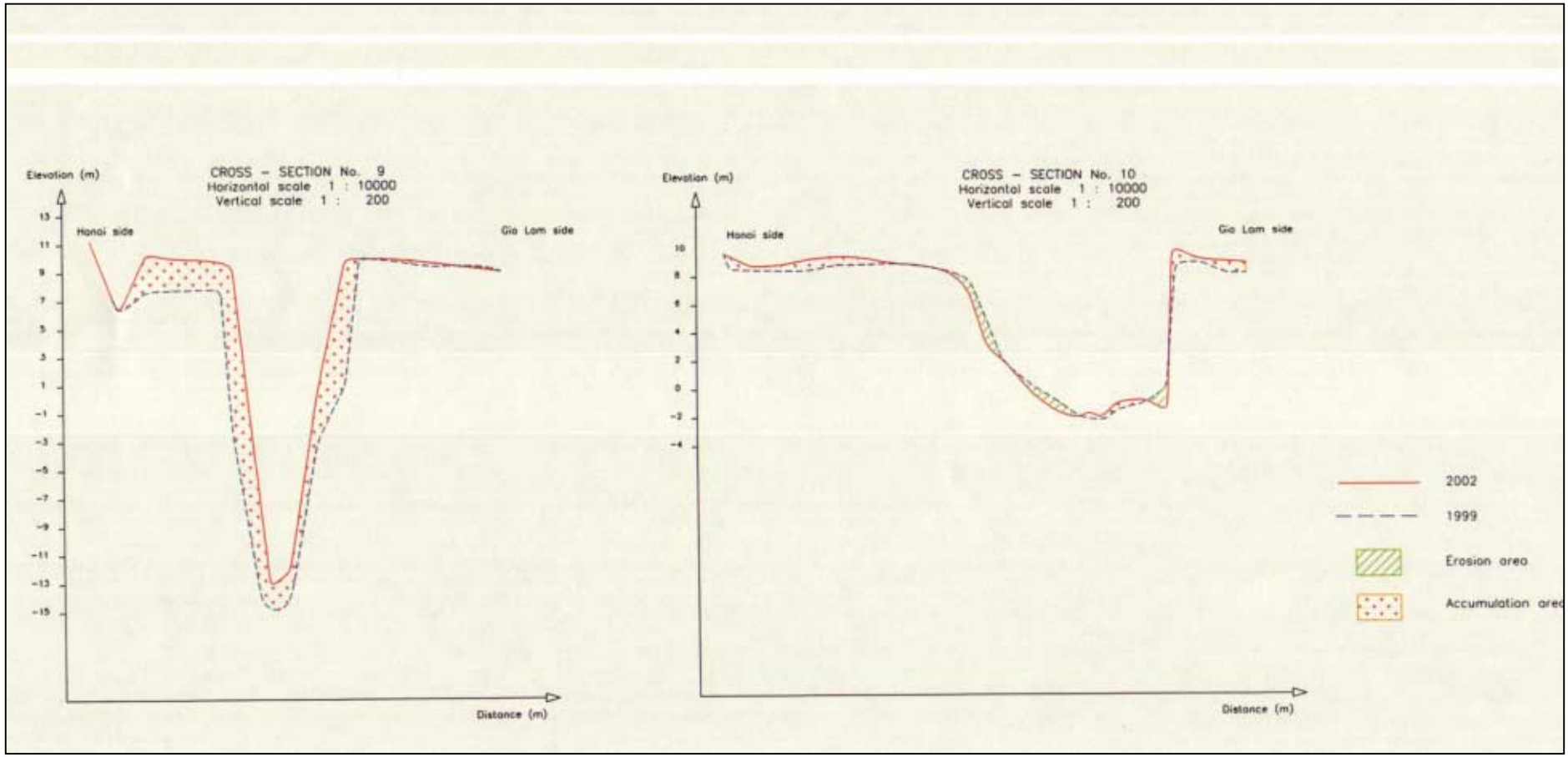


Figure 14.4.7 (5) Cross Sectional Comparison of Riverbed between 1999 and 2002

Source) JICA Study Team

14.4.5 Hydraulic section

As mentioned already earlier (see figure 14.4.6), 12 cross-sections have been surveyed in January 2002 in the studied Hanoi section of the Red River. For some of these respective cross sections, bathymetrical data from earlier surveys (1987, 1995, 1996 and 1999) are also available. A direct comparison of the respective cross-sections shows the evolution in time and along the river reach, indicating the morphological dynamics of the meandering-braiding river. As a result, erosion and sedimentation areas over the last 15 years can be identified. Still, it is very difficult to draw some general conclusions on the river morphology trends.

Nevertheless, as illustrated in Figure 14.4.8 the river cross-sections downstream Hanoi port (section 6) and the sections upstream Thang Long Bridge (section 2) are relatively stable. On the contrary, the river reach in between the Thanh Long Bridge and the (planned) Thanh Tri Bridge seems to be very dynamic, developing from a one-channel meandering system towards a complex braided river (Figure 14.4.9). A clearly significant shift of the main and secondary channel is noticed, with a clear formation of more secondary, braided channels and sand banks.

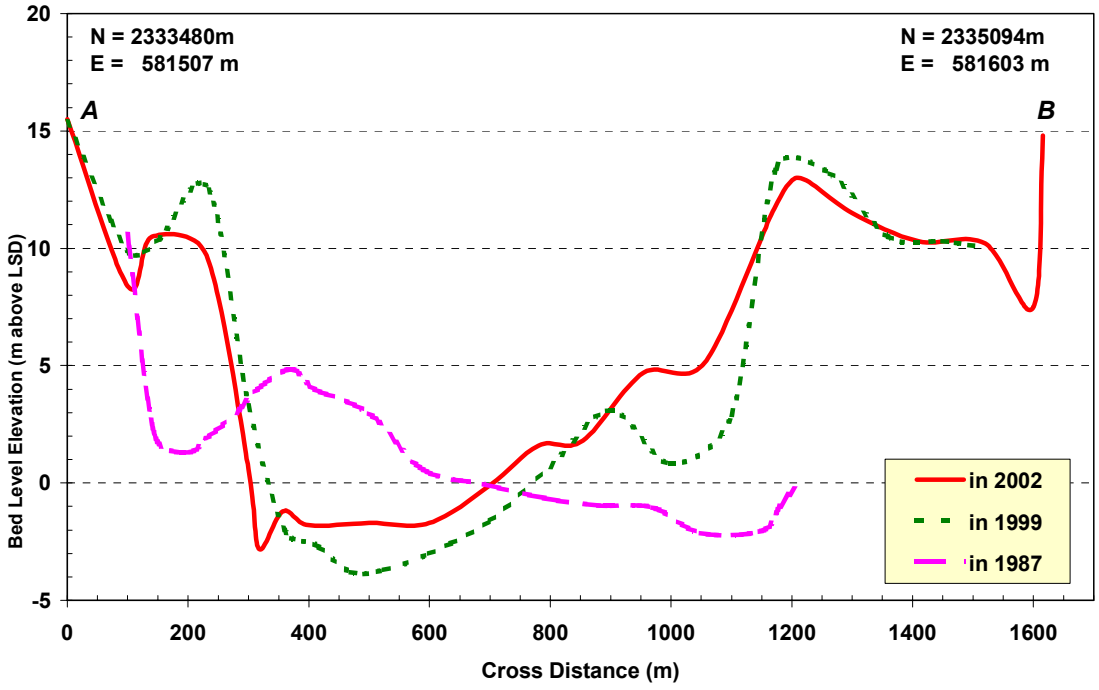


Figure 14.4.8 Evolution of (Stable)Cross-Section 2 Thang Long Bridge