Department of Highways
Ministry of Transport
Kingdom of Thailand

PREPARATORY SURVEY REPORT
ON
THE REHABILITATION PROJECT OF THE OUTER BANGKOK RING ROAD
IN
THE KINGDOM OF THAILAND

October 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.
ORIENTAL CONSULTANTS CO., LTD.
NIPPON KOEI CO., LTD.
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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey and entrust the survey to CTI Engineering International Co., Ltd (in joint venture with Oriental Consultants Co., Ltd, Nippon Koei Co, Ltd. and CTI Engineering Co., Ltd).

The survey team held a series of discussions with the officials concerned of the Government of Thailand, and conducted field investigations. Based on the results of the discussions and field investigations, along with further studies in Japan, the survey team has finalized this report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the concerned officials the Government of Thailand for their close cooperation extended to the survey team.

October, 2012

Masami FUWA
Director General,
Global Environment Department
Japan International Cooperation Agency

October 2012

Letter of Transmittal

We are pleased to submit to you the preparatory survey report on the rehabilitation project of the outer Bangkok ring road in the Kingdom of Thailand.

This study was conducted by CTI Engineering International Co., Ltd. (in joint venture with Oriental Consultants Co., Ltd., Nippon Koei Co., Ltd. and CTI Engineering Co., Ltd.) under a contract with JICA, during the period from December 2011 to October 2012. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of the Philippines and formulated the most appropriate basic design for the project under Japan's Grant Aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

MISHINA Takahiro
Project manager,
Preparatory Survey team on the rehabilitation
project of the outer Bangkok ring road
in the Kingdom of Thailand

SUMMARY

(1) Country Overview

The Kingdom of Thailand is located at the centre of the Indochina peninsula in Southeast Asia. It is bordered to the north by Burma and Laos, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and the southern extremity of Myanmar. Geographic coordinates is from 5.00 to 21.00 N and from 97.00 to 106 E.

The country has an area of approximately 513,115square kilometers (km2). For economic, social and ecological reasons, Thailand is usually classified into five geographical regions.

They are: the central region (including Bangkok Metropolitan Region) comprising the basin of the Chao Phraya River which runs from north to south and after crossing Bangkok flows to the Gulf of Thailand. The northern region, mountainous and was traditionally the most heavily forested area of the country. The north-eastern region constitutes approximately one third of the area of the Kingdom and comprise the Korat Plateau which is bounded on the north and east by the Mekong River and the south by the Dongrek escarpment. The south-eastern, which comprises the hilly countryside from Bangkok to the Cambodian border, is characterized by higher rainfall and poorer solids than the adjoining central region. The southern region has highest rainfall in the country.

In terms of climate, located outside the typhoon belt, Thailand can be divided into two climatic zones. The north, north-east and central regions including Bangkok have a climate with three distinct seasons: rainy, from mid-May to October; cool, from November to February; and hot with highest temperatures and sunny weathers from March to May. The average annual rainfall in these regions is 1,500 mm. The southern region has a characteristic tropical rainforest climate. Rainfall occurs virtually throughout the year, although a number of micro-climates can be found. The longest distance in national land is 1,860km, and difference in latitude between north and south is 14 degree. Therefore, it shows various weather changes according to the district though the climate is the same. There is little variation in temperature, which is on average 29C throughout the year. March and April are normally the driest months in the south and the periods of maximum rainfall in these areas vary according to climatic sub-regions.

The total population of Thailand is 65.5million (as of September 2010). Local ethnic is mostly composed of Thai ethnic. Although the Chinese, which is the second –largest ethnic living in Thailand, has become localized in recent years, it has not caused any serious ethnic problems so far. Malay ethnic lives in southern 4 prefectures and most of them are Muslim.

Thai and English are used as public language. Buddhism and Muslim are two major religions. 94 percent (%) of the population is Buddhists and 5% Muslims.

GDP per capita of Thailand in 2011 is 4,972 US dollar (source : world bank). The percentage of the population engaged in agriculture is 40 and their GDP stays at 12%. Whereas, the percentage of workers in the manufacturing sector is 15, however, their GDP accounts for 34% of all. The government of Thailand (hereinafter referred to as GOT) has promoted industrialization policy and export by direct investment from abroad, including Japan, and achieved rapidly the economic development from the late 80's. Although Thailand was appearing aspect to be bubble economy due to inflow of money from foreign countries, the inconsistency between the inflow and monetary policy by dollar-peg system was expanded. International professional speculator sold baht with pointing out the inconsistency, GOT introduced floating rate system in July 1997. The baht was extensively sold due to the floating rate system. Such a movement spread to other Asian countries, and became a cause for the occurrence of the Asian economic crisis. Receiving support of the global community including IMF and Japan, afterwards, Thailand recovered from its slumping economy from performing an effort of the economic rebuilding such as disposal of bad

loans. In addition to a conventional export promotion policy, it proposed a promotion plan of a farm village and the medium and small-sized business in order to take domestic demand as power of traction of the economy. By effect of expansions of domestic demand policies, the economy continued relatively high growth until about 2007. On receiving the effect of foreign demand decline due to the world economy crisis in the wake of Lehman shock in 2008, the economy remained sluggish. The growth rate of 2009 and 2010 were observed to be as low as 2.5% and -2.3% respectively. In contrast to this, Thailand supported its economy by implementing the stimulus measures under large-scale government spending. After that, the economy of Thailand was restored with the economic recovery of the overseas export market, and recorded 7.8% of growth rates (the agriculture, forestry and fisheries industry: -2.3%, Non- the agriculture, forestry and fisheries industry: 8.8%).

(2) Project Background and Outline

The Kingdom of Thailand (hereinafter referred to as "GOT") suffered from a flood in year 2011, which is said to be "the worst recorded flooding yet in terms of the volume of water and damages inflicted to the people/property", which was caused by the incessant rainfall that started in July. Flooding soon spread through the provinces of North, Northeastern and Central Thailand along the Chao Phraya river basins, having a catchment area of approximately 160,000 km2. In October, floodwaters reached the Chao Phraya and inundated parts of the capital city of Bangkok. Sixty five of Thailand's 77 provinces were declared flood disaster zones, and approximately 17,000 km2 of farmland was damaged. Flooding persisted in some areas until mid-January 2012, and took away lives of 446 peoples and more than 3.2 million people in 25 provinces were severely affected.

Fully aware of the significant impacts from the floods, the government set up the Strategic Committee for Water Resource Management (SCWRM). Later on, the SCWRM formulated the Master Plan on Sustainable Water Resource Management for both urgent and long term, in order to ensure the continuity of the country's development even with future droughts and floods. The SCWRM has adopted the King's initiatives and the Philosophy of Sufficiency Economy as guiding principles in drafting the Master Plan.

The Master Plan on Water Resource Management consists of 2 action plans, which are; (a) Action Plan of Water Management for the Urgency Period, that is set as short term goal to reduce the loss and damage caused by the flood in 2011, and (b) Action Plan of Integrated and Sustainable Flood Mitigation in the Chao Phraya Floodplain, that is set as long term goal to improve overall and sustainable flood management system in floodplain of Chao Phraya River. The details of the Plans are as follows:

(a) Action Plan of Water Management for the Urgency Period

Action Plan of Water Management for the Urgency Period in response to the possible future flood in 2012. The key principle of this Action Plan is to reduce losses and damages due to flood, and to minimize the economic and social impacts. There are 6 main work plans. The outline is shown in Table 1.

(b) Action Plan of Integrated and Sustainable Flood Mitigation in the Chao Phraya Floodplain

"Action Plan of Integrated and Sustainable Flood Mitigation in the Chao Phraya Floodplain" in which the upper stream, mid stream and downstream of the river basin is taken into account. The action plan for upper stream/river basin therefore, should focus on regulation/reduction of the velocity of the current while the mid and the downstream of the river basin should focus on restoration and drainage respectively. The Action Plan of Integrated and Sustainable Flood Mitigation in Chao Phraya River Basin will be implemented in 2012 and onwards with total

amount of the budget estimated at 340 billion baht.

In the transportation sector, the damages caused to the roads by the flood together with the dysfunctions of the existing transportation network resulted from the closure of the objective road segment due to inundation by the flood is having severe impact on the economy of Thailand. Therefore, not only the restoration or rehabilitation works, but also measures for securing sustainable logistic network during flooding has become the urgent issue of the GOT.

Under such circumstances, the government of Japan (hereinafter referred to as GOJ) dispatched the survey team since October 19th 2011, to investigate the impact of the flood and to analyze the potential assistance for restoration and rehabilitation from the damages. In due course, GOT expressed its expectation to Japan International Cooperation Agency (hereinafter referred to as JICA), due to the fact that JICA had prepared a master plan under "The Study on Integrated Plan For Flood Mitigation in Chao Phraya River Basin" from 1996 to 1999 for flood control around Chao Phraya river basin surrounding industrial estates in Ayutthaya and Bangkok, to reanalyze the master plan based on urbanization, industrialization, and climate change that was not assumed in the initial master plan.

In response to the request from the GOT, the GOJ decided to conduct a Project, "Comprehensive Flood Management Plan for the Chao Phraya River Basin" (hereinafter referred to as "the umbrella project") that commenced in November, 2011. The project consists of (i) Comprehensive flood management plan (Component 1), (ii) Outline design for Japanese Grant Aid (Component 2) and (iii) Pilot Projects for emergency rehabilitation (Component 3), since November 2011. Among those projects, Component 2 is expected to be the disaster prevention and restoration grant aid project.

The importance of this project to be implemented under the grant aid scheme of Japan was confirmed by both the GOJ and the GOT during the field work and survey carried out in cooperation with the counterparts in January 2012.

The objective of the project is to secure the function of logistic network even in the time of flood by means of raising the existing road surface level of the North Bound Direction of the Outer Bangkok Ring Road (also known as NR-9), which is composed of 4 lanes. The implementation of the project is expected not only to enable the NR-9 to function as an industrial road inter-connecting the Gulf of Thailand, Suvarnabhumi International Airport, and industrial estate in the north of Bangkok, but also help mitigate the impact during flooding in and around areas in Ayutthaya and Bangkok and eventually contribute in sustaining the economic growth around the Chao Phraya river basin.

The GOT, Department of Highways (hereinafter referred to as DOH) has designated the rehabilitation plan as one of the mid-term plan among its development plan (urgent restoration, mid-term and long-term plan). The project is to be carried out under JICA and is considered as a part of DOH Plan.

(3) Summary of the Project Findings

JICA dispatched the Preliminary Survey Team three times in the Kingdom of Thailand to conduct site surveys and investigations required for the project. They are; i) from 22nd to 29th February, 2012 for explanation and discussion on the Inception Report, ii) from 27th May to 1st June, 2012 for explanation and Discussion on the Inception Report for survey (DD I), and iii) from 26th to 30th August, 2012 for explanation of the draft final report prepared after completion of the third site survey and the outline design in Japan, to the concerned authorities in the Kingdom of Thailand.

The policies and principles for the planning and construction of the road section and facilities that

needs to be raised and as presented in **Table 1**, are based on the results of the field surveys and discussions held with the GOT.

Table 1 Project Digest

Item	Contents
Objective Area	Objective Road : North Bound L=30.0km Raising Existing Road Elevation : Design Flood Level – 20cm : L=13,856m Design Flood Level + 10cm : L=1,200m Total : L= 15.056km (Excluding Transition Length)
Design Speed	120km/h Full Access Control Motorway
Number of Lanes	4 Lanes (North Bound)
Cross-section Composition	Median 5.0m + Road Way 14.4m + Shoulder 3.0m
Pavement	[Standard Section] Surface Course: Asphalt Concrete 5cm (For Inner Two Lanes) Surface Course: Modified Asphalt Concrete 5cm (For Outer Two Lanes) Binder Course : Asphalt Concrete 5cm Bound Base : Asphalt Concrete 10cm Base Course : 25cm Sub-Base : More than 20cm Performance Period :10 years [Toll Gate Section] Surface Course: Modified Asphalt Concrete 5cm Binder Course : Modified Asphalt Concrete 5cm (Sta.24+875~Sta.25+600) Pavement Slab : Reinforced Concrete 25cm Sand Cushion : 10cm Sub-Base : Various
Toll Gate	Raising Toll Booths (10 Points) and Pedestrian Overpass
Interchange	Adjustment to On / Off Ramp
Drainage	Adjustment of Catch Basin and Natural Drainage Facilities
Incidental Road Facilities	Adjustment of Concrete Barrier, Overhead Crossing Facilities, Traffic Signs Delineators (Studs), Pavement Markings, Emergency Parking, Motorway Fence, Toll Gate, Overpass and Road Studs

(4) Project Implementation Schedule Summary of Project Costs

The period for the detail design and tendering stage is estimated at 4.0 months and for the construction stage is estimated at 19.0 months including demobilization etc. However the period of the traffic control for the construction on the objective road including its facilities shall be 18.0 months.

(5) Project Evaluation

The project plans to raise the level of the existing road surface of the north bound direction of the Outer Bangkok Ring Road. This means that the objective road will be passable, although the number of passable lanes will be reduced, at all times – even during the flood having similar intensity as that of the 2011 flood. The objective road stretches from Bangkok toward the north passing through strategically important places and facilities.

If the project is implemented, it is expected not only to enable to function as an industrial road and maintain the link between the major economical hubs such as the Gulf of Thailand, Suvarnabhumi International Airport, and industrial estate in the north of Bangkok. It will also

help mitigate the impact during flooding in and around areas in Ayutthaya and Bangkok and eventually contribute in sustaining economic growth around the Chao Phraya river basin

[Relevance]

- The group that will benefit directly from this project are the general people. The majority of these people belong to the bottom of the social pyramid and live near the objective road (Bangkok metropolitan city, Ayutthaya and Pathum Thani provinces)
- The project is deemed to contribute to reduce the impacts from severance of distribution of goods and human interaction, and it is an emergency assistance for sustaining secure and stable life of the prople.
- The adverse effect to the environment is low.
- This project is deemed to contribute to the short-term, mid-term and long-term flood countermeasure plans of Thailand.
- The project demands application of highway engineering knowledge and skills/techniques of Japan.
- Implementation of this project under the Grant Aid Scheme of Japan can be carried out without significant difficulties/challenges.
- The scope of the project is consistent with the disaster prevention and reconstruction measures/policies of Japan.

[Effects]

1） Quantitative Effect

The road was completely shut for public traffic during the flood in 2011. Rehabilitation of the road is expected to ensure stable, smooth and safe mobility of traffic under similar condition experienced during the flood. **Table 2** shows the prospective quantitative effect that the project is considered to have.

As it is not possible to predict the occurrence of a flood, the flood year is not set.

Table 2 Quantitative Effect

Index	Standard Value	Target Value
Resolution of road blocked period	10 Days	Zero

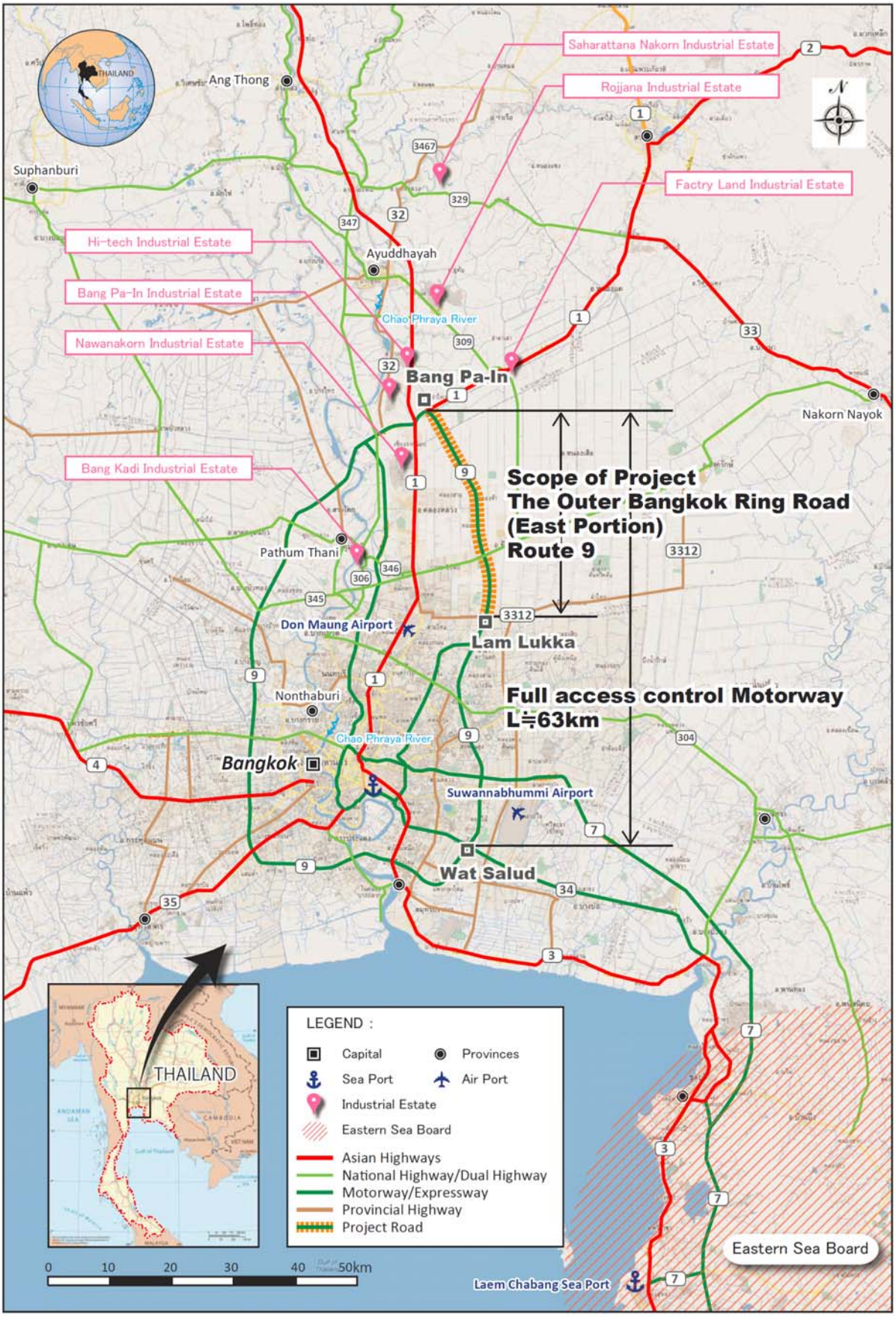
2） Qualitative Effect

- Securing stable supplies of goods
  During flood time, the supply of goods can be severed due to bad transport condition as well as shortage of goods caused from price hike expectation. The rehabilitation of the objective road would enable transportation of the goods thus, securing stable flow of goods.
- Securing of Basic Human Needs (BHN)
  Rehabilitation of the objective road will secure access from and to the center of Bangkok even during flood securing transportation route for medical purpose and/or procurement of goods for basic human needs.
- Maintaining mobility
  Rehabilitation of the objective road will allow people living along NR-9 will be able to move freely for commuting and for other activities.
- Securing route for emergency transportation
  The road if rehabilitated, can be used for emergency purposes or for allowing vehicles such as ambulance, fire-brigade, police cars etc.

CONTENTS

[APPENDICIES]

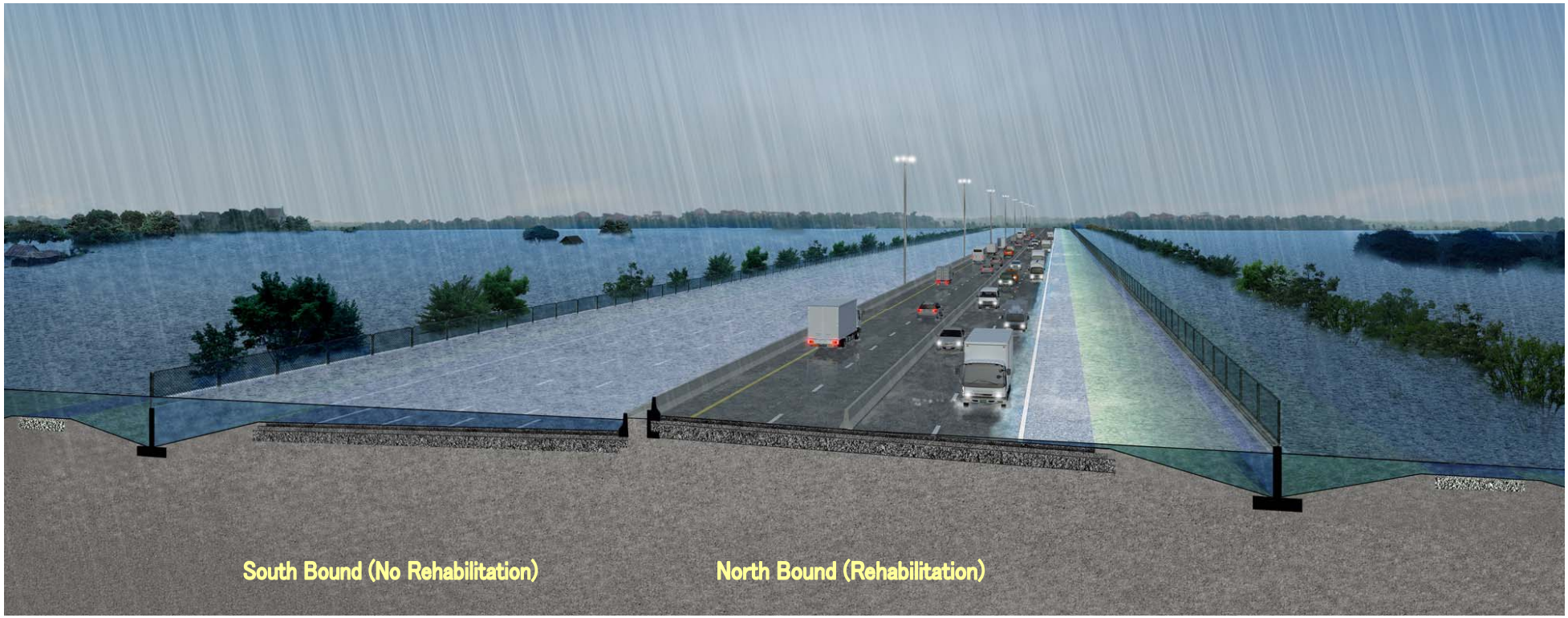
ATTACHMENTS



Location Map

PERSPECTIVE

The Image View（Traffic Flow in Normal Condition）



The Image View（Traffic Flow in Flooding Condition）

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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Office
ADB	Asia Development Bank
ADT	Average Daily Traffic Volume
ASEAN	Association of Southeast Asian Nations
BMA	Bangkok Metropolitan Administration
CBR	California Bearing Ratio
CD	Capacity Development
CU	Chulalongkorn University
DDPM	Department of Disaster Prevention and Mitigation
DIW	Department of Industrial Works
DOH	Department of Highways
DORR	Department of Rural Roads
DD-1	Detailed Design
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
ESAL	Equivalent Single Axle Load
F.L.	Flood Level
G/A	Grant Agreement
GDP	Gross Domestic Product
GOJ	Government of Japan
GOT	Government of Thailand
HIA	Health Impact Assessment
HWL	High Water Level
IEAT	Industrial Estate Authority of Thailand
IMF	International Monetary Fund
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
LAO	Local Authority Organization
MD	Marine Department
MEA	Metropolitan Electricity Authority
MI	Ministry of Industry
MOAC	Ministry of Agriculture and Cooperatives

MOD	Ministry of Defense
MOI	Ministry of Interior
MONRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
MOSTE	Ministry of Science, Technology and Environment
MOT	Ministry of Transport
MWA	Metropolitan Water Authority
N.B.	North Bound
NEB	National Environmental Board
NR-1	National Highway Route 1
NR-9	National Highway Route 9
OCS	Office of the Council of the State
OD	Outline Design
OEPP	Office of Environmental Policy and Planning
ONEP	Office of Natural Resources and Environmental Policy and Planning
OPM	Office of the Prime Minister
OSCWRM	Office of Strategic Committee for Water Resource Management
PCD	Pollution Control Department
PCV	Prefabricated Vertical Drain
PM	Particulate Matter
PSI	Present Serviceable Index
RID	Royal Irrigation Department
ROW	Right of Way
RTSD	Royal Thai Survey Department
S.B.	South Bound
SCRFD	Strategic Committee for Reconstruction and Future Development
SCWRM	Strategic Committee for Water Resource Management
SN	Structural Number
SRT	State Railway of Thailand
Sta.	Station
THB	Thai Baht
TMD	Thai Meteorological Department
TOR	Terms of Reference
UNEP	United Nations Environment Program

CHAPTER 1. BACKGROUND OF THE PROJECT

1-1 BACKGROUND OF THE GRANT AID

The government of the Kingdom of Thailand (hereinafter referred to as "GOT") suffered from a historical flood in year 2011, said to be "the worst recorded flooding yet in terms of the amount of water and damages inflicted to the people/property", which was caused by the incessant rainfall that started in July. Flooding soon spread through the provinces of North, Northeastern and Central Thailand along the Chao Phraya river basins, which has a catchment area of approximately 160,000 km2. In October floodwaters reached the Chao Phraya and inundated parts of the capital city of Bangkok. Sixty-five of Thailand's 77 provinces were declared flood disaster zones, and approximately 17,000 square kilometers of farmland was damaged. Flooding persisted in some areas until mid-January 2012, and took away lives of 446 peoples and more than 3.2 million people in 25 provinces were severely affected.

Most of the damages and losses due to this recorded flooding disaster were to the manufacturing industries. Not only Bangkok City, but Ayutthaya Prefecture, where seven major industrial estates are located, Pathum Thani Province and Nonthabury Province that lie north of Bangkok were also inundated. The government of Japan (hereinafter referred as GOJ) assisted in implementing relief and recovery operation, and then dispatched experts and engineers to help coordinate with Thailand.

Although emergency relief operation such as emergency disaster prevention measures has been seen to be implemented by the GOT, occurrence risk of similar type/scale flood can be anticipated again next year. Implementation of measures based on mid-term and long-term is as equally important as are the urgent restoration or repair of the facilities damaged by the flood.

In the transportation sector, the damages caused to the roads by the flood together with the dysfunctions of the existing transportation network that resulted from the closure of a segment of the objective road due to inundation caused by the flood, is having severe impact on the economy of Thailand. Therefore, not only restoration or rehabilitation works, but also measures for securing sustainable logistic network during flooding has become the urgent issue of the GOT.

Under such circumstances, the GOJ dispatched a survey team since October 19th 2011, to investigate the impact of the flood and to analyze the potential assistance for restoration and rehabilitation. In due course, GOT expressed its expectation to Japan International Cooperation Agency (hereinafter referred to as JICA), and requested to re-analyze the master plan based on urbanization, industrialization, and climate change that was not assumed in the initial master plan, due to the fact that JICA had implemented the master plan under "The Study on Integrated Plan For Flood Mitigation in Chao Phraya River Basin" from 1996 to 1999 for flood control around Chao Phraya river basin surrounding industrial estates in Ayutthaya and Bangkok,

In response to the request from the GOT, the GOJ decided to conduct a Project for Comprehensive

Flood Management Plan for the Chao Phraya river basin (hereinafter referred to as “the umbrella project”) which consists of (i) Comprehensive flood management plan (Component 1), (ii) Outline design for Japanese Grant Aid (Component 2) and (iii) Pilot Projects for emergency rehabilitation (Component 3), since November 2011. Among those projects, Component 2 is expected to be the disaster prevention and restoration grant aid project.

The Outer Bangkok Ring Road, also referred as National Highway route 9 (hereafter referred to as NR-9) is the objective road of this project. It is a full-access-controlled motorway that connects National Highway Route No.1 (hereafter referred to as NR-1) at Bang Pa-In and National Highway Route No.34 (hereafter referred to as NR-34) at Wat Salut and is approximately 63km long. Initially it was a 4-lane (2 lanes each on north and sound bound) motorway whose construction was completed in March 1999 under the loan assistance from Japan. It was then widened to its present state (8-lane motorway with 4 lanes each on the north and the south bound) in 2009. This road functions as a bypass for NR-1 where traffic congestion is significant. It is also a strategically important highway as an industrial road connecting the Ayutthaya industrial estate area with Bangkok metropolitan region, Suvarnabhumi International Airport, Eastern Sea Board, and Laem Chabang sea port.

However, the 2011 flood caused NR-9 to submerge to a highest depth of about 122cm and was closed to public traffic for almost a month, from October to November, causing disruption of the logistics network in and around Bangkok.

The objective of the project is to secure the function of logistic network even in the time of flood disaster by raising the 4 lanes on the north bound roadway surface of the Outer Bangkok Ring Road . The implementation of the project is expected not only to enable the NR-9 to function as industrial road by inter-connecting the Gulf of Thailand, Suvarnabhumi International Airport, and industrial estate in the north of Bangkok, but also help mitigate the impact during flooding in areas in Ayutthaya and Bangkok and eventually contribute in sustaining economic growth around the Chao Phraya river basin.

The importance of this project to be implemented under the grant aid scheme of Japan was confirmed by both the GOJ and the GOT during the field work and survey carried out in cooperation with the counterparts in January 2012. GOT thus requested the GOJ for the grant aid to implement the project. Discussions were held between the study team dispatched by JICA and the officials of the Department of Highway (DOH), the implementing organization of GOT, where the requested components from GOT were confirmed as follows;

- Raising one side of the road elevation of the Outer Bangkok Ring Road (East portion) which goes to the approximately 30km long north bound where:
- The level of road surface is 20 cm or lower than the highest level of the 2011 flood, and
- The toll gates are situated.

1-2 NATURAL CONDITION

(1) Policy that Satisfies the Function of the Objective Road

The Outer Bangkok Ring Road (East Portion), which is the objective road of this project and is a full access-controlled motorway that links the outer fringes of greater Bangkok. Its eastern portion is toll section, which extends from Bang Pa-In through Lam Lukka, Ram Inthra, Wat Salud and meets with Motorway Route 7 at Thap Chang interchange. The Outer Bangkok Ring Road (East Portion) is designated as a bypass of NR-1, where traffic congestion is significant. On the other hand, it serves as a major transportation link as it connects the strategically important and economically vital places such as Ayutthaya Industrial Estate Area, Bangkok Metropolitan Region, Suvarnabhumi International Airport, Eastern Sea Board, and Laem Chabang Sea Port, the Outer Bangkok Ring Road (East Portion) serves as a major transportation links.

The project objective is to rehabilitate the objective road to keep it functioning even during floods similar to that of year 2011. The project will be carried out based on the following policies.

1) The section of the Project is planned based on the design flood level calculated from the results and findings of the survey and hydrological analysis carried out from the 2011 flood.
2) The design road surface level along the typical section is raised with 20cm allowance of submergence at the shoulder of the objective road during similar flooding. Even so, due to standard normal crossfall of 2.5%, although the shoulder sees submergence of 20cm, 2 of 4 lanes is expected to remain above the water. The design road surface level at the toll gate on the other hand is necessarily raised over the flood level.
3) The consistency between the objective road level and existing service road level is secured in terms of geometric design and carriage lane number.
4) Pavement design and slope protection at the section of the project are planned based on the mitigation strategy of flood damage and road drainage system.
5) Design of merging point between the main road and access road is considered based on vertical profile and gradient, to secure smooth and safe traffic flow.
6) Incidental road facilities such as median, pedestrian overpass for toll gate access etc. are designed with consistency with the raising road elevation.

(2) The Reason for Selection of Outer Bangkok Ring Road

As shown in **Figure 1-2.1**, the Outer Bangkok Ring Road (East Portion) stretches from north to south in parallel with the direction of the flood flow.The objective road to be raised in the project (approximately 30km) equips viaducts for crossing irrigation channels. There are altogether 7 rivers including canals traversing the objective road. These water ways have a cross sectional area from 74 to 80m2 and have capacity to channelize 24 to 34m3 of water downstream. In addition, there are a total of 116 pipe culverts whose diameter ranges from 1.00 to 1.50m and is fundamentally used for irrigation and surface drainage purpose. Furthermore, there are 2 box culverts of 3.00m by 3.25m, and

two-cell box culvert for irrigation. Raising the existing road surface level of the Outer Bangkok Ring Road (East Portion) will not keep back flood water and change flood flow direction between the East and West side, and also will not affect flood condition and areas damaged by flood.

As mentioned above, the objective road is not a dike road and as such, it neither functions to dam water during flood nor influence in changing the water flow direction. Therefore, raising the existing level of this road has no influence on the manner of flow or the damage/risk it poses.

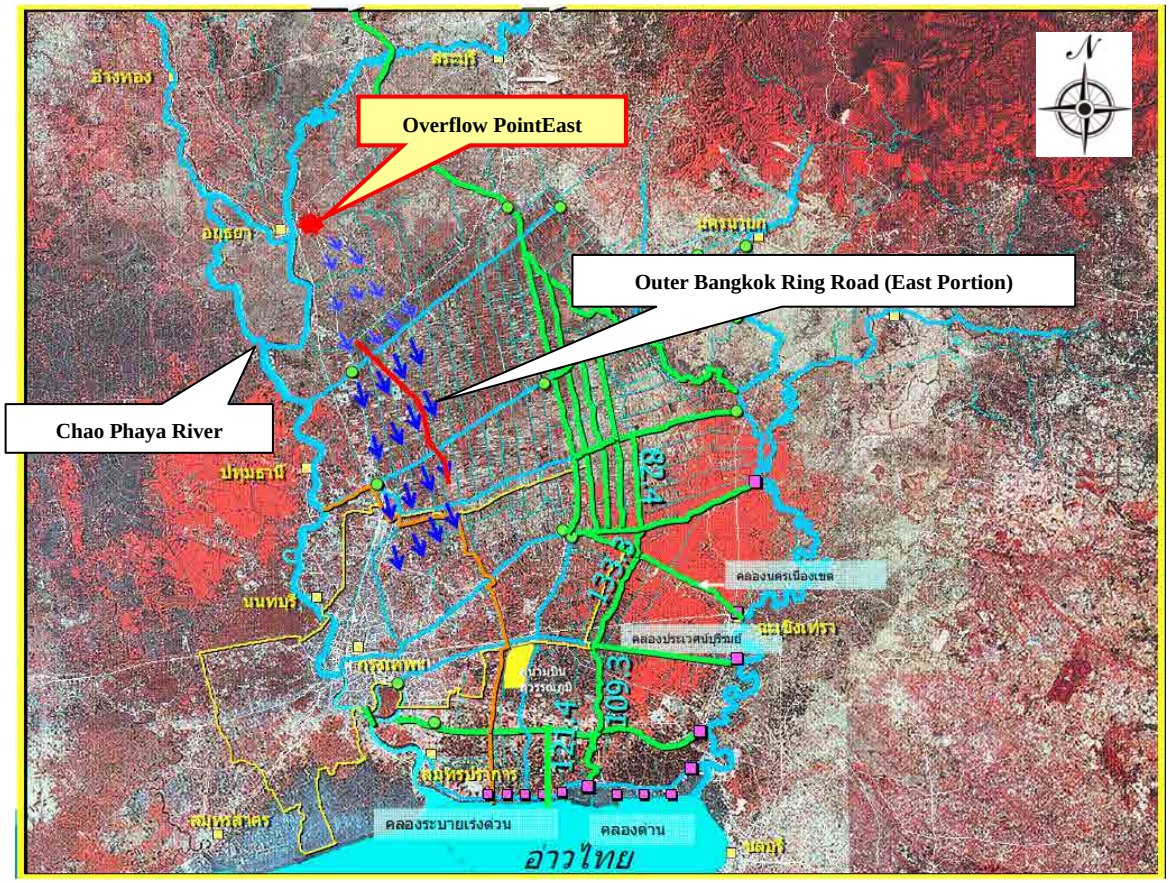


Figure 1-2.1 Flood Condition around Outer Bangkok Ring Road(Source:RID)

Another reason for selecting this road comes from the result of site investigation carried out on the aftermath of 2011 flooding on the roads that run east-west around Greater Bangkok.

As shown in **Photo 1-2.1**, the concrete barrier along the median on NR-1 was demolished during flood to lower the water level at the north side of NR-1. The barrier was demolished for an approximate length of 200m. The reason for this demolishment can be concluded from the results as follows:

1) The flood spread from north to south,
2) The submergence of the north side along NR-1 due to blockage by the existing concrete barrier at the median of the road,
3) The breaking of the concrete barrier by residents, and

4) Spreading of flood water to the south side of NR-1 from the north following demolishment of the concrete barrier.

The results of the investigation suggest that a detailed flood flow analysis is indispensable for raising the surface level of existing roads stretching from east to west.

Photo 1-2.1 Demolition Condition of Concrete Barrier on the Median of NR-1

(3) Rehabilitation Policy for Damages in the Submerged Segment of the Objective Road

Raising road elevation refers to raising the existing base/subbase of the road by removing the existing impermeable asphalt concrete to enhance uniform drainage between the existing and the new base courses. The existing road have experienced many floods in the past, including one in 2006. The existing base-course, sub-base and sub-grade are thus assumed to be potentially damaged. However, CBR values obtained from field CBR test was bigger than the CBR values of the previous design. Therefore, it is considered that the existing base/subbase has not been damaged.

1-3 ENVIRONMENTAL AND SOCIAL INSTITUTIONAL STRUCTURE

1-3-1 Outline

(1) Summary of the Project

The project plans to undertake the rehabilitation works for a segment of 30km on the Outer Bangkok Ring Road between Ayutthaya and Pathum Thani Province. The major scopes are as follows :

1. Raising the inundated parts of the road elevation
2. Improving facilities like drainage channels and the toll gate structures

In particular, two (2) plans of raising road elevation will be conducted with the purpose to secure the traffic from floods similar to the one occurred in 2011.

1. Minus twenty (-20) cm from the largest recorded level in 2011 (historical highest flood level)
2. Plus ten (+10) cm from the largest recorded level in 2011 (historical highest flood level)

The latter plan is to be adopted at the toll gate section so that the level would not be inundated. For detail information, refer to Chapter 2.

(2) Activity Requiring Environmental and Social Considerations

In the Project, activities requiring environmental and social considerations are as follows:

1. Road rehabilitation work (raising road elevation and improvement of peripheral equipments)
2. Material handling (truck operating)

Details of Road rehabilitation works consists of work types listed in **Table 1-3.1**.

Table 1-3.1 Outline of the Road Rehabilitation Work

Work Type	Outline	Main equipments	Working Period
Existing Pavement Removal	High-standard pavement structure (t-20cm), Medians (RC barrier)	Backhoe, Backhoe-type concrete breaker	Under Process
Roadbed	High-standard pavement structure (raising), Medians (raising of RC barrier)	Motor grader, Vibratory roller, Tired roller	
Pavement		Asphalt finisher, Vibratory roller, Tired roller	
Road Drainage	Slope protection, U-shaped side ditch, Box culvert with flap gates.	Concrete mixing vehicle, Backhoe	
Facility and Equipment Improvement	Settlement of: Crush barrier, Pavement markings, Electronic road signs	Crane, Crane for truck mount	
Renovation of Pedestrian Overpass	Acquiring road clearance limit	Crane, Crane for truck mount	
Ancillary Works	Relocation of traffic control system, Facility for two-lane separation on the south bound road (4 lanes).	Crane, Crane for truck mount	

(3) Categories of the Project and Environmental Assessment

According to Thai law[1], 34 project types and activities require Environmental Impact Assessment (EIA) and approval through the national approval process. The Project is sure to be outside the scope of the EIA category in accordance with the Thai environmental assessment system and the confirmation by DOH.

On the other hand, impacts on the environment may arise mainly by construction activities of the Project. To ensure minimal environmental impacts, JICA decided that conducting an Initial Environmental Examination (IEE) should be essential according to the JICA Guidelines for Environmental and Social Consideration.

1-3-2 Comparative Review of Alternatives

A comparative review of the Project and the alternatives is shown in **Table 1-3.2**, including the without project (zero option).

[1] The Enhancement and Conservation of National Environmental Quality Act (NEQA) of B.E. 2535 (1992).

Table 1-3.2 Comparative Review of Alternatives

Items		Zero Option	Option 1	Option 2	Proposed Project
Outline		・No project is planned	・Raising the north bound lanes above the flood level in 2011.	・Raising the flooded parts of road elevation in 2011 on the south bound lanes, with minus twenty (-20) cm from the largest recorded flood level. Travelled ways are available during flooding under usable lane limitation because of an effective cross slope of the lanes for drainage.	・Raising of the flooded parts of road elevation in 2011 on the north bound lanes, with minus twenty (-20) cm from the largest recorded flood level. Roads are available during flooding under usable lane limitation because of an effective cross slope of the lanes for drainage.
Technical & Economical Aspects	Advantages	・Nothing	・Negative impacts on local economy will be reduced as a smooth traffic can be assured in case of flooding the roads. ・Most debris is recyclable. ・ Impact on generating local employment is expected greatest among the three (3) listed projects.	・Negative impacts on local economy will be reduced because it can assure road traffic when flooded at the same level in 2011. ・Most debris is recyclable. ・ Possibly contributing to generate local employment.	・Negative impacts on local economy will be reduced because it can assure road traffic when flooded at the same level in 2011. ・Most debris is recyclable. ・ Possibly contributing to generate local employment. ・Low-cost work is possible compared to that in Option 1.
	Disadvantages	・In case that a flood similar in size to the 2011 flood ccurs, lots of impassable sections would increase and impacts on logistics and local economic activity would be apprehended.	・ Project costs may increase by increasing the elevation of raising road . ・Extension of work period would be required due to an increase of the roads to be raised.	・In case that flood with the same scale in 2011 occurs, traffic volume would be restricted by the flooded parts of road in spite of being assured of road traffic. ・Project costs could increase because the number of on-and-off ramps to the service roads is more than those with the north bound lanes. ・Extension of existing drainage or new introduction of drainpipes is probable because the cross slope on NR.9 runs east to west. More work is required.	・In case that a flood with the same scale in 2011 occurs, traffic volume would be restricted by the flooded parts of road in spite of being assured of road traffic.

Items		Zero Option	Option 1	Option 2	Proposed Project
Environmental & Social Aspects	Advantages	・Any human-caused environmental or social impacts do not occur because no project is conducted.	・Improving the existing road does not need new land expropriation and resettlement of residents. ・No natural environment and cultural property requiring special considerations exists because of the work for the existing road improvement.	・Improving the existing road does not need new land expropriation and resettlement of residents. ・No natural environment and cultural property requiring special considerations exists because of the work for the existing road improvement. ・Impact on the environment would be limited to smaller extent compared to that in Option 1.	・Improving the existing road does not need new land expropriation and resettlement of residents. ・No natural environment and cultural property requiring special considerations exists because of the work for the existing road improvement. ・Impact on the environment would be limited to smaller extent compared to that in Option 1.
	Disadvantages	・Flooded road may induce social disruption because the flood obstructs logistics and give a bad impact on local economy. ・Disruption of logistics may give impacts on economy at a level of not only global but also local scale. This could incur Thai's disrepute.	・Elongation of road construction increases a generation of debris. ・Impacts on the environment are expected biggest among the three (3) listed projects by extension of work and traffic congestion period. ・Impact on landscape (visibility) is concerned because heightening level is higher than that in the proposed project. ・Extension of work leads to greatest possibilities of traffic congestion and accidents among the three (3) listed projects.	・Possibilities of occurrence of traffic congestion and accidents are expected. ・Cross slope of the road may increase in the time for draining. ・Impact on the environment by the option may increase because more ramps or drainage facilities are needed compared to those in the proposed project.	・Possibilities of occurrence of traffic congestion and accidents are expected.
Judgment and Verification		**Not Recommended** ・No contribution to measures for the flood is expected. ・Worst impacts on local economy, environment and society are concerned compared to 'with project' options.	**Not Recommended** ・Impact on an increase of the project cost is concerned bigger than the expected benefit by the project. ・Vulnerable period against disasters may be longer as it takes long hours providing disaster-prevention functions. In addition, prolonged work period would not be acceptable because the project must be an emergency assistance.	**Not Recommended** ・Project cost is expected higher than that in the proposed project though the performance could be the same scale. ・Impact on the environment is probably greater than that in the proposed project.	**Recommended** ・Most economical work is possible among the all listed projects. ・The highest benefits is expected compared to the costs among the listed projects. ・Impacts on the environment and society are expected lowest among the listed projects.

1-3-3 Scoping

As mentioned in the previous sections, this Project does not require an EIA report to be conducted in accordance with the EIA system in Thailand, and this is agreed with the operator, DOH. However, as impacts on the environment by using construction equipments are expected, an initial environmental examination (IEE) is essential according to the latest JICA Guidelines. The scoping of the Project regarding both environmental and social issues is shown in **Table 1-3.3**.

Table 1-3.3 Scoping Result of the Project

Project Entity			Department of Highways (DOH)		
Category	No	Impacts	Evaluation		Reasons
			Pre-/ At-work	In-use	
Pollution	1	**Air Pollution**	B-	B-/+	**At-work**: Work of construction equipment may cause air pollution such as exhaust gas or dust. **In-use**: Reduction of traffic congestion and road improvement may reduce the air pollution.
	2	**Water Pollution**	B-	D	**At-work**: Drainage from the construction sites is concerned to be a potential source of water pollution.
	3	**Waste**	B-	D	**At-work**: Wastes from the construction work like concrete debris or from workers are expected.
	4	**Soil Contamination**	D	D	No impact on soil contamination is expected because of without using hazardous chemicals.
	5	**Noise and Vibration**	B-	B-	**At-work**: Operation of construction equipment may generate noise and vibration. **In-use**: Traffic noise from raising road can travel further and impact more receptors given that roadside environment acting as noise barrier remains unchanged.
	6	**Ground Subsidence**	D	D	Any impact on ground subsidence is not expected because the project is for improving the existing road.
	7	**Offensive Odor**	D	D	No impact to generate offensive odor is expected because there are few sources in the project site.
	8	**Bottom Sediment**	D	D	No impact on bottom sediment is expected because the project is for improving the existing road.
Natural Environment	9	**Sanctuary**	D	D	There are no national parks or sanctuaries around the project site.
	10	**Ecosystem**	D	D	No impact on the ecosystem is expected because the project is for improving the existing road and any rare species of animals and plants have not been found in the project area.
	11	**Hydrological Situation**	D	D	No changes in water flow or river-bed sediment are expected.
	12	**Topography and Geographical Features**	D	D	No changes in topography and geographical features are expected because the project is for improving the existing road.
Social Environment	13	**Involuntary Resettlement**	D	D	No involuntary resettlement is expected as any land expropriation is not required.
	14	**Poverty Group**	D	D	No impact on the poverty group eligible for compensation is expected because there is no involuntary resettlement.
	15	**Indigenous and Ethnic People**	D	D	No impact on indigenous and ethnic people is expected because settlement of these people is not confirmed around the project site.
	16	**Local Economy such as Employment and Livelihood, etc.**	B+	B+	**At-work**: Increase of job opportunity is expected. **In-use**: Road improvement is expected to ensure the flow of goods and passengers, and contribute to local economy on floods.

Project Entity			Department of Highways (DOH)		
Category	No	Impacts	Evaluation		Reasons
			Pre-/ At-work	In-use	
	17	**Land Use and Utilization of Local Resources**	B-	D	**At-work**: Land use for material storage and the office is expected.
	18	**Water Usage or Water Rights and Rights of Common**	B-	D	**At-work**: Water use for sprinkling during construction is expected, but the use should be limited not to disturb local water rights.
	19	**Existing Social Infrastructures and Services**	B-	B+	**At-work**: Traffic congestion is possible on the national Route 1 running parallel the project road due to the cars that detour from the project road. **In-use**: The project is expected to contribute to improving local social services on floods.
	20	**Social Institutions Such as Social Infra-structures and Local Decision-making Institutions**	B-	D	**At-work**: Existence of an opponent against the project is concerned, but the impact is expected to be minor due to improvement of the existing road.
	21	**Misdistribution of Benefit and Damage**	D	D	Nothing is expected about the unfair benefit and damage affecting to the surrounding area due to improvement of the existing road.
	22	**Local Conflict of Interests**	B-	D	**Pre-work**: Local conflict of interests is possible against the project, but the impact is expected to be minor due to improvement of the existing road.
	23	**Cultural Heritage**	D	D	There is no cultural heritage in and around the project site.
	24	**Landscape**	B-	B-	**At-work**: Construction equipments in the work site may slightly spoil the sight. **In-use**: Visibility from the dwellers around the project site may be worse by raising road elevation, but the impact is limited because of one (1) meter of raising road elevation.
	25	**Gender**	D	D	No impact on gender issues is expected because there is little negative impact on the local society or economy by the project.
	26	**Children's Right**	D	D	No impact on children's right is expected because there is little negative impact on the local society or economy by the project.
	27	**Infectious Diseases such as HIV/AIDS**	B-	D	**At-work**: Transmission of infectious diseases may be considered when an infected worker inflows.
	28	**Work Environment (incl. Work Safety)**	B-	D	**At-work**: Considering work environment is needed to prevent occupational injury or accidents.
	29	**Accident**	B-	D	**At-work**: Accidents induced by traffic congestion or construction work are probable
Other	30	**Transboundary Impact and Global Warming**	B-	B+	**At-work**: Operation of construction equipments or vehicles and possible traffic congestion during construction may increase the emission of global warming gases like CO_2. **In-use**: Considering an increase of traffic volume and a decrease of congestion in the future, this project is expected to contribute to reducing the global warming gas emission compared with the 'without project' option.

A+/-: Serious positive (+)/negative (-) impact is expected.

B+/-: Some positive (+)/negative (-) impact is expected.

C+/-: Extend of positive (+)/negative (-) impact is unknown (A further examination is needed, and the impact could be clarified as the study progresses).

D : No impact is expected.

1-3-4 Survey Results on Environmental and Social Considerations

Table 1-3.4 indicates the survey results in accordance with the TOR in Section 1.4.

Table 1-3.4 Survey Results on Environmental and Social Considerations

<table>
<tr><th>Impact</th><th>Result</th></tr>
<tr><td>Air Pollution</td><td>
1. A summary of environmental standards in Thailand and Japan is shown in Table 1-3.5.
2. The table below indicates the results of ambient air monitored along the Route 9 conducted by DOH.
<table>
<tr><th>Station (STA.)</th><th>Period</th><th>TSP 24 hr (mg/m^3)</th><th>NO_2 1 hr (ppm)</th><th>CO 1 hr (ppm)</th></tr>
<tr><td rowspan="2">0+000</td><td>2011.5</td><td>0.061
(0.048-0.093)</td><td>0.014
(0.0067-0.036)</td><td>0.27
(0.14-0.95)</td></tr>
<tr><td>2011.10</td><td>0.060
(0.047-0.078)</td><td>0.011
(0.0054-0.0025)</td><td>0.33
(0.18-0.91)</td></tr>
<tr><td rowspan="2">22+000</td><td>2011.5</td><td>0.050
(0.040-0.059)</td><td>0.0068
(0.0040-0.015)</td><td>0.28
(0.15-0.99)</td></tr>
<tr><td>2011.10</td><td>0.039
(0.032-0.045)</td><td>0.0092
(0.0042-0.019)</td><td>0.43
(0.20-0.81)</td></tr>
<tr><td colspan="2">Standard</td><td>0.12</td><td>0.17</td><td>30</td></tr>
</table>
Note: Figures indicate average values. The ranges from minimum to maximum during monitoring period are provided in brackets below.
Source: DOH(2012) ‘Monitoring of Environmental Quality of Motorway, Outer Ring Road, Eastern Part of Bangkok’ (in Thai)
According to these results, air quality along the project site is sure to meet the environmental standards at the stage of pre-construction.
3. In accordance with a rough prediction by a DOH’s traffic planner, future traffic volume could grow at +10% annually next five (5) years, and less than 10% in following five years. Assumed that the ratio of running car classification (passenger vehicle/light-truck/heavy-truck/etc.) was not changed in the future, approximately 60% of traffic volume would increase five years later. Even if an increment of pollutants from a pollutant source could simply affect without considering pollutant diffusion, any monitored pollutants would not exceed the standards with support of the result by a simple diffusion model. Furthermore, given an optimistic scenario, it is expected that car maintenance condition and vehicle standards will be improved in the future. Taking into account these conditions, air pollution caused by traffic could be much lower than the case of assumption above mentioned.
4. Contents regarding the project are indicated in Table 1-3.1. The number of vehicles worked and used for the project is under estimation. Trucks are contingent on every construction work. Sulfur dioxide (SO_2) could be listed as an air pollutant caused by the construction equipment operation as well as the substances monitored. These pollutants may diffuse toward the resident area depending on wind directions. DOH does not force the contractor to use a low-emission vehicle in order to reduce air pollution now. Measures will be recommended to reduce trips of trucks or strengthening the maintenance of construction equipments etc.
</td></tr>
<tr><td>Water Pollution</td><td>
1. A summary of environmental standards in Thailand and Japan is shown in Table 1-3.5.
2. Same as No.4 in Air Pollution. Possible polluted water from the construction site is sprinkled water for suppressing dust diffusion and rainwater. Most of them could dry off naturally. According to comments from an expert in DOH, normally no special measures are taken for drainage from/to a construction site in a domestic basis project. However, good environment practice is being promoted towards better environmental safeguards such as those implemented in DOH projects involving international organizations such as ADB, JICA etc.
</td></tr>
<tr><td>Waste</td><td>
1. Wastes generated by the construction work consist of debris of paved asphalt and RC barrier for median. The amount is under estimation. These wastes from the construction work will be stored at a stock place (ex. empty lot near the I.C.) for a certain period, and then processed for a recycling use, according to a comment from an expert in charge in DOH.
</td></tr>
</table>

<table>
<tr><th>Impact</th><th>Result</th></tr>
<tr><td>Noise and Vibration</td><td>1. A summary of environmental standards in Thailand and Japan is shown in Table 1-3.5.
2. The table below indicates the results of noise monitoring along the Route 9 conducted by DOH.
<table>
<tr><th>Station (STA.)</th><th>Period</th><th>L_{eq} 24hr (dB(A))</th><th>L_{max} (dB(A))</th><th>Distance from Roadside</th></tr>
<tr><td rowspan="2">0+000</td><td>2011.5</td><td>64
(63-64)</td><td>95
(83-95)</td><td rowspan="2">20.0m</td></tr>
<tr><td>2011.10</td><td>63
(62-64)</td><td>91
(85-91)</td></tr>
<tr><td rowspan="2">22+000</td><td>2011.5</td><td>64
(59-66)</td><td>101
(83-101)</td><td rowspan="2">18.0m</td></tr>
<tr><td>2011.10</td><td>60
(58-64)</td><td>100
(82-100)</td></tr>
<tr><td colspan="2">Standard</td><td>70</td><td>115</td><td></td></tr>
</table>
Note: Figures on the upper row are the daily average (L_{eq}) and the maximum during the monitoring period (L_{max}). The range from minimum to maximum during the monitoring period are in the blanks.
Source:DOH (2012) ‘Monitoring of Environmental Quality of Motorway, Outer Ring Road, Eastern Part of Bangkok’ (in Thai)
Noise levels at every stations did not exceed the standard (L_{eq}:70dB(A), L_{max}:115dB(A)). Table 1-3.6 shows the locations and characters of potential houses to be affected by the construction work along the service road of the Route 9. The scenario for noise impact estimation is chosen from one of the potentially affected house. Provided that an asphalt breaker that is one of main noisy equipments (115dB(A) of PWL in theory) was operated at STA. 22+000, the estimated noise level from the equipment would mark 82dB(A) at the station. This value is within the background noise level of L_{max}. And if there were two backhoe-type concrete breakers operating at the same time, the noise level is estimated to be 85dB(A). As for vibration level, the standard has not been defined yet and evaluation is not realized because of a lack of monitoring results.
3. Contents regarding the project are indicated in Table 1-3.1. The works that would be required considering noise and vibration are ‘removal of existing pavement’ and ‘roadbed’</td></tr>
<tr><td>Land Use and Utilization of Local Resources</td><td>1. It was confirmed that DOH will provide the lands for office, car parking and material storage use by an agreement between DOH and the Study Team.</td></tr>
<tr><td>Infectious Diseases such as HIV/AIDS</td><td>1. There are no national laws or regulations relating to infectious diseases against construction workers. However, with the existing Labor Protection Law and Social Security Law under the Labor Protection Act 1998, construction workers are entitled to social security in which their health and welfare are covered. Any case of illness and infectious disease would be examined by medical professional provided according to the Social Security Law. Discharge of workers with infectious disease may entail compensation. In the past, DOH launched an indoctrination program against infectious diseases such as HIV/AIDS for construction workers and local people with a help of JBIC and other organizations (The Second Mekong International Bridge Construction Project).</td></tr>
<tr><td>Work Environment (including Work Safety)</td><td>1. DOH does not have a specific regulation regarding the issue, but follows national laws. One of the laws for work environment in Thailand is Labor Protection Act in 1998. As for a guideline regarding construction work includes the Ministerial Ordinance for Determining the Standards of Operation and Administration on Work Safety, Sanitation and Environment Regarding Construction Work in 2008. The ordinance stipulates points of concern every construction works.</td></tr>
<tr><td>Accident</td><td>1. The Road Traffic Act in 1979 is the dominant law to regulate the road traffic in Thailand. In Thailand, concrete actions to avoid a traffic accident include: to notice the construction section using digital billboards or message boards, to lead cars to the detour way by barriers or a guide etc. On an accident, DOH and the contractor promptly call the police and the emergency medical service for following supports.</td></tr>
<tr><td>Transboundary Impact and Global Warming</td><td>1. Emission of the global warming gas (CO_2) by a construction work was estimated by a basic unit method with the guideline of ‘A Proposal for Estimation Method of CO_2 Emission in the Highway Project’, issued by the Technology Center of Expressway, Dec. 2004. Basic units of CO_2 for each construction work are shown in Table 1-3.7.</td></tr>
</table>

Impact	Result
	<table><tr><th rowspan="2">Type of Construction</th><th colspan="2">Emission of global warming gas</th></tr><tr><th>(t-C)</th><th>(t-CO_2)</th></tr><tr><td>Road (earthwork)</td><td>9,388.8</td><td>34,425.2</td></tr><tr><td>Facility (I.C.)</td><td>397.6</td><td>1,457.9</td></tr><tr><td>Total</td><td>9,786.4</td><td>35,883.1</td></tr></table> Note: Work section length:15.175km, Number of facility:1 Mind that this estimation is not considered for the existing pavement removal associated with the existing road improvement work, but for a new road project. In addition, emission from running trucks carrying materials and equipments is out of estimation as well because the operation plan is under calculation. Detailed data will enable to estimate the emission more exhaustively.
Alternatives	1&2. Refer to Section 1-2 'Comparative Review of Alternatives'.
Stakeholder Consultation	1&2. No stakeholder consultation is planned at present, according to DOH. It's because DOH evaluates that, with mitigation measures implemented, there will be insignificant impacts on the residents with the improvement of the existing road. However, public information regarding the project shall be made available and channels for receiving comments/complains from stakeholders shall be setup in addition to what DOH normally operates, i.e. DOH call center.

Table 1-3.5 Comparison of the Environmental Standards between Thailand and Japan

Items	Unit	Environmental Standard				Note
		Thailand*1		Japan		
Ambient Air Quality						
TSP	mg/m^3	0.33		-		24-hr average
PM10	mg/m^3	0.12		0.10		24-hr average *Categorized in SPM in Japan
SO_2	Ppm	0.12		0.04		24-hr average
NO_2	ppm	0.17		0.06		1-hr average
CO	ppm	30		10		1-hr average
O_3	ppm	0.10		0.06		1-hr average
Surface Water Quality		**Class 3**	**Class 4**	**Type B**	**Type C**	Refer to the legend for classification of Class (Thailand) and Type (Japan)*2
pH	-	5-9	5-9	6.5-8.5	6.5-8.5	
SS	mg/l	-	-	<25	<50	
DO	mg/l	>4	>2	>5	>5	
BOD	mg/l	<2	<4	<3	<5	
TCB	MPN/100ml	<20,000	-	<5,000	-	
Noise		**L_{eq}**	**L_{max}**	**L_{eq}**	**Specified Construction Work**	
	dB(A)	70	115	45-55 (60-65)	85	L_{eq} applicable to resident areas. Values in ( ) for an area facing the road with two lanes or more.
Vibration				**Specified Factory**	**Specified Construction Work**	
	dB	No environmental standard determined.		55-65	75	

*1 Thai environmental standard is defined in Section 32 of the Enhancement and Conservation of National Environmental Quality Act in 1992

*2 Class 3: Water quality is classified in middle-class, mainly for irrigation use. Water processing is needed with a standard water processor before use.

Class 4: Water quality is less than that in Class 3, mainly for industrial use. Water processing is needed with a special processor before use.

Type B: Equivalent to water level 3 and fishery level 2, and to Class 3 in Thailand.

Type C: Equivalent to fishery level 3 and industry water level 1, and to Class 4 in Thailand.

Table 1-3.6 Social Environment to be considered along the Project Area (North Bound)

Station (STA.)	Surroundings	Characteristics
12+000 ~ 12+500	*Two (2) settlements of houses (10 houses in total) *Storehouses of a construction company	The storehouses are along the service road. The settlements are at 10m outside from the service road.
13+700	*Container stock space in a freight company	Along the service road.
14+500	*A flock of four (4) small shops *Small factories	Both are along the service road, with much traffic volume.
16+200	*Office and factories (machine production)	Along the service road.
16+600	*A Christian church	Locating approx. at 200m away from the road boundary.
17+500	*A Hindu temple	Locating approx. at 50m away from the road boundary.
24+300	*Factories	Along the service road.
26+000	・A settlement incl. A few houses	Along the service road.

Table 1-3.7 Base Unit of CO_2 Derived from a Four-Lane Highway Construction

Type of Construction	Main Work	Base unit of CO_2	
		t-C/km	t-CO_2/km
Earthwork	Cutting & embankment, Slope, Lower part of pedestrian overpass, Box culvert, Ancillary (service road), Drainage, Traffic control device, Pavement	618.5	2267.8

Base unit of CO_2 derived from the facility construction

Facility	Main Work	Base unit of CO_2	
		t-C/unit	t-CO_2/unit
Inter Change	Road lighting device, Information sign, Power unit, Communication facility, Toll gate, Cables	397.6	1457.9

1-3-5 Impact Evaluation

Table 1-3.8 shows the re-evaluation of the scoping, based on the survey results on environmental and social considerations in Section 1.5.

Table 1-3.8 Impact Evaluation Based on the Survey Results

Category	No	Impacts	Evaluation in Scoping		Evaluation on surveys		Reasons
			Pre-/ At-work	In-use	Pre-/ At-work	In-use	
Pollution	1	**Air Pollution**	B-	B-/+	B-	B-/+	**At-work**: Concrete impacted areas were not determined because the operating plan of construction equipments has been under determination. However, negative impacts by the work are not expected because the current air quality is well below threshold of respective standards. **In-use**: Concentrations of monitored pollutants will not exceed the respective standards in spite of the estimation of more traffic volume in the future. Non-structural measures like spread of low-emission vehicles or TDM shall contribute to reduction of air pollution in the future.
	2	**Water Pollution**	B-	D	B-	D	**At-work**: There is a possibility of polluted water discharged to the paddy fields around the project area without any measures because the road shoulder is not sufficiently prepared. However, no use of hazardous materials may cause a serious pollution. During the construction, sufficient measures will be taken to prevent water discharge. **In-use**: No impact on the ambient environment is expected due to an absence of origins of polluted water.
	3	**Waste**	B-	D	B-	D	**At-work**: A sufficient operation system by DOH including land securement was confirmed on waste management. **In-use**: no impact on the ambient environment is expected due to any waste non-occurrence.
	4	**Soil Contamination**	D	D	N/A	N/A	Same evaluation as the scoping.
	5	**Noise and Vibration**	B-	B-	B-	B+	**At-work**: Noise from construction equipments is estimated to still be below noise standard level. However, modification of work plans to further reduce noise impact should be taken into account. **In-use**: Any change of outreach of traffic noise to receptors is not expected because of approx. one (1) meter of raising road elevation. However, reduction of traffic noise is expected after improving the road surface.
	6	**Ground Subsidence**	D	D	N/A	N/A	Same evaluation as the scoping.
	7	**Offensive Odor**	D	D	N/A	N/A	Same as above.
	8	**Bottom Sediment**	D	D	N/A	N/A	Same as above.
Natural Environment	9	**Sanctuary**	D	D	N/A	N/A	Same as above.
	10	**Ecosystem**	D	D	N/A	N/A	Same as above.
	11	**Hydrological Situation**	D	D	N/A	N/A	Same as above.
	12	**Topography and Geographical Features**	D	D	N/A	N/A	Same as above.

Category	No	Impacts	Evaluation in Scoping		Evaluation on surveys		Reasons
			Pre-/ At-work	In-use	Pre-/ At-work	In-use	
Social Environment	13	**Involuntary Resettlement**	D	D	N/A	N/A	Same as above.
	14	**Poverty Group**	D	D	N/A	N/A	Same as above.
	15	**Indigenous and Ethnic People**	D	D	N/A	N/A	Same as above.
	16	**Local Economy such as Employment and Livelihood, etc.**	B+	B+	B+	B+	**At-work**: Positive impacts on local employment and relating industries are expected with demands by the project. **In-use**: Road improvement is expected to ensure the flow of goods and passengers, and contribute to local economy from floods.
	17	**Land Use and Utilization of Local Resources**	B-	D	D	D	**At-work**: The site for a stockyard and the office will be one that DOH operates thus no additional impact on additional area.
	18	**Water Usage or Water Rights and Rights of Common**	B-	D	D	D	**At-work**: Use of public water supply should be dominant for sprinkling, or another option is the water resource that DOH permits to use instead. No disturbance to local water usage is expected.
	19	**Existing Social Infrastructures and Services**	B-	B+	B-	B+	**At-work**: Ease of traffic congestion is expected because the number of lanes shut during the construction will be minimized as much as possible. **In-use**: Any facilities like schools or hospitals required a special concern do not exist. In addition, effects of road development may contribute to improvement of local social services.
	20	**Social Institutions such as Social Infra-structures and Local Decision-making Institutions**	B-	D	B-	D	**At-work**: Extent of impact is still vague at present because opponents may be more apparent around the inauguration of the construction. However, impacts should be minor.
	21	**Misdistribution of Benefit and Damage**	D	D	N/A	N/A	Same evaluation as the scoping.
	22	**Local Conflict of Interests**	B-	D	B-	D	**Pre-work**: Though any local conflict of interests has not been confirmed, the impact is expected minor because of improving the existing road.
	23	**Cultural Heritage**	D	D	N/A	N/A	Same evaluation as the scoping.
	24	**Landscape**	B-	B-	B-	B-	**At-work**: Construction equipments in the project area may spoil the landscape. **In-use**: Approx. one (1) meter of raising road elevation is considered for little impact on the landscape along the project area.
	25	**Gender**	D	D	N/A	N/A	Same evaluation as the scoping.
	26	**Children's Right**	D	D	N/A	N/A	Same as above.
	27	**Infectious Diseases such as HIV/AIDS**	B-	D	B-	D	**At-work**: DOH has experienced to do with an anti-AIDS activity. Risk aversion against infectious diseases is expected by this DOH's experience.

Category	No	Impacts	Evaluation in Scoping		Evaluation on surveys		Reasons
			Pre-/ At-work	In-use	Pre-/ At-work	In-use	
	28	**Work Environment (incl. Work Safety)**	B-	D	B-	D	**At-work**: National regulations or guidelines regarding management of work safety in construction are available. Complying with these rules will assure a better work environment.
	29	**Accident**	B-	D	B-	D	**At-work**: Accidents can be reduced if information on roundabout roads and the direction for safe driving are sufficient.
Other	**30**	**Transboundary Impact and Global Warming**	B-	B+	B-	B+	**At-work**: There remains some room to study even though emission of CO_2 was estimated by using a model case. **In-use**: The improved road is expected to contribute to reduce CO_2 emission from driving vehicles as the increment of future traffic volume is a given condition regardless of the improvement.

A+/-: Serious positive (+)/negative (-) impact is expected.
B+/-: Some positive (+)/negative (-) impact is expected.
C+/-: Extend of positive (+)/negative (-) impact is unknown (A further examination is needed, and the impact could be clarified as the study progresses).
D : No impact is expected.
N/A: Not Applicable.

1-3-6 Mitigation Plan

Table 1-3.9 shows a possible mitigation plan for mitigating or minimizing the impacts on environmental and social concerns that were argued with. Note that the cost to implement the plan is in blank except monitoring costs because the cost estimation is under argument.

Table 1-3.9 Mitigation Plan

No.	Impacts	Mitigation Plan	Implementing Organization	Responsible Organization	Cost[*1] (THB)
Pre-/At-work					
1	**Air Pollution**	1. Conduct maintenance of construction equipments in order to keep good conditions. Take construction management to reduce unnecessary operation of the equipment. 2. Do watering on a proper area to suppress dust emission. 3. Manage and direct to use trucks and vehicles complying with the national requirements for the emission criteria. In case of carrying sands or wastes, drive on the shortest route to minimize both CO_2 emission and dispersing of dust. Cover material stockpile and apply wind fence to reduce dust generation. 4. Set the monitoring items and monitor them at proper intervals according to the standards in Table 1.5.2.	Contractor	DOH	240,000 (Monitoring)
2	**Water Pollution**	1. As for the polluted water like rainwater or sprinkled water generated in the project site, process the following ways: a) Discharge the processed water into the public drainage after processing with a simple wastewater treatment unit, i.e. sedimentation pond. b) Direct contractor to use sanitation tank unit for camp site sewage treatment 2. Set the monitoring items and monitor them at proper intervals according to the standards in Table 1.5.2.	Contractor	DOH	180,000 (Monitoring)
3	**Waste**	1. Construction debris: Convey the debris to the station specified by the operator (DOH) like a yard in the interchanges and process them properly under DOH's control. 2. Garbage from workers: Pile up at the designated place inside the project area, and process them under control by the contractor. At all time, maintain the work site clean.	Contractor	DOH	
5	**Noise and Vibration**	1. Conduct maintenance of construction equipments in order to keep good conditions. With piling work, apply the method not using a hammer-typed pile driver. 2. Make a work plan to avoid the work in night time. In case the work at night is necessary, inform nearby residents in avoidance and minimize work duration. 3. When complained by residents, immediately stop the work and take measures by the operator and contractor. 4. Set the monitoring items and monitor them at proper intervals according to the standards in Table 1.5.2.	Contractor	DOH	252,000 (Monitoring)
17	**Land Use and Utilization of Local Resources**	1. In case of requiring the ground outside the project site for a material storage or an office, the operator (DOH) shall be responsible to prepare the ground and the contractor shall manage the area properly.	Contractor	DOH	

No.	Impacts	Mitigation Plan	Implementing Organization	Responsible Organization	Cost[*1] (THB)
19	**Existing Social Infrastructures and Services**	1. In order to mitigate the traffic congestion, the contractor shall take measures through advance consultation with the operator and the local police. 2. Limit speed for construction vehicles and place signs and protective facilities to prevent accident. 3. Put out a bulletin on the information regarding the work schedule through the media such as television or radio programs or announcing via signboards.	Contractor	DOH	
20	**Social Institutions such as Social Infra-structures and Local Decision-making Institutions**	1. Contractor shall try to explain the objective and advantages of the project to the opponent under approval by DOH, and obtain consent and agreement.	Contractor	DOH	
22	**Local Conflict of Interests**	1. DOH shall play reconciliatory role and assist in solving any conflicts arising from the Project.	DOH	DOH	
24	**Landscape**	1. The contractor shall manage to arrange the layout of equipments in the work site and enhance cleaning in order to maintain good landscape.	Contractor	DOH	
27	**Infectious Diseases such as HIV/AIDS**	1. Organize regular training sections to learn the correct knowledge about infectious diseases. 2. Project manager shall oversee workers to prevent risk activities.	Contractor	DOH	
28	**Work Environment (incl. Work Safety)**	1.Observe the working conditions according to Thai related regulations includes the Ministerial Ordinance for Determining the Standards of Operation and Administration on Work Safety, Sanitation and Environment Regarding Construction Work in 2008 (working time, wage etc.). 2. Mandate to put on a work wear and a helmet. 3. Practice educational activity regarding work safety utilizing morning meetings or training sessions. 4. Establish an emergency response system in case of an accident.	Contractor	DOH	
29	**Accident**	1. Allocate traffic controllers and arrange the passing vehicles properly on the roads around the project area. 2. In order to mitigate the traffic congestion, the contractor shall take measures through advance consultation with the operator and the local police. 3. Limit speed for construction vehicles and place signs and protective facilities to prevent accident. 4. Put out a bulletin on the information regarding the work schedule through the media such as television or radio programs or announcing via signboards.	Contractor	DOH	

No.	Impacts	Mitigation Plan	Implementing Organization	Responsible Organization	Cost[*1] (THB)
30	**Transboundary Impact and Global Warming**	1. Estimate the emission of global warming gases generated during the project. 2. Specify a potential factor to reduce emission based on the estimated values, and strive to reduce the emission as much as possible (vehicles, work equipments etc.).	JICA[*2] Contractor	DOH	
In-use					
1	**Air Pollution**	1. Monitor air quality and compare results with the data acquired before the project. If pollutants increase significantly due to congestions, enhance the control of exhaust gas emission from the driving cars by controlling traffic volume (by car type, time zone).	DOH	DOH	160,000 (Monitoring)
5	**Noise and Vibration**	1. Monitoring of noise and vibration will be included in the monitoring program by DOH as stipulated by law. In case of receiving complains from residents, get opinions from the concerned residents, and then check changes of noise and vibration compared with the status in pre-construction work. 2. In the case of generating noise or vibration after operation exceeds legal limits or resulting in complains, take measures to reduce the impact, i.e. sound-proof wall, speed control.	DOH	DOH	168,000 (Monitoring)
24	**Landscape**	1. Maintain pleasant landscape along the project road, i.e. maintain plants in good condition and clear the road of debris. Upon residents claims, properly take inputs from concerned residents to hear their comments. 2. In case of future landscape modification, obtain consent and agreement from the residents affected by holding a stakeholder consultation and showing a picture of the situation in use prior to the construction.	DOH	DOH	
				Total cost	

*1: Monitoring costs are estimated based on a regular implementation of monitoring. See Table 1.8.1 for details.

*2: Estimation of gas emission is followed by the guideline of 'A Proposal for Estimation Method of CO_2 Emission in the Highway Project', issued by the Technology Center of Expressway, Dec. 2004

1-3-7 Environmental Management Plan and Monitoring Plan

The facts that the Project is to improve the existing highway and the area is urbanized indicate that any specific living things or cultural heritages to be eco-changeable, and the ethnic minority that needs protection do not exist. However, regarding the items including air and water quality that are easy to influence on the natural environment, it is required to conduct a schematic monitoring, analysis and observation.

Judging from the surveys of this report, it is expected that the Project has little impact on the environmental and social activities. But it still requires an action to proof the absence of intentional pollution. An implementation system of environmental management and monitoring is illustrated in **Figure 1-3.1**. During construction, results will be reported following the reporting flow (black arrow) in series. If results are doubtful or have something to be re-checked, they will be fed back according to the red arrow. Basically the feed-back follows the direction of arrows in red. But in case that an urgent measure is required by a serious impact on the environment, a direct feed-back (blue arrow) could occur from JICA to DOH. On the other hand, DOH will be in charge of monitoring implementation for the rehabilitated motorway in-use phase. Then DOH should manage monitoring activities including implementation and record control. Monitoring results which DOH will file are to be reported to Japanese side (JICA/Study Team). Japanese side will feed back the results to DOH, if needed. **Table 1-3.10** indicates a draft of environmental monitoring plan, but there remains room to review the contents by changing the work plan in the future.

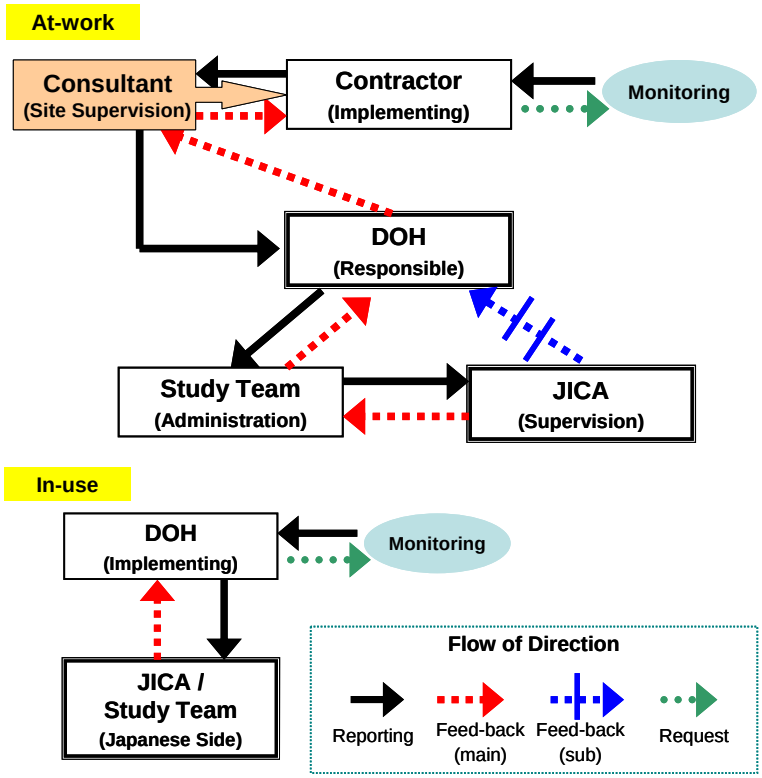


Figure 1-3.1 Implementation System of Environmental Management and Monitoring

Table 1-3.10 Environmental Monitoring Plan

Item	Check Item	Location	Frequency	Criteria[*1]	Responsible Organization	Cost[*2] (THB)
At-work[*3]						
Air Quality	TSP, CO, NO_2, SO_2	2 sites including sensitive receptors near the project site or others (ex. STA 16+000, 26+000)[*4]	Quarterly, or adjusted based on air pollutant-generating activities	Thai Standard	Contractor	240,000
Water Quality	pH, SS, BOD, DO, Oil	1 processed water (final effluent)	Bimonthly (once every 2 months)	Thai Standard[*5]		180,000
Noise and Vibration	L_{eq}, L_{max} Vibration level	2 sites including sensitive receptors near the project site or others (ex. STA 16+000, 26+000)[*4]	Quarterly, or adjusted based on noise-generating activities	Thai Standard[*6]		252,000
In-use						
Air Quality	TSP, CO, NO_2, SO_2	Same points as the case at-work[*4]	Semiannually (2 years after the service)	Thai Standard	DOH	160,000
Noise and Vibration	L_{eq}, L_{max} Vibration level	Same points as the case at-work[*4]	Semiannually (2 years after the service)	Thai Standard[*6]		168,000

*1: See **Table 1-3.5** for details.
*2: Costs are estimated based on a regular implementation of monitoring. The estimated total duration of the Project is 15 months.
*3: Monitoring results regarding environmental issues (air and water quality, noise & vibration) before the Project basically refer to those from previous surveys. An actual monitoring would be done when DOH judges it is necessary.
*4: Sites chosen to match the sampling sites carried out in prior monitoring study by DOH in 2011
*5: To apply criteria in Class 4. As for SS criterion, however, apply the one in Japanese Type C. The criterion for oil is defined as 'no oil slick on the water surface'.
*6: Vibration criterion applies the Japanese standard for construction work (75dB).

1-3-8 Stakeholder Consultation

DOH does not plan to hold a stakeholder consultation at present because the Project is for improving the existing highway. However, as referred to the mitigation plan etc., it should be essential to make an announcement to involved parties and hold a consultation in case that any concerned residents or groups would ask for, or DOH or local authority considers it necessary. A smooth performance of work needs a prompt action and handling of any complaints or conflicts.

1-4 LAND EXPROPRIATION AND RESETTLEMENT

The Project does not need land expropriation as all activities are limited in the ROW. The Project does not negatively affect the livelihood of residents because of improvement work (raising road elevation) of the existing motorway. Thus an involuntary resettlement of relating residents is not expected to take place. In addition, if some impacts induce land expropriation or resettlement that might affect the environmental and social issues, DOH as the responsible authority shall take actions as soon as possible.

CHAPTER 2. CONTENTS OF THE PROJECT

2-1 BASIC CONCEPT OF THE PROJECT

2-1-1 OVERALL GOAL AND PROJECT PURPOSE

The GOT has proposed the rehabilitation plan packages classified as urgent plan, mid-term and long-term plan. These three plan packages, called as the master plan for the Chao Phraya Flood Management, have been approved by the cabinet meeting in December 27, 2011. The objective of the Master Plan varies with the location along the Chao Phraya River basin. At the upper portion of the basin, it plans restoration of forests and land as well as construction of reservoirs. At the middle portion, it plans measures for protection of local cities from natural flooding as well as flood induced by human acts. And, at the lower portion of the basin it envisages to undertake measures for protection of important industrial zones and to construct well regulated channels and spillways. It also includes plans for restrictions on development or use of land and early warning system.

In addition to the overall Master Plan, each ministry or department concerned has been planning the post-flooding disaster management and urgent restorations after the flooding had occurred.

Department of Highways (DOH) has designated the rehabilitation plan as one of the mid-term plan among its development plan (urgent restoration, mid-term and long-term plan). The project is to be carried out under Japan International Cooperation Agency (hereinafter referred to as JICA) as a part of DOH Plan.

In response to the request from the GOT, the GOJ decided to conduct a Project for Comprehensive Flood Management Plan for the Chao Phraya River Basin (hereinafter referred to as “the umbrella project”) which consists of (i) Comprehensive flood management plan (Component 1), (ii) Outline design for Japanese Grant Aid (Component 2), and (iii) Pilot Projects for emergency rehabilitation (Component 3). Among those projects, Component 2 is likely to be implemented under the disaster prevention and restoration grant aid project of Japan.

The project is planned to be implemented with an objective to secure the function of logistic network even in the time of flood disaster by raising the 4 lanes on the north bound roadway surface of the Outer Bangkok Ring Road (also known as NR-9) within a segment of approximately 30km. The implementation of the project is expected to enable the NR-9 to function as industrial road by inter-connecting the Gulf of Thailand, Suvarnabhumi International Airport, and industrial estate in the north of Bangkok, as well as help mitigate the impact during flooding in areas in Ayutthaya and Bangkok and eventually contribute in sustaining economic growth around the Chao Phraya River Basin.

2-1-2 OBJECTIVE OF THE PROJECT

The requested components by GOT were confirmed following discussions with the DOH as follows;

- Raising road surface elevation of one side (North Bound) of the Outer Bangkok Ring Road (East portion) which has the approximately 30km long where:
- The level of the road surface is 20 cm or more lower than the highest level of the 2011 flood, and
- The toll gates are situated.

The objectives of the Survey in connection with this project are;

1) To identify and confirm the scope and components of the requested project, necessary for the Japan's Grant Aid Scheme, especially as the disaster prevention and restoration project, and appraise and evaluate the technical and the economic viability of the Project,
2) To make the general layout and detailed design, and to estimate the cost of the Project and schedule required for implementing its construction and/or procurement, and
3) To coordinate with development plan at national, regional, sectoral and other levels.

Furthermore, the scope and the schedule of this project are as summarized below.

1) Study the background, objectives, contents, organizational structure of the requested project and to examine the current situation in relation to national, regional, and/or sector development plans.
2) Confirm the relation between the entire project and the requested project, necessary for the Japan's Grant Aid Scheme, as the disaster prevention and restoration project, and collect the required information and data for preliminary and detailed design.
3) Make clear the appropriateness and efficiency of the project in terms of disaster prevention and restoration and establish the optimal cooperative plan, including preparation of preliminary and detailed design, cost estimation, sustainable plan for the operation and maintenance, and a set of reference documents for bidding.
4) Establish the effectiveness index, to conduct the base-line survey method, and make planned project schedule.
5) Confirm the undertakings and obligations of the counterpart necessary for the achievement of the objectives and for smooth implementation of the Project, as well as recommend the administrative and technical plan for operation and maintenance for the project.
6) Prepare a progress report of the Preparatory Survey and explain its contents to DOH and organizations concerned (May 2012). The results of and the discussions has been reflected in the detailed design and the reference documents for bidding purpose. The following contents comprise the progress report:
    1. Technical Notes

2. Preliminary Design
3. Undertakings and Inputs from each Government
4. Necessary Measures for Environmental and Social Consideration

7) JICA will prepare the final report of the preparatory survey and dispatch a mission to explain its contents in August, 2012. Contents of the progress report will consist of the following:

1. Detailed Design
2. Implementation Plan
3. Cost Estimation
4. Maintenance and Monitoring Plan
5. A set of Reference Documents for making Bid Documents

2-2 OUTLINE DESIGN

2-2-1 Design Policy

2-2-1-1 Basic Policy

The objective of the project is to secure the function of logistic network even in the time of flood disaster. The elevation of the existing road of the North Bound Direction of the Outer Bangkok Ring Road (East Portion), which consists of 4 vehicular lanes, will be raised so that the public traffic will still be able to ply on the road. The rehabilitation work undertaken through implementation of the project is expected not only to enable the NR-9 to function as industrial road by inter-connecting the Gulf of Thailand, Suvarnabhumi International Airport, and industrial estate in the north of Bangkok, but also help mitigate the impact during flooding in around areas in Ayutthaya and Bangkok and eventually contribute in sustaining economic growth around the Chao Phraya River Basin.

Based on the present condition of the objective road and the purpose of the project, the basic policies to be undertaken by this Project are set as below.

1) The scope of the project will include the raising of the road elevation of the north bound direction (4 lanes) only to enable the road to sustain its function for logistic network even during the time of flood.
2) The elevation of the existing road to be raised will be determined based on the historical highest flood level (return period of 80 years) recorded in 2011.
3) The design road elevation is raised by 20cm allowance of submergence at the shoulder of the objective road during similar flooding. Even so, due to standard normal crossfall of 2.5%, although the shoulder sees submergence of 20cm, 2 of 4 lanes is expected to remain above the water.
4) The design road elevation at the toll gate will be necessarily raised over the flood level (10cm above design flood level).
5) The consistency between the objective road level and existing service road level is secured in terms of geometric design and carriage lane number.
6) Pavement design and slope protection at the section of the project are planned based on the mitigation strategy of flood damage and road drainage system.
7) Design of on/off ramps at the merging/diverging points with the main road is conducted, if required, based on vertical profile and gradient so as to secure the smoothness and safety of traffic flow. Since the merging point is not totally covered in this project, the most optimal and appropriate plan is to be suggested toward DOH from the standpoint of flooding risk mitigation.
8) AASHTO (American Association of the State Highway and Transportation Officials) or Thai Design Standards based on AASHTO will be basically applied to the Project. Also, the

Japanese Standards will be applied if there is no applicable item in the AASHTO or Thai Design Standards. AASHTO Guideline 1993 will be used for the pavement design and calculation.

9) Taking into account the urgency of the project, the construction will be conducted 24 hours − day and night- in two stages. The south bound lanes will be used for the public traffic during construction period. Three lanes on the south bound direction will be open for the south bound traffic while north bound traffics will have two lanes on the north bound direction and one lane on the south bound direction.

2-2-1-2 Policy on Natural Environmental Condition

Considering climate condition, flooding status and results of various natural surveys conducted in this preparatory survey of the project, the policy of this project are set as below.

(1) Geography and Climate

The Kingdom of Thailand is located at the centre of the Indochina peninsula in Southeast Asia. It is bordered to the north by Burma and Laos, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and the southern extremity of Myanmar. Geographic coordinates is from 5.00 to 21.00 N and from 97.00 to 106 E.

The country has an area of approximately 513,115km2. For economic, social and ecological reasons, Thailand is usually classified into five geographical regions.

They are the central region (including Bangkok Metropolitan Region) comprising the basin of the Chao Phraya River which runs from north to south and after crossing Bangkok flows to the Gulf of Thailand. The northern region, mountainous and was traditionally the most heavily forested area of the country. The north-eastern region constitutes approximately one third of the area of the Kingdom and comprise the Korat Plateau which is bounded on the north and east by the Mekong River and the south by the Dongrek escarpment. The south-eastern, which comprises the hilly countryside from Bangkok to the Cambodian border, is characterized by higher rainfall and poorer solids than the adjoining central region. The southern region has highest rainfall in the country.

In terms of climate, located outside the typhoon belt, Thailand can be divided into two climatic zones. The north, north-east and central regions including Bangkok have a climate with three districts seasons: rainy, from June to October; cool, from November to February; and hot of highest temperatures and sunny weathers from March to May. The average rainfall in these regions is 1,500 mm per year. The southern region has a characteristic tropical rainforest climate. Rainfall occurs virtually throughout the year, although a number of micro-climates can be found. The longest distance in national land is 1,860km, and difference in latitude between north and south is 14 degree. Therefore, it shows various weather changes according to the district though the climate is the same. There is little variation in temperature, which is on average 29C throughout the year. March and April are normally the driest months in the south and the periods of maximum rainfall in these areas vary

according to climatic sub-regions.

(2) Design Flood Level and Establishment of Flood Probability

1) The section and longitudinal profile of the Project are calculated in accordance with the historical highest flood level recorded in year 2011.
2) The design flood level is measured from the results and findings of flood-marks and hydrological analysis.
3) Outline of the hydrological analysis regarding to flood probability is given below.

・Data:	Nakhon Sawan Observatory（N15°40′14.99″,E100°06′45.00″）Data Source: Area of Basin in Nakhon Sawan Province 105,000km^2
・Sample :	The Past 55 years from 1957 to 2011.
・Annual Flow Volume:	Annual Total Discharge in Nakhon Sawan Province: 47,456Mm^3（4.75B m^3）, Half Year Discharge:38,519M m^3 (3,85B m^3) *(Note: M m^3 = million cubic meter, B m^3 = billion cubic meter)*
・Analysis Result:	The large flooding occurrence same to 2011 flood is 80 year's return period. The flood probability is equal to 1/80. The probability density function's suitability is high (least squares error less than 0.04), Gumbel method which has estimated error small is used.
・Remarks:	a) Decrease in flow volume due to overflow at upstream in Nakhon Sawan Province is included. (Natural Condition) b) The flood probability of the large river such as Chao Phraya River is not exactly evaluated based on the peak discharge in flooding. c) As a result, simulation for flow probability is reasonable d) It is highly confidential that total flow volume in flooding within 6 months should be useful due 6 month flooding duration.

The results of survey and analysis of flood level in 2011 is given in **Figure 2-2-1-2.1**, and the result for establishing the base for determining the design flood level is indicated in **Table 2-2-1-2.1**.

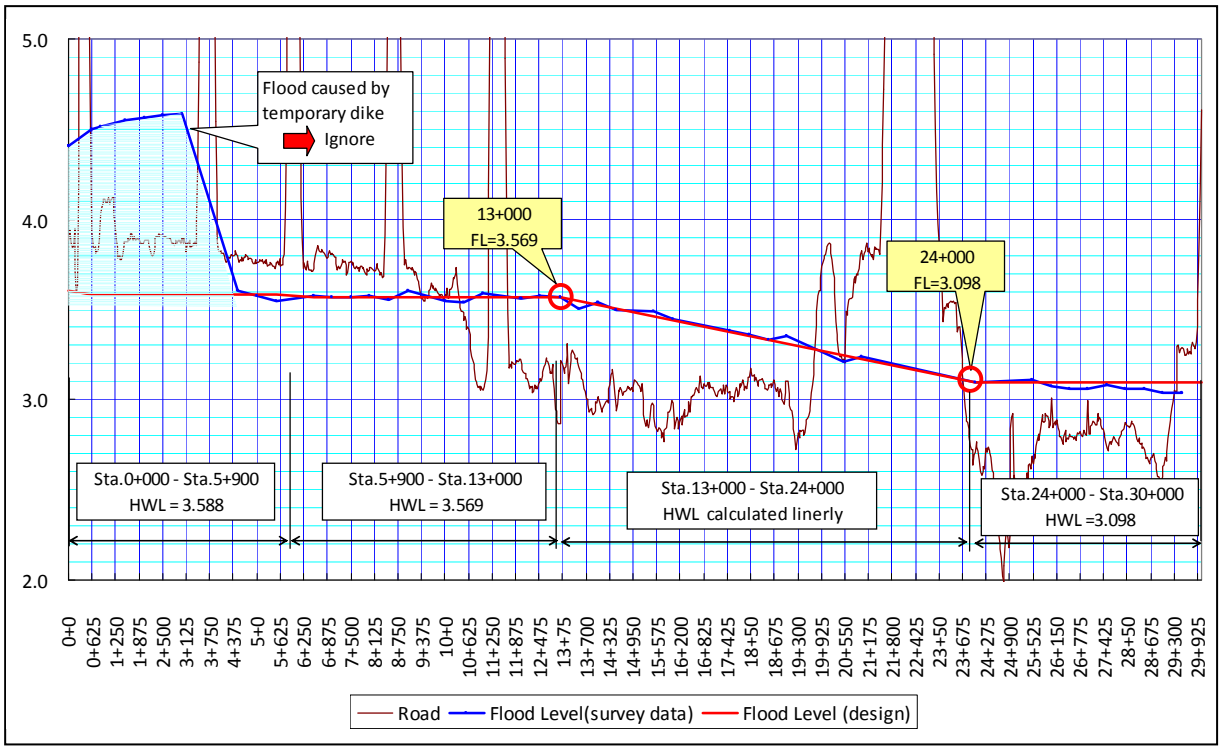


Figure 2-2-1-2.1 Results of Flood Level Survey/Analysis (2011 Flood)

Table 2-2-1-2.1 Design Flood Level

Section	Design Flood Level	Remarks
Sta.0+000～Sta.5+900	FL. 3.588	Average
Sta. 5+900～Sta.13+000	FL. 3.569	Average
Sta.13+000～Sta.24+000	Varies	Linearly calculated
Sta.24+000～Sta.30+000	FL. 3.098	Average

(3) Natural Condition Survey

1) Scope of Works

Natural Condition and Topography Survey was conducted on the entire project area and the scope of works is shown in the **Table 2-2-1-2.2**.

Table 2-2-1-2.2 Natural Conditions and Topographic Survey

Survey	Purpose	Location	Scope	Methodology
Site Survey				
1. Topography Survey	To collect data and information on the flood level and the features of the site to prepare the documents required for conducting the design works	Areas along objective road	a) Longitudinal survey b) Cross section survey c) Plane table survey d) Flood level survey e) Temporary bench mark	Subcontracting

Survey	Purpose	Location	Scope	Methodology
2. Geo-Technical Investigation (Transport sector)	For collecting data to understand the soil properties and its distribution condition for conducting design of pavement and the facilities of the objective road	Areas along objective road and borrow pit	f) Existing ground investigation and CBR test g) Drilling h) Embankment material investigation i) Base course investigation	Subcontracting
3.Inventory Survey	To comprehend the existing condition of road incidental facilities so that it could be reflected in the design work	Areas along objective road	j) Existing Inventory Survey	Collection of available data and site observation
Natural Condition Survey				
4.Climate/Hydrology	To understand as well as to collect the data for conducting suitable construction planning	Areas along objective road	k) Temperature, precipitation, water level of gullies, natural disaster, etc.	Collection of available data and site observation

2) Outline of Subcontracting Works

The scope of subcontracting works, its progress and result are given in **Table** 2-2-1-2.3.

Table 2-2-1-2.3 Outline of Subcontracting Works

Subcontracting Scope	Quantity	Progress/Result
Topography Survey		
1. Temporary bench mark	To investigate the bench mark managed by Department of Highway (DoH) along the section of South Bound （Sta. 0+000～Sta. 38+000）	Bench Mark (B/M, coordinate) is marked in topography plan
2. Flood level survey	To survey and analyze 2011 flood marks on the facilities along the objective road section（Sta. 0+000～Sta. 30+000）at 500m pitch	Results of flood level survey/analysis (2011 flood)（**Table 2-2-1-2.1**）
3. Plane table survey	Section：30.0km（Sta. 0+000～Sta. 30+000） Cross Section ：50m （Median barrier of South Bound direction to Right of Way boundary on the north bound side） Toll Gate Cross Section：100m （North and South Bound）	Plane：S=1/1,000
4. Profile Survey	Length：30.0km（Sta. 0+000～Sta. 30+000） Station interval：25.0m pitch	Profile：S(V)=1/50 S(H)=1/1,000
5. Cross Section	Length：30.0km（Sta. 0+000～Sta. 30+000）	Cross Section：S=1/100

Subcontracting Scope	Quantity	Progress/Result
Survey	Station：25.0m pitch Cross section width：Average 50m （Median of South Bound to Right of Way boundary of North Bound direction）	
Geo-Technical Investigation		
6. CBR Test	For pavement design and to investigate the strength of the existing pavement as well as to determine the design CBR value Upper subbase：74 Nos. Under subbase：74 Nos. Subgrade：74 Nos.	Final report of 222 Nos. of CBR Test result
7. Boring Test	To analysis and study the occurrence of residual subsidence due to raising the road elevation. In-site test：25.0m/1 Nos.×9 locations Laboratory test：15 samples Unit weight・Specific Gravity, Atterberg Limits（Liquid and Plastic Limit）, Sieve Analysis	Final report of Laboratory Test of Soil Histogram
8. Embankment Material Test	Sample to be tested：2 test pits（sand） Laboratory Test：2 samples Sieve Analysis, Unit Weight, Specific Gravity, Natural Water Content, Permeability Coefficient, Modified CBR Value, Degree of Compaction、Plastic and Liquid Limit	Final report of Laboratory Test
9. Base Course Material Test	Sample to be tested：Crushed stone plant 4 locations Laboratory test：4 samples Abrasion loss and wearing, Sieve Analysis, Specific Gravity and Moister Coefficient	Final report of Laboratory Test

Table 2-2-1-2.4 Topography Survey

Contents	Unit	Quantity
1) Topography Survey (Road Sector)		
・Plane Table Survey（W=60m）	Km	30.5
・Profile Survey（Shoulder）	Km	30.5
・Cross Section Survey（50m @25m）	Location	1,230
2) Flood Level survey（@500）	Location	62
3) Temporary Bench Marks	LS	1

Some of the natural condition survey works mentioned above were subcontracted to local contractors/consultants. Brief information of these companies is as follows.

Topography Survey

Subcontractor : STS Engineering Consultants Co., Ltd.

Local Address : 196/10-12 Soi Pradipat 14, Samsennai, Phayathai, Bangkok, Thailand

Representative : Pernu Songpaibool

Geo-Technical Investigation (Road Sector)

Subcontractor : Geo-technology Consultants Co., Ltd.

Local Address : 889 Thai CC Tower, 15th Floor, Room 159, South Sathorn Road, Yannawa, Sathorn, Bangkok Thailand

Representative : Krittanon Nilpanich

a) Topographic Survey (Profile Survey)

The result of topography survey for measuring the profile of the existing road surface is shown in **Table 2-2-1-2.**. The output of this survey and the survey of the flood level was used as the base document in determining the section to be raised as well as the necessary height to be raised of the said section.

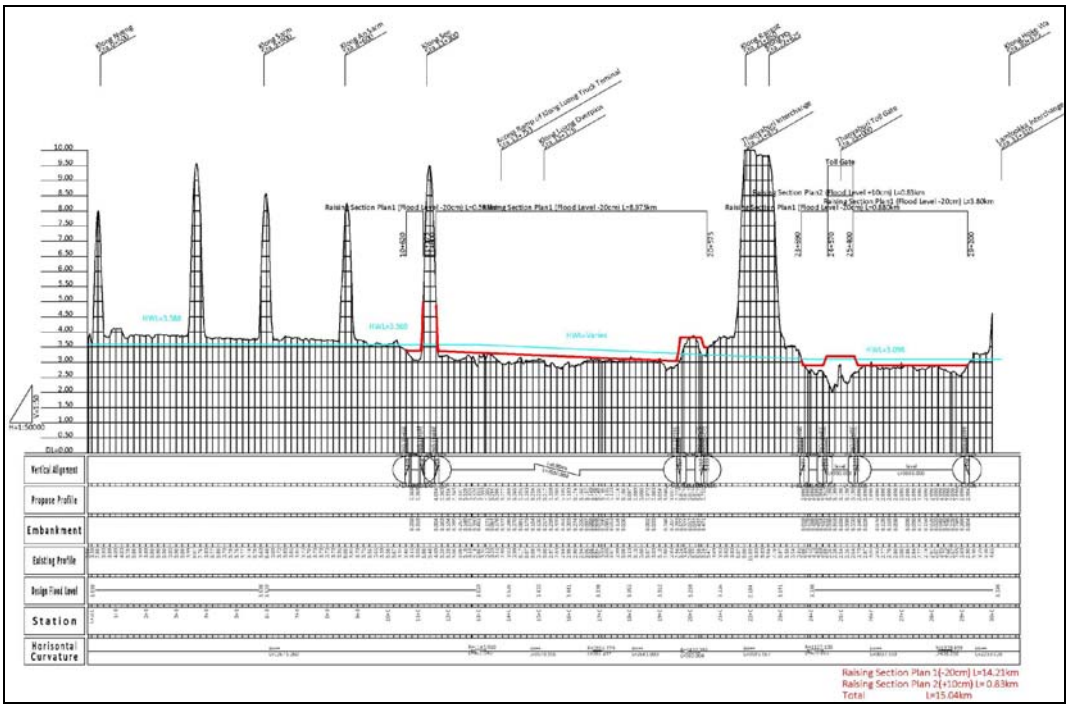


Figure 2-2-1-2.2 Result of Profile Survey

b) Geo-technical Investigation

The geo-technical investigation and laboratory test were additionally conducted. The main purpose is not only to supplement the existing condition for the detailed design, but also to analyze the estimated consolidation settlement (residual) anticipated to occur following the raising of the existing road elevation of the objective road. **Photo 2-2-1-2.1** shows a glimpse of drilling work being carried out.

Photo 2-2-1-2.1 Drilling Work in Progress

c) Inventory Survey of Existing Facilities

Inventory survey of the existing road facilities which is utilized to clarify and categorize size and quantity of the existing road facilities was conducted by the survey team on its own. This was done to verify the condition of the existing incidental road facilities. The size, location, and end point of the cross sectional drainage pipe, traffic signs, guard rails etc. were some of the major facilities surveyed.

Photo 2-2-1-2.2 Condition of Existing Drainage Facility

2-2-1-3 Policy for Social and Economic Condition

(1) Policy that Satisfies the Function of the Objective Road

The Outer Bangkok Ring Road (East Portion) is the objective road and is a full access-controlled motorway that links the outer fringes of greater Bangkok. Its eastern portion is toll section, which extends from Bang Pa-In through Lam Lukka, Ram Inthra, Wat Salud and meets with Motorway

Route 7 at Thap Chang interchange. The Outer Bangkok Ring Road (East Portion) is designated as a bypass of NR-1, where traffic congestion is significant most of the time. Also, by connecting the strategically important and economically vital places such as Ayutthaya Industrial Estate Area, Bangkok Metropolitan Region, Suvarnabhumi International Airport, Eastern Sea Board, and Laem Chabang Sea Port, the Outer Bangkok Ring Road (East Portion) serves as a major transportation links.

To effectively functionalize the Outer Bangkok Ring Road, the objective of the rehabilitation project is planned to meet the criteria shown below.

1) The section of the Project is planned based on the design flood level calculated from the results and findings of the survey and hydrological analysis.
2) The design road surface level is raised with 20cm allowance of submergence at the shoulder of the objective road, by which it is expected that 2 of 4 lanes is not flooded due to normal crossfall 2.5%. In addition to the level of typical section, the design road surface level at the toll gate is necessarily raised over the flood level.
3) The consistency between the objective road level and existing service road level is secured in terms of geometric design and carriage lane number.
4) Pavement design and slope protection at the section of the project are planed based on the mitigation strategy of flood damage and road drainage system.
5) Design of merging point between the main road and access road is considered based on vertical profile and gradient, to secure smooth and safe traffic flow.
6) Incidental road facilities such as median, overhead crossing facility etc. are designed with consistency with the raised road surface level.

(2) The Reason for Selection of Outer Bangkok Ring Road

As shown in **Figure 2-2-1-3.**, the Outer Bangkok Ring Road (East Portion) stretches from north to south in parallel to the direction of the flood flow. The objective road to be raised in the project (length of 30km) equips viaducts for crossing irrigation channels. There are altogether 7 rivers including canals traversing the objective road. These water ways have a cross sectional area from 74 to 80m2 and have capacity to channelize 24 to 34m3 of water downstream. In addition, there are a total of 116 pipe culverts whose diameter ranges from 1.00 to 1.50m and is fundamentally used for irrigation and surface drainage purpose. Furthermore, there are 2 box culverts of 3.00m by 3.25m, and two-cell box culvert for irrigation. Raising the existing road surface level of the Outer Bangkok Ring Road (East Portion) will not keep back flood water and change flood flow direction between the East and West side, and also will not affect flood condition and areas damaged by flood. As mentioned above, the objective road is not a dike road and as such, it neither functions to dam water during flood nor influence in changing the water flow direction. Therefore, raising the existing level of this road has no influence on the manner of flow or the damage/risk it poses.

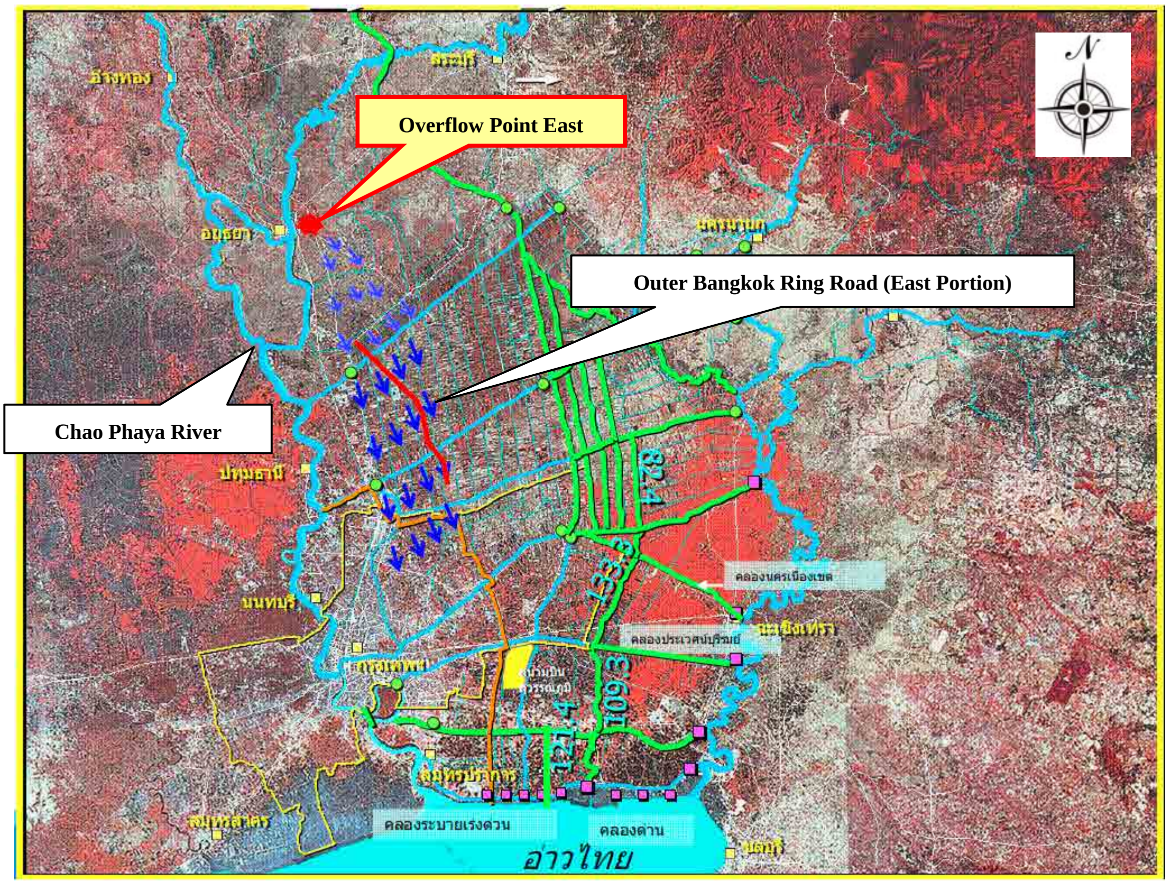


Figure 2-2-1-3.1 Flood Condition around Outer Bangkok Ring (source:RID)

As mentioned above, the objective road is not a dike road and as such, it neither functions to dam water during flood nor influence in changing the water flow direction. Therefore, raising the existing level of this road has no influence on the manner of flow or the damage/risk it poses.

Another reason for selecting this road comes from the result of site investigation carried out on the aftermath of 2011 flooding on the roads that run east-west around Greater Bangkok.

As shown in **Photo 2-2-1-3.1**, the concrete barrier along the median on NR-1 is apparently demolished during flood to lower the flood level of the north side of NR-1, as the concrete barrier dammed the flood. The length of the barrier that was demolished is approximately 200m. The following can be concluded from the results of the flood analysis conducted under this project.

- the flooding running from north to south,
- the submergence of the north part along the route 1 due to the existing concrete barrier at center median,
- the breaking of the concrete barrier by residents, and
- The flood water running over the route 1 from north to south.

The results of the investigation suggest that heightening of a road stretching east to west should not be

done without any detail flood flow analysis.

Photo 2-2-1-3.1 Demolition Condition of Concrete Barrier on the Median of NR-1

(3) Rehabilitation Policy for Damages in the Submerged Segment of the Objective Road

Raising road elevation refers to raising the existing base/subbase of the road by removing the existing impermeable asphalt concrete to enhance uniform drainage between the existing and the new base courses. The existing road have experienced flood for many years in the past, including 1995 and 2006, and it is anticipated that the existing base-course, sub-base and sub-grade are potentially damage. Thus, field CBR test was conducted and compared with the previous design CBR value. The results, showed high CBR values which is evident that the existing pavement structure has not been damaged by the effect of the flooding and retains its strength.

2-2-1-4 Policy on Construction/Procurement Condition

Most of the transport infrastructure in Thailand, especially arterial roads, is fundamentally owned by the DOH and its structure is mainly viaduct and asphalt concrete pavement. The implementation of this projects is will basically be conducted by a local construction company.

There are 52 extraordinary class and 60 first class construction companies registered with DOH. 6 are large-scaled companies and listed on the Thailand Stock Exchanges. Maximum annual revenue recorded by these 6 companies totals approximately 43.7 billion THB, which is equivalent to 113.6 Billion JPY (exchange rate 2.6 JPY for one THB). These companies independently enter into contracts with DOH for large scale project or other 54 small and medium size companies create joint ventures to implement the project execution. The small- or medium-sized companies sometimes win the contract for medium size project.

Most of the large scaled construction companies deliver the project as the general contractor, not as the specialist contractor. As a result, these contractors are expected to decline to participate in the Project as a subcontractor, because the contract is awarded to Japanese company only. Thus, it should be

reasonable that only small or middle-scaled companies enter in the subcontract to tie with Japanese contractors.

The policy on the procurement is set as discussed below. These policies are based on the findings and results of the survey of local procurement condition along with the material, equipment and labor requirements in the Project.

(1) Policy of Procurement of Labors

Most of the contractors, from small to large scale, have experience of road construction. Thus, given that the above mentioned companies can be involved in this Project, local construction supervision engineer, skilled labor and operators of special equipment are readily available. These contractors are also capable of undertaking for sub-contract for the construction work.

(2) Policy on Procurement of Construction Materials

The basic construction material such as asphalt, cement, reinforcement bars, and steel structures are available locally. There are sufficient amount of these materials at the wholesalers and needs not to be imported for a particular project. The findings of these investigations should be reflected in the formulation of procurement method of these materials, along with comparison with type, specification, and quantity, economical analysis, certainty of procurement.

Major material items require for the Project are crushed rock and aggregates for base and sub-base course. Nine Plants that are capable of supplying these materials are located within 80 to 100km from the Project area. Result of the plant capacity investigation indicates the availability of these major materials in terms of quality and schedule.

Considering quality and schedule, procurement of cement, reinforcement bar, steel structure and precast concrete product registered with Thai Industrial Standard is available in the local market.

Concrete Barrier for temporary use needs to be procured locally. The total length of the concrete barrier required extends to about 39km. From view of the construction schedule and the number of days required for delivery, preparation for procurement of these barriers need inevitably to be done in advance. As such, a strategic plan with detailed analysis followed by further discussions is indispensable. There are three concrete manufacturing companies, having production capacities that normally range from 100 to 300m per day. However, due to the current increase in implemented projects in Bangkok, the actual quantity that these companies will be able to provide exclusively for this Project is assumed to be less than 100m per day. From the quantity that this project demands, the expected period for its procurement is estimated to be about 5.2 months even as the procurement is done from the three companies simultaneously.

(3) Policy on Procurement of Construction Equipment

Four asphalt manufacturing plants are located within 20 to 30 km from the Project site. These plants

are considered capable of providing asphalt of required quality. Also, there are several general contractors or special contractors that possess asphalt manufacturing plant close to the Project site. There are ten manufacturing plants from where ready-mix concrete can be procured. Several contractors own concrete manufacturing plant system and agitator trucks.

In the Project, schedule is considered as one of the key factor and has the highest priority over any other managerial categories. As such, the construction method planned considers 24 hours (day and night) execution work with two shifts and allows exclusive use of the work area to the contractor in order to shrink the schedule. Given the schedule constraint, both concrete and asphalt manufacturing plants should be installed, by the above mentioned contractors, near the Project site. Application of this kind of construction method can enable day and night work shift.

Most of the major construction equipment used for the construction of road is available locally. Fundamentally, the equipment is owned by construction companies, but equipment leasing or supplying companies are also capable of providing the equipment. Considering the purpose to shrink project schedule through day and night work shift, it is reasonable that the contractor make a subcontract with a local contractor, from the perspective of procurement risk management to use the equipment in the possession of the contractor instead of leasing them.

Therefore, procurement of equipment necessary for the Project, such as manufacturing plants and heavy construction machine owned by local construction companies, should be analyzed based on size, specification, environmental standards, quantity, current market condition, price, and time. Several alternatives should be considered and compared to select the most economical and optimal supplier.

2-2-1-5 Policy on Effective Use of Local Construction Companies

Although the construction work for this project will be awarded to a Japanese Contractor, the local companies will participate in the subletting works, such as provision and management of labor etc. Thai local contractors, manufacturing companies, and leasing companies have enough capacity and technical knowledge and can be efficiently and effectively utilized during the implementation.

2-2-1-6 Policy on Construction Method (Occupation of Road)

The scope of this Project is to implement rehabilitation works on the north bound direction of the full access-controlled motorway (4 lanes in each north and south bound: total 8 lanes).

Time is the prime concern or the most essential factor of the Project. Also, being a full access-controlled motorway, the construction-related vehicles are allowed to enter/exit the work area only from/to one direction. Therefore, the rehabilitation works of the objective road is planned to be executed 24 hour – day and night. Based on these conditions, the total width required exclusively for construction work area was calculated to be more than 14.20m, particularly from the aspect of construction schedule.

On the other hand, traffic flow for public vehicle is set up on south bound (18.90m width: 4 lanes and shoulder), outside of construction work. 3 lanes for south bound and 2 lanes for north bound are planned to be placed. Also, on the north bound (18.90m width: 4 lanes and shoulder) work zone, only one lane for north bound is planned to be placed. The total lanes in operation for public vehicle on south and north bounds in the construction stage amounts 6 lanes.

As mentioned above, the construction work requires partly occupation of a motorway presently in operation and a round-the-clock (day and night) work for completing the project in the stipulated period of time. Further discussions should be held with Office of Intercity Motorway and organizations for management and operation of the objective road. Safety facilities for traffic control during construction have to be planned in conformity with the motorway traffic regulation of Thailand.

2-2-1-7 Policy on the Scope and Contents of the Assistance

(1) Condition of Existing Principal Arterial Network

The objective road, the Outer Bangkok Ring Road (East Portion) is connected to NR-1 in the North and Route No. 34 in the South East with an approximate length of 63 km. It is a full access-control freeway with 8 lanes (4 North Bound and 4 South Bound lanes) with asphalt pavement designed for a performance period of 15 years. The construction was completed in 1993 under the loan from the Japanese government as a full access-control freeway of 4 lanes (Toll highway: North Bound 2 lanes and South Bound 2 lanes) and 4 lanes as free access road (frontage road: North Bound 2 lanes and South Bound 2 lanes). The GOT has completed the project of widening the existing freeway to 4 lanes of full access control freeway (Toll Freeway: North Bound 2 lanes and South Bound 2 lanes) by its own capital in 2009 (**Figure 2-2-1-7.1**). It is a redundant route of NR-1, where traffic jam is prominent across the city center, and functions as the road to support the logistics from North-South axle road as well as an industrial road inter-connecting Laem Chabang Port, Eastern Coastal Area, Bangkok Port, Suvarnabhumi Airport, Bangkok Metropolitan Area to the Ayutthaya Industrialized Zone. The main arterial road network surrounding the objective area is shown in **Figure 2-2-1-7.2**.

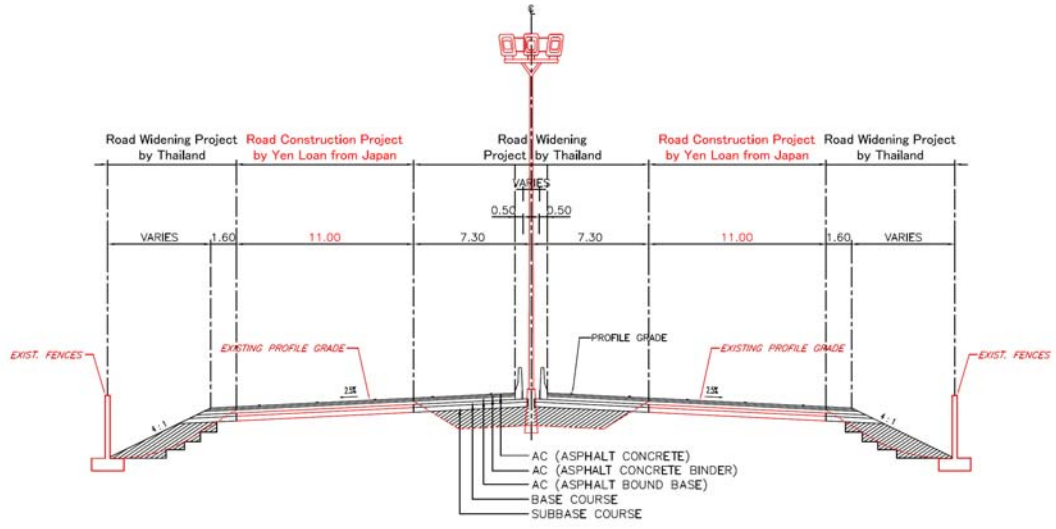


Figure 2-2-1-7.1 Classification of Implemented Project of the Outer Bangkok Ring Road

(2) Scope of the Project and Section of the Road to be Raised

As a motorway, the objective route of this project plays a significant role in the logistic network.

During the 2011 flood, the existing road surface of the objective road was submerged in water by a maximum depth of 122cm, making the road impassable to public vehicles for approximately a month in between October – December and caused severe disruption of the North-South logistic network.

This route, which is basically located at the section between NR-1 in Bang Pa-In area, and provincial road 3312, Lam Luka Area have been tremendously affected and damaged. As a result, this section, approximately 30km, was completely interrupted during October – November in 2011. In order to remedy the situation, the project plan is to rehabilitate the road profile of the north bound of 4 lanes. The implementation of the project is expected to sustain the logistic network by mitigating the flooding damage.

Section of the road to be raised including its scale is fundamentally determined from the results of the topography survey and flood analysis. The section of the road to be raised is mentioned below, while the scope of the project and section of the road to be raised is shown in **Figure 2-2-1-7.2**.

Elevating plan 1:	*Minus twenty (-20) cm from the largest recorded flood level in 2011 (historical highest flood level) The control point for minus twenty (-20) cm from the level is set at the road shoulder. Of 4 lanes of the north bound, 2 lanes are not to be submerged due to the crossfall of 2.5 %* *North bound: Sta.10+600 to Sta.11+124, Sta.11+558 to Sta.20+580, Sta.23+690 to Sta.24+400, Sta.25+600 to Sta.29+200* Length 13.856km
Elevating plan 2:	*Plus ten (10) cm from the largest recorded flood level in 2011 (historical highest flood level) The level enables toll gate operation to avoid the flooding damage.* *North bound: Sta.24+400 to Sta.25+600* *The length: 1.200km*
Total Length	***15.056km***

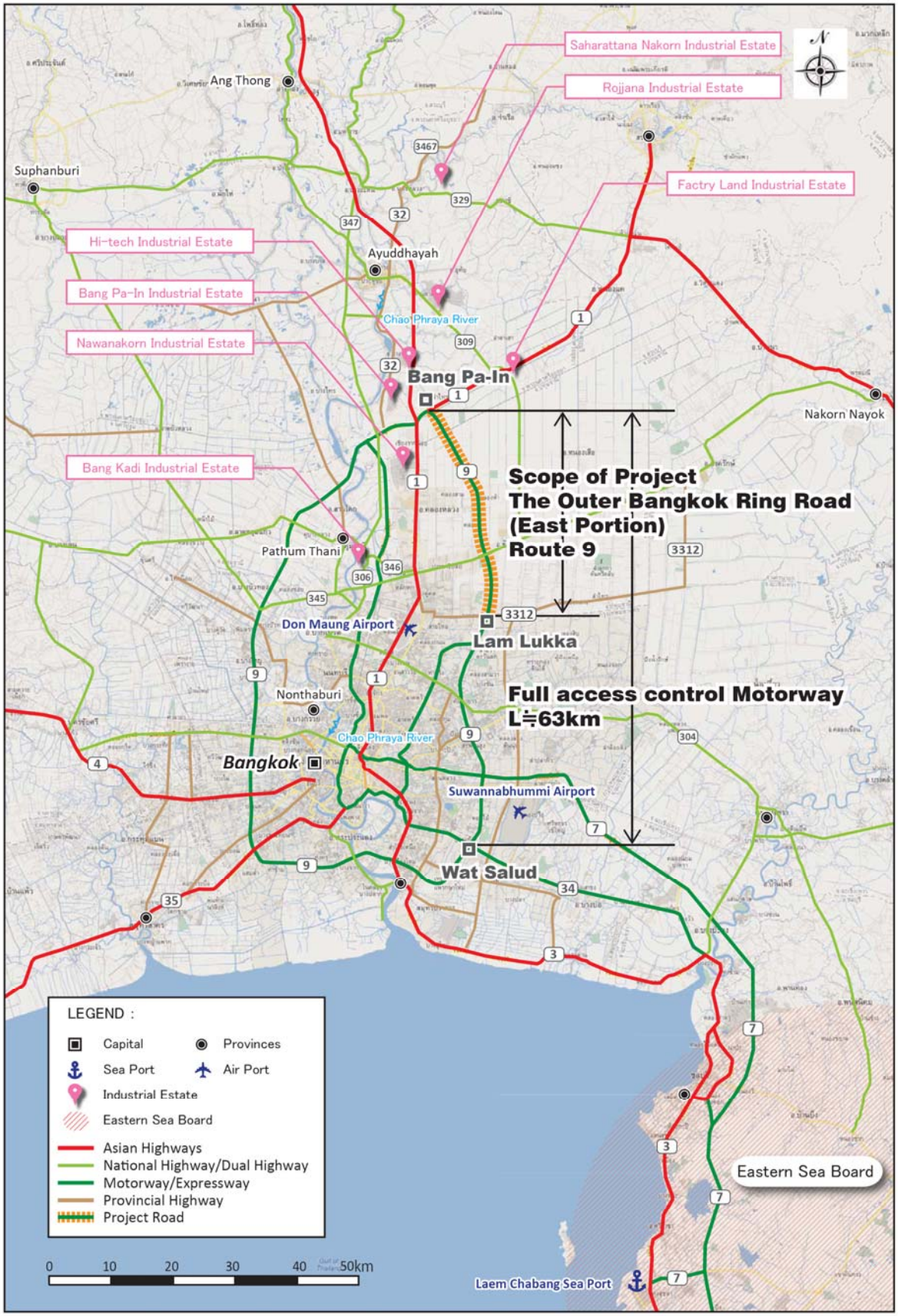


Figure 2-2-1-7.2 Network of Existing Principal Arterial Roads

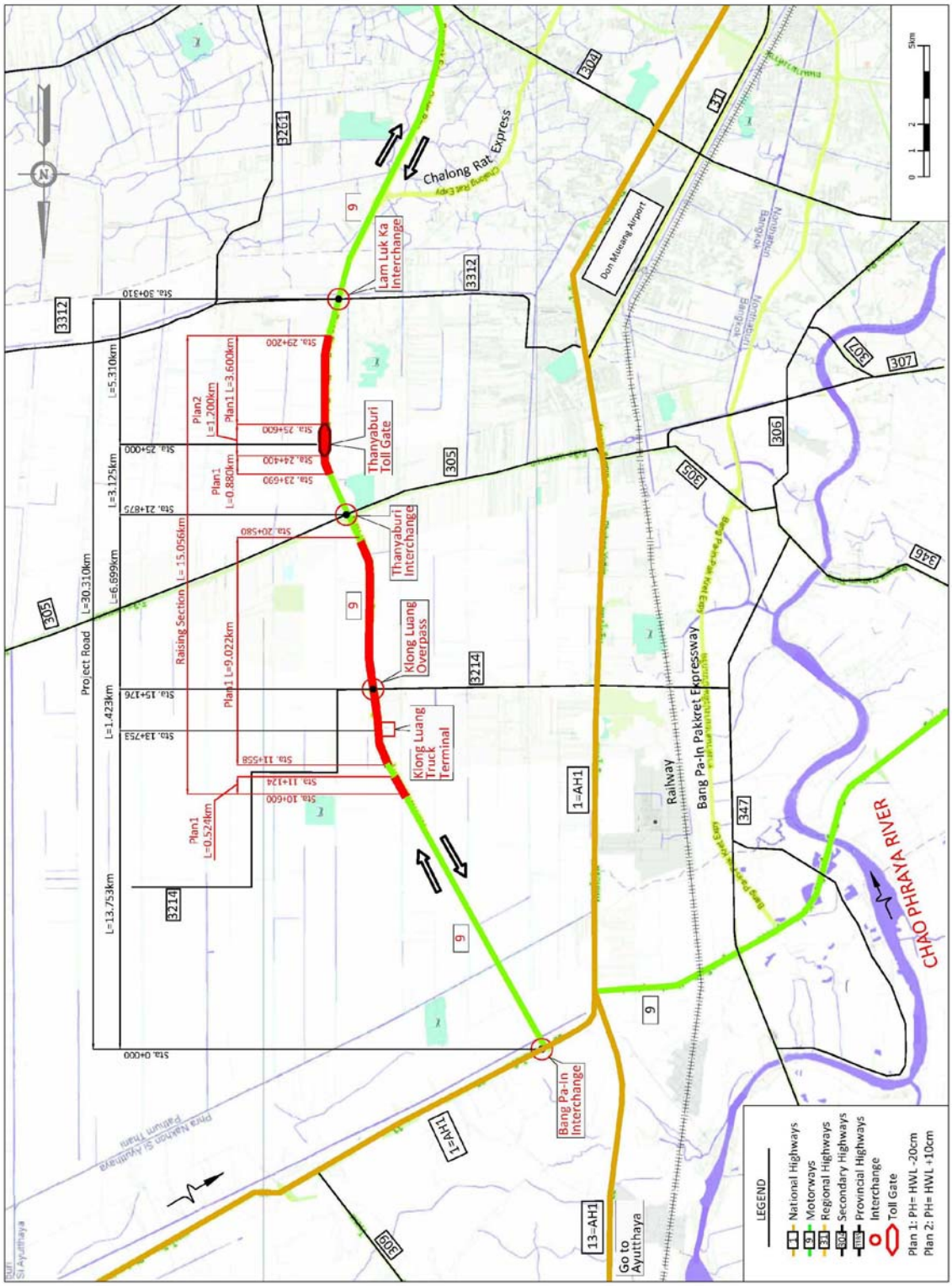


Figure 2-2-1-7.3 Objective Section of the Project and the Sections to be Raised

(3) Mitigation of flood damage by Raising of the Road Elevation

As can be observed from **Figure 2-2-1-7.4**, Sta. 10+600 to Sta. 30+000 on the objective road NR-9 has been significantly affected by the 2011 flood. The lowest existing road elevation at the shoulder point was approximately 110cm below the highest recorded flood level. The complete submergence by the flooding caused dysfunction of the logistic transportation networks. Under such circumstances, the section of the objective road whose existing road elevation needs to be raised and the criteria for

raising the road surface was determined in view with mitigating the flood damage in the future.

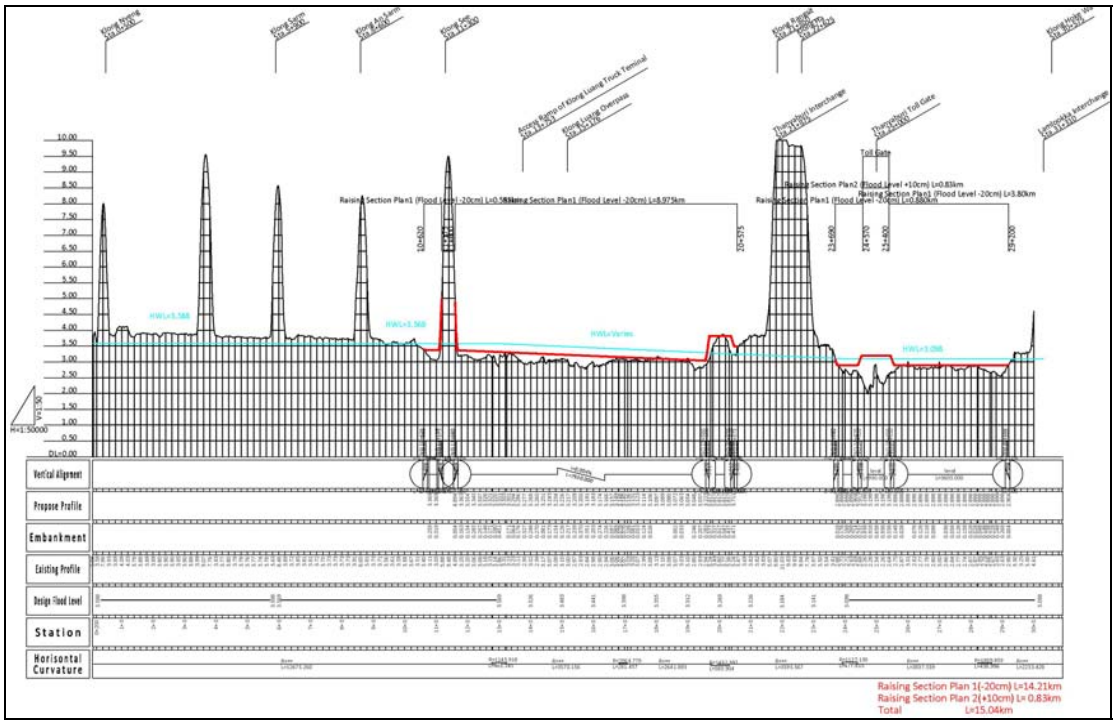


Figure 2-2-1-7.4 Comparison between Level of Flood and Existing Road Surface level

(4) Alignment of the Existing Road

1) Horizontal and Vertical Alignment

The horizontal alignment of the objective road is relatively smooth. There are 5 horizontal curves within the section of the road to be raised. **Table 2-2-1-7.1** shows the parameters of these curves. Radius of each curve is greater than 1,000m which meets the requirement of the design speed of 120km/h, which is the design speed of the objective road.

Vertical alignment (profile) of the existing road on the shoulder of the north bound direction is shown in **Figure 2-2-1-7.5**. The vertical difference in height between the highest and the lowest level of the existing road surface within the extent of 30km, which is the scope of this project, is less than 2m, and the gradient (slope) applied is from 0.000% to 0.122%. However, these values do not include the elevation and the grades at the bridge sections.

Table 2-2-1-7.1 Parameters of Curvature within the Objective Section to be Raised

Curve No.	Intersection Point	Beginning of Curve	End of Curve	Curve Radius (m)	Curve Length (m)	Direction
1	Sta.13+009.708	Sta.12+403.420	Sta.13+201.704	1145.918	465.545	Right
2	Sta.16+950.223	Sta.16+500.930	Sta.17+068.811	2864.779	281.457	Right
3	Sta.20+028.794	Sta.19+391.852	Sta.20+286.490	1432.397	583.904	Left
4	Sta.24+154.753	Sta.23+539.086	Sta.24+351.818	1127.130	477.815	Right
5	Sta.28+448.045	Sta.27+916.068	Sta.28+643.775	1909.859	438.996	Right

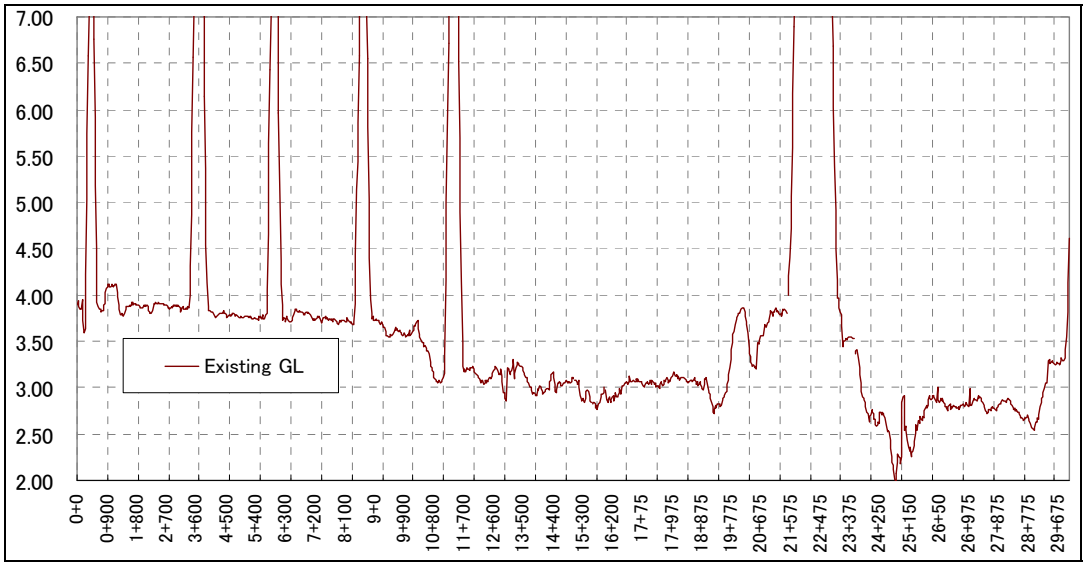


Figure 2-2-1-7.5 Profile of the Existing Road Surface (Shoulder)

2) Typical Cross Section

Typical cross section of the existing road is shown in **Figure 2-2-1-7.6**. The objective road (the Outer Bangkok Ring Road), has a total width of 39.8 meters at standard sections, which includes a 3m wide shoulders and 1.5m wide median strip on each direction, 2.5m wide median, and 8 lanes, each having a width of 3.6m. The 3.6 m width for a lane is secured for 120 km design speed, taking into consideration the function of the Outer Bangkok Ring Road as an important portion of the logistic network. The road is a divided motorway. Concrete barriers are provided along the median sides of both the north and south bound directions. Street lights, generally called as high mast, are provided at the median in an interval of 80m. Additional street lights are provided at the on and off ramps. Fences are provided at the toe of the slope on both directions which segregates the motorway from the side roads. The embankment slopes have a maximum grade of 4:1 and are basically provided with vegetation (sodding).

Normal crossfall is 2.5% and the maximum superelevation applied at curves is 5.0%.

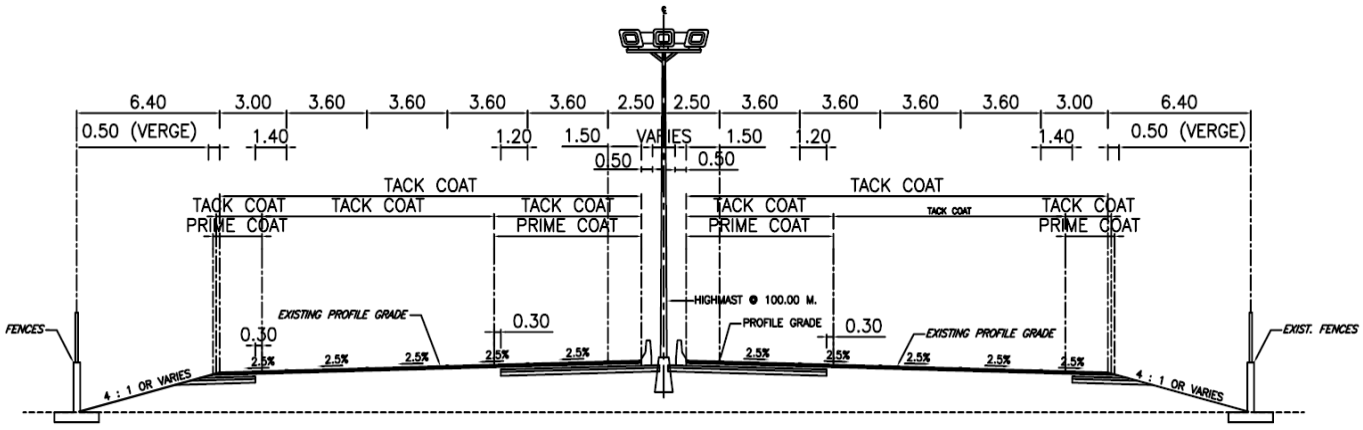


Figure 2-2-1-7.6 Typical Cross Section

3) Traffic Volume Survey and Designed Traffic Volume

In order to comprehend the current traffic volume along the Outer Bangkok Ring Road, traffic volume data in the last 4 years, whose survey was carried-out every year by DOH, was obtained. The average daily traffic volume (ADT), for the last 4 years from 2007 to 2010 is listed in Table 2-2-1-7.2. According to the collected data, the total ADT of vehicle heading to the north on NR-9 at Sta.0+000, is 59,138 vehicles per day, while middle point (Sta.20+500) of the Project it is 49,138 vehicles per day. Additionally, DOH predicts the future traffic volume based on the survey result. DOH analyzes the result of traffic volume survey and indicates that the growth rate of total traffic volume for the coming 5 years will be approximately 10%.

Table 2-2-1-7.2 ADT Volume of the Outer Bangkok Ring Road (North Bound)

Year	No	Route No	Control Section	Route Name	Observation Point	Passenger car (person<7)	Passenger car (person >7)	Light Bus	Medium Bus	Heavy Bus	Light Truck (4 wheels)	2-axel truck (6 wheels)	3-axel truck (10 wheels)	Trailer (3>-axel)	Semi-Trailer (> 3axel)	Total	% Heavy Vehicle
2007	190	9	401	Junction route No.1 (Bang Pa-IN) - Klong Raphipat (connect to Pathumthani Highway's District)	1+500	12,252	13,104	22	9	245	6,768	4,552	2,492	2,250	1,797	43,491	26.09
	191	9	401	Junction route No.1 (Bang Pa-IN) - Klong Raphipat (connect to Pathumthani Highway's District)	20+500	9,860	8,984	0	16	992	5,473	3,960	3,399	3,165	1,744	37,593	35.32
2008	191	9	401	Junction route No.1 (Bang Pa-IN) - Klong Raphipat (connect to Pathumthani Highway's District)	1+500	12,275	12,272	233	103	278	7,434	4,660	1,408	2,611	1,051	42,325	23.89
	192	9	402	Klong Raphipat (connect to Ayudthaya Highway's District) - Lamlookka (connect to Bangkok Higyway's District)	20+500	12,603	11,825	607	696	2,116	3,448	2,352	2,513	2,044	995	39,199	27.34
2009	1+500	9	401	Junction route No.1 (Bang Pa-IN) - Klong Raphipat (connect to Pathumthani Highway's District)	1+500	10,697	5,210	189	234	246	10,848	3,407	1,911	1,926	2,085	36,753	26.69
	20+500	9	402	Klong Raphipat (connect to Ayudthaya Highway's District) - Lamlookka (connect to Bangkok Higyway's District)	20+500	13,412	4,688	0	0	192	26,588	4,979	2,634	4,740	0	57,233	21.92
2010	1+500	9	401	Junction route No.1 (Bang Pa-IN) - Klong Raphipat (connect to Pathumthani Highway's District)	1+500	14,738	8,509	56	3	131	13,077	4,782	3,466	4,362	0	49,124	25.94
	20+500	9	402	Klong Raphipat (connect to Ayudthaya Highway's District) - Lamlookka (connect to Bangkok Higyway's District)	20+500	14,550	5,955	45	58	127	24,638	5,257	3,397	5,111	0	59,138	23.59

(5) Traffic Flow in Normal and Flooding Condition after Rehabilitation Project

Traffic flow in the Outer Bangkok Ring Road in the normal condition after the rehabilitation project will be exactly in the same condition as the existing. To be precise, each direction will have 4 lanes in service. The speed will also be retained to its normal speed, 120km/h and the degree of congestion will also not differ from present condition. This enables to secure the function of the objective road as the logistic network. The traffic flow in the normal condition is illustrated in **Figure 2-2-1-7.7**.

The rehabilitation project serves the flooding risk mitigation and road closure avoidance in the north bound direction when Outer Bangkok Ring Road experiences flood similar to the 2011 flood. The traffic flow in the Outer Bangkok Ring Road in the flooding condition after the rehabilitation project will be as following: From Sta.0+000 to Sta.11+300, vehicles heading to either direction can run through 4 lanes in each bound not submerged in the flooding, from Sta.11+300 to Sta.30+000, as the south bound is anticipated to be flooded, vehicles on the south bound direction will take a detour through the north bound, sharing with vehicles going to the North. In the emergency situation by flooding, it is considered to be impossible for vehicles heading South to access to Klong Lung Truck Terminal, Kong Luang Overpass, and Thanyaburi Interchange. By contrast of the unavailability of the interchange or ramp, the toll gate area will not be flooded and can be used in the flooding condition since the road surface level of the area is planned such that the existing road elevation is raised higher than the design flood level (historical highest flood level recorded in 2011). The reason is that the toll

gate area includes an administration office and an operational control system significant to the toll gate. **Figure 2-2-1-7.8** shows the flow of traffic during emergency period during flooding.

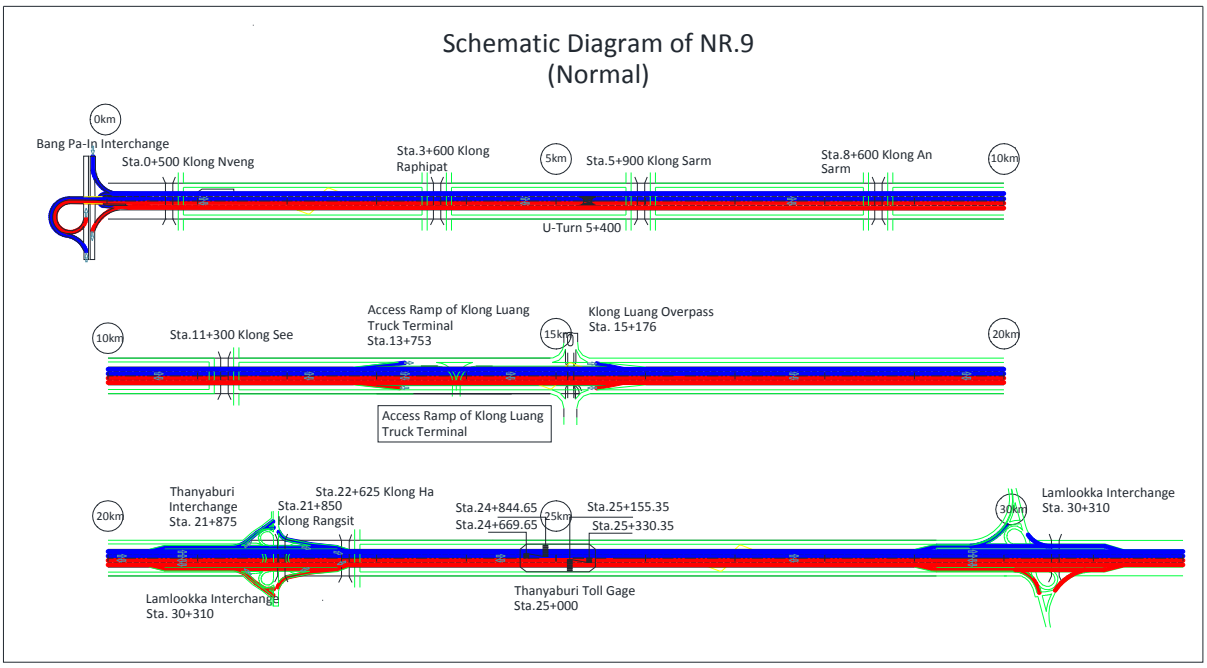


Figure 2-2-1-7.7 Schematic Diagram of NR.9 in Normal Condition

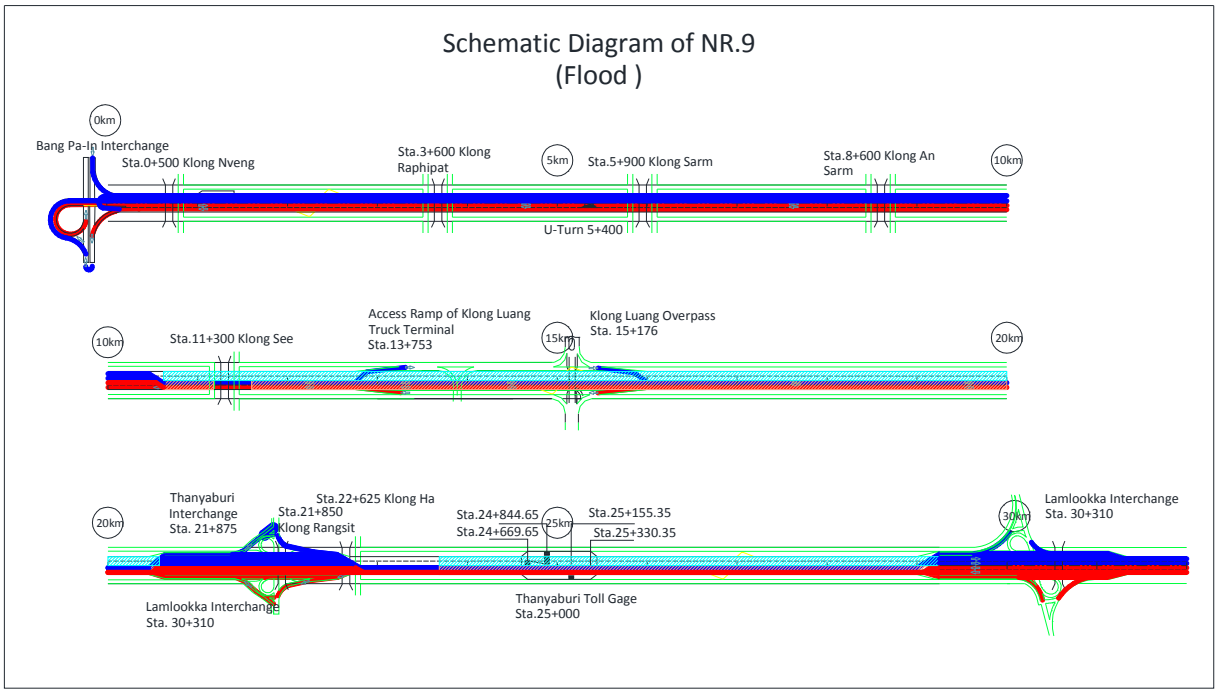


Figure 2-2-1-7.8 Schematic Diagram of NR-9 during Flooding

(6) Rehabilitation Plan at Toll Gate Area and Toll Gate Facilities

Toll Gate facilities (Toll Gate and Management Space) as shown in **Figure 2-2-1-7.9** are located near Sta. 25+000 of the objective road.

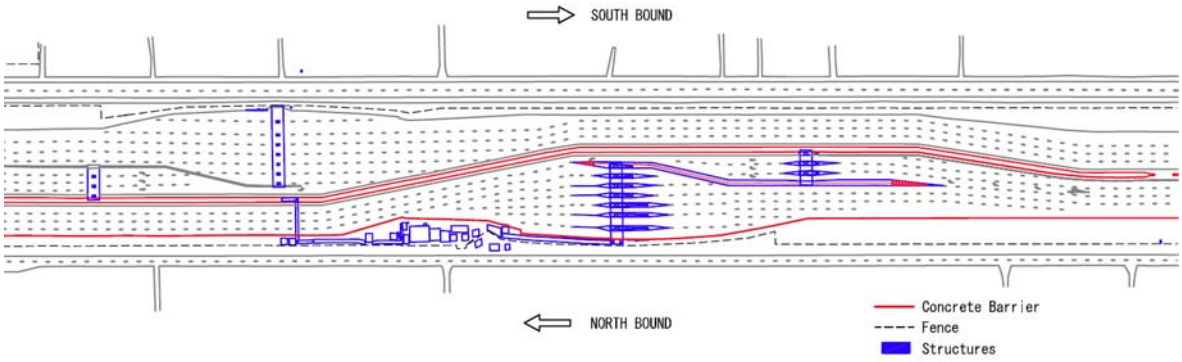


Figure 2-2-1-7.9 Condition of Toll Gate Plaza・Staggering Booths Layout

The length of Toll Gate section including control and operation as well as the taper length (Sta. 24+850~Sta. 25+600) is approximately 750m. Initially, there were 7 toll booths in each direction in operation. The number of toll booths was increased to its present number (10 in each direction) during expansion of the motorway with an aim to improve the traffic congestion and to attain smooth and safe flow of traffic, as toll gates often became bottlenecks causing traffic congestion,.

Staggering Booth system was applied during expansion in order to increase the number of booths without widening the toll gate area. They were expanded at the interval of 174m between 3 Booths in the front (Sta. 25＋327) and 7 Booths behind (Sta. 25＋153). Open toll system is used in collecting the toll fee, where road users pay a fixed amount of fee, according to the category of the vehicle, at the toll gate regardless of the driving distance.

The raising of the surface level of the existing road will require removal and replacing of the toll gates. Discussion with DOH concluded in undertaking only the construction of the structures by this project, while the system required for operation will be installed by the obligations of the recipient country.

This project aims to raise the elevation of existing booths but the locations, size and shapes will be similar to the original. Also, only concrete pavement work will be carried out in this project. GOT has agreed to take charge of the prospect of foundation work of asphalt pavement, electric work and administration building. There is a pedestrian overpass for toll gate access to the South Bound (Sta.24+856). The vertical clearance of this facility is 5.5m at present. This will be insufficient by 0.95m if the existing road is raised to the proposed height. Thus, it has to be reconstructed. However, the existing structures of foundation pile, footing and steel girder of L=18.2m will not have any effect. Therefore, these portions will be reused in order to reduce the construction cost.

(7) Interchange and Service Road within the Section of Road to be Raised

There are 5 Interchanges to access from the main roads and frontage roads. The approximate location shown in **Table 2-2-1-7.3** in the project area.

Table 2-2-1-7.3 Interchanges in the Planning Objective Road Section

No.	Interchange	Location	Connecting Roads and Access Points
1	Bang Pa-in Interchange	STA.0+000	Route No.1
2	Klong Luang Truck Terminal	STA.13+753	Klong Luang Truck Terminal
3	Klong Luang Overpass	STA.15+176	Provincial Road No.3214
4	Thanyaburi Interchange	STA.21+875	National Road No.305
5	Lamlokka Interchange	STA.30+310	Provincial Road No.3312

Raising the road elevation of the existing access roads is not considered in this Project. However, run-off segment to secure smooth and safe access from/to the ramp will be planned in accordance with the proposed profile of the main road.

Among the five interchanges, two interchanges connect with the main roads and frontage roads parallel to the project road. The names, its approximate location and the details to how they are connected are show in **Table 2-2-1-7.4**.

Table 2-2-1-7.4 Interchanges within the Section of the Road to be Raised

Interchange	Location	Connection
Klong Luang Truck Terminal	STA.13+753	Entrance and Exit Ramp of Interchange to access to Klong Luang Truck Terminal
Thanyaburi Interchange	STA.21+875	Entrance and Exit Ramp of Interchange to access to National Road No. 305. Ramp is constructed in parallel to frontage road at the beginning side of 1.4km from the Interchange.

(8) Right of Way and Project Area of the Existing Road

The objective road is separated from the frontage road by a fence. Frontage roads exist at both sides of the motorway. The width of the objective road, between the fences is approximately 53m. The width of the right-of-way on the other hand is approximately 100m and is owned and managed by DOH. This width includes the width of the motorway and the width of the frontage roads/service road. Acquisition of land is not required for implementing this project as the objective of this project is to raise the surface level of the existing road and all the work is considered to be within the fences The width of the Project area and the right-of-way is shown in **Figure 2-2-1-7.10**.

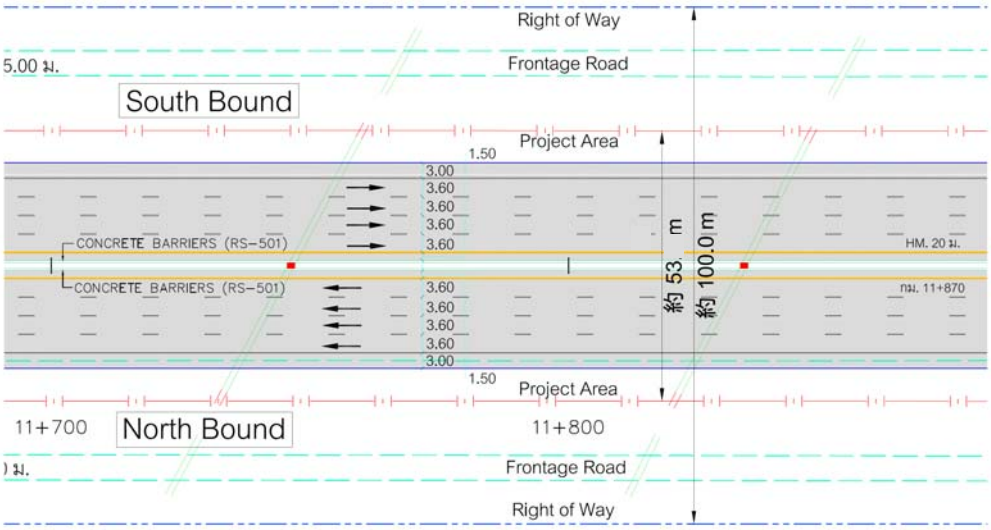


Figure 2-2-1-7.10 Right of Way of the Objective Road (Outer Bangkok Ring Road)

(9) Road Drainage System

1) Existing Condition of Road Drainage System

116 cross drainage facilities are installed at site within the Project area (30km). The interval of these facilities is between 200 to 300m. The existing drainage facilities were provided mainly for connecting the existing irrigation canals that would have been disrupted by the construction of the Outer Bangkok Ring Road in March 1999 as a four-lane full access-controlled motorway (South Bound 2 lanes and North Bound 2 lanes). **Figure 2-2-1-7.11** illustrates a general idea on how the present drainage facility is being installed.

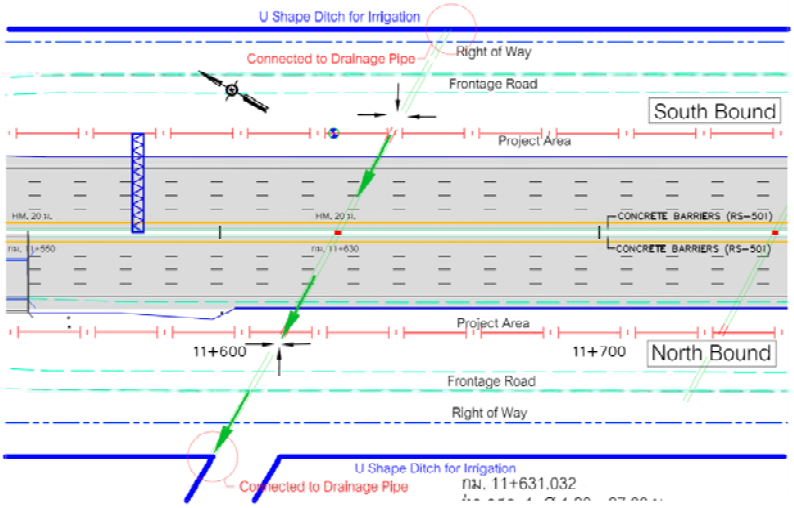


Figure 2-2-1-7.11 Existing Cross Drainage System

The drainage facilities are being used to both collect and discharge the surface drainage of the existing road and as an irrigation channel following adjustment of these pipes (116 locations) during expansion of the initial 4 lane motorway to its present 8 lane motorway. **Figure 2-2-1-7.11** illustrates the present cross drainage system.

Among the 116 drainage facilities, 71 of them are located within the Project area (3 sections, length 15.056km). The inlets/outlets are normally located outside the fence of the road as illustrated in **Figure 2-2-1-7.12**. This type of inlets/outlets accounts to 17 locations. There are some other inlets/outlets that have the opening at both sides of the fence as illustrated in **Figure 2-2-1-7.13**. The number of such places is 8.

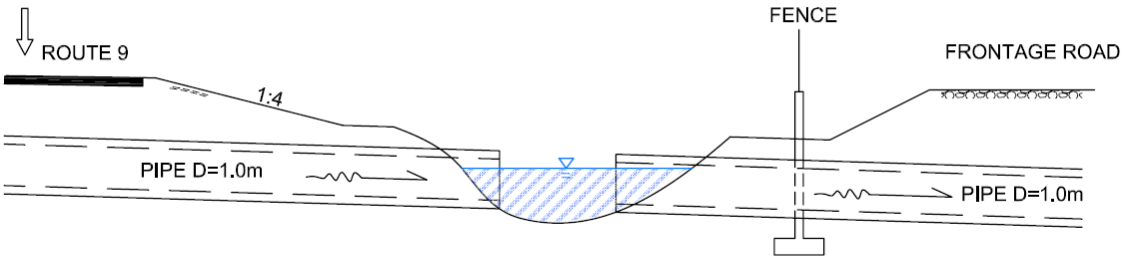


Figure 2-2-1-7.12 Catch Basin and Outlet Structure not Inside or Outside of Fence

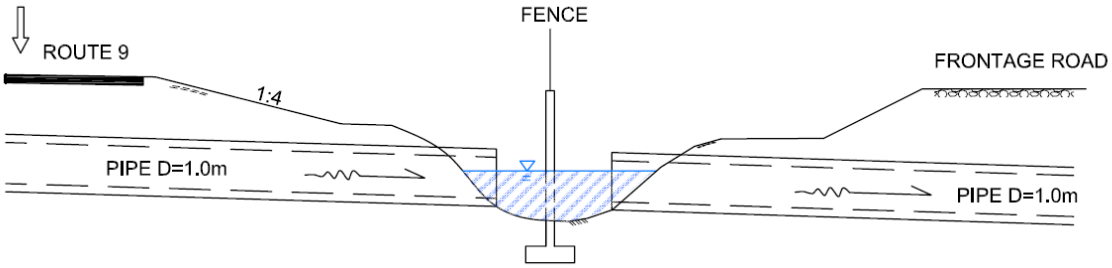


Figure 2-2-1-7.13 Catch Basin and Outlet Structure Inside of Fence

Most of the drainage facilities are not functioning fully. In other words, the drainage capacity of these facilities is lower than its original capacity. The biggest reason is that the inlet/outlet of most of the existing drainage facilities is buried due to soil deposition. This is causing the delay in discharging the water collected at the openings.

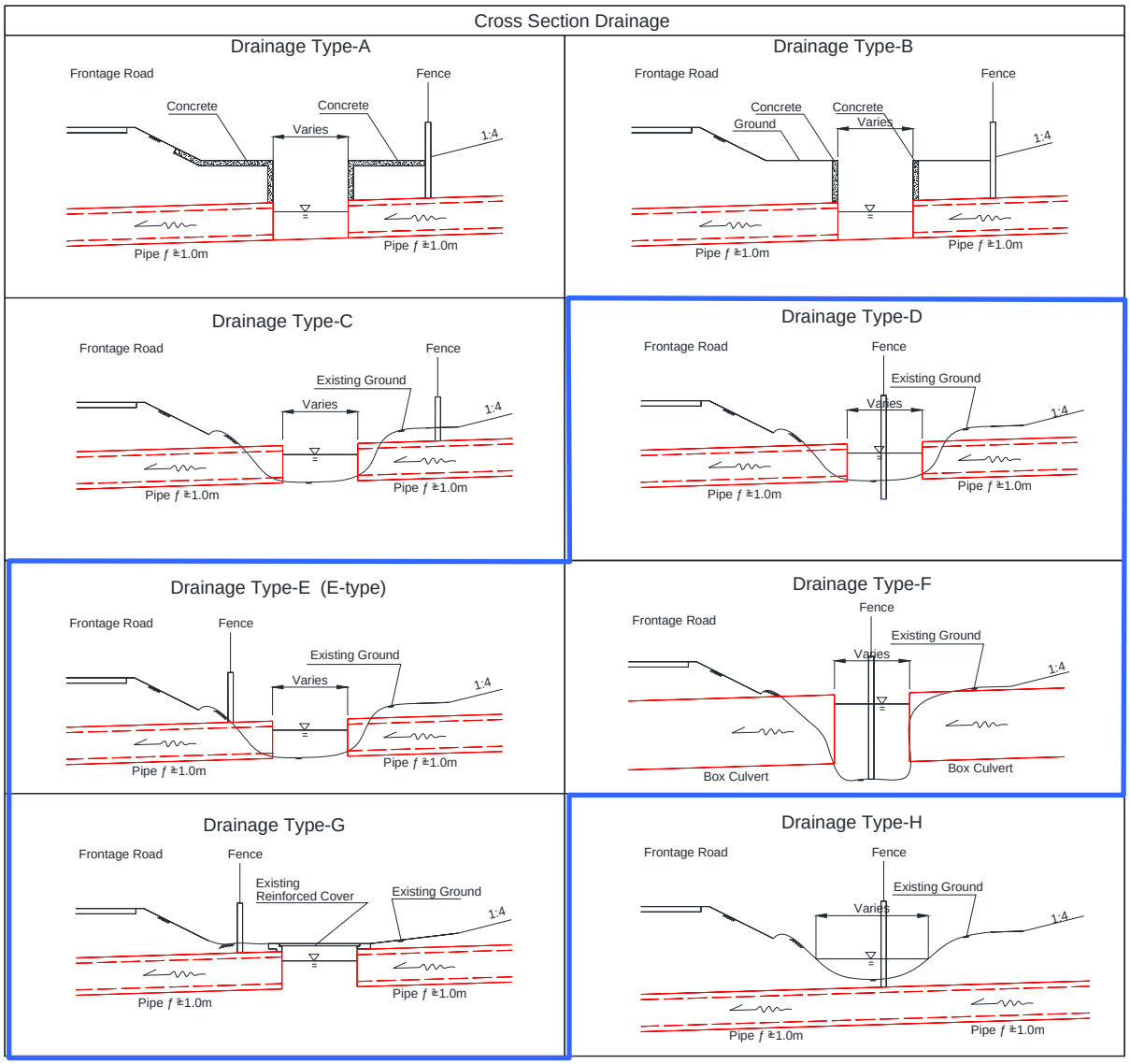
From above, rehabilitation of the existing facilities is necessary for facilitating smooth drainage. Therefore, where the section of the objective road is subject to be raised, the facilities will be rehabilitated. However, the treatment will be limited to ditches and inlet/outlet facilities within the existing fence.

2) Plan of Cross Drainage System

Based on the site observation and inventory survey results, more than 100 cross drainage pipes were identified within the limits of the project. Those cross drainage pipes can be classified into 8 categories, which are schematically explained in **Figure 2-2-1-7.14**. In terms of Type A, B, and C, the drainage is discharged into the catch basin placed outside of the existing fence along the NR-9. Another 4 categories of Type D, E, F, and G is the catch basin which discharges run-off into cross drainage pipe inside of the fence along the NR-9. The other is Type H, where drainage pipe exists,

but without any catch basin, neither inside nor outside the fence and is directly discharged into the fields

The existing drainage system will be studied by estimation of run off volume and required capacity of the drainage facilities, and then additional drainage will be provided only if the existing drainage facilities lack capacity. Rehabilitation of the existing facilities will be studied for facilitating smooth drainage within the raising section, but the treatment will be limited inside the existing fence.



: Drainage Type in Raising Area

Figure 2-2-1-7.14 The Existing Cross Sectional Drainage Type

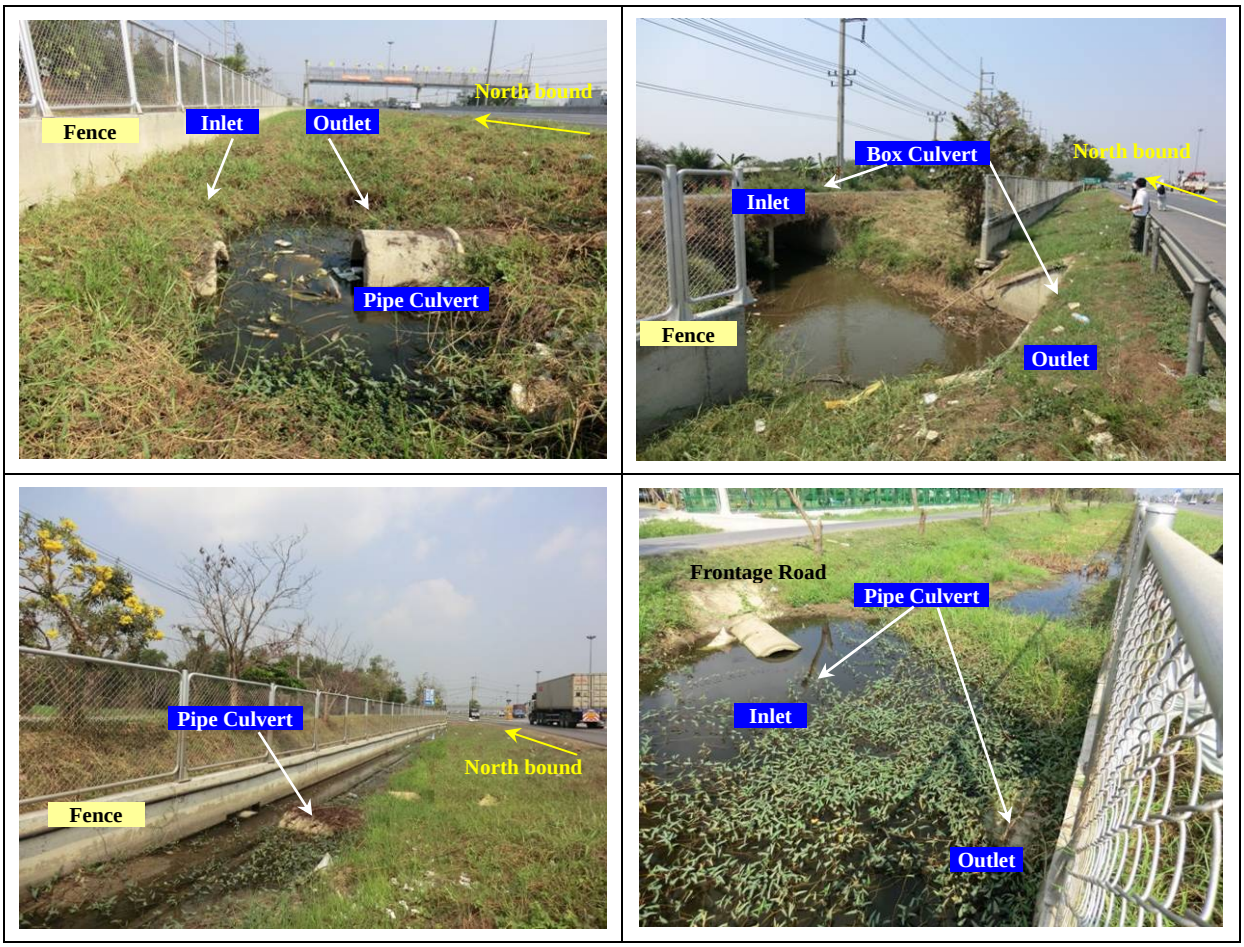


Photo 2-2-1-7.1 Types of Inlet / Outlet of Drainage Facilities

(10) Consideration for Underground Facilities

The alignment near Sta.20+000 is a curve where superelevation is imposed. As such, the median side is lower than the outer edge of the road. To collect surface water and discharge it properly, catch basins are provided at the median in an approximate interval of 6m to 20m.

However, the length of Superelevation runoff is not sufficient and needs to be improved in conformity with the requirements recommended by AASHTO Standards. This will apparently necessitate provision of additional catch basins at the additional superelevation runoff section. Therefore, catch basins (6 each at the beginning and the end of additional superelevation runoff section) and pipe culverts are planned to be newly installed to collect/discharge the surface water at the right side of the motorway.

On the other hand, as only the north bound lanes will be raised (Average h=0.83m), south bound lanes in the section between Sta.24+425 to Sta.24+975 will be lower than the north bound lanes. Here the center of the road lies in the south bound direction as illustrated in **Figure 2-2-1-7.15**. Therefore, a portion of south bound road will have the same cross fall as that of the north bound. This means the rainwater of this portion will be dammed by the concrete barrier.

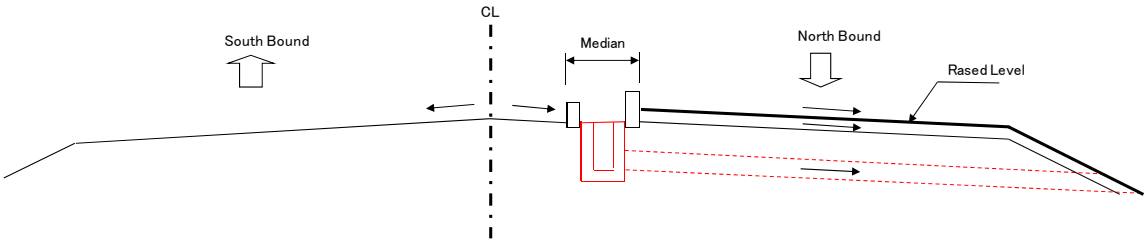


Figure 2-2-1-7.15 Drainage System at Toll Gate Area

Thus, as catch basin of the south bound will be isolated by the raising of the north bound lanes elevation, ditch will be constructed at the median and new concrete pipe will also be provided to discharge surface drainage outside the fence. The total number of pipe to be provided is 10.

71 existing pipe culverts (1 cell to 3 cells) for road cross drainage with diameters varying from ϕ 1000 to ϕ 1500 are confirmed to be installed at an approximate interval of about 200 to 300m within the project road where the section is to be raised. The electrical facilities for road lightning are installed at the median. These cables are joined to the incoming panel near the fence. At the stage of construction, it is necessary to take safety measures, plan protection work and reinforcement according to the current condition of the underground facilities.

(11) Incidental Road Facilities

1) Slope Protection

The embankment slopes of the project motorway have a standard grade of 4:1 and are provided with block sodding. A layer of top soil (clay material with low permeability coefficient), 10cm in thickness is provided on the slopes for the purpose of avoiding infiltration of rainwater and protection from erosion.

The similar method will be applied for protection of embankment slopes under this Project also. However, as slope damage and erosion was observed in several places during the survey conducted in March 2012, the thickness of the top soil is planned to be increased as a preventive measure for damages during flooding.

The topography of the project area is in general plain. Therefore, the land becomes waterlogged during flooding and the water is almost stagnant having a very small flow velocity. As flood level takes a long period to subside, the embankment slopes are exposed to water longer raising concerns of damage or erosion of embankment slopes. As the purpose of the Project is to improve the profile alignment by raising the elevation of the existing road surface embankment work at the shoulder and the slopes will be required. Step cut will be applied prior to embankment in order to avoid slip of the new embankment.

Thus, the existing embankment ground/slope will be scarified and newly constructed. A layer made from a low permeability material such as clay will be provided. The layer will be 20cm thick. The slopes will be further provided with block soddings for protection.

2) Median Barrier

Concrete barrier is installed at the median side for safety and smooth traffic flow. The width of median at standard section is 1.5m. The barrier is 1.0m high. (**Figure 2-2-1-7.16**).

From the aspects of cross section elements there is no discontinuity and thus safety is ensured. In addition, the median is used as a space for the road light facilities.

It is mentioned in the technical note that the existing concrete barrier for median within the project section shall basically be removed and reconstructed.

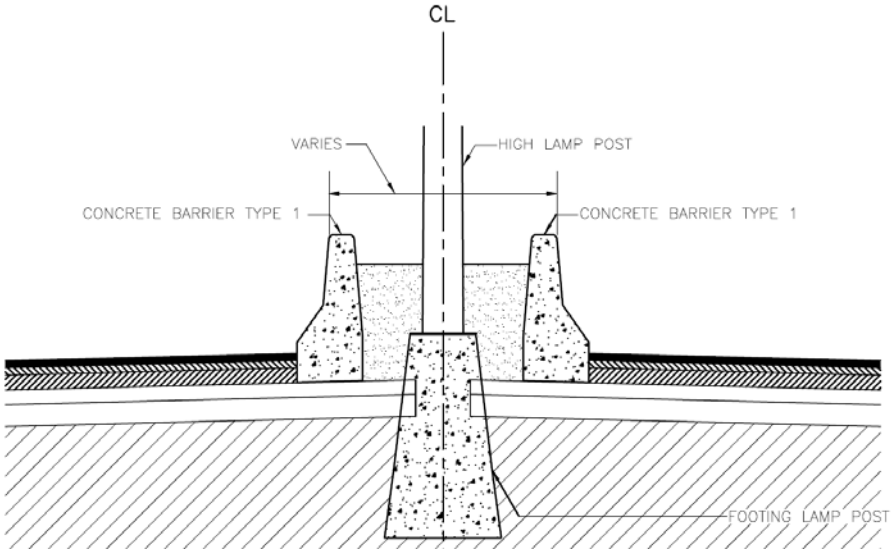


Figure 2-2-1-7.16 Structure of Median

3) Pavement Markings

The objective road being a full-access controlled motorway has extensive amount and kind of pavement markings (**Photo 2-2-1-7.2**). The details are shown in **Table 2-2-1-7.5**.

Table 2-2-1-7.5 Pavement Marking Type

Name	Color	Type	Dimension	Remarks
Edge Line	Yellow	Continuous Line	Width:=20cm	Median
Lane Line	White	Dashed Line	Width=20cm,Length=3.0m Pitch=9.0m	
Edge line		Continuous Line	Width=20cm	Typical Section
Give-way Line		Dashed Line	Width=0.3 to 0.5cm, Length=2.0m,Pitch=4.0m	
No Passing Line		Continuous Line	Width=0.3 to 0.6m	
Allow		Continuous /Dashed Line	Width=0.15cm to 0.75cm	Directional (Straight, Straight-Left/Right,Left
Zebra		Continuous Line	Width=0.5m Pitch=3.0m	Nose and merging point
Road Studs	-	-	Imbedding	

All road marking and traffic marking will be restored to current situation.

		
Regulated Speed Sign Post	Regulated Driving Sign Post	Direction Sign Board
		
Vehicle Distance Sign Post	Precaution Sign Post	Kilometer Post in Shoulder
		
Kilometer Post in Shoulder	Kilometer Post in Median	Kilometer Post in Median

Photo 2-2-1-7.2 Road Sign and Kilometer Post

4) Overhead Crossing Facilities

The existing overhead crossing facilities such as flyover, pedestrian overpass, power line cable, and gate type signboard were installed along the objective road. **Table 2-2-1-7.6** shows clearance from the surface for overhead crossing facilities. DOH defines that desirable clearance is more than 5.25m and minimum clearance is 5.0m in toll motor way.

These structures were verified during the site reconnaissance conducted by the Survey Team and the vertical clearances were measured during topography survey. The list of these facilities including its location and vertical clearance of each facility are shown in **Table 2-2-1-7.6**.

In case the clearance defined by DOH standard can not be secured, these facilities will be raised.

Table 2-2-1-7.6 Overhead Crossing Facilities

Overhead Crossing Facilities	Location	Vertical Clearance（m）	Overhead Crossing Facilities	Location	Vertical Clearance（m）
Power line cable	Sta.11+650	7.37	Gate type signboard	Sta.16+802	6.43
Power line cable	Sta.12+225	7.87	Gate type signboard	Sta.17+980	6.40
Flyover	Sta.13+762	5.20	Power line cable	Sta.20+352	6.66
Power line cable	Sta.14+459	6.77	Gate type signboard	Sta.23+570	6.04
Power line cable	Sta.14+863	7.05	Gate type signboard	Sta.23+975	6.10
Flyover	Sta.15+156	5.56	Gate type signboard	Sta.24+381	5.97
Power line cable	Sta.15+398	8.07	Pedestrian bridge	Sta.24+856	5.50
Power line cable	Sta.15+417	9.02	Gate type signboard	Sta.25+791	5.97
Power line cable	STA.15+427	9.34	Pedestrian bridge	STA.26+262	5.20
gate type signboard	STA.15+815	6.10	Electronic gate type signboard	STA.27+797	5.67
gate type signboard	STA.16+313	6.44			

5) Road Lights

Road lights, commonly called as high mast, are provided basically along the objective road mainly at the median. These lights are approximately 30m high and installed at an interval of about 80m. At interchanges or on-off ramps, additional lights are provided near the existing boundary fence for illuminating these sections.

According to the result of the inventory, the foundation and the structures as well as its functions are considered to be unaffected by the raising of the existing road surface.

Therefore, high mast is to be kept same as current situation.

6) Traffic Signs and Kilometer Posts

The objective road is equipped with various traffic signs as shown in **Photo 2-2-1-7.2**. Kilometer posts are provided at every kilometer on the slopes of the embankment. Traffic signs are classified according to its purpose into regulatory, precaution and information types.

On the other hand, a concrete-made and a sign board type of kilometer post are installed at the shoulder. The sign post type is placed at every 1 kilometer, but the concrete ones are placed only at certain locations. Kilometer posts are also installed at the median.

Traffic sign posts and kilometer posts will be in principal out of the scope of this Project. However, the traffic signs and the kilometer posts that are affected by the Project will be replaced.

2-2-2 Basic Plan (Construction Plan / Equipment Plan)

2-2-2-1 Overall Plan

(1) Scope of the Project

The scope of the Project is shown in **Table 2-2-2-1.1**. As aforementioned in Section 2-1-7(1), the scope was determined based on the design flood level, calculated from the results and findings of flood level survey and hydrological analysis of the flood that occurred in year 2011, the elevation of the existing road elevation of the Outer Bangkok Ring Road (East Portion), also known as Motorway No.9, and results of the discussions with the Department of Highway (DOH), government of Thailand.

Table 2-2-2-1.1 Scope of the Project Road

Objective Sections (Sta.)			Length (m)	Scope of Rehabilitation (Criteria for Raising)	Remarks
1	10+600 to 11+124	North Bound	524	-20cm or less from the Design Flood Level	
2	11+558 to 20+580	North Bound	9,022	-20cm or less from the Design Flood Level	
3	23+690 to 24+400	North Bound	880	-20cm or less from the Design Flood Level	
4	24+400 to 25+600	North Bound	1200	10cm or above from the Design Flood Level	Toll gate section
5	25+600 to 29+200	North Bound	3,600	-20cm or less from the Design Flood Level	
Total Objective Length			15,056		

(2) General Description of Outline Design（D/D 1）

The general description on the outline design of the objective road is described in **Table 2-2-2-1.2**.

Table 2-2-2-1.2 Design Criteria of the Objective Road

Items	General Description
Project Length	Approx. 30km（Length of sections to be raised is 15.056km of the north bound roadway ）
Road Classification	Full access-controlled motorway
Design Speed	Main road: 120km/h Ramp: 50km/h
Number of Lanes	8 (However, only north bound 4 lanes are under the scope of this Project)
Composition	Shoulder 3.0m + Lanes 14.4m + Median 5.0m + Lanes 14.4m + Shoulder 3.0m However, the objective of this Project is limited to the north bound roadway
Median Strip	Median width is 2.0m
Project ROW	Approximately 53m（Within the fences installed at both ends of the Motorway）
Pavement	[Standard Section] Surface Course: Asphalt Concrete 5cm (For Inner Two Lanes)

Items	General Description
Composition	Surface Course: Modified Asphalt Concrete 5cm (For Outer Two Lanes) Binder Course : Asphalt Concrete 5cm Bound Base : Asphalt Concrete 10cm Base Course : 25cm Sub-Base : More than 20cm Performance Period of pavement :10 years [Toll Gate Section] Surface Course: Modified Asphalt Concrete 5cm Binder Course : Modified Asphalt Concrete 5cm (Sta.24+875~Sta.25+600) Pavement Slab : Reinforced Concrete 25cm Sand Cushion : 10cm Sub-Base : Various
	Performance period of the pavement：10 years
Overhead Crossing Facilities	Fly-overs 2 locations, Pedestrian overpass 2 locations, Road signs 13 locations, Electric cables 3 locations
Cross-drainage	Irrigation canals:7 locations Road surface/irrigation drainage: Pipe culverts115 places, Box culverts 3 places Catch basin (median side): At super-elevated sections
Road Ancillaries	Guardrail, Electronic road signs, Emergency parking, Roadway markings, Delineators
Utilities (Underground)	Water pipe, Gas pipe, Optic fiber cables（Utilities required to be relocated was not confirmed）

The design flood level, which is the base for determining the raising height of the existing road elevation and the section to be raised, was established as mentioned in Section 2-2-1-2 (2).

The design flood level was calculated from the results and findings of the survey and hydrological analysis based on the aftermath of the flood in year 2011 and the documents of road inundation recorded by the DOH. The observed/measured water level from the survey and the design flood level established from this water level are shown in **Figure 2-2-2-1.1**. The blue line represents the water level that was actually observed and the red line represents the water level determined from the line of the water level actually observed. For the first 3.4km from the origin (Sta. 0+000 to Sta. 3+400), the observed water level shows a drastic rise. This is believed to be caused due to the construction of a temporary dike by the government of Thailand (RID) during the 2011 year flood. Therefore, the design flood level for this section will be referred to the result of the flood analysis, which is 3.588m.

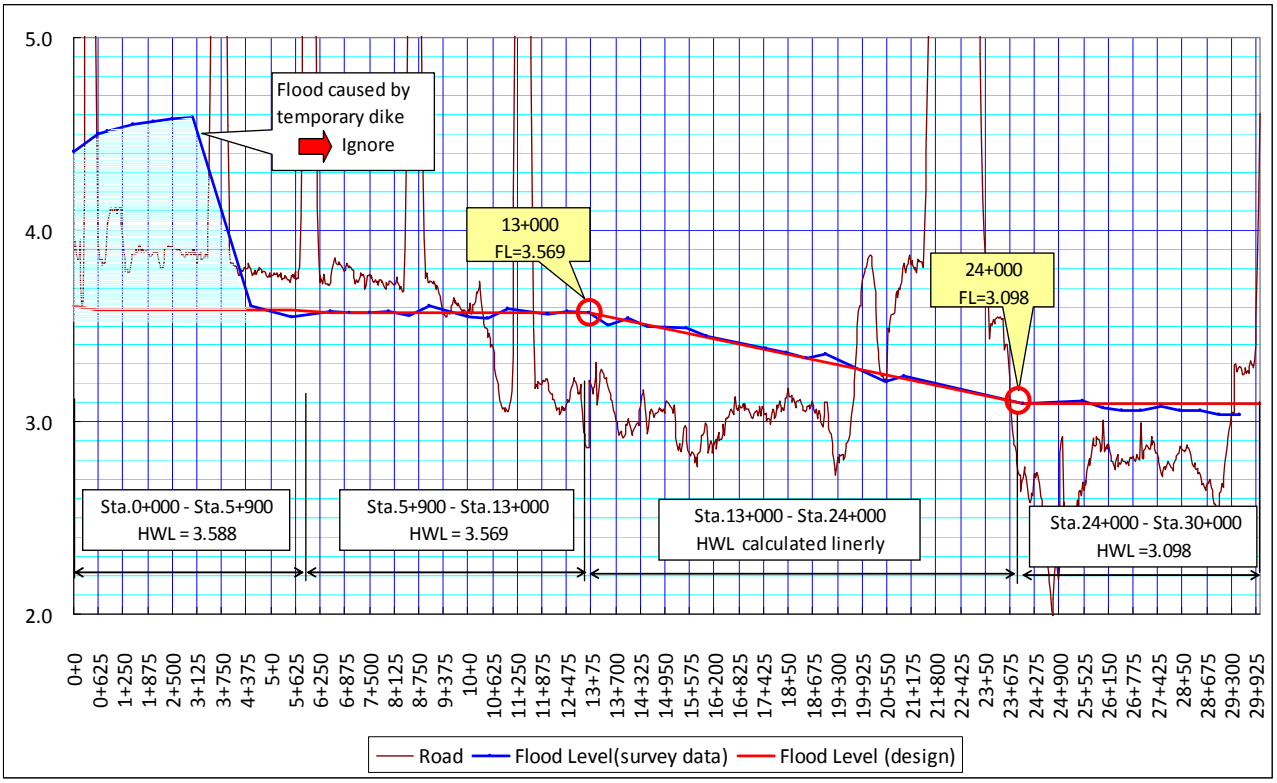


Figure 2-2-2-1.1 Observed Water Level and Design Flood Level

To conclude, the design flood levels of the objective sections of this Project are as shown in **Table 2-2-2-1.3**.

Table 2-2-2-1.3 Design Flood Level of the Project Section

Section	Design Flood Level	Calculation Method
Sta.0+000 to Sta.5+900	FL.3.588	Average value (Comprehensive)
Sta.5+900 to Sta.13+000	FL.3.569	Ditto
Sta.13+000 to Sta.24+000	FL.3.569～3.089 (Varies)	Proration
Sta.24+000 to Sta.30+000	FL.3.098	Average value (Comprehensive)

2-2-2-2 Planning of Road and its Facilities

(1) Design Controls and Criteria

1) Design Standards

As already mentioned in Section 2-2-1, the design of the objective road will be based on the available standards of Thailand. American Standards (American Association of State Highway and Transportation Officials: AASHTO) or the Japanese Standards (Road Structure Guidelines) will be referred for the standards that is not covered in the Thai Standards.

The list of the standards mentioned above is as follows:

- Detailed Engineering Design on Motorways in Thailand (Motorways Design Standards

August 1996）

- Standard Drawings for Highway Construction, Department of Highways 1994
- AASHTO Policy on Geometric Design of Highways and Streets 2004
- AASHTO Guide for Design of Pavement Structures 1993
- Road Structure Guidelines, Japan Association of Roads, February 2004

In addition, the elevation of the road to be raised will be planned based on the design flood level established in Section 2-2-1-2(2).

2) Design Speed and Design Elements

The objective road of the Project is classified as full access-controlled motorway and its design speed is 120km/h. **Table 2-2-2-2.1** shows the geometric conditions set in the Thai Standards.

Table 2-2-2-2.1 Geometric Conditions

Items	Desirable	Critical
A. MAIN SECTIONS OF MOTORWAY		
Lane Width	3.60m	3.60m
Outer Shoulder Width	3.00m	3.00m
Inner Shoulder Width	1.00m	1.00m
Ultimate Median Width	4.30m	3.60m
Outer Verge Width	0.50m	0.50m
Inner Verge Width	0.50m	0.50m
Minimum Vertical Clearance	5.25m	5.00m
Maximum Gradient	3%	5%
Maximum Superelevation	5%	7%
R.O.W	70m	50m
B. DESIGN SPEED RELATED STANDARDS FOR MAIN MOTORWAY		
Design Speed	120kph	100kph
Min. Stopping Sight Distance	290m	210m
Min. Horizontal Radius with 4% superelevation	1500m	-
Min. Horizontal Radius with 7% superelevation	-	720m
Vertical Curvature K Value (crest)	165	100
Vertical Curvature K Value (sag)	65	40

3) Horizontal Alignment

The horizontal alignment of the existing road will remain same and will not be altered as the Project is only related to altering the profile for raising the existing road surface.

4) Vertical Alignment

The vertical alignment of the objective road will be determined from the design flood level (refer to Section 2-2-1-2(2)) and the results of the profile survey conducted on the existing road. To be precise, the proposed height for raising the existing road elevation at the toll gate section, which

lies approximately between Sta. 24+400 and Sta. 25+600, will be ten (10) cm or more from the design flood level, and for the rest of the section, it will be more than -20cm or lower from the design flood level. But it is to be noted that, unlike in normal surveys, the base point for measuring the profile of the existing road for this particular Project has been taken at 2.5m from the end of the travelled way for safety reasons.

5) Typical Cross Section

Figure 2-2-2-2.1 shows the typical cross section of the road at the toll gate plaza, while **Figure 2-2-2-2.** shows the typical cross section for other sections. The major difference between the two cross sections is the criteria for raising the height of the existing road elevation. As aforementioned in Section 2-2-1-7(2), the criteria for raising the existing elevation of the road surface is to secure 10cm or more from the design flood level at the toll gate section and -20cm or less from the design flood level at other sections.

The composition of the roadway at the sections to be raised will be similar to that of the existing road. Therefore, the composition of the road at standard sections will have 4 lanes, each 3.6m wide, a 3.0m wide shoulder and a 1.5m wide strip at the median. Other sections, such as the emergency parking strip or the ramps will also be planned to have dimensions similar to that of the existing ones. Also, the normal crossfall (2.5%) to be applied on the sections of the road to be raised will be similar to that of the existing road.

6) Superelevation

The curved section of the existing road is designed with proper superelevation, having its maximum value as 5%. As aforementioned, the main purpose of the rehabilitation work to be undertaken by this Project is to raise the existing road elevation. This implies that there will be virtually no change in the horizontal alignment of the existing road. As such, the superelevation to be applied at the curved section should be the same to the superelevation that has been applied on the existing road. However, the details of the superelevation and the transition section are not mentioned explicitly in the available drawings and documents. Therefore, where the existing superelevation and the transition length are unclear, it will be applied based on the recommended values of Thai Standard or the AASHTO Standard.

7) Embankment Slope and Bench Cuts

Widening of the existing embankment will be required following the raising of the existing road elevation. The slope of the embankment will be designed to have a grade of 4:1. At existing slopes equal or steeper than 4:1, embankments will be planned such that the existing ground will be cut in steps (bench cuts) prior to the embankment work to enhance stability of the embankment.

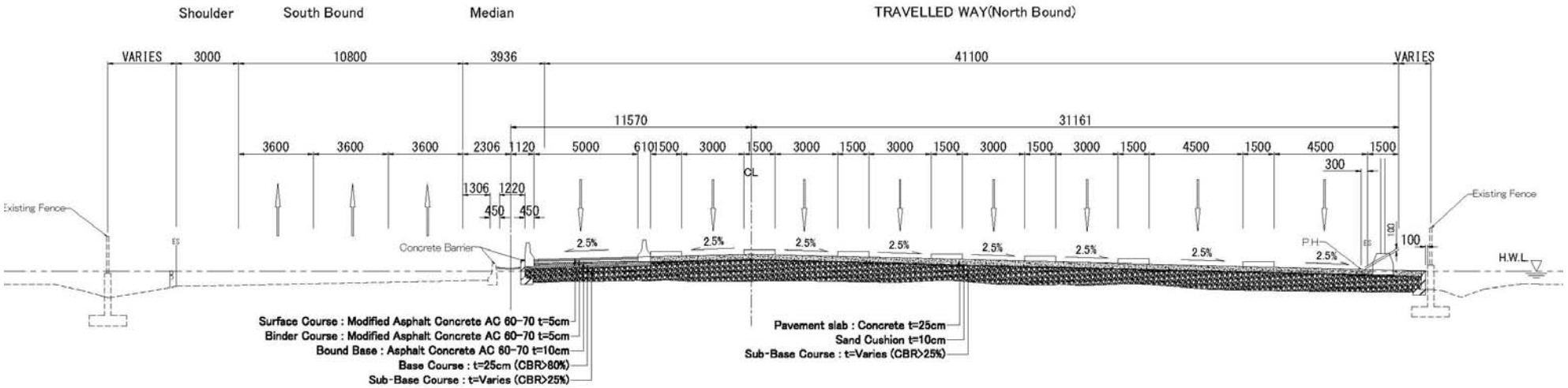


Figure 2-2-2-2.1 Typical Cross Section (Toll Gate Area)

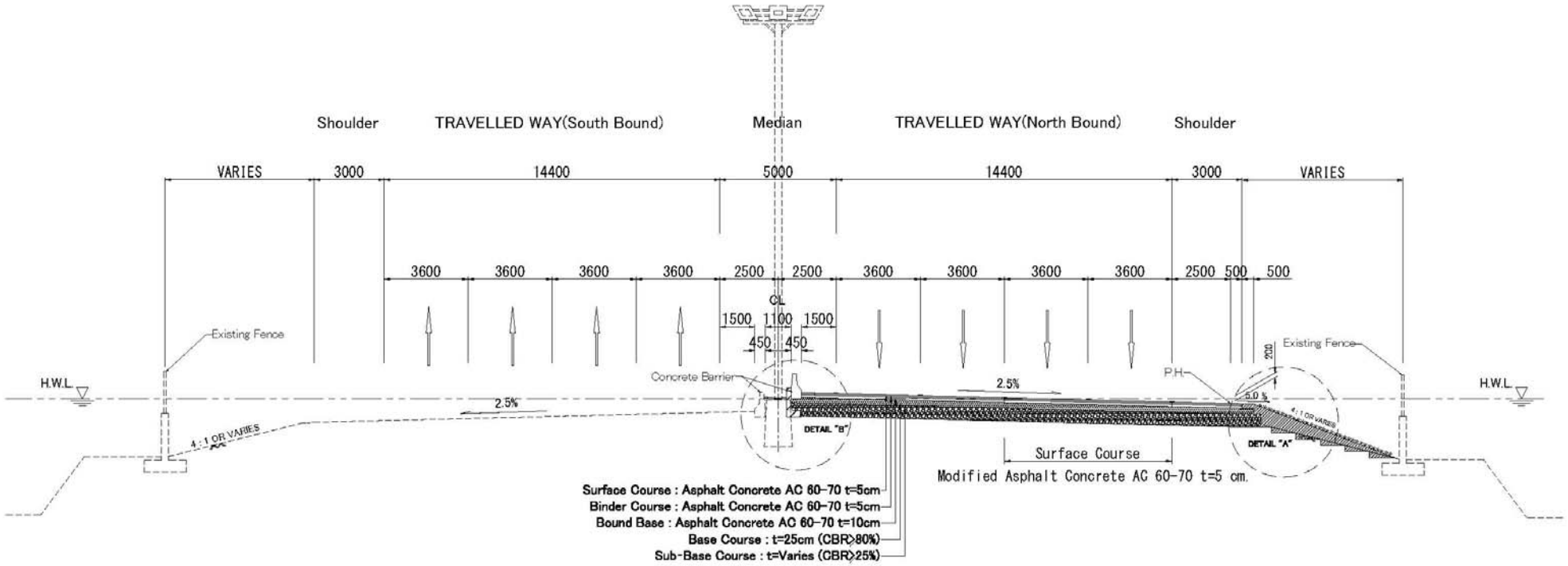


Figure 2-2-2-2.2 Typical Cross Section (Standard Section)

8) Pavement Design

Present Pavement Condition of the Objective Road

The 30km segment of the existing road, which is the objective length of this Project, is provided with a flexible pavement. Only a short segment at the toll booth has a rigid pavement. The objective road was expanded from its initial stage (4-lane road) by the GOT in year 2009. Therefore, the pavement is relatively new and in a healthy state. No significant distresses of the pavement were observed during the site reconnaissance. It is evident, the incessant rainfall from July till November in year 2011, which is considered as the heavy rainfall once in 80 years, had no remarkable damage on the pavement. A short segment at one of the toll gates on the north bound roadway were seen to have been damaged where potholes, rutting and surface cracks were conspicuous. However, the segment has retained its healthy state following improved works conducted by DOH in around March.

The CBR tests carried out under this Project showed signs of overlay (1, 2 times) applied to the existing pavement. The details of the overlay work were not able to be confirmed due to unavailability of documents (road ledgers, log books) or the records of the repair works.

Verification of Pavement Structure of the Existing Road

The pavement structure of the existing road was designed by the Department of Highways (DOH) of the GOT. The pavement composition according to the design and as-built drawings are;

- Surface course : Asphalt concrete, t=5cm
- Binder course : Asphalt concrete, t=5cm
- Bound Base :Asphalt concrete (porous), t=10cm
- Base course :Cement stabilized material, t=25cm
- Subbase course :Soil Aggregate, t=20cm (CBR >25)
- Subgrade replacement : Sand embankment, t= 60cm (design CBR10)

The Project length is 30km, whereas the section to be raised is only 15.056 km of the north bound roadway. The objective of the Project can be accomplished only if the pavement structures of the entire 30km segment can bear the traffic load up to its performance period. Therefore, pavement design as well as verification of the strength of the existing pavement is also equally important.

To confirm the strength of the existing pavement, verification was conducted. The prerequisites for the verification/calculation are listed below, the design inputs and calculation results are shown in **Table 2-2-2-2.2** and **Table 2-2-2-2.3** respectively.

Prerequisites for the verification (Calculation)

- The calculation will be based on AASHTO Guide for Design of Pavement Structures 1993. Prior approval from the DOH for its application has already been confirmed

- The Structural Number (SN) required for the asphalt pavement be calculated from the following formula

$$\mathrm{Log}_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \mathrm{Log}_{10}(SN+1) - 0.20 + \frac{\mathrm{Log10}\{\Delta PSI/(4.2-1.5)\}}{0.40 + \{1094/(SN+1)^{5.19}\}} + 2.32 \times \mathrm{Log}_{10}(M_R) - 8.07$$

Source: AASHTO

- The traffic volume including the growth rate provided by the DOH will be basically applied for the calculation

Table 2-2-2-2.2 Inputs for Checking Existing Pavement

Item	Description	Design Condition	Design Inputs
Performance Period	The period of time that an initial pavement structure will last before it needs rehabilitation.	10-15 years (2009-2013)	15 years (2009-2023)
Traffic Load	The traffic load is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications (w_{18}) during the performance period. and is calculated based on the future traffic volume which is converted to 18-kip ESALs applying the axle load equivalency factors given in the AASHTO Guide.	For 2009 and 2010, the actual traffic volume surveyed by DOH is used while the traffic volume beyond that was calculated based on the growth rate provided by DOH.	w_{18}=**199,484,302**
Reliability	Means of incorporating some degree of certainty into the design process.	The level of reliability (R) Standard normal deviate corresponding to level of reliability (Z_R) Combined standard error of the traffic prediction and performance prediction (S_o)	R=80% Z_R = -0.841 S_o = 0.45
Performance Criteria	The Present Serviceability Index (PSI) is used to represent pavement performance. The total change in PSI (△PSI) is defined as the difference between initial serviceability index (p_0: value immediately after construction) and terminal serviceability index (p_t: lowest index that will tolerate before rehabilitation, resurfacing or reconstruction)	p_0 = 4.2 pt = 2.5	p_0=4.2 pt=2.5 △PSI=1.7
Roadbed Soil Property	The resilient modulus (M_R) is used. The AASHTO Guide introduces the equation estimating M_R from CBR as M_R = 1,500 x CBR (CBR is regarded as 10 in case of CBR more than 10)	CBR=7.6 （calculated based on CBR investigation）	M_R=11,400psi (CBR≥7.6)
Pavement Layer Material Properties	The pavement strength is expressed by the structural number (SN) which is calculated as : $SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$ where a_i=i^{th} layer coefficient D_i=i^{th} layer thickness (inches) m_i=i^{th} layer drainage coefficient	Asphalt concrete surface course: a_1=0.42 (E_{AC}=425,000 psi) Asphalt concrete binder course: a2=0.42 (E_{AC}=425,000 psi) Bound base：a3=0.41(E_{AC}=350,000 psi) Base course:a_4=0.20(CBR=80%) Subbase course: a_5=0.11 (CBR=20%)	a_1=0.42 a_2=0.42 a_3=0.41 a_4=0.20 a_5=0.11
Drainage Condition	The factor to modify the SN considering the effects of drainage.	m_4=m_5=1.0 (water removed within 1 week, and pavement structure is exposed to moisture levels approaching saturation during 5% of the year)	M_4=1.0 m_5=1.0

Table 2-2-2-2.3 Result of Checking Existing Pavement

Material		Layer Coefficient (a)	Thickness(inch) (D)	Drainage Coefficient (m)	SN = a*D*m	Thickness (cm) (D)
Thickness	Surface course	0.420	1.969	—	0.827	5
	Binder course	0.420	1.969	—	0.827	5
	Bound base	0.400	3.937	—	1.575	10
	Base course	0.230	9.843	1	2.264	25
	Subbase course	0.114	7.874	1	0.898	20
total						65
Structural Number			6.144 (required)	> **NG**	6.102 (calculated)	

The structural number calculated (6.102) is smaller than the required structural number (6.144). Therefore, the existing pavement structure is considered incapable to bear the traffic load for its performance period. The performance period where the structure of the existing pavement is able to support the traffic load is assumed, based on the above conditions, as 14.5 years – till the middle of year 2022.

Pavement Design of Raising Sections

a) Prerequisites for Pavement Design

Flexible pavements (asphalt concrete) are commonly used in the Kingdom of Thailand. The existing pavement of the Project objective road is also asphalt concrete. Also, asphalt concrete is easy to be maintained or repaired. From these aspects, asphalt concrete will be applied to the surface course, binder course and the bound base course for the section where the road elevation will be raised. However, considering the static load of the traffic, a part of toll gate plaza will be designed to have rigid pavement (concrete pavement).

b) Consideration of the Existing Pavement

The pavement to be newly applied obviously has to be laid on top of the existing pavement as the main objective of this Project is to raise the existing road surface elevation. However, unlike adding asphalt layer on top of the existing asphalt surface, as is often done in case of overlays, the pavement to be applied could be up to the subbase depending on the height to be raised. In such case, superimposing the subbase course on top of the existing asphalt course could cause damage to the pavement as the joint (asphalt surface) could potentially become a path for the infiltrated water. Therefore, all existing asphalt layers (surface course (t=5cm), binder course (t=5cm) and the bound base (t=10cm)) of the existing pavement is planned to be removed before applying the new pavement.

c) Pavement Calculation

Calculation of pavement structure is done based on AASHTO. The input parameters are listed in **Table 2-2-2-2.4** and the results of the calculation are summarized in **Table 2-2-2-2.5**.

Table 2-2-2-2.4 Design Inputs for Calculation of Pavement Structure

Item	Description	Design Condition	Design Inputs
Performance Period	The period that initial pavement structure requires rehabilitation.	10years	10years (2014-2023)
Traffic Load	The traffic load is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications (w_{18}) during the performance period.	The actual traffic volume surveyed by DOH is used for 2009 and 2010, while the traffic volume beyond that was calculated based on the growth rate provided by DOH. w_{18}=**157,166,441**	w_{18}=**157,166,441**
Reliability	Means of incorporating some degree of certainty into the design process.	The level of reliability (R)=80% Standard normal deviate corresponding to level of reliability (Z_R) = -0.841 Combined standard error of the traffic and performance prediction (S_o) = 0.45	R=80% Z_R = -0.841 S_o = 0.45
Performance Criteria	The Present Serviceability Index (PSI) is used to represent pavement performance. The total change in PSI (△PSI) is defined as the difference between initial serviceability index (p_0: value immediately after construction) and terminal serviceability index (p_t: lowest index that will tolerate before rehabilitation, resurfacing or reconstruction)	p_0 = 4.2 pt = 2.5	p_0=4.2 pt=2.5 △PSI=1.7
Roadbed Soil Property	The resilient modulus (M_R) is used. The AASHTO Guide introduces the equation estimating M_R from CBR as M_R = 1,500 x CBR (CBR is regarded as 10 in case of CBR more than 10)	CBR=7.6 （calculated based on CBR investigation）	M_R=11,400psi (CBR≥7.6)
Pavement Layer Material Properties	The pavement strength is expressed by the structural number (SN) which is calculated as : $SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$ where a_i=i^{th} layer coefficient D_i=i^{th} layer thickness (inches) m_i=i^{th} layer drainage coefficient	Asphalt concrete surface course: a_1=0.42 (E_{AC}=425,000 psi) Asphalt concrete binder course: a2=0.42 (E_{AC}=425,000 psi) Bound base：a3=0.41(E_{AC}=400,000 psi) Base course:a_4=0.20(calculated based on soil investigation) Subbase course: a_5=0.11 (calculated based on soil investigation)	a_1=0.42 a2=0.42 a3=0.41 a_4=0.20 a_5=0.11
Drainage Condition	The factor to modify the SN considering the effects of drainage.	m_4=m_5=1.0 (water removed within 1 week, and pavement structure is exposed to moisture levels approaching saturation during 5% of the year)	

Table 2-2-2-2.5 Result of Checking Planned Pavement

Material		Layer Coefficient (a)	Thickness(inch) (D)	Drainage Coefficient (m)	SN = a*D*m	Thickness (cm) (D)
Thickness	Surface course	0.42	1.969	—	0.827	5
	Binder course	0.42	1.969	—	0.827	5
	Bound base	0.41	3.937	—	1.575	10
	Base course	0.20	9.843	1	2.264	25
	Subbase course	0.11	7.874	1	0.898	20
total						65
Structural Number			SN=5.952 (required)	< OK	SN=6.102 (calculated)	

The calculated structural number exceeds the required. Therefore, the pavement structure is capable to function until its performance period.

d) Performance Period and Traffic Forecast

According to the Thai Standards, the performance period is set at 15 years for new roads and 7 years for maintenance or rehabilitation of the existing road. The performance period for the pavement on the sections to be raised under this Project is set at 10 years for the following reasons.

- The performance period for Grant Aid is usually 10 years.

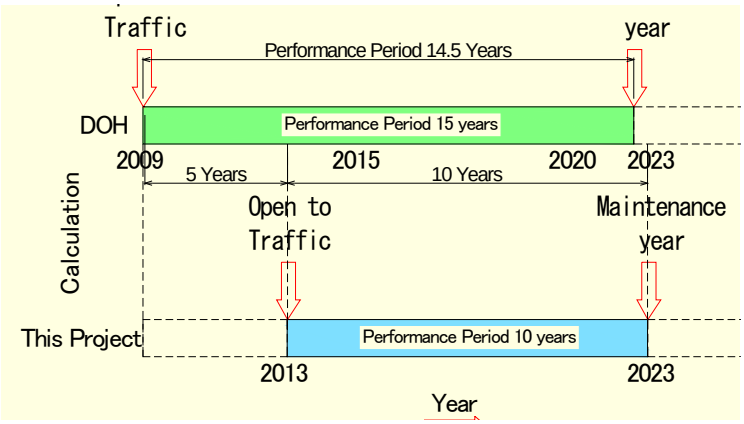


Figure 2-2-2-2.3 Comparison of Performance Period

- As mentioned above, the performance period is set as 15 years for new roads and 7 years for the rehabilitation and maintenance of the road. The objective road was constructed in year 2009. According to the above standards the existing pavement will need some sort of maintenance in year 2023. If a performance period of 10 years is applied for the sections to be raised, then the period that the pavement will require to be maintained will be the same with other sections. In other words, the pavement of the entire section will be subjected to maintenance in the same period. This will contribute to the formulation of maintenance plan of the pavement. The concept is illustrated in .

- One of the design input parameters of pavement design is the equivalent single axle load. Taken the performance period as 10 years, and using the same growth rate that was used for the calculation for verifying the pavement structure of the existing road, the traffic forecast for the performance period will also be similar to the one estimated for the same.

Pavement Structure of the Sections to be Raised

Depending on the raising height of the existing road surface, 4 types of pavement structures are planned to be applied. **Figure 2-2-2-2.5** illustrates these pavement structures.

As aforementioned, the main purpose of the Project is to raise the existing road surface elevation. It has already been verified that the existing pavement of the objective road is strong enough to

tolerate the traffic load until its performance period. Also, the performance period and other design input parameters for the calculation are same to those used for the verification. Given that the pavement structure of the sections that would be raised has same or thicker pavement structure, it is explicit that it would be strong enough to support the traffic load.

However, it is clear that the thickness of the pavement to be applied differs according to the elevation to be raised. First, a height of the existing road surface to be raised is not constant. The maximum is about 120cm while the minimum is zero; at the ends of the objective sections for transitions to the existing road surface. And second, both the longitudinal and the transverse surface of the existing road are not flat. Therefore, applying a uniformly thick pavement is considered to be extremely complicated and difficult. Although, applying the pavement in accordance with the elevation to be raised is economical in terms of material cost, it may turn out to be more expensive as the construction period will be longer due to the complication.

The pavement structure similar to the existing road will be applied at the transition sections. For other sections, the pavement thickness up to the bound base will be similar to the existing one. The thickness of the sub-base course will be adjusted in accordance with the elevation to be raised.

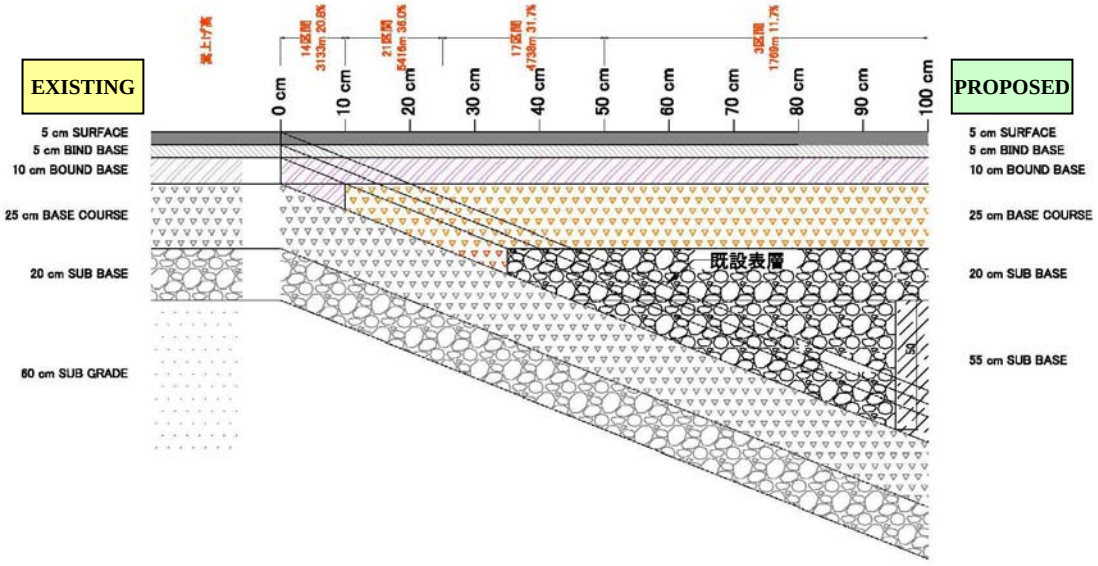


Figure 2-2-2-2.4 Types of Pavement Structure of the Sections to be Raised (1)

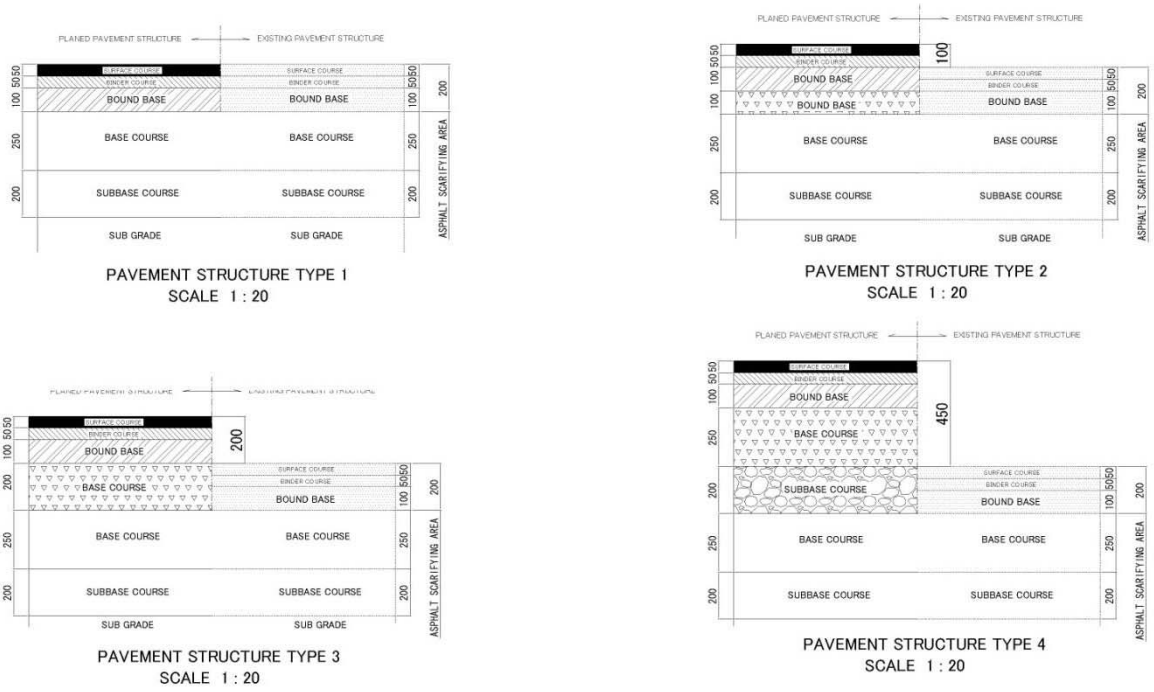


Figure 2-2-2-2.5 Types of Pavement Structure of the Sections to be Raised (2)

(2) Toll Gate

A toll gate for collecting toll fee from the vehicles that use the objective road is located near Station 24+400. In addition, a building for supervision, control and operation of toll gate and toll booth is also located in this area. Apart from these, there is a pedestrian overpass provided for access from and to the control building to the toll gate at the south. Some of these facilities are deemed to be affected by the raising of the existing road surface and therefore requires to be replaced. The policy for rehabilitation of this section, which explains its scope and size, is mentioned in section 2-2-2-1.

1) Raising Road Elevation Plan

The scope of elevating plan is from Sta. 24+400 to Sta. 25+600, (the total length: 1,200m). The elevating height is plus ten (10) cm from the largest recorded flood level in 2011, determined from the results of the topography survey and flood analysis.

2) Raising Toll Gate Facility

The construction for raising the toll gate will include removal of the existing toll gate (including toll booth, roof, and foundation) and reinstallation of a new toll gate. The location and the size of the facilities will be similar to the existing facilities. The structure of pavement under the toll gate, and rigid (concrete) pavement, will also be similar to the existing one (**Figure 2-2-2-2.6**).

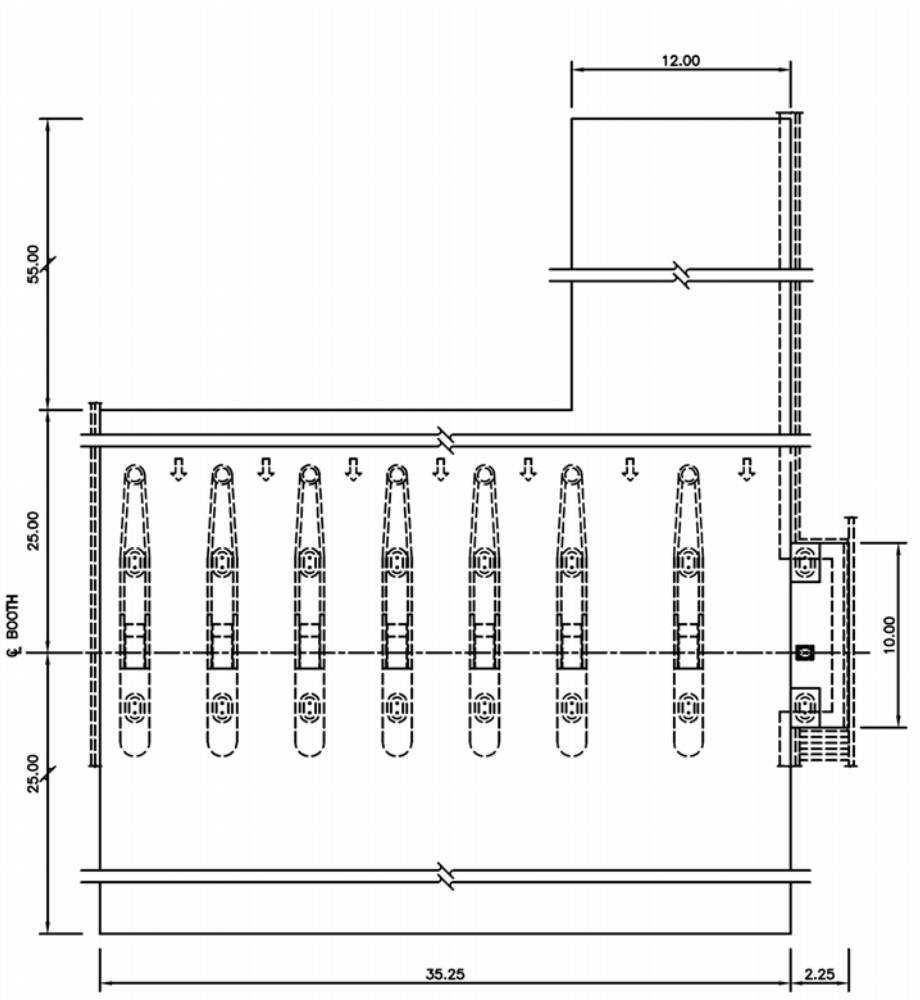


Figure 2-2-2-2.6 Paved Area

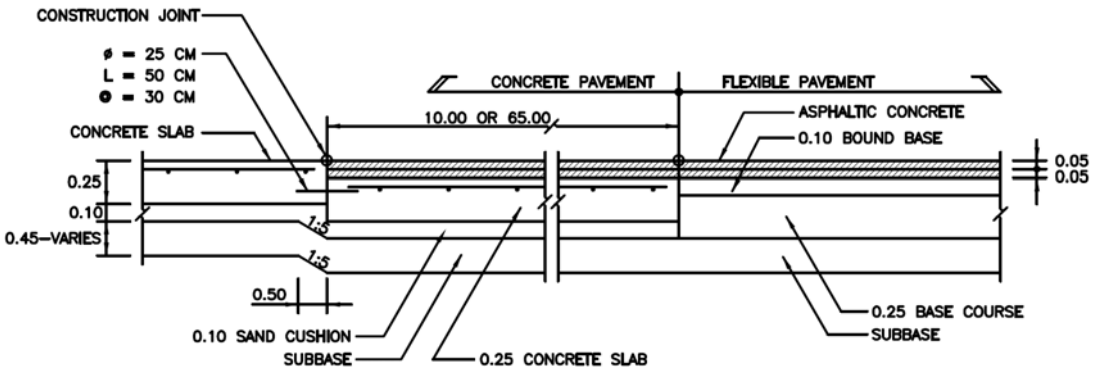


Figure 2-2-2-2.7 Pavement Structure

3) Raising Pedestrian Overpass for Toll Gate Access

As a result of raising the existing road surface in correspondence to the proposed profile, the existing pedestrian overpass, which is used for access between the control building and the south bound toll gates, will lack the desirable vertical clearance of 5.5m required by Thai Standards by 0.95m. Therefore, the overpass is planned to be raised to meet the required clearance after the rehabilitation of the road. However, as the existing foundation, the superstructure and the steel girder (L=18.2m) are new and strong, these structures are considered to be reused.

4) Stairway Installation

The control building is not required to be raised as it is out of scope of this project. However, as the existing road surface is subject to raising, there will be a big difference in the height (maximum 1.1m) of these surfaces causing diffuculty in access between the control building and the toll gates.

A stairway is planned to be provided for access purpose. The location of the stairway to be provided is illustrated in **Figure 2-2-2-2.8**, while its sideview is shown in **Figure 2-2-2-2.9**.

Figure 2-2-2-2.8 Location of Planned Stairway

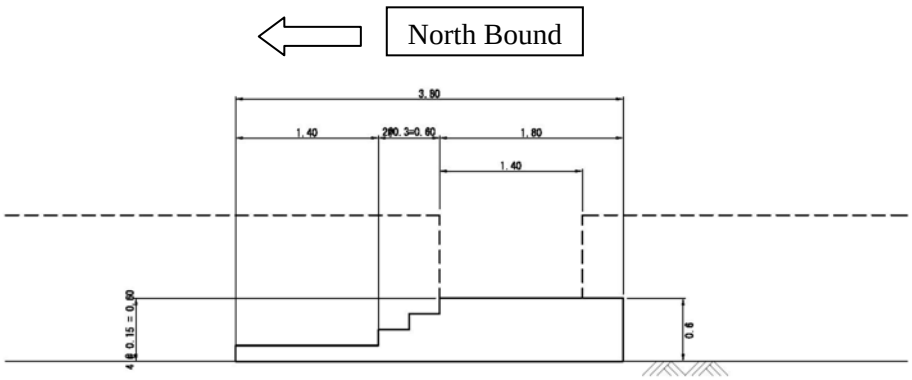


Figure 2-2-2-2.9 Stairway (Side view)

5) Drainage Improvement

Some locations not necessarily have crossfalls divided at the middle of the median and rather have at the centerline of the roadway as shown in **Figure 2-2-2-2.10**. The drainage at these locations will be obstructed due to the rise in the surface of the north bound lanes.

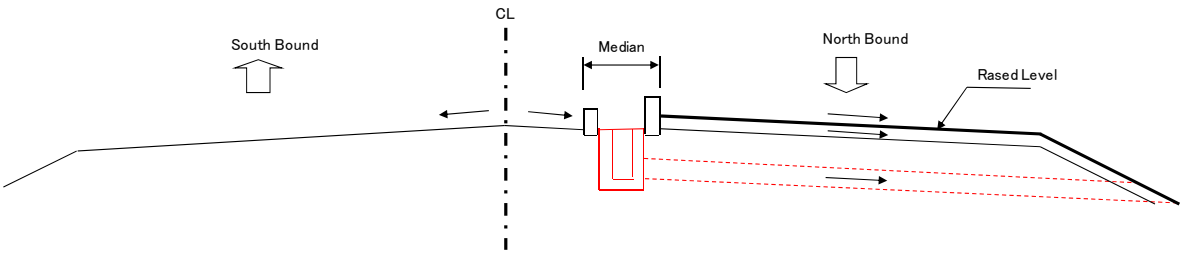
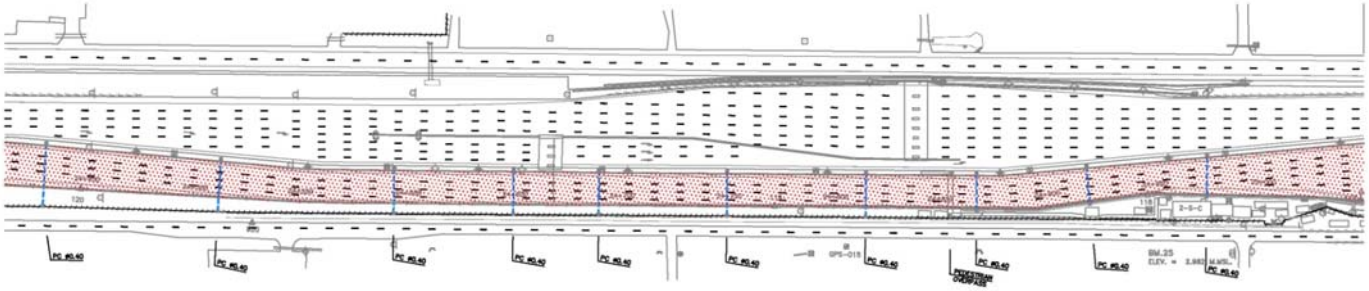


Figure 2-2-2-2.10 Current Condition of Drainage at Toll Gate Plaza

Therefore, catch basins and pipe culverts will be installed at 10 locations to collect the surface runoff and facilitate to be discharged outside the road (refer to **Figure 2-2-2-2.11**).



2-2-2-3 Road Drainage

(1) Capacity Verification of Existing Drainage Facilities

1) Condition of Existing Drainage Facilities

The condition of the existing drainage facilities is aforementioned in Section 2-2-1-7(9).

2) Conditions for Verification

Following are the major conditions to be applied for the verification of the capacity of the existing drainage facilities.

- There is no change in the catchment area and the discharge volume in comparison to the existing condition as the Project pertains with raising the existing road surface level only
- The existing drainage facilities in and around the Project site is properly functioning
- The calculation will be based on the Rational Method
- Rainfall intensity (I) for a return period of 10 years will be applied in accordance with the standard of Thailand

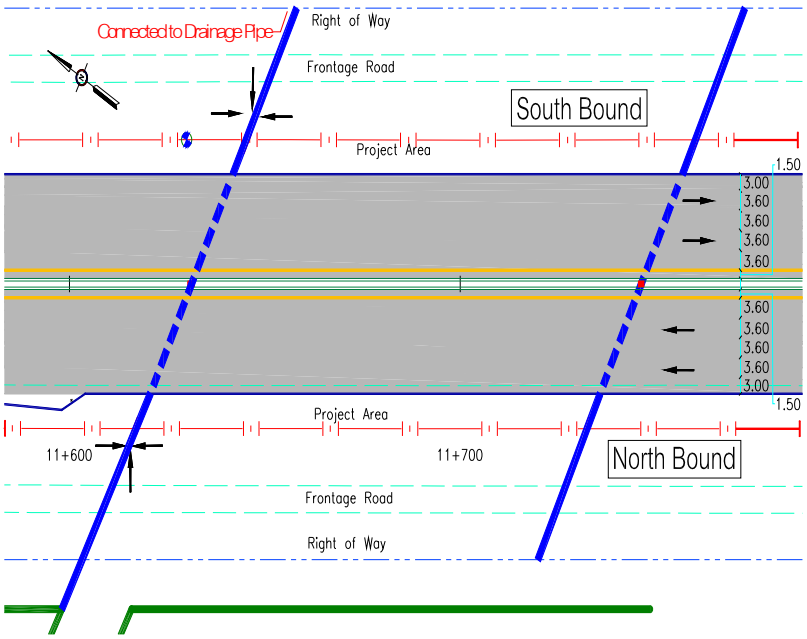


Figure 2-2-2-3.1 Model for Checking Capacity of Existing Drainage Facilities

Table 2-2-2-3.1 Input for Calculation

Conditions (parameters)

Items	Abbrev.	Unit	Values	Remarks
Rainfall Intensity	I	mm/h	82.9	Return period 10 years
Coefficient of runoff (average)	C	—	0.79	(0.95×18.9+0.35×7.0)/25.9
Width of catchment area	W	m	25.9	18.9+7.0 (Roadway＋Side slope) The north bound roadway
Channel Slope (average)	i	%	0.10	
Coefficient of Roughness (average)	n		0.083	(0.10×3.092+0.015×0.75)/3.842
Ratio of allowable conveyance to maximum conveyance	r	%	80	

$A=1/2\times3.0\times0.75 = 1.125m^2$

$P=\sqrt{(3.0^2+0.75^2)} + 0.75= 3.842m$

$R=1.125 / 3.842 = 0.2928$

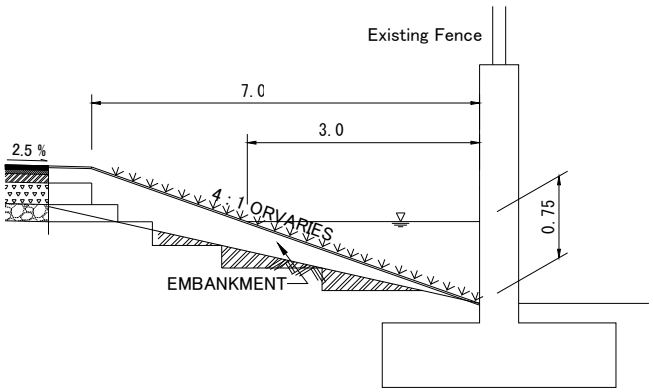


Figure 2-2-2-3.2 Explanation Drawing

Discharge volume per unit length of the roadway is calculated from the Rational Method, which is given by the following formula.

Discharge, $$q = \frac{C \times I \times W}{3.6 \times 10^6} = \frac{0.79 \times 82.9 \times 25.9}{3.6 \times 10^6}$$
$$= 0.000471 \quad (m^3 / S / m)$$

Allowable interval of Inlets (catch basins)

$$Q = 1/n \times i^{1/2} \times R^{2/3} \times A \times r$$
$$= 1/0.083 \times 0.001^{1/2} \cdot 0.2928^{2/3} \times 1.125 \times 0.80$$
$$= 0.1512 (m^3/S)$$

$$L = \frac{\gamma * Q}{q}$$
$$= \frac{1.00 \times 0.151}{0.000471}$$
$$= 320.6 > 285.8 (\text{Average Interval of Existing Pipe Culvert})$$

(2) Drainage at Superelevated Sections

At superelevated sections of the existing road, there are catch basins provided along the median barrier at an interval of 10m in average to facilitate the rain water that flows towards the center (median) of the road. The rain water collected at the median side is collected through these basins and is discharged out of the roadway through the underground culverts.

The existing catch basins are therefore required to be raised following the raising of the existing road surface level in order to secure the existing drainage system. As illustrated in **Figure 2-2-2-3.**, the existing catch basins will be planned to be raised in accordance with the raising height of the existing road surface level.

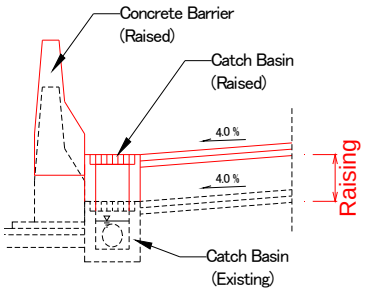


Figure 2-2-2-3.3 Raising of Existing Catch Basin

(3) Protection of Inlet/Outlet of Existing Drainage Facilities

Protection work at 25 locations of the inlet and the outlet of the existing drainage facilities will be conducted by providing wire mattresses. **Figure 2-2-2-3.4** and **Figure 2-2-2-3.5** Illustrate the outline of the protection work to be applied.

There are altogether about 59 locations on the north bound roadway where the culverts have an opening to intake the rain water (surface runoff) of the existing road. However, 34 of them have its openings beyond the fences. Protection work will not be practiced at these locations as there is information that the government of Thai is planning raising the elevation of the frontage road. In such case, even if the protection work is applied now, it will have to be done so again then.

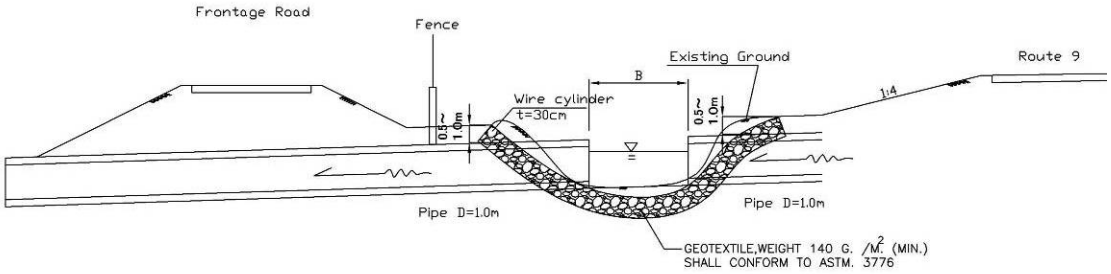


Figure 2-2-2-3.4 Protection Work at Inlet/Outlet of Drainage Facilities

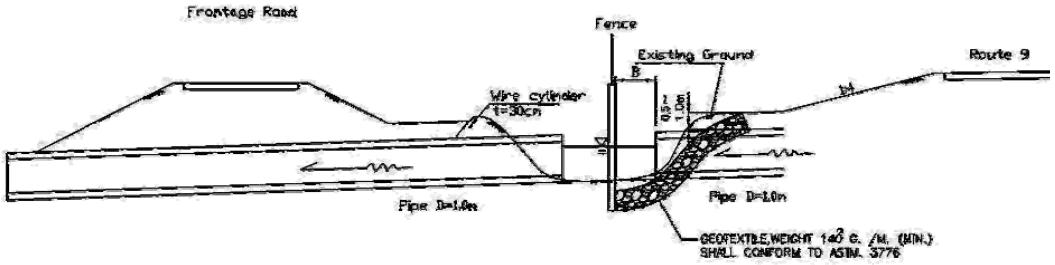


Figure 2-2-2-3.5 Protection Work at Inlet/Outlet of Drainage Facilities

2-2-2-4 Slope Protection

The method of slope protection planned to be applied for the objective sections of the Project road is illustrated in **Figure 2-2-2-4.1**. As shown in the figure, the top 20cm of the embankment slope will be furnished with clay material with low water permeability which will be covered by block sodding.

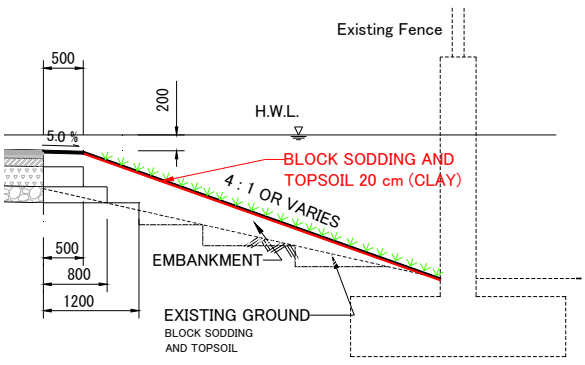


Figure 2-2-2-4.1 Slope Protection

The existing embankment has a layer of 10cm clay on the top of the embankment slope, which is covered by block sodding. Small sized cracks

were observed during the site reconnaissance, which is considered to be caused by/during the 2011 year flood. In order to strengthen the embankment and to protect the pavement from the infiltration of water, the clay layer has been increased from its initial 10cm thickness to 20cm in this Project.

2-2-2-5 Interchanges, Ramps and Frontage Roads

This Project covers only the main carriageway of the north bound roadway. The interchanges and the ramps are not included. However, the ramps require to be smoothly connected to the raised surface of the main carriageway. Therefore, only the run off section required for smooth connection with the main carriageway will be included in this Project. The run off section will be planned to have a maximum profile grade of 3%.

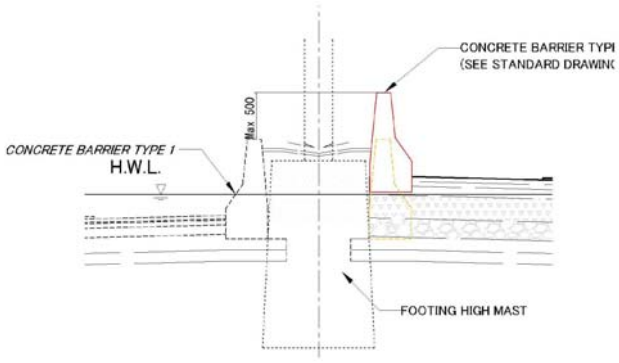


Figure 2-2-2-5.1 Standard Concrete Barrier

2-2-2-6 Incidental Road Facilities

(1) Median Barrier

The objective road is a divided motorway. Concrete barriers are provided to separate the north and the south bound roadways. These concrete barriers are required to be removed and restored following the raising of road elevation.

Concrete barrier as shown in **Figure 2-2-2-5.1** will be provided at sections where the height of the existing road surface to be raised is less than 50cm.

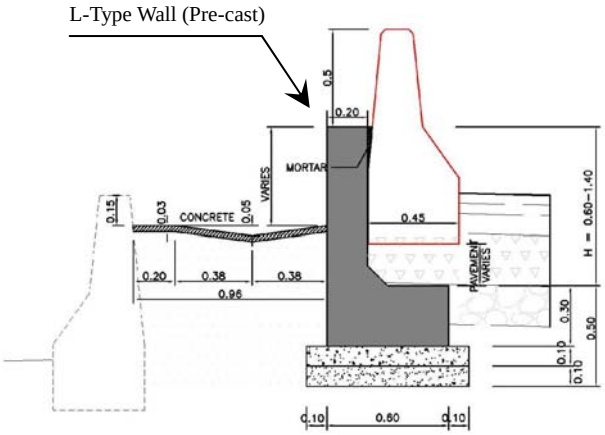


Figure 2-2-2-6.1 Concrete Barrier with L-Type Wall

On the other hand, at sections where the height of the existing road surface to be raised exceeds 50cm, such as sections with sharp horizontal curves like at Sta.13+100 (right turning for north bound roadway) or at places where the existing surface level is comparatively low, a pre-cast L-type concrete wall as shown in **Figure 2-2-2-6.1** will be applied to prevent the collapse (overturning) of the standard concrete barrier.

Both of the above mentioned structures will be planned in accordance with the standards of Thailand.

Re-use of the existing barriers is not considered to be practiced for the following reasons;

a) The precast barriers are joined at the top and needs extra time to disjoin before removal,
b) The type of structures differ (cast-in place, precast),
c) The cast-in place barriers can not be removed without being damaged, and
d) It is sometimes attached to the street light foundation or the concrete fillings of the median.

(2) Overhead Crossing Facilities

There are two fly-overs, two pedestrian bridges, and 9 overhead traffic signs including one eletronic sign that traverse the existing road within the section subject for raising under this Project. The desirable and the minimum vertical clearance set by Thai Standards for structures traversing a motorway are 5.25m and 5.0m respectively. **Table 2-2-1-7.6** lists the structures and its existing clearances. Among these facilities, the structures that are deemed to be affected due to the raising of the existing road surface is a pedestrian overpass at Sta. 13+762 and a pedestrian bridge at Sta. 26+262. There are about 4 alternatives to deal with such situation. They are;

a) lowering the vertical profile of the road,
b) adjusting the normal crossfall,
c) securing the critical clearance height but providing a sign to draw attention, and
d) raising the structures by jacking it up

The altenatives were discussed with DOH. Based on the discussion, the third alternative,i.e. ‘securing the critical clearance height (5.0m) but providing a sign to draw attention of the drivers’ was selected.

2-2-2-7 Protection of Underground Facilities and Reinforcing Plan

No detailed information on underground facilities were made available in the course of the design (reference are made in section 2-2-1-7(10) also). Under such circumstances, no specific plans can be formulated regarding reinforcing of these facilities. If any kind of underground facilities are discovered during construction, it will be discussed with DOH and the concerned authorities and necessary measures will be taken at the construction stage.

2-2-2-8 Facilities for Traffic Safety

The objective road is classified as a full access-controlled motorway where the speed is very high. For securing safety of the road users, the road is equipped with various safety facilities. The facilities that will be affected by the raising of the existing road elevation of the objective road as well as its countermeasures are discussed below.

(1) Traffic Signs

Overhead traffic signs are high enough for being affected by the raising of the existing road surface. However, the road signs installed at the shoulder side or in the median are required to be removed during construction. Therefore, the traffic signs that will potentially be affected will be replaced by a new one and installed at its existing location.

(2) Delineators (Studs)

The existing delineators that may be affected by the raising of the existing road surface of the objective road are planned to be removed and replaced. The types and the material of the delineators will be similar to that of the existing ones. The delineators will be provided at an interval of 20m; similar to that of the existing one.

(3) Pavement Markings and Road Studs

All the sections that is subject to raising needs to be provided with pavement markings. The type of pavement markings, its location and the material will all similar to the existing pavement markings. **Table 2-2-2-8.1** shows some of the major markings to be applied. Road studs will basically re-used.

Table 2-2-2-8.1 Major Pavement markings

Classification	Color	Line Type	Dimension	Remarks
Edge line (median)	Yellow	Continuous	W=20cm	Median side
Carriageway line	White	Dashed	W=20cm,L=3.0m Pitch=9.0m	
Edge line		Continuous	W=20cm	Standard section
Give way line		Continuous	W=0.3 ～ 0.5cm 、L=2.0m、Pitch=4.0m	
No passing line		Continuous	W=0.3～0.6m	
Arrows		Continuous/Dashed	W=0.15cm～0.75cm	Directional
Zebra		Continuous	W=0.5m Pitch=3.0m	Nose, merge,divergence
Road Studs	-	-	Embedded	

(4) Emergency Parking

Emergency parking strips are provided at two locations within the objective section subject to raising of the existing road elevation, which will required to be restored. These emergency strips will be planned in accordance with the standard of Thailand. **Figure 2-2-2-8.1** illustrates the standard emergency parking strip of Thailand.

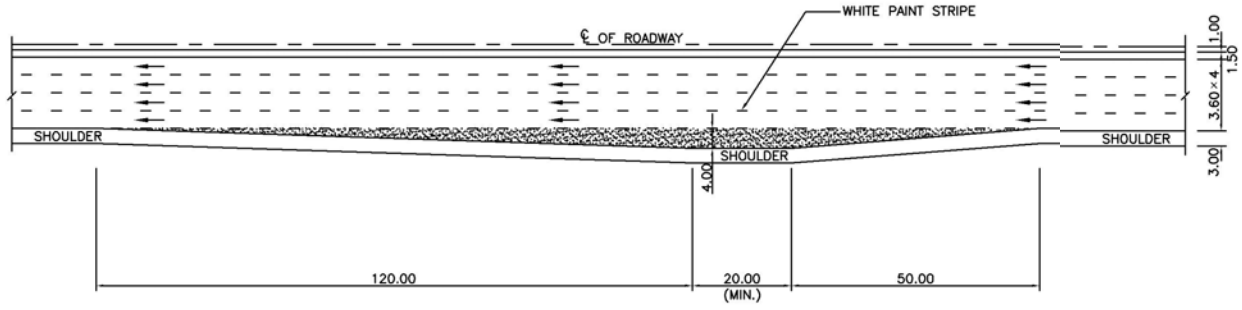


Figure 2-2-2-8.1 Standard Type of Emergency Parking Strip

(5) Existing Fence

The objective road is classified into a full access-controlled motorway. To secure smooth traffic flow

by controlling access of non-vehicular traffics, both sides of the motorway are fenced. However, these fences will not be subject to rehabilitation as the Project is deemed to have no effect on these fences.

2-2-2-9 Effect of Consolidation Settlement

(1) Current Situation and Issues

Consolidation settlement is deemed to occur after construction because the objective road was constructed on soft ground. Although about 13 years have passed since the initial construction (1999) of the road, the objective road is still thought to be experiencing settlement. The marks used for maintenance and repair on the road surface are evident to the settlement. However, DOH does not have any information and data pertaining to the consolidation settlement.

As urgent restoration/ rehabilitation is the objective of the project, and considering constraint of work period and limited budget, countermeasures for consolidation settlement are not included in this Project . This section describes about the study conducted (analysis of consolidation settlement) on the potential influence if the Project is implemented by analyzing the consolidation.

(2) Outline

1) History of Construction

Table 2-2-2-10.1 shows the history of construction projects within the objective area on the Outer Bangkok Ring Road (East Portion) in a chronological order.

Table 2-2-2-9.1 History of Embankment Work

Year	Work	Remarks
1998	Beginning of 2-lane Road Construction Project by Loan (Yen) assistance from Japan	
1999	Completion of 2-Lane Road Construction Project by Loan (Yen) assistance from Japan	
2008	Beginning of Road Widening (2-lane to 4-lane) Project financed by Thailand	
2009	Completion of Road Widening (2-lane to 4-lane) Project financed by Thailand	
2013～	Raising Road Elevation (north bound lanes only)	This Project

According to the results of soil investigation, studied cross sections of the ground were set as below, which have different soil property respectively.

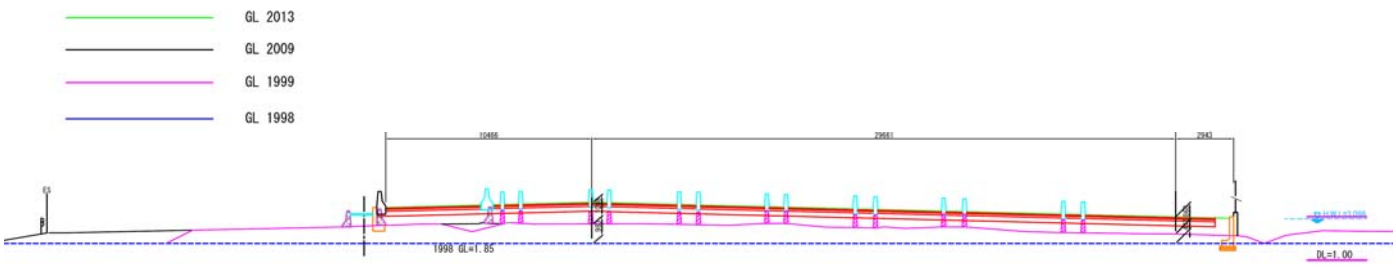


Figure 2-2-2-9.1 Studied Cross Section (Around Sta.25 Toll Gate Area : BH-1)

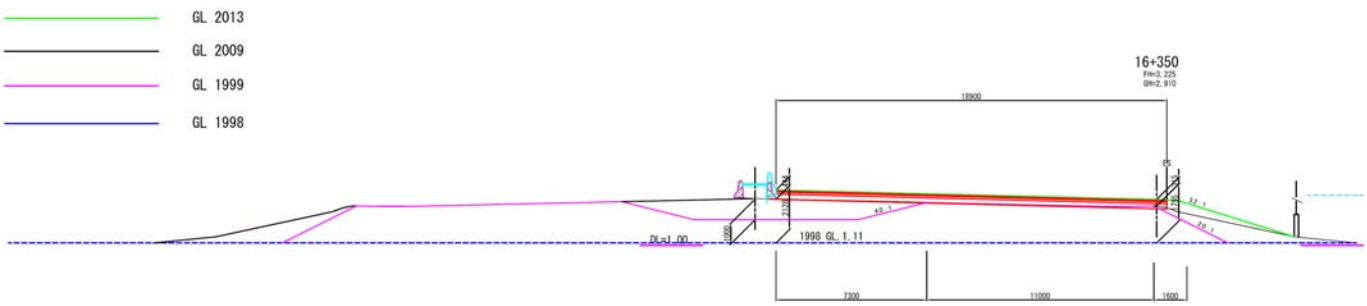


Figure 2-2-2-9.2 Studied Cross Section (Sta.16+700 Standard Section :BH-3)

2) Result of Boring Survey and Consolidation Test

Figure 2-2-2-9.4 shows the 3 locations where drilling was conducted. **Figure 2-2-2-9.** shows the geological profile of the area. From the figure it is understood that a 5 to 11m deep layer composed of Bangkok Clay, which has high consolidation rate (anisotropic) is distributed in the Project area. The Soil Investigation initially was conducted on the slope area for safety reasons. Additional boring was conducted on the carriageway to improve accuracy of consolidation analysis result. The results of boring and consolidation test are shown in **Table 2-2-2-9.2**.

Table 2-2-2-9.2 Summary of Result of Boring Survey and Consolidation Test

ID	Location of boring	Sta.	Consolidation Layer		Initial Void Ration e0			Compression Ratio CR=Cc/(1+e0)			Recompression Ratio RR==Cr/(1+e0)		
					Position of Specimen			Position of Specimen			Position of Specimen		
			Thickness	Soft Clay	Upper Part	Middle Part	Bottom Part	Upper Part	Middle Part	Bottom Part	Upper Part	Middle Part	Bottom Part
BH-1	Slope Area	25+320	11m	11m	2.5065	2.3612	2.1542	0.302	0.311	0.282	0.050	0.056	0.0.47
	Carriage Way	25+90	8m	3m	2.1723	2.1449	1.9127	0.328	0.339	0.278	0.049	0.049	0.044
BH-3	Slope Area	16+700	9m	6m	2.2471	2.0430	1.9767	0.266	0.251	0.208	0.042	0.038	0.034
	Carriage Way	16+700	8m	1m	2.3276	1.9673	1.7282	0.349	0.300	0.327	0.052	0.046	0.051

3) Methodology of Study

The flow of the study is shown in **Figure 2-2-2-9.3**. In order to secure accuracy of the calculation result, two distinguished methods for soil analysis are used to calculate total settlement.

a) One-Dimensional Analysis

This method is generally used based on Terzaghi's consolidation theory. This is characterized by using constant soil parameters without considering plasticity of the soil.

b) Two-Dimensional Finite Element Analysis (2D-FEM)

"Sekiguchi-Ohta" model is considered to be a constructive formula to reproduce consolidation behavior of such type of soil. This can represent non-linearity with high accuracy. This method is characterized by below.

- ✓ Considering non-linear behavior due to dissipation of excess pore pressure
- ✓ Considering plasticity of the soil with shearing deformation and

✓ Considering two-dimensional behavior by eccentric load

Also, two types of ground constant from boring survey and consolidation test at slope area and on carriage way are used for analysis by FEM. In analyzing, the assumptions are set as below;

[At Slope Area]

Using the ground constant at slope area, and considering previous consolidation from 1999 up to 2013, as the same ground constant as 1999

[On Carriage Way]

Using the ground constant on carriage way, and considering future consolidation from 2013 (not considering previous consolidation) because of ground constant on carriage way

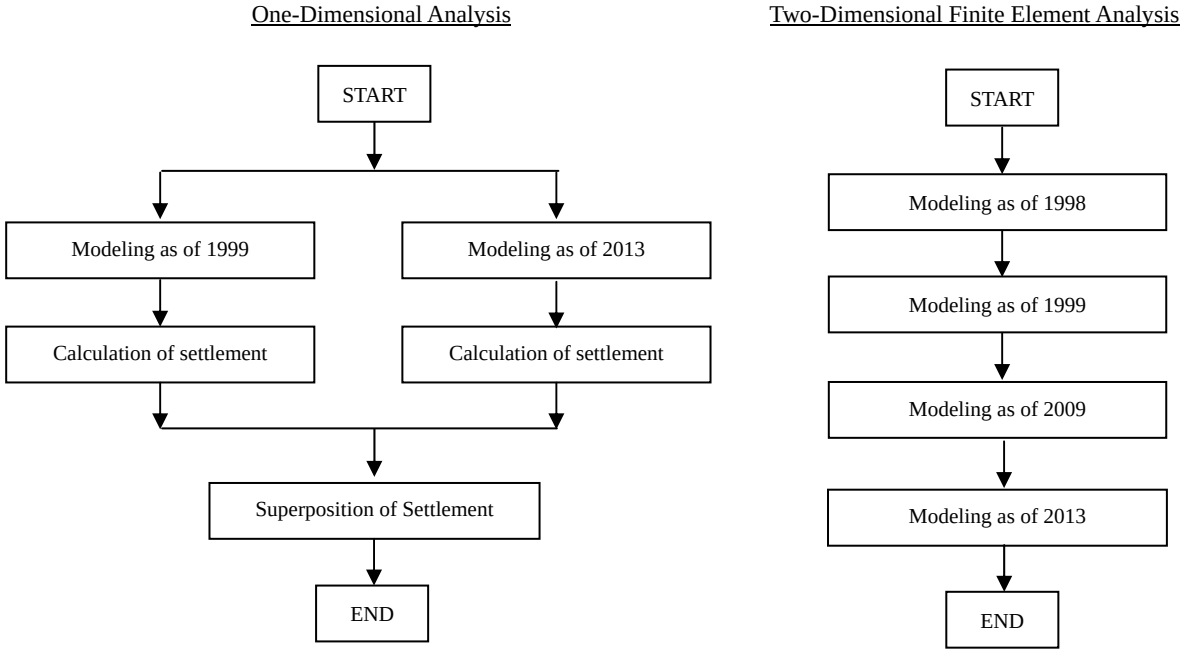


Figure 2-2-2-9.3 Flow of Analysis

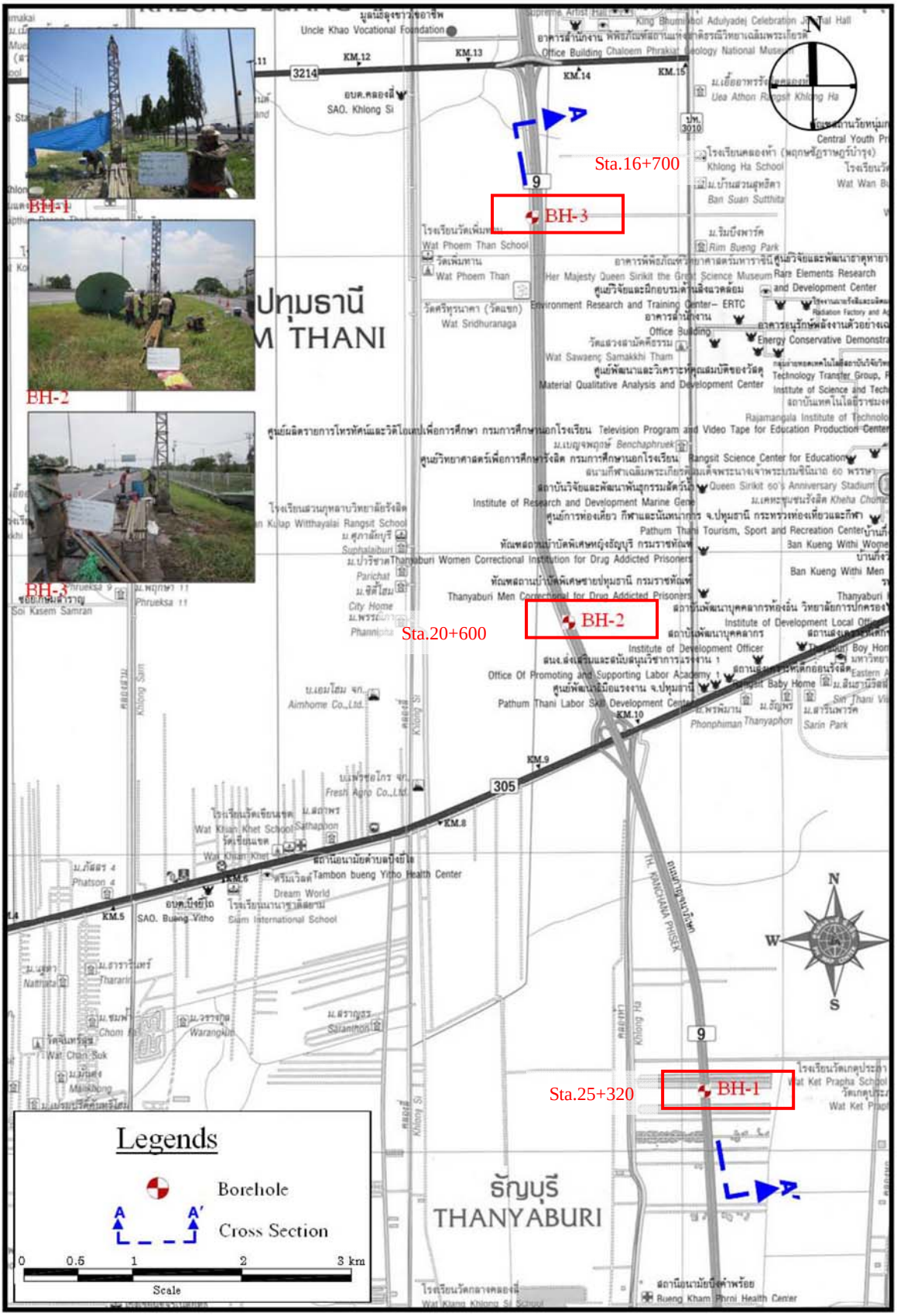


Figure 2-2-2-9.4 Location Map of Boring

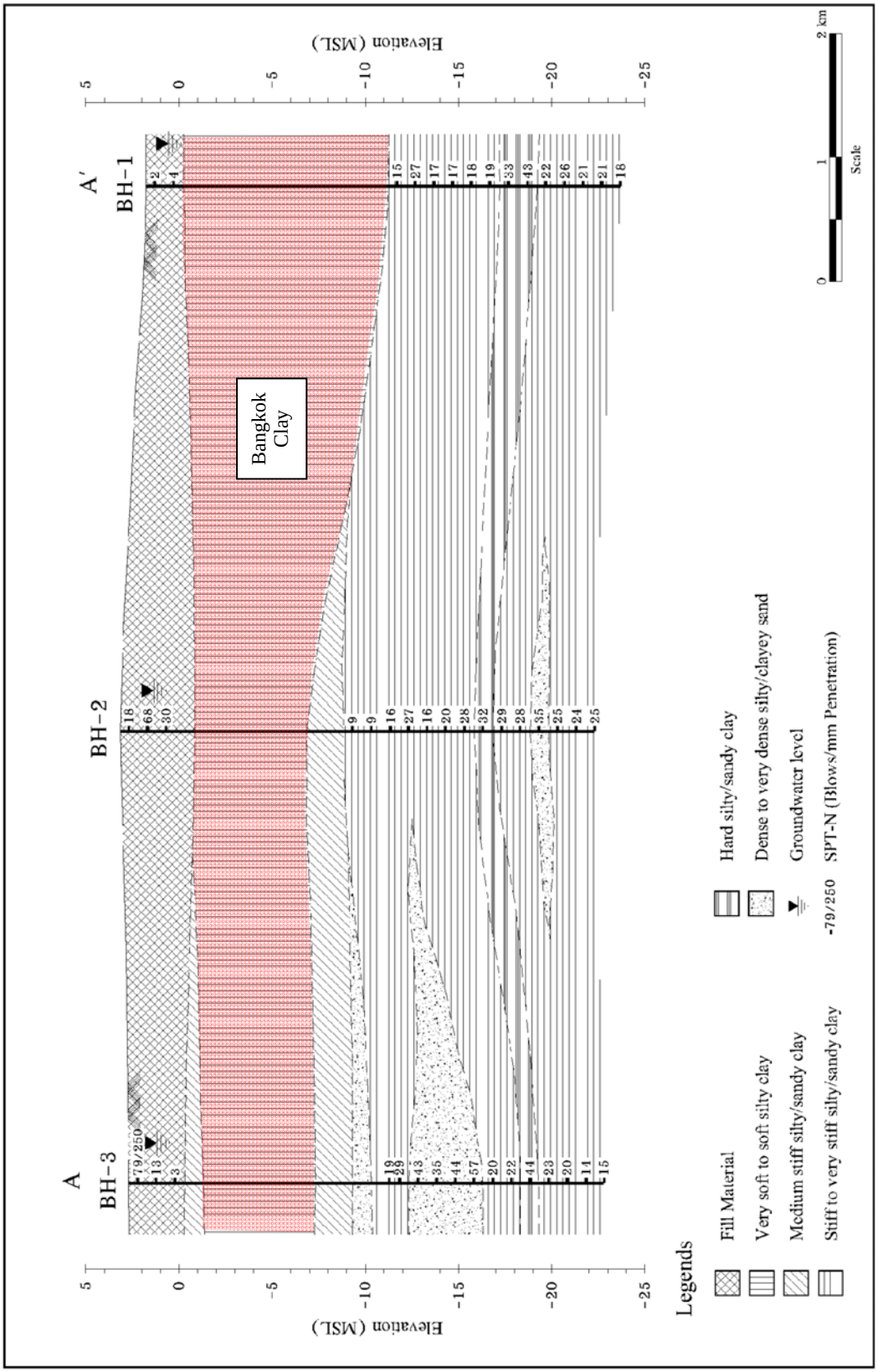


Figure 2-2-2-9.5 Geological Profile

(3) Analysis Result

1) One-Dimensional Finite Element Analysis

a) Sta.25+320 (BH-1: At Slope Area)

[1999 to 2013]

Location : **BH-1**

I. Imposed Loading *{Fill Height =* *0.98* *m }*

Dead load of fill material = 18.68 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 18.68 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **18.68**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	Precomp. Settl. S_1 (m)	Virgin Settl p_f/p_c'	Virgin Settl S_2 (m)	Settl. (m)
3.00	16.5		16.2	32.7							
2.00	38.0	39.0	13.8	51.8	0.302	0.050	1.03	0.001	1.33	0.075	0.076
2.00	48.0	49.0	12.9	60.9	0.302	0.050	1.02	0.001	1.24	0.057	0.058
2.00	58.0	59.0	12.0	70.0	0.311	0.056	1.02	0.001	1.19	0.046	0.047
2.00	67.5	69.0	11.3	78.8	0.311	0.056	1.02	0.001	1.14	0.036	0.037
1.00	74.3	76.0	10.8	85.1	0.311	0.056	1.02	0.001	1.12	0.015	0.016
2.00	81.0	83.0	10.4	91.4	0.282	0.047	1.02	0.001	1.10	0.024	0.025
							Total	0.005		0.253	**0.258**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 2 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 12 H (m)= 14.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.258

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	26	52	77	103	129	155	181	207	232	245	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------- >	0.403	0.567	0.848	1.129	
t (yrs)	0.13	0.51	1.15	2.05	3.21	4.62	6.58	9.26	13.85	18.44	One way
t (yrs)											Two way

[2013 to 2023]

Location : **BH-1**

I. Imposed Loading *{Fill Height =* *0.90* *m }*

Dead load of fill material = 17.10 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 17.10 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **17.10**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	Precomp. Settl. S_1 (m)	Virgin Settl p_f/p_c'	Virgin Settl S_2 (m)	Settl. (m)
3.00	16.5		14.9	31.4							
2.00	38.0	39.0	12.7	50.7	0.302	0.050	1.03	0.001	1.30	0.069	0.070
2.00	48.0	49.0	11.8	59.8	0.302	0.050	1.02	0.001	1.22	0.052	0.053
2.00	58.0	59.0	11.0	69.0	0.311	0.056	1.02	0.001	1.17	0.042	0.043
2.00	67.5	69.0	10.4	77.9	0.311	0.056	1.02	0.001	1.13	0.033	0.034
1.00	74.3	76.0	9.9	84.2	0.311	0.056	1.02	0.001	1.11	0.014	0.014
2.00	81.0	83.0	9.5	90.5	0.282	0.047	1.02	0.001	1.09	0.021	0.022
							Total	0.005		0.231	**0.236**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 2 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 12 H (m)= 14.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.236

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	24	47	71	95	118	142	165	189	213	225	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<------- **For U < 60 %**				
	For U > 60 % ------- >						0.403	0.567	0.848	1.129	
t (yrs)	0.13	0.51	1.15	2.05	3.21	4.62	6.58	9.26	13.85	18.44	One way
t (yrs)											Two way

[Superposition]

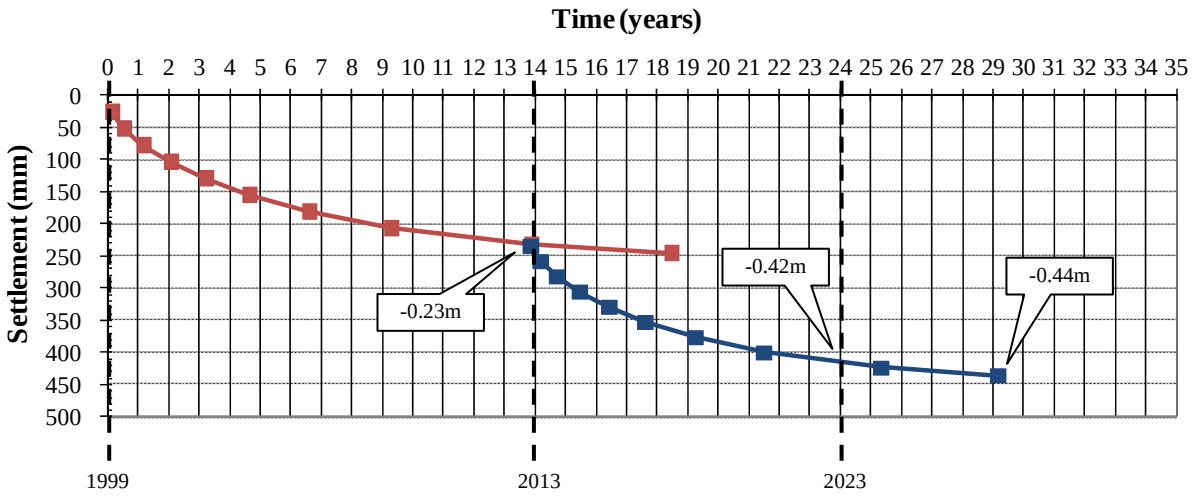


Figure 2-2-2-9.6 Time-Settlement Curve at Sta.25+320 (At Slope Area)

b) Sta.25+90 (BH-1: On Carriage Way)

[1999 to 2012]

Location : **BH-1**

I. Imposed Loading *{Fill Height =* *0.98* *m }*

Dead load of fill material = 18.68 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 18.68 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **18.68**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	S_1 (m)	Virgin Settl p_f/p_c'	S_2 (m)	Settl. (m)
3.00	16.5		16.2	32.7							
2.00	38.0	39.0	13.8	51.8	0.302	0.050	1.03	0.001	1.33	0.075	0.076
2.00	48.0	49.0	12.9	60.9	0.302	0.050	1.02	0.001	1.24	0.057	0.058
2.00	58.0	59.0	12.0	70.0	0.311	0.056	1.02	0.001	1.19	0.046	0.047
2.00	67.5	69.0	11.3	78.8	0.311	0.056	1.02	0.001	1.14	0.036	0.037
1.00	74.3	76.0	10.8	85.1	0.311	0.056	1.02	0.001	1.12	0.015	0.016
2.00	81.0	83.0	10.4	91.4	0.339	0.047	1.02	0.001	1.10	0.028	0.029
							Total	0.005		0.257	**0.263**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.5 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 12 H (m)= 14.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.263

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	26	53	79	105	131	158	184	210	237	250	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------->	0.403	0.567	0.848	1.129	
t (yrs)	0.13	0.51	1.15	2.05	3.21	4.62	6.58	9.26	13.85	18.44	One way
t (yrs)											Two way

[2012 to 2023]

Location : **BH-1**

I. Imposed Loading *{Fill Height =* *0.90* *m }*

Dead load of fill material = 17.10 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 17.10 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **17.10**

H	p_o'	p_c'	dp	$p_f=p_o'+dp$	$C_c/(1+e_o)$	$C_r/(1+e_o)$	Precomp. Settl.		Virgin Settl		Settl.
(m)	(kN/m^2)	(kN/m^2)	(kN/m^2)	(kN/m^2)	**CR**	**RR**	p_c'/p_o'	S_1 (m)	p_f/p_c'	S_2 (m)	(m)
3.00	16.5		14.9	31.4							
2.00	38.0	39.0	12.7	50.7	0.328	0.049	1.03	0.001	1.30	0.075	0.076
2.00	48.0	49.0	11.8	59.8	0.328	0.049	1.02	0.001	1.22	0.057	0.058
2.00	58.0	59.0	11.0	69.0	0.339	0.049	1.02	0.001	1.17	0.046	0.047
2.00	67.5	69.0	10.4	77.9	0.339	0.049	1.02	0.001	1.13	0.036	0.037
1.00	74.3	76.0	9.9	84.2	0.339	0.049	1.02	0.000	1.11	0.015	0.016
2.00	81.0	83.0	9.5	90.5	0.282	0.049	1.02	0.001	1.09	0.021	0.022
							Total	0.005		0.249	**0.254**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.5 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 12 H (m)= 14.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.254

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	25	51	76	102	127	153	178	204	229	242	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------>	0.403	0.567	0.848	1.129	
t (yrs)	0.13	0.51	1.15	2.05	3.21	4.62	6.58	9.26	13.85	18.44	One way
t (yrs)											Two way

[Superposition]

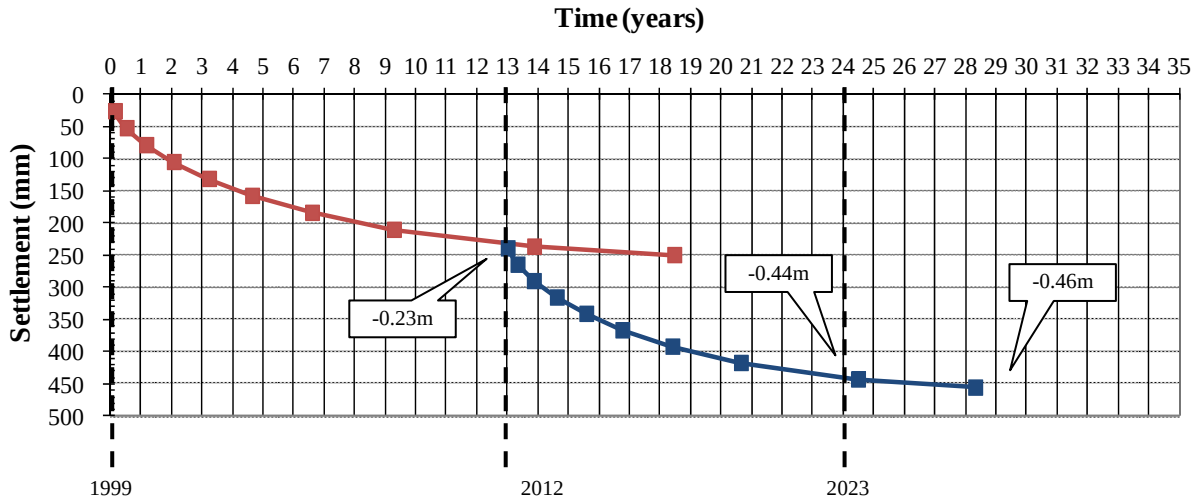


Figure 2-2-2-9.7 Time-Settlement Curve at Sta.25+90 (On Carriage Way)

c) Sta.16+700 (BH-3:At Slope Area)

[1999 to 2013]

Location : **BH-3**

I. Imposed Loading *{Fill Height =* 1.99 *m }*

Dead load of fill material = 37.81 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 37.81 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **37.81**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	S_1 (m)	Virgin Settl p_f/p_c'	S_2 (m)	Settl. (m)
3.00	16.5		32.9	49.4							
1.00	37.2	45.0	28.5	65.7	0.266	0.035	1.21	0.003	1.46	0.044	0.047
2.00	46.7	51.0	27.0	73.7	0.266	0.042	1.09	0.003	1.45	0.085	0.088
2.00	57.7	61.0	25.2	82.9	0.266	0.042	1.06	0.002	1.36	0.071	0.073
2.00	68.5	70.0	23.6	92.1	0.251	0.038	1.02	0.001	1.32	0.060	0.061
2.00	79.6	81.0	22.2	101.8	0.208	0.034	1.02	0.001	1.26	0.041	0.042
							Total	0.009		0.301	**0.310**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.25 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 10 H (m)= 12.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.310

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	31	62	93	124	155	186	217	248	279	295	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<------- **For U < 60 %**				
	For U > 60 %					------->	0.403	0.567	0.848	1.129	
t (yrs)	0.11	0.45	1.02	1.81	2.83	4.07	5.80	8.17	12.21	16.26	One way
t (yrs)											Two way

[2012 to 2013]

Location : **BH-3**

I. Imposed Loading *{Fill Height =* *0.45* *m }*

Dead load of fill material = 8.55 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 8.55 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **8.55**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ CR	$C_r/(1+e_o)$ RR	Precomp. Settl. p_c'/p_o'	S_1 (m)	Virgin Settl p_f/p_c'	S_2 (m)	Settl. (m)
3.00	16.5		7.4	23.9							
1.00	37.2	45.0	6.5	43.6	0.266	0.035	1.17	0.002	0.00	0.000	0.002
2.00	46.7	51.0	6.1	52.8	0.266	0.042	1.09	0.003	1.04	0.008	0.011
2.00	57.7	61.0	5.7	63.4	0.266	0.042	1.06	0.002	1.04	0.009	0.011
2.00	68.5	70.0	5.3	73.8	0.251	0.038	1.02	0.001	1.05	0.012	0.012
2.00	79.6	81.0	5.0	84.6	0.208	0.034	1.02	0.001	1.04	0.008	0.008
							Total	0.009		0.037	**0.045**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.25 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 10 H (m)= 12.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.045

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	5	9	14	18	23	27	32	36	41	43	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------>	0.403	0.567	0.848	1.129	
t (yrs)	0.11	0.45	1.02	1.81	2.83	4.07	5.80	8.17	12.21	16.26	One way
t (yrs)											Two way

[Superposition]

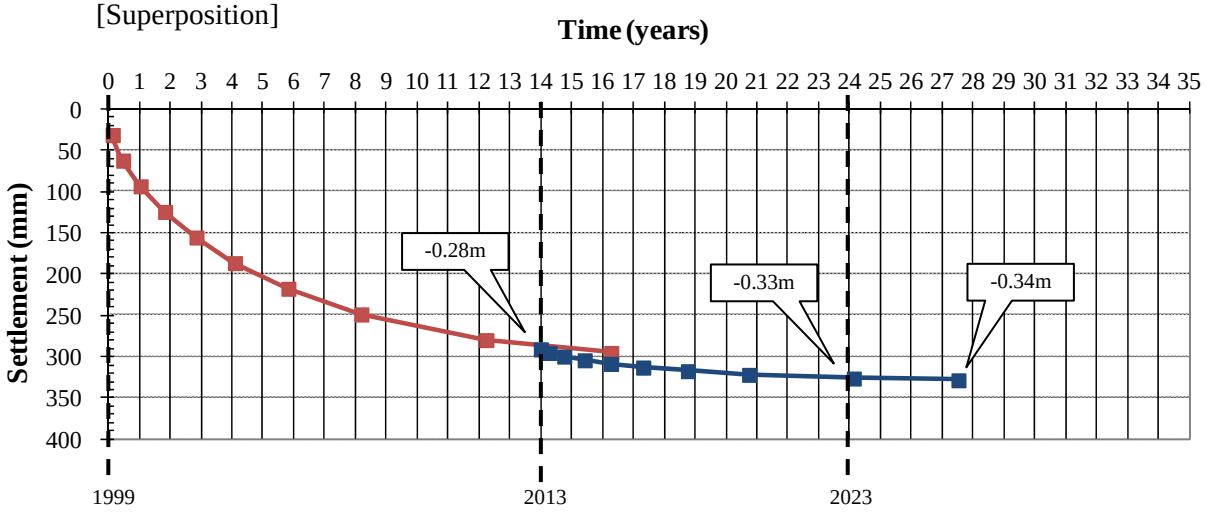


Figure 2-2-2-9.8 Time-Settlement Curve at Sta.16+700 (At Slope Area)

d) Sta.16+700 (BH-1: On Carriage Way)

[1999 to 2012]

Location : **BH-3**

I. Imposed Loading *{Fill Height =* *1.99* *m }*

Dead load of fill material = 37.81 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 37.81 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **37.81**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	S_1 (m)	Virgin Settl p_f/p_c'	S_2 (m)	Settl. (m)
3.00	16.5		32.9	49.4							
1.00	37.2	45.0	28.5	65.7	0.266	0.035	1.21	0.003	1.46	0.044	0.047
2.00	46.7	51.0	27.0	73.7	0.266	0.042	1.09	0.003	1.45	0.085	0.088
2.00	57.7	61.0	25.2	82.9	0.266	0.042	1.06	0.002	1.36	0.071	0.073
2.00	68.5	70.0	23.6	92.1	0.251	0.038	1.02	0.001	1.32	0.060	0.061
2.00	79.6	81.0	22.2	101.8	0.208	0.034	1.02	0.001	1.26	0.041	0.042
							Total	0.009		0.301	**0.310**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.25 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 10 H (m)= 12.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.310

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	31	62	93	124	155	186	217	248	279	295	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------- >	0.403	0.567	0.848	1.129	
t (yrs)	0.11	0.45	1.02	1.81	2.83	4.07	5.80	8.17	12.21	16.26	One way
t (yrs)											Two way

[1999 to 2012]

Location : **BH-3**

I. Imposed Loading *{Fill Height =* *0.45* *m }*

Dead load of fill material = 8.55 kN/m^2 (γ = 19.00 kN/m^3)

Loading for settlement calculation = 8.55 kN/m^2

II. Formulae Used

Precompression Settlement : $S_1 = C_r / (1+e_o) H \log_{10} \{p_c' / p_o'\}$

Virgin Settlement : $S_2 = C_c / (1+e_o) H \log_{10} \{p_f / p_c'\}$

III. Consolidation Settlement: Increase in Effective Overburden Pressure, dp (kN/m^2) = **8.55**

H (m)	p_o' (kN/m^2)	p_c' (kN/m^2)	dp (kN/m^2)	$p_f=p_o'+dp$ (kN/m^2)	$C_c/(1+e_o)$ **CR**	$C_r/(1+e_o)$ **RR**	Precomp. Settl. p_c'/p_o'	S_1 (m)	Virgin Settl p_f/p_c'	S_2 (m)	Settl. (m)
3.00	16.5		7.4	23.9							
1.00	37.2	45.0	6.5	43.6	0.266	0.035	1.17	0.002	0.00	0.000	0.002
2.00	46.7	51.0	6.1	52.8	0.266	0.042	1.09	0.003	1.04	0.008	0.011
2.00	57.7	61.0	5.7	63.4	0.266	0.042	1.06	0.002	1.04	0.009	0.011
2.00	68.5	70.0	5.3	73.8	0.251	0.038	1.02	0.001	1.05	0.012	0.012
2.00	79.6	81.0	5.0	84.6	0.208	0.034	1.02	0.001	1.04	0.008	0.008
							Total	0.009		0.037	**0.045**

IV. Rate of Settlement

$T_v = c_v * t / H^2$ $t = (H^2 * T_v) / c_v$

Average lab C_v = 1.25 m^2/yr ; Field Cv = 8 x lab; Cv (m^2/yr)= 10 H (m)= 12.0

[U=0-60%] $T_v=(\pi/4)*(U\%/100)^2$

[U>60%] $T_v=1.781-0.933 \log(100-U\%)$ Total Settlement (m) = 0.045

U (%)	10	20	30	40	50	60	70	80	90	95	Drainage
S_t (mm)	5	9	14	18	23	27	32	36	41	43	
T_v	0.008	0.031	0.071	0.126	0.196	0.283	<-------	**For U < 60 %**			
	For U > 60 %					------->	0.403	0.567	0.848	1.129	
t (yrs)	0.11	0.45	1.02	1.81	2.83	4.07	5.80	8.17	12.21	16.26	One way
t (yrs)											Two way

[Superposition]

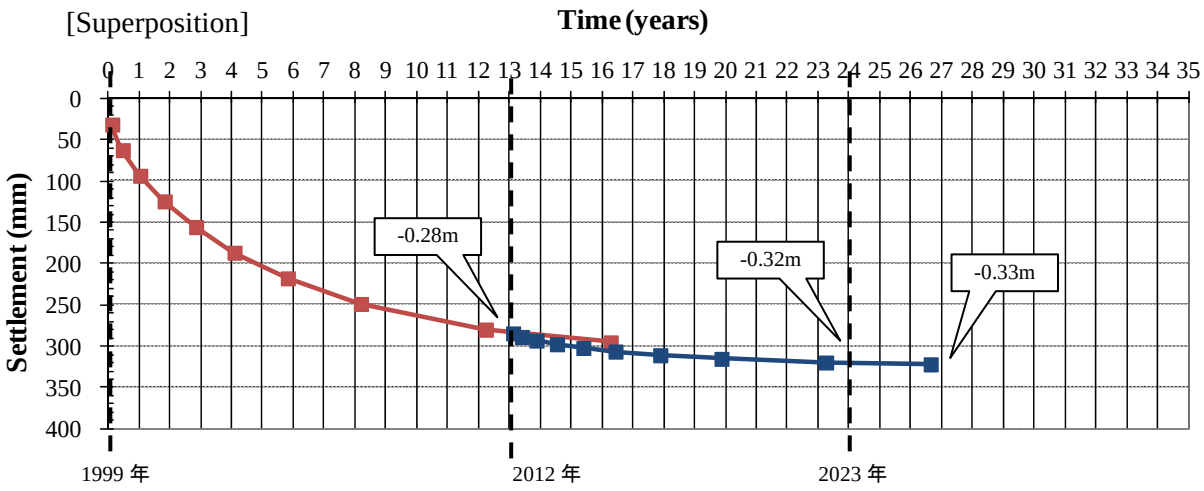


Figure 2-2-2-9.9 Time-Settlement Curve at Sta.16+700 (On Carriage Way)