社会開発調査部報告書

No. 62

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF COMMUNICATIONS
THE SULTANATE OF OMAN

THE STUDY ON THE ROAD DEVELOPMENT PROJECT IN THE SULTANATE OF OMAN FINAL REPORT

VOLUME I: EXECUTIVE SUMMARY

JANUARY 1995

PACIFIC CONSULTANTS INTERNATIONAL
FUKUYAMA CONSULTANTS INTERNATIONAL

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NOTE

The following exchange rate was adopted through this report:

US$1.00 = R.O 0.385 = Yen 99.6 (September 1994)

PREFACE

In response to a request from the Government of the Sultanate of Oman, the Government of Japan decided to conduct a Feasibility Study on THE ROAD DEVELOPMENT PROJECT IN THE SULTANATE OF OMAN and entrusted the study to the Japan International Cooperation Agency (JICA).

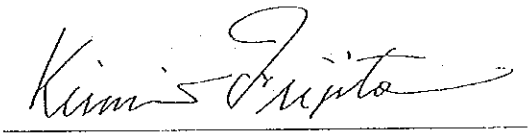
JICA sent a study team to the Oman between February 1994 and October 1994. The study team was headed by Mr. Satoshi WATABE and composed of members of Pacific Consultants International and Fukuyama Consultants International.

The team held discussions with the officials concerned of the Government of Oman, 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 Sultanate of Oman for their close cooperation extended to the team.

January 1995



Kimio FUJITA
President
Japan International Cooperation Agency

January 1995

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

Dear Mr. Fujita

Letter of Transmittal

We are pleased to submit you the study report on the Road Development Project in the Sultanate of Oman. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. Also included are comments made by the Ministry of Communications, the Sultanate of Oman during technical discussions on the draft final report which were held in Muscat.

This report presents a scheme for construction of flyovers and pedestrian underpasses and maintenance and rehabilitation study on the existing bridges.

In view of the urgency of the road development plan in the Sultanate of Oman and of need for socio-economic development of Oman as a whole, we recommend that the Sultanate of Oman implement this project as a top priority.

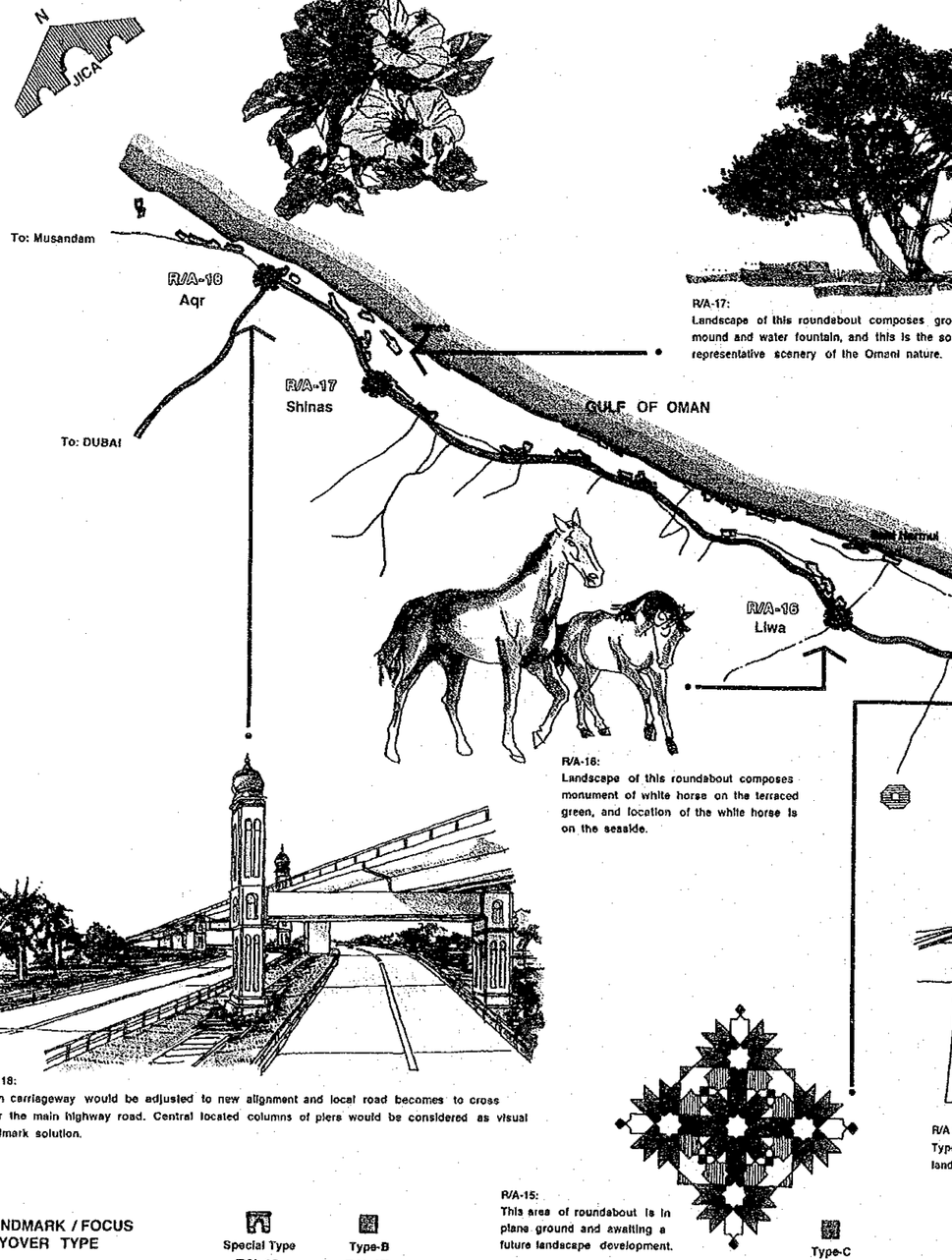
We wish to take this opportunity to express our sincere gratitude to your agency and the Ministry of Foreign Affairs. We also wish to express our deep gratitude to the officials concerned of Ministry of Communications, the Japanese Embassy at Oman for the close cooperation and assistance extended to us during our investigation and study

Very truly yours,

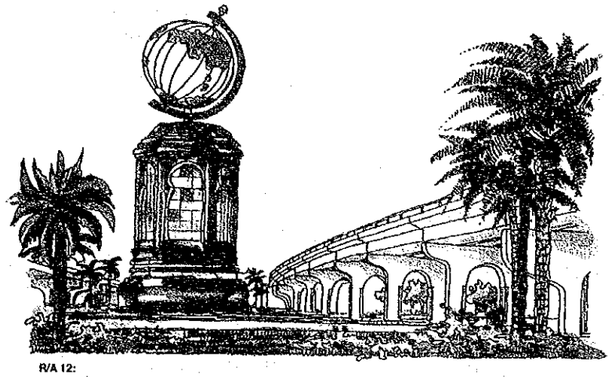
Satoshi Watabe
Team Leader
The Study on the Road Development Project
in the Sultanate of Oman

THE STUDY ON ROAD DEVELOPMENT PROJECT

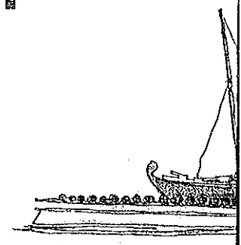
LANDSCAPE PLAN FOR FLYOVERS AND ROUNDABOUTS THROUGH BATINAH HIGHWAY



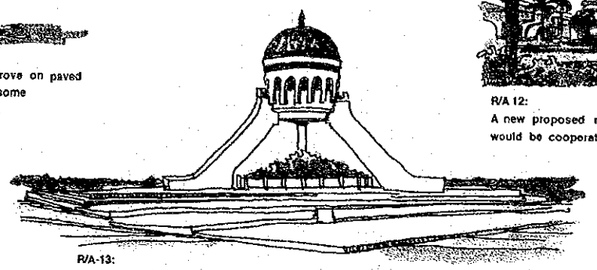
R/A-17:
Landscape of this roundabout composes grove on paved mound and water fountain, and this is the some representative scenery of the Omani nature.



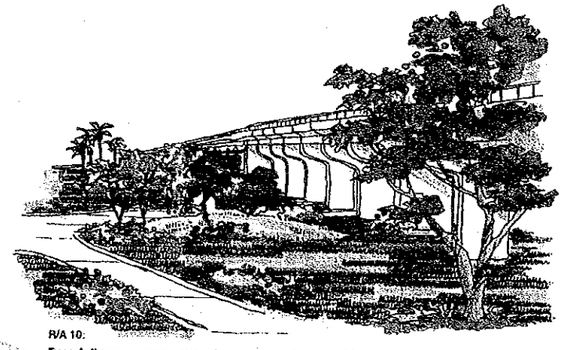
R/A 12:
A new proposed monument would become a significant landmark of Sohar. The type-B flyover would be cooperated with some arch design continuity to the new monument.



R/A-6:
Traditional Dhow ship on the wate
monument and distinctive silhouet



R/A-13:
Landscape of this roundabout composes monument of islamic Omani observation dome on the air, and this monument looks distinctive impression.



R/A 10:
Type-A flyover passes over the roundabout area with slight mounds and groves. It would be appeared an image of a flyover passing through rich foliaged green area.

R/A 8:
Type-A fly
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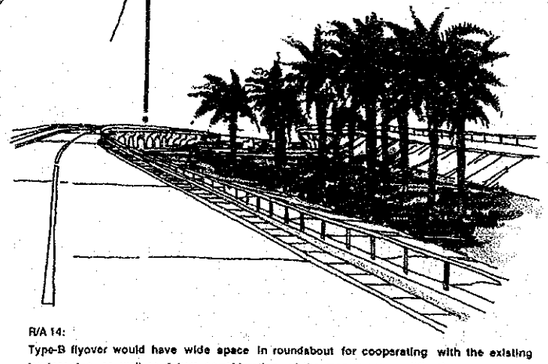
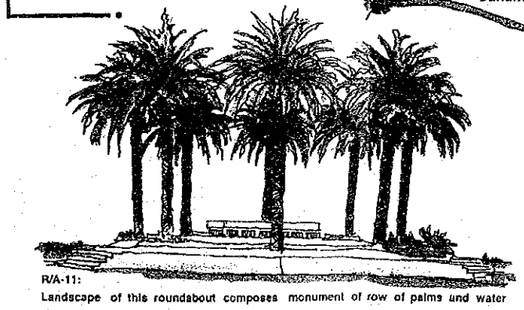
continuity.

R/A-16:
Landscape of this roundabout composes monument of white horse on the terraced green, and location of the white horse is on the seaside.

R/A 18:
Main carriageway would be adjusted to new alignment and local road becomes to cross over the main highway road. Central located columns of piers would be considered as visual landmark solution.

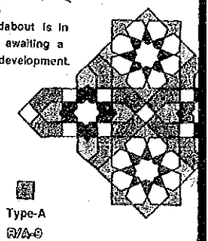


R/A 14:
Type-B flyover would have wide space in roundabout for cooperating with the existing landscaping as well as future consideration of the monument modification.



R/A-11:
Landscape of this roundabout composes monument of row of palms and water element, so called oasis concept.

R/A-15:
This area of roundabout is in plane ground and awaiting a future landscape development.



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LANDMARK / FOCUS
FLYOVER TYPE

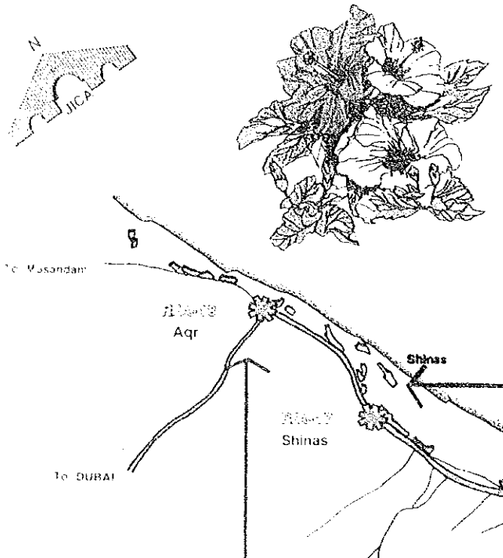
Special Type	Type-B	Type-C	Type-A	Type-B	Type-C	Type-B (Type-D)	Type-C	Type-A	Type-A
R/A-18	R/A-17	R/A-16	R/A-15	R/A-14	R/A-13	R/A-12	R/A-11	R/A-10	R/A-9

FLYOVER PRIORITY

Aqr — Shinas — Liwa — Majis — 0.702km — Falaj Al Qabail — Sallan — Sohar — Suwaihrah — Saham — Al Hijari

THE STUDY ON ROAD DEVELOPMENT PROJECT

LANDSCAPE PLAN FOR FLYOVERS AND ROUNDABOUTS THROUGH BATINAH HIGHWAY



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LANDMARK / FOCUS FLYOVER TYPE			Special Type		Type-B				Type-C		Type-A	Type-B		Type-C	Type-B (Type-D)	Type-C			Type-A			Type-A	
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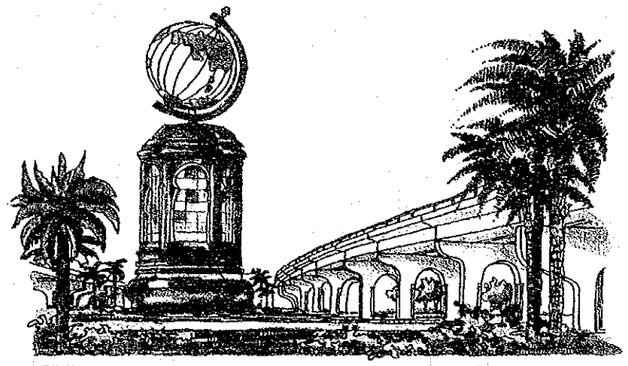
			Aqr	7.00km	Shinas	28.75km			Liwa	11.648km	Majis	0.762km	Falaj Al Qabail	10.30km	Sallan	6.048km	Sohar	5.402km	Suwaihrah	22.05km	Saham	17.616km	Al Hijan	11.64km
FLYOVER PRIORITY																							

ENT PROJECT

ABOUTS THROUGH BATINAH HIGHWAY



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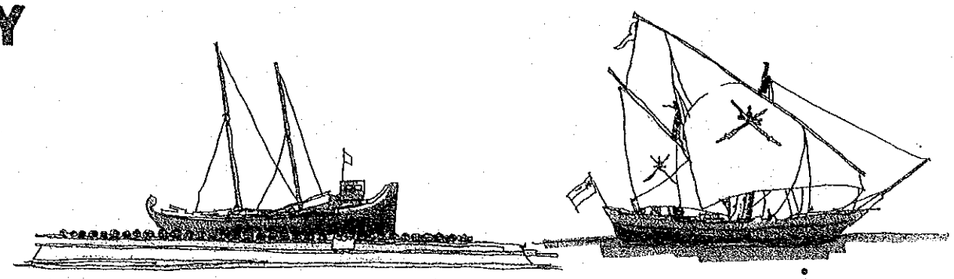

R/A-6:
Traditional Dhow ship on the water concept is considered as a significant symbol monument and distinctive silhouette. It should be preserved with high priority.

R/A 3:
Existing water fou
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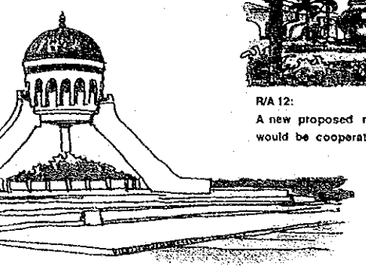

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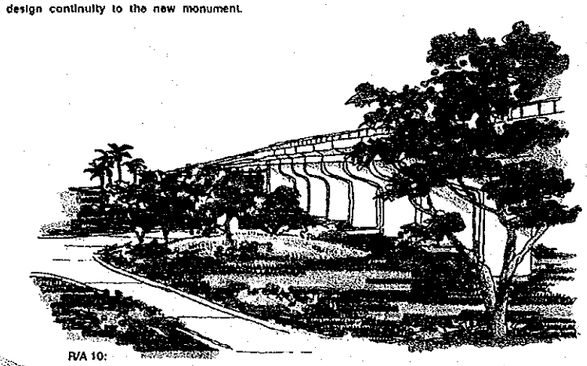

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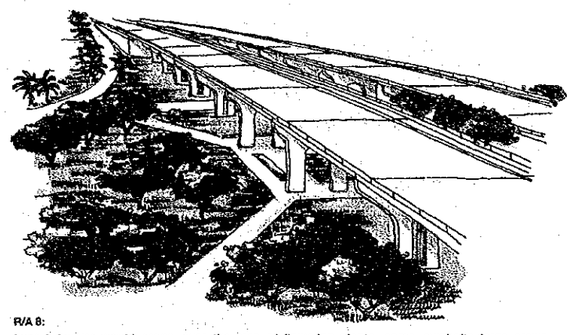
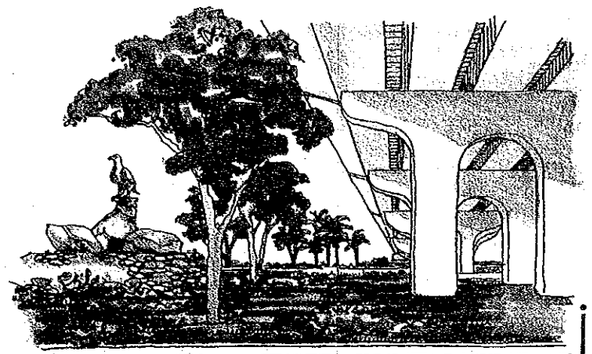


R/A 8:
Type-A flyover would cross over the area of flowering plants, some symbolic large crown trees would be recommended to plant at the central area for emphasizing landscape continuity.



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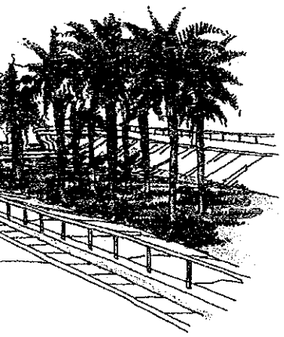
A new landscape of this area would be organized by reflection of a type-A flyover and relocation of a pair of eagle become a new effective landscape focus.



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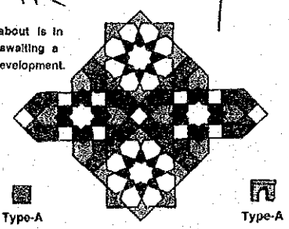

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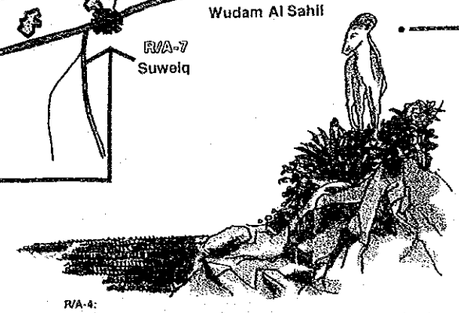
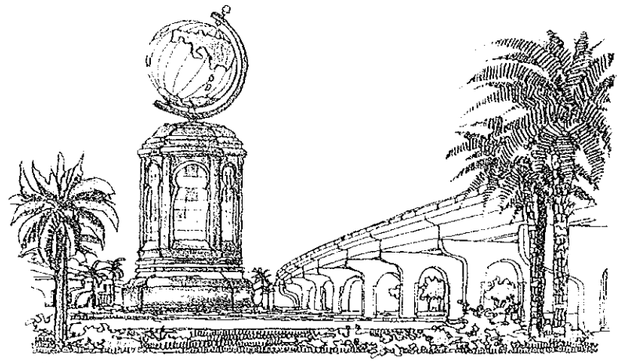


R/A-4:
Rock piled mound with animal sculptures on the flat garden is landscape character of the area, and this landscape concept shall be express part of representative Omani natural features.

Retaining wall:
Long expanded
of the engrave

ENT PROJECT

ABOUTS THROUGH BATINAH HIGHWAY



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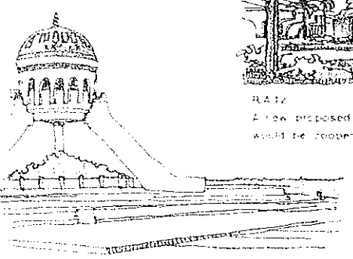

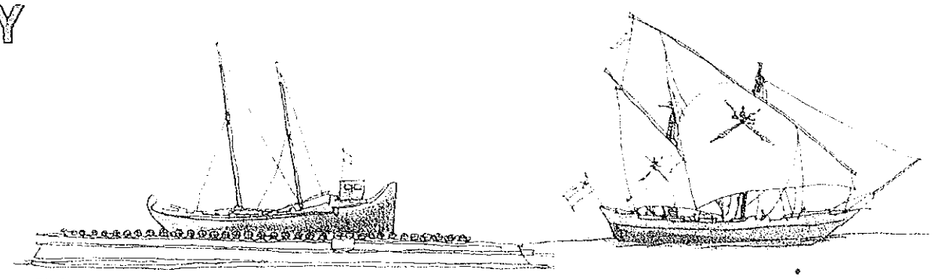

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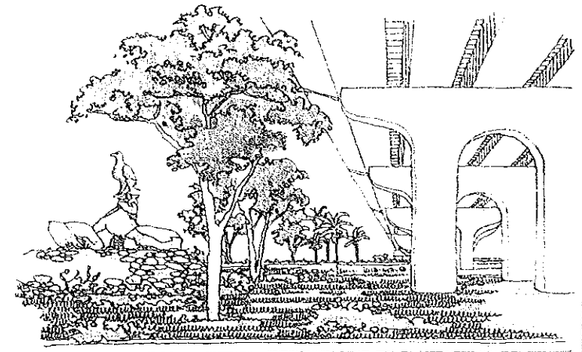

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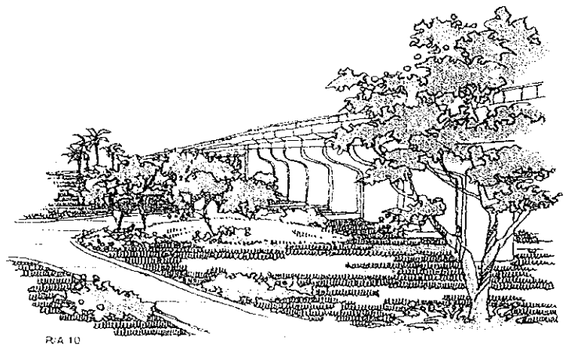

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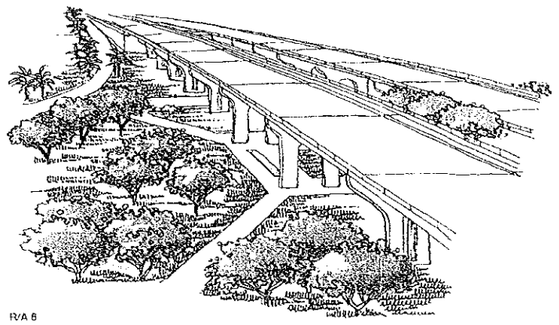

R/A-8
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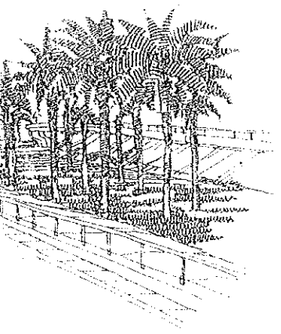

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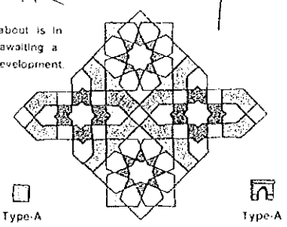

R/A-9
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R/A-7
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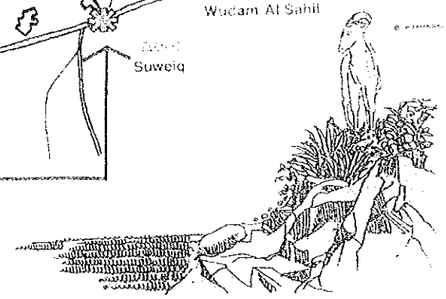

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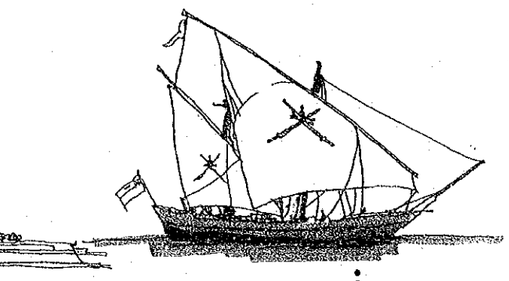

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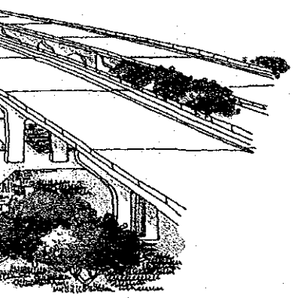

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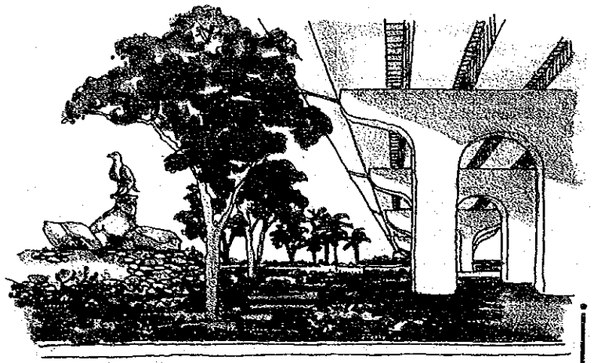
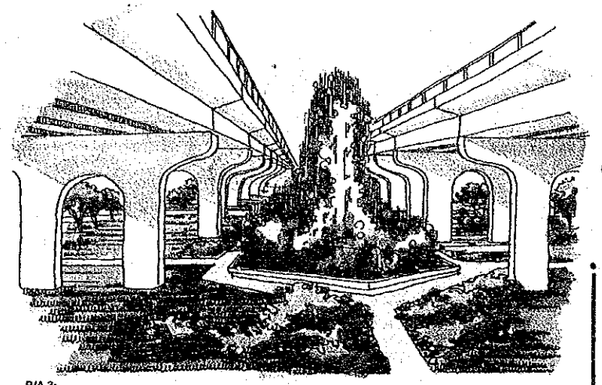
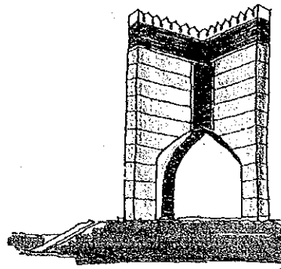


R/A 5:
A new landscape of this area would be organized by reflection of a type-A flyover and relocation of a pair of eagle become a new effective landscape focus.



R/A 3:
Existing water fountain would be observed at openings between central piers of the flyover, and the water fountain appears in white and elegant silhouette with arch formed piers.



R/A-1:
Traditional Omani citadel arch gate is considered as a significant monument and distinctive silhouette of the monument should be preserved with high priorit

R/A 2:
Type-A flyover would be a new symbol of the roundabout, an image of white flyover and white garden tower with flowering plants would represent Naseem Garden environment.

LEGEND

- ROUNDABOUT / JUNCTION
- COMMUNITY & TOWNSHIP
- LANDMARK
- LANDSCAPE FOCUS
- FLYOVER PRIORITY
- INDUSTRIAL ESTATE

R/A-4:
Rock piled mound with animal sculptures on the flat garden is landscape character of the area, and this landscape concept shall be express part of representative Omani natural features.

Retaining wall:
Long expanded solid surface of the retaining wall would need familiar features, introduction of the engrave of traditional patterns to the wall would present more harmony and continuity.

Entrance facility of pedestrian underpass:
Location identification, community amicable and attractive appearance design feature of the entrance facility would encourage peoples to use the pedestrian underpass.

R/A-7:
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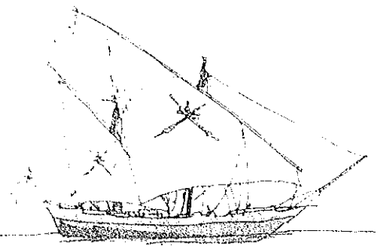
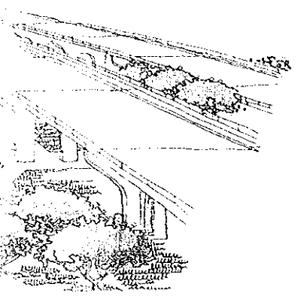
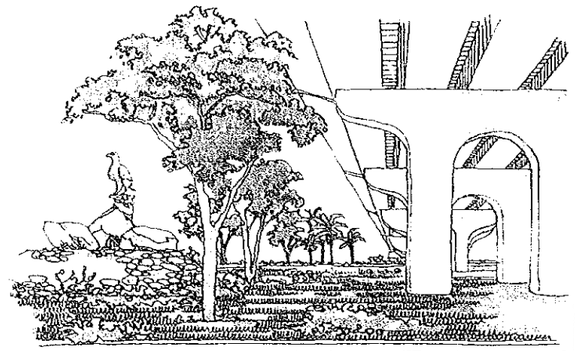
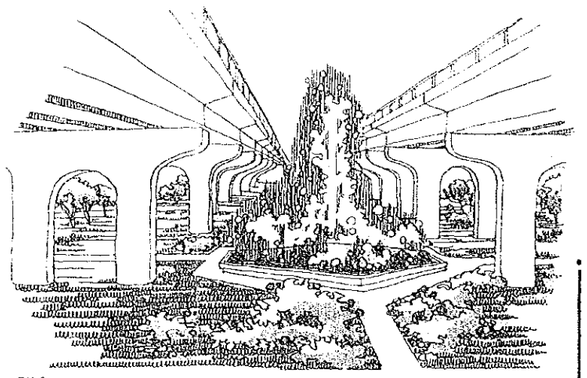


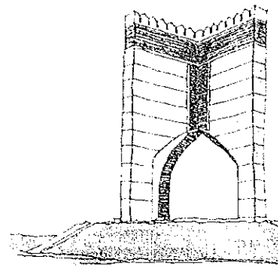




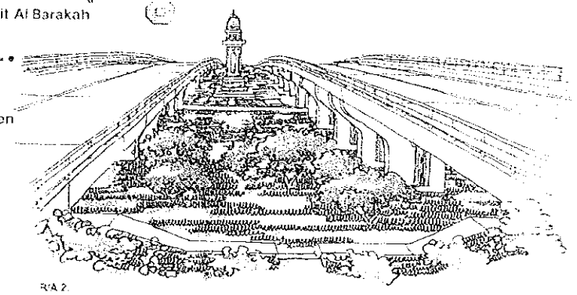
R/A 5
A new landscape of this area would be organizec by reflection of a type-A flyover and relocation of a pair of eagle become a new effective landscape focus



R/A 3
Existing water fountain would be observed at openings between central piers of the flyover, and the water fountain appears in white and e·egant silhouette with arch formed piers

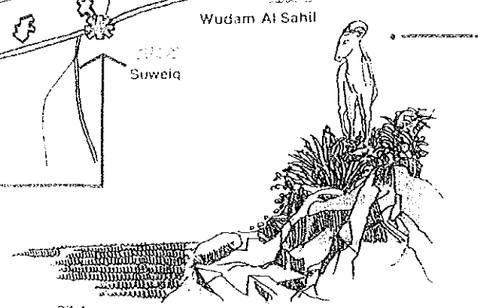


R/A-1
Traditional Omani citadel arch gate is considered as a significant monument and distinctive silhouette of the monument should be preserved with high priority

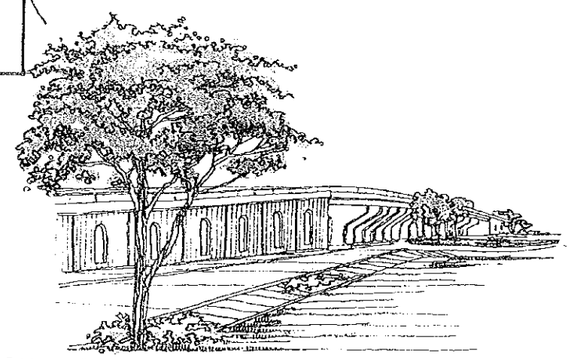


R/A 2
Type-A flyover would be a new symbol of the roundabout, an image of white flyover and white garden tower with flowering plants would represent Naseem Garden environment

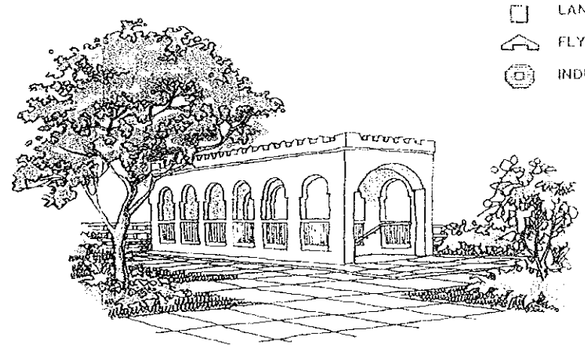
The roundabout is consisted flower garden on the ... and major objectives are groups of plants



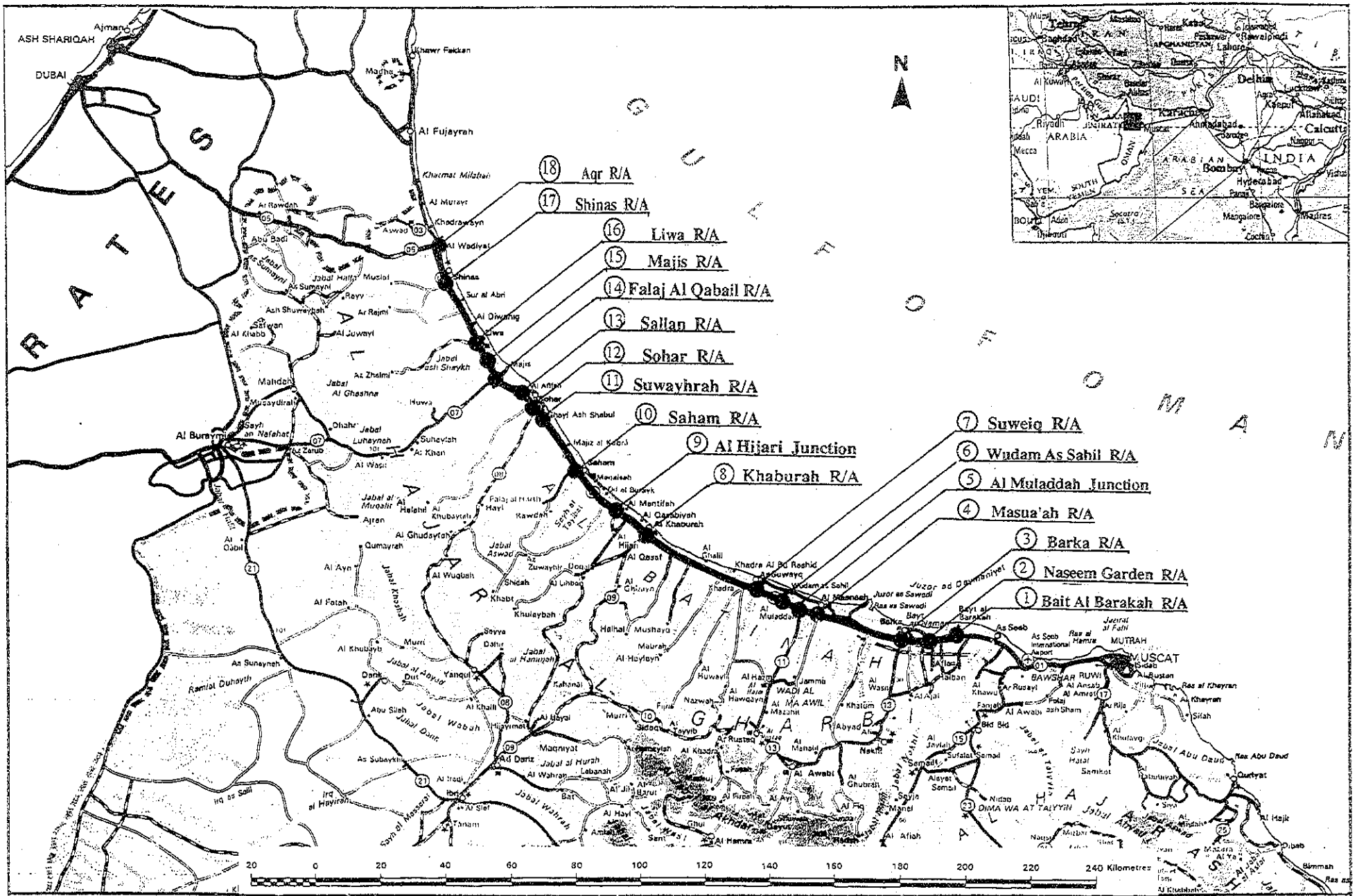
R/A-4
Rock piled mound with animal sculptures on the flat garden is landscape character of the area, and this landscape concept shall be express part of representative Omani natural features.



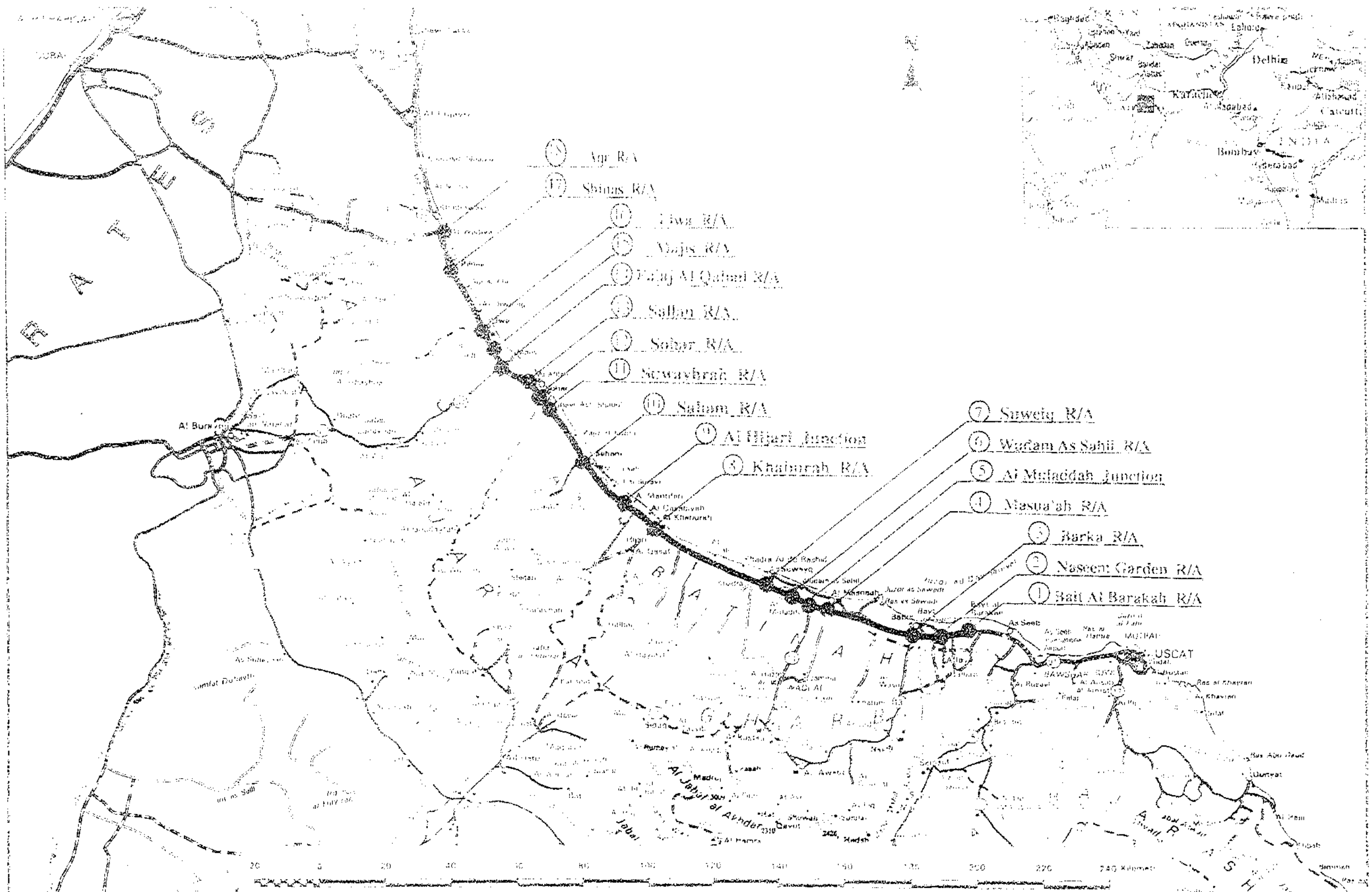
Retaining wall
Long expanded solid surface of the retaining wall would need familiar features, introduction of the engrave of traditional patterns to the wall would present more harmony and continuity



Entrance facility of pedestrian underpass:
Location identification, community amicable and attractive appearance design feature of the entrance facility would encourage peoples to use the pedestrian underpass



THE STUDY ON ROAD DEVELOPMENT PROJECT	JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION MAP FOR FEASIBILITY STUDY ON CONSTRUCTION OF FLYOVERS AND PEDESTRIAN UNDERPASSES



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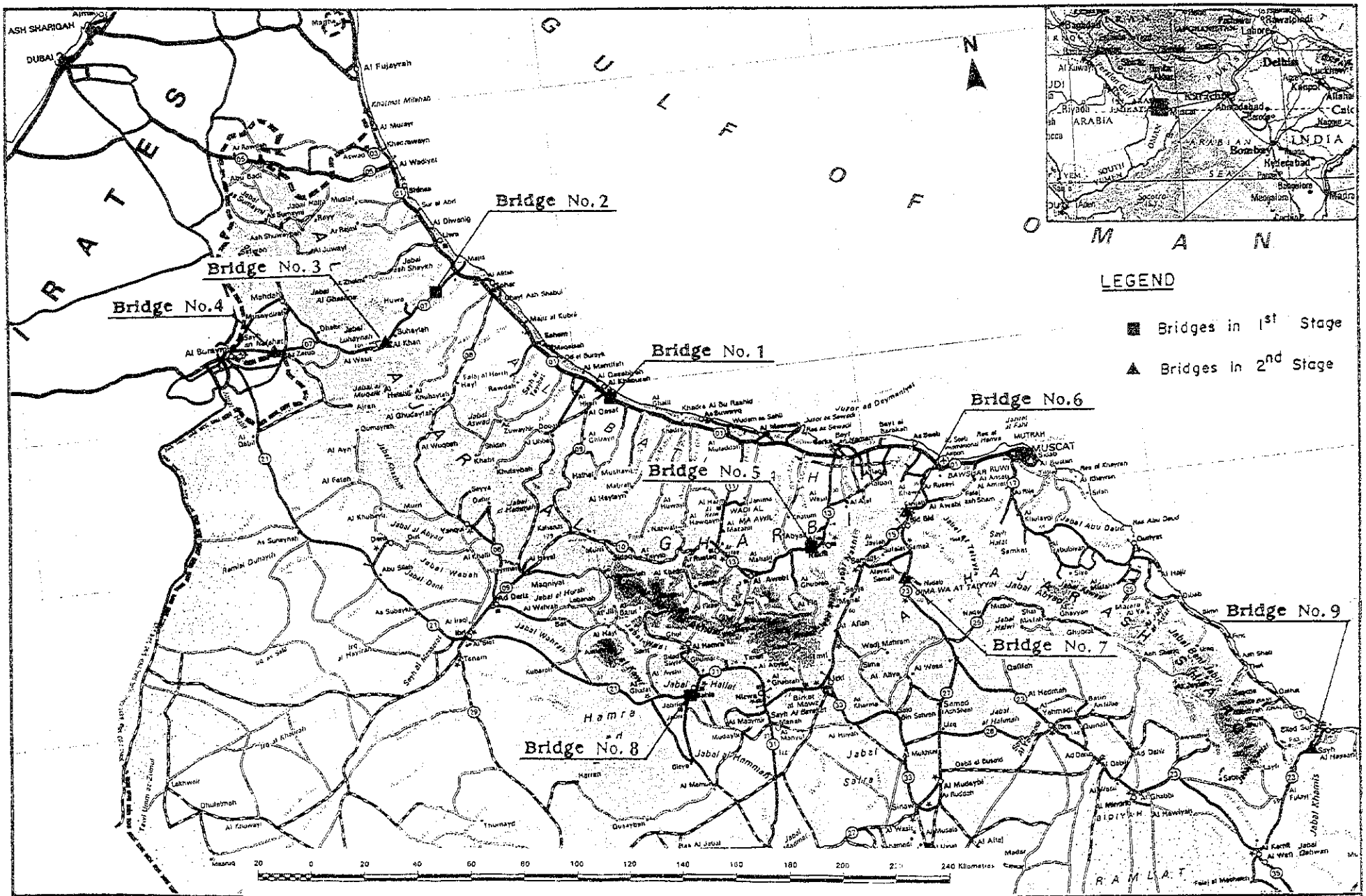
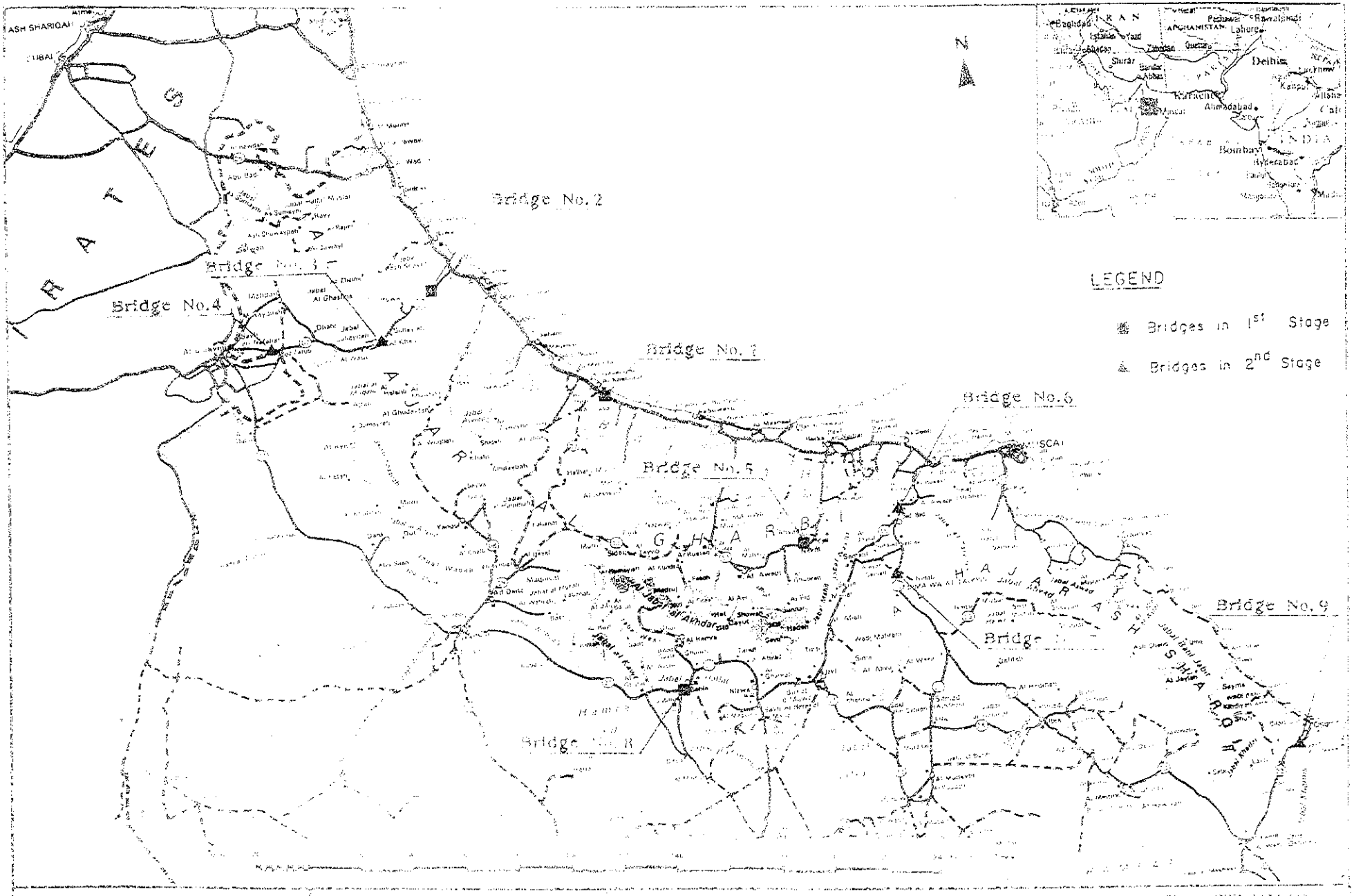


THE STUDY ON ROAD DEVELOPMENT PROJECT	JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION MAP FOR MAINTENANCE AND REHABILITATION STUDY ON NINE EXISTING BRIDGES



THE STUDY ON ROAD DEVELOPMENT PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

LOCATION MAP FOR MAINTENANCE AND REHABILITATION STUDY ON NINE EXISTING BRIDGES

SUMMARY

SUMMARY

The Batinah Highway (National Road No. 1) is an expressway (speed limit: 120 km/hr) stretching 274 kilometers from the capital of Muscat along the Gulf of Oman all the way to Khatmat near the United Arab Emirates. The Batinah Highway is positioned as a vital road link connecting Muscat to agricultural regions in the interior and to the neighboring United Arab Emirates.

The Batinah Highway has rotary-type at-grade intersections (roundabouts and junctions) in 18 locations. Monuments and other objects are positioned within the rotaries for scenic effect for the benefit of vehicle occupants and local residents. Nevertheless, while the highway is designed for a maximum speed of 120 km/h, an almost complete absence of grade separations forces local residents to walk across the road. As a result, there are constant pedestrian accidents involving vehicles travelling at more than 100 km/h. For the residents of villages divided by the highway, crossing over to the other side can be a dangerous undertaking. The construction of flyovers and pedestrian underpasses along the Batinah Highway is an urgent task for the Sultanate of Oman in the interests of public safety and smooth traffic flow.

Furthermore, while the Batinah Highway has few bridges itself, there are many bridges on trunk roads also along secondary roads, which link the interior to the Batinah Highway. Most of these bridges were built in the 1970s and after, and design loads are unclear for many of them. There are currently 58 bridges (44 reinforced-concrete bridges, 12 pre-stressed concrete bridges and 2 structural steel bridges) maintained by the Directorate General of Roads (DGR). With an increase in traffic volume accompanying the economic development of the Sultanate and a greater number of heavy vehicles, the deterioration of these bridges is proceeding more rapidly than expected. In relation to the Sultanate's roadway development program, the maintenance of existing bridges is of equivalent importance to the construction of new ones. Here, the DGR is hurrying to formulate a general maintenance and rehabilitation plan that includes routine inspections and examinations, determinations of load bearing capacity and measures for maintenance and rehabilitation.

To resolve these problems, the Sultanate of Oman, believing that the development of roadways as an important infrastructural element for conveyance and transport is a basic

requirement for domestic economic growth, has requested that the government of Japan perform the following:

- Feasibility Study on the Construction of Flyovers and Pedestrian Underpasses along the Batinah Highway
- Maintenance and Rehabilitation Plan for Bridges (DGR to select nine bridges as model cases)

In response, the Japanese government dispatched a study team to Oman in February 1994 to conduct a study. Presented below are the findings of the Study. The Sultanate of Oman is currently studying these results with the intent of incorporating them in the 5th Five Year Plan to be implemented in 1996.

(1) Feasibility Study on the Construction of Flyovers and Pedestrian Underpasses

1) Future Traffic Volume and Socio-economic Framework

Traffic volume in the Batinah district is high at about 20,000 vehicles per day. This demonstrates the attracting power of Muscat, the capital. An analysis of the socio-economic framework of this area leads to the forecast that, by 2010, the population of Batinah area will reach 808,000 and the number of registered vehicles will increase 3.6 times to 975,000. Traffic volume is also forecast to increase by about three times from the present 69,700 vehicles to 210,000 vehicles by that time. Considering the likely apportionment of this traffic onto the Batinah Highway, it becomes apparent that, in areas with much traffic influx from roundabouts and junctions, traffic volume will become excessive and traffic demand will exceed the level at which it can be efficiently handled.

Consequently, to assure a smooth traffic flow well into the future, it is necessary to promptly construct flyovers for major roads and, in addition, take measures to assure pedestrian safety.

2) Design Outline of Flyovers

The following design standards are applied in the design of the highway and ramps.

Highway design speed:	120 km/h
Ramp design speed:	80 km/h
Bridge design:	Design load to be twice that of AASHTO HS-20; 60-ton truck load
Superstructure:	Simple box-beam bridge of pre-stressed concrete
Substructure:	Abutment; Reinforced-concrete inverted-T-type
	Pier; Same as above or rigid frame π shape
Standard span:	20 ~ 30 m
Foundation:	Reinforced-concrete piles 500 x 500

3) Pedestrian Underpass

The pedestrian underpasses are to be used by residents along the Batinah Highway in fairly specific areas. For this reason, we selected 40 candidate sites by considering village land area and the presence of facilities with much pedestrian traffic, such as schools, public buildings and mosques. From these 12 priority sites were selected for underpasses.

The internal dimension of these underpasses is to be 3m x 3m per design specifications for underpasses already in place within the Sultanate.

4) Environmental Impact and Aesthetics

Environmentally speaking, while there will be some impact on the environment during the construction of the facilities, there will be no fundamental, lasting impact. As for aesthetics, there are already a variety of monuments placed alongside the road and the construction of flyovers at crossings will produce some visual obstructions. For this reason a type judged to be the most aesthetically pleasing was selected for each roundabout. In the design stage, work was conducted to assure the visual attractiveness of the superstructure, substructure and retaining walls.

5) Project Cost

Project cost for 8 roundabouts and 12 pedestrian underpasses were calculated based on 1994 project cost. As a general figure, each roundabout will require about 1 to 1.2 billion yen; each pedestrian overpass, about 30 million yen.

6) Economic Evaluation

As for the economic analysis, benefits resulting from a change in traffic flow which are brought about by the construction of flyovers, the cash flow method was used to calculate the economic internal rate of return, the net present value and the cost-benefit ratio. The economic internal rate of return (EIRR) was found to equal 12.9; the net present value (NPV), RO 2,146,000; and the cost-benefit ratio (B/C), 1.09. This shows that the project is economically feasible.

Economic Cost*	Benefit*	EIRR (%)	B/C	NPV*
23,848	25,994	12.9	1.09	2,146

* in thousands R.O.

As for the construction of pedestrian underpasses, an analysis of construction costs and traffic functions showed that this aspect would not be entirely economically feasible. However, in consideration of pedestrian safety, the implementation of this part of the project will certainly prove beneficial for those living along the Batinah Highway.

Economic Cost*	Benefit*	EIRR (%)	B/C	NPV*
1055	915	10.4	0.87	-140

7) Conclusions and Recommendations

Converting roundabouts into flyovers would enhance traffic-related functions and reduce accidents. Likewise, construction of pedestrian underpasses would have great impact on the social and economic development of communities along the highway by making it easier to cross the road, thereby strengthening the community bonds among those residents and also reducing traffic accidents. Because the construction of flyovers is economically feasible in terms of the national economy, we recommend that this be carried out beginning with those expecting the most congestion. The pedestrian underpasses cannot be called economically feasible, but it is desirable in terms of traffic safety that this aspect of the project also be implemented.

Another benefit arising from the execution of this project is that the linkage between cities will be reinforced, thereby contributing to the development of an

economic sphere and to be strengthening of ties with neighboring countries. Furthermore, the new social and economic ties that will form among the areas that straddle the Batinah Highway will lead to a sense of unity among the villages and promote wide-scale development.

It will be necessary to conduct the detailed design in consideration of economic feasibility and aesthetics after full consideration of the present situation in Oman, its facilities, and capability in construction. At the same time, one must consider the importance of the Batinah Highway as an important route of the Arabian peninsula when considering the bridging of Irish crossings, the use of box culverts and/or the supplying of a flood-warning system.

(2) Maintenance and Rehabilitation Plan for Bridges

On occasion of the formulation of a bridge maintenance and rehabilitation plan, we conducted inspections and loading tests to determine the degree of soundness of existing bridges. The results are outlined below.

1) Inspections

To determine the soundness of each bridge covered by this survey, investigation of bridge condition, construction condition, cracks, concrete quality and reinforcing bar condition were conducted for the superstructure, the substructure and the foundation. The results were compiled on a damage list for each bridge.

2) Loading Tests

Loading tests were carried out for all of the applicable bridges by first selecting the most deteriorated span on each bridge, loading a test vehicle on that span and then measuring the resultant strain, deflection, crack, etc. The results were compiled on the lists and used as indices for determining the degree of soundness.

3) Conclusion

The soundness of the bridges was judged from the results of the above tests. As for the reinforced-concrete bridges, almost all the main girders and deck slabs had structural cracks. As for the pre-stressed concrete bridges, each

had deterioration-related problems caused by structural defects. The bridge most damaged was cited as requiring prompt action because of an especially low degree of soundness, and the necessary repairs and maintenance were performed in 1994 by the DGR in accordance with its maintenance, and rehabilitation plans. Currently, none of the other bridges require immediate action, although it is desirable that action be taken in order of bridge deterioration per the maintenance and rehabilitation plan formulated by the study team.

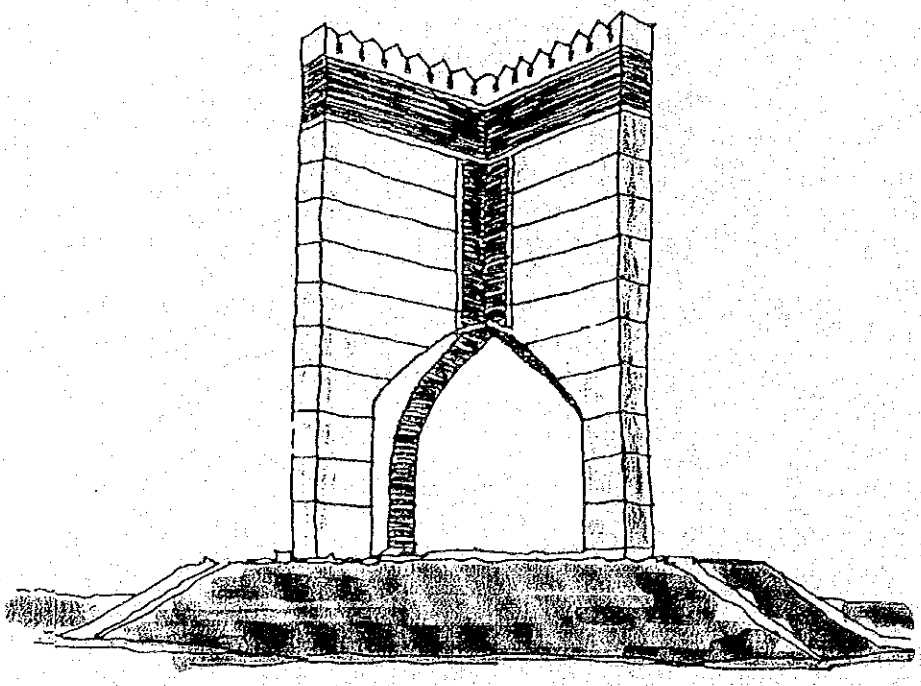
4) Recommendations

We recommend that action be taken as below with regards to the maintenance and administration of existing bridges and of bridges to be built.

- Provision of axle load restrictions (weight restriction signs) for vehicles passing over the bridge
- Levelling of deck surface (pavement repair)
- Repair of cracks (mortar injection)
- Reinforcement and repair of structural defects (recasting of slabs, installation of cross beams)
- Establishment of a maintenance and rehabilitation system
- Filing construction records and inspection records
- Storage of as-built drawings and design drawings

CONTENTS

CHAPTER 1 INTRODUCTION



CHAPTER 1

INTRODUCTION

This report is the result of the Study for "The Road Development Project in the Sultanate of Oman" which has been conducted from January 1994 to January 1995.

1.1 Background of the Study

The Batinah Highway (National Road No. 1) is an expressway stretching 274 km from the capital of Muscat along the Gulf of Oman all the way to Khatmat near the United Arab Emirates as a vital road of the Sultanate.

The Batinah Highway has 18 locations of roundabouts and junctions. However, pedestrians have to walk across the expressway because it has no grade separations, and there are constant pedestrian accidents involving vehicles.

While the Batinah Highway has few bridges itself, there are many bridges on connecting roads linking the highway to the interior. These bridges are deteriorating as the traffic volume and the number of heavy vehicles both increase.

As the above, there are two major problems plaguing the Batinah Highway.

- Pedestrian safety
- Bridge deterioration

In accordance with the fifth Five Year Development Plan due to start in 1996, the Directorate General of Roads (DGR) will resolve the above problems by implementing a policy of isolating pedestrians from vehicles by construction of flyovers at eight high-priority locations among the 18 roundabouts and junctions and on the Batinah Highway.

Bridges in the interior are expected to continue deteriorating as the volume of traffic and number of heavy vehicles on the roads both increase. DGR is hurrying to formulate a general maintenance and rehabilitation plan that includes routine inspections and examinations regarding deterioration from decreased load bearing capacity and measures for maintenance and rehabilitation. This plan will be

reflected in the fifth Five Year Development Plan incorporating nine bridges as model cases.

The Sultanate of Oman believes that the road development plan as transportation infrastructure is the key point of national economy.

In view of the situation, there is necessity of urgent investigation for the feasibility study on construction of flyovers and pedestrian underpasses, and maintenance and rehabilitation study on existing bridges to be reflected in the fifth Five Year Development Plan. To resolve these problems, the Sultanate of Oman requested the government of Japan to carry out the following studies.

- Feasibility Study on the Construction of Flyovers and Pedestrian Underpasses along the Batinah Highway
- Maintenance and Rehabilitation Plan for Bridges (DGR to select nine bridges as model case)

1.2 Study Objective

In accordance with the conditions described above and in response to a request from the Sultanate of Oman, the Study will be carried out to achieve the following goals.

(1) To carry out a feasibility study on construction of flyovers and pedestrian underpasses on the Batinah Highway located along the northern coast of the Sultanate of Oman, in order to obtain a smooth flow of traffic and road safety.

(2) To carry out soundness tests including inspections and load test of existing nine bridges.

(3) To establish the maintenance and rehabilitation plan for the existing bridges.

1.3 Study Area

The Study is to be conducted in the following locations.

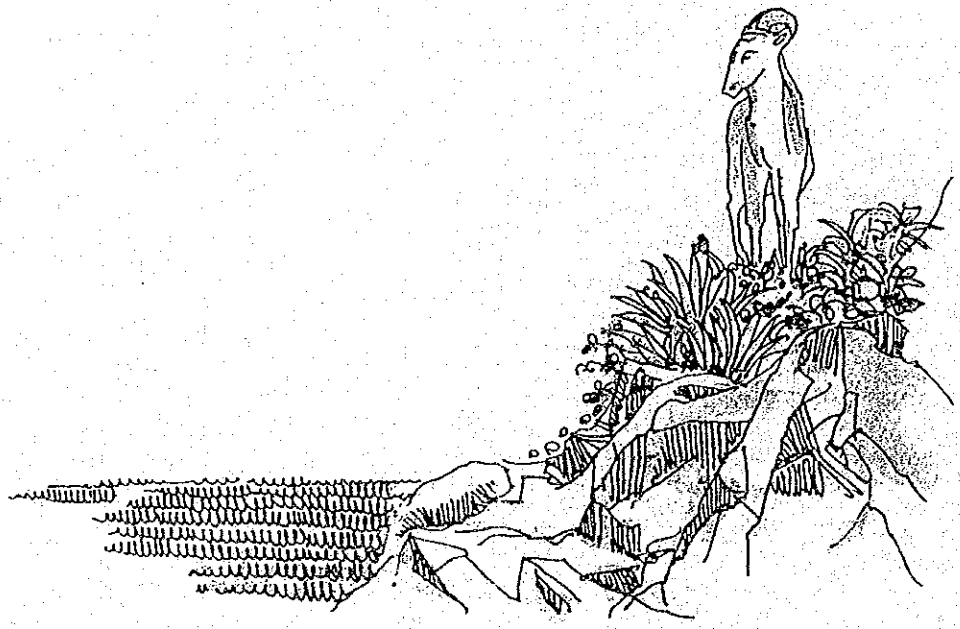
(1) Feasibility study on construction of flyovers and pedestrian underpasses

At 18 roundabouts for flyovers and at 40 locations selected for pedestrian underpasses on the Batinah Highway (Seeb to Aqr, 250 km) along the coast in the north part of the Sultanate of Oman.

(2) Maintenance and rehabilitation plan for existing bridges

Maintenance and rehabilitation plan for existing bridges are to be selected for nine representative bridges selected as model cases in advance by the Government of Oman.

CHAPTER 2 FEASIBILITY STUDY ON CONSTRUCTION OF FLYOVERS AND PEDESTRIAN UNDERPASSES



CHAPTER 2

PART A

FEASIBILITY STUDY ON CONSTRUCTION OF FLYOVERS AND PEDESTRIAN UNDERPASSES

2.1 General Condition of Project Area

Table A.1 is a summary of the general reconnaissance survey notations.

(1) Physical Features of Roundabouts

All the existing 16 roundabouts were designed in an oblong shape in the direction of the highway, to give smoother running path to the traffic. Such a design concept is probably intending to maintain a fairly reasonable speed for the through traffic when passing through the roundabout.

When the traffic approaching from the side approaches becomes substantial, then difficulty entering to roundabout from approaching leg may occur and this can create long queues and conflicts.

(2) Conditions of the Highway and Roundabouts

Severe rutting and cracking of highway pavement were observed at several locations between Bait Al Barakah R/A up to Al Khaburah R/A. Section of the Batinah Highway beyond Al Khaburah are in fairly good conditions based on visual observations. All the roundabouts are well maintained and in excellent conditions.

(3) Median Openings

There are many median openings for accesses to neighboring villages. Although safety measures such as turning lane, channels and islands are provided at some locations, the slow speed of turning traffic at these openings are potential accident hazards in view of the high speed of through traffic.

(4) Service Roads

The old coastal road has become the service road for villages and buildings fronting the highway. Traffic on these service roads is collectively discharged at the roundabouts or major junctions in some locations. However, there are still many small direct accesses to the service roads or single building or plot along the highway. Traffic accessing the highway via such side-openings are potential accident hazards.

(5) Irish Crossings

There are many Irish crossing along the highway. They are identified by the red and white water level measuring rods on both sides of the carriageway. There is evidence of scouring of curbs by rocks occasionally carried down by rain along the wadis.

(6) Beautification Efforts by Local Municipality

Local municipal authorities along the Batinah Highway have made great efforts in various beautification schemes at the roundabouts and major junctions. Impressive monuments for example are erected at 5 locations, namely Bait Al Barakah, Sohar, Sallan, Suwayhrah and Wudam As Sahil Roundabouts. At the other 9 roundabouts, beautification efforts include generous planting of flowering shrubs, installation of rock gardens, water fountains and live-size animal statues.

(7) New Development at Roundabout and Junction

The improved accessibility at roundabouts and junctions have obviously attracted new development. New buildings of 2 or 3 story high and those under construction can be observed at Masna'ah R/A, Al Muladdah Junction, Saham and Khaburah Roundabouts.

Except for the new roundabouts at Majis, Naseem Garden and Bait Al Barakah R/A, there is a general conglomeration of shops, restaurants and other services such as vehicle workshops, gas stations at the roundabouts and major junctions. Denser conglomerations were observed at Barka, Khaburah, Saham, Sohar, Falaj Al Qabail, Shinas and Aqr Roundabouts and Al Muladdah, Al Bidayah and Al Tarif Junctions.

(8) Pedestrian Crossings

Evidence of pedestrians crossing the highway is directly correlated to the density and type of shops, services and public facilities found fronting the highway. The denser the conglomeration of such facilities, the higher the number of pedestrians crossing the highway was observed.

Significant number of pedestrians crossing the highway was observed at Barka, Wudam AS Sahil, Khaburah, Saham, Sohar, Liwa, Shinas and Aqr Roundabouts, and Al Muladdah, Al Bidayah and Al Tarif Junctions.

(9) Public Buildings

The presence of public buildings such as schools, mosques, clinic, market near and at the roundabout or junctions are obviously major generators of pedestrian traffic crossing the highway. School children were observed to cross the highway after they got down from the school buses on their way to school. Shoppers and worshipers are also forced to cross the highway to get to the market or mosque.

(10) Roadside Vendors

There were also vegetable vendors hawking farm produce from nearby vegetable gardens observed along the Batinah Highway. The vendors and vehicles stopping to patronize these informal stalls are potential traffic hazards.

Table A.1 Summary of Results of Site Reconnaissance Survey

No.	Name of R/A or Junction	Type of Structure in R/A	Landuse in the Vicinity	National Route	Access to Towns or Development Areas	Public Building	Pedestrian Volume	Service Road to Highway	Alignment	Others/Remarks
1.	Bait Al Barakah R/A	Religious Monument	Palace Ground and Military School		Private access road to Palace and Military		Nil	Paved service road	Good	Need to preserve aesthetic of R/A
2.	Naseem Garden R/A		Agriculture and public park		Access to Naseem Garden Park	Public park	Nil		Good	New R/A to development area
3.	Barka R/A	Water fountain and shrubs	Commercial and agriculture	Route No. 13	Access to Barka coastal town and inland to Rustaq		Significant	Paved & unpaved service roads	Good	Major junction to Rustaq from the east (Muscat)
4.	Masna'ah R/A	Rock garden	Agriculture, some new commercial development		New road to coastal town		Sizeable	Unpaved service roads	Good	
5.	Al Muladdah Junction	(T-Junction)	Commercial and residential, informal bus terminal for Rustaq, presence of new development	Route No. 11	Access to Rustaq		Significant	Paved service road	Good	Major junction to Rustaq from traffic from the west (Sohar and Aqr)
6.	Wudam As Sahil R/A	Cultural Monument (Bat-tail Ship)	Established commercial and residential areas		Access to coastal town	Mosque, fort	Significant	Unpaved	Good	Preserve monument
7.	Suweiq R/A	(Shrubs)	Public institution, residential		New access roads to coastal town and public institution	ROP station	Small	Unpaved service roads	Good	
8.	Khaburah R/A	(Lawn)	Established commercial and residential areas	Route No. 9	Access to Rustaq and to coastal town	Mosque, clinic	Significant	Paved & unpaved	Good	
9.	Al Hijari Junction	(T-Junction)	Established commercial and residential areas, agriculture		Access to Hijari town and to coastal area		Sizeable	Unpaved	Good	
10.	Saham R/A	(Shrubs)	Estalbished commercial areas, evidence of new development		Access to coastal town and to interior Rawdah	Mosque, clinic	Significant	Unpaved	Good	
11.	Suwayhrah R/A	Cultural monument (date palms & fountain)	Residential and agriculture		Access to Sohar	Mosque	Small	Paved & unpaved	Good	Preserve monument
12.	Sohar R/A	Cultural monument	Established commercial areas, agriculture	Route No. 8	Main access to Sohar and to interior Wadi Hibi		Significant	Paved & unpaved	Curve	Preserve monument
13.	Sallan R/A	Religious monument	Residential areas, agriculture		Access to Sohar		Small	Unpaved	Curve	Preserve monument
14.	Falaj Al Qabail R/A	Rock Garden	Established commercial and residential areas	Route No. 7	To Buraimi and to coastal town	Mosque	Significant	Paved & unpaved	Curve	Major junction to Buraimi and U.A.E.
15.	Majis R/A		Agriculture and new industrial estate		Access to new industrial estate		Nil	Unpaved	Good	Access to industrial estate
16.	Liwa R/A	(Shrubs)	Commercial on one side and agriculture		Access to coastal town		Significant	Unpaved	Good	
17.	Shinas R/A	(Shrubs and rock garden)	Established commercial and residential areas				Significant	Unpaved	Curve	
18.	Aqr R/A	(Shrubs)	Established commercial areas and residential	Route No. 5	Access to coastal Aqr town and to U.A.E.	Mosque	Significant	Paved & unpaved	Good	Major access point to U.A.E.

2.2 Future Development Frame and Traffic Volume

Present traffic volume on the Batinah Highway decreases as one gets further from Muscat. For example, Bait Al Barakah Roundabout reaches approximately 20,000 vehicles per day while Aqr Roundabout remains at approximately 5,000 per day. This demonstrates the gravitational effect Muscat has in the area.

According to results of an analysis on the social and economic framework, the population of Batinah region in the year 2010 will reach 808,000, or approximately 1.5 times the 1993 population. Vehicle registration is expected to increase by about 3.6 times to a total of about 975,000 vehicles by year 2010 from the current level of 270,680 vehicles in 1993.

Traffic volume along the Batinah Highway is growing at a rate of 4.66 % yearly. However, population and automobile registration statistics are growing at an even greater rate: furthermore, increases in per capita mobility are also predicted. The amount of predicted overall traffic volume was calculated by taking the average of the yearly traffic volume growth rate (4.66 %) and yearly growth rate of automobile registration (7.9 %), which comes out to 6.28 %. The total of 210,000 trips for the Batinah Highway was predicted for 2010 is nearly triple the figure of 69,000 vehicles for 1993.

Assigning this trips to the network of the Batinah Highway, Bait Al Barakah Roundabout will have approximately 59,000 vehicles per day, while Aqr Roundabout will have about 16,000. Many of the roundabouts, particularly ones with high volumes of cross traffic, would not be able to accommodate such traffic volume efficiently.

Existing daily traffic volume and forecasted future traffic demand are shown in Fig. A.1 and A.2.

Fig. A.1 Existing Daily Traffic Volume on Batinah Highway, 1994

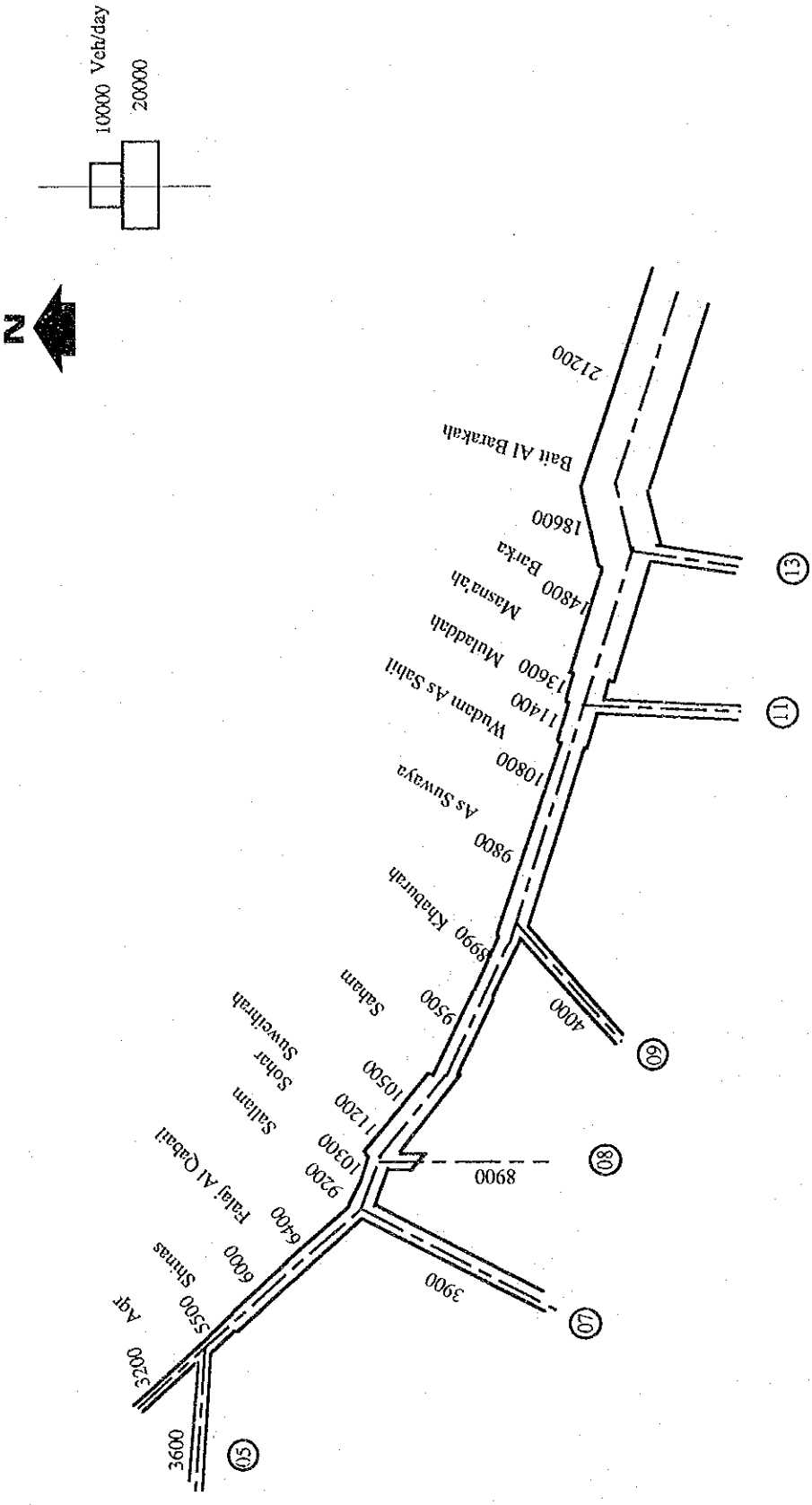
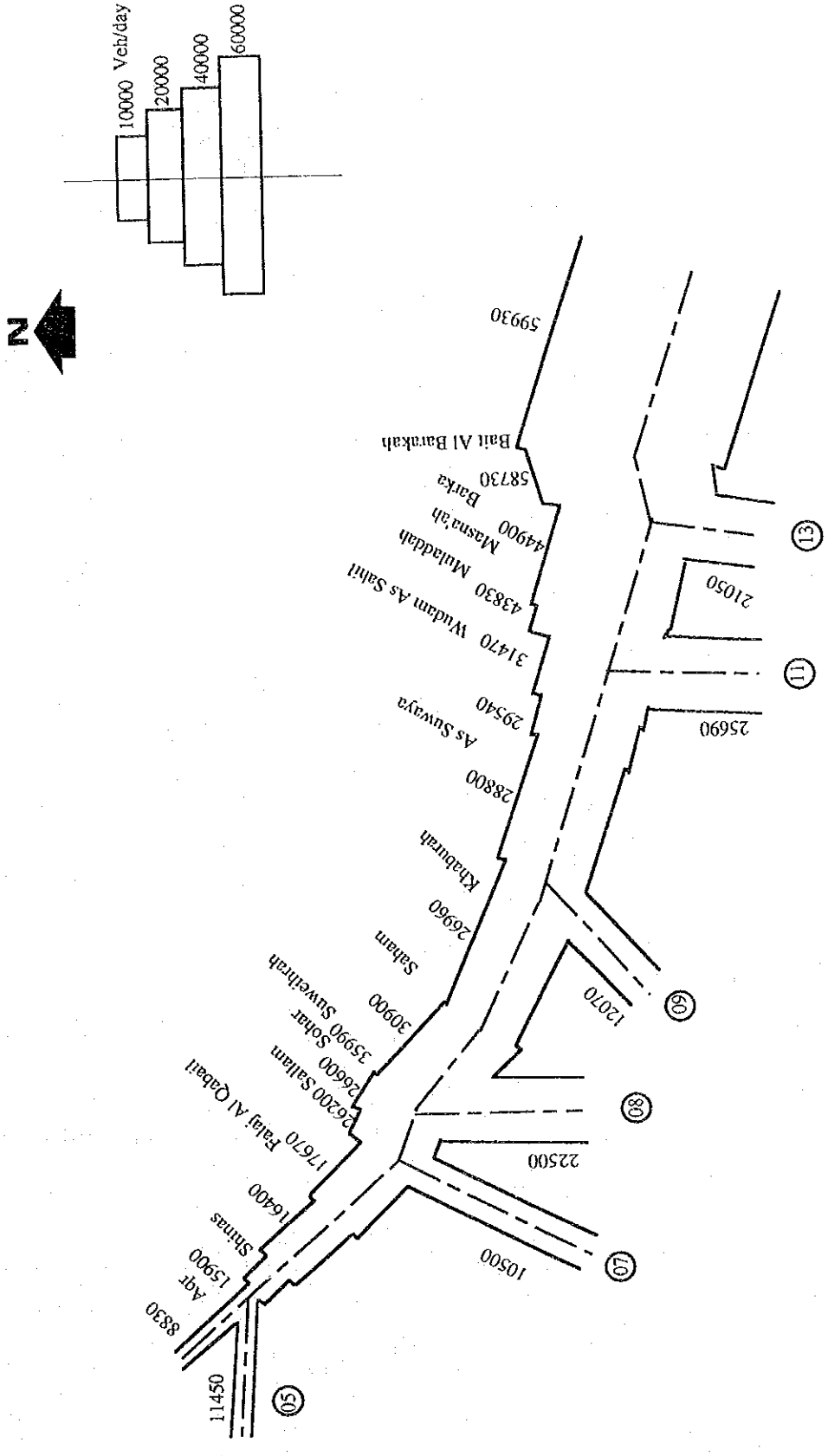


Fig. A.2 Forecasted Future Traffic Demand on the Batinah Highway, 2010



2.3 Grade Separation of Roundabouts

2.3.1 Design Overview

(1) Basic Consideration in Planning Grade Separation

1) Planned area should be retained within present right-of-way as much as possible.
2) Emphasis to be placed on scenic value.

(2) Design Speed and Element

The flyovers are designed with the design speed of 120 km/h as the Batinah Highway was designed for speeds (V) of V = 120 km/h. Interchange ramps will be designed for speeds of 80 km/h in consideration of vehicles which will be exiting to and entering from connecting roads.

Geometric design standard used for design of the flyovers in the study is shown in Table A.2.

(3) Typical Cross Section

Based on forecasts of future traffic demands, the number of necessary lanes along the Batinah Highway for the time being remain at four. The number of lanes for ramps will be one per direction at each roundabout, with the exception of the ramp connecting National Route 13 with Muscat-bound lanes on the Batinah Highway (Barka Roundabout), which are two lanes.

Typical cross section is shown in Fig. A.3.

(4) Bridge Planning

Bridge planning was conducted applying the design standards formulated by the Government of Oman, and considering existing construction conditions.

The main planning items are listed below:

- Design live load: AASHTO HS-20 x 2, or 60-ton truck weight load.
- Superstructure design: Simple box-beam bridge of pre-stressed concrete.

- Standard span length: 20m
- Substructure design: abutment; reinforced concrete reversed T-type piers; same as above or rigid frame π shape pier
- Foundation: Reinforces concrete piles, 500x500 square

Comparative bridge plan is shown Fig.A.4.

(5) Change in Roundabout Shape

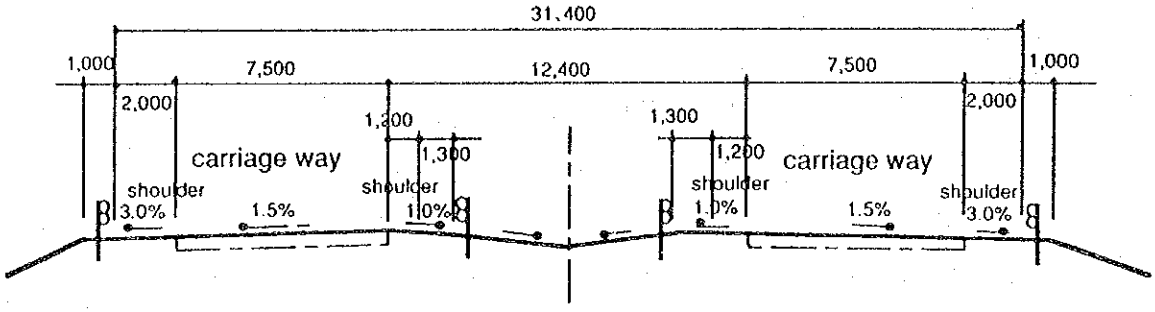
The roundabouts at present are all designed in an elliptical shape to give smoother path to the traffic traveling along Batinah Highway, but this will be changed to a circular design with construction of grade separation.

TableA.2 Geometric Design Standard

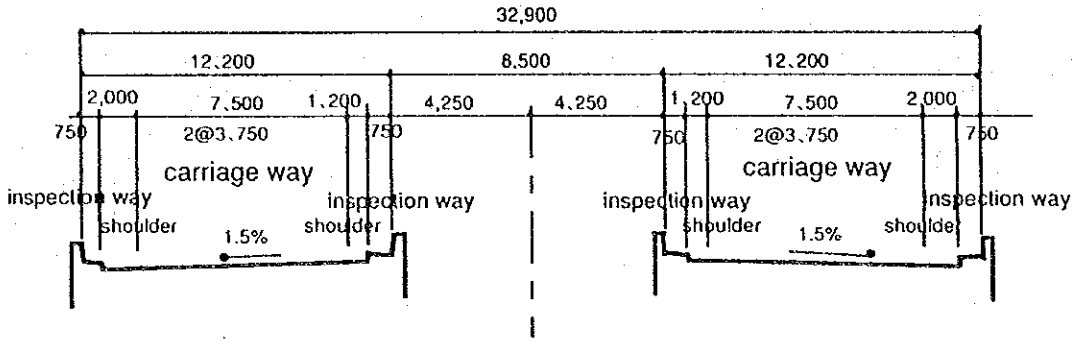
Item	Unit	Batinah Highway	Rampway
Terrain		Flat	Flat
Design Speed	km/hr	120	80
Stopping Sight Distance	m	200	115
Lane Width	m	3.75	3.50
Number of Lanes	Lanes	4	1 or 2
Median Width	m	12.4	-
Inner Shoulder	m	1.20	0.75
Outer Shoulder	m	2.00	2.00
Minimum Radius	m	585	230
Minimum Radius not Requiring Transition Curve	m	1,000	1,000
Maximum Gradient	%	3 (5)	5 (7)
Minimum Vertical Curve Length	m	Fig.6.3	Fig.6.3
Superelevation	%	8	8
Vertical Clearance	m	5.0	5.0

Note:() shows absolute minimum values.

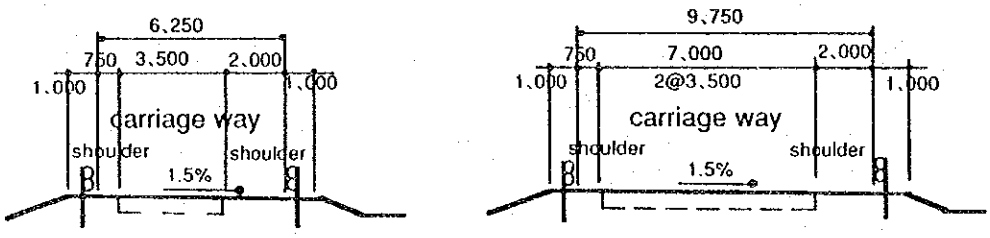
Fig. A.3 Typical Cross Section



HIGHWAY SECTION



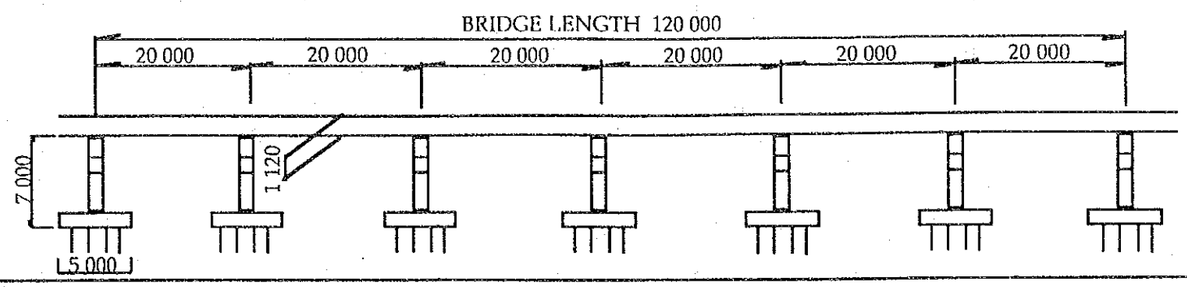
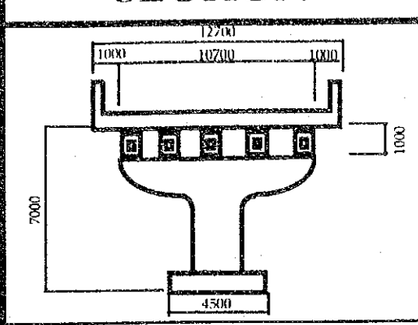
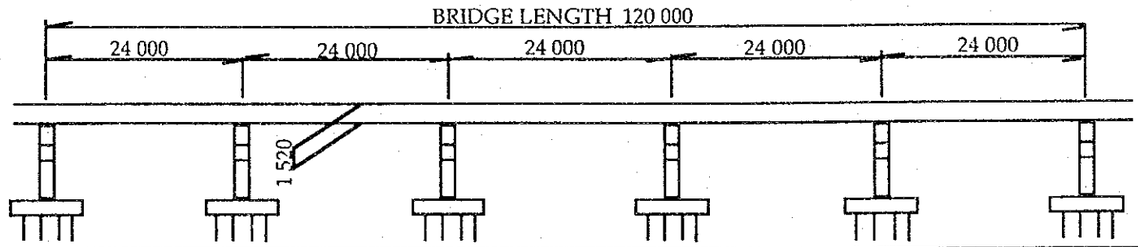
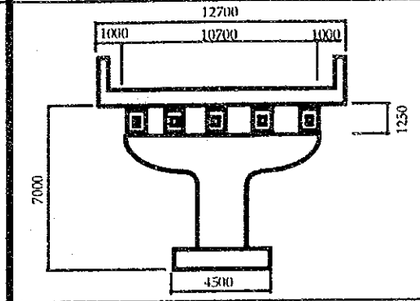
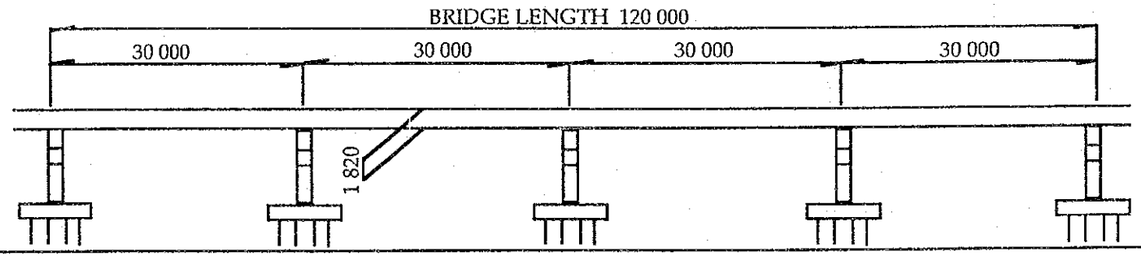
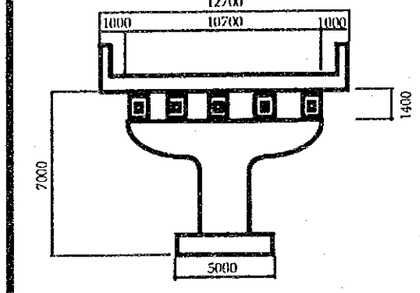
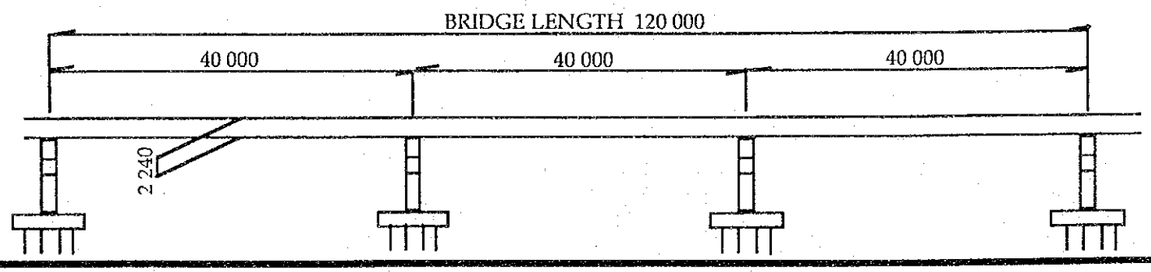
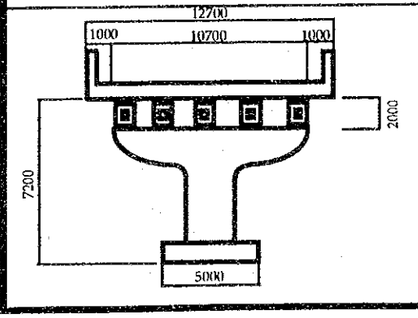
BRIDGE SECTION



ONE LANE

TWO LANES

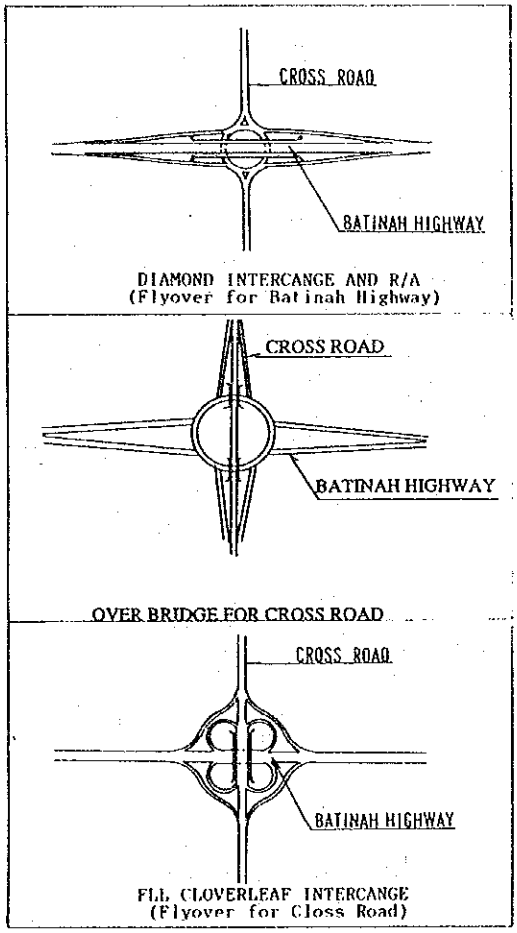
RAMP WAY SECTION

	PROFILE	SECTION	RANKING (COST RATIO)
CASE-I SPAN 20.0M			1 (1.00)
CASE-II SPAN 24.0M			2 (1.05)
CASE-III SPAN 30.0M			3 (1.15)
CASE-IV SPAN 40.0M			4 (1.40)

THE STUDY ON THE ROAD DEVELOPMENT PROJECT	JAPAN INTERNATIONAL COOPERATION AGENCY	**Fig A.4 Comparative Bridge Plan**

2.3.2 Basic Type of Grade Separation

The following three types of grade separation were considered:



i) to grade separation straight traffic of the Batinah Highway by an overpass or an underpass.

ii) to grade separate crossing road.

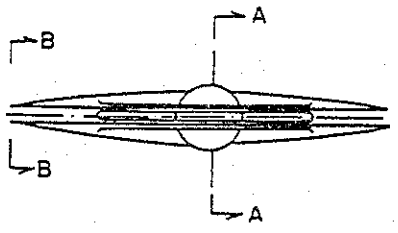
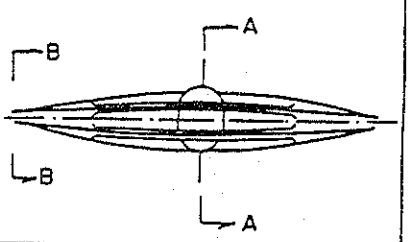
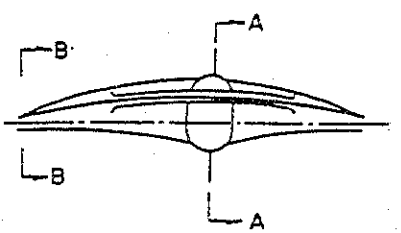
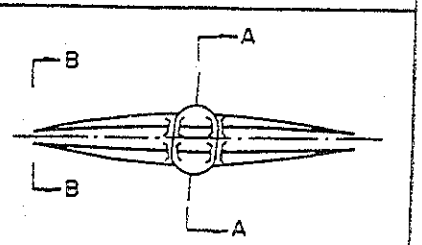
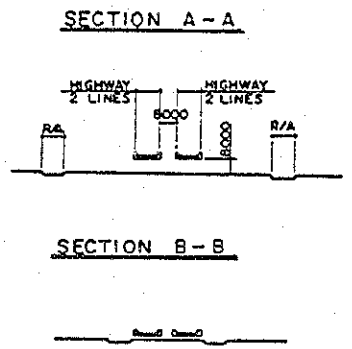
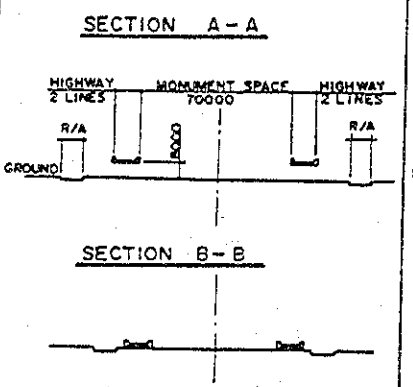
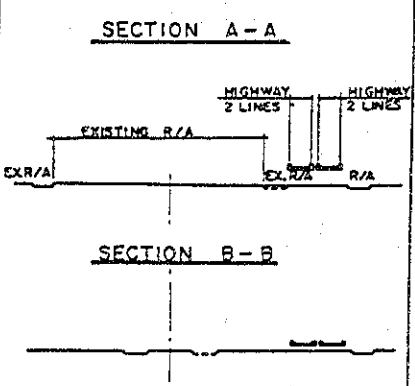
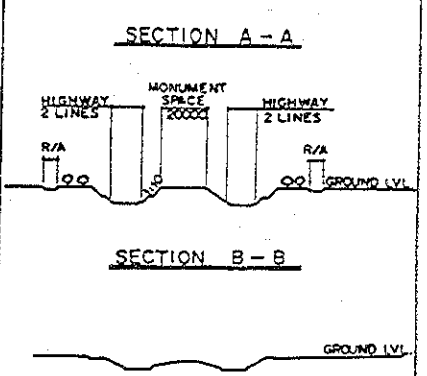
iii) to change roundabout type intersections into another type of interchanges such as cloverleaf or diamond interchanges.

Of the several types of grade separation, type (i) is recommended as the most preferred type for the following reasons:

This configuration (Type (i) above) allows the passage of main traffic flow and will be more effective.

The above Type (i) can be divided four types as shown next Table A.3 due to surrounding land use and size and shape of monument.

Table A.3 Comparison Table of Basic Type of Flyover

	TYPE A	TYPE B	TYPE C	TYPE D
SKETCH				
TYPICAL CROSS SECTION				
DESCRIPTION OF TYPE	Directly Connecting Through Roadway. Passing Center of R/A.	Flyovers be Shifted to Both Side of Edge of Existing R/A.	Flyovers be Shifted to One Side of Edge of R/A.	Alignment be Same as Type B but Through Roadway be Depressed.
RELATIONSHIP TO MONUMENT	Monument not be Preserved.	Almost All of Monument be Preserved.	Flyovers be Shifted to Preserve Monument.	Same as Type B

2.3.3 Proposal of Grade Separation Type by Roundabouts (18 Locations)

Types of grade separation for each roundabout along Batinah Highway, considering the above-mentioned characteristics as well as scenic value, are proposed in Table A.4.

Table A.4 List of Recommended Grade Separation Type of Roundabouts

Intersection	Name	Recommended Type
R/A - 1	Bait Al Barakah	D
R/A - 2	Naseem Garden	A
R/A - 3	Barka	A
R/A - 4	Masna'ah	B
R/A - 5	Al Muladdah Junction	A
R/A - 6	Wadam As Sahil	D
R/A - 7	Suweiq	A
R/A - 8	Khaburah	A
R/A - 9	Al Hijari Junction	A
R/A-10	Saham	A
R/A-11	Suwayhrah	C
R/A-12	Sohar	B (D)
R/A-13	Sallan	C
R/A-14	Falaj Al Qabail	B
R/A-15	Majis	A
R/A-16	Liwas	C
R/A-17	Shinas	B
R/A-18	Aqr	Special

Note : ( ) show second priority

2.3.4 Selection of High-Priority Locations for Grade Separation Facilities

Among the eighteen roundabouts, certain locations were selected as demanding more attention than others in regards to priority of construction. Such prioritizations were based on the following list of evaluation. Eight locations which were selected as a result are presented in Table A.5.

(1) Batinah Highway's traffic volume at the roundabout
(2) Traffic volume capacity ratio on the approach to the roundabout
(3) Role in the road network

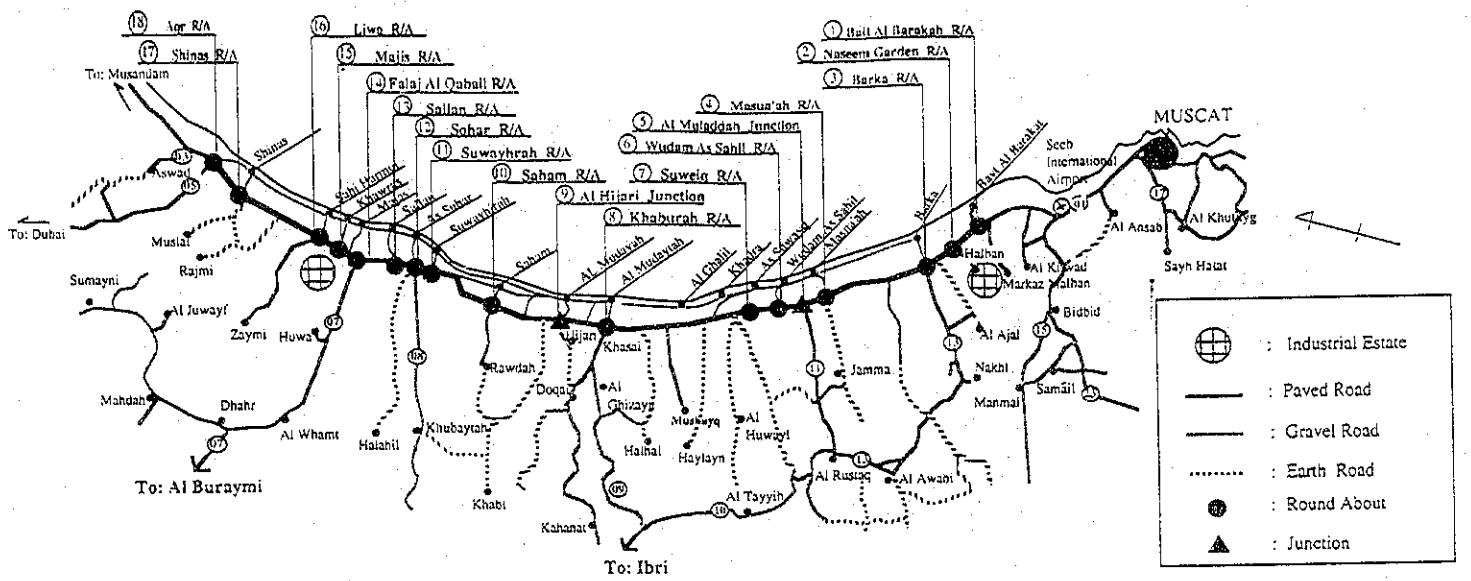
(4) Role in local community integration

(5) Supporting role in development plans

Table A.5 Calculate for Order of Priority

	Evaluation Item					Total weighted score	Rank
	V/C ratio	Batinah Volume	Highway Network	Local Community	Develop-ment		
Weight	50	10	20	10	10	100	
1. Bait Al Barakah R/A	70 35.0	90 9.0	0.0	0.0	0.0	44.0	8
2. Naseem Garden R/A	75 37.5	85 8.5	0.0	0.0	85 8.5	54.5	3
3. Baraka R/A	90 45.0	80 8.0	80 16.0	80 8.0	0.0	77.0	1
4. Masna'ah	60 30.0	75 7.5	0.0	0.0	0.0	37.5	10
5. Al Muladdah Junction	65 32.5	70 7.0	75 15.0	0.0	0.0	54.5	4
6. Wadam As Sahil R/A	40 20.0	65 6.5	0.0	70 7.0	0.0	33.5	11
7. 'Suweiq R/A	45 22.5	55 5.5	0.0	0.0	0.0	28.0	13
8. Khaburah R/A	55 27.5	50 5.0	70 14.0	0.0	0.0	46.5	6
9. Al Hijari Junction	30 15.0	40 4.0	60 12.0	75 7.5	80 8.0	46.5	7
10. Saham R/A	80 40.0	45 4.5	0.0	85 8.5	0.0	53.0	5
11. Suwayhrah R/A	50 25.0	60 6.0	0.0	0.0	0.0	31.0	12
12. Sohar R/A	85 42.5	35 3.5	65 13.0	90 9.0	0.0	68.0	2
13. Sallan R/A	35 17.5	30 3.0	0.0	0.0	0.0	20.5	15
14. Falaj Al Qabail R/A	25 12.5	25 2.5	90 18.0	65 6.5	0.0	39.5	9
15. Majis R/A	20 10.0	20 2.0	0.0	0.0	90 9.0	21.0	14
16. Liwas R/A	15 7.5	15 1.5	0.0	60 6.0	0.0	15.0	17
17. Shinas R/A	10 5.0	10 1.0	0.0	0.0	0.0	6.0	18
18. Aqr R/A	5 2.5	5 0.5	85 17.0	0.0	0.0	20.0	16

Notes : V/C rate refer to Chapter 5 "Traffic Capacity of Road"
: upper row shows score of each location
: lower row shows the weighted score



Number of R/A			(18)	(17)	(16)	(15)	(14)	(13)	(12)	(11)	(10)	(9)	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)
Name of R/A or Junction			Aqr R/A	Shinas R/A	Liwa R/A	Majis R/A	Falaj Al Qabail R/A	Sallan R/A	Sohar R/A	Suwayhrah R/A	Saham R/A	Al Hijari Junction	Khaburah R/A	Suweiq R/A	Wudam As Sahil R/A	Al Multaddah Junction	Masua'ah R/A	Barka R/A	Naseem Garden R/A	Bait Al Barakah R/A
Station			231 +316	224 +316	195 +566	186 +018	183 +316	173 -016	166 +968	161 +566	139 +516	121 +750	110 +016	71 +946	61 +616	54 +156	46 +682	20 +850	5 +090	0 +000
Length (km)			7.00	28.75	9.548	2.702	10.30	6.048	5.402	22.05	17.766	11.734	38.07	10.33	7.46	7.474	25.832	15.76	5.09	
Cross Road			N.R 5				N.R 7		N.R 8				N.R 9			N.R 11		N.R 13		
Access	To Interior Town		Dubai				Al Buraimi		Wadi Hibi		Rawdah	Al Hijari	Rustaq			Rustaq		Rustaq		
	To Coastal Town			Shinas	Sahi Hormul	Khawr As Sammi	Majas	Sallan	Suhar	Suwayhrah	Saham	Al Muntenfah	Al Khabourah	Al Suwayq	Wudam As Sahil		Masna'ah	Barka	Naseem Garden Park	Bait Al Barakah
Criteria for Evaluation: Traffic Volume	Batinah Highway	1994	4,500	6,200	6,500	6,600	7,700	9,800	11,700	11,000	10,200	8,600	9,600	11,600	11,500	11,700	13,900	16,200	18,300	20,100
		2010	13,600	16,100	16,600	17,200	22,100	25,200	26,400	29,700	28,700	26,800	27,900	29,200	30,600	37,700	44,300	51,800	58,700	59,700
	Cross Road	2010	5,400	2,300	2,100	1,000	7,700	7,300	27,200	7,400	23,200	1,600	11,300	4,500	2,500	12,100	2,700	21,700	2,900	1,300
	Volume/Capacity (V/C)	2010	0.29	0.31	0.32	0.32	0.61	0.57	1.93	0.68	1.45	0.51	0.74	0.61	0.60	1.05	0.87	2.76	1.16	1.13
Evaluation Lanking	Batinah Highway	2010	(18)	(17)	(16)	(15)	(14)	(13)	(12)	(7)	(9)	(11)	(10)	(8)	(6)	(5)	(4)	(3)	(2)	(1)
	V/C Ratio	2010	(18)	(17)	(16)	(15)	(14)	(12)	(2)	(9)	(3)	(13)	(8)	(10)	(11)	(6)	(7)	(1)	(4)	(5)
	Relation with Road Network		(2)				(1)		(6)			(7)	(5)			(4)		(3)		
	Local community Integration				(7)		(6)		(1)		(2)	(4)			(5)			(3)		
	Relation with Industrial Development							(1)				(3)							(2)	
Priority			(16)	18	17	14	(9)	15	(2)	12	(5)	7	(6)	13	11	(4)	10	(1)	(3)	8

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Table A.6
Priority on Grade Separation of Roundabout

2.3.5 Preliminary Design Drawings for Selected High-Priority Locations for Grade Separation

Preliminary design drawings as selected in previous chapter are shown in Volume IV, Drawings.

There are comparison plans for R/A-5 (Al Muladdah Junction), R/A-12 (Sohar) and R/A-18 (Aqr) as shown below;

- R/A-5 (Al Muladdah Junction) : Priority road plan from and to Muscat.
- R/A-12 (Sohar) : Importance to Aesthetic
- R/A-18 (Aqr) : Lower design speed of 60 km/h was used to design smaller radius of curvature.

2.4 Pedestrian Underpass

2.4.1 Structural Type of Pedestrian Facility

Grade separated pedestrian crossing facility has two type namely underpass and flyover which are compared in Table A.4.

Underpass type was selected judging from economical and aesthetic.

TableA.4 Comparison of Pedestrian Facility

Criteria	Underpass	Flyover
1. User's Convenience	The pedestrians are psychologically liable to use due to less climbing height than flyover	Opposite of underpass due to much more climbing height than underpass
2. Comfort	Good	Fair but bad in summer
3. Crime Prevention	Lighting required and other measures	None required
4. Aesthetic	Good	Required harmony with surroundings
5. Effect on Surroundings	Almost none	Protective measures on highway are required
6. Construction Cost	Low	Slightly High
7. Maintenance	Required	Little
8. Ease of Construction	Normal	Less than Underpass

2.4.2 Design Overview

The structures will be planned according to the existing design made by the Government of Oman.

- Internal section of underpass: 3,000x3,000
- Entrance facility: Both side of Highway
- Opening: Median
- Drainage: Drainage Pit

2.4.3 Candidate Locations for Pedestrian Underpasses

The users of the underpasses will be a limited number of people living and/or working along the Batinah Highway; mostly those within walking distance of the underpass itself. This distance is theoretically 200 m.

Forty different locations have been chosen as candidates for underpasses, in consideration of inhabited area mass within a 200 m sphere as well as presence of school, mosque, etc.

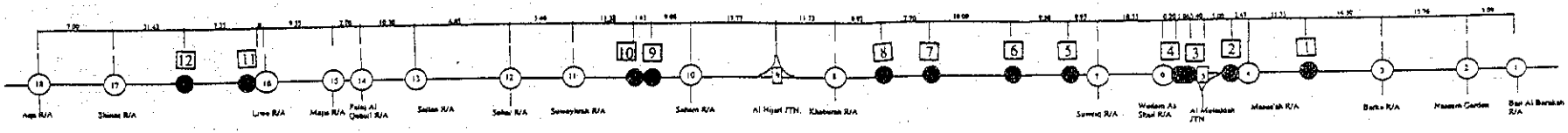
Selection result is shown in Table A.8.

2.4.4 Selection of High-Priority Locations for Pedestrian Underpasses

Among the forty locations chosen in 2.4.3, those with communities on both sides of the highway and those with schools nearby were selected, while those in proximity to the priority roundabout for construction of the flyovers were omitted, leaving twelve high-priority locations. At the location which coincide with the priority roundabout pedestrian crossing will be provided at ground level under the flyovers to which main traffic flow will be converted. The twelve priority locations for underpasses are shown in Table A.9.

2.4.5 Design Overview of Pedestrian Underpass

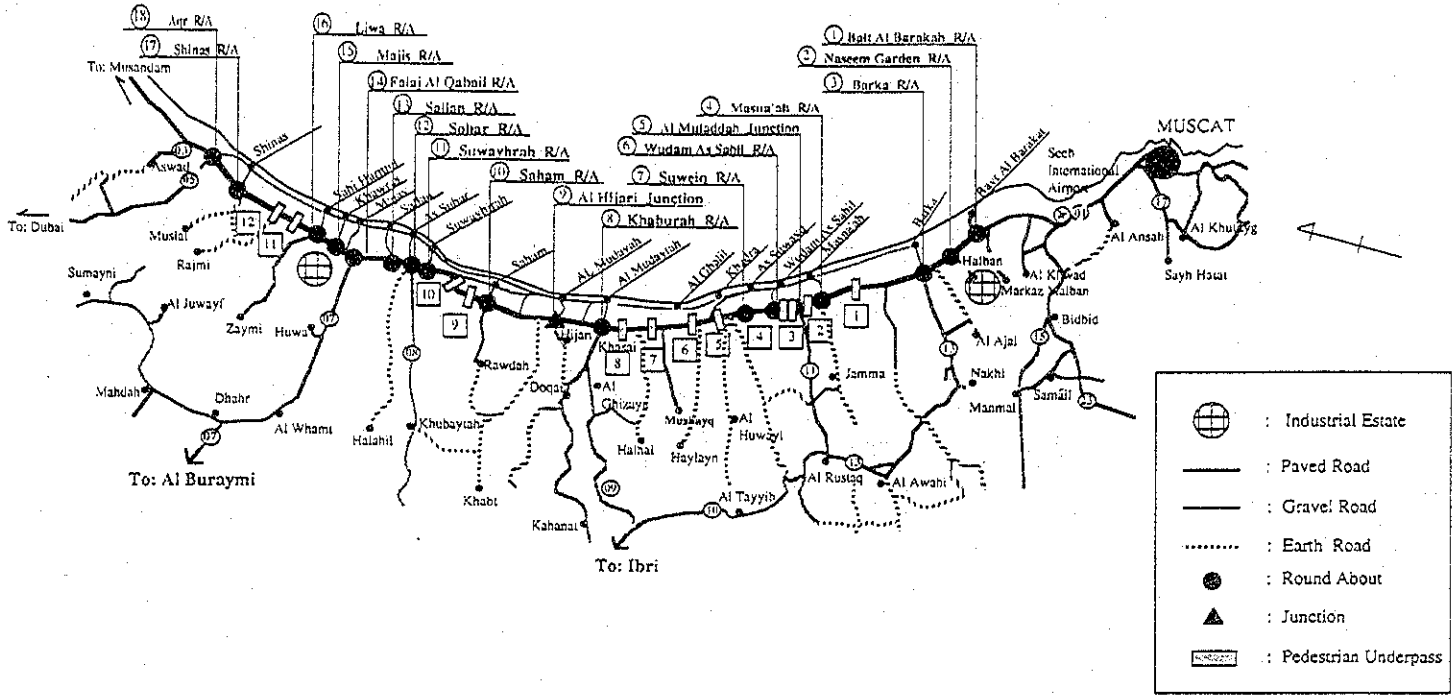
Design drawings of selected 12 numbers of pedestrian underpasses are shown in Volume IV, Drawings.

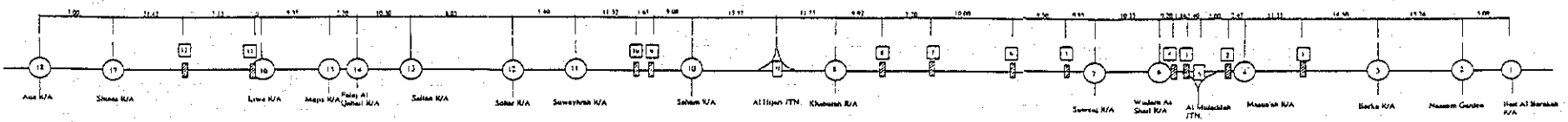


Candidates for Selection						Criteria-1	Criteria-2	Criteria-3	Recommendation
Location		Name of Settlement	Area (km2)		School	Settlement area is more than 0.1km2 both side of highway	There is school at one side of highway	Side of high priority R/A for flyover	
No.	Sta. N.o		Mountain Side	Sea Side					
1	Sta. 20+400	As Somhan	0.10	0.26	---	○		R/A-3	
2	Sta. 35+400	Al Billah	0.05	0.06	Sea Side		○		1 ● 2 ●
3	Sta. 49+200	Al Tarif	0.19	0.14	---	○			
4	Sta. 55+150	Al Muladdah	0.38	---	---				
5	Sta. 59+600	Al Qart	0.12	0.12	---	○			3 ●
6	Sta. 61+416	Al Tharmad	0.14	0.26	---	○			4 ●
7	Sta. 63+150	Al Manfash	---	0.20	Sea Side				
8	Sta. 72+900	Bataha Hilal	0.04	0.08	Sea Side		○		5 ●
9	Sta. 79+200	Sur Al Hilal	---	0.10	---				
10	Sta. 81+000	Al Uriq	0.08	0.16	---				
11	Sta. 82+350	Al Khadra	0.06	0.03	Sea Side		○		6 ●
12	Sta. 91+700	Dhyan-1	0.20	0.04	---				
13	Sta. 92+400	Dhyan-2	0.04	0.08	Sea Side		○		7 ●
14	Sta. 93+000	Dhyan-3	---	0.06	---				
15	Sta. 100+100	Al Bidayah	0.14	0.12	Sea Side	○	○		8 ●
16	Sta. 110+016	Sur Al Duwahnah	---	0.52	---			R/A-8	
17	Sta. 115+550	Qasbyat Al Hawashnah	0.16	0.09	---				
18	Sta. 139+516	Saham	0.07	0.20	Sea Side		○	R/A-10	
19	Sta. 141+350	Al Badi	---	0.20	---				
20	Sta. 142+400	Al Ghuwaisah	---	0.20	---				
21	Sta. 143+400	Al Hadheeb	---	0.10	---				
22	Sta. 147+500	Hilat Al Rawashid	---	0.10	---				
23	Sta. 148+600	Hilat Al Rawashi1	0.12	0.22	---	○			9 ●
24	Sta. 150+250	Mujaz As Sughra	0.12	0.14	---	○			10 ●
25	Sta. 159+000	Khor Siyabi	---	1.08	---				
26	Sta. 159+900	Otab	0.06	---	---				
27	Sta. 166+968	Al Waqaybah	---	0.26	Sea Side			R/A-12	
28	Sta. 170+200	Sallan	---	0.80	---				
29	Sta. 174+200	Al Gushbah-1	---	0.30	---				
30	Sta. 175+400	Al Gushbah-2	---	0.10	---				
31	Sta. 176+900	Falaj Al Ouhi	---	0.22	---				
32	Sta. 183+316	Falaj Al Qabail	0.20	0.24	Sea Side	○	○	R/A-14	
33	Sta. 195+766	Liwa	N.a	N.a	---	○			11 ●
34	Sta. 200+850	Liwa-1	---	0.08	---				
35	Sta. 201+750	Liwa-2	---	0.08	---				
36	Sta. 202+900	Liwa-3	0.10	0.13	Sea Side	○	○		12 ●
37	Sta. 221+500	Al Hazari	---	0.18	---				
38	Sta. 212+700	Sur Al Abril	0.30	0.09	---				
39	Sta. 213+800	Sur Bani Gizmah	0.30	0.08	---				
40	Sta. 215+100	Tari Hajih	---	0.30	---				

Legend
● Recommended Pedestrian Underpass
□ Recommended Number

THE STUDY ON ROAD DEVELOPMENT PROJECT	JAPAN INTERNATIONAL COOPERATION AGENCY	**Table A.8** SELECTION OF SITE FOR PEDESTRIAN UNDERPASS





Number of Pedestrian Underpass		12	11	10	9	8	7	6	5	4	3	2	1
Name of Pedestrian Underpass		Liwa-3	Liwa	Mujas As Sughra	Hilat Al Rawashid	Al Bidayah	Dhyan-2	Al Khadra	Bataha Hilal	Al Tharmad	Al Qart	Al Tarif	Al Billah
Location		202+900	195+766	150+250	148+600	100+100	92+400	82+350	72+900	61+416	59+600	49+200	35+400
Area (km2)	Coastal Side	0.13	N.a	0.14	0.22	0.12	0.08	0.03	0.08	0.26	0.12	0.14	0.06
	Mountain Side	0.10	N.a	0.12	0.12	0.14	0.04	0.06	0.04	0.14	0.12	0.19	0.05
School		Sea Side	N.a	-----	-----	Sea Side	Sea Side	Sea Side	Sea Side	-----	-----	-----	Sea Side

THE STUDY ON ROAD DEVELOPMENT PROJECT	JAPAN INTERNATIONAL COOPERATION AGENCY	**Table A.9** PROPOSED LOCATION OF PEDESTRIAN UNDERPASS

2.5 Environmental Impact

This project is basically an amelioration project of existing highway; therefore it will not be cause of major impact on natural environment such as geophysical features and flora and fauna against a peripheral area of Batinah Highway. This project is to improve a running condition of Batinah Highway and deemed to contribute reduction of pollutant exhaust. However, impact of atmospheric pollution that faces a peripheral area are thought about, as a estimated traffic volume is quite large, approximately 60,000/day. Therefore, monitoring stations is recommended to be facilitated to monitor a contamination condition. As for socio-economic environment there might be a relocation of a highway peripheral resident but at this stage of preliminary design the influence can not be determined exactly. In future, at a detail design stage, geometric design of flyover will be so made to minimize the influence to relocation of the dweller along the highway. There will be some impact for aesthetic environment by the construction of flyovers of the project. But, they will be designed to harmonize peripheral aesthetic environments and to create new landscape, so the impact will be mitigated.

2.6 Aesthetics

Roundabouts and junctions have been landscaped by government authorities with several impressive monuments and grades along the Batinah Highway. Construction of grade separation facilities at these locations may have adverse effects on landscape aesthetics. In order to minimize negative impact on the landscape, a number of grade separation types (A, B, C, D) have been established and assigned according to appropriateness in each site, evaluated in terms of aesthetics, function, and structure.

(1) Evaluation According to Basic Structure Type

The amount of negative impact a grade separation may have on existing monuments differ depending upon size, height, length and/or direction of the monument itself. For example, monuments which are relatively low but with some width are more affected by the number of piers rather than the entire bridge itself, while a monument whose appeal depends upon its height will be more aesthetically affected by the thickness of the bridge's superstructure. As drivers tend to grasp the structure from afar, the overall visual effect will depend upon the width between the separated carriage ways. Considering

these points and others, four patterns have been formulated according to environmental factors.

(2) Three Major Factors Considered in Structural Planning

1) Planning should be conducted with consideration of the balance between superstructure and substructure.

The balance between bridge length and thickness of superstructure (including handrailing), as well as the balance between the thickness of the superstructure and height of piers should be considered. In other words, it is most important to impress the thickness of superstructure by visionary.

2) Considering substructure design

The substructure is especially important designwise, as it is the part of the entire structure which is most apparent to the surrounding area. Piers which are long and slender would be the most recommended structural factor, these arranged in a fashion that would most effectively bring out the beauty of the monument.

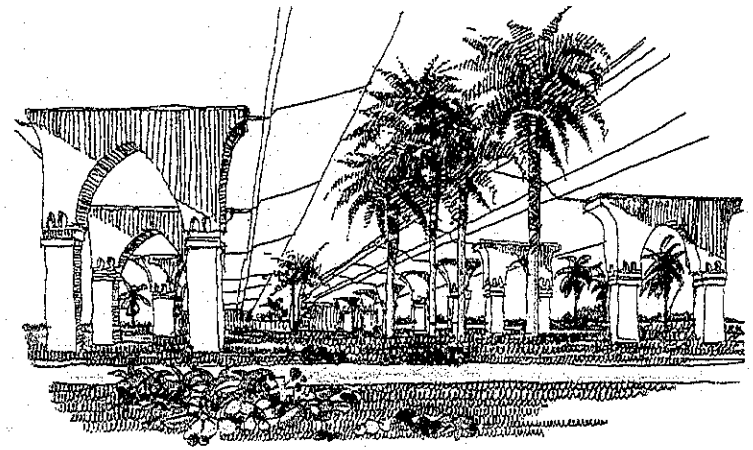
3) Considering aesthetic design for the retaining walls

The retaining wall is of substantial length, and often carries a monotonous image. To soften this image, a harmonious and flowing design needs to be considered.

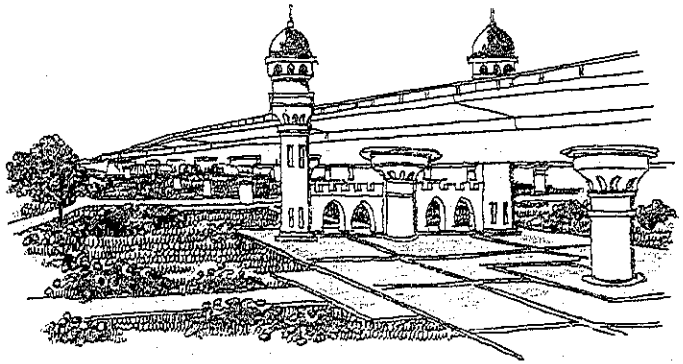
Table A.10 shows the present landscape features at roundabouts and their vicinity. Islamic and Arabic design concept as shown in Fig. A.5 should be incorporated to the flyover structures at detail design stage.

2.7 Traffic Safety

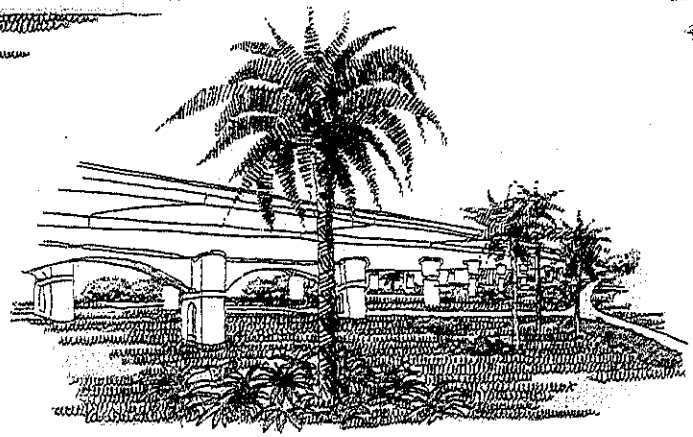
Although the incidence of traffic accidents in Oman has gone down after peaking in 1985, but still there are 11,754 accidents occurred in 1993. A great number of these occur in the Batinah region, which includes the Batinah Highway. The most common causes of these accidents have been speeding, negligence, and poor driving, which together make up 90 % of the cases. Accidents involving pedestrians are not unusual: children under the age of ten are the most common victims.



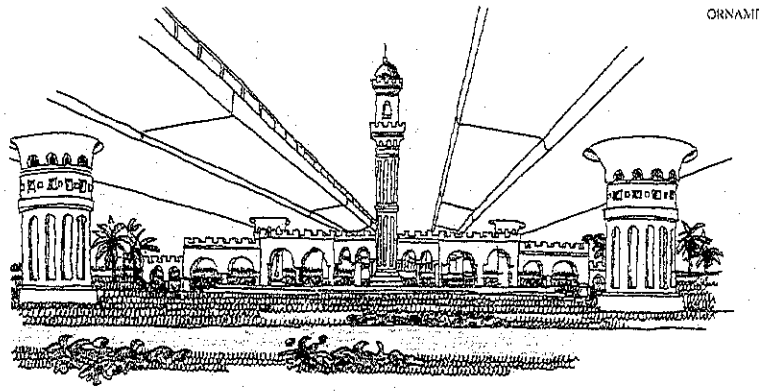
ISLAMIC ARCHES AND SINGLE COLUMN PIERS



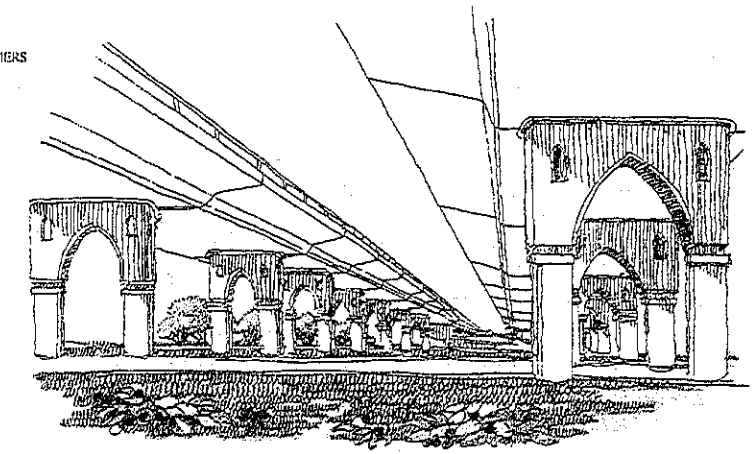
SINGLE COLUMN PIER WITH GATE TYPE MONUMENT



ORNAMENTAL ARCHES AT CENTER OF ROUNDABOUT AND SINGLE COLUMN PIERS



NEW ROUNDABOUT SYMBOL AND SINGLE COLUMN PIERS



ISLAMIC ARCH TYPE PIERS

Fig. A.5 Islamic and Arabic Design Concept

Table A.10 (1) Landscape Analysis and Study for Flyover at Roundabouts and Junctions

R/A & JN	Location	Monument and Landscape Components at R/A and JN					Vicinity Landscape Components			Flyover Type Consideration				Recommended Flyover Type
	Super-intendency	Characteristics	Direction	Dimension	Perception	Visibility	Characteristics	Locality	Continuity	Type-A	Type-B	Type-C	Type-D	
R/A-1	Bait Al Barakah (M.M)	Traditional Omani citadel arch gate	All directions	H = 12.1 m W = 12.0 m L = 12.0 m	Distinctive monument silhouette	Clear vertical	Flat dry land, Date palms row on the road side, view to Mt.	Even at seaside, Mt. side	Omani arch design element	-	-	* Mt. side	*	Type-D (Type-C)
R/A-2	Maseem Garden (M.P.E)	Plane ground, Paved sidewalks (Garden reserve site)	-	-	Horizontal expansion	-	Flat dry land, Date palms and groves at medium distance	Habitat at seaside	Palm grove, Arch-type design	*	-	-	-	Type-A
R/A-3	Barka (M.P.E)	Flat garden and water fountain	All directions	H = 0.5 m W = 15.0 m	Level to downward view	Lower horizontal	Small township with canopy trees	Habitat at seaside	Green and plants	*	*	-	-	Type-A or (Type-B)
R/A-4	Masna'ah (M.P.E)	Rock piled mound with animal sculptures on the flat garden	All directions	H = 2.5 m W = 15.5 m L = 16.5 m	Level to downward view	Lower horizontal	Flat land with palm grove at Mt. side	Township at seaside	Good view to Mt side	*	*	-	-	Type-B
JN-5	Al Muladdah (M.P.E)	Plane ground (Garden reserve site)	-	-	Horizontal expansion	-	Township on Mt. side Groves at seaside	Mt. side	Green elements	*	-	-	-	Type-A
R/A-6	Wudam As Sahil (M.P.E)	Dhow on the water and flat garden surroundings	Dhow faces to the sea	H = 20.0 m W = 15.0 m L = 31.0 m	Distinctive monument silhouette	Clear vertical horizontal	Township on seaside	Township at seaside	Green or horizontal elements	-	-	* Mt. side	*	Type-D or (Type-C)
R/A-7	Suweiq (M.P.E)	Flower garden on the slight mounded green	All directions	H = 2.0 m Ground level	Level to downward view	Lower horizontal	Township on seaside	Even at both side	Green and flower elements	* Shade prov.	-	-	-	Type-A
R/A-8	Khaburah (M.P.E)	Green mound with flower bed	All directions	H = 2.0 m Ground level	Level to downward view	Lower horizontal	Township on seaside Groves at Mt. side	Township at seaside	Trees and Palms	* Shade prov.	-	-	-	Type-A
R/A-9	Al Hijari (M.P.E)	Plane ground	-	-	Horizontal expansion	-	Township on seaside	Even but rather seaside	Trees and Palms	* Shade prov.	-	-	-	Type-A
R/A-10	Saham (M.P.E)	Mounded garden with shrubs and medium trees	All directions	H = 2.0 m Ground level	Level to downward view	Lower horizontal	Township on seaside	Even but rather seaside	Trees and Palms	Shade prov.	* Dawn view	-	-	Type-A or (Type-B)

Note: (M.M) Muscat Municipality
(M.P.E) Ministry of Provincial Municipality and Environment

Table A.10 (2) Landscape Analysis and Study for Flyover at Roundabouts and Junctions

R/A & JN	Location Super-intendency	Monument and Landscape Components at R/A and JN					Vicinity Landscape Components			Flyover Type Consideration				Recommended Flyover Type
		Characteristics	Direction	Dimension	Perception	Visibility	Characteristics	Locality	Continuity	Type-A	Type-B	Type-C	Type-D	
R/A-11	Suweyhrah (M.M)	Monument of row of palms and water element. Oasis design concept	All directions	H = 12.0 m W = 28.0 m L = 28.0 m	Distinctive monument silhouette	Clear vertical horizontal	Many groves on seaside Access to Sohar	Even but rather seaside	Palms and groves	-	*	* Mt. side	-	Type-C or (Type-B)
R/A-12	Sohar (M.M)	Blueish globe on the top of triangle tower/Now monument is porposed by Muscat Munic.	All directions	H = 12.3 m W = 12.3 m L = 12.3 m /H = 40 m	Light structure siluhoette	Clear vertical	Township with much groves on seaside	Seaside	Tree groves	-	*	-	*	Type-B or (Type-D)
R/A-13	Sallan (M.M)	Islamic Omani designed observation dome on the air and water fountain	All directions	H = 12.0 m W = 20.1 m L = 20.1 m	Distinctive monument silhouette	Clear vertical	Wadi and flat land Expansion of groves	Even but rather seaside	Omani islamic feature	-	*	* Mt. side	-	Type-C or (Type-B)
R/A-14	Falaj Al Qabail (M.M)	Rock hill with waterfalls and wild animal sculptures on the flat garden	Rock faces to the sea	H = 4.5 m W = 8.0 m L = 15.0 m	Omani nature	Vertical horizontal	Township on both sea and Mt. side. Groves continuity	Even at both side	Horizontal expansion of green	-	*	* Mt. side	-	Type-B or (Type-C)
R/A-15	Majis (M.M)	Plane ground (Garden reserve site)	-	-	Horizontal expansion	-	Savanna type dry land expansion and Industrial estate at Mt. side	Even at both side	Green elements	*	-	-	-	Type-A
R/A-16	Liwa (M.P.E)	Monument of white horse on the terraced green	Horse faces to the sea	W = 5.0 m H = 2.5 m W = 10.0 m	Focal statue	Horizontal	Savanna type dry land expansion and wadi	Seaside	Horizontal green elements	*	-	* Mt. side	-	Type-C or (Type-A)
R/A-17	Shinass (M.P.E)	Grove on stone paved mound and water fountains	All directions	H = 2+5 m W = 25.0 m L = 30.0 m	Green grove	Soft horizontal	Township on seaside	Even but rather seaside	Canopy trees and palms	-	*	-	-	Type-B
R/A-18	Aqr (M.P.E)	Group planting of Shrubs on the terraced green	All directions	H = 3+2 m W = 17.0 m L = 30.0 m	Green expansion	Soft horizontal	Township on seaside Savanna type dry land expansion at Mt. side	Even at both side	Horizontal green or focal trees	-	-	* Mt. side	-	Type-C

Note: (M.M) Muscat Municipality
(M.P.E) Ministry of Provincial Municipality and Environment

The number of accidents at different roundabouts is shown in (PART A 4-3) in order of frequency. Roundabouts with high numbers of accidents are, in turn, high-priority locations. Although there is no exact data available on numbers and locations of accidents involving pedestrians along the highway, on-site surveys indicated that immediate attention is required for procuring pedestrian crossing at Al Bidayah and Al Tarif. Other places with high traffic volume share similar situations, indicating urgency of facility construction at such locations.

2.8 Cost Evaluation

The project cost of the eight (8) priority roundabouts and twelve (12) priority underpasses is shown below, estimated at 1994 prices.

Grade Separation Project Cost

(Financial Cost Unit: 1,000 RO)

Type of Cost	R/A-2	R/A-3	R/A-5	R/A-8	R/A-10	R/A-12	R/A-14	R/A-18
Construction Cost	2,992	3,048	2,979	3,146	3,177	3,428	3,438	2,565
Contingency	299	305	298	315	318	343	344	257
Design & Supervision	329	335	328	346	349	377	378	282
Land Acquisition	3	0	4	5	5	13	72	194
Project Cost	3,623	3,688	3,609	3,812	3,849	4,161	4,232	3,298

Pedestrian Underpass Project Cost

(Financial Cost Unit: 1,000 RO)

Type of Cost	P/U-1	P/U-2	P/U-3	P/U-4	P/U-5	P/U-6	P/U-7	P/U-8	P/U-9	P/U-10	P/U-11	P/U-12
Construction Cost	95	101	92	100	94	94	97	97	94	95	88	92
Contingency	9	10	9	10	9	9	10	10	9	9	9	9
Design & Supervision	10	11	10	11	10	10	11	11	10	10	10	10
Project Cost	115	122	111	121	114	114	117	117	114	115	106	111

2.9 Execution Plan

Roundabout grade separation and pedestrian underpass projects which are to be undertaken over the next five-year plan beginning in 1996, are to be implemented as follows: (Table A-11 Implementation Plan)

Table A-11 Implementation Plan

		Implementation Plan					
		1995	1996	1997	1998	1999	2000
Final Engineering Design							
Flyover	Barka Roundabout R/A						
	Sohar R/A						
	Naseem Garden R/A						
	Al Mulladah J/C						
	Saham R/A						
	Khaburah R/A						
	Falaj Al Qabail R/A						
	Aqr R/A						
Pedestrian Underpass	Priority 1						
	Priority 2						
	Priority 3, 4, 5						
	Priority 6, 7, 8						
	Priority 9, 10						
	Priority 11,12						

- Roundabout Implementation

  : Roundabout grade separations are to be constructed two per year in order of priority.

- Pedestrian Underpass Implementation

  : The two pedestrian underpasses of greatest priority are to be constructed in the first year, while the remaining are to be constructed two or three per year.

2.10 Economic Analysis

(1) Economic Analysis for Flyovers

To examine economic feasibility of the project, cost and benefit was compared. Cost was economic cost that deduct tax and land acquisition cost from the cost written in 2.8 Cost Evaluation, but maintenance cost was included. For the benefits, saving of running cost and travel time were considered and they were transformed in monetary team. Financial analysis was not conducted. Because, construction and maintenance of roads are undertaken by governmental organization using general revenue and not considering project.

Discount rate of 12% was considered to evaluate the cost and benefit in the future in present value.

The result of analysis is shown in the following table.

Economic Cost*	Benefit*	EIRR (%)	B/C	NPV*
23,848	25,994	12.9	1.09	2,146

* in thousands R.O.

These figures were derived from direct countable effect only and would become bigger, if uncountable direct effect such as traffic safety and uncountable indirect effect such as social developing were taken into consideration.

(2) Economic Analysis for Pedestrian Underpasses

Economic indices for pedestrian underpasses was calculated as shown in following table considering benefit by removal of speed limit on Batinah Highway.

Economic Cost*	Benefit*	EIRR (%)	B/C	NPV*
1055	915	10.4	0.87	-140

The results turned out not feasible. However, if consider the important factors such as pedestrians' waiting time for crossing or reduction of traffic accidents, construction of underpass will contribute to resident safety. Especially at Al Bidayah where many pedestrians are crossing, and at Al Tarif where visibility is bad, the construction of underpasses are urgently needed.

2.11 Conclusion and Recommendation

The results of this survey indicate that this project is feasible both from a technological viewpoint as well as an economic one. Aside from the direct benefits to be gained by the region as a whole, a number of indirect benefits are also expected to bolster the economy of the Batinah region. Judging from the EIRR value, financial feasibility is not necessary high, but there are sufficient expectations towards indirect benefits coming out of the actualization of the project. We hereby propose the priority actualization of grade separation for the following roundabouts: Barka Roundabout, Sohar Roundabout, Al Muladdah Roundabout, Saham Roundabout, and Naseem Garden Roundabout. All of these locations are expected to become overcrowded within the next few years and demand priority actualization.

An analysis was also conducted for underpasses in the same manner as for flyovers, but they were not deemed economically sound. However, this analysis took only traffic functions into consideration, so this project is believed to hold sufficient merit out when the safety of pedestrians is considered.

[Effects of the Project]

Grade separation of the roundabouts will ameliorate traffic flow by allowing traffic to pass through at higher speeds, improving safety and comfort conditions, as opposed to conditions of yield regulation, etc., imposed by ground-level rotaries. Neighboring communities which have been divided by the highway will also benefit due to improved integratability and safe crossings for children and elderly. All of these factors will work together to improve the quality of life in the region. Furthermore, accompanying the construction of these two types of facilities, fulfillment of the roles described below will also be attained:

- Straightening of the intercity infrastructure, further development of economic sphere centered in Muscat, strengthening of transportation network with neighboring countries, increasing Batinah region's potential as an important role-player in the development of the Sultanate.

- Forming of new economic and social relations of communities on both sides of the highway.

- Widened social and economic integration of communities on both sides of the highway.

Effects of the project should be made classifying the effects as follows:

Effects	Direct	Countable	-	Running cost and time saving
		Uncountable	-	Safety, comfortable
	Indirect	Countable	-	Impact to local contractor
		Uncountable	-	development effect

It will be necessary to conduct the detailed design in consideration of economic feasibility and aesthetics after full consideration of the present situation in Oman, its facilities, and capability in construction. At the same time, one must consider the importance of the Batinah Highway as an important route of the Arabian peninsula when considering the bridging of Irish crossings, the use of box culverts and/or the supplying of a flood-warning system.