JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF TRANSPORT AND COMMUNICATIONS,
THE GOVERNMENT OF THE ARAB REPUBLIC OF EGYPT

THE FEASIBILITY STUDY
ON
A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

FINAL REPORT

SUMMARY

OCTOBER 1996

PACIFIC CONSULTANTS INTERNATIONAL
CHODAI CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF TRANSPORT AND COMMUNICATIONS,
THE GOVERNMENT OF THE ARAB REPUBLIC OF EGYPT

THE FEASIBILITY STUDY

ON

A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

FINAL REPORT

SUMMARY

OCTOBER 1996

PACIFIC CONSULTANTS INTERNATIONAL
CHODAI CO., LTD.

1131981 (1)

NOTE

The following exchange rate was adopted through this report:

US$1.00=LE3.4 (February 1996)

PREFACE

In response to a request from the Government of the Arab Republic of Egypt, the Government of Japan decided to conduct a Feasibility Study on A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent a study team to the Republic of Egypt between May 1995 and October 1996. The study team was headed by Mr. Minoru SHIBUYA and composed of members of Pacific Consultants International and Chodai Co., LTD.

The team held discussions with the officials concerned of the Government of the Arab Republic of Egypt, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Arab Republic of Egypt for their close cooperation extended to the team.

October 1996

Kimio Fujita

Kimio FUJITA
President
Japan International Cooperation Agency

October 1996

Mr. Kimio FUJITA
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

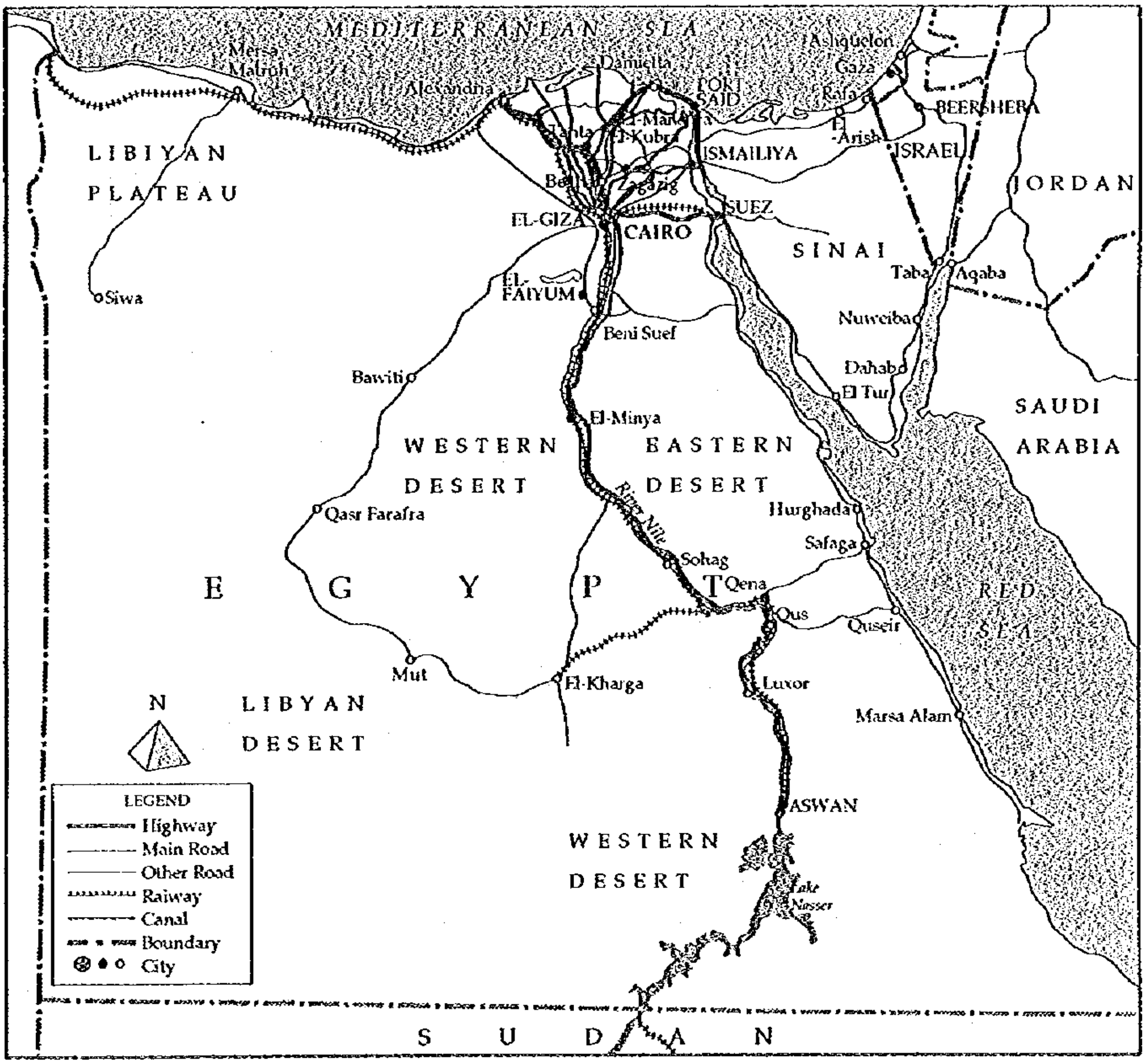
We are pleased to submit you the report on the Feasibility Study on A Bridge over Northern Part of the Suez Canal. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the comments made by the Ministry of Transport, General Authority for Roads and Bridge & Land Transport and the authorities concerned in the Arab Republic of Egypt. The report consists of four volumes; a Executive Summary, a Main Report, a Drawing and an Appendix. This report presents the Feasibility Study on the construction of the Bridge over the Suez Canal at Qantara.

The Sinai Peninsula occupies the North-Eastern quarter of Egypt, and is expected to become the important center of economy, culture and politics with the development of the Sinai Peninsula. We believe that this project will contribute greatly to upgrade the transport system across the area which is presently provided with the Ahmed Hamdi Tunnel and six ferry systems crossing the Suez Canal.

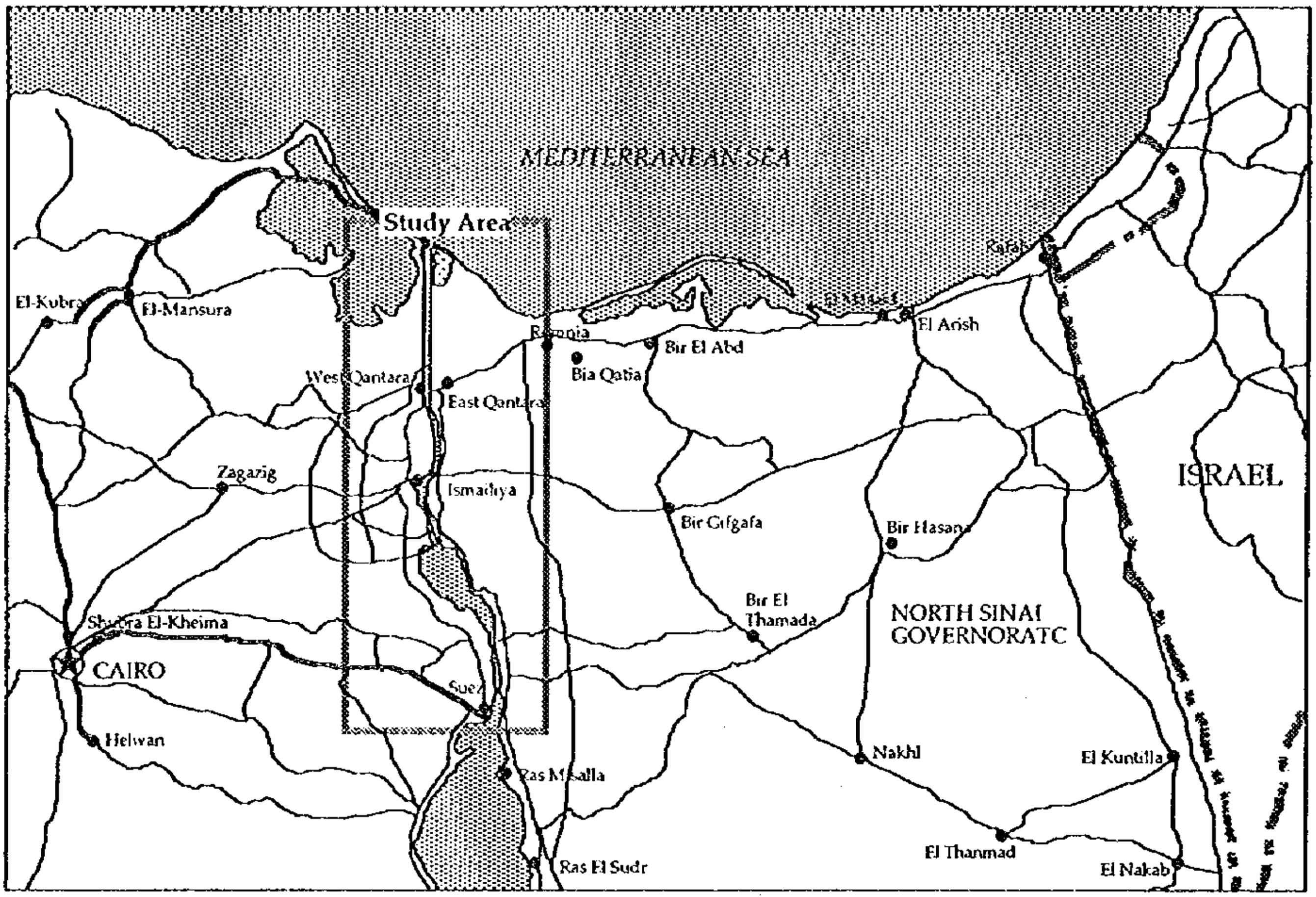
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction and the Ministry of Transport. We also wish to express our deep gratitude to the Ministry of Transport and the Governmental Agencies concerned in the Arab Republic of Egypt, the Japanese Embassy at Egypt for the close cooperation and assistance extended to us during our study. We hope this report will contribute to construct a bridge crossing the Suez Canal at Qantara.

Very truly yours,

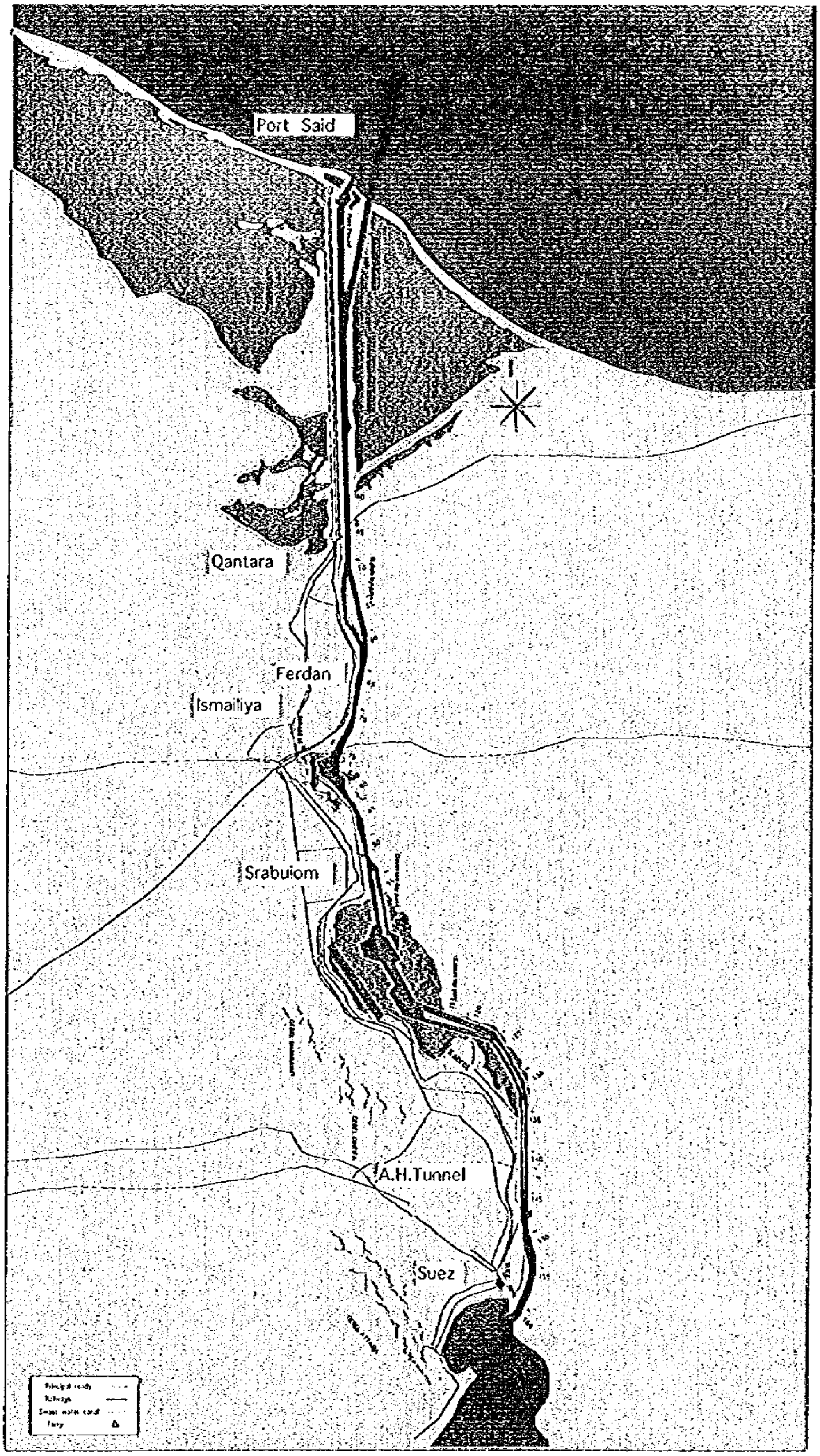
Mr. Minoru SHIBUYA
Team Leader
The Feasibility Study on A Bridge
over Northern Part of the Suez Canal



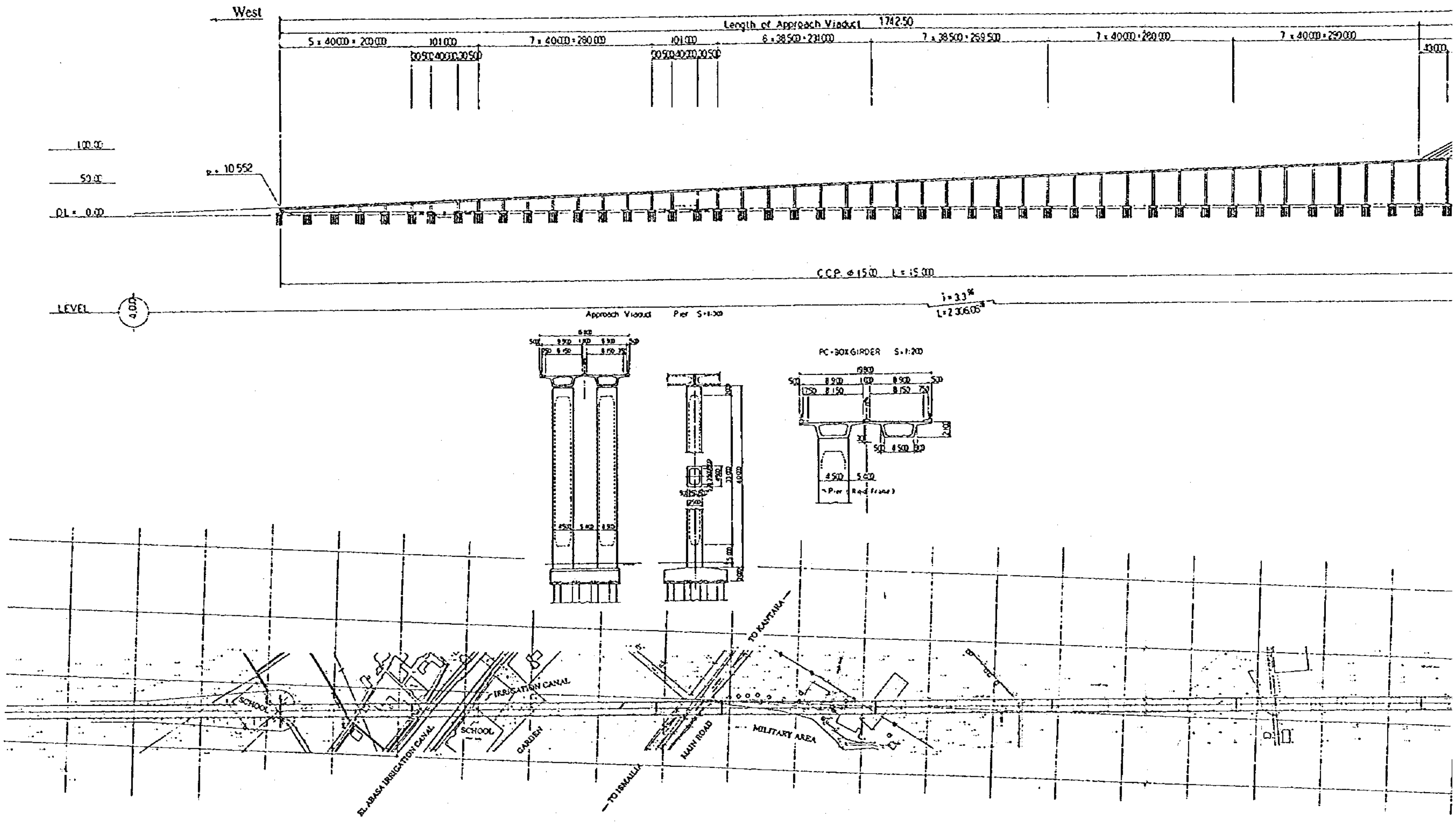
Location Map



Location Map of Study Area (1)



Location Map of Study Area (2)

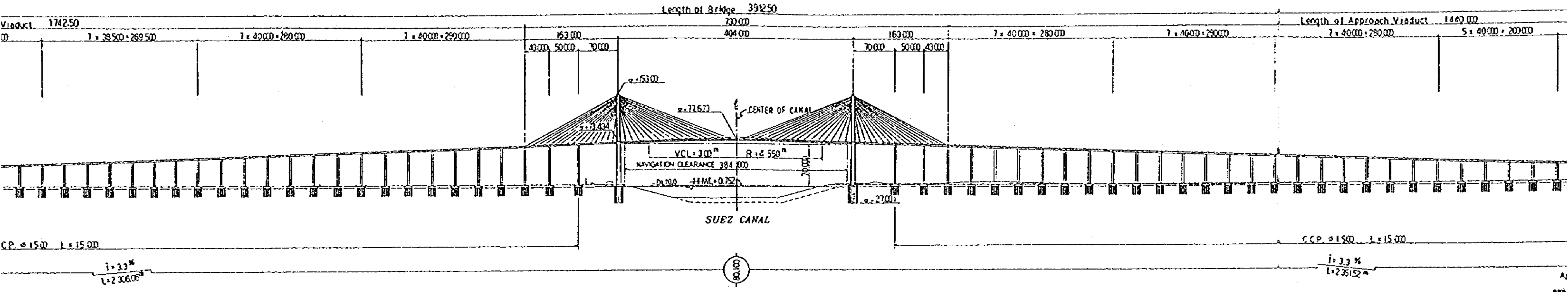


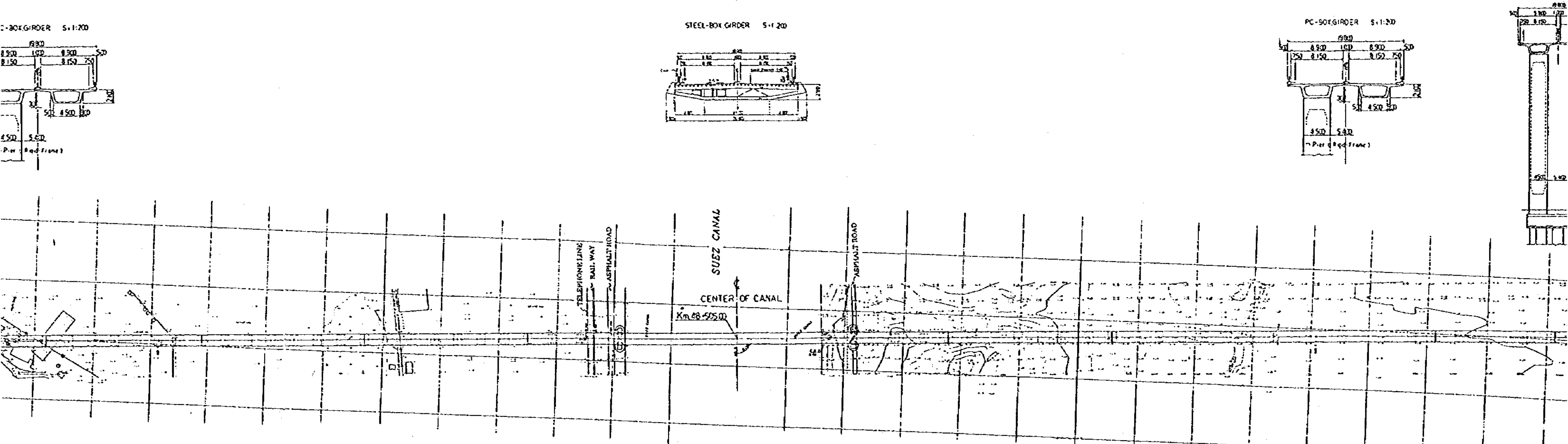
West
Length of Approach Viaduct 1742.50
5 x 40.000 = 200.000
101.000
7 x 40.000 = 280.000
101.000
6 x 38.500 = 231.000
7 x 38.500 = 269.500
7 x 40.000 = 280.000
7 x 40.000 = 290.000
100.00
50.00
DL = 0.00
CCP. ø 1.500 L = 15.000
LEVEL
Approach Viaduct Pier S=1:300
PC-BOX GIRDER S=1:200
SCHOOL
EL ABASA IRRIGATION CANAL
IRRIGATION CANAL
SCHOOL
GARDEN
TO ISMAILIA
MAIN ROAD
TO KANTARA
MILITARY AREA

GENERAL VIEW

STEEL-BOX GIRDER ALTERNATIVE

PROFILE S=1:2000





PLAN S=1:2000

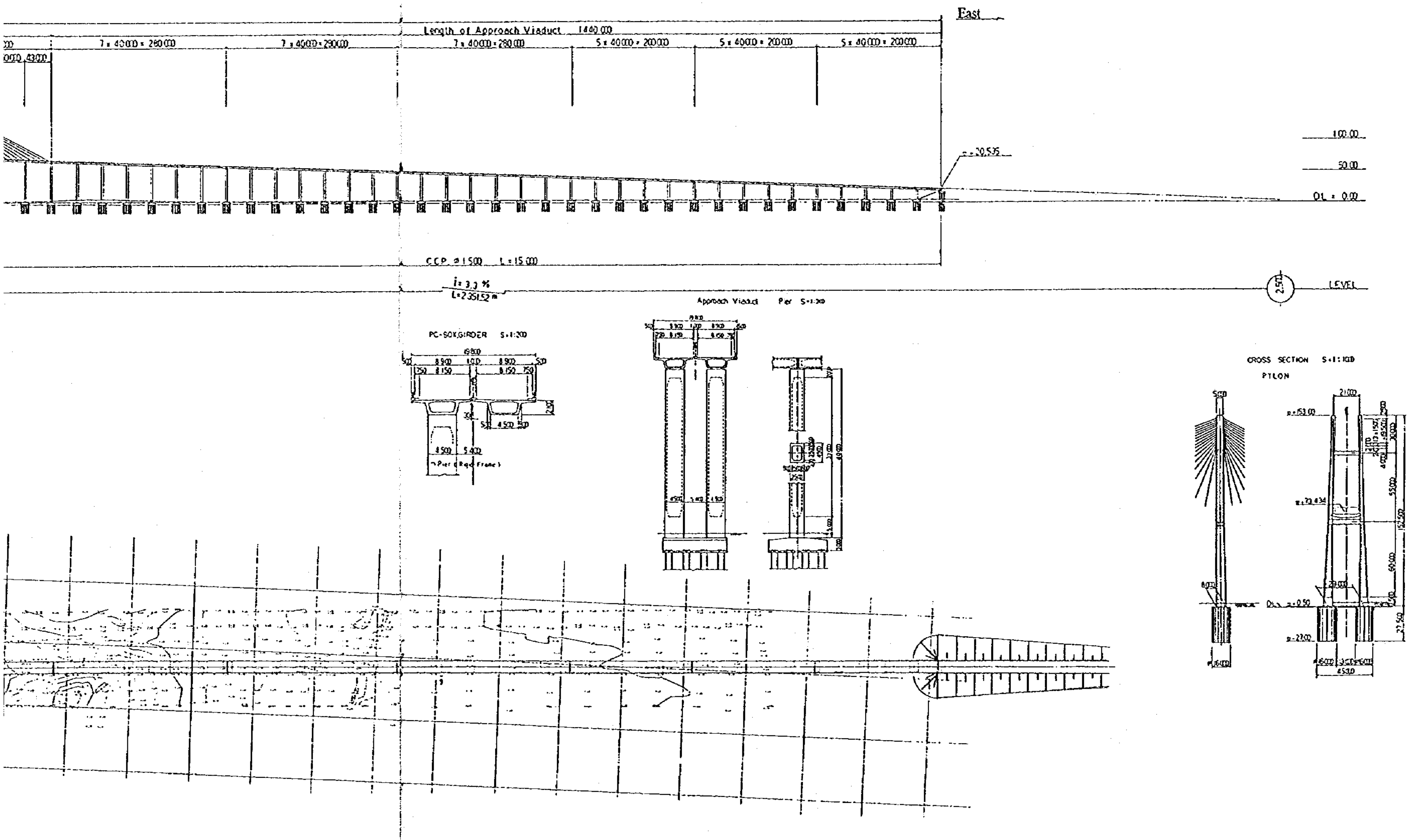


Fig. 1 General View of Bridge

SUMMARY

1 Background of the Study

As a result of the progress of the peace arrangements in the Middle East, the Sinai Peninsula is now becoming an important area for regional development potential. As a gateway to the countries in the Middle East, this eastern side of Egypt will become an even more important location as time goes on.

Accordingly, the Government of the Arab Republic of Egypt (hereinafter referred to as "Egypt"), has started a plan for the Sinai Peninsula to become a principal economic, cultural and political center, and launched comprehensive development plans for agriculture, mining, industry and tourism.

At the present time the Sinai Peninsula is separated by the Suez Canal from a district which includes the Greater Cairo Municipality to which it is connected by one tunnel and approximately seven ferry crossing over the Canal.

However, the Suez Canal has future plans to not only increase the numbers but also the size of the ships which ply the Canal. Should this happen, the ferry boats which are managing the ever increasing transportation demands would not be able to operate efficiently and there would have to be constraints made on the vessels plying the canal in order to ensure their safety.

In order to solve these future problems, Egypt evolved a plan to connect both sides of the Suez Canal by the construction of a crossing system either over or beneath the Canal.

To achieve this goal, the Government of Egypt requested the Government of Japan to conduct a Feasibility Study on a Bridge over Northern Part of the Suez Canal. In response to this request, the Government of Japan agreed to conduct such a study.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs on behalf of the Government of Japan, undertook to conduct the Study. JICA sent the preparatory study team to Egypt, headed by Mr.Hidehiko Kuroda, in January 1995, in order to conclude the practical arrangements as well as the Scope of Work for the study. These were subsequently agreed upon between the General Authority for Roads and Bridges and Land Transport, Ministry of Transport and Communications (hereinafter referred to as "GARBLT"), and JICA.

2 Objectives of the Study

The objectives of the Study are:

- To formulate a plan for a bridge crossing over the northern part of the Suez Canal, and
- To conduct the technical, economic and financial feasibility study on the bridge construction project.

The study was conducted in Japan and Egypt from May 1995 to October 1996, divided into 4 phases according to the Fig.2 Work Items and Basic Flow Diagram. In phase 1~3, field survey,and data collection and its analysis were carried out. The best alternative, that is, most suitable crossing point, the best crossing structure, number of lanes, and vertical grade were selected in these phases. Furthermore, in phase 4, the preliminary design regarding the selected best alternative was conducted.

3 Project Description

The description of the project which is recommended in the study are as follows:

(1) The best alternative

The best alternative was selected after the investigation and the study as follows:

- Traffic Demand

Future traffic demand is forecasted as 28,800 vehicles based on the projected socio-economic indices consisting of population, employees and GRDP in 2017 as the forecast year, through the critical review of the Sinai Peninsula Development Plan.

- Vertical clearance

Based on the Suez Canal traffic forecast considering the future canal development plan, the vertical clearance above the Canal was determined as 70m from the HHWL of the Canal. Out of the various vessels presently using the Suez Canal, there are five vessels that will run counter to the clear height of 70m, and they will no longer be able to use this route. Rather than change this height clearance of 70m for the sake of a few vessels, it was considered more economical to maintain the clearance of 70m for the bridge.

- Type of the crossing Structure

Bridges and tunnels were compared as the crossing structure and the bridge crossing over the Canal at Qantara was selected from the view point of its economic and financial viability.

Four types of structures for the bridges such as Steel Arch Bridge, Steel Truss Bridge, Suspension Bridge and Cable-Stayed Bridge were compared as a main bridge over the Canal and the Cable-Stayed Bridge was selected as the most preferable one for the main bridge because of its economic viability and superior structural stability for the length of the center span of the structure.

Four types of approach viaduct such as Steel-Box Girder Bridge, Steel Plate Girder Bridge, PC Box Girder Bridge and PC-I Girder Bridge were also compared and the PC Box Girder Bridge was selected because of its economic viability.

- Crossing Point

Qantara is eventually selected as the best crossing location based on the examination of all the items concerned such as Sinai Development, traffic flow and arterial road network, engineering aspect, and economic evaluation, navigation safety, and future development of the Suez Canal.

- Number of lanes

According to the future traffic demand analysis, four lane crossing structure is recommended at Qantara in 2017.

- Vertical Grade

3.2 % of vertical grade is recommended considering the characteristics of the vehicles passing the bridge.

(2) Preliminary Design

The preliminary design was conducted regarding the selected best alternative, that is, Cable-Stayed Bridge as a main bridge, PC box Girder Bridges as approach viaduct, 4 lane structure and 3,3 % of vertical grade.

The results are shown in the Fig. 1 and the outline of the preliminary design is described below.

1) Type of Structure

- Main bridge

Structure : Cable-stayed bridge with One-Box Steel Girder

Span Arrangement : 163m+404m+163m

Bridge Width : 19.8m

Number of Lane :2x(2x3.65m)

Bridge Length : 730m

Vertical Clearance :70m

- Approach Viaduct

Structure : PC Box Girder Bridge

Span Arrangement :40m base

Bridge Width : 19.8m

Number of Lane : 2x(2x3.65m)

Bridge Length : Refer to Fig. 1.

2) Proj ect Cost

Based on the construction plan and the preliminary design, project cost is estimated as follows:

Foreign currency portion : US$ 70.7 million

Local Currency Portion : LE 295.7 million

3) Implementation Plan

Construction period is estimated to take 51 months.

(Refer to Fig. 3)

4) Economic Analysis

The economic analysis resulted in approximately 10 % Of IRR. However, the economic analysis was only treated with countable benefits and costs. There are still many uncountable benefits such as contribution of formation of international road network expansion of common market, effective use of national land in Egypt and other development impacts. When taking into consideration these uncountable impacts, this project seems to have a big advantage in economic terms.

5) Environmental Evaluation

The results of environmental impact evaluation have concluded that the project is environmentally sound.

In conclusion, the Study Team considers that construction of a bridge crossing the Suez Canal at Qantara is technically and economically feasible under finance and accordingly recommends that it be immediately implemented.

TABLE OF CONTENTS

TABLE OF CONTENTS

1 Outline of the Project

Table 1 Outline of the Project

No.	Items	Results of the Study	Remarks
1	Crossing Location	Qantara has been selected as the best alternative for the location of the bridge, after considering the following items. 1) Traffic flow and Sinai development 2) Engineering aspect 3) Financial cost/ economic evaluation 4) Navigation safety 5) Future development of the Canal	The bridge alternatives are more favorable than the tunnel alternatives.
2	Best Structure	The best structure for the crossing structure has been determined as follows; Crossing location : Qantara Type of crossing structure : Bridge Number of lanes : 4 lanes Vertical grade : 3.3%	
3	Preliminary Design	Following the selection of the best structure, the preliminary design was undertaken. The results are as follows : **Main Bridge** Bridge Type : Cable-Stayed Bridge Span Arrangement : 163 m + 404 m + 163 m Main Girder (superstructure) : Single Box Steel Girder with Steel Deck Pylon : H-Shaped Concrete Pylon Foundation : Caisson **Approach Viaducts** Span Arrangement : 40 m base Bridge Type (superstructure) : Prestressed Concrete Box Girder Substructure : Twin Column Concrete Pier Foundation : Cast-In-Situ Concrete Pile Foundation	Refer to Fig. 1 General View of Bridge

2 Summary of the Project

2.1 Background and Objective of the Study

2.1.1 Background

As a result of the progress of the peace arrangements in the Middle East, the Sinai Peninsula is now becoming an important area for regional development potential. As a gateway to the countries in the Middle East, this eastern side of Egypt will become an even more important location as time goes on.

Accordingly, the Government of the Arab Republic of Egypt (hereinafter referred to as "Egypt"), has started a plan for the Sinai Peninsula to become a principal economic, cultural and political centre, and launched comprehensive development plans for agriculture, mining, industry and tourism.

At the present time the Sinai Peninsula is separated by the Suez Canal from a district which includes the Greater Cairo Municipality to which it is connected by one tunnel and approximately seven ferry crossing over the Canal.

However, the Suez Canal has future plans to not only increase the numbers but also the size of the ships which ply the Canal. Should this happen, the ferry boats which are managing the ever increasing transportation demands would not be able to operate efficiently and there would have to be constraints made on the vessels plying the canal in order to ensure their safety.

In order to solve these future problems, Egypt evolved a plan to connect both sides of the Suez Canal by the construction of a crossing system either over or beneath the Canal.
To achieve this goal, the Government of Egypt requested the Government of Japan to conduct a Feasibility Study on a Bridge over Northern Part of the Suez Canal. In response to this request, the Government of Japan agreed to conduct such a study.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs on behalf of the Government of Japan, undertook to conduct the Study. JICA sent an preparatory study team to Egypt, headed by Mr.Hidehiko Kuroda, in January 1995, in order to conclude the practical arrangements as well as the Scope of Work for the study. These were subsequently agreed upon between the General Authority for Roads and Bridges and Land Transport, Ministry of Transport and Communications (hereinafter referred to as "GARBLT"), and JICA.

2.1.2 Objectives of the Study

The objectives of the Study are:

1) To formulate a plan for a bridge crossing over the northern part of the Suez Canal, and
2) To conduct the technical, economic and financial feasibility study on the bridge construction project.

2.1.3 Study Area

The study area concentrated on the Northern part of the Suez Canal and the surrounding areas, including access roads. However, the whole country including the Sinai Peninsula has been taken into consideration in order to project future traffic demand for the canal crossing.

2.2 Study Organization and Implementation

(1) This study is divided into four phases as follows:

Phase Ⅰ : Data collection and formulation of the Detailed Plan of Study,

Phase Ⅱ : Traffic projection and formulation of alternative designs for the crossing structure,

Phase Ⅲ : Selection of the best alternative, and

Phase Ⅳ : Preliminary design and evaluation of the project's feasibility.

(2) The Flow Chart for the Study

The flow chart is shown in Fig. 2, Work Items and Basic Flow Diagram. The chart gives the various classifications of the Study, the submission of reports and their scheduled timing, and a description of the Study performed.

(3) Implementation and Report

The study was conducted in Japan and Egypt from May 1995 to October 1996. Several reports have been submitted to report on the progress of the study. These are the Inception Report (June 1995), DPS (August 1995), Progress Report (January 1996), Interim Report (April 1996), the Draft Final Report (August 1996) and the Final Report (October 1996). The Final Report comprises four volumes:

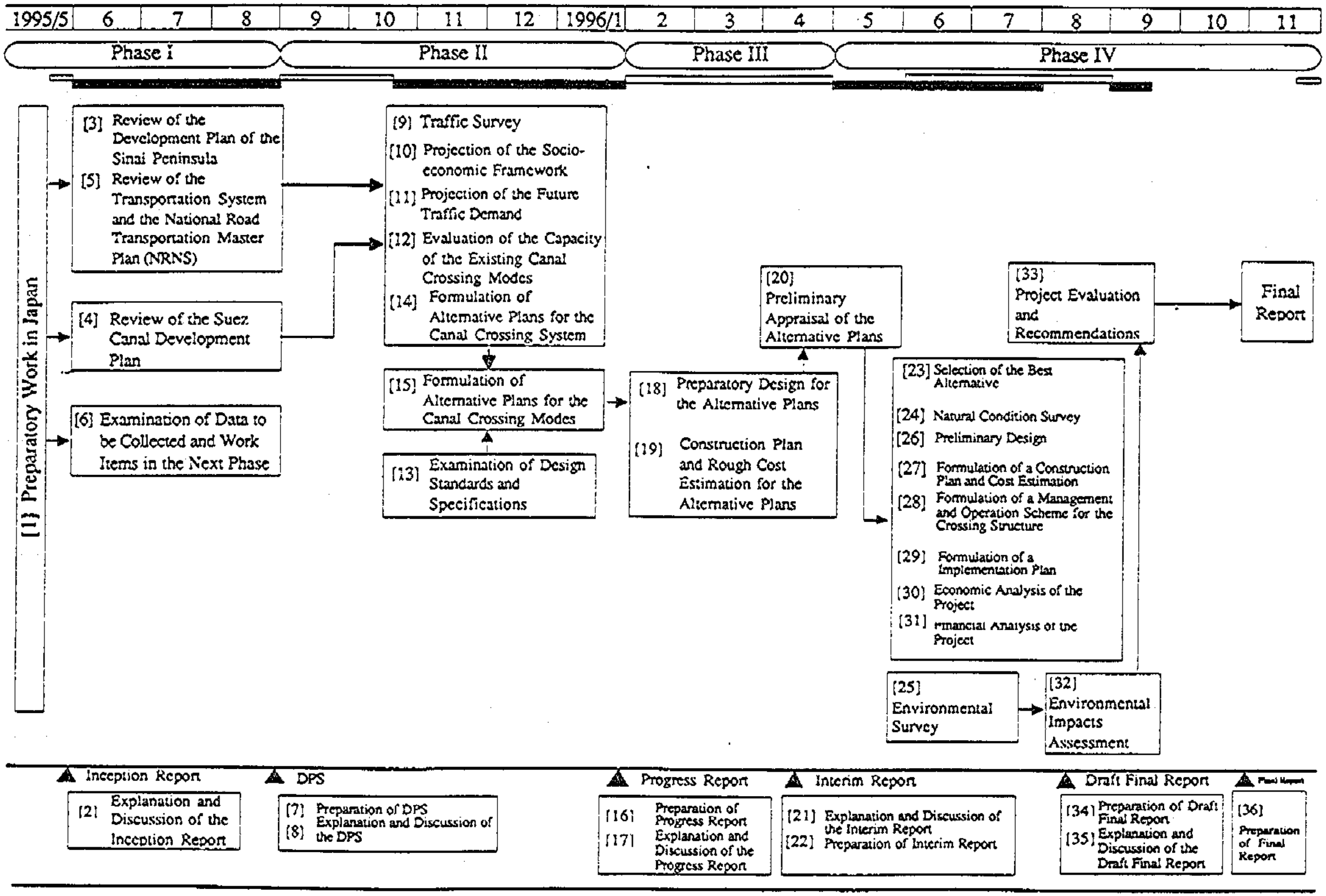


Fig. 2 Work Items and Basic Flow Diagram

Volume 1 : Executive Summary
Volume 2 : Main Text
Volume 3 : Drawings
Volume 4 : Appendix

2.3 Project Description

The key criteria of the project which have been studied in accordance with the above background and method of investigation are as follows;

(1) Socio-Economic Framework

1) Socio-Economic Index

The following three socio-economic indices are the basic data for the demand forecast;

- Population
- Employees
- GRDP.

2) Project Life

The final year of the project life is 2017.

3) The Sinai Peninsula Development Case

The Development Project for the Sinai Peninsula was considered for the following 3 cases;

Case 1 : The full implementation of the development project in 2017,
Case 2 : Approximately 60 to 70 % implementation of the development in 2017,
Revised Case 3 : Approximately less than 50 % implementation of the development in 2017.

(2) Suez Canal Development Plan

Seaborne cargo forecasts for the Suez Canal, shipping traffic and data collection of the current situation and ship mast heights were made.

The planning of the structures crossing the Suez Canal is in relation to the development of the Canal. The future configuration of the Canal was confirmed after the Study Team studied this Canal development plan and with the Suez Canal Authority.

The navigation clearance was determined as being 70 m height above H.H.W.L. of the Suez Canal.. Out of the various vessels presently using the Suez Canal, there are five vessels that will run counter to the clear height of 70m, and they will no longer be able to use this route. Rather than change this height clearance of 70m for the sake of a few vessels, it was considered more economical to maintain the clearance of 70m for the bridge.

(3) Crossing Location Alternatives

The following 6 crossing locations where ferry boat services operate, were studied;

- Port Said
- Qantara
- Ferdan
- Ismailiya
- Serabiom
- A. H. Tunnel (Shatt Ferry)

(4) Traffic Demand

Studies of future traffic demand were conducted for the above Cases 1 through 3 at the candidate crossing points. Refer to the results of these studies in Paragraph 4.8 Result of Traffic Projection.

(5) Crossing System

A bridge and a tunnel option were both studied to select the crossing system.

(6) The Best Alternative

To arrive at the best crossing alternative of the Suez Canal, the alternative crossing locations and structures were studied, and the best selection was then made as shown in Paragraph 2.4 The Best Alternative.

(7) Preliminary Design

The best alternative selected is as follows;

- Crossing Location : Qantara
- Type of Crossing Structure : Cable-Stayed Bridge (One-Box Steel Girder)
- Number of Lanes : 4 Lanes

- Vertical Grade : 3.3%

The Preliminary Design was conducted using the above design parameters.
Construction plans, construction cost estimation, implementation plans and maintenance and operation plans were prepared in accordance with the above design parameters.

The vessels transiting the Canal are controlled by the Suez Canal Vessel Traffic Management System (VTMS) . When this bridge is constructed, it will adversely affect the system and the effects were investigated to overcome these problems.

(8) Economic Evaluation

Using the results of the Preliminary Design, the Economic Internal Rate of Return (EIRR) was calculated based on Project Costs, O&M Cost, and the direct benefits. The EIRR was about 10 %, and taking account of the other indirect benefits that can be derived, this project can be considered as feasible.

(9) Environmental Considerations

Environmental studies were conducted for the case when this project will be implemented. The results are as follows;

a) There are no special problems related to the natural environment of the project area.

b) However, there may be some problems of environmental pollution, and some noise pollution caused by traffic.

c) Of the people residing at the site, 50 % are not in favour of the project. Caution must be exercised in relocating any residences, and in the acquiring of land and property in connection with the project.

(10) Conclusions and Recommendations

Refer to Paragraph 2.6 Conclusions and Recommendations.

2.4 The Best Alternative

(1) Crossing System

1) Future Traffic Demand

Three scenarios of socio-economic development have been considered in this study in order to analyze an appropriate crossing structure for the Suez Canal. Case 1 has

been taken as the basic case and the Revised Case 3 indicates the minimum socio-economic framework even under the worst case condition.
Future traffic demand can therefore be estimated as ranging from 6,000 to 33,000 vehicles per day at the crossing locations, in 2017, excluding Port Said and Ras El Esh, depending on the socio-economic framework cases.

2) Number of Lanes

A two lane crossing structure would only meet the future traffic demand in 2017 at Srabuiom in the socio-economic framework of Case 2 and Revised Case 3 under the condition of Level of Service C in the Highway Capacity Manual. On the other hand, four lane crossing structures will have to be provided at Srabuiom in 2017 under Case 1, the basic socio-economic framework case.

It will be necessary to provide a four lane crossing structure at either Qantara, Ferdan or Ismailiya in 2017 in any socio-economic framework case, even under the condition of Level of Service D which has a higher two lane traffic capacity than that of Level of Service C.

3) How to Provide the Four Lane Crossing Structure

There are two possible methods available of providing a four lane capacity crossing structure. One is to construct a four lane crossing and the other is to construct one two-lane crossing initially, and at a later stage to construct another two-lane crossing at an adjacent location, in order to meet the traffic increase. This is the so- called staged construction method. Using the stage construction method, it should be noted that after completion of the second structure, it will be necessary to revert to a one way flow system on each structure. This is necessitated by the need to rationalize the crossing approach or access road layout, and to ensure a safe, efficient and uninterrupted traffic flow pattern.

From the results of the evaluation presented in Paragraph 7.1, Evaluation of Crossing System Alternatives, it is preferable to construct one four lane crossing structure. If two two-lane structures are selected, the second two lane crossing structure has to be opened up in 2009 even under the condition in the Revised Case 3.

(2) Structural Alternatives

Structural alternatives (bridge/tunnel, location and physical configuration) have been compared and the best alternative (cable-stayed bridge with four lanes and 3.3% vertical grade) has been selected for the following reasons.

1) Bridge or Tunnel

From the viewpoint of economic viability, a bridge at the locations of Qantara, Ferdan or Ismailiya, or a tunnel at the locations of Ferdan and Ismailiya can be demonstrated to be viable with respect to the Economic Internal Rate of Return of these alternatives.

The estimated costs of the tunnels are much higher than the costs of the bridge alternatives, but the EIRRs of the former are only 1-2 % higher than the latter. Taking account of the massive anticipated financial expenditures for the Sinai Development in the coming two decades, it is essential to minimise expenditure on the infrastructures as much as possible.

Comparing the results of economic and financial factors between these two alternatives, it can be said that the bridge alternatives are more favorable than the tunnel alternatives.

2) Crossing Location

The four possible bridge location alternatives have been compared: Qantara, Ferdan, Ismailiya and Srabuiom, and the results of these comparisons are as follows;

a. Traffic Flow and Sinai Development

Comparing the projected future traffic flows of these four locations, Qantara, Ferdan and Ismailiya are expected to have the greatest traffic volumes and to become the most important components of the arterial road network connecting Sinai to the rest of Egypt. Expected traffic volumes at Qantara, Ferdan and Ismailiya in the year 2017 are 28,800, 33,300 and 32,900 vehicles respectively.

b. Engineering Aspect

From the engineering aspect, no significant difference in engineering difficulties can be observed between these four alternative locations.

c. Financial Cost / Economic Evaluation

From the results of the EIRR, they rank in the following order of preference,

1. Ismailiya
2. Ferdan,
3. Qantara, and
4. Serabuiom.

d. Navigational Safety

Egyptian National Railways have decided that the new railway swing bridge is to be constructed at Ismailiya, and consequently SCA has required that the road bridge be constructed at a different location. The new crossing bridge must be located at least 3 km away from the end of the curve of the channel and the new railway bridge, to ensure that there is sufficient stopping distance for the maximum sized vessels in transit on the Canal to avoid the risk of colliding with the bridges. This distance of 3 km, which is six to seven times the length of the maximum sized vessel (about 450 m length), has been confirmed as reasonable by the Study Team.

Taking this constraint into consideration, only Qantara and Serabuiom will satisfy this navigational safety requirement.

e. Future Development of the Canal

SCA has a plan to construct a second channel to by-pass the channel at Srabuiom in the near future, and this will cause a considerable increase in the construction cost of the bridge at Srabuiom.

As a result of all these comparisons, Qantara has been selected as the best crossing location due to the navigational safety being the main factor dictating the selection of the crossing location.

3) Vertical Grade

When considering the forecast traffic volume for the target year of the plan, a vertical grade of 4 % for the bridge would appear to suffice with reference to the international design standards. It should be noted, however, that many of the vehicles currently used in Egypt are overloaded and aged trucks, and these vehicles will make up a large percentage of the vehicles crossing the bridge. These factors indicate that it is desirable to design vertical grade of 3.3 % for the bridge. In addition, as the heavy vehicle ratio is about 20% of the road crossing traffic, the effect on the environment around the crossing including noise and air pollution especially by heavy vehicles will be considerable and hence providing a vertical grade of 3.3% for the bridge should be considered.

(3) Best Alternative

Based on the above discussion, the following option will be recommended.

Crossing location	:	Qantara
Type of crossing structure	:	Bridge
Number of lanes	:	4 lanes
Vertical grade	:	3.3 %

2.5 Preliminary Design

(1) Main Bridge

The following bridge types are considered to be suitable for the spans required of approximately 400 m.

- Steel Arch Bridge
- Steel Truss Bridge
- Suspension Bridge
- Cable-Stayed Bridge

After an initial study, a cable-stayed bridge type was selected because the cable-stayed bridge has the advantages of structural efficiency and economy as well as aesthetics.

Finally, a single-box steel girder structure with steel deck was selected. The span arrangement is 163 m + 404 m + 163 m, for the side span, center span and side span, respectively.

An H-shape type pylon was selected after comparison with an A-shaped type pylon.

A twin caisson type foundation was selected after comparison with a pile type foundation.

(Refer to Fig. 1)

(2) Approach Viaducts

The profile of the approach viaducts is largely dictated by the change in elevation of the road from about +10 m to +70 m. The following viaduct types and span lengths were studied;

- Steel Box Girder (Span length of 50 m to 60 m)
- Steel Plate Girder (Span length of 20 m to 50 m)
- Prestressed Concrete Box Girder (Span length of 40 m to 60 m)
- Prestressed Concrete I Girder (Span length of 20 m to 40 m)

After the study, a presstressed concrete box girder type (Span length of 40 m) was selected.

Twin column concrete piers were selected for the substructure.
Cast-in-situ concrete piles (Diameter 1,500 mm) were selected for the foundations.

(Refer to Fig. 1)

(3) Approach Embankments and Access Road

Typical cross sections of the approach embankments and access roads are shown in Fig. 4.

(4) Project Cost

The project cost is summarized in Table 2.

Table 2 Project Cost

Unit : million US$
million £E

Section	Cost		Remarks
	Foreign	Local	
Main bridge	25.0	33.8	L=730m, 4 lanes
Approach Viaduct (West)	8.1	70.5	L=1,743m, 4 lanes
Approach Viaduct (East)	6.8	61.6	L=1,440m, 4 lanes
Access road	0	28.6	L=5.4km
Others	3.7	4.1	Road lighting, safety facilities
Radar system	1.2	1.4	Management facilities
Subtotal	44.8	200.0	
Price contingency	4.0	18.0	9%
Physical contingency	3.1	14.0	7%
Subtotal	51.9	232.0	
Indirect cost	10.4	46.4	20%
Engineering cost	8.4	12.2	10%
Land acquisition, etc.	-	5.1	
Grand total	70.7	295.7	

Exchange Rate : 1 US$ = 3.4£E (February, 1996)

(5) Implementation Plan

Implementation plan for the construction stage by international tendering is shown in Fig. 3.

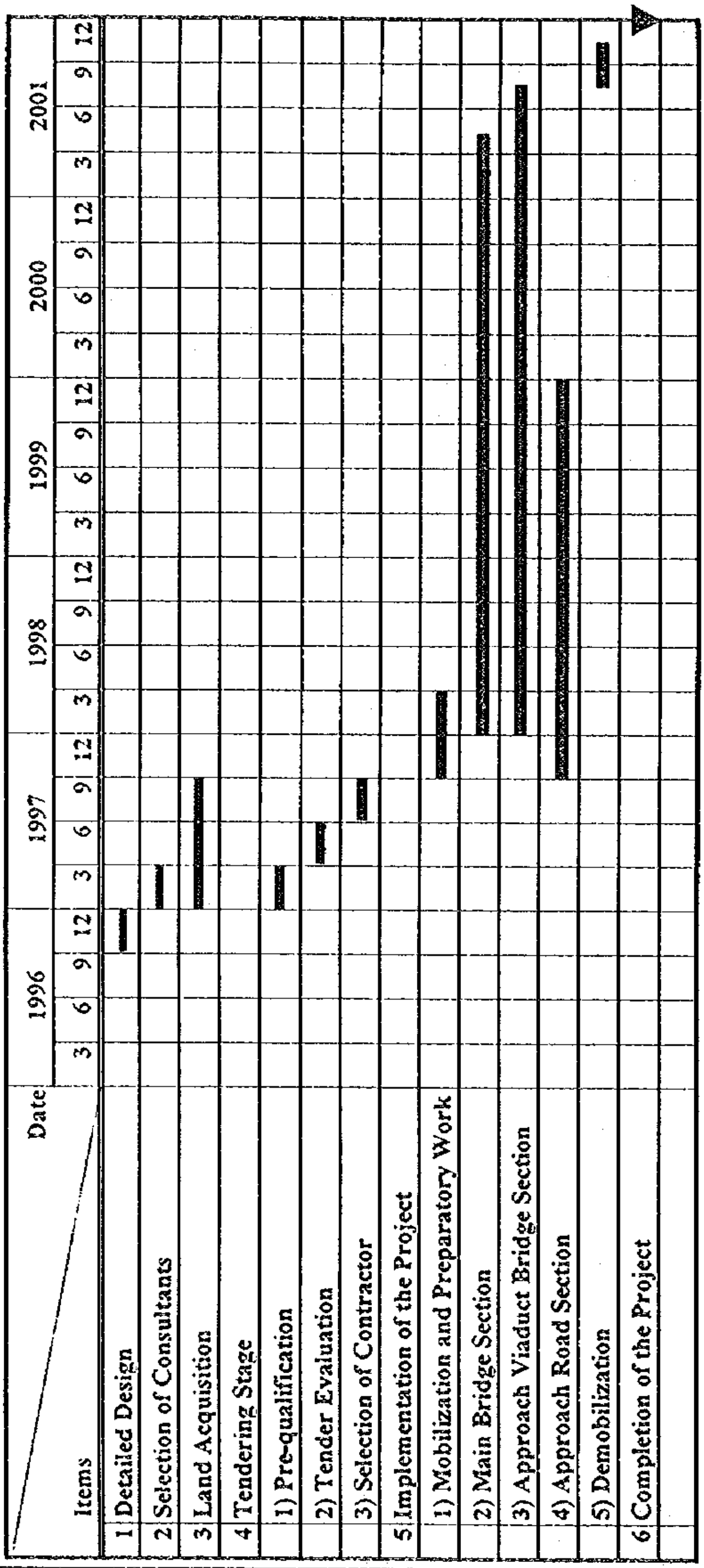


Fig. 3 Implementation Schedule

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

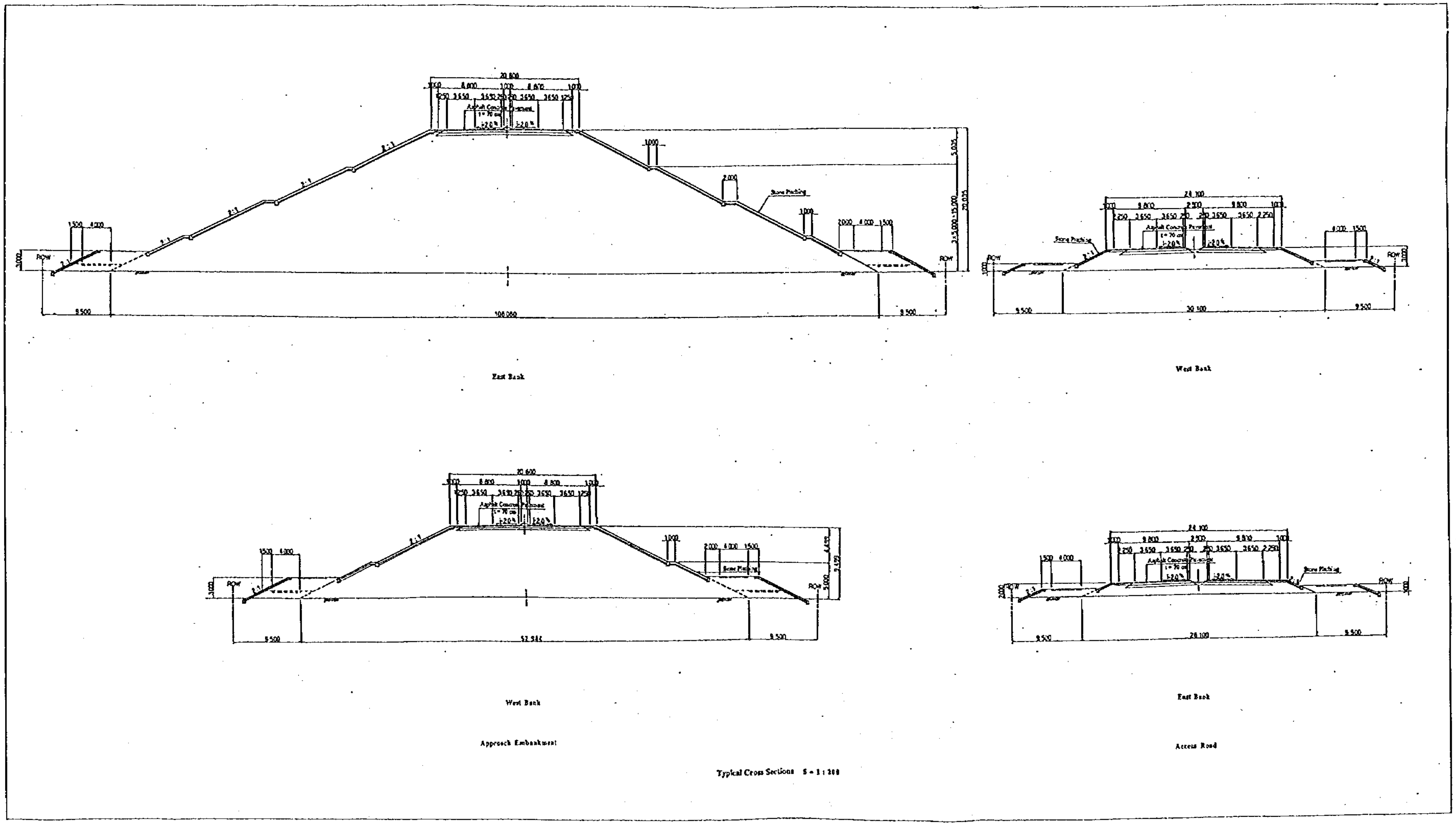


Fig. 4 Typical Cross Sections of Approach Embankments and Access Roads

2.6 Conclusions and Recommendations

2.6.1 Crossing System

(1) Future Socio-economic Framework

The socio-economic framework is considered for the following three cases based on the future projected development of Sinai. The respective framework cases are as follows:

-Framework Case 1 is a case based on a projected population of Sinai of 3.2 million in 2017 which is the estimate assumed in the National Project for the Development of Sinai, and is considered as the basic case in the study;

- Framework Case 2 is a case based on a projected population of Sinai of 2.0 million in 2017; and

-Framework Revised Case 3 is a case based on a projected population of Sinai of 1.5 million in 2017, in the event of the worst projection.

(2) Future Traffic Demand

The future traffic demand was estimated for the alternative crossing locations of Qantara, Ferdan, Ismailiya and Srabuiom. Qantara, Ferdan and Ismailiya showed relatively large traffic volumes of around 30,000 vehicles in 2017 in Framework Case 1.

(3) Number of Lanes

According to the result of the future traffic demand analysis, a four lane crossing structure is recommended at Qantara, Ferdan and Ismailiya for all three socio-economic framework cases in 2017.

(4) Crossing Structure Alternatives

1) Road Design Conditions

The design of roads crossing the Suez Canal will be based on the international standards, whilst taking into consideration the Egyptian Standards. American, Japanese or European Standards will be employed as the international standards. Design speed of 80 km/h for bridges and approach roads, and 60 Km/h for tunnels have been selected.

2) Design Conditions for Structures

The design specifications of the Japan Road Association and other international standards have been adopted for the design of structures, in conjunction with the

Egyptian Standards so as to correspond to 60 ton truck loading. The UK BS 5400 was referred to for the critical design method of the main structural section. 70 meters of clearance height above the H.H.W.L. has been used for the navigational limit. Ground acceleration of 125 gals has been used to analyze effects of earthquakes. The vertical traffic clearance envelope of roads used for bridges and tunnels was 5.5 m.

(5) Structure Type

Bridge and tunnel options have been compared. The following four different types of bridge structures were selected for comparison as a first step in this study; Steel Arch Bridge, Steel Truss Bridge, Suspension Bridge and Cable-Stayed Bridge. The following four types of approach viaduct were also selected for comparison; steel-box girder bridge, steel plate girder bridge, PSC-box girder bridge and PSC-I girder bridge. As a result of examining these alternative types of bridges, Cable-Stayed Bridge has been selected as the most suitable one for the main spans because of its economic viability and superior structural stability for the length of the center span of the bridge.

For the tunnel structure, primary segmental lining and primary segmental plus in-situ secondary lining have been compared. The primary segmental plus in-situ secondary lining was selected because of the greater security and water toughness capabilities and hence easier maintenance of the tunnel structure.

(6) Bridge or Tunnel

Comparison of the bridge and tunnel options showed that the bridge option was more advantageous from an economic and financial viability aspect.

(7) Crossing Location

Qantara was eventually selected as the best crossing location based on the studies of all the main factors including Sinai Development, traffic flow and arterial road network, engineering aspect, financial and economic evaluation, navigation safety, and future development of the Suez Canal.

(8) Vertical Grade

A vertical grade of 3.3 % was finally chosen because of the characteristics of the present traffic crossing the bridge.

2.6.2 Preliminary Design Stage

(1) Main Bridge

1) Superstructure

For the structural types of girders of the main bridge, the Single Box Girder was recommended mainly because of its rigidity, reliability as a structure, pleasing appearance and easier maintenance than the other types of girders, due to the lower exposed surface area for repainting and maintenance. However, it will be necessary to carry out wind tunnel tests to confirm the aerodynamic stability of the proposed girder and deck system.

2) Span Arrangement

Span of 404 meters for the center span and 163 meters for the side spans were selected based upon the future development plan of the Canal.

3) Other Dimensions

- Bridge Width	:	19.80 m	
- Traffic Lanes	:	2×(2×3.65 m)	
- Inspection Way	:	2×0.75 m	
- Bridge Length	:	730 m	(Main Bridge)
		3,162.9 m	(Approach Viaducts)
- Navigation Clearance	:	70 m height above H.H.W.L. of the Suez Canal	

4) Type of Cable

The three stay cable types, Fan Pattern, Semi Fan Pattern and Harp Pattern were compared, and the Fan Pattern was selected because it is advantageous on the rigidity of the bridge.

5) Pylons

The two types of the pylons were compared, the A-shaped and H-shaped types. The H-shaped pylon was selected from an aesthetic viewpoint.

6) Substructure (piers in the side span of the main bridge)

A twin column concrete pier supports in the side span were adopted because of its structural stability of the cable-stayed bridge as a result of the comparison of three alternatives.

7) Foundations

The twin concrete open caisson type foundation for the pylon foundation was selected because of its lower cost in corresponding to H-shape pylons proposed.

(2) Approach Viaducts

After comparing the several types of superstructures for the approach viaducts, a PSC Box Girder was selected from an economical and structural stability viewpoints.

For the span arrangement of the approach viaducts, a 40 m span was used basically from the viewpoints of cost effectiveness and ease of construction.
In addition, reinforced concrete piers and the cast-in-situ reinforced concrete foundations were selected because they cost the least.

(3) Construction Cost

On the basis of this preliminary design and construction plan, the construction cost was estimated at approximately 70.7 million US dollars for foreign portion and 295.7 million Egyptian Pounds for local portion respectively using the ICB conditions. The total construction cost is 157 million US dollars.

(4) Implementation Plan

GARBLT is the only responsible authority for main roads network throughout Egypt in relation to planning, construction, operating maintenance etc. In respect to the implementation plan for the construction stage, the main schedule is as follows:

- Selection of consultants; takes 3 months after completion of detailed design
- Selection of contractors; takes 9 months after completion of detailed design
- Land acquisition; takes 9 months after completion of detailed design
- Commencement of construction; takes 9 months after completion of detailed design
- Completion of construction; takes 51 months after commencement of construction

The effective construction period required including the preparatory work is estimated as 51 months.

(5) Economic Analysis

The following six beneficial factors have been considered for the economic analysis:

- Vehicle time saved waiting for ferries
- Passengers time saved waiting for ferries
- Vehicle running time saved
- Vehicle passengers running time saved
- Saving of vehicles running costs
- Restriction on passage of large oil tankers on the Canal

The economic analysis resulted in 9.79% of EIRR. However the economic analysis only dealt with countable benefits and costs. There are still many uncountable benefits including the contribution to the formation of an international road network, expansion of a common market, effective use of national land in Egypt and other development impacts. When taking into consideration these uncountable impacts, this project appears to have a big advantage in economic terms.

(6) Environmental Evaluation

The results of the environmental impact evaluation have concluded that the proposed project is environmentally sound. It is, however, recommended that the following necessary countermeasures be taken to mitigate the assessed environmental impacts and to minimize the unavoidable adverse effects of this project:

a) Relocate the people living in the boundaries of the construction site, and
b) Take early action to acquire the necessary land property.

In conclusion, the Study Team considers that construction of a bridge crossing the Suez Canal at Qantara is technically and economically feasible under proper finance, and accordingly recommends that it be immediately implemented. The implementation of this project will contribute to promote the development of the Sinai Peninsula.

JICA