MYANMA PORT AUTHORITY (MPA)
THE REPUBLIC OF THE UNION OF MYANMAR

DATA COLLECTION SURVEY REPORT FOR IMPROVEMENT OF NAVIGATION CHANNEL OF YANGON PORT IN THE REPUBLIC OF THE UNION OF MYANMAR

FINAL REPORT

SEPARATE VOLUME

CURRENT SITUATION OF RIVERBANK EROSION OF YANGON RIVER

MARCH 2016

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
ASIA AIR SURVEY CO., LTD.

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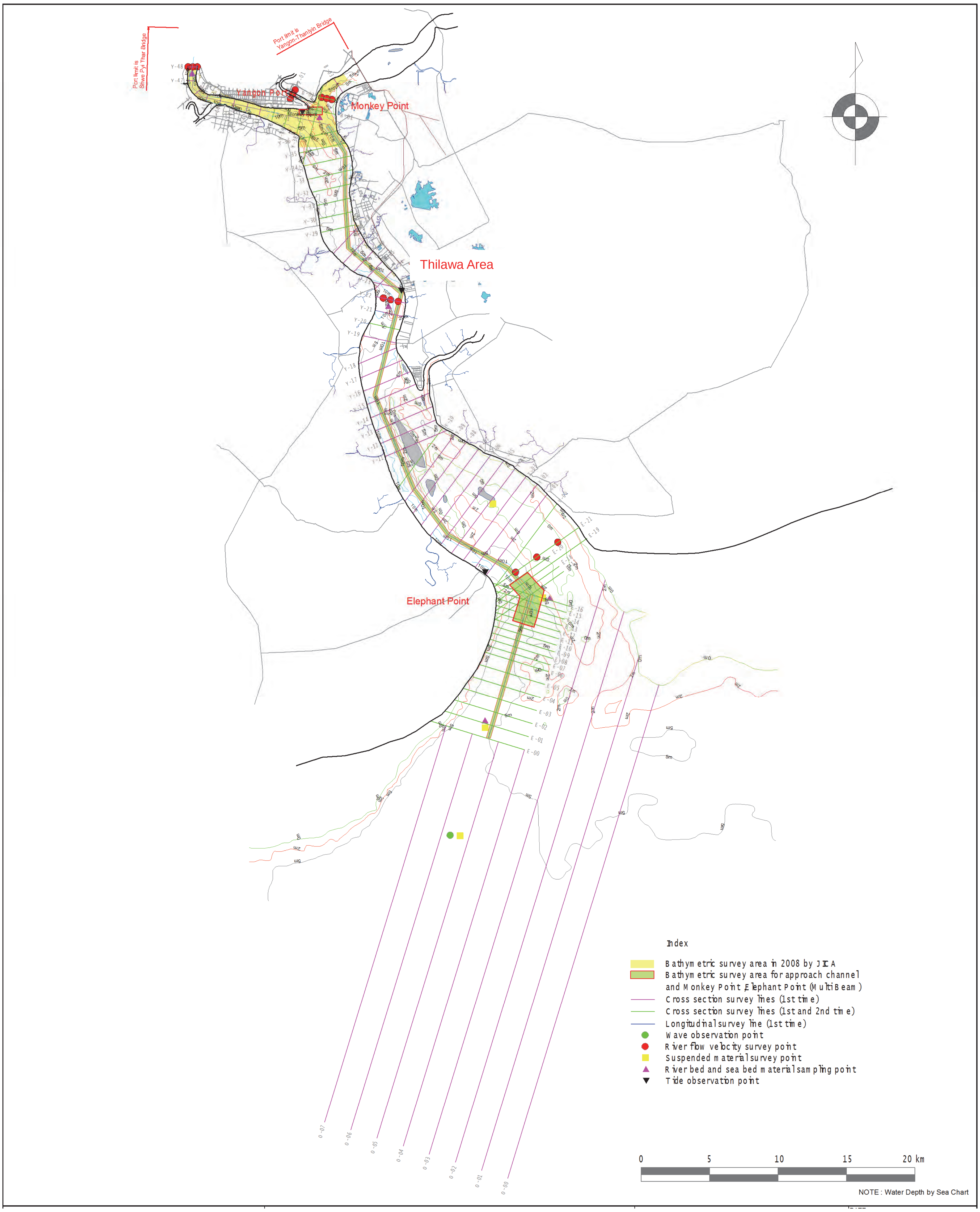
Yangon River


Port limit is Shwe Pyi Thar Bridge
Port limit is Yangon-Thanlyin Bridge
Yangon Port
Monkey Point
Thilawa Area
Elephant Point
Index
Bathymetric survey area in 2008 by JICA
Bathymetric survey area for approach channel and Monkey Point, Elephant Point (MultiBeam)
Cross section survey lines (1st time)
Cross section survey lines (1st and 2nd time)
Longitudinal survey line (1st time)
Wave observation point
River flow velocity survey point
Suspended material survey point
River bed and sea bed material sampling point
Tide observation point
0
5
10
15
20 km
NOTE : Water Depth by Sea Chart

Study Area

CONTENTS

Photo
Study Area

Chapter 1: General 1
1-1 Background of the Study and the Target of this Examination 1
Chapter 2: Basic Policy of the Following Examinations 2
2-1 Necessary Materials for the Examination of the Secular Change of Yangon River 2
Chapter 3: Site Investigations 3
3-1 Cliff Type 3
3-2 Right Bank of Yangon River from Thilawa Area to the River Mouth 4
3-3 Natural Gentle Slope Type 8
Chapter 4: Secular Change of the Riverbank 10
4-1 Steps of Image Processing 10
4-2 Secular Change of Yangon River Bank 11
4-3 Riparian Forest Trend 14
4-4 Decreasing of Natural Forest in the Upstream of the Yangon River 16
4-5 Sand Mining Activities 17
Chapter 5: Collection of Related Information 19
5-1 Rainfall 19
5-2 Old Marine Chart of 1904 and Map of 1930 20
5-3 Hearing Interview with the Village near Elephant Point 27
5-4 Current Situation of Waves Caused by Large Cargo Ships 28
5-5 Protection of the Riverbank 29
Chapter 6: Volume of Discharged Sediment 31
6-1 Estimation of Cliff Height 31
6-2 A Brief Estimation of Annual Discharged Sediment Volume Caused by Erosion 32
Chapter 7: Results of the Examinations 35
Chapter 8: Recommendations 36
Attachment 1: Samples of Satellite Image Analysis 37
Attachment 2: Satellite Image Analysis of Each Monitoring Point 41

Tables and Figures

Tables

Table 4-1: Measurement Points to Estimate the Secular Change of Yangon Riverbank............. 11
Table 4-2: Date / Month / Year of Images in the Points 11
Table 4-3: Coverage Ratio of Riparian Forest on the Right Bank 14
Table 4-4: Coverage Ratio of Riparian Forest on the Left Bank.. 14
Table 6-1: Estimation of Cliff Heights 32
Table 6-2: Estimation of Annual Diffluence Soil Volume from Right Riverbank Erosion 33
Table 6-3: Estimation of Annual Diffluence Soil Volume from Left Riverbank Erosion 34

Attachment Table 2-1: The Calculation Results of the Secular Change at Point A 41
Attachment Table 2-2: The Calculation Results of the Secular Change at Point B 42
Attachment Table 2-3: The Calculation Results of the Secular Change at Point C 44
Attachment Table 2-4: The Calculation Results of the Secular Change at Point D 46
Attachment Table 2-5: The Calculation Results of the Secular Change at Point E..................... 47
Attachment Table 2-6: The Calculation Results of the Secular Change at Point F..................... 49
Attachment Table 2-7: The Calculation Results of the Secular Change at Point G 51
Attachment Table 2-8: The Calculation Results of the Secular Change at Point H 52
Attachment Table 2-9: The Calculation Results of the Secular Change at Point I...................... 54
Attachment Table 2-10: The Calculation Results of the Secular Change at Point J.................... 55
Attachment Table 2-11: The Calculation Results of the Secular Change on the Middle bank ... 56

Figures

Figure 3-1: A Typical Image of Cliff Type Riverbank without Step 3
Figure 3-2: A Typical Image of Cliff Type Riverbank with Multiple Steps 4
Figure 3-3: A Part of the Right Bank at Upper Elephant Point (Vertical Cliff Without Step)....... 4
Figure 3-4: A Part of the Right Bank near Thuang Gon Village (Sloped Cliff Without Steps)..... 5
Figure 3-5: A Part of the Right Bank near Elephant Point (Cliff With One Step)......................... 5
Figure 3-6: A Part of the Right Bank near Elephant Point (With 2 Steps) 6
Figure 3-7: Western Side of the River Mouth (With 2 Steps) 6
Figure 3-8: Part of Right Bank at Lower Elephant Point (With 4 Steps)...................................... 7
Figure 3-9: A Part of the Right Bank in High Tide (A distant view)... 7
Figure 3-10: Part of the Seaside Line near the River Mouth on the Right Bank Side 8
Figure 3-11: A Tributary Inflow at the Right Bank 9
Figure 3-12: A Stable Gentle Slope on the Downstream Side of the Thilawa Area...................... 9

Figure 4-1: The Results of Satellite Image Analysis on the Secular Change of the Yangon River Bank 13
Figure 4-2: The Distribution Map of Riparian Forest in 2003 and 2014 15
Figure 4-3: Forest Density in 2003 16
Figure 4-4: Forest Density in 2010 (Deep Forest is rapidly decreasing) 17
Figure 4-5: The Work Vessels Mining the Construction Sand (April, 2015) 18
Figure 5-1: Rainfall at Nyaungshwe 19
Figure 5-2: Rainfall at Kaba Aye 19
Figure 5-3: Rainfall in July at Kaba Aye 20
Figure 5-4: Collected Old Marine Chart and Map 21
Figure 5-5: Brief Comparison of Riverbank Lines among 1904 Marine Chart, 1930 Map and 2015 Satellite Image 22
Figure 5-6: Brief River Depth Comparison between 1904 and 2015 25
Figure 5-7: A Brief Comparison of River Section near the River Mouth between 1904 and 2015 26
Figure 5-8: Influence of Ship Waves Observed on the Right Bank near the River Mouth 28
Figure 5-9: Sea Wall Constructed by the Municipal Government 29
Figure 5-10: A Sample of the Gabion type Revetment in Japan 30
Figure 6-1: A Sample of Height Estimation by AutoCAD (Reference No. 4.2.1) 31

Attachment Figure 1-1: A Satellite Image of the Right Bank near the River Mouth 37
Attachment Figure 1-2: A Satellite Image of the Right Bank in Lower Tide 38
Attachment Figure 1-3: A Satellite image of the Right Bank in Higher Tide 38
Attachment Figure 1-4: Satellite image Showing the Two Steps on the Right Bank 39
Attachment Figure 1-5: Satellite image of the Right Bank 39
Attachment Figure 2-1: Secular Change at Point A (Section 2~3) 41
Attachment Figure 2-2: Secular Change at Point B (Section 1~3) 42
Attachment Figure 2-3: Secular Change at Point C (Section 4~12) 43
Attachment Figure 2-4: Secular Change at Point D (Section 1~6) 45
Attachment Figure 2-5: Secular Change at Point E（Section 3~14） 47
Attachment Figure 2-6: Secular Change at Point F (Section 1~9) 48
Attachment Figure 2-7: Secular Change at Point G (Section 12~15) 50
Attachment Figure 2-8: Secular Change at Point H (Section 1~6) 52
Attachment Figure 2-9: Secular Change at Point I (Section1~9) 53
Attachment Figure 2-10: Secular Change at Point J (Section 9~12) 54
Attachment Figure 2-11: Secular Change at the Middle Bank 56

Abbreviations

A	AWPT	Asia World Port Terminal (Yangon)
	AIPT1	Ahlone International Port Terminal (Yangon)
B	BSW	Bo Aung Gyaw Street Wharf (Yangon)
C	CAD	Computer Aided Design
	CDL	Chart Datum Level
D	dm	diameter
	D60R	representative grain size
	Dwell time	The time cargo remains in a terminal's in-transit storage area
F	FY	Fiscal Year
G	GDP	Gross Domestic Product
	GPS	Global Positioning System
	GRT	Gross Register Tonnage
H	HOB	Hteedan Oil Terminal (Yangon)
	HPT	Hteedan Port Terminal (Yangon)
I	ICD	Inland Container Depot
	IMF	International Monetary Fund
K	knot	1 knot = 0.514444 m/s
L	LOA	Length overall (of the ship)
M	MIP	Myanmar International Port (Yangon)
	MIPL	Myanmar Integrated Port Limited (Thilawa)
	MITT	Myanmar International Terminal Thilawa (Thilawa)
	MSL	Mean Sea Level
N	NLD	National League for Democracy
S	SPW	Sule Pagoda Wharf (Yangon)
T	TEU	Twenty-foot Equivalent Unit
	TSHD	Trailing Suction Hopper Dredger
U	UN	United Nations Development Programme
	UTM	Universal Transverse Mercator
	USDP	Union Solidarity and Development Party
V	VTS	Vessel Traffic Service
W	WGS-84	World Geodetic System 1984

Chapter 1: General

1-1 Background of the Study and the Target of this Examination

Under the rapid economic growth in the Republic of the Union of Myanmar (hereafter Myanmar), the importance of the Yangon City Ports is increasing. The Yangon City Ports includes the Yangon Port and the Thilawa Area Port, both of which are river ports along the Yangon River Channel. Yangon Port is located 32 km upstream of the Yangon River mouth and it is adjacent to central Yangon city. Thilawa Area Port is 16 km upstream of the Yangon River mouth and it is developing as a new national logistics hub. Although the land side of the port development in Thilawa Area is ongoing under the instruction of the Myanma Port Authority (hereafter MPA), for the Yangon River Channel, which is the other key factor for port development, even the basic information has not been collected properly. Therefore, it was decided that “The Data Collection Survey for Improvement of Navigation Channel of Yangon Port” (hereafter the Study) would be conducted.

The main contents of the Study include a survey, and observation and monitoring at Yangon River and offshore. Based on these results, collected data should be processed for further analyses/studies in the next stage. To conclude the Study, technical examinations based on the results are requested. The main contents of the Study are:

1) Hydrographic survey commenced by Japanese sub-consultant
- Multi-beam surveys at Monkey and Elephant Points (2 times pre / post rainy season)
- Sectional surveys of Yangon River (2 times in pre / post rainy season)
- Longitudinal river channel surveys (2 times in pre / post rainy season)
- Offshore survey

2) Observation / monitoring commenced by Japanese sub-consultant
- River flow observation
- Bottom sampling of riverbed / seabed and related laboratory tests
- Suspended-solid survey and related laboratory tests
- Offshore wave observation at about 20 km offshore from river mouth

3) Collection of related information / data of Yangon River

4) Examinations based on the results of survey, observation and monitoring.

The above-mentioned contents were confirmed by MPA and JICA in the Inception Meeting held in March 2015. After the Inception Meeting, JICA Study team visited Elephant Point in April 2015 and found that the tide station at Elephant Point had sunk a long time ago due to riverbank erosion. After further investigations, it was found that the riverbank erosion was happening on a large scale and expanded in a large part of the objective Study area of Yangon River.

From the above-mentioned background, this examination commenced to confirm the general condition of present river erosion along the Yangon River within a part of the above work item 3) Collection of related information / data of Yangon River, and it aims to find a direction for further studies.

Chapter 2: Basic Policy of the Following Examinations

The main work of the Study is to get and confirm basic information about the Yangon River through the surveys, the monitoring and the observations. Therefore, although the theme of this examination—Yangon River erosion—is huge, this examination should be done within a limited range, by collecting existing information.

2-1 Necessary Materials for the Examination of the Secular Change of Yangon River

Generally, the following three items are necessary for examination of the secular change of riverbank.

- ✓ Topographic map (both analogue and digital)
- ✓ Aerial photograph
- ✓ Satellite image

These materials should have the following conditions.

- ✓ Multiple materials can show the same place and each is from a different time to trace the secular change
- ✓ Each of the materials should be identified with its date of issue
- ✓ Each of the materials should be identified with coordinates superposed on a map
- ✓ Each of the materials should have a required accuracy

In present-day Myanmar, the Law / Regulations of the Country prohibit providing such materials, or materials themselves do not exist, especially on the old records. On the other hand, recently the quality of Google Earth is 50 cm resolution, and multiple satellite images for about 15 years also can be accessed. So, in this time, the following examinations commenced mainly based on the multiple satellite images of Google Earth from the year 2003 to 2015. Besides, the site investigation results and the collected records / materials during the Study period are added and this examination is continued.

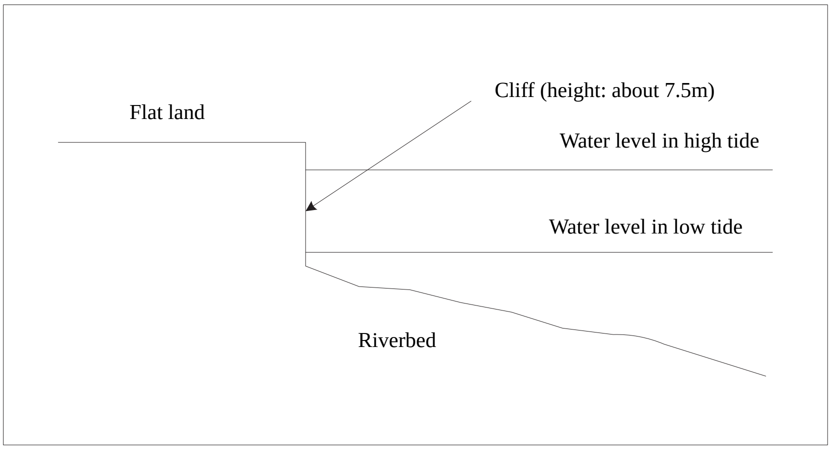
Chapter 3: Site Investigations

In the objective survey area of the Yangon River, basically there are two types of natural riverbank: 1) Cliff type and 2) Gentle slope type. The former 1) seems to have been eroded relatively recently and the latter 2) seems to be relatively stable for a long time.

3-1 Cliff Type

In almost all sections of cliff type riverbank along the Yangon River, there is no vegetation nor riparian forest on the cliff, which can work as a natural river bank protection, and the flat land used as arable land, grass and bare ground starts just behind the clifftop edge. There are several types of cliff, with and without step(s). The height of the cliff is almost 7 metres from the bottom to the top edge either without steps or with multiple steps because of the influence of tide fluctuation ranging about 6 metres in daily difference.

The following drawing shows a typical image of the cliff without steps. The exact bottom end depth of the cliff is unknown since there was no chance to conduct a level survey in this Study.

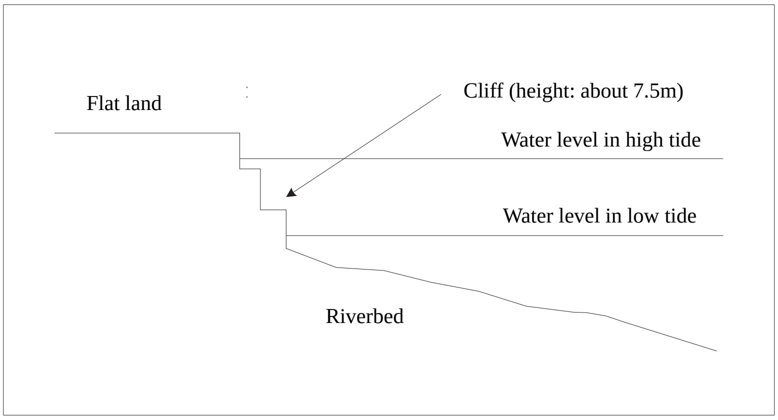


Source: JICA Study Team

Figure 3-1: A Typical Image of Cliff Type Riverbank without Step

Generally, in a river bend, the superficial river flow moves from the inside to the outside, and on the contrary, the river flow near the riverbed goes from the outside to the inside. As the result, a spiral flow is generated. The spiral flow generates an influence to fluctuate the shape of the riverbank and/or the riverbed. That is, the spiral flow makes a riverbank erosion at the outside of the river twist and it brings the river flow centre further to the outside and those movements create a larger clean flow and further erosion is caused on the outside of the riverbend. In Yangon River, a large riverbend can be seen from the Thilawa area to the river mouth, that is, the right bank (western side) of the Yangon River shows an erosional trend and the left bank (eastern side) has an accumulation trend.

The following figure shows a typical image of the cliff with multiple steps. Flat land starts just behind the cliff top edge, same as the cliff without steps. The exact bottom end depth of the cliff is unknown due to the same reason as the case without steps.



Source: JICA Study Team

Figure 3-2: A Typical Image of Cliff Type Riverbank with Multiple Steps

The sectional shape of the cliff is not only vertical as mentioned in the above figure; sloped cliffs can also be seen. The latter seems to be the result of old cliffs collapsing.
The Yangon River has a large daily tide difference of about 6 m. The same factors that make riverbank erosion take effect at each water level, therefore, such a stepped cliff would be made.

3-2 Right Bank of Yangon River from Thilawa Area to the River Mouth

The long consecutive cliff continuing over 20 km can be seen on the right bank of the Yangon River from the Thilawa area to the river mouth. The following shows the general condition of it.

Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of picture is upstream side)

Figure 3-3: A Part of the Right Bank at Upper Elephant Point (Vertical Cliff Without Step)

The next figure shows a part of the right bank near Thaung Gon village, located near Elephant Point. The figure of the cliff shows not a vertical but a gentle slope without steps. This picture was taken during lower tide and the water level at high tide would reach the level indicated by the red arrow, which is about 6 m higher than the water level shown in the following picture.

Source: JICA Study Team (taken in low tide on September 5, 2015. Right side of picture is upstream side)

Figure 3-4: A Part of the Right Bank near Thuang Gon Village (Sloped Cliff Without Steps)

The next figure shows a cliff with one step, which can be seen near Elephant Point. A sea wall (About 1 m height x 1 m width, rubble stone mound) constructed by the municipal government can be seen on top of the cliff. Water level at high tide would be around the level indicated by the red arrow.

Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is upstream side)

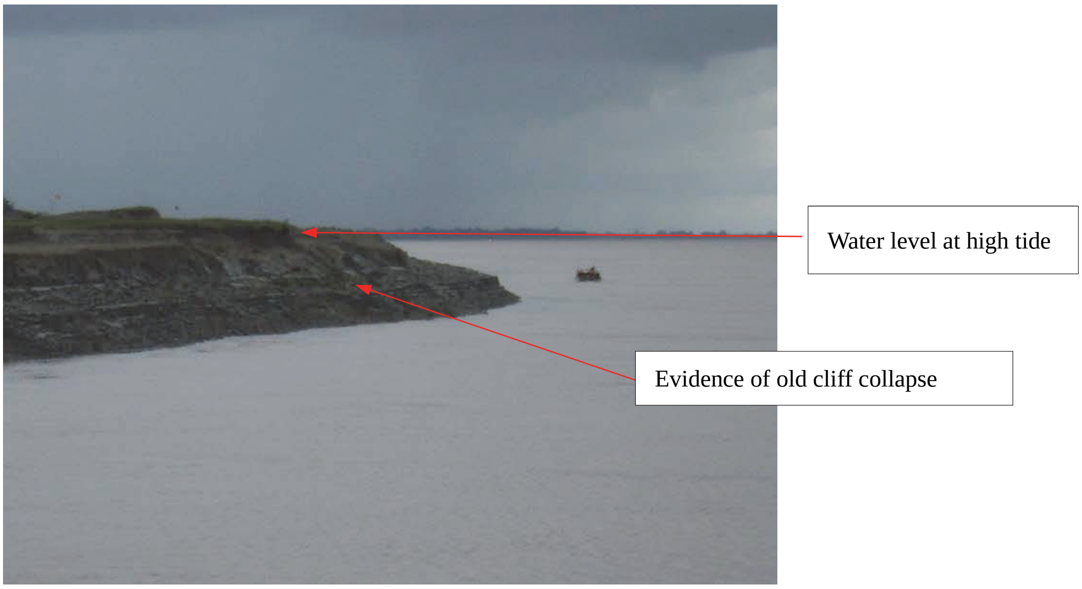
Figure 3-5: A Part of the Right Bank near Elephant Point (Cliff With One Step)

The next figure shows a cliff with 2 steps, which can be seen at a part of the right bank near Elephant Point. Evidence of the cliff collapse is shown in the centre of the picture. The water level at high tide would be at the level indicated by the red arrow.

Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is upstream side)

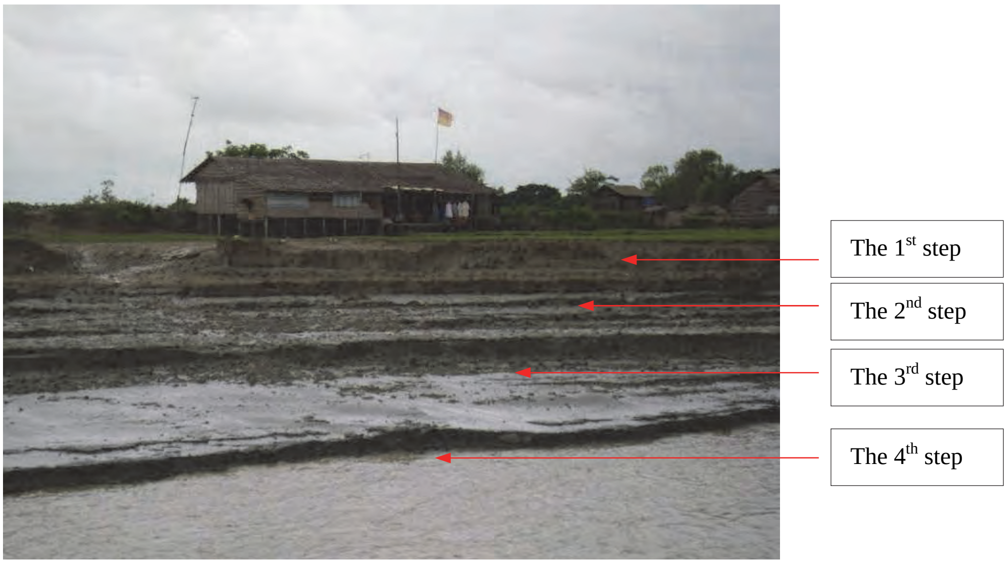
Figure 3-6: A Part of the Right Bank near Elephant Point (With 2 Steps)

The next figure shows a cliff with 2 steps, which can be seen at the river mouth along the right bank. The picture was taken with a distant view. Near the centre, evidence of a relatively large-scale cliff collapse can be found.



Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is the river mouth)

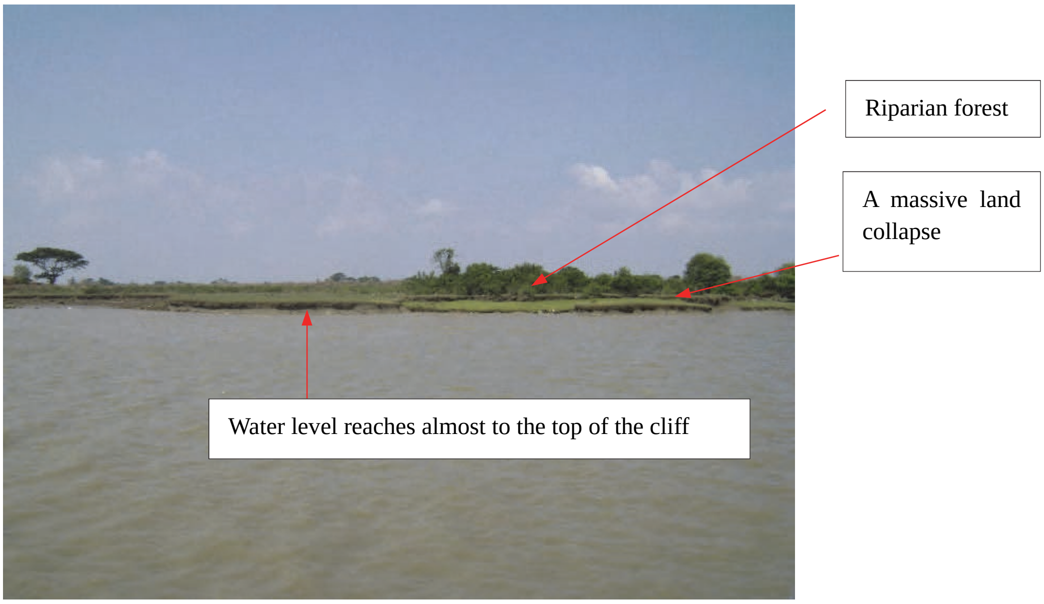
Figure 3-7: Western Side of the River Mouth (With 2 Steps)



Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is upstream side)

Figure 3-8: Part of Right Bank at Lower Elephant Point (With 4 Steps)

The above figure shows many steps in a cliff, which can be seen downstream of Elephant Point. There are more small steps between the 2nd and the 3rd steps.



Source: JICA Study Team (taken at high tide on April 25, 2015. Right side of the picture is upstream side)

Figure 3-9: A Part of the Right Bank in High Tide (A distant view)

Although Figures 3-1~3-8 were taken in low tide, the above Figure 3-9 was in high tide and it shows that the water level is very close to the top of the cliff. It can be said that the impression of the Yangon River is very different between low tide and high tide. On the right side of the above picture, evidence of a mass land collapse can be seen.

3-3 Natural Gentle Slope Type

As shown in the previous chapter, the entire right bank from the Thilawa Area to the river mouth, a distance of over 20 km, shows the cliff type bank. On the other hand, the left bank over the same distance has much less cliff than the right side. The left bank has less than 1/3 the cliff of the right bank. In the other parts, natural gentle slope can be seen. The left bank between the Thilawa area and the river mouth is inside a large river bend and that might be a reason there are fewer cliffs compared to the right side. In most cases having natural gentle slope, riparian forest can be seen behind the slope.

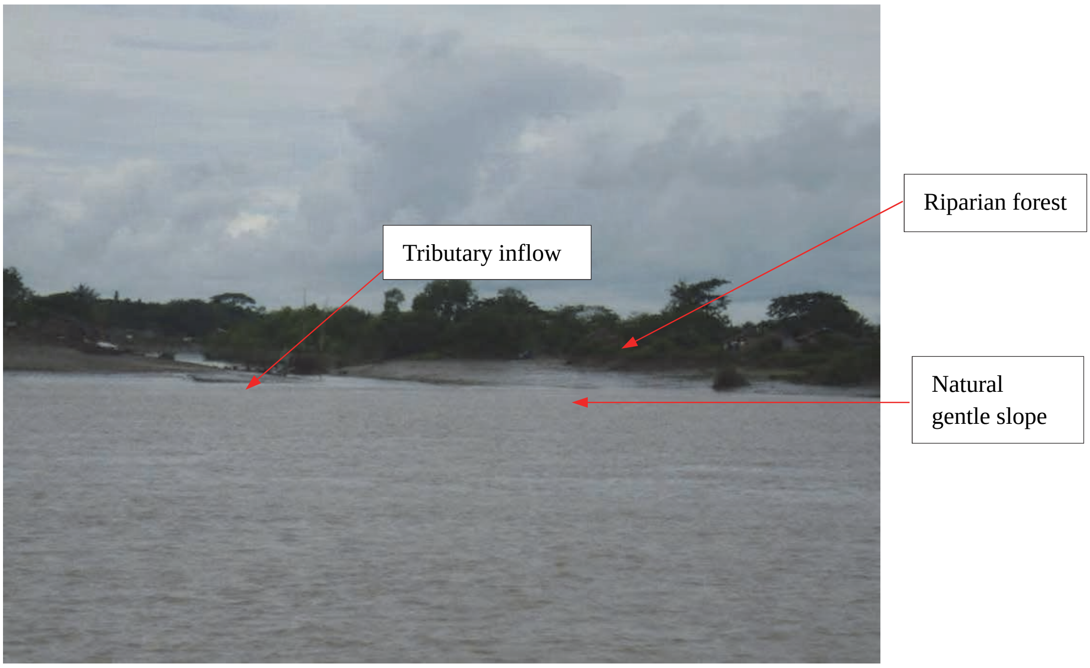
Also, both east and west shorelines near the river mouth show very gentle slope which would have been generated mainly by the accumulation of sedimentation from the Yangon River. Besides, the natural gentle slope can be seen in the inflow of the tributaries on both banks.

Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is upstream side)

Figure 3-10: Part of the Seaside Line near the River Mouth on the Right Bank Side

The above Figure 3-10 shows a part of the seaside line near the river mouth on the right bank side and it shows a natural, stable, gentle slope. In contrast to the gentle slopes along the river, there is no riparian forest behind this slope.

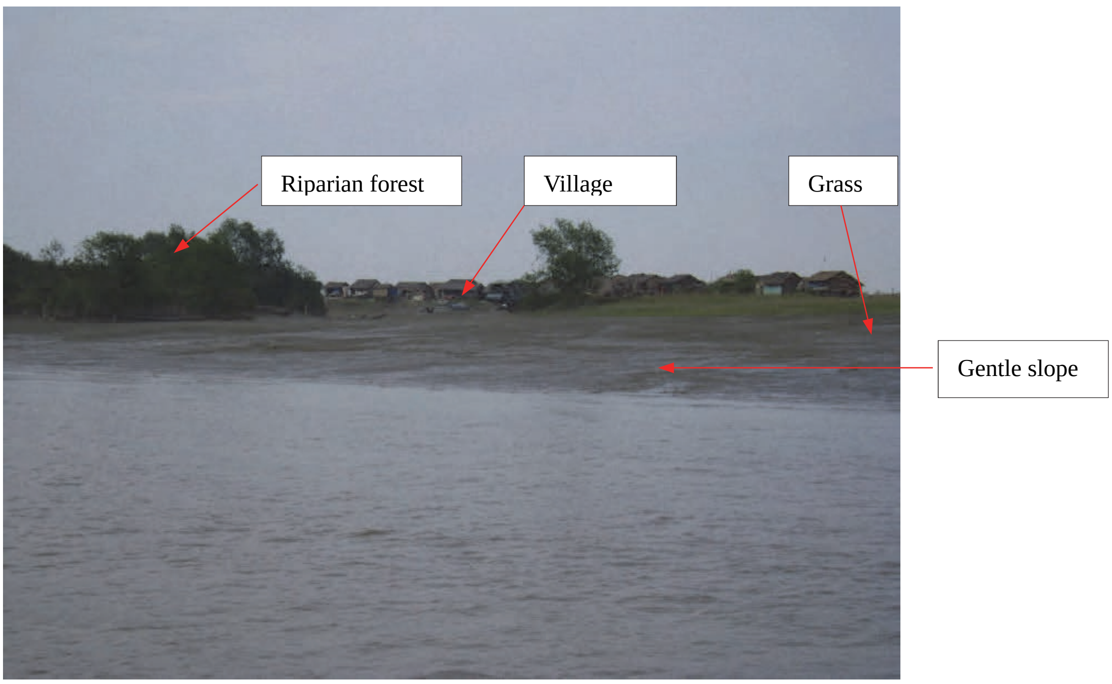
The next figure shows the location of tributary inflow along the right bank. The natural gentle slope can be seen on both ends of the inflow, and riparian forest can be seen behind the gentle slope.



Source: JICA Study Team (taken at low tide on September 5, 2015. Right side of the picture is upstream side)

Figure 3-11: A Tributary Inflow at the Right Bank

The next figure shows a tributary inflow on the left bank near a village located downstream of the Thilawa Area. The riparian forest exists on both riverbanks of the tributary. Only gentle slopes can be seen and there is no cliff near here.



Source: JICA Study Team (taken at low tide on March 25, 2015. Left side of the picture is upstream side)

Figure 3-12: A Stable Gentle Slope on the Downstream Side of the Thilawa Area

Chapter 4: Secular Change of the Riverbank

4-1 Steps of Image Processing

Multiple satellite images from the year 2002 to the latest year have been extracted from Google Earth, converted into AutoCAD files, and superimposed to ascertain the secular change of the riverbank. The concrete steps of the digitization are briefly introduced in the following.

Step-1 Startup Google Earth and select the objective area. Start the browser of the past images and acquire multiple images of the objective area. Analyse the quality of the acquired images, and select the images that fulfill the requirements.

Step-2 Due to the big difference in daily tidal change in the Yangon River, which is confirmed to be over 6 m, the riverbank line changes significantly between low tide and high tide. The past images were taken various times of day. Therefore, the water front line of each image shall be converted into the same timing of tide fluctuation to compare the riverbank line in each image. Generally, the water front line is regarded when it is at the mean water line but in this case the water front line at high tide is used. Concretely, in the case of a cliff type bank and an artificial vertical revetment, the top edge is selected. In the case of a sloped bank, the top end of the darker coloured line, which is influenced by water moisture, is regarded as the water front line, if it can be identified. In cases in which a riparian forest exists in the river water area, the edge of the forest is regarded as the riverbank line.

Step-3 After the identification of the riverbank line in each Google Earth image, digitise the line, road alignments, houses, riparian forests and other particulars on the image. Each of the digitised data shall be kept respectively.

Step-4 The Google Earth satellite image is sometimes slightly different on the coordinates. In this case, coordination adjustment is necessary. For this adjustment, unchanged objects like pagodas shall be digitised for the benchmarks.

Step-5 Digitised data shall be converted into KLM file and saved.

Step-6 Saved KLM file shall be converted into SHP file and saved.

Step-7 Saved SHP file shall be allocated Earth Ellipsoid and the projection manner of Google Earth.

Step-8 Earth Ellipsoid of Google Earth shall be converted into WGS-84 and projection shall be in UTM.

Step-9 Above data shall be converted into DWG file.

Step-10 DWG file shall be opened in AutoCAD and data cleaning executed. After the cleaning, the grid lines of UTM are drawn. Setting the unit and allocation of coordination system shall be done and finalised as AutoCAD data.

Step-11 Completed AutoCAD data for each time shall be layered exactly as in above Step-4. More recent Google Earth images have better accuracy compared to past images. Therefore the latest image should be the base data and multiple old images should be layered in reverse chronological order.

Step-12 The line type and colour should be decided for each time respectively, superimposed drawings should be finished for easy viewing.

Step-13 To confirm the secular change of the river bank, tentative measurement lines are set with a regular interval and measured the difference by using the measurement function of AutoCAD.

Step-14 Measured distance shall be averaged based on the interval time of each image and computed out the amount of the annual secular change in each measurement point.

Samples of the detailed image process are shown in Attachment 1.

4-2 Secular Change of Yangon River Bank

The following points have been selected to identify the secular change of the Yangon Riverbank in this examination.

Table 4-1: Measurement Points to Estimate the Secular Change of Yangon Riverbank

Point	*Location*	*Coordinates (UTM、Zone 47 N)*	
		X	**Y**
A	Near Elephant Point (right bank)	210100	1824600
B	Upstream of Elephant Point (right bank)	208600	1826500
C	Opposite bank of Thilawa area (right bank)	205500	1840000
D	South side of Monkey Point	200500	1853700
E	Near the inflow of the Bago River (left bank)	203500	1856500
F	Downstream of Thilawa Area (left bank)	208000	1840500
G	Opposite bank of the Middle Bank (left Bank)	210400	1833200
H	Upstream of the Elephant Point (left bank)	217000	1829200
I	Shoreline near the river mouth at the left bank	229500	1823500
J	Right side of the river mouth	214100	1821800
Island	Existing middle bank	209000	1831000

Source: JICA Study Team

The date, month and year of each image taken from Google Earth are shown in the following.

Table 4-2: Date / Month / Year of Images in the Points

Point	*Date / Month / Year of Images*			
A	Mar. 23, 2006	Feb. 10, 2010	Feb. 3, 2014	
B	Nov. 25, 2003	Mar. 23, 2006	Feb. 10, 2010	Dec. 31, 2014
C	Nov. 25, 2003	Dec. 31, 2014		
D	Nov. 25, 2003	Apr. 10, 2015		
E	Nov. 25, 2003	Apr. 10, 2015		
F	Nov. 25, 2003	Mar. 9, 2015		
G	Mar. 23, 2006	Feb. 3, 2014		
H	Feb. 10, 2010	Mar. 10, 2015		
I	Apr. 20, 2002	Feb. 10, 2010	Nov. 20, 2014	
J	Feb. 10, 2010	Dec. 31, 2014		
Island	Nov. 25, 2003	Mar. 23, 2006	Feb. 10, 2010	Feb. 13, 2014

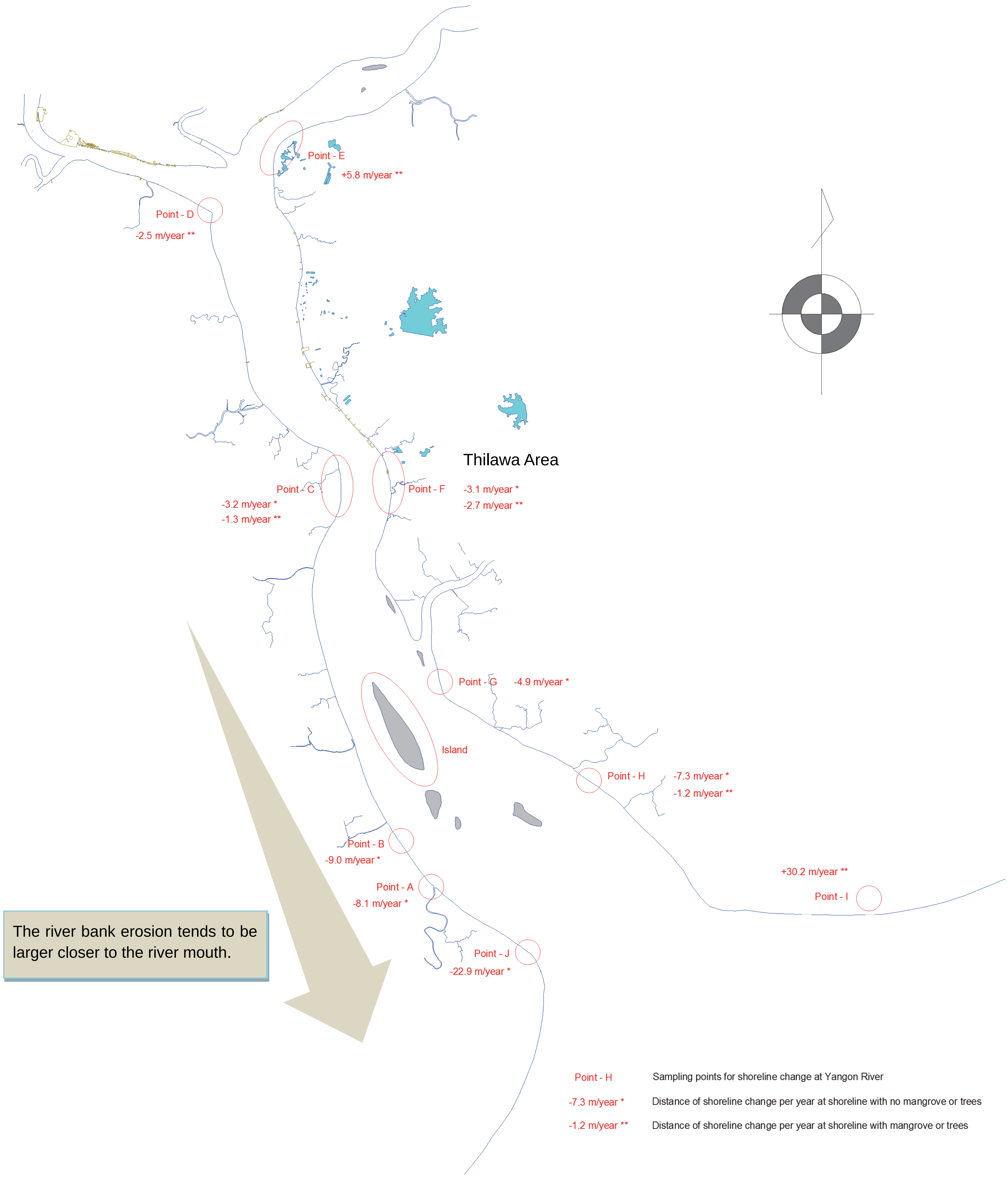
Source: JICA Study Team

As the results of image analysis from the year 2002 to 2015 on the above points, the trends of secular change of the Yangon River bank are as follows:

- Severe riverbank erosion can be seen continuously from the Thilawa Area to the river mouth, especially along the right bank. The erosional collapse is heavier as it gets closer to the river mouth and happens at a rate of 22 m/year on average along the right bank, near the river mouth.
- The erosion can be seen along the left bank as well but it is only about 1/3 of the erosion of the right bank. Many stable natural sloped banks can be seen along the left bank. The maximum erosion along the left bank is annually 7 m on average, which can be seen near the river mouth.

- The secular change of the riverbank tends to be larger if there is no riparian forest behind the bank. On the contrary, it is smaller if there is forest. (See the following Chapter 4-3)
- The upper side of the middle bank has no big change but the lower side has a certain change.
- Although the shoreline of the left side of the river mouth advances in an offshore direction, it is the result of expansion of fishponds artificially, not naturally.

The following drawing shows the result of the image analysis on the secular change of the Yangon Riverbank.



Source: JICA Study Team

Figure 4-1: The Results of Satellite Image Analysis on the Secular Change of the Yangon River Bank

* The detailed results of the analysis are shown in the Attachment 2.

4-3 Riparian Forest Trend

The amount of the secular change of the Yangon Riverbank tends to be larger when the objective bank has no riparian forest. In contrast, the secular change is smaller if there is riparian forest along the bank. On the Yangon River, continuous cliff can be seen along the right bank from the Thilawa area to the river mouth, and such places do not have riparian forest. In this chapter, satellite images are further analysed to know the coverage ratio of the riparian forest and its trend.

Two appropriate satellite images, having the required quality for knowing the coverage ratio of the riparian forest, were selected from the Google Earth images of the past 20 years, which are from November 25, 2003 and December 31, 2014.

The coverage ratio of the riparian forest was measured for every 10-km interval from Monkey Point to the lower side. (The last section is 5 km) The results are shown in the following table.

Table 4-3: Coverage Ratio of Riparian Forest on the Right Bank

From	***To***	***Coverage Ratio***		***Rate of Change***
		Nov. 25, 2003	**Dec. 31, 2014**	
Monkey Pt.	10 km	46.1%	48.2%	+2.1%
10 km	20 km	56.5%	44.5%	-11,9%
20 km	30 km	3.5%	6.2%	-2.7%
30 km	35 km	No data	0.9%	No data

Remarks: The satellite image in 2003 does not have the required image quality for the west side of the river mouth (from 30 to 35 km).

Source: JICA Study Team

Table 4-4: Coverage Ratio of Riparian Forest on the Left Bank

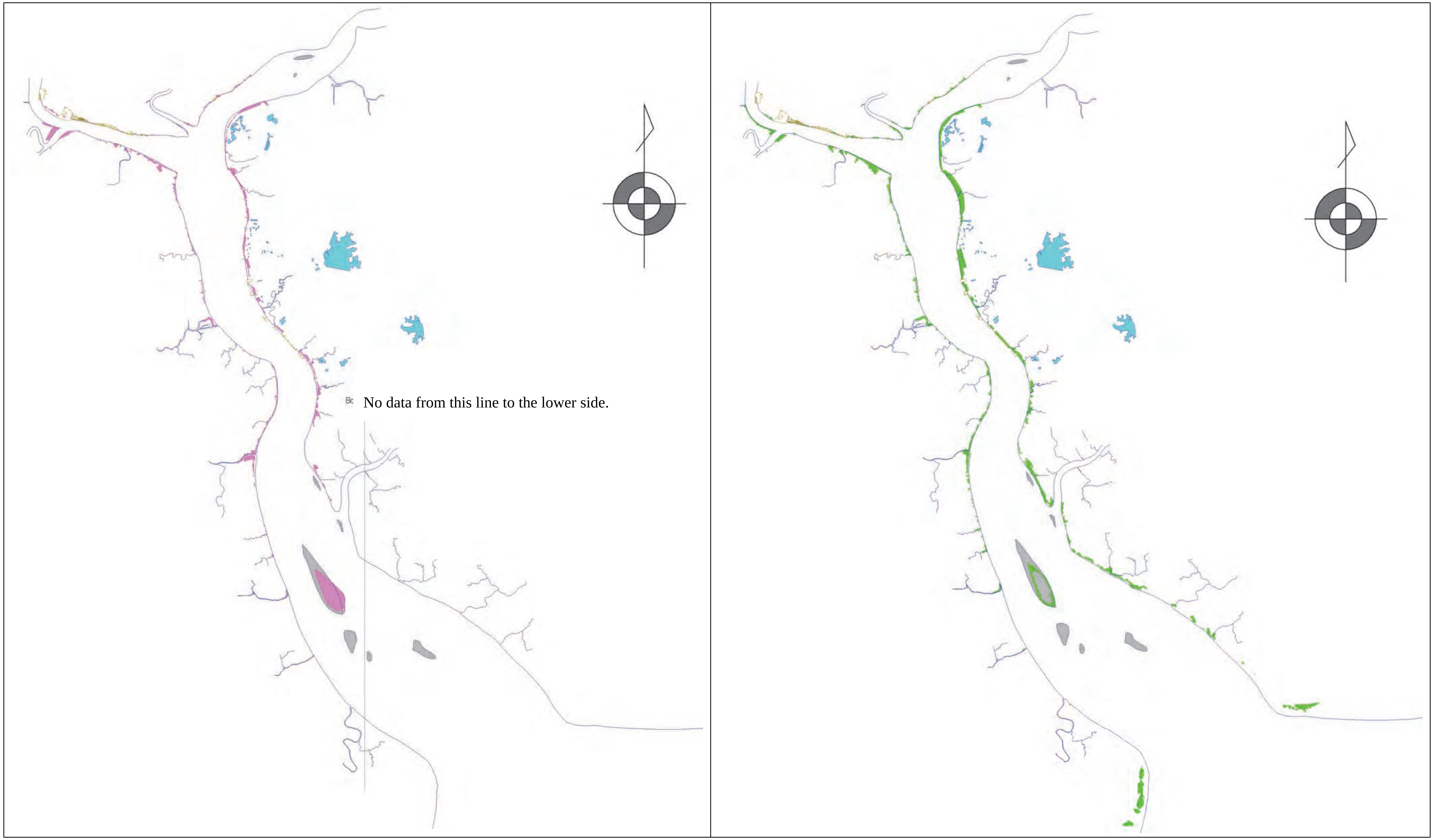
From	***To***	***Coverage Ratio***		***Rate of Change***
		Nov. 25, 2003	**Dec. 31, 2014**	
Monkey Pt.	10 km	79.1%	73.8%	-5.3%
10 km	20 km	51.6%	66.2%	+14.6%
20 km	30 km	No data	53.4%	No data
30 km	35 km	No data	15.7%	No data

Remarks: The satellite image in 2003 does not have the required image quality from 20 to 35 km.

Source: JICA Study Team

As clearly shown in the above tables, there is no riparian forest along the right bank of the lower Thilawa Area where can be seen the cliff type bank continuously, in other words, where riverbank erosion has happened. As for the left bank, although the coverage ratio of riparian forest is slightly increasing at the block from 20 to 30 km, basically the coverage ratio of the riparian forest along both banks decreases as it gets closer to the river mouth. On the other hand, the riparian forest along the middle bank remains up to now and no large change can be seen.

The following drawing shows the distribution of riparian forest in 2003 and 2014.



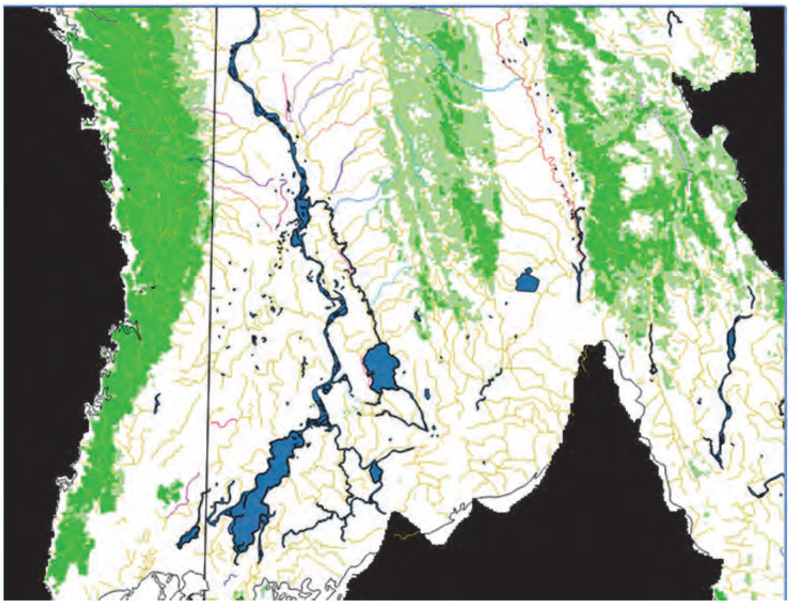
Distribution Map of Riparian Forest in 2003 | **Distribution Map of Riparian Forest in 2014**

Source: JICA Study Team

Figure 4-2: The Distribution Map of Riparian Forest in 2003 and 2014

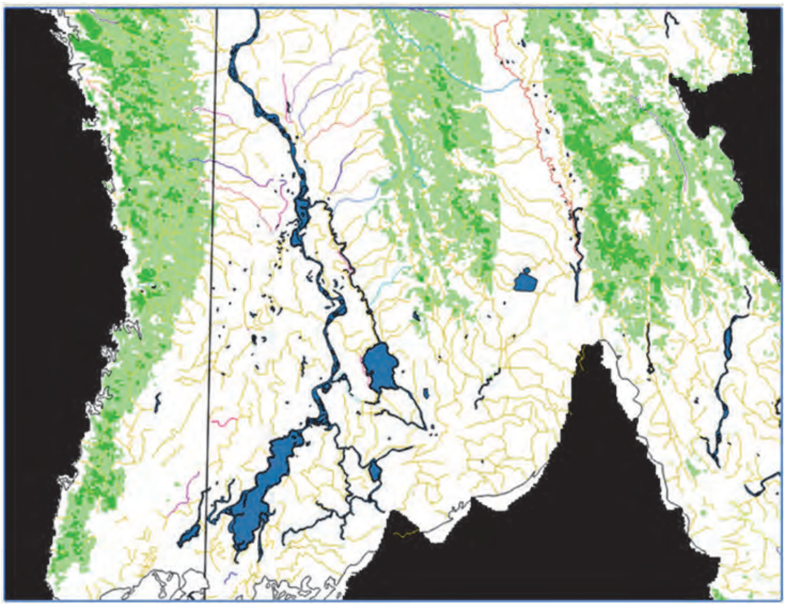
4-4 Decreasing of Natural Forest in the Upstream of the Yangon River

The following satellite images are from the SPOT satellite (the Centre national d'études spatiales: CNES satellite from France) showing the condition of natural forest in the year 2000 and 2010. The green colour shows the area of the forest, the darker green indicates denser forest and the brighter green means thinner forest. Deep forest was widespread in 2003 but by 2010 it was lost in most of the area and thin and small forests are spotted and distributed. The result shows that natural forest in Myanmar is being rapidly damaged and the trend would be continue or increase in 2015.



Source: JICA Study Team

Figure 4-3: Forest Density in 2003



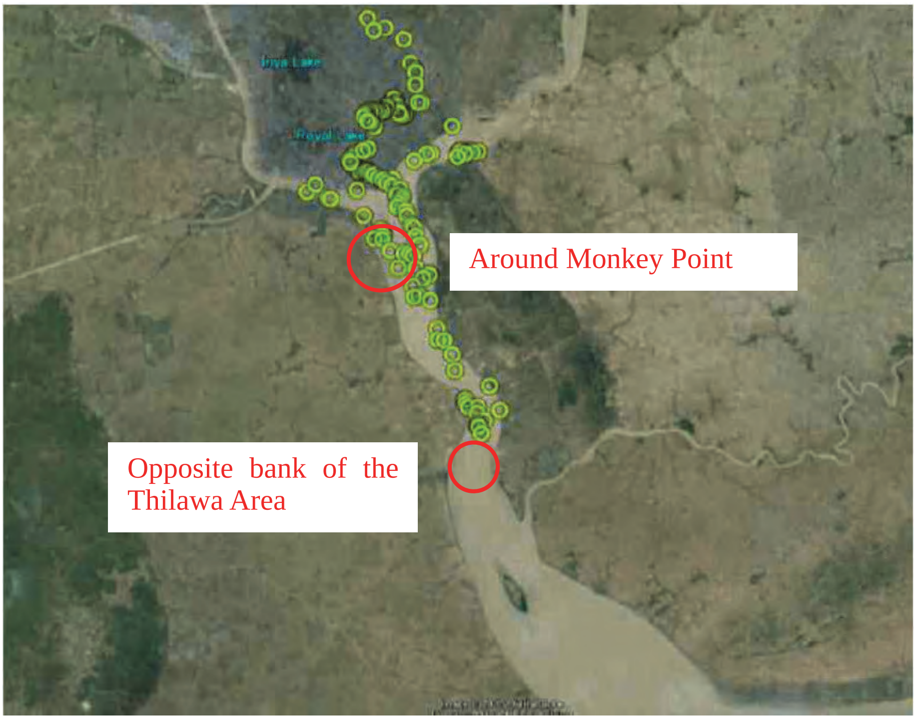
Source: JICA Study Team

Figure 4-4: Forest Density in 2010 (Deep Forest is rapidly decreasing)

As a result, the soil percolation capacity of upstream is decreasing due to the loss of forest and it will likely result in larger volume and stronger river flow downstream on the Yangon River.

4-5 Sand Mining Activities

Many sand mining activities can be seen in the objective Study area of the Yangon River. The extracted sand is used for the purpose of mixing concrete and for land reclamation material. The detailed report is done in the main report of the Study. The following satellite image shows the condition of work vessels mining the sand.



Source: Google Earth and JICA Study Team

Figure 4-5: The Work Vessels Mining the Construction Sand (April, 2015)

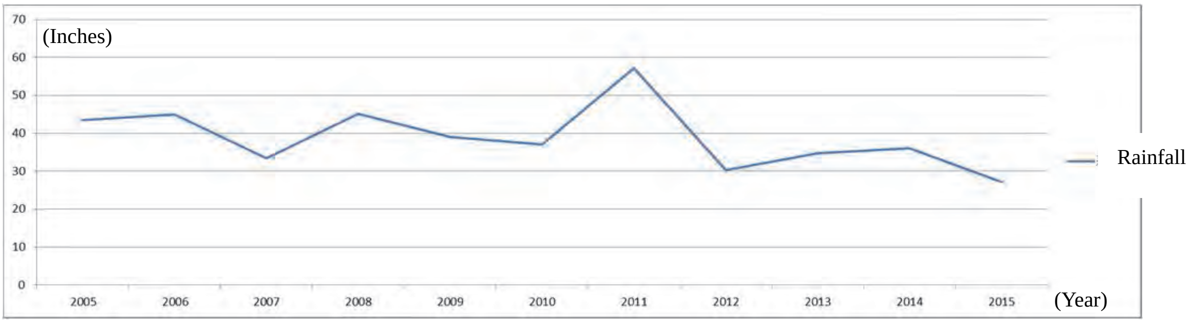
In addition to the above satellite image, 4 other images taken in 2015 have been analysed. These analyses show that the main mining works are done in the two circles indicated above, around Monkey Point and on the opposite bank of the Thilawa area. The mined volume from the former is estimated at approximately 2 million m^3 per year and the latter is about 1.3 million m^3 per year and the total is over 3 million. Considering the present surging demand of the construction in / around Yangon City Area, the mining activities will have an increasing tendency in the future.

Continuous river bank erosion can be seen at the most downstream part of of the mining activities, which is at the opposite bank of the Thilawa Area, the extraction of the sand would be likely to influence the present river bank erosion.

Chapter 5: Collection of Related Information

5-1 Rainfall

It is very difficult to acquire old rainfall data in Myanmar. The following is the rainfall data from the year 2005 to 2015 in Nyaungshwe, located in the centre of Myanmar.

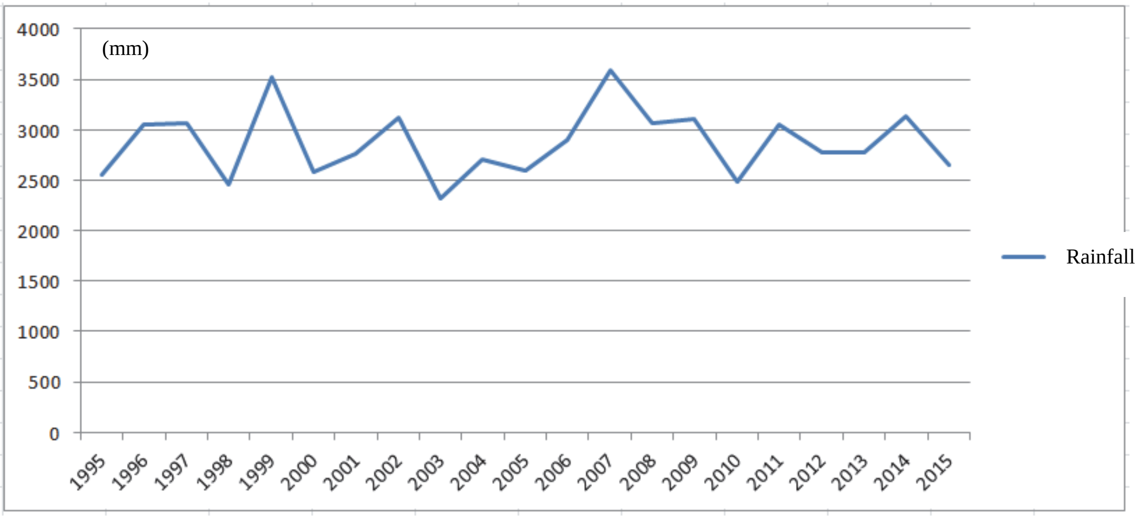


Source: JICA Study Team

Figure 5-1: Rainfall at Nyaungshwe

As shown in the above line graph, the annual rainfall at Nyaungshwe has no change or a slight decrease during the decade.

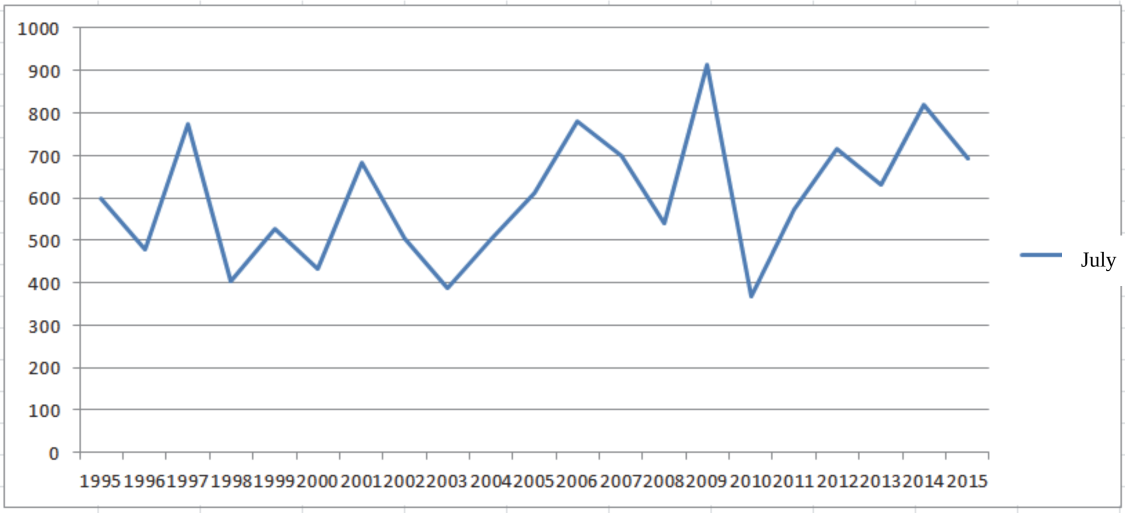
The following is rainfall data from the year 1995 to 2015 at Kaba Aye located in Northern Yangon.



Source: JICA Study Team

Figure 5-2: Rainfall at Kaba Aye

It cannot be seen that the rainfall at Kaba Aye is in the increasing tendency. As further data investigation, rainfall in July, which is a peak of the rainy season in each year, is shown in the following. As the result, a massive rainfall over 800 mm per month can be seen recently in 2009 and 2014.



Source: JICA Study Team

Figure 5-3: Rainfall in July at Kaba Aye

The frequency of torrential rain (having instantaneous strong rainfall) is increasing in the world widely, which would be mainly caused by climate change. It can be seen in Japan as well. The possibility of a similar trend in Myanmar can be seen from the above graph.

5-2 Old Marine Chart of 1904 and Map of 1930

In the Study period, fortunately JICA Study team acquired an old marine chart from 1904 issued by the Survey Department of the former Japanese imperial navy. And an old map from 1930 issued by England was also collected. The former is the revised version of an even older marine chart from 1857 issued by England and India. Considering the classic survey skills in those days, it is assumed that the marine chart was completed with such an effort and finalised based not only on the survey result from one year but the results from multiple years.

As shown by the historical fact, the Yangon River has played an important role as the main access channel for the country. Therefore, the accuracy of the information recorded on the old map and the chart was very high for the time. Although detail comparable to the latest technological information would be impossible, such old information could be compared to the modern survey results in macro view.

The collected old marine chart and map are attached on the following page. After that page, there is a brief comparison, which layers the riverbank lines referred from the chart from 1904 and a satellite image from 2015 superimposed on the old map from 1930.

The Rangoon River in the 1930 Map issued by England.	The 1904 marine chart of the Rangoon River issued by the former Japanese navy * Note: A very deep point over 14 Fathoms, which is equal to about 25 m, can be seen at Elephant Point.)

Source: England and the former Japanese Navy

Figure 5-4: Collected Old Marine Chart and Map

Remarks: To compare the latest survey result and the collected old map / chart, the old information was converted into the Earth ellipsoid as WGS-84 and Projection as UTM.
Source: JICA Study Team

Figure 5-5: Brief Comparison of Riverbank Lines among 1904 Marine Chart, 1930 Map and 2015 Satellite Image

In this Study, a report for the examination of the Yangon River issued in 1976 by the United Nations Development Programme*1 (hereafter: UN Report) was also collected. Considering the UN Report and the brief comparison of the riverbank line in Figure 5-5, the features of the change on the riverbank lines of the Yangon River would be regarded as follows:

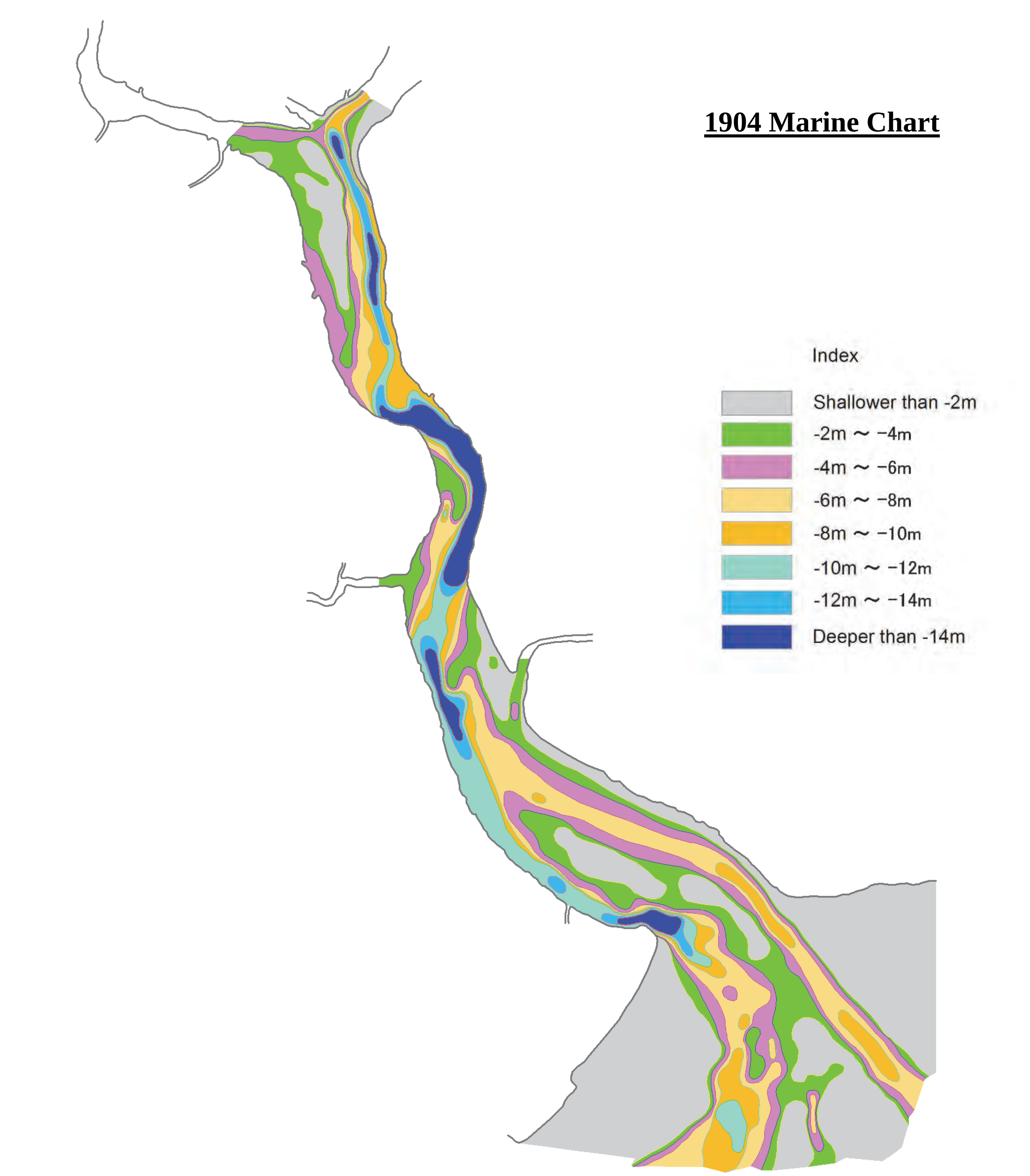
- ✓ According to the symbolic information indicated on the 1930 map, both banks of the Yangon (Rangoon) River were sloped stable bank. Generally, English information related to access channels is reliable even if it is so old.
- ✓ According to the brief comparison, both riverbank lines go backward to the land side and especially the erosion at the right bank has larger.
- ✓ The width of the river mouth in 1904 was about 5.6 km and it widened slightly to 5.8 km in 1930. According to the UN Report, it was 6.6 km in 1976 and presently it grows up to 7.6 km. So, the secular change of the river mouth width is briefly recognised as follows:
  - ✧ For 26 years from 1904 to 1930: Average erosion is 7 m annually
  - ✧ For 44 years from 1930 to 1974: Average erosion is 18 m annually
  - ✧ For 41 years from 1974 to 2015: Average erosion is 25 m annually

    (Note: the result of the satellite image analysis in Chapter 4 of this examination was 29 m annually.)

  So, it can be said that the growth speed of expanding the river mouth has been increasing recently.
- ✓ Related to the right bank erosion, alignment of the lower Thilawa of the Yangon River is closer to being straightened.
- ✓ The present Middle Bank did not exist in 1930 but there were many small islands near the river mouth at that time.
- ✓ Recently there is no sand bar near Monkey Point but it existed in 1930 and 1904.
- ✓ The left riverbank line at the junction point between Monkey Point and Bago River has advanced about 1 km.
- ✓ Only a very small change of the riverbank line can be seen at the Thilawa Area since 1904.
- ✓ There were 2 access channels called west channel and east channel in 1904 but according to the UN Report, the east channel was naturally shallowed during the year 1932 and 1950 and finally only the west channel remains at the present time.

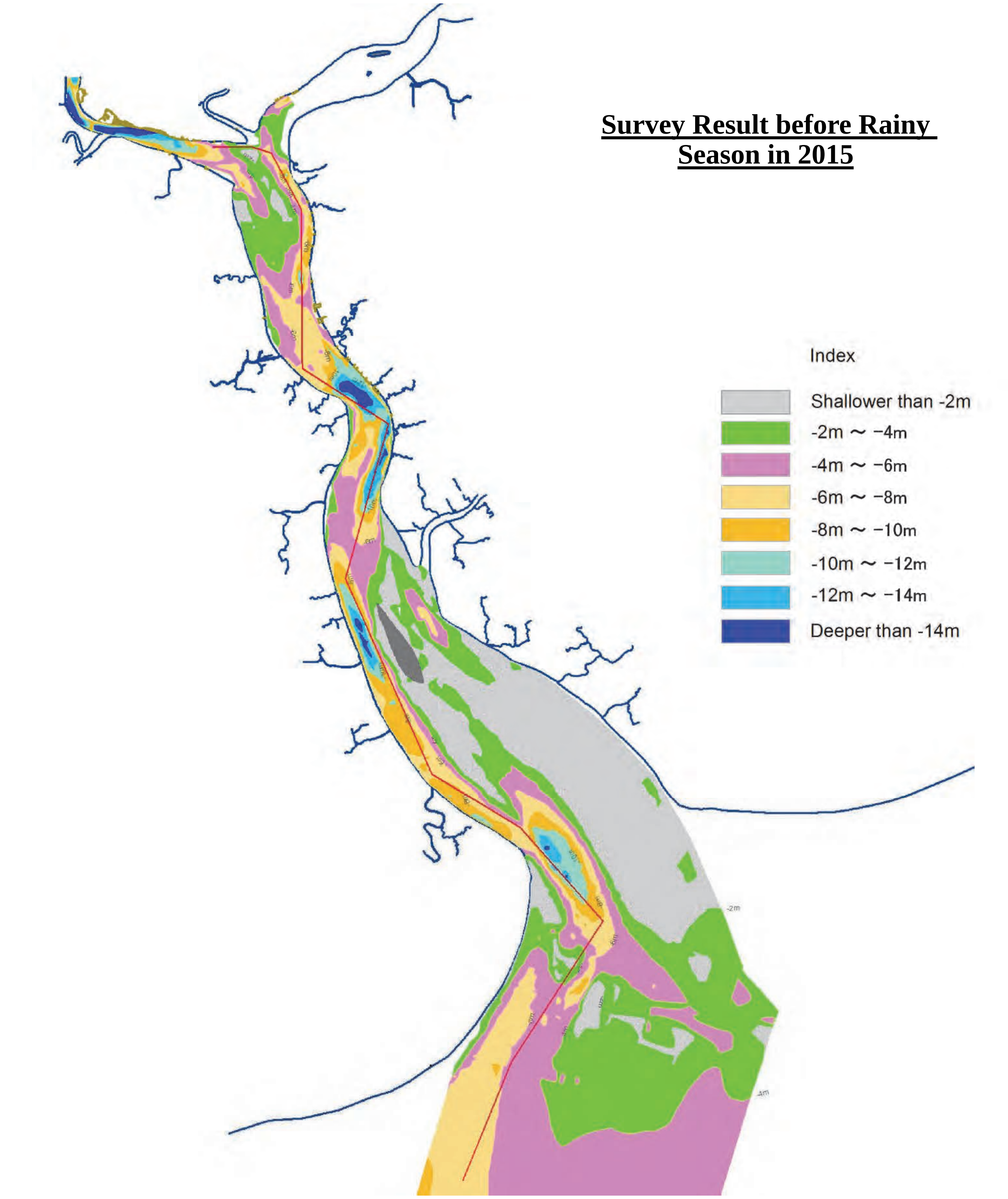
  *1: Rangoon Sea Access Channel and Associated Port Improvement Study in March 1976, issued by United Nations Development Programme.

According to Earth History, it is generally said that all of the downstream land of Hinthada, located about 80 km north of Yangon, was made of the accumulation of river sedimentation about 5,000~6,000 years ago, therefore, it is easily imaginable that all of the area, especially the land as it gets closer to the shoreline, is relatively softer subsoil, and it would be one of the reasons why the land near the river mouth would collapse more easily. On the other hand, no major erosion can be seen in the Thilawa Area, although the Thilawa Area is located downstream of Hinthada and the land is located at the outside of the river bend and the river flow hits the area directly. Probably the land of the Thilawa Area is comprised of harder, dense subsoil due to other long-ago factors and it is mentioned in the UN Report as well. From this viewpoint, Thilawa is a good location for the development of a river port. The following is the result of a brief river depth comparison between the year 1904 and 2015.



Note: Very deep points having over CD-20 m can be seen at Elephant Point and near Thilawa in this old chart. Those are catabolized in "deeper than -14 m" for this brief comparison to the survey result in 2015.

Coloured 1904 chart map with 2 m contour interval (Conversion: 1 FATHOM = 1.8288 m)



Coloured survey result before rain in 2015 with 2 m contour interval

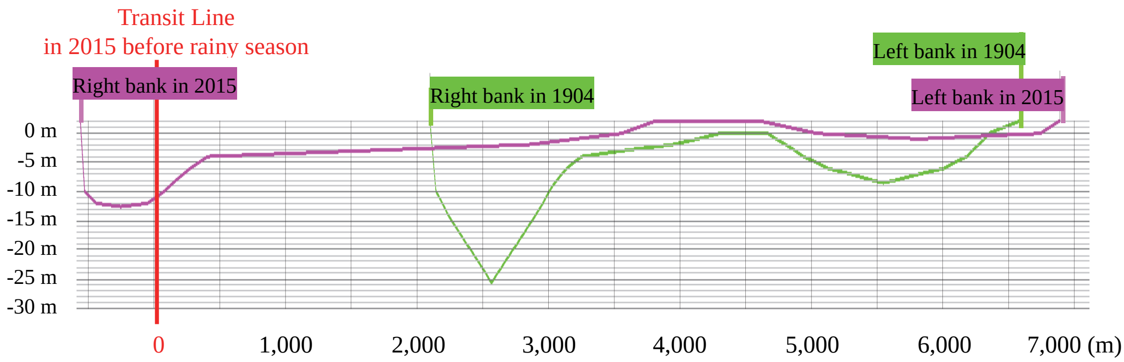
Source: JICA Study Team

Figure 5-6: Brief River Depth Comparison between 1904 and 2015

Very deep points with over CD-20 m were seen in the Rangoon River in 1904 even though such a deep point cannot be seen in 2015. In those days, the deepest point in / around the lower Thilawa Area was CD-21 m and Elephant Point had CD-25 m as the maximum. The survey results in the Study show Maximum CD-19 m in the lower Thilawa Area and a maximum of CD-13 m at Elephant Point. Those figures are recorded in the survey after the rainy season.

The depth of the access channel from Monkey Point to Elephant Point surveyed in 2015 is generally kept at CD -6 m in both survey results before / after the rainy seasons. On the other hand, it can be seen that the depth in the same area in 1904 was CD-10 m according to the marine chart. Also, the area called the east channel is presently very shallow, within CD-2 m, but it was kept at least CD-6 m in 1904 and it is almost the same depth as the present west channel. Considering these facts, it can be said that the access channel of the Yangon River is getting shallower compared to the depth in 1904.

The following is a brief comparison of river section between the year 1904 and 2015 in an arbitrary section near the river mouth.



Note 1: The above section is a view from the downstream side.
Note 2: Both maps, from 1930 and 1904, were recorded with the unit of inches and fathoms, which are different units from the survey results in 2015, therefore, old figures had to be converted into metric units to be compatible with figures from 2015. Related to the unit conversion, some small discrepancies between the actual surveyed figures and the contour lines are evidednt in those old maps, however, it will be no problem for such a brief comparison at this time.

Source: JICA Study Team

Figure 5-7: A Brief Comparison of River Section near the River Mouth between 1904 and 2015

As shown in the above figure, the maximum depth at Elephant Point is CD-25 m (-14 Fathoms on the Marine Chart). It is obvious that the width of the river mouth is widening and the river bottom has been getting shallower from the year 1904 to 2015. For a trial calculation, the above two areas were compared but both results were similar value.

5-3 Hearing Interview with the Village near Elephant Point

The erosional collapse of the riverbank of the Yangon River is remarkable especially on the right bank. The right riverbank line recedes annually 22 m according to the satellite image analysis in this examination. In present Myanmar, it is very difficult to get further materials like marine charts / maps / satellite images from different years, even other records to know more details about the secular change of the riverbanks. So, JICA Study Team conducted a hearing interview in Thuang Gon village, located on the right bank near the river mouth. The results are as follows:

- ✓ Both riverbanks had naturally stable sloped banks about 50 years ago (Note: this matches the information of the 1930 map)
- ✓ In those days, large ships sailed along both riverbanks (Note: that means they used both east and west channels)
- ✓ The cause of the riverbank erosion is waves caused by ship navigation
- ✓ Usual seasonal high waves from the east are remarkable every September and after, and they hit the right riverbank strongly. When a large ship passes in front of the right riverbank causing a strong wave, the right riverbank is collapsed largely.
- ✓ Already two villages have disappeared due to the loss of land caused by the riverbank erosion.
- ✓ The riverbank line recedes about 100 ft (30 m) annually.

In the 1930s, the size of cargo ships passing the Rangoon Channel was much smaller than the present ships and the ship traffic volume would be quite small compared to recent volume, therefore it is assumed that the riverbanks would be much safer in those days compared to recent times.

Usually people living near the river far from city areas have lower income and sometimes those people cut the riparian forest and use it for the cooking fuel. As a result, the riverbank lost its natural protection and resulted in erosional collapse at the riverbank, which is the start of the loss of land. This phenomenon has happened occasionally in other countries in ASEAN. In the case of Indonesia, people living near the coastline cut the trees along the shoreline and it brought loss of land. It is a big problem for the country, and the government of Indonesia has started to educate the people not to cut the trees, and at the same time, the government commences afforestation by their funding to protect the coastal land against further loss.

It can be assumed that previously the stable riverbanks started erosion caused by such a reason over 80 years ago in the 1930s. However, the evidence could not be found at this time.

5-4 Current Situation of Waves Caused by Large Cargo Ships

After the above hearing interview, a brief observation of ship waves created by a large vessel was done to know how big the wave influences to the right riverbank are.

Arbitrarily selected, a day has no remarkable waves under a good sunny day without any strong wind. The observation point is located at the Thuang Gon village near Elephant Point.

① Objective Cargo Ship

② Ship Waves reached the riverbank (splash height: about 1.5 m)

③ Normal condition without ship waves (1 hour after the ship passed)

Source: JICA Study Team

Figure 5-8: Influence of Ship Waves Observed on the Right Bank near the River Mouth

As examined in the main report of this Study, normally large cargo ships pass by Elephant Point at a relatively fast speed of 10 knots or faster so it makes big waves as shown in the above figure. According to the image analysis and visual estimation by the observer, the height of the splash is about 1.5 m.

It should be confirmed in a further investigation how big an impact the ship waves have on the riverbank.

5-5 Protection of the Riverbank

The Municipal government constructs rubble-stoned sea wall along the riverbank. The dimension is 1 m height x 1 m width, and the main purpose of the wall is a countermeasure to storm surges caused by cyclones. The sea wall has to be remade every 6 months or 1 year due to the backdown of riverbank caused by erosion, according to the local people.

Note: Riverbank erosion comes just by the sea wall
Source: JICA Study Team

Figure 5-9: Sea Wall Constructed by the Municipal Government

If the Yangon River had less tide fluctuation and slower river flow, the afforestation might be effective to restore natural riverbank protection, however, actual Yangon River has very hard natural conditions like over 6 m of large tide fluctuation and very fast flow speed with 4 knots as maximum in both ebb / neap tide. Furthermore, the influence of ship waves is added, so afforestation would be impossible as it is.

Normally, armor-stoned or concrete-blocked protection is a preferable countermeasure to stop further riverbank erosion. Also, the protection could contribute to the protection of hinterlands and villages. The Yangon River has very hard natural condition as mentioned, and the area requiring urgent protection is quite long, about 20 km on the right bank only. Considering the difficult conditions and the long work range, the policymaking of the countermeasure work should be carefully examined. If a cheap structure was procured, it would be need frequent updating with a short lifecycle. On the other hand, if a more expensive structure was procured, the initial construction cost would be quite huge and at the same time, it would bring a certain volume of environmental impact.

In the case that concrete blocks or armor stones were placed at the riverbank, spiral flow would make a force of riverbed scour. The Yangon River is a big river and the force would be quite strong so a strong foundation should be placed under the cooping structure In the case that a lowering of wave influence was requested, the structure would need to have a wave-dissipating effect. In any case, the objective area is very long, over 20 km, and it will make a huge initial cost easily, therefore, the first step of comparative study is to decide that the structure type should be started from relatively cheaper and easier type like gabion structure.

If the length to be protected was 20 km and the unit price per longitudinal metre was US$10,000, the initial construction cost would be US$10,000 x 20,000 m = US$ 2 million, which would already be a huge burden.

Source: JICA Study Team

Figure 5-10: A Sample of the Gabion type Revetment in Japan

Chapter 6: Volume of Discharged Sediment

As discussed in the previous Chapter 4 of this examination, the secular change of the riverbank line was confirmed based on the satellite image analysis. Usually, the level survey shall be done to know the height at the erosion point and then the volume of discharged sediment caused by the riverbank erosion can be calculated. However, this time, the height information was referred from the pictures taken in the site investigations and a rough estimate of soil volume flowing out by the erosion can be calculated.

6-1 Estimation of Cliff Height

For the estimation of the cliff height by the photo finish, the picture has to show the cliff with a thing of known length. This time, a man with height assumed as 165 cm was used for the estimation.

The following sample was taken 15 km upstream of the right river mouth. A man's height was set as 165 cm as mentioned above, and the cliff height was estimated. At the same time, other height information shown in the background like a house was used for the estimation as well.

Aiming to the best accuracy within the limited information from the photo, firstly, the picture was passed to AutoCAD and then both the cliff and the person (or the thing) height were measured exactly in the model space of AutoCAD. Finally the cliff height was calculated based on the measured ratio in the model space.

Source: JICA Study Team

Figure 6-1: A Sample of Height Estimation by AutoCAD (Reference No. 4.2.1)
(The above picture was taken during low tide, September 5, 2015)

The above estimation process was repeated 6 times at the different points, and finally the average height of the cliff was calculated. The result is shown in the following.

Table 6-1: Estimation of Cliff Heights

Reference No.	*Object*	*Length in AutoCAD*	*Ratio*	*Assumed Length (m)*	*Estimated Cliff Height (m)*
4.2.1	A person	6.675	3.27	1.65	5.4
	Cliff	21.850			
4.2.2	A person	2.509	7.00	1.65	11.6
	Cliff	17.569			
4.2.3	A person	3.916	4.13	1.65	6.8
	Cliff	16.181			
4.2.4	A person	3.031	4.19	1.65	6.9
	Cliff	12.689			
4.2.5	A pole	3.243	3.81	2.00*1	7.6
	Cliff	12.385			
4.2.6	A person	4.472	3.75	1.65	6.2
	Cliff	16.791			
				Total	44.52
				Average	7.42

Note 1: In the reference No. 4.2.5, fortunately the picture showed a survey pole whose length was known as 2.0 m so it was used instead of 1.65.

Note 2: All above data was collected along the right bank due to the luck of the pictures of the left bank. The following estimation of discharged sediment was continued by using the same data based on an assumption that both bank heights were equal.

Source: JICA Study Team

As the result, the cliff height was set as 7.42 m in this examination.

6-2 A Brief Estimation of Annual Discharged Sediment Volume Caused by Erosion

In the steps of satellite image analysis discussed before, 1) the average secular change of the Yangon Riverbank, 2) coverage ratio of the riparian forest, and 3) the length of the riverbank line where the erosion can be seen, were calculated. In addition to these figures, the estimated cliff height calculated in the above chapter is used for the calculation of a brief estimation of the discharged soil volume caused by the riverbank erosion.

$$V = S \times H \times L$$

V: Brief diffluence soil volume caused by the riverbank erosion (m^3)

S: Average secular change of the riverbank line (m)

H: Estimated cliff height (m)

L: Length of the riverbank line where the erosion can be seen (m)

The following are the premises of this trial calculation.

- ✓ The objective calculation range is at both riverbanks from Monkey Point to the river mouth
- ✓ The figures of the secular change of the riverbank are based on the result in Chapter 4
- ✓ Each of the maximum values of the secular change was used
- ✓ Estimated cliff height is set as 7.42 m for all areas tentatively
- ✓ The change of the middle bank was ignored in this trial calculation

The following table shows the calculation results.

Table 6-2: Estimation of Annual Diffluence Soil Volume from Right Riverbank Erosion

Range	*Length of Riverbank (m)*	*Coverage ratio*	*Riparian Forest*	*Distance (m)*	*Annual Secular Change (m)*	*Loss of Land (m^2/year)*	*Cliff Height (m)*	*Diffluence Soil (m^3/year)*
Monkey Point								
	10,432	0.482	Yes	5,028	0		7.42	0
			No	5,404	-2.5	13,510	7.42	100,240
10 km								
	11,946	0.445	Yes	5,316	0		7.42	0
			No	6,630	-3.2	21,216	7.42	157,423
20 km								
	10,115	0.062	Yes	627	0		7.42	0
			No	9,488	-9.0	85,392	7.42	633,608
30 km								
	5,629	0.009	Yes	51	0		7.42	0
			No	5,578	-22.9	127,736	7.42	947,803
River Mouth				Annual Loss of Land (m^2)		247,854		
					Annual Diffluence Soil Volume(m^3)			1,839,074

Note: "－" in secular change means erosion.

Source: JICA Study Team

As the result, annual land loss of the right bank is quite large: 24.7 Ha. The related diffluence soil volume is briefly estimated as 1.83 million m^3 per year.

The following is the result for the left bank.

Table 6-3: Estimation of Annual Diffluence Soil Volume from Left Riverbank Erosion

Range	*Length of Riverbank (m)*	*Coverage Ratio*	*Riparian Forest*	*Distance (m)*	*Annual Secular Change (m)*	*Loss of Land (m^2/year)*	*Cliff Height (m)*	*Diffluence Soil (m^3/year)*
Monkey Point								
	10,583	0.738	Yes	7,810	0		7.42	0
			No	2,773	-2.5	6,932	7.42	51,439
10 km								
	10,936	0.662	Yes	7,240	0		7.42	0
			No	3,696	-3.1	11,457	7.42	85,015
20 km								
	11,343	0.534	Yes	6,057	0		7.42	0
			No	5,286	-4.9	25,901	7.42	192,188
30 km								
	5,265	0.157	Yes	827	0		7.42	0
			No	4,438	-7.3	32,397	7.42	240,388
River Mouth					Annual Loss of the Land (m^2)	76,687		
						Annual Diffluence Soil Volume (m^3)		569,030

Note: "－" in secular change means erosion.

Source: JICA Study Team

Per the above result, the left bank loses about 7.6 Ha of land annually, which is almost 1/3 of the right bank, and the related diffluence soil volume is 0.56 million m^3 per year.

Consequently, the total lost area of the riverside land caused by riverbank erosion is about 32 Ha per year and it is equal to half the area of Kan Daw Gyi Lake in Yangon. Related to the land loss by erosion, the annual diffluence soil volume is about 2.4 million m^3 and such a large volume is diffluent to the downstream of the Yangon River.

Chapter 7: Results of the Examinations

The following are confirmed as the results of the examinations.

Examination Results

- A certain large scale of riverbank erosion can be seen especially from the Thilawa Area to the downstream side, and the erosion speed is in an increasing tendency after the 1930s.
- The erosional trend is bigger as it gets closer to the river mouth and the erosion along the right bank is about 3 times bigger than that of the left bank.
- The right riverbank near the river mouth recedes 22 m/year and the left bank near the river mouth recedes 7 m/year according to the satellite images analysis. So, the river mouth is getting wider by about 30 m in total every year.
- The loss of land caused by the riverbank erosion is about 32 Ha, which is equal to half of Kan Daw Gyi Lake in Yangon and it brings about 2.4 million m^3 of annual diffluence soil volume, according to the satellite images analysis.
- The Yangon River mouth is getting wider since 1904 and it is in an increasing tendency according to the examination results.
  - For 26 years from 1904 to 1930: 7 m/year of erosion
  - For 44 years from 1930 to 1974: 18 m/year of erosion
  - For 41 years from 1974 to 2015: 25 m/year of erosion

  As the result of satellite images analysis for about 10 years done in this examination, 29 m/year of the river mouth widening can be seen.

  Also, the river bed is getting shallower since 1904. That is:
- According to the Chart Map in 1904, the Yangon River from Monkey Point to Elephant Point had CD-10 m consecutively. On the other hand, our survey results in both pre- and post-rainy season show generally CD-6 m all over the same area. Almost 4 m difference between 1904 and 2015 can be seen.

Speculation on the Reasons for the Riverbank Erosion

- There is a possibility resulted from the increasing river flow volume caused by the increased torrential rain fall, which is brought on by world climate change.
- There is a possibility resulted from bad influences from seasonal wind and waves.
- There is a possibility resulted from the increasing river flow volume caused by decreasing water-holding capacity of the upper land, which is a human disaster.
- A possibility resulted from the other human disaster caused by ship waves created by cargo vessels, which are gradually increasing in size, and the traffic volume is more often due to Myanmar's recent increasing cargo demand.

Chapter 8: Recommendations

Our examinations showed that the riverbank lines are receding 30 m annually due to riverbank erosion. Until the time of the 1930s, both riverbanks of the Rangoon River were stable and several sensitive natural conditions were balanced but the balance was lost for some reason(s) and the riverbank erosion was started. Recently, the collisional speed is increasing. It has arisen from not only natural hazards but also human disasters, probably.

Recently, worldwide climate change is problematic. In Japan, the amount of torrential rainfall is dramatically increasing currently and it is regarded as one of the influences of climate change. In Myanmar, normally cyclones go to the west but a particular cyclone, Nargis, went to the east in 2008 and brought a huge casuality of over 130,000 people, mainly in the Yangon River basin. It is important for Myanmar to make efforts to decrease damages caused by such disasters.

The Yangon River is a big river. To know the mechanism of such a big river, data was collected from several surveys and monitoring / observation is essential and it is important to collect the data continuously. Consecutive data accumulation over 10 years or more would be good material for further examinations and analyses for the better operation and maintenance and the improvement of the Yangon River Channel.

In this opportunity, this examination was conducted as a supplement of the Study, within a limited work range as a part of collecting existing information, and only a part of the current situation of the Yangon River could be seen in this time. However, the erosional collapse, especially along the right riverbank, is clearly seen and it means that the riverside land is vanishing, many paddy fields and villages are disappearing day by day.

To confirm the reasons of the collapse, further study and analyses are necessary but some possible reasons could be seen. Those arose from not only natural hazards caused by worldwide climate change but also human disasters like ship waves and the decreasing of natural forest.

This issue happening in the Yangon River is very important not only for maintaining the Yangon River Channel but also for multiple sectors like disaster prevention, the natural environment, agriculture, and so on. Therefore, further study and analysis to investigate the reason and to find countermeasures should be done as early as possible.

Attachment 1: Samples of Satellite Image Analysis

Based on the results of the field surveys, the satellite image analysis was conducted. The land use was basically catabolized into the following four items: 1) untouched yard, 2) grass field, 3) riparian forest, and 4) agricultural use.

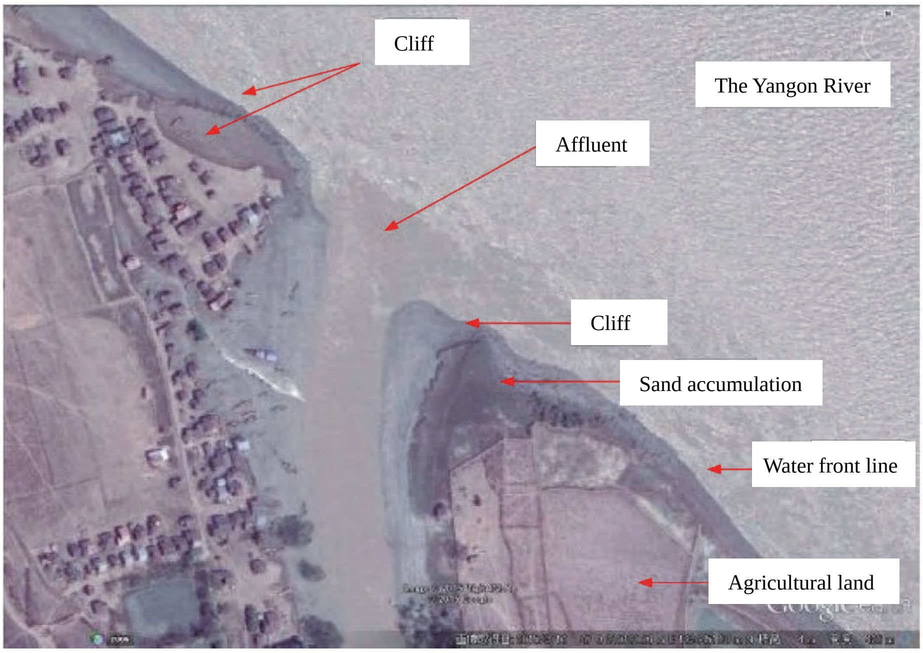
Source: Google Earth (The image is as of Feb. 10, 2015. The upper picture is upstream side)

Attachment Figure 1-1: A Satellite Image of the Right Bank near the River Mouth

The above picture shows a part of the right riverbank of the Yangon River near the river mouth. The cliff line can be identified based on the shadow. A part of the cliff has only one step but the other place has two steps. The area of simple gray colour with fine texture would be the natural accumulation of the river sand and it would be untouched land.

The following image shows a part of the right riverbank of the Yangon River near the river mouth as well but in a different part from the above location. In the centre of the image, there is an affluent. Both banks of the affluent have no cliff but the gentle-sloped banks can be seen. On the other hand, the riverbank of the Yangon River has a cliff type with one and / or two steps in the middle. This affluent has no major riparian forest but basically all other affluents have forest along both riverbanks.

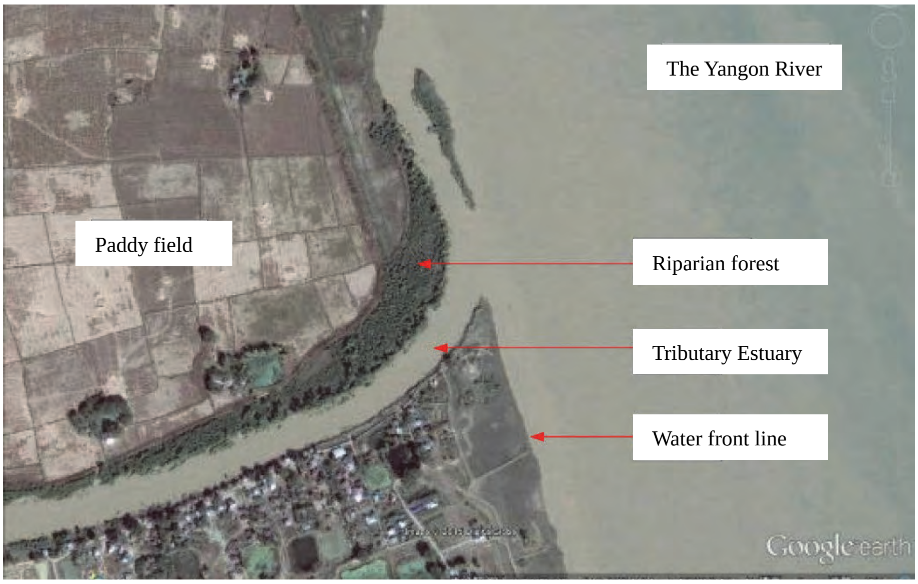
There is no clear ridge in the agricultural land so it is used for paddy fields. In the tributary estuary, a sloped riverbank can be seen along the downstream side and it shows a part of darker gray coloured and which is probably caused by wetness from river water, so the picture was likely taken in lower tide.



Source: Google Earth (The image is as of Mar. 10, 2015. The upper picture is upstream side)

Attachment Figure 1-2: A Satellite Image of the Right Bank in Lower Tide

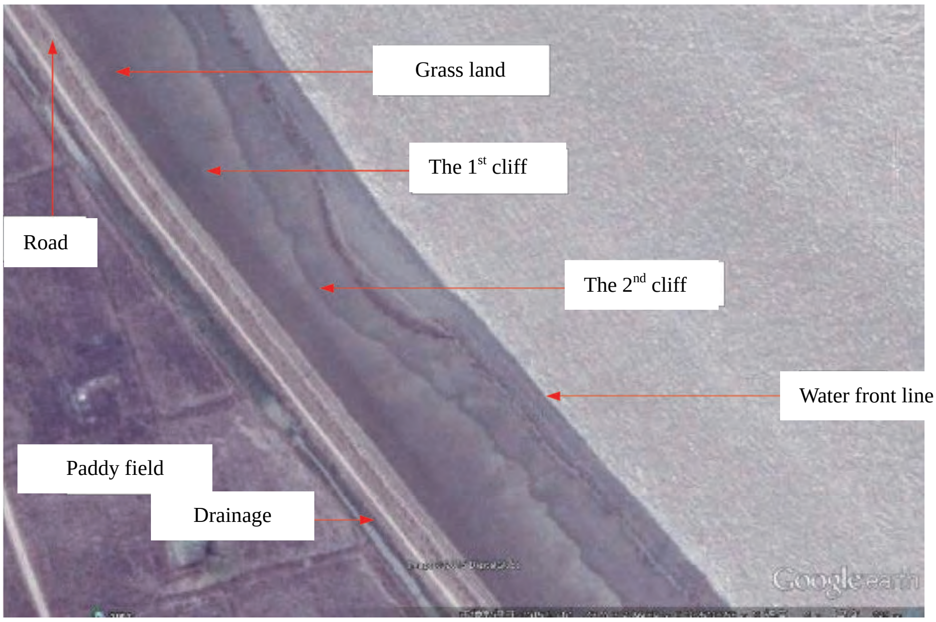
The following image shows a different tributary estuary and it was taken in higher tide. The river water is not clean so it makes it difficult to identify the shape of the riverbank. As for the upper side of the riverbank, a riparian forest can be seen. The farther left side is used for agricultural purposes but there is no clear ridge so it would be used for paddy fields.



Source: Google Earth (The image is as of Dec. 31, 2014. The upper picture is of the upstream side)

Attachment Figure 1-3: A Satellite image of the Right Bank in Higher Tide

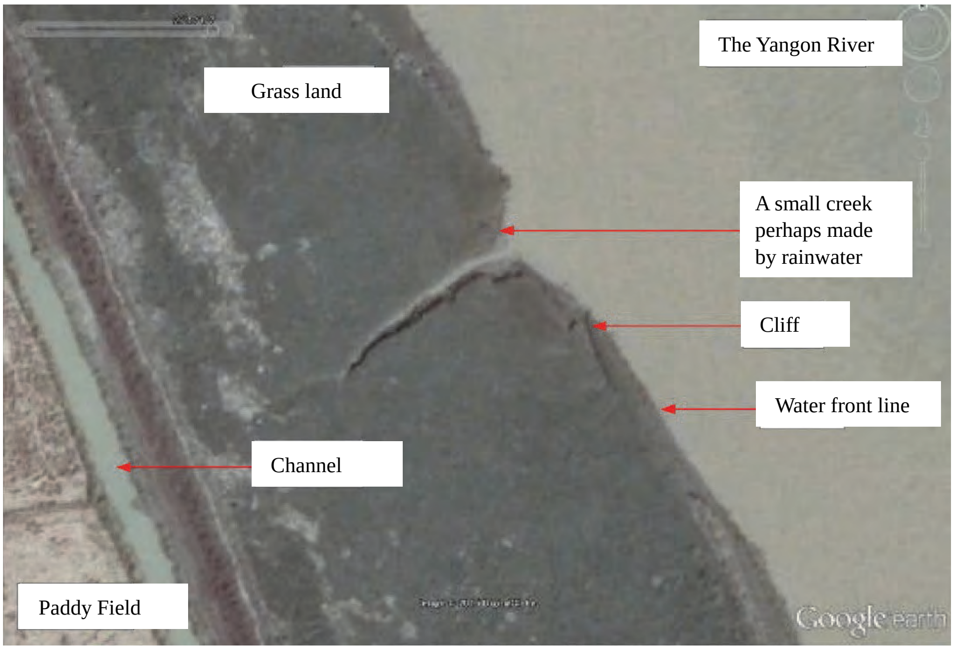
The next figure shows 2 steps in a cliff. In the middle of the image, a recessed area can be seen and it would be the result of blocked land settlement.



Source: Google Earth (The image is as of Mar. 10, 2015. The upper picture is of the upstream side)

Attachment Figure 1-4: Satellite image Showing the Two Steps on the Right Bank

It is not cleared but the part between the 1st cliff and the road would be grass land. Drainage at the roadside can be seen. Considering the long distance from the water line to the cliff top edge, the picture would have been taken in lower tide.



Source: Google Eart h(The image is as of Dec. 31, 2014. The upper picture is of the upstream side)

Attachment Figure 1-5: Satellite image of the Right Bank

The above figure shows a part of the right bank and there is a small creek which was probably made by rainwater flow. The outlet of the creek is recessed and it would be made due to the stream of creek water especially in the rainy season. The paddy field can be seen on the left side of the image and an irrigation channel (or drainage) also can be confirmed in the north-south direction. Considering that the river water can be seen in the channel, the image was taken in higher tide.

Attachment 2: Satellite Image Analysis of Each Monitoring Point

In this chapter, the detailed results of satellite image analysis to calculate the secular change of the riverbank described in the Chapter 4 are shown in the following.

Point A indicates a part of the village located a little upstream of Elephant Point. Three satellite images—from March 23, 2006, February 10, 2010, and February 3, 2014—were selected from Google Earth. The centre road alignment did not change during the period but it was confirmed that many houses shifted farther to the land side due to the recession of the riverbank line.

Legend: -2006 -2010 -2014
Source: JICA Study Team

Attachment Figure 2-1: Secular Change at Point A (Section 2~3)

The following table shows the calculation results of the secular change at Point A.

Attachment Table 2-1: The Calculation Results of the Secular Change at Point A

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Mar. 23, 2006	*Feb.3, 2014*
1	-67.8	105	-0.646	-7.7	No	No
2	-63.7	105	-0.607	-7.3	No	No
3	-55.7	105	-0.530	-6.4	No	No
4	85.4	105	-0.813	-9.8	No	No
5	80.9	105	-0.770	-9.2	No	No
			Total	-40.4		
			Average	-8.1	No	No

Note: "—" means the erosional trend.
Source: JICA Study Team

As per the above result, the secular change of the riverbank line at Point A is in the erosional trend and the amount is 8.1 m/year on average.

Point B is a little on the upper side of Point A and 4 satellite images—on November 25, 2003, as of March 23, 2006, February 10, 2010 and December 31, 2014—were selected from Google Earth. The line of the cliff top edge, roads, and boundaries of the agricultural area and so on were traced from these images.

Legend: -2003 -2010 -2006 -2014
Source: JICA Study Team

Attachment Figure 2-2: Secular Change at Point B (Section 1~3)

The following Table shows the calculation results of the secular change at Point B.

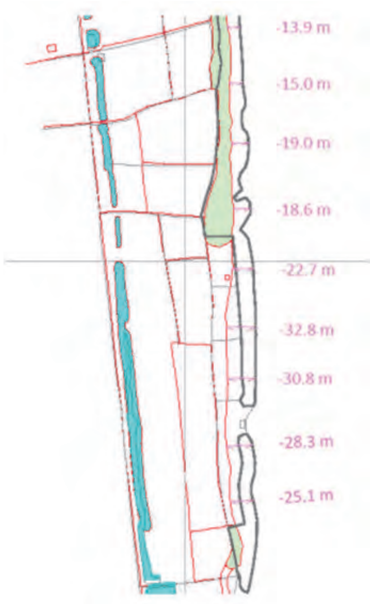
Attachment Table 2-2: The Calculation Results of the Secular Change at Point B

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov.25, 2003	*Dec.31, 2014*
1	-95.4	133	-0.717	-8.6	No	No
2	-108.7	133	-0.827	-9.8	No	No
3	-100.7	133	-0.757	-9.1	No	No
4	-101.8	133	-0.765	-9.2	No	No
5	-93.4	133	-0.702	-8.4	No	No
			Total	-45.1		
			Average	-9.0	No	No

Note: "—" means the erosional trend.
Source: JICA Study Team

As shown in the above Figure, a recessed area can be seen in each year and the area would have softer subsoil or would be a part of rain water catchment so is easy to get erosion. As the result of the above calculation, the secular change of the riverbank line at the point B is in the erosional trend and the amount is 9.0 m/year on average.

The Point C is located in the relatively long straightened right bank with about 4 km. 2 satellite images, on November 25, 2003 and December 31, 2014, were selected from Google Earth. The line of the cliff top edge, roads, houses and boundaries of agricultural area and so on were traced from these images. Also, secular change of the area of the riparian forest was traced.



Legend: -2003 -2014 **-bold line: Area of riparian forest in 2003** ■ Area of riparian forest in 2014
Source: JICA Study Team

Attachment Figure 2-3: Secular Change at Point C (Section 4~12)

The following table shows the calculation results of the secular change at the Point C. According to the results, there was a riparian forest with 30~40 m width in November 25, 2003 but the area decreased in December 31, 2014.

As the results of the calculation, the secular change of the riverbank line at the point C is in the erosional trend and the amount is 3.2 m/year on average.

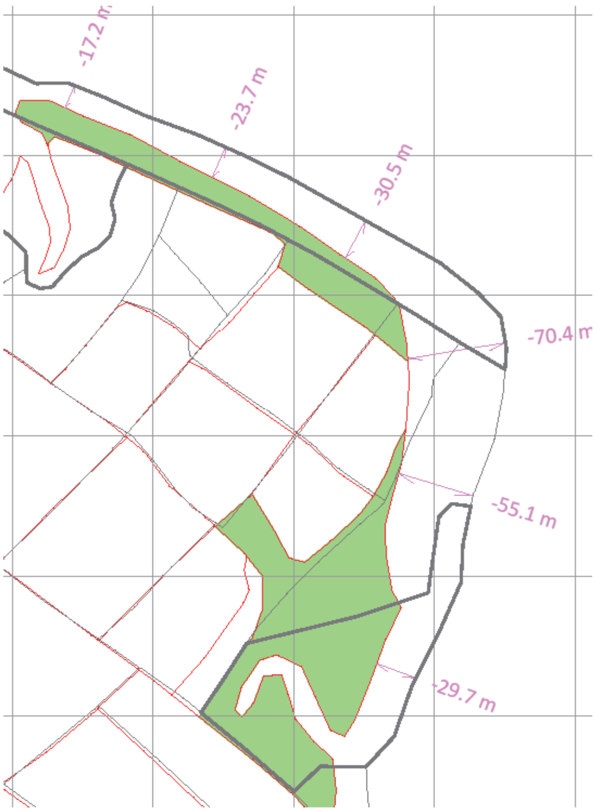
Attachment Table 2-3: The Calculation Results of the Secular Change at Point C

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov.25, 2003	*Dec.31, 2014*
1	-15.2	133	-0.114	-1.4	Yes	Yes
2	-19.2	133	-0.144	-1.7	Yes	Yes
3	-14.8	133	-0.111	-1.3	Yes	Yes
4	-13.9	133	-0.105	-1.3	Yes	Yes
5	-15.0	133	-0.113	-1.4	Yes	Yes
6	-19.0	133	-0.143	-1.7	Yes	Yes
7	-18.6	133	-0.140	-1.7	Yes	Yes
			Total	-10.4		
			Average	-1.5	Yes	Yes
8	-22.7	133	-0.171	-2.0	Yes	yes
9	-32.8	133	-0.247	-3.0	Yes	No
10	-30.8	133	-0.232	-2.8	Yes	No
11	-28.3	133	-0.213	-2.6	Yes	No
12	-25.1	133	-0.189	-2.3	Yes	No
			Total	-12.6		
			Average	-2.5	Yes	No
13	-34.6	133	-0.260	-3.1	Yes	No
14	-34.3	133	-0.258	-3.1	Yes	No
15	-43.8	133	-0.329	-4.0	Yes	No
16	-54.0	133	-0.406	-4.9	Yes	No
17	-41.8	133	-0.314	-3.8	Yes	No
18	-39.9	133	-0.300	-3.6	Yes	No
			Total	-22.4		
			Average	-3.7	Yes	No
19	-28.6	133	-0.215	-2.6	Yes	Yes
20	-37.0	133	-0.278	-3.3	Yes	Yes
21	-16.1	133	-0.121	-1.5	Yes	Yes
22	-40.8	133	-0.307	-3.7	Yes	Yes
23	-34.7	133	-0.261	-3.1	Yes	Yes
24	-30.0	133	-0.226	-2.7	Yes	Yes
			Total	-16.9		
			Average	-2.8	Yes	Yes
Yes	Yes	Yes	Yes	Yes	Yes	Yes
25	-23.6	133	-0.177	-2.1	Yes	Yes
26	-23.6	133	-0.177	-2.1	Yes	Yes
27	-17.7	133	-0.133	-1.6	Yes	Yes
28	-15.4	133	-0.116	-1.4	Yes	Yes
29	-20.8	133	-0.156	-1.9	Yes	Yes
30	-22.3	133	-0.168	-2.0	Yes	Yes
31	-16.6	133	-0.125	-1.5	Yes	Yes
			Total	-12.6		
			Average	-1.8	Yes	Yes
32	-14.4	133	-0.108	-1.3	Yes	Yes
33	-13.8	133	-0.104	-1.2	Yes	Yes
34	-14.8	133	-0.111	-1.3	Yes	Yes
35	-15.5	133	-0.117	-1.4	Yes	Yes
36	-11.9	133	-0.089	-1.1	Yes	Yes
37	-8.4	133	-0.063	-0.8	Yes	Yes
38	3.0	133	0.023	0.3	Yes	Yes
39	-6.0	133	-0.045	-0.5	Yes	Yes

40	-9.2	133	-0.069	-0.8	Yes	Yes
41	-5.1	133	-0.038	-0.5	Yes	Yes
42	3.3	133	0.025	0.3	Yes	Yes
43	3.4	133	0.026	0.3	Yes	Yes
44	-4.9	133	-0.037	-0.4	Yes	Yes
45	-14.1	133	-0.106	-1.3	Yes	Yes
46	3.4	133	0.026	0.3	Yes	Yes
47	5.5	133	0.041	0.5	Yes	Yes
48	8.0	133	0.060	0.7	Yes	Yes
			Total	-8.3		
			Average	-0.5	Yes	Yes
		Average		-3.2	Yes	No
				-1.3	Yes	Yes

Note: "—" means the erosional trend.
Source: JICA Study Team

Point D is located at the sharp bend of the right bank where it is almost the opposite bank of the Thilawa Area. Two satellite images, from November 25, 2003 and April 10, 2015, were selected from Google Earth. The line of the cliff top edge, roads, and the riparian forest areas were traced.



Legend: -2003 -2015 -**Bold line: Area of riparian forest in 2003** Area of riparian forest in 2015
Source: JICA Study Team

Attachment Figure 2-4: Secular Change at Point D (Section 1~6)

As per the results of the comparison of the 2 images, it can be seen that the area of the riparian forest decreases together with the recession of the riverbank. The following table shows the calculation results of the secular change at Point D.

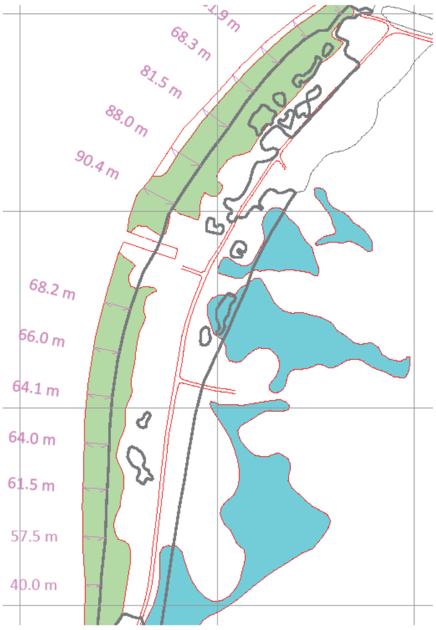
Attachment Table 2-4: The Calculation Results of the Secular Change at Point D

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov. 25, 2003	*Apr.10, 2015*
1	-17.2	148	-0.116	-1.4	Yes	Yes
2	-23.7	148	-0.160	-1.9	Yes	Yes
3	-20.5	148	-0.139	-1.7	Yes	Yes
4	-70.4	148	-0.476	-5.7	Yes	Yes
5	-55.1	148	-0.372	-4.5	Yes	Yes
6	-29.7	148	-0.201	-2.4	Yes	Yes
7	-27.0	148	-0.182	-2.2	Yes	Yes
			Total	-19.8		
			Average	-2.8	Yes	Yes

Note: "－" means the erosional trend.
Source: JICA Study Team

As per the results of the above calculation, the secular change of the riverbank line at Point D is in the erosional trend and the amount is 2.8 m/year on average.

Point E is located on the left bank of the lower side of the junction point between the Yangon River and the Bago River. The satellite images, from November 25, 2003 and April 10, 2015, were selected from Google Earth. The line of the cliff top edge, roads, houses, ponds, riparian forest areas and boundaries of agricultural areas were traced from these images.



Legend: -2003 -2015 -**bold line: Area of riparian forest in 2003** ■ **Area of riparian forest in 2015**

Source: JICA Study Team

Attachment Figure 2-5: Secular Change at Point E（Section 3~14）

This area shows the accumulation tendency. Although the width of the riparian forest gets thinner, it still remains.

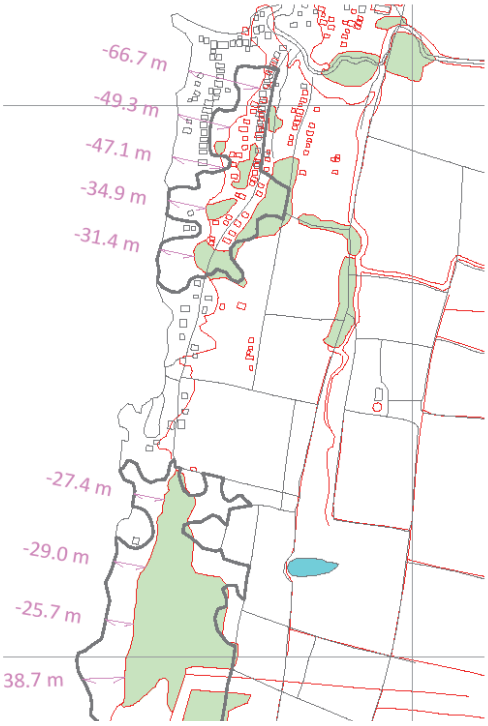
Attachment Table 2-5: The Calculation Results of the Secular Change at Point E

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov. 25, 2003	*Dec.31, 2014*
1	+52.0	136	+0.382	+4.6	Yes	Yes
2	+56.3	136	+0.414	+5.0	Yes	Yes
3	+61.9	136	+0.455	+5.5	Yes	Yes
4	+68.3	136	+0.502	+6.0	Yes	Yes
5	+81.5	136	+0.599	+7.2	Yes	Yes
6	+88.0	136	+0.647	+7.8	Yes	Yes
7	+90.4	136	+0.665	+8.0	Yes	Yes
8	+68.2	136	+0.501	+6.0	Yes	Yes
9	+66.0	136	+0.485	+5.8	Yes	Yes
10	+64.1	136	+0.471	+5.7	Yes	Yes
11	+64.0	136	+0.471	+5.6	Yes	Yes
12	+61.5	136	+0.452	+5.4	Yes	Yes
13	+57.5	136	+0.423	+5.1	Yes	Yes
14	+40.0	136	+0.294	+3.5	Yes	Yes
			Total	+81.2		
			Average	+5.8	Yes	Yes

Note: "+" means the accumulation trend.
Source: JICA Study Team

As per the results of the above calculation, the secular change of the riverbank line at Point E is in the accumulation trend and the amount is 5.8 m/year on average.

Point F is located a little to the lower side of the Thilawa Area. Two images, from November 25, 2003 and March 9, 2015, were selected from Google Earth. The line of the cliff top edge, roads, houses, a pond, riparian forest area and boundaries of agricultural areas were traced.



Legend: -2003 -2015 -Bold line: Area of riparian forest in 2003 ■ Area of riparian forest in 2014
Source: JICA Study Team

Attachment Figure 2-6: Secular Change at Point F (Section 1~9)

Three types of change of the riparian forests are confirmed. The first is both images have the forest, the second is both have no forest and the third is the forest was disappeared in 2014. The following calculations were done for each type, respectively.

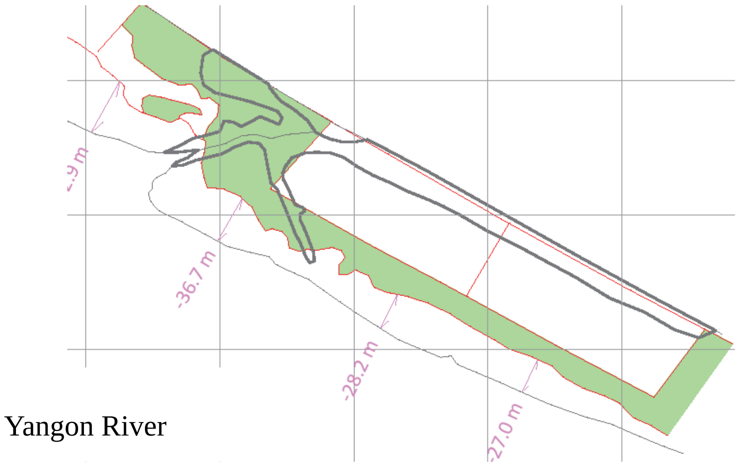
Attachment Table 2-6: The Calculation Results of the Secular Change at Point F

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov. 25, 2003	*Dec. 31, 2014*
1	-66.7	135	-0.494	-5.9	No	No
2	-49.3	135	-0.365	-4.4	No	No
3	-47.1	135	-0.349	-4.2	No	No
			Total	-14.5		
			Average	-4.8	No	No
4	-34.9	135	-0.259	-3.1	Yes	No
5	-31.4	135	-0.233	-2.8	Yes	No
			Total	-5.9		
			Average	-2.9	Yes	No
6	-27.4	135	-0.203	-2.4	Yes	Yes
7	-29.0	135	-0.215	-2.6	Yes	Yes
8	-25.7	135	-0.190	-2.3	Yes	Yes
9	-38.7	135	-0.2287	-3.4	Yes	Yes
			Total	-10.7		
			Average	-2.7	Yes	Yes
10	-23.6	135	-0.175	-2.1	No	No
11	-37.7	135	-0.279	-3.4	No	No
12	-21.9	135	-0.162	-1.9	No	No
13	-13.7	135	-0.101	-1.2	No	No
14	-51.3	135	-0.380	-4.6	No	No
15	-36.1	135	-0.267	-3.2	No	No
16	-23.2	135	-0.172	-2.1	No	No
17	-17.8	135	-0.132	-1.6	No	No
18	-20.2	135	-0.150	-1.8	No	No
			Total	-21.8		
			Average	-2.4	No	No
19	-26.3	135	-0.195	-2.3	No	No
20	-34.3	135	-0.254	-3.0	No	No
21	-42.1	135	-0.312	-3.7	No	No
22	-40.3	135	-0.299	-3.6	No	No
23	-34.1	135	-0.253	-3.0	No	No
			Total	-15.7		
			Average	-3.1	No	No
				-3.1	No	No
			Average	-2.9	Yes	No
				-2.7	Yes	Yes

Note: "－" means the erosional trend.
Source: JICA Study Team

As per the results of the above calculations, all types are in erosional trend. In the case that both have forest, the amount is 2.7 m/year on average. In the case that both have no forest, the amount is 3.1 m/year on average. In the case that the forest was lost, the amount is 2.9 m/year on average and no big difference could be found among the 3 types.

There is a sand bank near the river mouth of the Yangon River. Point G was located just to the east of the opposite bank of the sand bank and a little downstream of a tributary estuary. Two images, from March 23, 2006 and February 3, 2014, were selected from Google Earth. The line of the cliff top edge, roads, houses, ponds, riparian forests and boundaries of agricultural areas were traced from these images.



Legend: -2006 -2014 -Bold line: Area of riparian forest in 2006 ■ Area of riparian forest in 2014
Source: JICA Study Team

Attachment Figure 2-7: Secular Change at Point G (Section 12~15)

Some parts of this area had riparian forest from 2006 to 2014 but a part was found in 2014 to have been recently forested, although it had no forest in 2006. So the following calculations were conducted in each trend of the forest, respectively, same as for Point F.

Attachment Table 2-7: The Calculation Results of the Secular Change at Point G

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Mar. 23, 2006	*Feb. 3, 2014*
1	-38.6	109	-0.354	-4.2	No	No
2	-38.7	109	-0.355	-4.3	No	No
3	-33.8	109	-0.310	-3.7	No	No
4	-33.9	109	-0.311	-3.7	No	No
5	-41.7	109	-0.383	-4.6	No	No
			Total	-20.6		
			Average	-4.1	No	No
6	-42.5	109	-0.390	-4.7	No	No
7	-55.4	109	-0.508	-6.1	No	Yes
8	-50.1	109	-0.460	-5.5	No	Yes
9	-56.3	109	-0.517	-6.2	No	No
10	-73.4	109	-0.673	-8.1	No	No
			Total	-30.6		
			Average	-6.1		
11	-43.5	109	-0.399	-4.8	No	No
12	-42.9	109	-0.394	-4.7	No	No
13	-36.7	109	-0.337	-4.0	No	Yes
14	-28.2	109	-0.259	-3.1	No	Yes
15	-27.0	109	-0.248	-3.0	No	Yes
			Total	-19.6		
			Average	-3.9		
			Average	-4.9	No	No
				-4.3	No	Yes

Note: "－" means the erosional trend.
Source: JICA Study Team

As per the results of the above calculations, basically all areas are in an erosional trend. In the case that both images have riparian forest, the amount is 4.1 m/year on average. In the case that the forest was newly found in 2014, the amount is 4.9 m/year on average.

Point H is located on the left bank near the river mouth of the Yangon River. The images, from February 10, 2010 and March 10, 2015, were selected from Google Earth. The line of the cliff top edge, roads, houses, riparian forests, and boundaries of agricultural areas were traced from these images.

Legend: -2010 -2015 -**Bold line: Area of riparian forest in 2010** ■ **Area of riparian forest in 2015**
Source: JICA Study Team

Attachment Figure 2-8: Secular Change at Point H (Section 1~6)

There is a part where riparian forest can be seen in both years and another part where the forest cannot be seen in the both. The following calculations were conducted for each type, respectively.

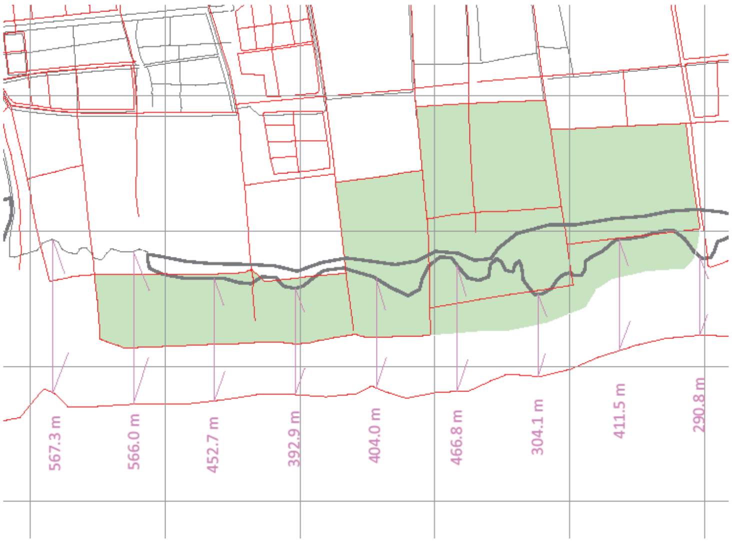
Attachment Table 2-8: The Calculation Results of the Secular Change at Point H

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Feb. 10, 2010	***Mar. 10, 2015***
1	-29.3	61	-0.480	-5.8	No	No
2	-54.7	61	-0.897	-10.8	No	No
3	-56.6	61	-0.928	-11.1	No	No
4	-43.7	61	-0.716	-8.6	No	No
5	-38.9	61	-0.638	-7.7	No	No
6	-18.4	61	-0.302	-3.6	No	No
7	-18.7	61	-0.3-7	-3.7	No	No
			Total	-51.2		
			Average	-7.3	No	No
1	-4.4	61	-0.072	-0.9	Yes	Yes
2	-4.5	61	-0.074	-0.9	Yes	Yes
3	-4.3	61	-0.070	-0.8	Yes	Yes
4	-7.4	61	-0.121	-1.5	Yes	Yes
5	-10.3	61	-0.169	-2.0	Yes	Yes
			Total	-6.1		
			Average	-1.2	Yes	Yes
			Average	-7.3	No	No
				-1.2	Yes	Yes

Note: "－" means the erosional trend.
Source: JICA Study Team

As per the results of the above calculations, both cases with/without riparian forest were in an erosional trend. In the case with the forest, the amount is 1.2 m/year on average and in the case without the forest, the amount is 7.3 m/year on average.

Point I is located on the eastern shore line. The images, from April 20, 2002 and November 20, 2014, were selected from Google Earth. The line of the cliff top edge, roads, riparian forests, and boundaries of fish ponds were traced from these images.



Legend: -2002 -2014 **-Bold line: Area of riparian forest in 2002** **Area of riparian forest in 2014**
Source: JICA Study Team

Attachment Figure 2-9: Secular Change at Point I (Section1~9)

The land in / around Point I just behind the shoreline is used for fish ponds and the shoreline is expanding to the offshore side according to the satellite image analysis. Therefore, this secular change is not natural, but artificial. The sectional shape of the shoreline would be a long gentle slope.

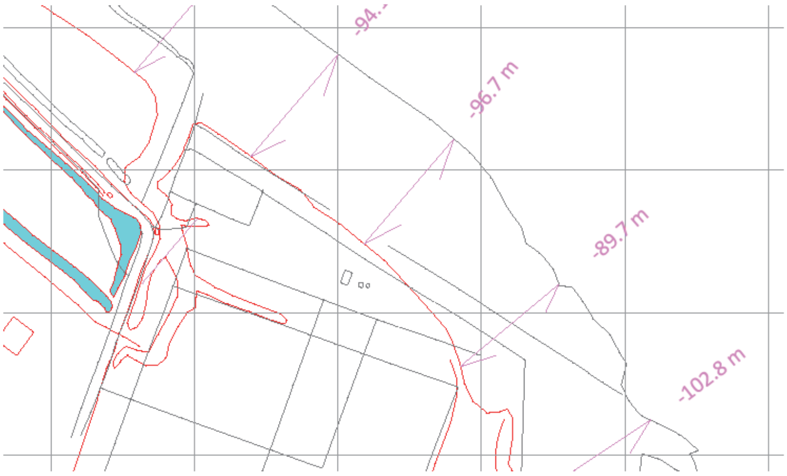
Attachment Table 2-9: The Calculation Results of the Secular Change at Point I

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Apr.20, 2002	*Dec. 20, 2014*
1	+567.3	151	+3.757	+45.1	No	No
2	+566.0	151	+3.746	+45.0	Yes	Yes
3	+452.7	151	+2.998	+26.0	Yes	Yes
4	+392.9	151	+2.602	+31.2	Yes	Yes
5	+404.0	151	+2.675	+32.1	Yes	Yes
6	+466.8	151	+3.091	+37.1	Yes	Yes
7	+304.1	151	+2.014	+24.2	Yes	Yes
8	+411.5	151	+2.725	+32.7	Yes	Yes
9	+290.8	151	+1.926	+23.1	Yes	Yes
10	+248.3	151	+1.644	+19.7	Yes	Yes
11	+171.6	151	+1.136	+13.6	Yes	Yes
12	+285.8	151	+1.893	+22.7	Yes	Yes
			Total	+362.5		
			Average	+30.2		

Note: "+" means the accumulation trend.
Source: JICA Study Team

As per the results of the above calculations, Point I was in an accumulation trend as mentioned before, and the amount is 30.2 m/year on average.

Point J is located at a little downstream of Elephant Point. Two images, from February 10, 2010, and February 10, 2014, were taken from Google Earth but the interval of the two was shorter compared to the other points. Google Earth has not many good quality images. The line of the cliff top edge, roads, and boundaries of agricultural area were traced from these images.



Legend:-2010 -2014
Source: JICA Study Team

Attachment Figure 2-10: Secular Change at Point J (Section 9~12)

Point J is in a larger erosional trend. Although the interval of these 2 pictures at Point J is shorter than the other points, almost half the intervals in other points, the amount of the secular change is larger than the others and it means that Point J has faster erosion compared to the others.

Attachment Table 2-10: The Calculation Results of the Secular Change at Point J

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Mar. 10, 2010	*Dec.31, 2014*
1	-91.2	49	-1.861	-22.3	No	No
2	-92.4	49	-1.886	-22.6	No	No
3	-89.4	49	-1.824	-21.9	No	No
4	-105.5	49	-2.153	-25.8	No	No
5	-86.4	49	-1.763	-21.2	No	No
6	-92.2	49	-1.882	-22.6	No	No
7	-86.6	49	-1.767	-21.2	No	No
8	-96.5	49	-1.969	-23.6	No	No
9	-94.1	49	-1.920	-23.0	No	No
10	-96.7	49	-1.973	-23.7	No	No
11	-89.7	49	-1.831	-22.0	No	No
12	-102.8	49	-2.098	-25.2	No	No
			Total	-275.1		
			Average	-22.9	No	No

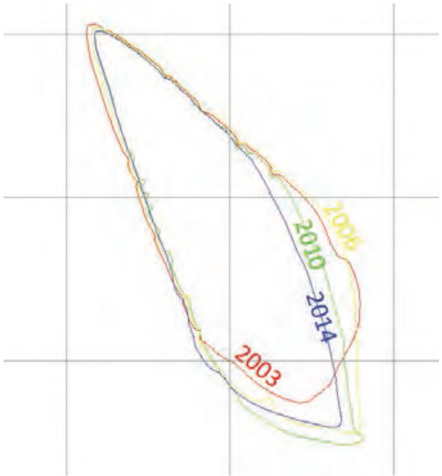
Note: "－" means the erosional trend.

Source: JICA Study Team

As per the results of the above calculations, Point J was in a larger erosional trend as mentioned before, and the amount is 22.9 m/year on average.

Regarding the shorelines of both sides of the river mouth, Google Earth did not have any good quality images for the analysis but it was confirmed that both have a long gentle slope according to the site investigations.

There is a middle bank on the downstream side of the Yangon River. Three images, from November 25, 2003, March 23, 2010, and February 13, 2014, were selected from Google Earth. The lines of roads, and riparian forests were traced from these images.



Source: JICA Study Team

Attachment Figure 2-11: Secular Change at the Middle Bank

Basically the entire island is covered by riparian forest during the above period but part of the middle of the west part (right bank side of the Yangon River) of the island has a cliff. As shown in the above drawing, the upper side of the island has no remarkable change but the middle and lower east side of the island show an erosional tendency. On the other hand, the lower west side shows an accumulation tendency.

Attachment Table 2-11: The Calculation Results of the Secular Change on the Middle bank

Survey Line	*Distance (m)*	*Period (months)*	*Average Change (m/month)*	*Average Change (m/year)*	*Riparian Forest*	
					Nov. 25, 2003	*Feb. 13, 2014*
Lower East Side						
1	-172.0	123	-1.398	-16.8	Yes	Yes
2	-198.3	123	-1.612	-19.3	Yes	Yes
3	-211.1	123	-1.716	-20.6	Yes	Yes
4	-205.8	123	-1.673	-20.1	Yes	Yes
5	-212.3	123	-1.726	-20.7	Yes	Yes
6	-270.9	123	-2.202	-26.4	Yes	Yes
7	-278.5	123	-2.264	-27.2	Yes	Yes
8	-263.6	123	-2.143	-25.7	Yes	Yes
			Total	-176.8		
			Average	-22.1	Yes	Yes
Lower West Side						
1	+101.8	123	+0.828	+9.9	Yes	Yes
2	+128.7	123	+1.046	+12.6	Yes	Yes
3	+116.6	123	+0.948	+11.4	Yes	Yes
4	+105.6	123	+0.859	+10.3	Yes	Yes
5	+100.8	123	+0.820	+9.8	Yes	Yes
6	+134.3	123	+1.092	+13.1	Yes	Yes
7	+227.5	123	+1.850	+22.2	Yes	Yes
			Total	+89.3		
			Average	+12.8	Yes	Yes

Note: "－" means the erosional trend and "+" is the accumulation trend.

Source: JICA Study Team

As per the results of the above calculations, the lower east side of the middle and lower bank were in a larger erosional trend and the amount is 22.1 m/year on average. On the other hand, the lower west side is in an accumulation trend and the amount is 12.8 m/year on average.