

Chapter 4 Detailed Design

In the corridor selected by the study shown in Chapter 3 and taking into consideration the site conditions and design premises, the design of the Parkway was developed, including setting the final route and alignment, both horizontally and vertically, cross section, pavement, drainage, bridges, etc.

4.1. Route of the Parkway

A study was conducted to determine the route of the Parkway from various alternative routes within the selected corridor Option-1.

The Parkway route was divided into the following sections:

- Part-A: The northern part in the cliff area with very steep slope: with 4 Alternatives, and
- Part-B: The southern part with rather moderate slope area: 6 options,

Furthermore, Part-B is sub-divided into 2 sections:

- Section-1, and
- Section-2.

The parts and sections are shown in Figure 4.1.

4.1.1. Alternative Study to set the Route of the Parkway

(1) Evaluation Criteria

All alternatives and options are evaluated separately. The evaluation criteria are:

Geometry:

The evaluation included studying the percent of straight segments within the route, number of horizontal curves and the sharpness of curves. Each alternative was given a score depending on the above.

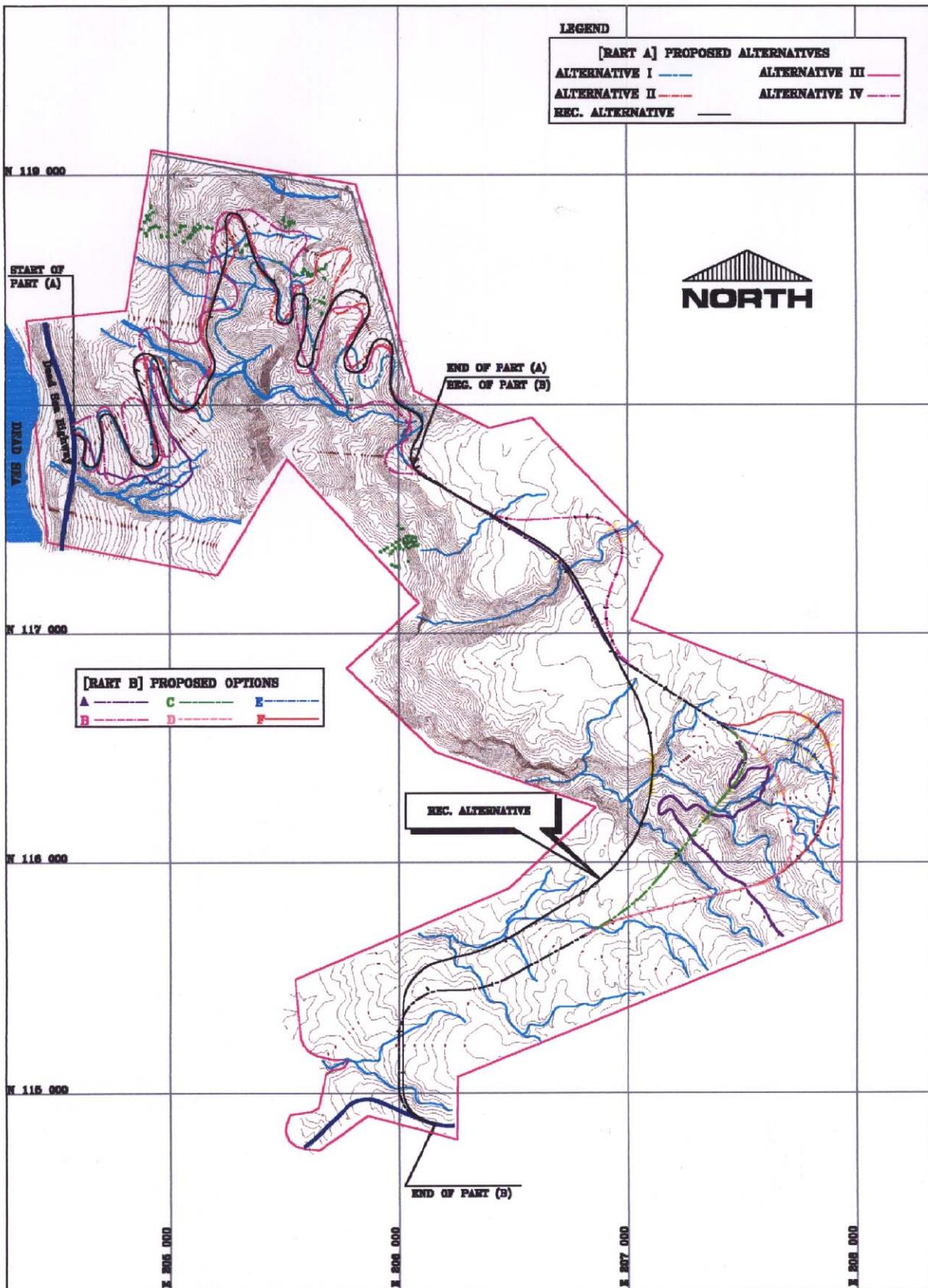
Geology:

Each alternative and option is evaluated geologically. Bearing in mind that most of the alternatives run within almost the same formations, the evaluation is based mainly on the length of the alternative within the Lisan Marl Gravel Formation. In addition to that, alternatives and options were evaluated depending on the sharpness of the wadi crossing besides the disturbance to the wadi banks.

Earthworks:

The vertical alignment of each alternative and option is properly designed with the same design criteria being applied to all alternatives. Road design software Civil Soft is used in the design and in calculating the quantities of earth works. The alternative and / or option with the minimum amount of earthworks is highly evaluated and vice versa.

Figure 4.1 Route Alternatives by Part and Section



Source: JICA Study Team

Archaeology:

In the design of all alternatives and options, archaeological sites discovered in the area are avoided as much as possible. However, despite all the efforts, some archaeological sites with varied importance are affected. The archaeological evaluation of each alternative and option is totally dependent on the number and importance (Category) of archaeological sites being affected and could not be avoided. Special care and attention is paid to Category I Archaeological Sites.

Ecology:

The main concern of the Ecologists when evaluating the alternatives is to examine the disturbance made to potentially high and medium sensitive areas within the study corridor. As previously discussed in related sections, the study corridor falls within a prohibited hunting zone. Each alternative and option is evaluated and given a score depending on the number of crossings of highly sensitive wadis and the opening of highly sensitive areas.

Hydrology:

Hydrological evaluation was based on the number of wadi crossings, the smoothness of the route and the need for main flood protection works.

Additionally, cost analysis is also carried out in order to evaluate all alternatives.

(2) Part-A

Comparison Study

In evaluating the alternatives, different weights are given for each aspect of evaluation. Geometry, Geology (Safety), Hydrology and Earthworks (Cost) are given more weight than others. The best alternative in terms of the above is carefully chosen and revised in order to improve its score in terms of Archaeology and Ecology.

The topographic survey, as described in the relevant section started from the Dead Sea side where four survey teams were able to survey the first section of the corridor starting from the Dead Sea shore until reaching and slightly exceeding the coordinate line of E 206.000.

Route selection and study for this section started immediately after the topographic survey was finished. Four alternative routes were carefully chosen on the detailed topographic maps and aerial photographs and examined on site through carrying out extensive site visits by all design team members.

After extensive site visits and careful study of both the detailed topographic maps and the available aerial photographs, it was found out that there is only one possible area on the Dead Sea Highway to start the project from. This intersection point is common for all alternatives.

The start point of the project, in addition to the following, guided the choosing process of the alternatives:selection

- The existing wadis
- Trying not to intersect perpendicularly with the Contour Lines as doing so will cause very steep slopes in the profile.
- Maximum desirable longitudinal slope of 10% and absolute maximum longitudinal slope of 12%.
- The steep right side of the study corridor (for Part-A) which should be avoided as it is not possible to construct a road in that area.

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- Madash Al Hammara at the extreme right side of the corridor.
 - The palm trees at the left side of part (A) corridor and trying to avoid as many trees as possible
 - The Archaeological and Ecological sites, especially those with great significance.
 - Avoiding huge quantities of cut especially in the hazardous zones described in the Geology section of this report.

Taking all the above into consideration, the following four alternatives as shown in Figure 4.1 are the results of the extensive study:

1) Alternative I

This alternative starts from the designated intersection point with the Dead Sea Highway Route 65 and runs east for a short distance, before starting to climb the mountainous terrain by running parallel to the contour lines as much as possible, to create a smooth profile.

Due to the difficult nature of the area, a series of small radius curves are introduced (min. $R = 30m$) forming a series of reverse and broken back curves

The design speed in this section is limited to 30kph due to the sharp curves.

Findings

The length of this route is 5.3km.

The profile of this alternative was designed taking into consideration the maximum allowable grade with the production of breaks in the slope in addition to minimising cut and fill.

Volume of cut for this alternative is $97,516m^3$, while volume of fill is $570,519m^3$.

The route crosses two Category I and one Category II Archaeological sites in addition to crossing one Ecologically highly sensitive wadi and opens up two highly sensitive areas.

From the Hydrological point of view, this route crosses three wadis where two pipe culverts and one box culvert are needed. Due to its route, this alternative needs major protection works at two locations, the first location is approximately at Station 2+100 while the second location is at Station 3+950.

In terms of Geology, this alternative is highly evaluated due to the shorter length and minimum cut in Lisan – Marl Gravel Formation.

2) Alternative II

This alternative starts like the rest of the alternatives from the same intersection point with the Dead Sea Highway and starts climbing the mountainous terrain limited from the right side of the corridor with Madash Al Hammara until it intersects with a main wadi at Station 1+950. The route continues running north for about 600m, during which it intersects with four small wadis.

After that the route continues in the east and south-east direction climbing the mountains in a series of reverse curves and running through zones of rural palm trees until it reaches the designated end point of this section.

Findings

The length of this route is 5.35km.

The profile of this alternative is designed taking into consideration the maximum

allowable grade with the production of breaks in the slope in addition to minimising cut and fill.

Volume of cut for this alternative is 144,358m³, while volume of fill is 402,711m³.

The route crosses five Category I and one Category II Archaeological sites in addition to crossing four Ecologically highly sensitive wadis and opens up to a large highly sensitive area.

From the Hydrological point of view, this route crosses eight wadis where seven pipe culverts and one box culvert are needed. No major flood protection works are found to be necessary due to the fact that the route crosses most of the wadis at almost right angles.

In terms of Geology, this alternative is not highly evaluated due to the fact that it passes through the Lisan – Marl Gravel Formation for considerable parts of its length.

3) Alternative III

This alternative starts like the other alternatives from the same intersection point with the Dead Sea Highway and starts climbing the mountainous terrain limited from the right side of the corridor with Madash Al Hammara until it intersects with a main wadi at Station 1+950 (almost the same as alternative II). The route continues running north for about 700m during which it intersects with three small wadis.

After that the route continues mainly in the south-east direction climbing the mountains and running through zones of rural palm trees (less than alternative II) until it reaches the designated end point of this section.

Findings

The length of this route is 5.57km.

The profile of this alternative is designed taking into consideration the maximum allowable grade with the production of breaks in the slope in addition to minimising cut and fill.

Volume of cut for this alternative is 264,263m³ while volume of fill is 602,505m³.

The route crosses four Category I and one Category II Archaeological sites in addition to crossing four Ecologically highly sensitive wadis and opens up to a large highly sensitive area.

From the Hydrological point of view, this route crosses seven wadis where six pipe culverts and one box culvert are needed. No major flood protection work is found to be necessary due to the fact that the route crosses most of the wadis at almost right angles.

In terms of Geology, this alternative is moderately evaluated due to the fact that it passes through the Lisan – Marl Gravel Formation for longer parts of its length when compared with Alternative I.

4) Alternative IV

This alternative starts like the rest of the alternatives from the same intersection point with the Dead Sea Highway. It starts climbing the mountainous terrain limited from the right side of the corridor with Madash Al Hammara, like all other alternatives, until it intersects with a main wadi at Station 1+800. The route continues running east and north-east for about 900m during which it intersects with three small wadis.

After that the route continues mainly in the south-east direction climbing the mountains

and running through zones of rural palm trees until it reaches the designated end point of this section.

Findings

The length of this route is 4.8km, which is the shortest.

The profile of this alternative is designed taking into consideration the maximum allowable grade with the production of breaks in the slope in addition to minimising cut and fill.

Volume of cut for this alternative is 495,463m³ while volume of fill is 677,186m³.

The route crosses three Category I and one Category II Archaeological sites in addition to crossing three Ecologically highly sensitive wadis and opens up two highly sensitive areas.

From the Hydrological point of view, this route crosses seven wadis where six pipe culverts and one box culvert are needed. No major flood protection work is found to be necessary.

In terms of Geology, this alternative is not highly evaluated due to the fact that it passes through the Lisan – Marl Gravel Formation for longer parts of its length (when compared with the other alternatives).

The evaluation of the alternatives is summarised in Table 4.1 (1) (2), where scores for different aspects of the evaluation are given based on the following:

- First rank evaluation: 4 points
- Second rank evaluation: 3 points
- Third rank evaluation: 2 points
- Fourth rank evaluation: 1 point

Further evaluation regarding cost comparison among the alternatives is summarised in Table 4.2.

Evaluation and Selection

The project is divided into two parts as previously discussed due to the progress of surveying works in addition to the nature of the area. Part-A is considered as the difficult part according to topographical conditions.

Alternatives for Part-A are examined and evaluated against different criteria as shown in the previous Chapter.

In the coming sections of this chapter, the findings of this section will be utilised in recommending the best alternative within the study corridor.

All Alternatives studied are shown in Figure 4.1.

1) Evaluation

According to the evaluation carried out as shown in Tables 4.1 (1) and (2), the following could be found:

- Alternatives I and III score the highest results in reference to the scoring system previously explained.
- Alternatives I and III have the highest score in terms of Geology and Ecology.
- Alternative III has the highest evaluation in terms of Geometry whereas Alternative I has the highest evaluation in terms of rough volume of cut.
- Alternative II is the cheapest whereas Alternative IV is the most expensive.

Table 4.1 (1) Evaluation of Alternative Route of Part-A (1)

Alt.	Archaeology (A)	Ecology (B)	Hydrology (C)	Total Score (A)+(B)+(C)
I	4	4	1	9
	- Crosses 2 Category-I* and 1 Category-II sites**	- Crosses one highly sensitive wadi, opens up two highly sensitive areas and crosses several medium sensitive wadis.	- Route OK. - Wadi crossings = 3 (2 pipe culverts+1 bridge) - Main flood protection works are required at two locations	
II	1	1	3	5
	- Crosses 5 Category-I* and 1 Category-II sites**	- Crosses four highly sensitive wadis, opens up large highly sensitive areas and crosses several medium sensitive wadis.	- Route OK. - Wadi crossings = 8 (7 pipe culverts+1 bridge) - No main flood protection works are required	
III	2	3	4	9
	- Crosses 4 Category-I* and 1 Category-II sites**	- Crosses two highly sensitive wadis, opens up large highly sensitive areas and crosses several medium sensitive wadis.	- Route OK. - Wadi crossings = 7 (6 pipe culverts+1 bridge) - No main flood protection works are required	
IV	3	2	2	7
	- Crosses 3 Category-I* and 1 Category-II sites**	- Crosses three highly sensitive wadis, opens up two highly sensitive areas and crosses several medium sensitive wadis.	- Route needs to be adjusted. - Wadi crossings = 7 (6 pipe culverts+1 bridge) - No main flood protection works are required	

Note: * Category I site to be avoided, but if not possible, they must be excavated and documented.

** Category II site to be avoided but if not possible, watching brief must be carried out during construction.

Source: JICA Study Team

Table 4.1 (2) Evaluation of Alternative Route of Part-A (2)

Alt.	Geology (D)	Geometry (E)	Earth Works (F)	Score (D)+(E)+(F)
I	4	1	4	9
	- Shorter length in lisan - Marl Gravel Formation	- No. of curves less than 50m. Radius = 18	- Cut (m ³) = 97,516	
II	1	2	3	6
	- Long section within the Lisan - Marl Gravel Formation	- No. of curves less than 50m. Radius = 9	- Cut (m ³) = 144,358	
III	3	4	2	9
	- Second Shorter length in Lisan - Marl Gravel Formation	- No. of curves less than 50m. Radius = 5	- Cut (m ³) = 264,263	
IV	2	3	1	6
	- Long section within the Lisan - Marl Gravel Formation in addition to expected large cut	- No. of curves less than 50m. Radius = 7	- Cut (m ³) = 495,463	

Source: JICA Study Team

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- One major deficit of Alternative I is its Geometry where sharp curves with radii below 50m, and down to 30m, form more than 50% of its entire length. Reverse and broken back curves form a major feature of this alternative.
 - Two main disadvantages of Alternative III are the crossing of four Category I Archaeological sites in addition to the volume of cut which is relatively large and its effect on cost.
 - One major disadvantage of Alternative II, despite the fact that it is the cheapest, is its long section within the Lisan - Marl Gravel Formation which is considered less stable, in addition to its difficult geometry. Many reverse and broken back sharp curves form a considerable part of its length.

2) Selection and Confirmation

Studying thoroughly Tables 4.1 (1) and (2), in addition to taking the above mentioned into consideration, will lead to choosing Alternative III as the best route.

Further clarification is made to the route of Alternative III in order to avoid some Archaeological sites in addition to reduce the earthwork quantities, as these form the major drawbacks of this alternative. The following clarifications and improvements are introduced for this alternative:

- Spiral curves with minimum lengths of 40m, which is considered as the minimum super-elevation runoff for the designed speed of 30kph proposed for this difficult part of the road. 50m spirals are introduced whenever possible.
- Most of the horizontal radii are increased having a minimum radius of 33m instead of 30m which is considered as the minimum for the proposed design speed.
- Some horizontal curves are omitted for a smoother route.
- A better and safer crossing point for the wadi at Station 1+750 is proposed avoiding a relatively dangerous reverse curve. In addition, another crossing point for the wadi at Station 5+000 is proposed for hydrological and topographic reasons.
- Some minor adjustments are introduced to the route for topographical reasons in addition to trying to avoid some Category I Archaeological sites; Site-33, 39 and 48.

After clarification, Alternative III is given the title of Alternative V as shown in Figure 4.1..

(3) Part-B

This part starts at the end of Part-A and continues in the east and south-east direction until it intersects with the existing road at approximately the intersection of the coordinate line E 206,000 and N 115,000.

Route selection and study for this section started immediately after the topographic survey was finished. Alternative routes were carefully chosen on the detailed topographic maps and aerial photographs and examined on site through carrying out extensive site visits by all design team members.

After extensive site visits and careful studying of both the detailed topographic maps and the available aerial photographs, it was found out that for most sections of the corridor for Part-B one alternative is highly recommended. Other alternatives in these sections will have similar properties due to the similar type of terrain the route passes through.

Different alternatives or options are identified for two sections in this section of the corridor, as follows:

- Section-1: the northern section between N 117,500 and N 117,000, two options of

Option-A and Option-B are identified, and

- Section-2: the southern section between N 116,700 and N 115,800, Option-C, Option-D, Option-E and Option-F are

The start point of this section, at the end of Section-1, in addition to the following, guided the selection process of the alternatives:

- The existing wadis
- Trying not to intersect perpendicularly with the Contour Lines as doing so will cause very steep slopes in the profile.
- Maximum desirable longitudinal slope of 10% and absolute maximum longitudinal slope of 12%.
- The steep banks of Wadi Hammara.
- The Archaeological and Ecological sites especially the ones with great significance.
- Avoiding huge quantities of cut especially in the hazardous zones described in the Geology section of this report.

Taking all the above into consideration, the following options are the results of the extensive study. For the route alignment of the options refer to Figure 4.1.

1) Option-A

This option starts at Station 0+300 and runs in the south-east direction. The route runs through flat terrain except when intersecting two wadis along its length.

The length of this route is 1.05km. Volume of cut for this alternative is 77,045 m³, while volume of fill is 5,933 m³.

The route is not crossing any known Archaeological site.

From the Hydrological point of view, this route crosses two wadis where one pipe culvert and one box culvert are needed. No major flood protection works are found to be necessary. It is decided to use a bridge for the second wadi for structural, topographical, archaeological and ecological reasons, despite the fact that the amount of flow in the wadi requires only a box culvert.

In terms of Geology, this alternative is not highly evaluated due to the sharper wadi crossing in addition to the expected relatively large disturbance it will cause to the wadi banks.

2) Option-B

This option starts at Station 0+300 like Option-A, and runs first in the east direction and then diverts south until it joins the original route. The route runs through flat terrain except when intersecting two wadis along its length.

The length of this route is 1.35km. Volume of cut for this alternative is 40,000m³, while volume of fill is 16,881m³.

The route passes close and potentially crosses one Category I Archaeological site.

From the Hydrological point of view, this route crosses two wadis where one pipe culvert and one box culvert are needed. No major flood protection work is found to be necessary. However, it can be clearly seen that the crossing location for the second wadi is less sharp and has relatively smaller catchment area. It is decided to use a bridge for the second wadi for structural, topographical, archaeological and ecological reasons, despite the fact that the amount of flow requires only a box culvert.

In terms of Geology, this alternative is highly evaluated due to the flatter wadi crossing in

addition to the less disturbance it will cause to the wadi banks.

3) Option-C

At almost Station 1+700, four options are identified to cross Wadi Hammara at four different locations. Option (C) turns right directly and runs in the south-west direction until joining the main route.

The length of this route is 1.3km. Volume of cut for this alternative is 111,685 m³, while volume of fill is 116,985 m³.

The route crosses two Category I sites including site No.2 which should be avoided at all costs.

From the Hydrological point of view, this route crosses two wadis where two box culverts are needed. No major flood protection work is found to be necessary. A bridge is proposed for the first wadi due to structural and topographical reasons in addition to environmental and ecological factors, despite the fact that no bridge is needed according to the amount of flow estimated from this catchment area.

In terms of Geology, this alternative is not highly evaluated due to the steep wadi crossing in addition to the excessive disturbance it will cause to the wadi banks.

4) Option-D

This option crosses Wadi Hammara further east and with a flatter curve than for Option-C. Option-D turns right directly and runs in the south direction until joining the main route.

The length of this route is 1.64km. Volume of cut for this alternative is 54,261 m³, while volume of fill is 130,656 m³.

The route crosses one Category II site, and passes through site No.2 of Category 1.

From the Hydrological point of view, this route crosses four wadis where two box culverts and two pipe culverts are needed. No major flood protection work is found to be necessary. A bridge is proposed for the first wadi due to structural and topographical reasons in addition to environmental and ecological factors, despite the fact that no bridge is needed according to the amount of flow estimated from this catchment area.

In terms of Geology, this alternative is highly evaluated due to the flatter wadi crossing in addition to the minimum disturbance it will cause to the wadi banks.

5) Option-E

This option crosses Wadi Hammara further east and with a sharper curve than for Option -D. Option-E turns right directly and runs in the south direction until joining the main route.

The length of this route is 2.0km. Volume of cut for this alternative is 98,974 m³, while volume of fill is 160,189 m³.

The route passes through one Category II and two Category III Archaeological sites.

From the Hydrological point of view, this route crosses seven wadis where two box culverts and five pipe culverts are needed. No major flood protection work is found to be necessary. A bridge is proposed for the first wadi due to structural and topographical reasons in addition to environmental and ecological factors, despite the fact that no bridge is needed according to the amount of flow estimated from this catchment area.

In terms of Geology, this alternative is not highly evaluated due to the steep wadi crossing in addition to the large disturbance it will cause to the wadi banks.

6) Option-F

This option crosses Wadi Hammara further east than other options and with relatively sharper curves. Option-F turns right directly and runs in the east and then south directions until joining the main route.

The length of this route is 2.13km. Volume of cut for this alternative is 109,900 m³, while volume of fill is 123,235 m³.

The route passes through one Category II and two Category III Archaeological sites.

From the Hydrological point of view, this route crosses seven wadis where two box culverts and five pipe culverts are needed. No major flood protection work is found to be necessary.

A bridge is proposed for the first wadi due to structural and topographical reasons in addition to environmental and ecological factors, despite the fact that no bridge is needed according to the amount of flow estimated from this catchment area.

In terms of Geology, this alternative is not highly evaluated due to the steep wadi crossing in addition to the large disturbance it will cause to the wadi banks.

The evaluation of the options is summarised in Table 4.2 (1) (2) where scores for different evaluation criteria are given.

Table 4.2 (1) Evaluation of Options of Part-B (1)

Option	Archaeology	Ecology	Hydrology	Score (A)+(B)+(C)
	(A)	(B)	(C)	
A	2	1	1	4
	- Does not cross any known sites.	- Crosses one major wadi and involves major cut/fill disturbance.	- Larger catchment area	
B	1	2	2	5
	- Passes close to and potentially crosses one Category I Site.	- Crosses five smaller tributaries as opposed to one large wadi. - Cut/fill disturbance is less	- Less catchment area - Better wadi crossing	
C	1	1	4	6
	- Crosses 2 Category-I* sites including Site No. 2 which should be avoided at all costs.	- Further down stream. Highest cut and fill disturbance and crosses two major wadis	- No. of crossings = 2 (BC)	
D	2	2	3	7
	- Crosses 2 Category-II** sites, passes close to Site No. 2 (Category-I) and crosses 4 category-III sites.	- Next route upstream, cut/fill disturbance is relatively high and crosses one high sensitive wadi	- No. of crossings = 4 (2BC + 2PC)	
E	4	3	2	9
	- Crosses 1 Category-II** and 2 Category-III - best avoiding 2 Category-I sites	- Second furthest upstream. Lower cut/fill disturbance	- No. of crossings = 7 (2BC + 5PC)	
F	3	4	1	8
	- Crosses 1 Category-II** site and 2 category-III sites, but comes close to 1 Category-I site (No. 41)	- Furthest upstream. Lower cut/fill disturbance	- No. of crossings = 7 (2BC + 5PC)	

Note: * Category I site to be avoided, but if not possible, they must be excavated and documented.

** Category II site to be avoided but if not possible, watching brief must be carried out during construction.

Source: JICA Study Team

Table 4.2 (2) Evaluation of Options of Part-B (2)

Option	Geology	Geometry	Earth Works	Score (D)+(E)+(F)
	(D)	(E)	(F)	
A	1	2	2	5
	- Flatter wadi crossing - Maximum disturbance to wadi banks	- Flatter curves - One reverse curve	- Cut (m ³) = 40,000	
B	2	1	1	4
	- Sharper wadi crossing - Maximum disturbance to wadi banks	- Sharper curves - Two reverse curves	- Cut (m ³) = 43,000	
C	1	4	3	8
	- Steep wadi crossing - Maximum disturbance to wadi banks	- shorter	- Cut (m ³) = 81,870	
D	4	3	4	11
	- Flat wadi crossing - Minimum disturbance to wadi banks	- Second shortest - Broken back curve	- Cut (m ³) = 54,260	
E	2	2	2	6
	- Steep wadi crossing - Moderate disturbance to wadi banks	- Long alignment - Sharp curve - Reverse curve	- Cut (m ³) = 99,000	
F	3	1	1	5
	- Steep wadi crossing - Acceptable disturbance to wadi banks	- Long alignment - Sharp curve - Reverse curve	- Cut (m ³) = 109,900	

Source: JICA Study Team

Evaluation and Selection

The major feature of Part-B is two bridges in two different locations in addition to the existence of more than 10 Category-I Archaeological sites. Furthermore, a stretch of a Roman Road was recently discovered near Wadi Hammara and running very close to Archaeological

Site No.2. The general terrain of Part-B is flat to hilly except for the two locations where for some technical reasons bridges were used. Options for Part-B were examined and evaluated against different criteria as shown in the previous Chapter.

In the coming sections of this chapter, the findings of this section will be utilised in recommending the best alternative within the study corridor. All studied alternatives and options are shown in Figure 4.1. As previously discussed, options are identified in two sections along Part-B.

1) Options-A and B in Section-1 of Part-B

Two options are identified in this section as previously discussed and results are tabulated and shown in Tables 4.2 (1) and (2). The following could be detected from those tables:

- Option-A has major advantages of smaller earthwork quantities and better geometry where flat curves are the main feature of this option.
- Option-B has major advantages in terms of shorter bridge required when crossing the main wadi, and this of course is reflected in the construction cost.
- Option B has one major disadvantage of having two successive sharp reverse curves which is not recommended especially when having a bridge as in this case. This option also crosses or passes by one Category I Archaeological site as shown in the drawings.

Taking all the above into consideration in addition to studying carefully the said tables, **Option-A** is recommended as the optimum route for this part.

2) Options-C, D, E and F in Section-2 of Part-B

Four options were identified and evaluated as shown in Tables 4.2 (1) and (2). The following represent the main findings:

- Option-D is ranked first in terms of Geology, Geometry and Earthworks whereas Option -F is ranked last.
- Option-E and F are ranked first in terms of Archaeology and Ecology but are ranked last in terms of Geometry and Earthworks.
- Option -C is ranked last in terms of Archaeology and Ecology as it hits and crosses one of the major important Archaeological sites in the study area.
- Option-C is ranked last in terms of Geology and first according to Hydrology due to the number of wadi crossings.
- In terms of Geometry, Options-E and F are ranked last due the route which consists of reverse and broken back curves at a very sensitive location (bridge)
- When studying the costs, Option-D has the lowest construction cost taking into consideration the construction cost for the four options is very close and falls within a 10% range.

For all the above, **Option-D** is recommended as part of the optimum route for Part-B. However, a stretch of Old Roman Road was discovered after extensive study of the Archaeological Sites with the presence of a representative from the Department of Antiquities in Wadi Hammara Area.

Studying the location and relation of this Roman Road with the Archaeological Sites discovered in the area, it is expected that this Road might extend at both ends of the discovered stretch to connect the various Archaeological Sites. In order to avoid all the above and taking into consideration that all Options hit either the Roman Road or its expected extensions in addition to some Archaeological sites, a new option was studied, analysed and recommended.

One major advantage of this recommended option is its short length (800m) in addition to the fact that it avoids totally all Archaeological sites and the Roman Road and its expected extensions. The smoother route of this option also made the lengths of the remaining sections of Part-B relatively shorter than all other options. The total length of Part-B was reduced by almost 1.0km.

The disadvantage of this option is the relatively steeper wadi crossing at Wadi Hammara where a relatively larger bridge than other options is required. In order to improve this steeper slopes were introduced (12%) in order to minimise both the length of the bridge and the height of piers. Flatter vertical curves were also introduced for better sight distance.

The recommended route through Part-A and Part-B is shown in Figure 4.1 and Figure 4.2 shows the longitudinal profile for the recommended route.

4.1.2. Connection Road Section Added (Part-C)

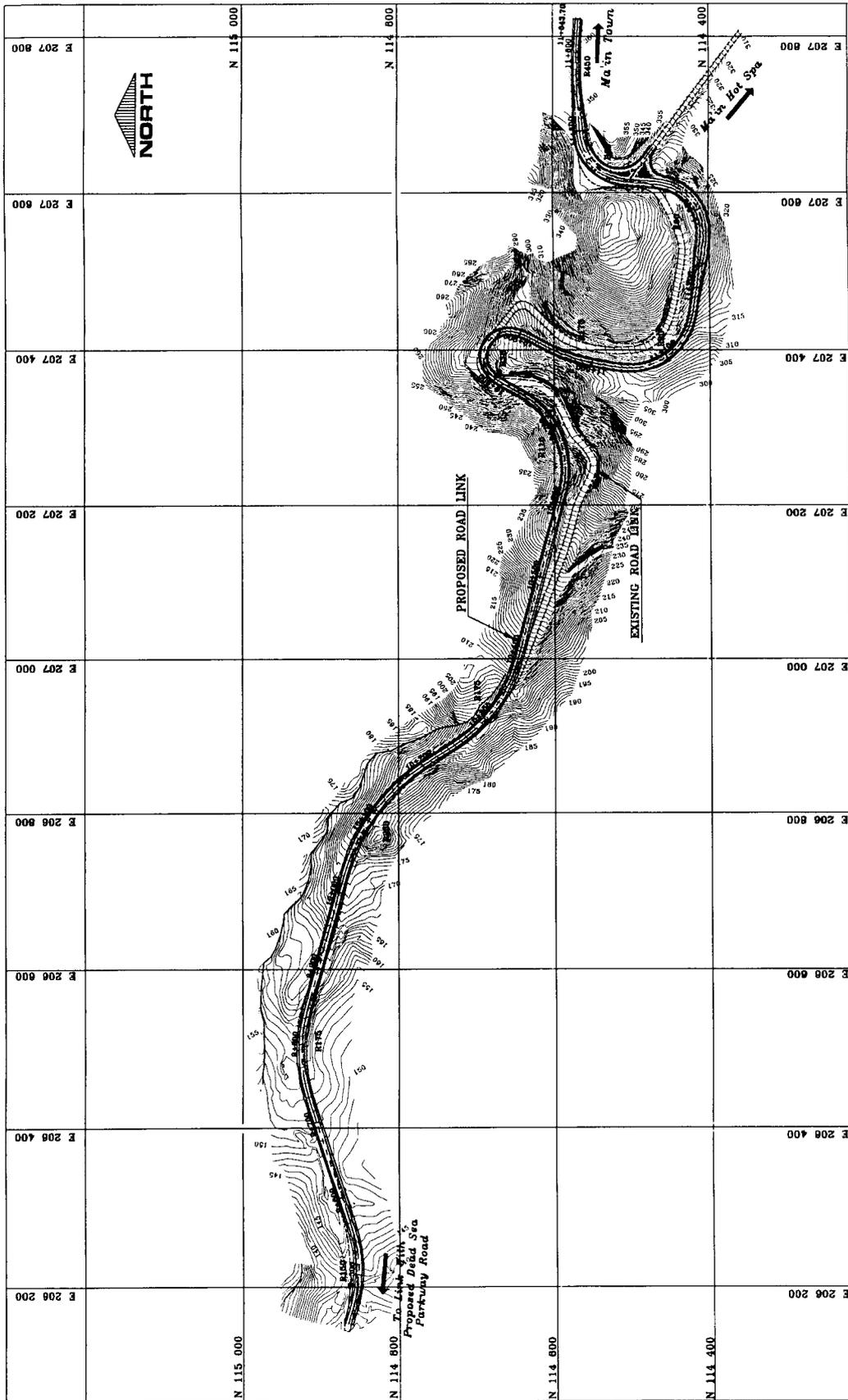
The original Terms of Reference for this road link pointed out that this existing road needs rehabilitation or up-grading. Through the extensive site visual inspections and topographic survey, the following are determined:

- The existing road is in very bad condition.
- The road suffers from very sharp horizontal curves not even appropriate for a design speed of 20kph in some stretches.
- Steep gradients exceeding 24% exist in some stretches.
- Many potholes were observed in addition to the failure occurring at the edges of the road making the available width critical at some locations.
- The existing road suffers from poor drainage that was reflected negatively on the shoulders, edges and even the roadway itself.
- The cut slopes at some sections were observed to be steep in addition to the fact that no protection works were observed although needed.

Taking all these facts into consideration, it was confirmed to re-construct the section based on the following, (refer to Figure 4.3):

- Re-align the first part of the link (from Ma'in side) and shift it from the existing road link considerably. This makes the horizontal alignment smoother where flatter curves are introduced and some broken back and reverse curves on the existing road link are omitted.
- The above enables having more gentle vertical slopes (gradients) where the maximum does not exceed 14%. Those slopes are to replace the existing steep slopes of 18% and 24%.
- The rest of the route (the flat part of the existing road link) is proposed to follow the existing one with some modifications to improve both the vertical and the horizontal alignments.
- The proposed cross section is similar to the one proposed for the original Dead Sea Parkway Project to integrate this link with the said main project.
- The proposed design speeds (30kph and 50kph) are also similar to the ones proposed for the original Parkway Project.

Figure 4.3 Final Alignment of Part-C



Source: JICA Study Team

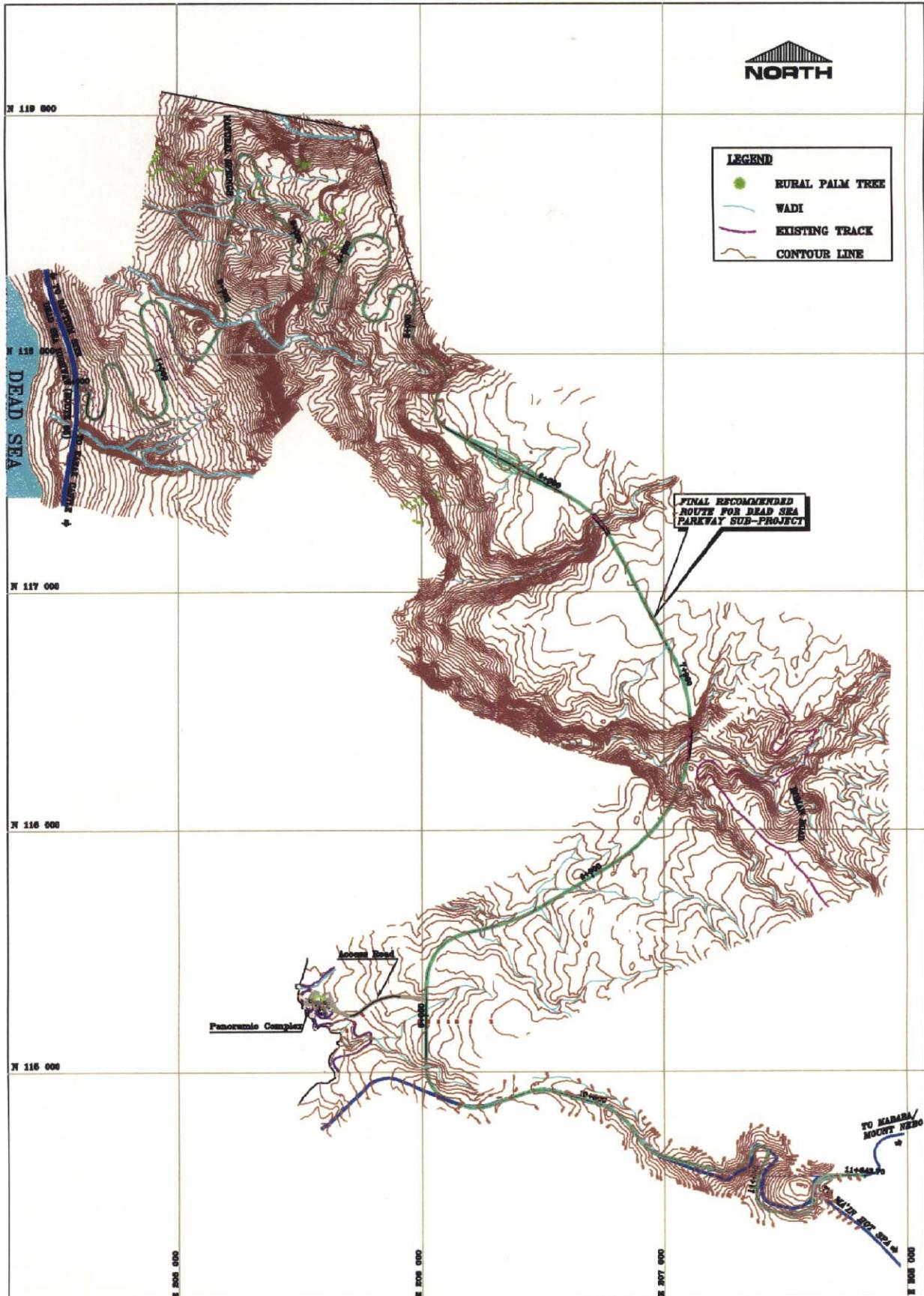
4.1.3. Items to be considered

The following matters should be confirmed regarding the design of this project:

- 1) The geo-technical investigation covered the following sections of the project:
 - Road section from approximately Sta.5 + 500 to Sta.9 + 436 (Part-A and B); the investigation was carried out by JICA D/D Study Team. However additional soil investigation by the contractor should be carried out prior to the construction at the bridges, retaining wall locations and any other location requested by the engineer, especially in Part-A.
 - Road section Sta. 9 + 436 until the end of the road at the intersection point with the Ma'in Main Road (Part-C); the investigation was carried out by the Local Consultant (Consolidated Consultants) under the instruction of MPWH.
- 2) MOTA and MPWH were informed officially that the first 5.5km of the Parkway from the North could not be accessed and hence could not be geo-technically investigated at this stage. Then it was agreed to conduct a study on the geological maps and extensive visual inspections at this stage by both the Local and the Japanese Geo-technical Experts of JICA D/D Study Team. This has helped in making useful assumptions regarding the stable cut and fill slopes and the required protection measures in this section of the Parkway Project. These are subject to be revised during construction if the assumptions fail to meet the results of the geo-technical investigation to be carried out by the contractor.
- 3) The contractor shall review and revise the design if necessary when preparing the shop drawings to meet all the results of the additional geo-technical investigation and tests subject to the approval of the engineer.
- 4) The design criteria used for the original Parkway (Sections of Part-A and B) is applied in full to Part-C, with one exception being the maximum vertical slope. Due to the steep slopes of the existing road link of Part-C, the reduction of the existing gradients from 24% and 18% to become 14% and 12% respectively is the optimum that could be done with minimum costs and within the same corridor.
- 5) While the topographic survey for Part-A and B carried out by JICA Study Team covered a width of 600m, the survey carried out by MOTA for the Part-C corridor was 2.25km long and 100m wide (50m from each side of the centreline of the existing road). This, of course, has reflected the lack of space to have an alignment other than the existing one.

Figure 4.4 shows the final recommended and confirmed route through the sections Part-A, B and C for the Parkway Project.

Figure 4.4 Final recommended and confirmed Route through Parkway (Part-A, B and C)



Source: JICA Study Team

4.2. Parkway Alignment Design

On the selected route, a detailed study to set the final vertical and horizontal alignment was made as described below.

4.2.1. Horizontal Alignment

After studying the topography of the corridor in addition to all other necessary factors, it was determined by the design team to utilise two design speed, namely, 30kph and 50kph.

The 30kph design speed is adopted mainly for the difficult parts of the alignment that can be summarised as follows:

- From Sta. 0 + 000 to Sta. 5 + 540, and
- From Sta. 10 + 595 to 11 + 643.7.

The 50kph design speed is adopted for the rest of the alignment (i.e. Sta. 5 + 540 to Sta. 10 + 595).

For the 30kph design speed stretches, series of reverse horizontal curves with radii that range between 30m to 725m are proposed to suit natural ground slopes and site conditions. In the last stretch of the alignment (the existing road link), the difficult topography in addition to the narrow width of the corridor (100m) containing the existing road link are main factors affecting the selection of the radii of the curves and hence, the adoption of 30kph design speed.

Spiral curves with minimum lengths of 40m (minimum super-elevation runoff) are introduced for all horizontal curves with radii less than 400m and in full accordance with the design standards applied. Whenever possible, longer spirals are introduced for better super-elevation rate of change. The maximum super-elevation applied is 6.00% while the equivalent relative slope is limited to 1/133 as an absolute minimum.

The terrain in the 50kph-design speed stretch is relatively flat to hilly with the exception of Wadi Abu El-Assal and Wadi Himara areas. This is a major reason for proposing a design speed of 50kph. In accordance with the General Geometric Design Criteria which is based on AASHTO, Japanese Standards and the Local MPWH Standards, the absolute minimum radius for the horizontal curves in this stretch is limited to 80m. Several horizontal curves with radii that range between 125m to 650m are applied to suit natural ground slopes, sight conditions and other main obstacles.

Spiral curves with minimum lengths of 50m (minimum super-elevation runoff is 45m at this design speed) are introduced for all horizontal curves with radii less than 1000m and in full accordance with the applied design standards. Whenever possible, longer spirals are adopted for better super-elevation rate of change. The applied maximum super-elevation is 6.00% while the equivalent relative slope is 1/150.

Widening of horizontal curves is determined from the design criteria applied (based on AASHTO and the Japanese Standards). Widening will be applied at both ends of the road for horizontal curves with spirals (w/2 for each side of the road).

Emergency escape ramps are provided at two different locations in the first 5km stretch of the road. Those ramps are designed to be able to stop any car safely and with the minimum hazards. Those two locations are shown in the detailed design drawings.

4.2.2. Vertical Alignment

The vertical design criteria adopted for this project covers two design speeds, namely 30kph and 50kph. For a design speed of 30kph, the absolute minimum grade applied is 0.3% while

the minimum grade is 2.0%. The maximum vertical slope used for this project is 10.5% in the Original Parkway Project. As for the added existing road link, a 14% maximum slope is adopted in the design for a length of 600m due to the following reasons:

- 1) The slope of the existing road link reaches 24% in some stretches in addition to other steep slopes.
- 2) Adopting 12% maximum slope within the same corridor would result in massive earthworks and costly protection measures especially in the last kilometre of the alignment. This is due to the fixed difference in elevation between the Ma'in Main Road and the Original 9.4km Parkway Project.
- 3) The levels of the existing Ma'in Main Road where the Parkway should connect represent another major restriction to the vertical slopes of the Parkway.
- 4) It was found out that the 14% max. slope represents the best safe and economical slope taking all the above factors into consideration.

Minimum vertical curvature (K) for crest vertical curves applied is 3 while the minimum used for this design speed is 7.9. Minimum vertical curvature (K) for sag vertical curves for a design speed of 30kph is 4 while the minimum used is 6. For a design speed of 50kph, the same minimum vertical slope is applied while the minimum used is 1.63%. Minimum applied (K) value for crest vertical curves is 9-10 while the minimum used is 13.2. Minimum applied (K) value for sag vertical curves is 11-12 while the minimum used is 12.5.

All vertical curves are designed to provide stopping sight distance as design for passing sight distance would not be economical. Most of the vertical curves are given comfortable and safe lengths that would result in having safe K values exceeding the minimums.

The profile starts with the vertical slopes in the range of 10% due to the steep topography from the Dead Sea side. Those steep slopes cover more than 5.5km of the length of the Parkway Project. Special breaks in the slope (2%) were introduced to the profile so as the average length of the steep slopes is less than one km each.

The profile until Sta. 10 + 000 has moderate vertical slopes except for the area where the route crosses Wadi Himara. It is decided that 10% slopes are better and more convenient. This is due to the reduced heights of cut at both banks of the wadi despite the fact that the piers for the bridge become higher.

Both AASHTO and the Japanese standard Speed–Distance Curves are utilised (see Figures 4.5 (1) (2) (3)). This is to check for the maximum possible running speed for trucks using the road from the Dead Sea Side and upwards (as trucks represent a more critical case than tourist busses). This check is carried out to cover only the first 5km of the Parkway and as an indication for the rest of the alignment. According to AASHTO curves, the following results are obtained:

The case of 0kph starting speed:

In this case, an at-grade intersection is proposed where trucks and buses coming from the Hotels and the recreational area on the Dead Sea have to make a full stop before turning left towards Ma'in/Parkway. The running speed will increase (with 2.0% slope) until it reaches a maximum running speed of 30kph after which it will decrease to 17.0kph.

The average running speed in this tested stretch for trucks (according to AASHTO) will range between 16kph to 17kph (refer to Figure 4.5(1)) except for areas where 2.0% slopes are introduced as breaks for the sharp slopes. In those areas, the running speed will go up as far as 42kph. As for the Japanese standards (refer to Figure 4.5(3)), the average running speed will be around 15kph except for 2.0% sloped areas where the running speed will go up as far as

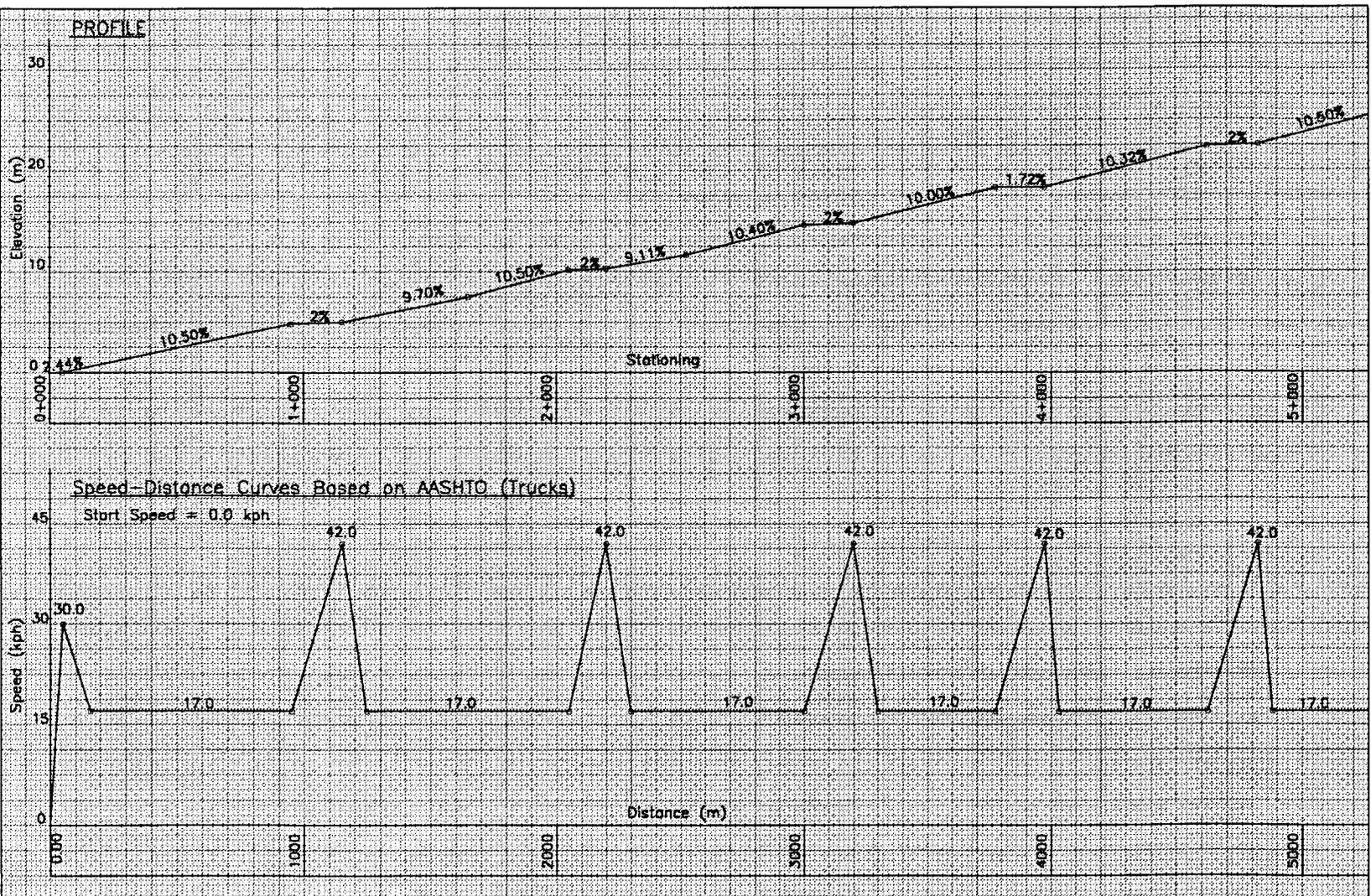
35kph. Not forgetting that the Japanese Standards are applied for a steeper slope of 12% and a length of 1.0km.

The case of 50kph starting speed:

In this case, a grade separation is proposed for buses and trucks coming from the Hotels area and continue upwards towards Ma'in with a speed of 50kph. It was found out that the running speed of trucks and buses in the case of a grade separation doesn't differ much from that in the case of an at-grade intersection, except for the first small stretch (refer to Figure 4.5(2)).

Taking the above into consideration, in addition to the fact that the Dead Sea Intersection Area is characterised by its difficult terrain (high and steep fill from the Dead Sea Side and high and steep cut from the mountains side), this will make the proposition of any loop and / or ramp a very costly alternative and hence, the option of having a grade separated intersection was totally omitted.

Figure 4.5 (1) Speed Distance Curve (AASHTO)



Source: JICA Study Team

Source: JICA Study Team

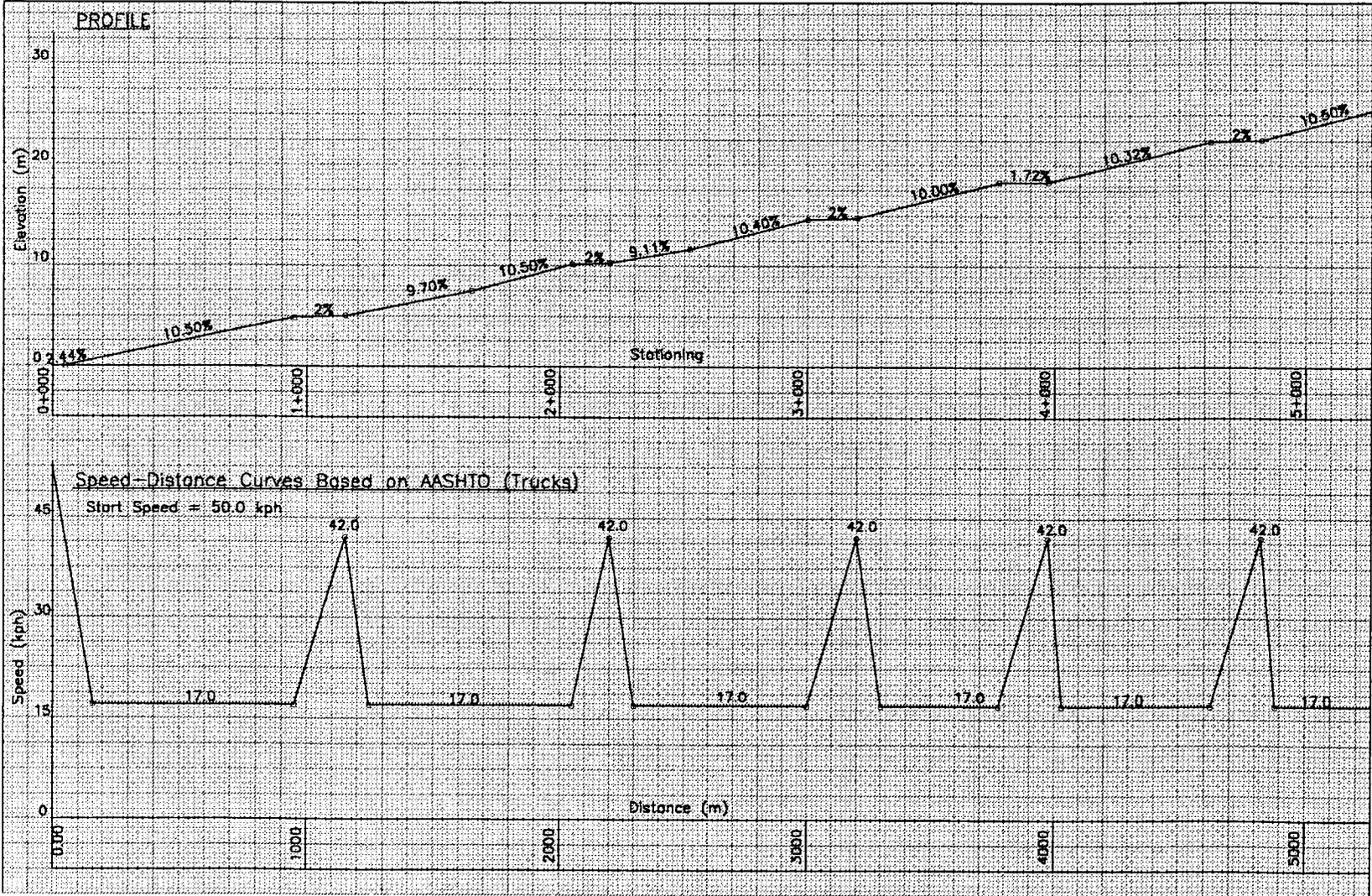
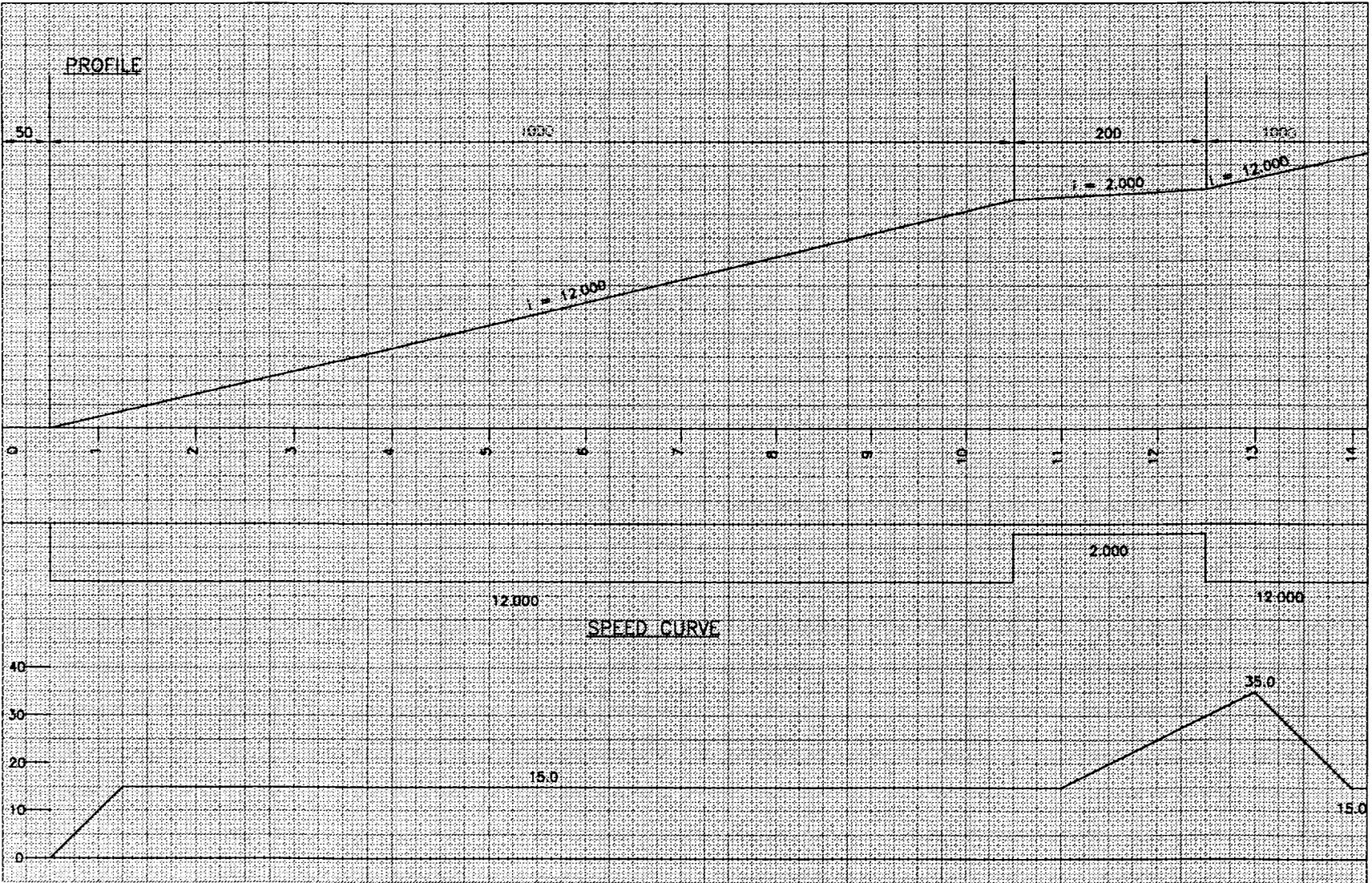


Figure 4.5 (2)

Speed Distance Curve (AASHTO)

Figure 4.5 (3) Speed Distance Curve (AASHTO)



Source: JICA Study Team