IMPROVEMENT OF ALIGNMENT IN SALT RANGE AREA OF MOTORWAY M-2

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DEDICATION

Dedicated to my Beloved Prophet Muhammad (ﷺ), my Parents and my Teachers.

ACKNOWLEDGEMENTS

I am heartily grateful to my supervisor, Dr. Zia-Ur-Rehman, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject. His dedication to his work and towards his students is noteworthy. His work ethics and eagerness are exemplary. He has been a source of great inspiration for me, both as my mentor as well as a professional. Words are not enough to express my gratitude but I just want to conclude that working on this thesis with such a great person was truly an honour.

I am also thankful to the Authorities who have facilitated me during the data collection process. They have been very helpful and cooperative. The consultants (who conducted the study before) have been a great help for the literature review and thesis writing which include “Daewoo” & “ECIL consultants”.

Lastly, I offer my best regards to Prof. Dr. Abdul Sattar Shakir, Dean Faculty of Civil Engineering, Prof. Dr. Ammad Hassan Khan, Chairman, Department of Transportation Engineering and Management and all the faculty members of Department of Transportation Engineering and Management who helped me during the completion of the thesis.

ABSTRACT

The precision of geometric design of a highway and its safety are directly linked. As the functionality of the highway increases, the criteria of safety and geometric design become more significant. Lahore Islamabad Motorway (M-2) is one of the major motorways of Pakistan, connecting the Provincial and Federal Capitals. Being such an important highway, it has to fulfil certain geometric and safety criteria to serve the purpose efficiently.

Despite of being a high class highway the Kalar Kahar Section of Motorway (Length Approx. 10 km) does not satisfy the required geometric design criteria and thus falls in one of the most dangerous roads to drive through. With the vertical grades going as high as 7% and the combinations of horizontal curves with the radius even lesser than 100 m, the speed of the vehicles reduce substantially, while heavy vehicles suffer the most.

The main objective of this study is to find the prospect for improvement of bottle necks in Salt Range area of Motorway M-2 to avoid fatal accidents. The study has the focus to evaluate the existing alignment of the Kalar Kahar Section of M-2 and proposes the remedies at problematic locations. The study also has the scope to look for the alternative alignments through the Kalar Kahar Section and choose the best of those based upon the comparison of required geometric criteria and cost.

The data has been collected and studied for the above set goals and the decision have been made based upon the analysis using relevant AASHTO guidelines. The modifications are recommended to improve the existing alignment. Four alternate alignments are also studied and based on comparison of several parameters, second alignment is recommended. The 31 km alignment is on the East of the existing alignment where it climbs the hill side between Hamat Nala and Saggar Nala through a series of wide hairpin bends and then takes a sharp turn towards the West to meet the existing alignment. This alignment satisfies the geometric design criteria and has enhanced safety of the existing alignment.

TABLE OF CONTENTS

Chapter 04

Analysis and Results

Chapter 05

Conclusions and Recommendations

APPENDICES

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

1.1 GENERAL

The Lahore – Islamabad Motorway M-2 was the first ever Motorway to be built and opened for operation in Pakistan. It was originally conceived by the Government of Punjab under the then constituted Punjab Highway Authority but soon was taken over as a fedral function. It was opened to regular traffic in 1997.

The Motorway starts near Thokar Niaz Beg at Lahore, passes close to Sheikupura to reach Pindi Bhatian, takes a slight right turn to cross River Chenab near Sial Mor, moves to Kot Momin, crosses River Jhelum near Bhera, passes close to Lilla to enter the Salt Range, comes out of the Salt Range close to Kallar Kahar, keeps turning right to pass close to Balkasar and Chakri to end near the juncture of Tarnol – Fatehjang Highway (N-80) and the Rawalpindi – Peshawar Highway (N-5). The alignment of the M-2 is shown in Figure 1.1.

The length of the Motorway M-2 is 358 km. It is a 6-lane motorway with 3 major river bridges, 8 interchanges, 27 flyovers, 17 bridges on canal, 39 bridges on drains and 4 overhead railway crossing, 183 subways and cattle creeps, 22 culverts on canals and 73 culverts on drains.

The salt range area of Motorway M-2 starts just after Lillah Interchange and after covering approximately 27 Km distance it ends at Simbal. Throughout the distance, the area consists of steep vertical grades and horizontal curves of small radii. Design speed too in this area the design speed is 50 Km/h. Several accidents are also been experienced in this area since the construction of Motorway.

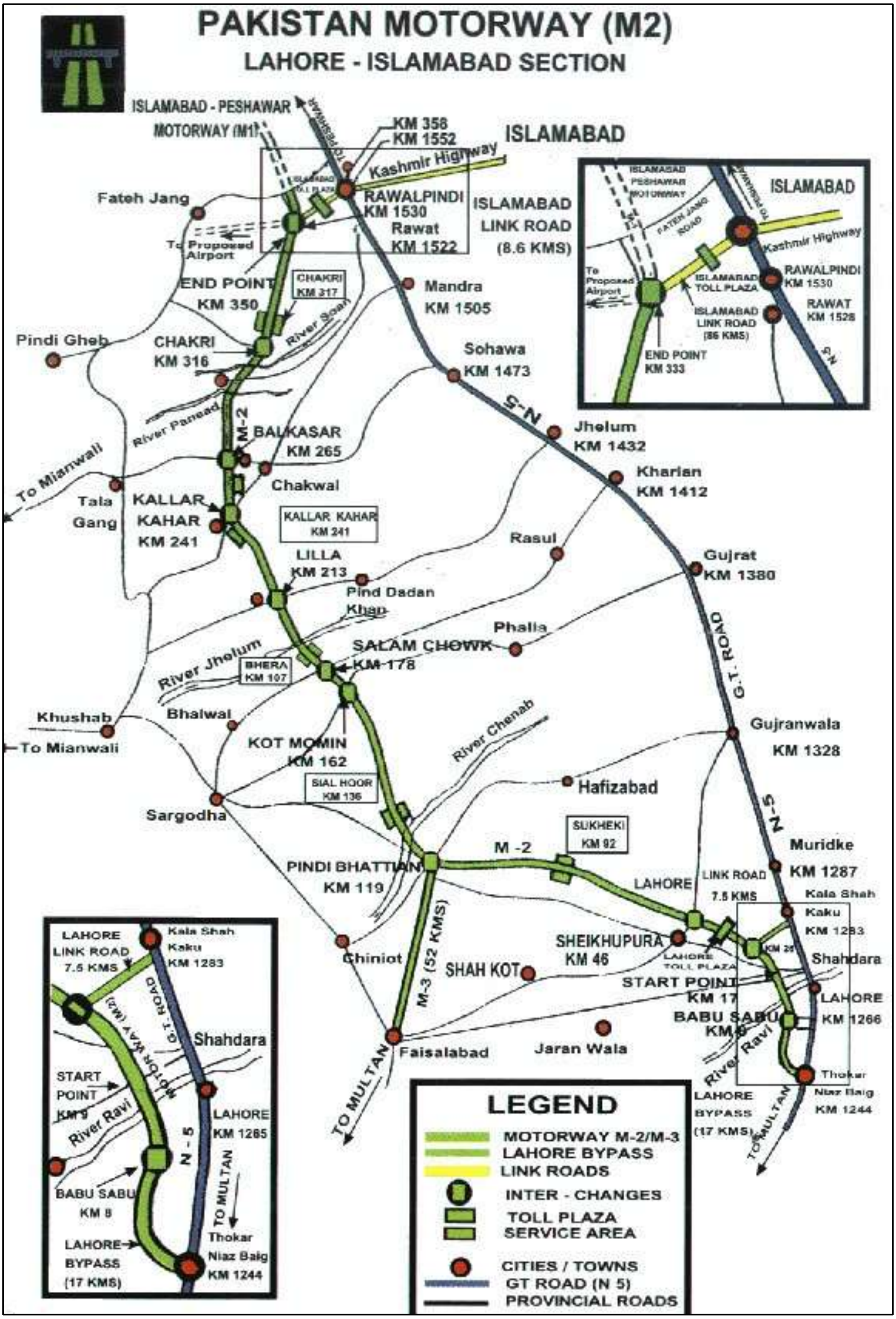

Figure 1.1: Route map of Lahore Islamabad Motorway M-2 ((NTTFC, 2010)

The Salt Range Section of M-2 comprises mountainous terrain and here the Motorway is characterized by steep vertical slopes (up to 7%) and very sharp horizontal curves. The Topo sheet of the area is provided in the Figure 1.2

Figure 1.2: Topographic Sheet of Salt Range Area (mapquest, 2007)

The section is also geologically unstable with appreciable land movement and sliding especially between the km 230+200 to 230+500. The section generally has the highest incidence of rainfall in all of the alignment of the Motorway.

In the recent past the importance of developing a viable Motorway Network for Pakistan has increased due to the following developments:

1. Political developments in Afghanistan necessitating strengthening of the existing infrastructure network between the Frontier / Tribal Regions and the rest of the country in order to facilitate the transit trade between the two neighbouring countries.
2. Strategic rethinking on the National Highway and Motorway Network in light of the developing trade routes with China and Central Asian states for which Pakistan holds a key geopolitical position.

As a consequence, the Government plans to extend the Motorway M-1 and link it to the Peshawar – Torkham – Jalalabad Highway. In the south, the Prime Minister has recently approved in principle the design and construction of all portions of the Motorway between Faisalabad and Karachi.

In all this scenario, the Salt Range section of the Motorway M-2 has become a critical point as it acts as a bottleneck against free and easy flow of traffic especially heavy vehicles between Lahore and Islamabad. Heavy loaded trucks still prefer to move via the G.T. Road where, unlike the Salt Range area of M-2, the vertical slopes and horizontal curves are more manageable.

The NHA must remove this irritant / bottleneck from the Motorway M2 if it is to make the whole Motorway Network in the Northern part of Pakistan economically viable and attract traffic from ECO and China.

Improvement of Bottle necks in Salt Range area motorway to avoid fatal accidents by improving existing alignment as well as Re-alignment.

The length of the Salt Range Section is approximately 10 Kilometres and it lies generally between the Kallar Kahar Interchange and the Lillah Interchange on the Motorway M-2.

Due to its peculiar terrain, the Salt Range Section of the Lahore – Islamabad Motorway M-2 has a compromised geometric design in this reach, which results in a number of operational drawbacks including:

a) Traffic Speed Restrictions
b) High rate & severity of accidents

c) Difficulty in manoeuvrability of heavy vehicles

In addition, to the steep slopes in the 6% to 7% range, there are a large number of sharp curves in the alignment with curve radii lesser than 200m and in six (6) cases even lesser than 100m.

Since opening of M-2 in 1997, the above stated factors have not only caused major problems for heavy vehicles in climbing the North-bound lanes and manoeuvring the downhill South-bound lanes but have also caused a large number of medium to severe accidents.

While moving from Lahore towards Islamabad, about 5 kms after the Lillah Interchange, the FRL are in the 250m – 300m range. On approach to the Salt Range, these levels rise rapidly and reach 700m - 750m range at the end of the Salt range as we approach Kallar Kahar. This rise of about 450 m occurs over a road length of approximately 10.5 kms. The portion has slopes as high as 7% and horizontal curves with radii as tight as 90m. This results in the reduction of driving speed over this portion and it is reduced from 120 km (LTV) and 110 km (HTV) to 70 km (straight portions) and 50 km (curve portions) and a number of fatal accidents have occurred, especially with heavy vehicles and buses, whose drivers either failed to heed to the speed restrictions in the area or which suffered brake failures and resultantly overturned or ran off the highway.

The current study is an effort to find the prospect for improvement of Bottle necks in Salt area of Motorway to avoid fatal Accidents. The study will be conducted in order to fulfill the following objectives:

1. Increased Vehicular Speed
2. Increased Vehicular Manoeuvrability
3. Decreased Vehicular Break-downs
4. Decreased Vehicular Accidents

1.2 OBJECTIVES

The objectives of the study include:

1. Improving the Existing Alignment by
    a) Reducing Vertical Slopes
    b) Increasing Horizontal Curve Radii

2. Finding an alternate alignment which
    a) Has Geometric Design based on a Speed in the 90 – 110 km range
    b) Has Relatively Stable Geology
    c) Has Minimum number of Drainage Structures
    d) Is economically feasible

1.3 SCOPE OF WORK

The study involves improvement of existing geometry of salt range and realignment of Motorway M-2 in salt range area to ensure improvement of bottlenecks in salt range area of Motorway to avoid fatal accidents and improve the manoeuvring of heavy vehicles by reducing the vertical grades which are exceptionally high in existing alignment ranging up to 7%.

The study will mainly concentrate on review of the existing geometric design of the Salt Range section, identification of the critical areas where safety is in question, to study the various improvements in the current alignment and to study various alternate alignments which can be feasible for achieving the required purpose of safety and manoeuvrability.

1.4 METHODOLOGY

Both Qualitative and Quantitative approaches were used to carry out the research. Previous Literature was used to identify the problems in the study area. Data was obtained from researchers and organization as well as site visits. Several Parameters were used for comparison of multiple alternatives studied. This qualitative approach led to the selection of proposed alternative. Detailed research methodology is described in Chapter 3 of this Thesis.

1.5 THESIS ORGANIZATION

The thesis has been organized in the following manner:

Chapter-1: Introduction

Chapter-2: Literature Review

Chapter-3: Research Methodology

Chapter-4: Analysis and Results

Chapter-5: Conclusions & Recommendations

There are 8 appendices in the thesis having following details:

Appendix A: Plan and Profile Sheets for Improvement of Existing Alignment

Appendix B: Plan and Profile Sheets for Proposed Alternative-1

Appendix C: Plan and Profile Sheets for Proposed Alternative-2

Appendix D: Plan and Profile Sheets for Proposed Alternative-3

Appendix E: Plan and Profile Sheets for Proposed Alternative-4

Appendix F: Study Carried out by DAEWOO in 1992

Appendix G: Study Carried out by SMEC in 1998

Appendix H: Study Carried out by ECIL in 2005

LITERATURE REVIEW

2.1 INTRODUCTION

Motor-vehicle crash studies have been a continuously researched topic in the past decades. Researchers have developed various methods, incorporated different types of data and concluded varieties of countermeasures to improve the highway safety condition. Freeway crash occurrences are highly influenced by geometric characteristics, traffic status, weather conditions and drivers' behaviour. (Abdel-At & Ahmed, 2013). The relationship between vehicle accidents and geometric design of road section, such as horizontal curvature, vertical grade, lane width, and shoulder width has been studied prudently in past years. The studies have proved that there is a direct link between erroneous road design and vehicle accidents. (Miaou, 1993). The trucks are also largely effected by geometric design of roads as proved by several statistical methods including Poisson and Negative Binomial Regression Models (Miaou & Lum, 1994). The mountainous areas are more susceptible to road accidents if geometric design standards are not followed because disruptions to road infrastructure occur more frequently in mountainous areas than elsewhere, due to the typically high intensity of natural events (such as debris-flows, avalanches, rock-falls) that can jeopardise network operations. Secondly, mountain road networks generally have a low level of connectivity, being more linear in configuration rather than forming a grid (Rupi, Bernardi, Rossi, & Danesi, 2014). In past decades, highway traffic safety has seen some improvements due to enhanced vehicle safety features and highway design. Nonetheless, crash frequencies in many countries have not significantly decreased as expected. (Agbelie, 2016).

The Motorway M-2 is one of the ten Motorways in Pakistan which provides access from Lahore to Islamabad. The North portion of the M-2 including Salt Range has experienced more accidents than South portion (Shah & Khattak, 2013). Since the inauguration of the motorway in 1997, there have been more than 350 accidents on the motorway in Salt Range and claimed more than 200 lives (Motorway Police Pakistan, 2015).

The salt range area on M-2, Pakistan has been studied in past and found vulnerable to accidents for trucks and other vehicles. The study is in continuation of past studies as well as it suggests the recommendations on geometric design of subject area based on thorough study on multiple alternatives.

2.2 REVIEW OF THE PREVIOUS STUDIES

A number of studies have been carried out in the past to investigate the possibility of finding the best route to traverse the Salt Range Area. The Consultants have gone through these studies and their findings are described as follows:

2.2.1 ALIGNMENT STUDY BY DAEWOO (1992)

In 1992, M/s Daewoo carried out an Alignment study with the aim to improve the alignment selected in the preliminary design stage. As a result, 5 alignments were identified, particulars of which are presented in the following pages (Figure 2.1 to Figure 2.6). After detailed deliberations by SMEC and discussions with the NHA, Alignment No. 2 was selected for detailed design and construction. The details of study carried out by DAEWOO have been provided in Appendix-A.

The basic considerations for this study were as follows:

a) it investigated the possible alignments only along one mountain within a 10 kms wide band
b) it was carried out with the aim to minimize cost
c) it maintained minimum design speed of 50 kph
d) it used maximum grade of 7%
e) it used minimum horizontal curve radius of 90m

As a result of the above considerations, the chosen alignment had compromised geometric design which did not follow the requirements of AASHTO. It did not facilitate the climbing of north bound loaded HTV and made downhill travel of southbound HTV’s difficult to manoeuvre.

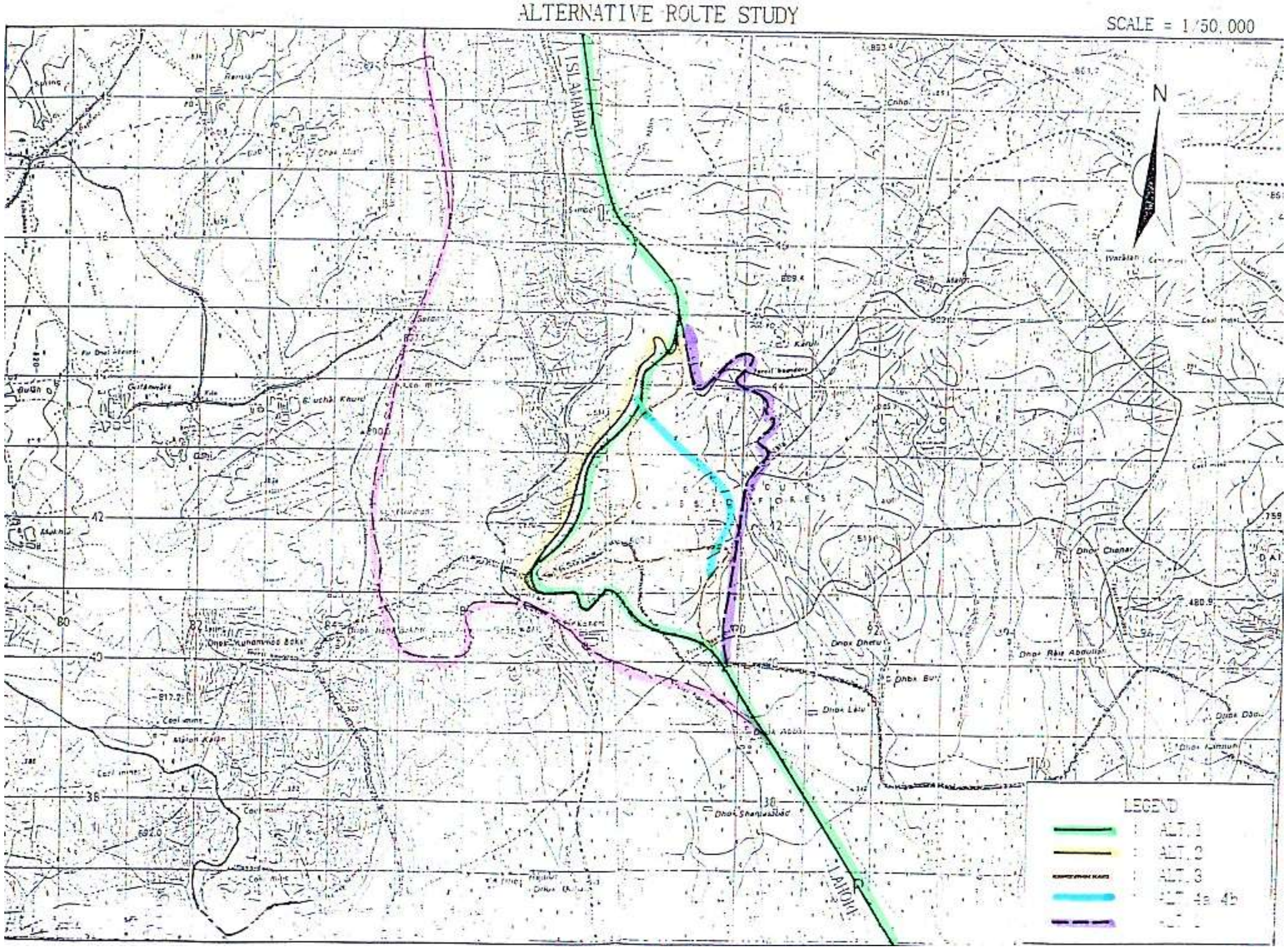

Figure 2.1: Alternative Study by Daewoo (Courtesy M/s Daewoo)

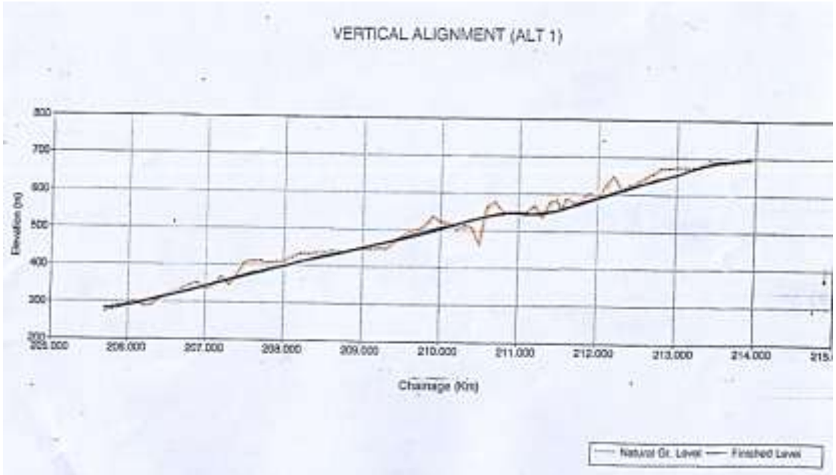

Figure 2.2: Vertical Profile of Alignment Alternative 1 by Daewoo

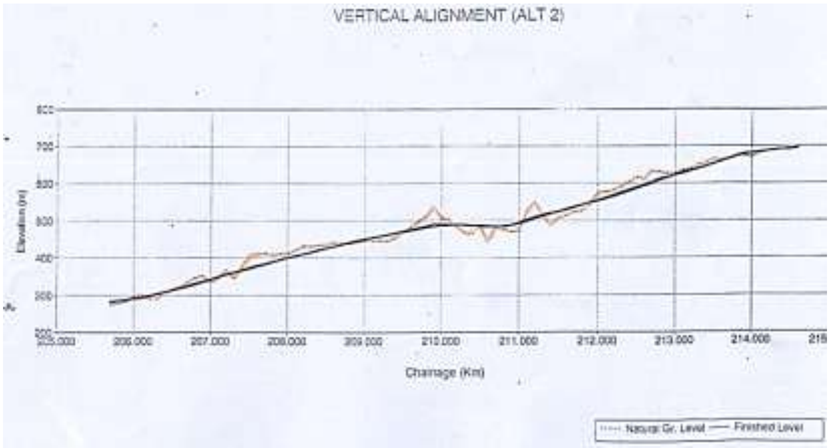

Figure 2.3: Vertical Profile of Alignment Alternative 2 by Daewoo

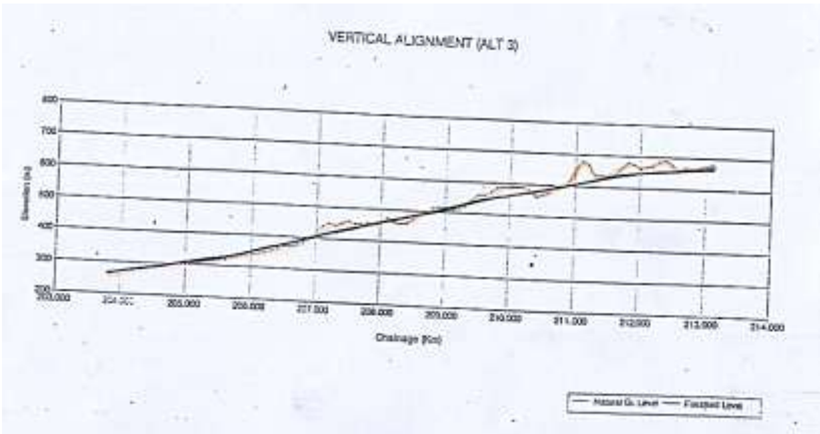

Figure 2.4: Vertical Profile of Alignment Alternative 3 by Daewoo

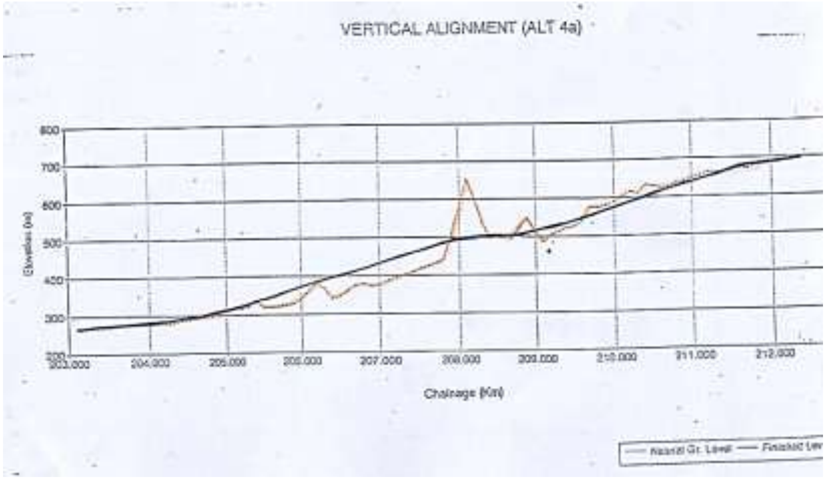

Figure 2.5: Vertical Profile of Alignment Alternative 4 by Daewoo

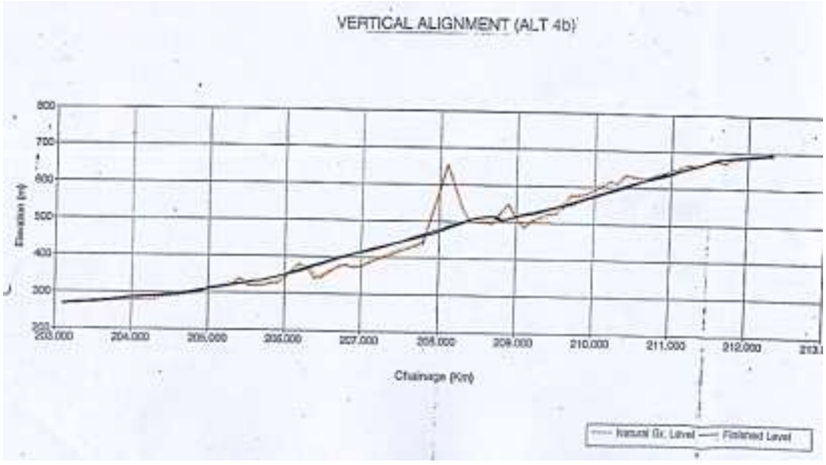

Figure 2.6: Vertical Profile of Alignment Alternative 5 by Daewoo

2.2.2 DESK STUDY BY SMEC (1998)

In 1998, after the Motorway was opened to traffic, M/s Snowy Mountains Engineering Consultants carried out a Desk Study to investigate an alternate route with lower gradient and larger curve radii. The details of the study are provided in the Appendix-B. Findings of the Study are summarized as follows:

i) PROPOSED ROUTE

M/s SMEC put forward only one possible route for the alternate alignment. The route takes off towards east of the existing alignment near km 215 through an interchange located 2 kms to the north of the Lillah Interchange. The first 10 kms pass through the Jhelum River flood plain and crosses nallahs originating from within the Salt Range to reach the Makrach Nala Valley. It moves along the western side of the Makrach Nala to reach the confluence with Nawabi Kas Nala and then turns west to move along the Nawabi Kas Nala. The alignment continues along the Nala to reach the Ghuku Valley and continues moving towards the Kallar Kahar – Choa Saidan Shah Road to join the existing alignment near Khandoyah.

ii) SALIENT FEATURES

- The length of the alignment is 31.2 kms
- Two interchanges will be required on the existing alignment at Km 215 and Km 239
- Design Speed assumed is 120 kph
- Minimum horizontal curve radius is 510m
- Maximum vertical grade is 4% over a length of 5 kms. Another 3.5% grade is required over a length of 5 kms. Thus a minimum of 10 kms of climbing lane is required in these reaches
- 5 kms of the alignment passes through red shales and mudstones which are unstable and prone to land-sliding
- Massive erosion protection works are required along the alignment in about 5 kms while passing along the Makrach and Nawabi Kas Nalas
- The central 8 kms of the alignment poses great construction problems with narrow valleys, steep and unstable side slopes and meandering nalas
- A total of 31 structures (2 flyovers, 5 bridges, 13 box culverts, 11 pipe culverts) are envisaged.
- Cost of construction was estimated at Rs. 5.1 Billion (at 1998 rates)

2.2.3 PRE-FEASIBILITY STUDY BY ECIL (2005)

In 2005, the National Highway Authority engaged M/s Engineering Consultants International (Pvt) Ltd to conduct a pre-feasibility study for an alternative route, in the salt range, where a motorway section of geometry suitable for high-speed facility, especially for heavy traffic, can be constructed. The details of the study are provided in Appendix-C. The findings of the Pre-Feasibility Study are summarized as follows:

i) ALTERNATE ROUTES

The Study identified four (4) alternate routes which are graphically depicted in Figure 2.7 and described as follows:

Route No. R-1

This route is about 30 km long having 9 km reach in the start at plain area having elevation of 230m and 11 km reach in the end at plain area having elevation of 700m while the remaining 10 km reach in the middle passes through steep gradient which is not suitable for motorway.

Route No. R-2

Route R-2 is 19 kms long. It takes off from existing motorway at Km 219 towards the eastern side of existing motorway, takes a loop around Hamat Nala (crossing it twice) with up to 40m high embankment fill and moves west to cross the existing alignment at approx. Km 224 with an underpass.

It then takes another loop in the Sohal River Valley towards the north to move between the River and the existing alignment. The alignment then turns out of the gorge (near the start point of the Nala), takes a loop to the right to join existing alignment near Kallar Kahar Interchange after deep cutting up to 30m

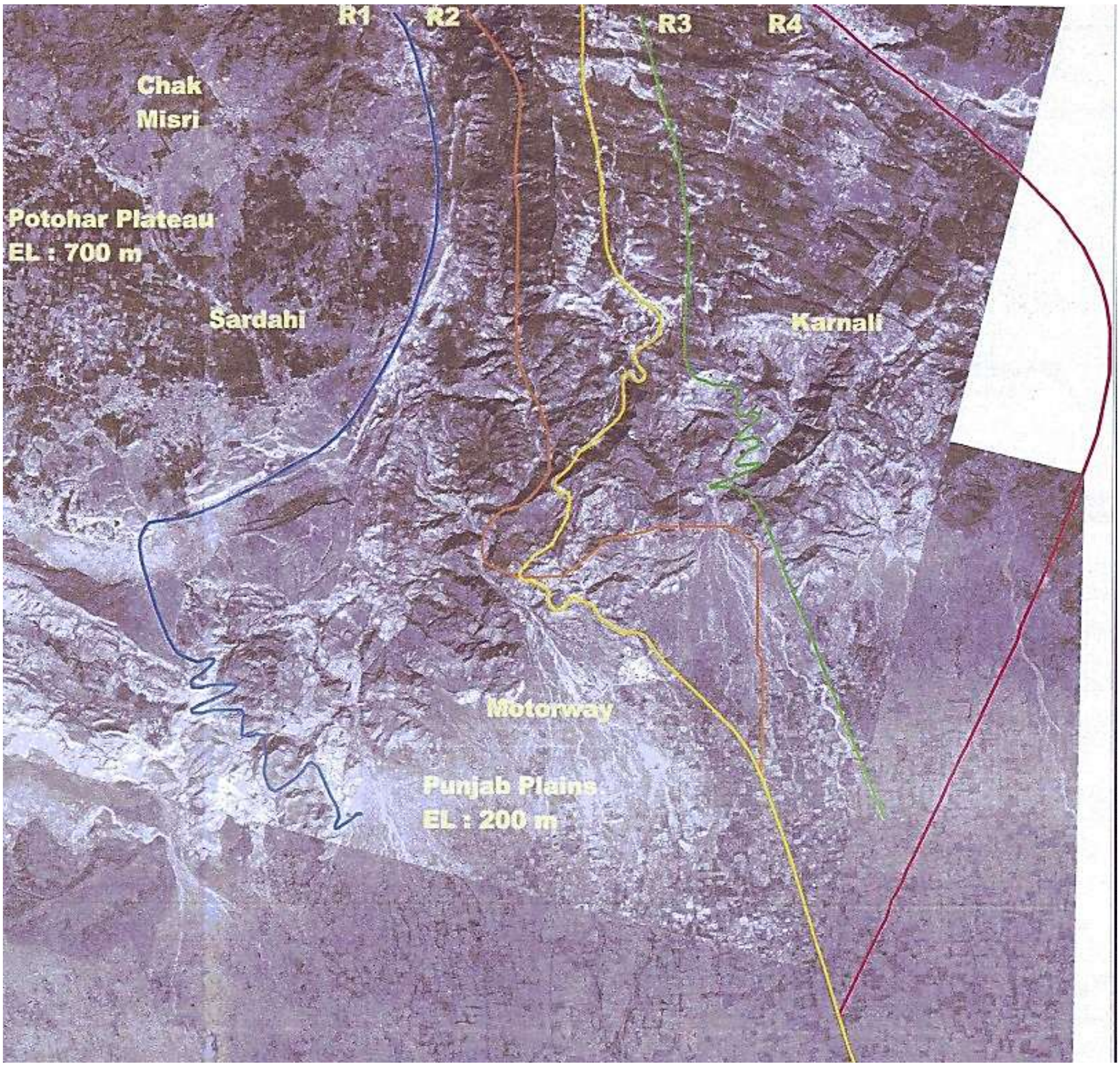

Figure 2.7: Previously Proposed Alternative Alignments (Courtesy SMEC International)

Route No. R-3

This route is on the eastern side of the existing Motorway with a length of 32 kms. Of this length, 12 km reach in the start is in plain area having elevation of 230m and 12 km reach at the end in is plain area having elevation of 700m. The middle 8 km reach in the middle passes through steep gradient which is not suitable for motorway.

This route is along the paved road joining Kalar Kahar - Choa Saidan Shah road on the one end and Toba-Lilla road on the other, passing through villages Simbal and Karoli on the high lands and then through steep gradient reaching the Punjab plains. It is an alternate route for the use of local residents of the area. This route is suitable for four wheel drive vehicles only.

<u>Route No R-4</u>

This alignment is about 30 Kms long. It starts 2km after Lilla interchange towards salt range on the existing motorway and after passing through flood plain enters into Makrach nallah valley, then turns to Nawabi Kas valley and reaches the Motorway near Khandoyah (same as SMEC proposal)

ii) COMPARISON OF ROUTES

- Routes R-1 and R-3 are not suitable for Motorway
- Length of R-2 is 19 km while that of R-4 is 30 km.
- Similar gradient is available in both routes.
- R-4 traverses a longer distance in the flood plain as compared to R-2.
- No. of horizontal curves might be more in case of R-2 as compared to R-4
- Cost of R-2 is Rs. 4 Billion while that of R-4 is Rs. 6 Billion

iii) RECOMMENDATIONS OF ECIL

Detailed investigations should be carried out for Routes R-2 & R-4 to select the final route and taking up detailed design of the approved route.

2.2.4 SUMMARY

A review of the Alignment Study by Daewoo and related correspondence on record, reveals that the priority at that juncture (i.e. in 1992) was <u>"to minimise the time and cost of construction in the Salt Range Area"</u>. Hence the design was based on a compromised design speed of 50 kph and slopes as high as 10% were considered for various alternate routes. Consequently, none of the alignments proposed by Daewoo fulfils the criteria set out for re-alignment now. However, an improved version of Daewoo's Alternative 3 has been considered by the Consultants and presented as Alignment No. 4 in the following section.

The Pre-Feasibility Report prepared in 2005 to study the problem of Re-alignment puts forward four alternate routes, which includes (as Route R-4) the route proposed by SMEC in its desk study of 1998. The details of the studies carried out by SMEC are provided in Appendix-B.

Reconnaissance and GPS survey by the Consultants of these routes confirm that Routes R-1 & R-3 (either as they stand or with any perceived improvements) are not worthy of consideration even on basis of geometric parameters

Figure 2.8: View showing steep gradients on Route R-1

Figure 2.9: View showing variable geology & cut up terrain on Route R-1

Figure 2.10: View showing variable geology & cut up terrain on Route R-1

Figure 2.11: View showing steep gradients on Route R-1

Figure 2.12: A view of steep hill side slope on Route R-3

Figure 2.13: A view of hairpin bends on steep slopes on R-3

Figure 2.14: A view of cut up terrain on Route R-3

Figure 2.15: A view from Route R-3 showing Hamat Nala Valley

Similar investigation into Route R-2 reveals that the it would be almost impossible to place the alignment on the eastern hill side of the gorge created by River Sohal as the contours here are very tight, creating very steep hillside slopes (Figure 2.16 to Figure 2.18). In addition, this reach has a band of vertical cliffs running overhead throughout for a distance of about 5 kms, which will pose a constant threat for the traffic plying underneath (as in case of Simbal Slide). The Route also envisages rock cuts and embankment fills exceeding 40m which are not practicable in such topographic conditions and geological formations.

Figure 2.16: A view of Sohal River valley from Sardhai showing difficulties in placing R-2

Figure 2.17: Another view of Sohal River valley showing cut up terrain along Route R-2

Figure 2.18: A panoramic view of eastern hillside of Sohal River valley on which Route R-2 is proposed to be placed illustrating steep slopes, vertical cliffs & cut up terrrain

While Route R-4 (also proposed by SMEC) qualifies on basis of geometrics (gradual slopes and wider curves), it poses major construction problems since the hillsides in the Makrach Nala and Nawabi Kas Nala are very steep. Placing of motorway embankment on these hillsides will pose major threats of landslides and rockfall from heights of up to 300m above the proposed road levels. An improved version of this Route has been studied by the Consultants and included in this exercise as Alignment 1.

Figure 2.19: A view of Nawabi Kas valley showing steep side slopes & ridges (Route R-4)

Figure 2.20: View of confluence of Makrach Nala with Nawabi Kas Nala (Route R-4)

Figure 2.21: A panoramic view of the Makrach Nala Valley from Nila showing cut up & steep slopes, unstable geology & paths of hill torrent (Route R-4)

Chapter 03

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter the general methodology adopted for carrying out the study has been described. Firstly, the data related to existing alignment of M-2 in Salt range is to be collected which involves the general geometric design parameters e.g. vertical profile data, curve radii etc. The alignment is then to be analysed for possible required improvements to achieve the desired purpose of safety, speed and manoeuvrability. The study also involves the proposal of potentially feasible alternate alignments. These alignments are to be compared with each other by selecting some common evaluation parameters e.g. length, vertical grades, curve radii and cost etc. Comparing the alternates with each other using evaluation parameters the final alignment will be chosen.

3.2 METHODOLOGY

The methodology adopted for the subject research work has been presented in in the Figure 3.1. The first step is to execute the desk study and then get the actual required data from the field. The whole quality of the research depends upon the accuracy of data collected so this step was carried out very carefully to ensure the accurate results so that the right decisions can be made. After data collection, the existing alignment has been viewed for possible improvements. The proposals for the new alignments have also been made which are compared with each other based on the parameters defined later in this section. After comparison, the conclusions and recommendations have been made for the appropriate action to be taken.

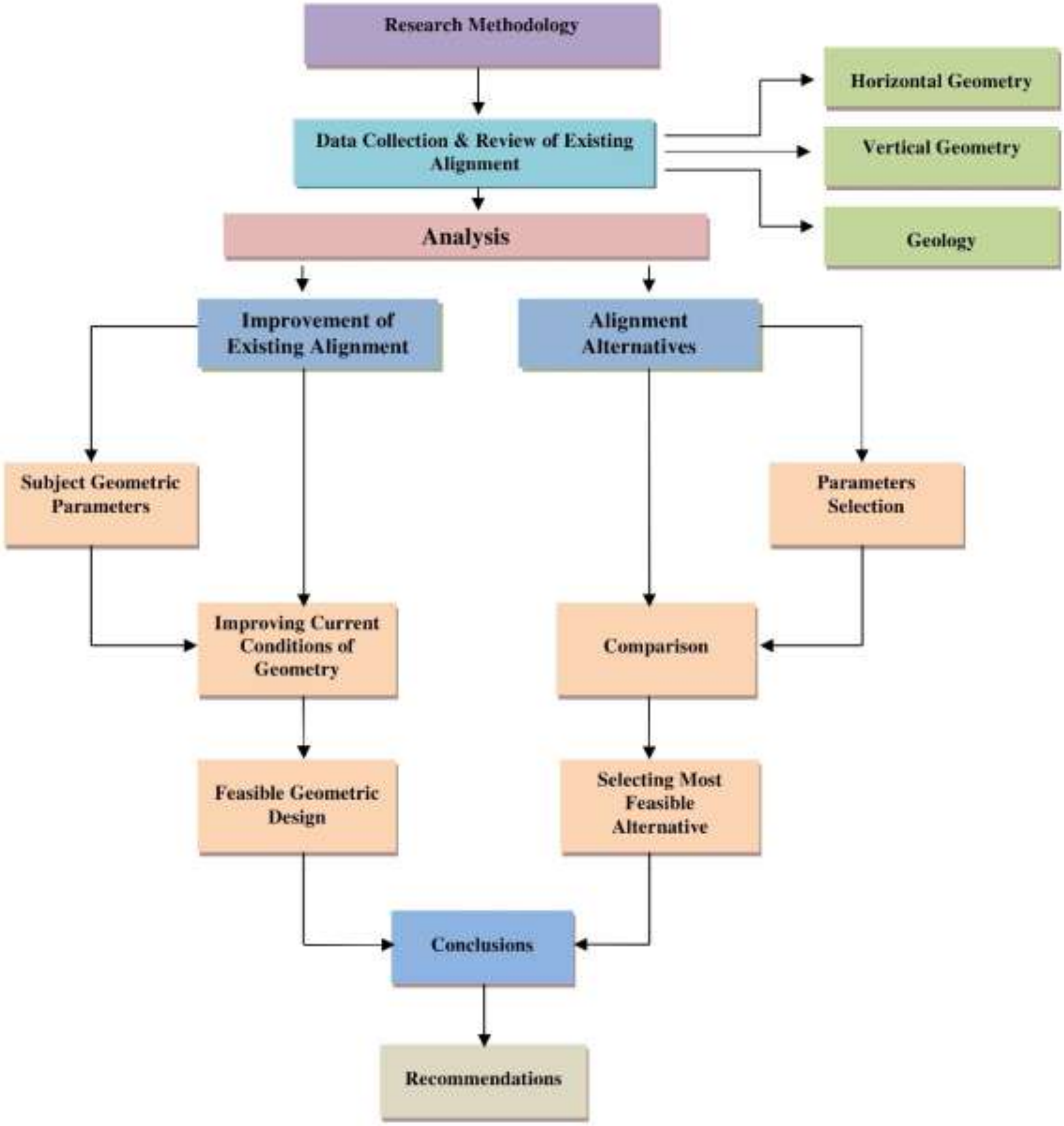

Figure 3.1 Research methodology adopted to carry out the work

3.2.1 Selected Comparison Parameters

The parameters selected for the comparison of the alternative alignments are following:

- Topography
- Length
- Geology

- Hydrology
- Construction (Problems in execution)
- Geometric Design
    - Horizontal Plan
    - Vertical Profile
- Estimated Cost

3.3 DATA COLLECTION

Data was collected from many sources for conducting the research. Site visits were carried out for existing road geometry conditions, strata and other requisite substances. The previous studies were obtained from concerned authorities including SMEC, ECIL and DAEWOO. Site photographs were obtained to properly analyse the problematic areas. Previous research on Motorway M-2 was also accesses through internet by other researches. Following data was obtained to carry out the research:

3.3.1 Existing Horizontal Alignment

While Entering the Salt Range Area, the speed limit reduces to 50 Kph. This is primarily because curve radii at some places are as low as 90m, making it very difficult for vehicles to maintain steady speed in this area, whether traveling northwards or southwards. Table 3.1 illustrates the extent of the problem:

Table 3-1 Curve Radii Data of Existing Alignment of Salt Range Section

Start Chainage	End Chainage	Radius (m)
205+485	205+603	250
205+871	205+976	200
206+074	206+168	150
206+415	206+583	90
206+587	206+838	150
206+838	207+092	150
207+092	207+290	142

Start Chainage	End Chainage	Radius (m)
207+463	207+602	220
207+602	207+839	96
208+129	208+180	200
208+403	208+504	200
208+876	208+944	200
209+206	209+438	100
209+438	209+698	121
209+962	210+302	200
210+235	210+302	200
211+707	211+975	90
211+975	212+138	90
212+138	212+302	90
212+557	212+671	150

The gravity of the situation is compounded by presence of sharp horizontal curves in series (as “s” or reverse curves) creating hazardous black spots at locations like Km 229.

shows the extent of geometric compromises made while designing the existing alignment in the Salt Range which have made it difficult for HTV’s to cross this 10 km stretch and have created hazardous driving conditions for other vehicles.

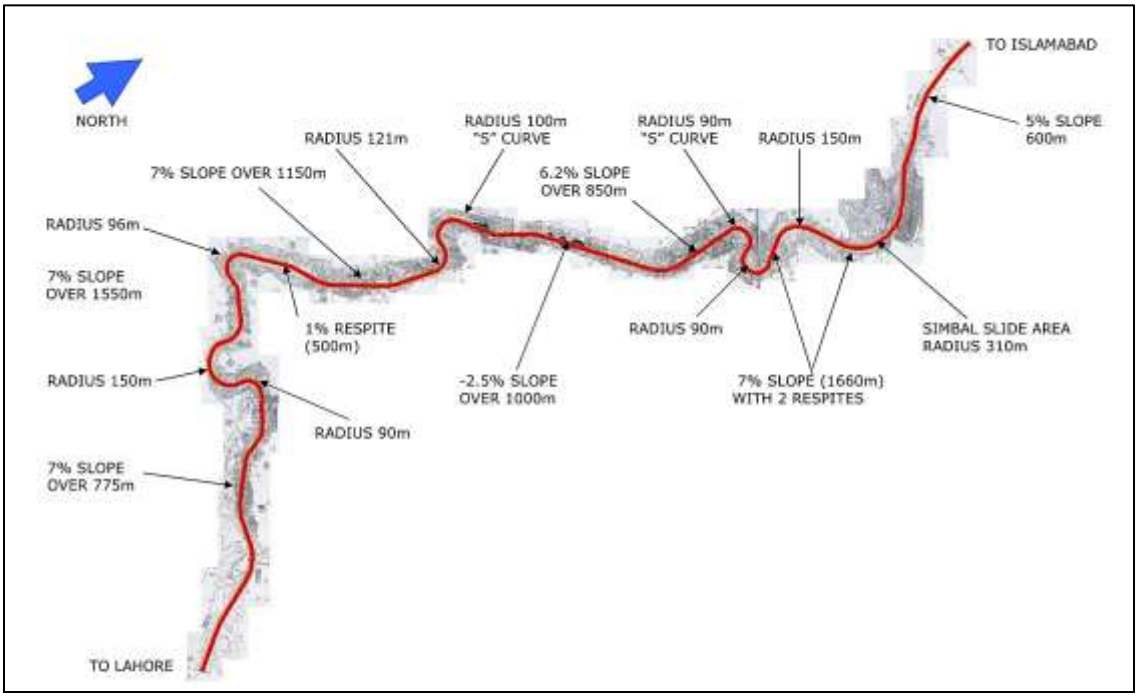

Figure 3.2 Existing Horizontal Alignment in Salt Range Area

3.3.2 Existing Vertical Profile

While moving from Lahore towards Islamabad, about 5 kms after the Lillah Interchange, the FRL are in the 250m – 300m range. At the end of Salt Range section of M-2 the FRL are in the range of 770-790 m. The existing grades of motorway in the Salt Range are generally around 7%

As per the (AASHTO Design Guide, 2011), the critical length of grade is taken as 350 m (i.e. the maximum length of a designated upgrade on which a loaded truck can operate without unreasonable reduction in speed).

The problem in the existing alignment is that it has grades above 6% for continuous stretches and no relief has been provided after 350m intervals in almost all such cases. This situation, coupled with the sharp horizontal curves, not only makes it impossible for loaded trucks to maintain their momentum while climbing but also makes it very difficult to maintain control while descending.

Vertical Grades and their respective lengths are summarized as follows:

a) km 222+425 ~ 223+200 6.82% 775 m
b) km 223+400 ~ 224+950 7.00% 1550 m
c) km 225+450 ~ 226+600 7.00% 1150 m
d) km 227+600 ~ 228+450 6.17% 850 m
e) km 228+900 ~ 229+250 7.00% 350 m
f) km 229+400 ~ 229+925 7.00% 525 m
g) km 230+125 ~ 230+400 7.00% 275 m
h) km 232+250 ~ 232+650 6.30% 400 m

As evident from the above summary, the relief provided at various points in the vertical profile is not sufficient to cater for the deceleration caused by steep north-bound gradient.

For example, the first grade from the Lahore end, which is 6.82% for a length of 850m, is quite substantial. It is very difficult for the loaded trucks to climb this steep grade in such a long stretch. After this a respite of about 3% is given (to accommodate the bridge BD-12C3) which is only 175m in length.

Enclosed Figure 3.3 shows the extent of geometric compromises made while designing the vertical profile in the Salt Range which have made it almost impossible for HTV's to cross this 10 km stretch and created hazardous driving conditions for other vehicles.

Based on the above concept, it will be attempted to break the grade on as much locations as possible. Wherever there is space available, necessary re-alignments within or close to the existing Right of Way will be carried out.

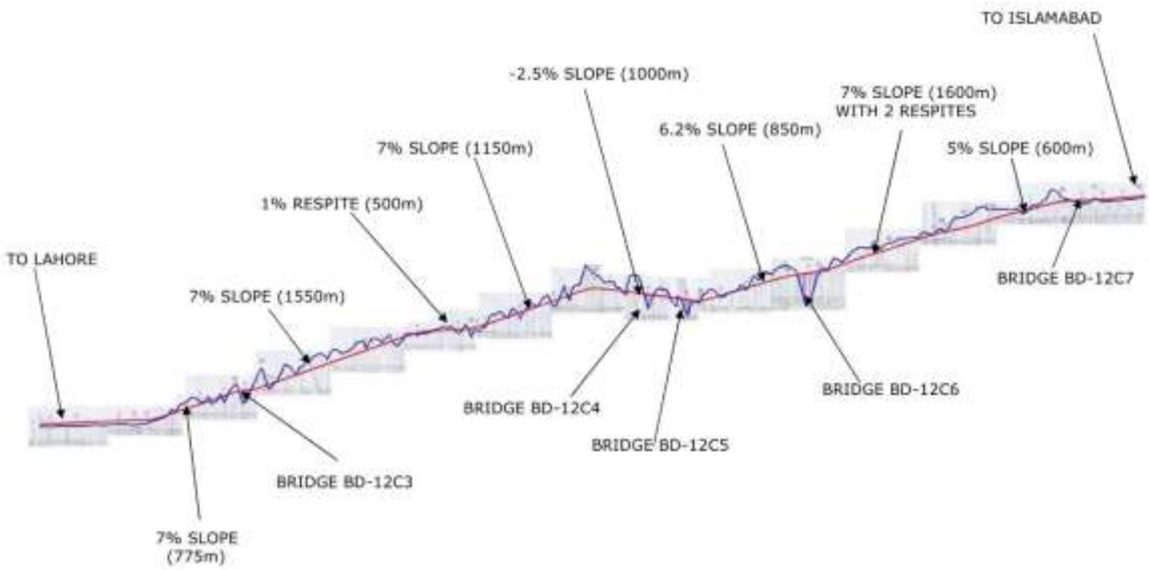

Figure 3.3 Vertical Profile of Existing Alignment in Salt Range Area

3.3.3 An Overview of Existing Alignment

While moving from Lahore towards Islamabad, about 5 kms after the Lillah Interchange, the FRL are in the 250m – 300m range. On approach to the Salt Range, these levels rise rapidly and reach 700m - 750m range at the end of the Salt range as we approach Kallar Kahar.

This rise of about 450 m occurs over a road length of approx. 10.5 kms. The portion has slopes as high as 7% and horizontal curves with radii as tight as 90m.

Resultantly:

1. the driving speed over this portion is reduced from 120 Km (LTV) & 110 Km (HTV) to 70 Km (straight portions) and 50 Km (curve portions)
2. a number of serious accidents have occurred, especially with heavy vehicles and buses whose drivers either failed to heed to the speed restrictions in the area or which suffered brake failures and resultantly overturned or ran off the highway
3. heavy vehicular traffic is not currently using the Motorway M-2 and instead prefer the G.T. Road (Highway N-5)

The Salt Range portion of the Motorway passes through a variety of geological formations which range from very stable limestone & dolomite to marl, shale, clays and alluvial layers. This rapid variation in geology has caused problems at a number of locations on the existing alignment.

A major land-slide developed in the Simbal area of the alignment in 2005 which has recently been re-activated and continues to pose serious threat to vehicular traffic. Another rock slide was witnessed towards the Lahore end of the section in July 2006. Other locations of small rock fall and debris flow are also visible along the way. All these locations need to be investigated in detail and preventive measures suggested for future. Locations where future slips / slides may develop also need to be identified.

Settlement and transverse cracking of existing pavement in some reaches of the existing alignment is also visible. These may indicate possible sub-soil movements or geological shifts. These needed to be looked into in greater details.

For all critical locations identified through reconnaissance survey, attempts have been made to recommend improvements in existing alignment based on the sound engineering practice.

All these proposals will be finalized, presented to the NHA and got approved prior to taking up their detailed design and cost estimates

The following pages give a pictorial account of the above stated problems being encountered on the existing alignment in the Salt Range area.

a) Speed Restrictions

The existing alignment in the Salt Range Area is characterized by a combination of sharp horizontal curves and steep vertical slopes. This compromised geometry forces a restriction on the operating speeds which is generally 70 kms. for the straight sections and 50 kms. on majority of the curves (Figure 3.4 & Figure 3.5).

Figure 3.4 Sign Board heralding speed restrictions on south bound traffic

Figure 3.5 Sign Board Warning of extra speed restrictions on approaching curve

b) Steep Slopes

The critical aspect of the existing alignment design is that the vertical slopes over 4% have been adopted without any respites or breaks and continuous stretches of up to 1400 m can be found.

Due to this undesirable configuration, it is extremely difficult for the loaded trucks to climb the northbound lanes or control their momentum on the southbound lanes (Figure 3.6 to Figure 3.10).

Figure 3.6 Steep gradient in Simbal area

Figure 3.7 The combination of steep slope & sharp curves

Figure 3.8 The combination of steep slope & sharp curves

Figure 3.9 A loaded truck struggling to scope with the 7% slope

Figure 3.10 Side view of the motorway showing severity of the slopes

c) Sharp Curves

Along with steep longitudinal slopes, the Salt Range alignment is also plagued by extremely sharp curves, unheard of on a Motorway. Within the 10 kms reach of the Salt Range, there are 8 curves of radii lesser than 300m, 6 curves of radii of 200m or lesser and 5 curves of radii of 100m or less (Figure 3.11 & Figure 3.12).

Figure 3.11 Chevrons to forewarn drivers of the sharp curve at night

Figure 3.12 Combination of sharp curves and steep slopes

At certain locations, these sharp curves come as reverse or “s” curves making manoeuvrability of vehicles (especially heavy vehicles) all the more difficult (Figure 3.13 to Figure 3.15).

Figure 3.13 The blind spot at km 229

Figure 3.14 Combination of vertical slope & sharp "s" curve

Figure 3.15 Approaching the Salt Range area from Lahore end

d) Brake Failures

Due to the steep downhill slopes on the southbound carriageway, most trucks and buses find it very hard to maneuver their vehicles through the Salt Range. With slopes mostly in the 6% - 7% range and due to absence of slope respites / breaks, the heavy vehicles cannot be controlled by brakes alone in case an emergency stop is required. Consequently, any brake failure or inadvertent speeding slightly over the prescribed limits usually result in very serious and even fatal accidents (Figure 3.16 & Figure 3.17).

Figure 3.16 Emergency Climb lane being improved

Figure 3.17 Emergency Climb Lane for safety

e) Road Safety

While a large number of road safety devices and features have been introduced in the Salt Range section since opening of the Motorway, the potential of accidents still exists. Most accidents in the past have been due to drivers of south bound heavy vehicles being unable to maintain control while turning on the sharp curves and hitting either the outside barriers or the central NJ barrier. In extreme cases heavy vehicles have also been known to cross over the central NJ barrier on to the NB carriageway (Figure 3.18 & Figure 3.19).

Figure 3.18 NJ Barrier on a sharp "s" curve showing damage by heavy vehicles

Figure 3.19 Vehicular traffic exposed to landslides and rock falls

f) Ground Movement and Unstable Strata

Due to unstable underlying strata in the area and presence of numerous fault lines in the rock formations, the Salt Range stretch of the Motorway has encountered a number of problems. Not only have there been instances of shifting of the foundations of structures but appreciable settlement and longitudinal movement along the alignment is also visible in some reaches. All these aspects need to be examined during the geological survey of the alignment (Figure 2.19 to Figure 3.22).

Figure 3.20 Bridge at km 227 that has to be shifted due to sub-soil complications

Figure 3.21 Erosion in week soil along the alignment

Figure 3.22 A view of rock fall area along the alignment

g) Rock Fall

At a number of locations along the existing alignment, periodic rock fall and debris flow is visible. While RCC walls and drains have been provided to catch such material from coming onto the carriageway, the matter needs to be re-examined during the study to suggest further remedial measures (Figure 3.23 & Figure 3.24).

Figure 3.23 RCC wall to prevent falling rock pieces from affecting traffic safety

Figure 3.24 RCC Barrier showing damage by falling boulders

h) Land Slide

A major land-slide developed in the Simbal area of the alignment in 2005 which has recently been re-activated and continues to pose serious threat to vehicular traffic. Another rockslide was witnessed towards the Lahore end of the section in July 2006. Other locations of small rock fall and debris flow are also visible along the way. All these locations need to be investigated in detail and preventive measures suggested for future. Locations where future slips / slides may develop also need to be identified. Following photos illustrate extent of problem at Simbal Slide (Figure 3.25 to Figure 3.31):

Figure 3.25 A view of potential land slide site along the alignment

Figure 3.26 Slipped strata comprises large boulders (2-3m dia) in alluvial material

Figure 3.27 Work in progress to keep southbound carriageway open to traffic

Figure 3.28 Severe Damage caused to central NJ Barrier by falling boulders

Figure 3.29 Blackish / Greyish liquid seeping at bottom of the land slide area

Figure 3.30 Collection of seeped water at bottom of the land slide area

Figure 3.31 Cracks on top the slide mass confirming changes of further movement

Figure 3.32 A panoramic view of the land slide near Simbal Motorway is visible on the extreme LHS

Figure 3.33 A panoramic view of the cliffs immediately above the land slide portion with the occurence of the land slide, these cliffs have become susceptible to movement

Figure 3.34 Panoramic view of the Heavy Cut at Simbal showing high Cliffs, rock benching & protection works. Land slide is visible in extreme RHS end

3.4 GUIDELINES ADOPTED

- AASHTO Highway Design Manual 2011 also known as AAHTO Green Book was used as a standard to limit horizontal and vertical grades and other geometric design parameters.

- For Cost estimation, Composite Schedule Rates were used.

3.5 SUMMARY

The methodology used for the study is quite comprehensive. Data was collected from reliable sources and reputable organizations. Previous studies were taken into consideration. Actual conditions were observed on the site. The Parameters used to compare the alternatives are based on the extensive experience and as per standard practices used in mega highway projects in Pakistan and other developing countries. The results obtained can be used for further study in the same area or else.

Chapter 04

ANALYSIS AND RESULTS

4.1 INTRODUCTION

In this chapter analysis is performed based upon the data collected from the site. The analysis has been divided into two parts, on which first is the determination of feasible improvements in the existing alignment in order to achieve the required objectives. In the second part, some potentially feasible alignment options have been chosen. The geometric parameters for these options have been studied and a comparison have been conducted among the selected parameters to choose the best possible options which will satisfy the set geometric criteria in the most economical way.

4.2 IMPROVEMENT OF EXISTING ALIGNMENT

4.2.1 Constraints in Improvement

4.2.1.1 Topography

The Salt Range lies in an east-west direction, north of the Jhelum River. Its lateral extent is about 200 km. The Salt Range forms an abrupt rise from the south and it is separated from the Kalachitta Range with the intervening Potohar Plateau towards the north. The existing alignment ascends from Jhelum River plain area having elevations in the 250-270m range to the Potohar Plateau, having an average elevation of about 700-800m.

This abrupt rise in ground levels and the location of the existing motorway on the steep eastern hillside of the Sohal River valley is a major constraint in contemplating any improvements in the geometric design of the existing motorway in this area.

4.2.1.2 Geology

Pir Khara to Kallar Kahar section of M-2 passes through hilly area of the Khewra Salt Range which rises from the Punjab plains forming an impressive escarpment that mainly trends east to west. The southern face of the salt range presents a series of escarpments rising abruptly from the plains and exposing pre-cambrian strata followed by a fairly continuous succession from the Permian to the Tertiary.

These all are the tectonic sub-divisions of the Himalayan fold belt which had been subjected to organic and epeirogenic force causing folding and faulting during Pliocene and early Pleistocene age. In recent geological history the continuous deposition and erosional cycles caused gulleying and soil accumulation and thus the topography was changed into a present stage.

The existing alignment passes through a severely dissected and eroded anticline with hills topped with course young taluvium and valleys filled with alluvium. The rocks are strongly jointed and faulted and there are major thrusts and folds associated with tectonic movements. The steep sloping faults and number of joints and faults control the erosion patterns and slope stability.

Instability created by presence of gypsum / salt deposits, marls and shale along the existing alignment needs to be taken into account while contemplating any geometric improvements. At certain locations (like the Simbal slide area) stable rocks like limestone, dolomite and sandstones are inter-bedded into alluvial deposits making the whole hillsides prone to slip-circles and slides.

4.2.1.3 Existing Bridges

There are five bridges on this 10 km long section of Motorway which are listed below:

Chainage	Length	Span	# of Spans
km 223+300	100 m	25m	4 Nos.
km 227+125	90 m	30m	3 Nos.
km 227+475	90 m	30m	3 Nos.
km 228+550	210 m	30m	7 Nos.
km 231+200	100 m	25m	4 Nos.

Most of these bridges are located on critical sections of the motorway with respect to any proposed improvement in the geometric design of the existing alignment.

In some cases, improvements in the vertical profile can be made if the constraint of the bridges is removed i.e. a bridge is allowed to be partially dismantled and height of the bridge is varied.

We may have to elevate or depress some of the bridges in order to improve the vertical profile at certain locations, keeping in consideration the hydrological aspects.

4.2.1.4 Costs

The existing alignment of the Motorway in the Salt Range traverses through a very tough terrain with abrupt variations in the topography. Rock Cut heights of up to 45m and Fill heights of up to 15m are encountered at certain locations.

Therefore, any proposed solution for improvement of this alignment is likely to involve massive rock cuts, embankment fills, retaining walls and slope stability measures which are likely to make the solutions quite expensive. This aspect needs to be kept in mind while devising any solution for improvement.

4.2.2 Proposals for Geometric Improvement

Existing alignment has been reviewed for geometric design improvement through the following mechanisms:

- Reducing the grades, wherever possible, by increasing the length of the alignment
- Elimination of sharp curves at some locations where the topography so permits.
- Decreasing the lengths of stretches with high grades (as per criteria set out by AASHTO Design Guide 2011)

In this section, 3 proposals have been presented for improvement of the geometric design of the existing alignment. Proposals 1 & 3 are short-term measures and proposal 2 can be implemented as a long-term measure.

The motorway will have to be closed to traffic in case of construction for Proposal 2. However, for Proposals 1 and 3 the execution can be carried out without significant disturbance of existing traffic.

Details of the proposed improvements are described in the following pages along with a tentative revised plan and profile of the alignment.

4.2.3 Proposal #1

Reducing the Vertical Slope Between

Km 222+425 To Km 223+200

A. Description

On the Lahore end of the Salt Range, improvement of the vertical profile can be carried out by shifting back the start point and introducing high embankment to reduce the steep grade of 6.82%.

B. Plan & Profile

The existing grade of 6.82% (length 775m) between Chainage 222+425 and 223+200 has been broken. Starting approx. 900 km before the current start point, a 4.0% grade (length 375m) has been introduced followed by a respite of 2.31% to give the relief to the vehicles. Then there is another grade of 4.86% (length 360m) and a respite of 2.46% (length 345m). Thus the initial grade of 6.82% (775m) has been eased out. The plan & profile sheets are provided in the Appendix-D

C. Construction

Maximum filling of approx. 20 m will be required to improve the gradients. The construction can be carried out in stages without closure of the motorway. The methodology adopted shall be such that the work on one carriageway will be carried out and the traffic will be diverted onto the second carriageway. Afterwards, traffic will be diverted onto the first carriageway and work will be taken up on the second carriageway.

Figure 4.1 A panoramic view of first steep rise of nearly 7% at start of Salt range (Lahore end) leading to Bridge BD-12C3

4.2.4 Proposal #2

Reducing the Vertical Slope Between

Km 225+450 To Km 228+400

A. Description

This proposal takes advantage of the negative slope present between Km 227 & Km 228 to break the steep grades of 7% (1150m length) & 6.17% (850m length) on either side of this stretch. The bridges at Km 227+125 (BD12-C4) & Km 227+490 (BD12-C5) need to be demolished and reconstructed for this proposed improvement.

B. Plan & Profile

This proposal utilizes the negative grade of 2.5% over a length of 1000m to improving the grades of 7% (1150m length) and 6.17% (850m length) that occur before and after this stretch respectively. The proposal is to reconstruct the bridge (BD-12C4) at Chainage 227+125 and hence the grade of 7% (1150m) will be improved to a grade of 4.84% (1200 m). Then a respite of 0.06% (925m) and an upgrade of 5.82% (840 m) will be introduced. This grade of 5.82% (840m) can further be improved but in that case bridge (BD-12C5) at Chainage 227+490 will also have to be reconstructed The Plans and profiles are provided in Appendix-D.

C. Construction

Maximum cutting up to 20m will be required on the existing alignment to improve the gradients. The construction can be carried out in stages without closure of the motorway. The methodology adopted shall be such that the work on one carriageway will be carried out and the traffic will be diverted onto the second carriageway. Afterwards, traffic will be diverted onto the first carriageway and work will be taken up on the second carriageway.

Figure 4.2 View from Km 229 of negative slope at Km 227

Figure 4.3 View showing negative slope at Km 227 followed by steep 7% slope leading to Bridge BD-12C6 at Km 229

4.2.5 Proposal #3

Increasing the length & reducing the vertical slope between km 228+900 to km 230+200

A. Description

This proposal relates to the critical area between Km 229 and end point (Islamabad end). Improvement of the horizontal plan and vertical profile in this stretch can be carried out by increasing the length of the alignment by about 900m. This is required to be done in order to reduce the steep grades of 7% (350m), 5% (150m), 7% (525m), 7% (275m) and 5.21% (600m) between Km 228+900 & Km 231+000.

B. Plan & Profile

The presence of above stated grades in this reach results in an average grade of 5.8%. The proposal is to increase the length of the alignment by improving the two curves at PI station 8+375 (new design chainage) and PI station 8+670 (new design chainage) which results in revised upgrades of 2.6% (305m length), 3.64%(415m length), 3.3% (450m length) and 4.29% (1245m length). Hence the average grade becomes 4.3% for the entire reach. The proposed increase in length is about 900 m.

If demolition and reconstruction of the bridge at station 231+200 (BD-12C7) is contemplated, then the above stated grade lengths can be further lessened and grades may further be flattened in this section. The plan & profile sheets are provided in the Appendix-D

C. Construction

Max filling of approximately 15 m and max cut of about 30 m will be required to improve the gradients. Apart from that approximately 900m of motorway will be re-aligned. Construction will be carried out without closure of the existing motorway.

The methodology adopted shall be such that the work on one carriageway will be carried out and the traffic will ply on the other carriageway. Afterwards the traffic will be diverted onto the newly constructed carriageway.

Figure 4.4 A panoramic view of double hairpin bend with 7% vertical slope at km 229 creating a black-spot

Figure 4.5 A view of Motorway alignment from top of Simbal slide showing possible route of re-alignment (Proposal - 3)

4.3 STUDY FOR AN ALTERNATE ROUTE

4.3.1 Objectives of Re-Alignment

The cost effectiveness of a motorway route is determined by the quantum of traffic that uses it. The observed heavy truck traffic using Motorway M-2 (Lahore - Islamabad) is less because of the steep gradients and sharp curves in the Salt Range area

The purpose of the study related to re-alignment is to identify and design a new route for the Motorway M-2 in the Salt Range Area that would act as a viable alternate to the current alignment by providing relief to the road users in terms of increased vehicular manoeuvrability and operational speed and reduced incidence of vehicular breakdowns and accidents.

Such a route would remove the current bottleneck created at Salt Range Area due to extremely tight horizontal curves (up to 90m radius) and steep slopes (up to 7%), which prevent heavy vehicles from using the Northbound Carriageway and cause numerous accidents to heavy as well as light vehicles on the Southbound Carriageway. Consequently, the whole Motorway Network from Gwadar to Peshawar would become viable for use by heavy traffic.

4.3.2 Traffic Configuration

With respect to re-alignment, a policy decision is required from the NHA, regarding the type of traffic configuration for the new alternate route. Three options in this respect are graphically illustrated in Figure 4.6, Figure 4.7 & Figure 4.8 and are described as follows:

A. Alternate Route for Entire Traffic

Under this arrangement, the entire traffic of Motorway M-2, (whether North-bound or South-bound and whether Heavy or Light Vehicular traffic) will be diverted to the new alternate route. Consequently, this configuration would require a 6-lane divided motorway.

While under this arrangement, the entire traffic will benefit from the reduced slopes and improved curve radii thereby making the Motorway more user-friendly, the NHA will have to bear a much higher construction cost. Furthermore, under this arrangement, the existing alignment would become redundant which would be a loss to the NHA.

B. Alternate Route for HTV Only

A second arrangement can be whereby the alternate route is used for Heavy Transport Vehicles (HTV) only, both for North bound as well as South bound traffic. For this a 4-lane divided motorway is proposed.

Under this arrangement all the buses and trucks, which are more prone to manoeuvrability problems on the existing alignment, will benefit from the improved geometry of the alternate alignment. These HTV's will have easier climbing on the North-bound lanes and will retain vehicular control during decent on the South-bound lanes.

In this manner cost of construction of 2 lanes will be saved while the existing alignment (with geometric and road safety improvements) will be utilized by the Light Vehicular Traffic (LTV) i.e. cars, jeeps etc.

C. Alternate Route for All North Bound Traffic

A third arrangement can be that the alternate route is used for ALL North-bound Traffic (whether HTV or LTV). For this a 3-lane single carriageway of the motorway is proposed.

Under this arrangement, the climbing problems faced by HTV's as well as majority of LTV's will be eased through a new route while the current alignment (with geometric and road safety improvements) will be utilized by South-bound traffic.

This will minimize the cost of construction for the NHA and maintain some utility for the existing carriageway as well.

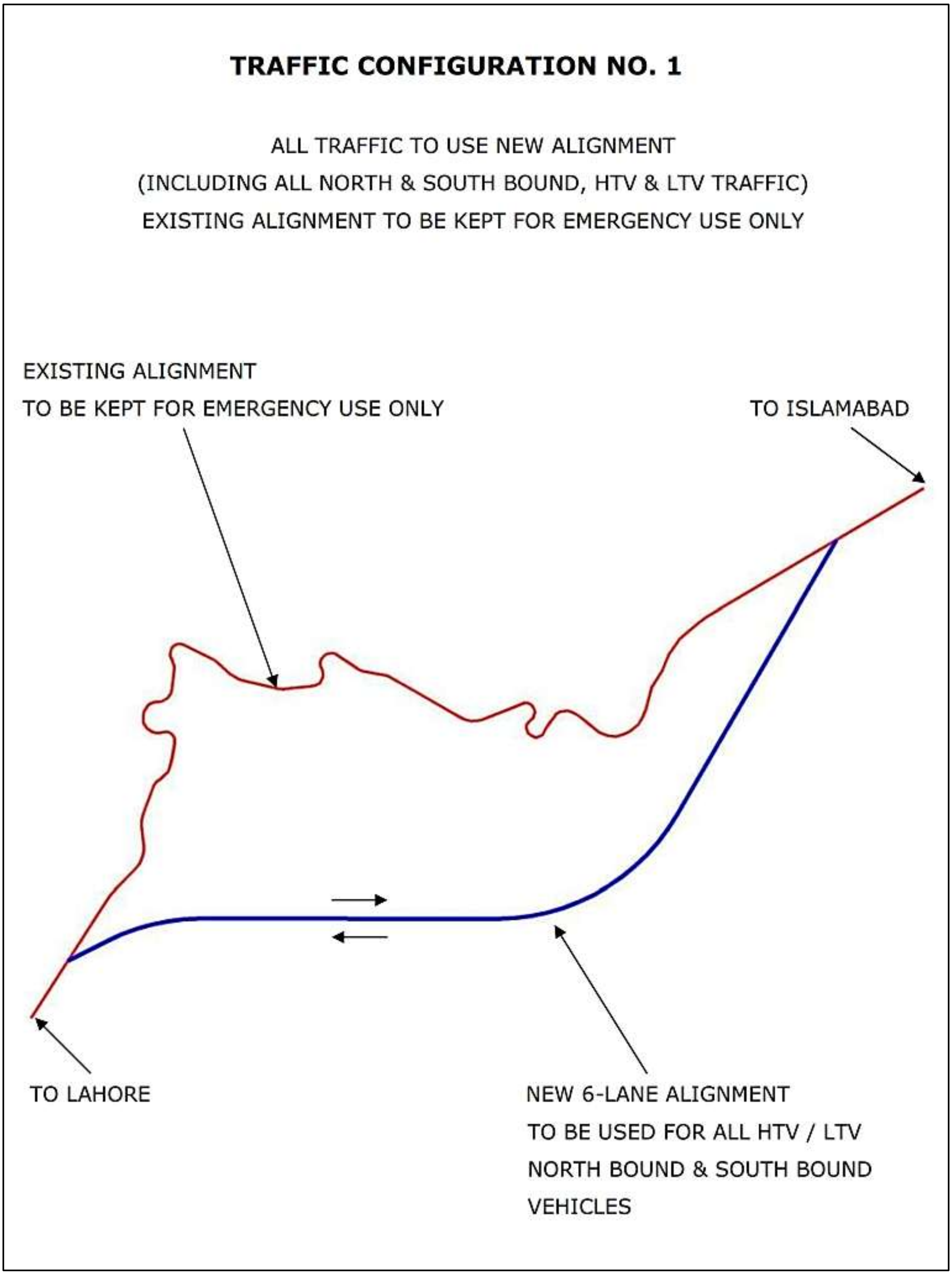

Figure 4.6 Traffic configuration No. 1

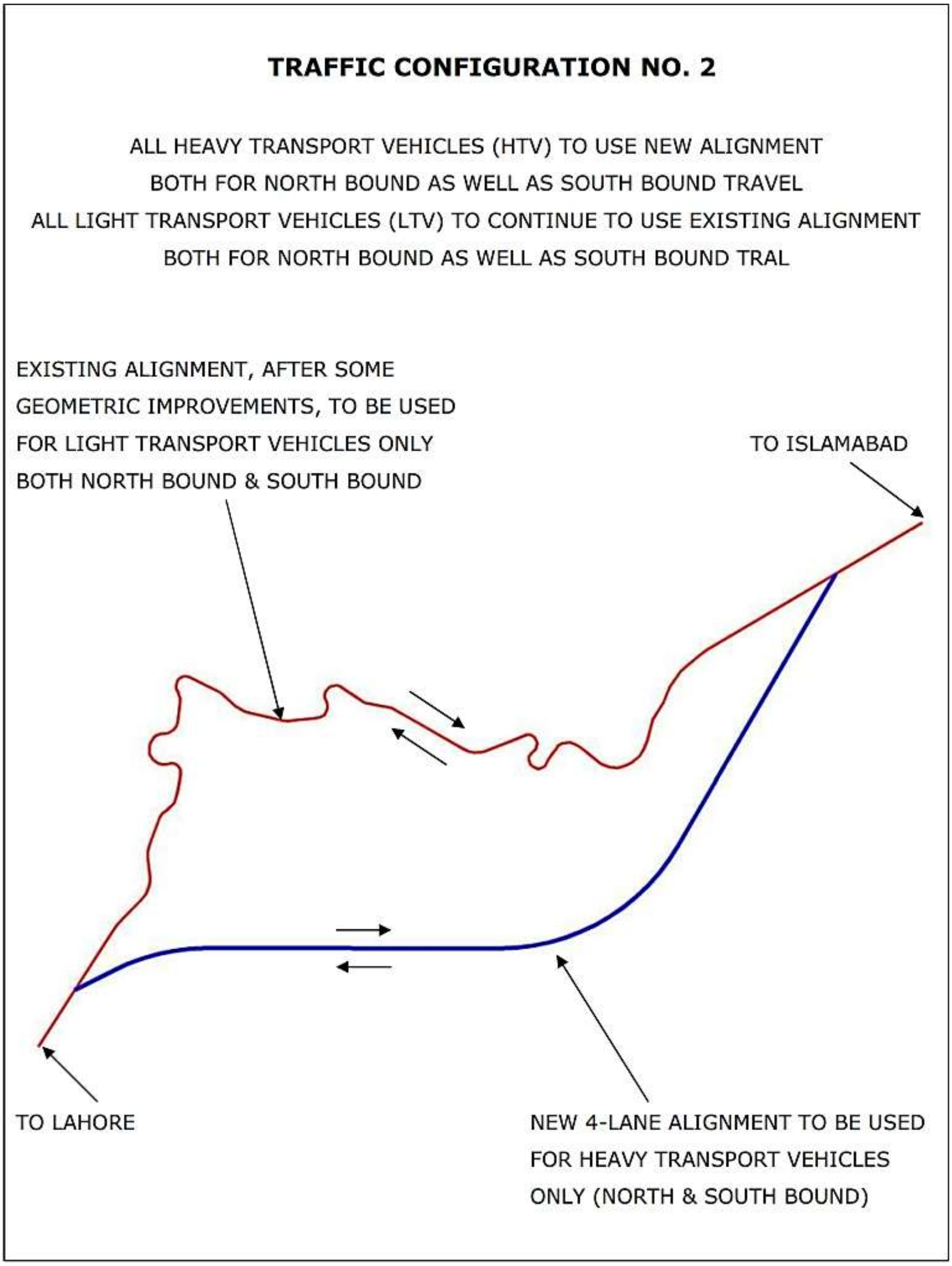

Figure 4.7 Traffic configuration No. 2

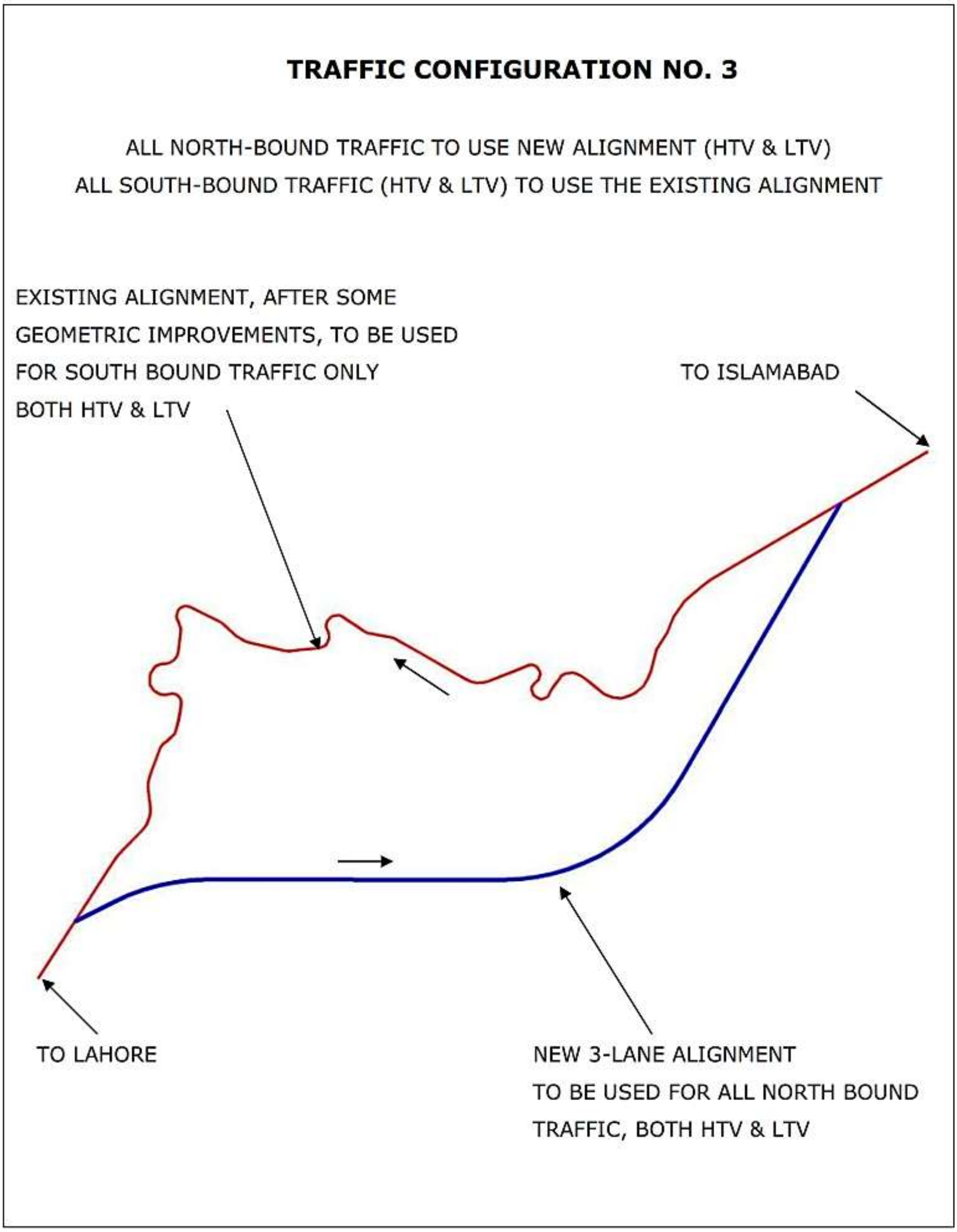

Figure 4.8 Traffic configuration No. 3

4.3.3 Proposed Cross Sections

For the Re-aligned portion of the Motorway M-2, three possible alternate lane-configurations are being considered (as given in the previous section) and consequently there are three possible Proposed Cross Sections. While these cross sections depict flexible pavement, Rigid Pavement will be provided wherever relatively steeper grade is encountered or where there is a possibility of future GROUND settlement. The Cross Sections are described below and graphically illustrated in Figure 4.9, Figure 4.10 & Figure 4.11:

A. X-Sec #1: 6-Lane Dual Carriageway

This cross section shall apply, in case the NHA decides to re-align the entire Motorway (i.e. 6-lanes) to the new alternate route.

In this x-section (like the existing x-section for Motorway M-2), the overall formation width is 31.9m. The width of asphalt pavement is 10.95m on either carriageway with 1.7m inner and 3.0m outer shoulders. The carriageways are separated by a 0.6m wide N.J. Barrier in the centre. The Cross Slopes shall be 2% for the asphalt surface and 4% for the outer shoulders.

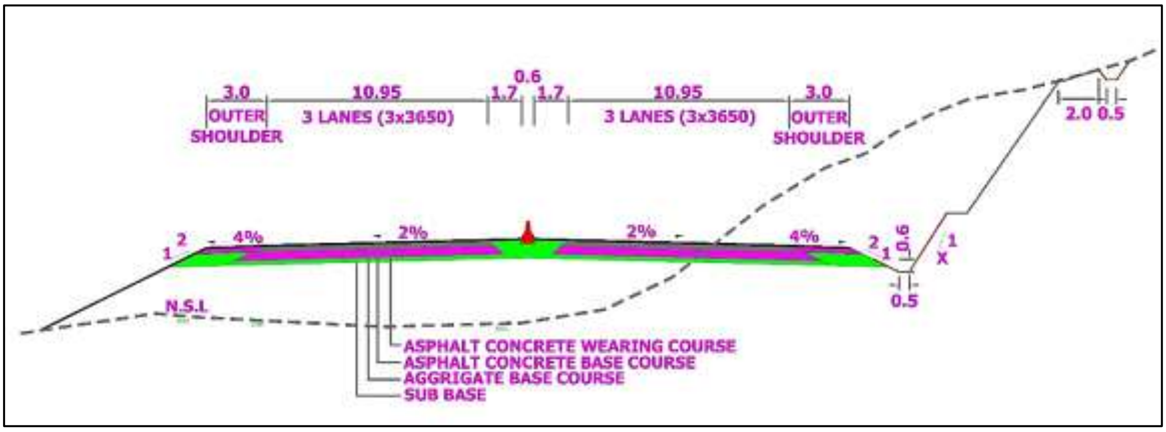

Figure 4.9 Proposed 6-Lane cross-section

B. X-Sec #2: 4-Lane Dual Carriageway

This cross section shall apply, in case the NHA decides to use the new alternate route for the Heavy Transport Vehicles (HTV) only, while the Light Transport Vehicles (LTV) continue using the existing alignment.

In this x-section, the overall formation width is 24.6m. The width of asphalt pavement is 7.30m on either carriageway with 1.7m inner and 3.0m outer shoulders. The carriageways are separated by a 0.6m wide N.J. Barrier in the centre. Cross Slopes shall be 2% for asphalt surface and 4% for outer shoulders.

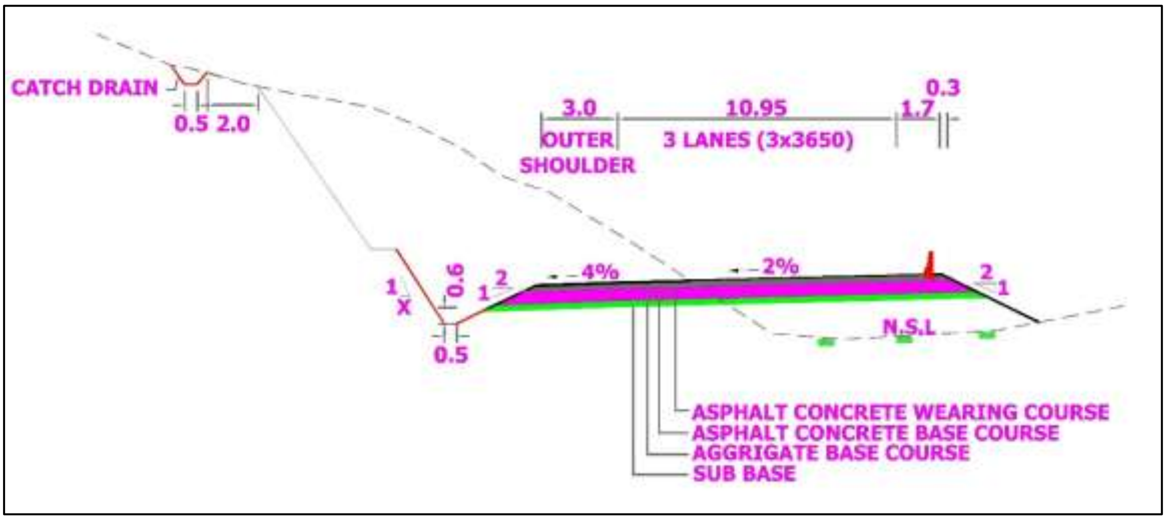

Figure 4.10 Proposed 3-Lane cross-section

C. X-Sec #3: 3-Lane Single Carriageway

This cross section shall apply, in case the NHA decides to use the new alternate alignment for all North Bound Traffic (HTV & LTV) only while the existing alignment is kept for the South Bound Traffic (HTV & LTV) only.

In this x-section comprising one carriageway, the overall formation width is 16.55m. The width of asphalt pavement is 10.95m with 1.7m RHS and 3.0m LHS shoulders. The carriageway shall have an RCC crash barrier on the fill side wherever the height of fill is greater than 3.0m. The Cross Slopes shall be 2% for the asphalt surface and 4% for the LHS shoulder.

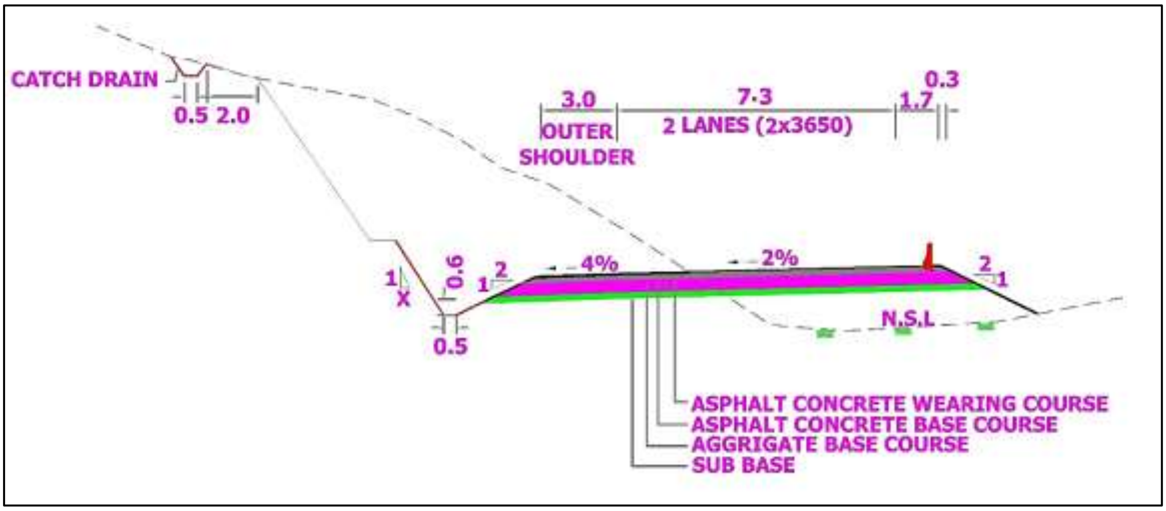

Figure 4.11 Proposed 2-Lane Cross-Section

4.3.4 Design Criteria for Re-Alignment

In order to meet the objectives of the study, firstly a new route has to be identified, which broadly qualifies the design criteria as set out in Table 4-1

Table 4-1: Design Criteria

Sr. No.	**Description**	**Design Parameters**
1	**Design Speed**	90 kph
2	**Road Cross Section**	
	(a) Width	3.65m
	1) Lane Width	
	2) No. of Lanes	6
	Traffic Configuration 1	4
	Traffic Configuration 2	3
	Traffic Configuration 3	2.0m
	3) Treated Shoulder on either side	
		2.0%
	(b) Carriageway Cross Slopes	4.0%
	1) Pavement	
	2) Shoulders	
		2:1
	(c) Embankment Slope	1.5:1 to 2:1
	1) Fill Slope (H:V) *	
	Height of Fill <= 3.0m	
	Height of Fill > 3.0m	
	2) Cut Slope *	1.5:1
	Height of Cut <= 4.0m	0.5:1 to 1.5:1
	Height of Cut > 4.0m	

3	**Horizontal Alignment**	
	(a) Minimum Radius	280m
	(b) Absolute Maximum Super-elevation	8%
	(c) Max. side friction factor	0.14
	(d) Sight Distances	
	1) Stopping Sight Distance	155m
	2) Passing Sight Distance	510m
	(e) Minimum length of circular curve for deflection angle of 5 degrees to avoid the appearance of a kink	150m
	(d) Minimum increase in circular curve for 1 degree decrease in deflection angle	30m
4	**Vertical Alignment**	
	(a) Minimum length of Vertical Curve	100m
	(b) Maximum Gradient	
	1) Desirable	3.0 %
	2) Absolute	5.0 %
	3) Minimum	0.3 %
	(c) Minimum “K” value	
	1) Desirable for Crest Curve	60
	2) Absolute for Crest Curve	49
	3) For Sag Curve (unlit road)	24

4.3.5 Topographic Constraints

Finding an alternate alignment in the Salt Range area is a very challenging assignment as illustrated in the G.T. Sheets and the Digital Elevation Model given as Figure 4.12 & Figure 4.13 respectively.

These figures illustrate that the Salt Range is located between two plateaus. While the northern plateau has elevations in the 700m - 800m range, the southern plateau has elevations in the 250m – 300 m range. The band between these two plateaus is 5 to 10 kms wide (horizontally) at various locations.

In other word, the problem of finding an alternate alignment tranSaltes into finding an alignment, which rises through an elevation difference of approx. 450m with a longitudinal slope equal to or lower than 4% in the shortest possible distance.

In ordinary mountain ranges, such a transition is achieved by climbing along the hillside with the desired longitudinal slope and bridging any nalas that fall on the way. Unfortunately, in case of the Salt Range, the topography is very rugged and broken and there is no chance of finding a long and continuous hillside that can be climbed in the above stated manner.

Consequently, any solution for an alternate alignment is likely to employ innovative measures, make certain geometric compromises and at locations adopt design features that would, under normal circumstances, be considered as uneconomical.

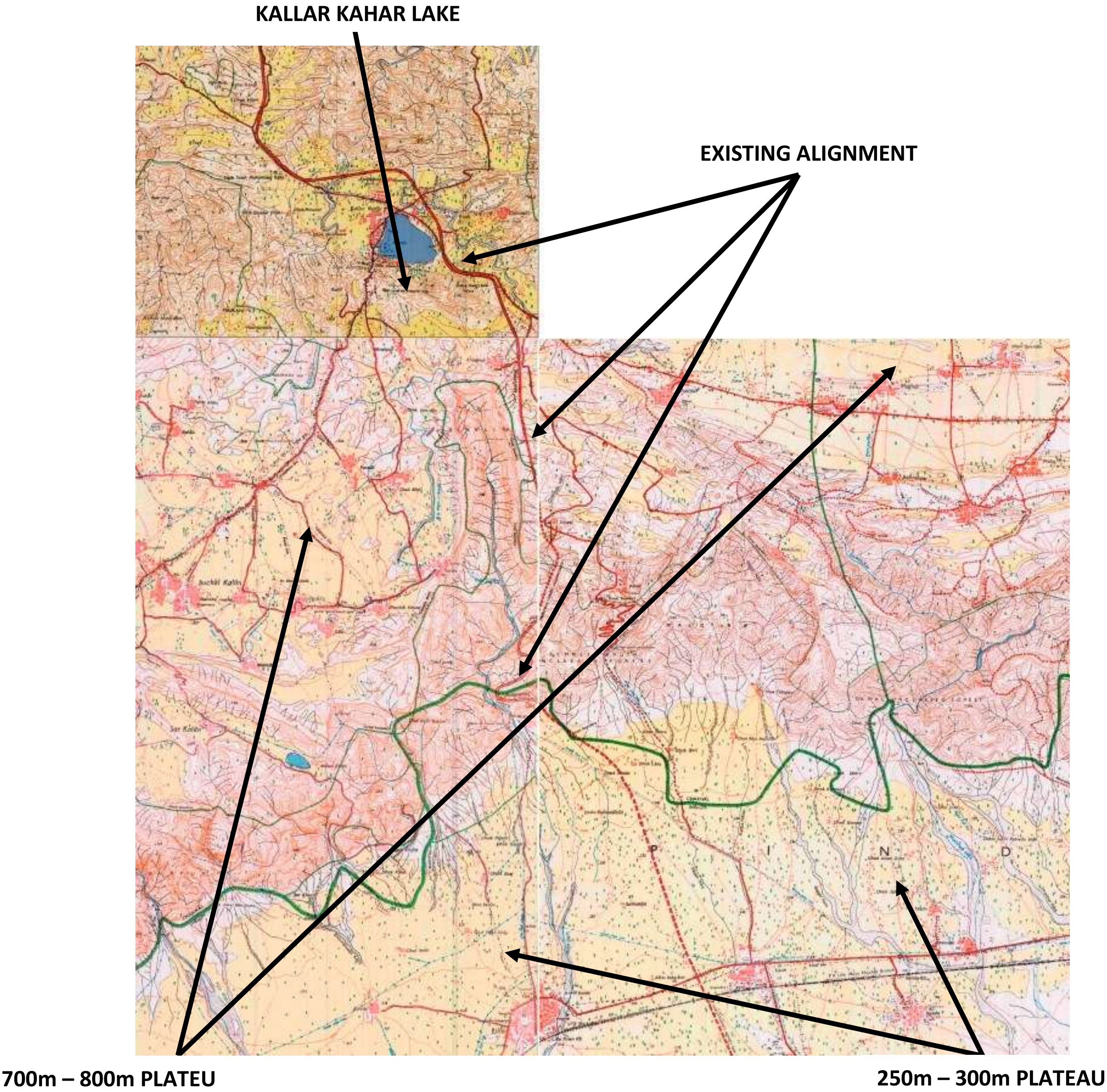

Figure 4.12: G.T. Sheets of the Salt Range Area (Survey of Pakistan)

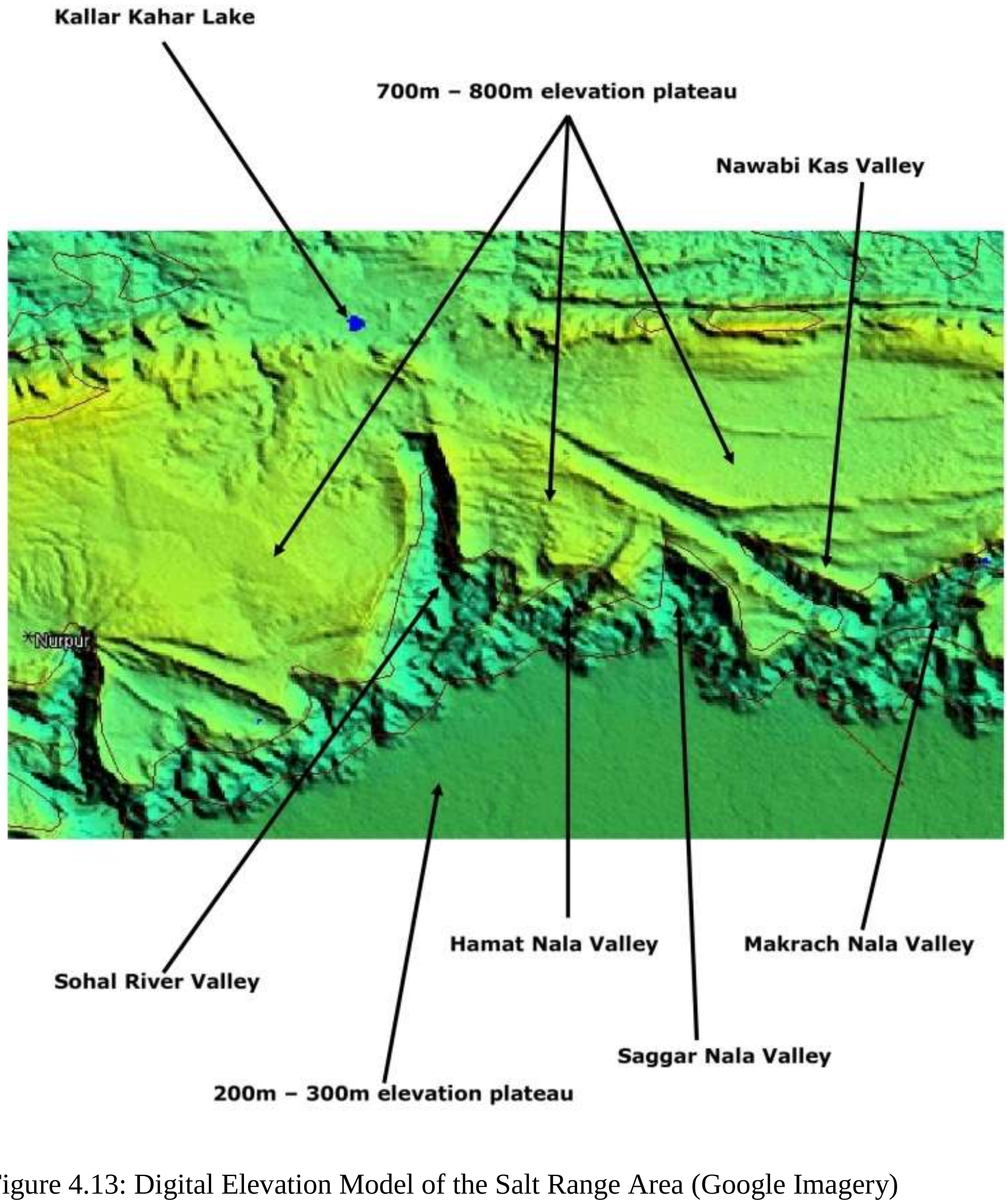

Figure 4.13: Digital Elevation Model of the Salt Range Area (Google Imagery)

4.4 APPROACH TO REALIGNMENT

As stated earlier in this Report and evident from enclosed Satellite Image (Figure 4.15), the problem with all the previously proposed or other routes to be considered, is that there is a sudden drop of level from 700m contours to 300m contours. Due to the broken terrain of the area, it is almost impossible to find a route that would allow gradual gain of elevation in a continuous manner. If we attempt to follow a contour and raise the elevations gradually, we end up with very tight / low radius curve.

It is however amply clear that the length of the re-aligned portion of the motorway shall be between 25 – 30 kms in order to achieve required gradients (i.e. 4% or less) with respites with an additional travel distance of approx. 15 – 18 kms over the current alignment. Any route shorter than this is bound to have compromised geometric design either in terms of steep slopes or tight curves (or both) that will cause loss of advantage over the current alignment and would render such an alternate unworthy of further consideration.

Once one or more alternate routes are identified that either wholly or partially meet the geometric standards set out for this exercise in Table 5.1, these will be compared with respect to their feasibility in terms of geology, hydrology and cost.

With this overall approach in mind, the topography of the Salt Range Area has been depicted in bands of 100m contour intervals in Figure 4.14 as follows:

Yellow band	300m – 400m contours
Orange band	400m – 500m contours
Green band	500m – 600m contours
Pink band	600m – 700m contours
Cyan band	700m – 800m contours
Purple band	800m – 900m contours

The logic is that each band of contours of 100m interval, needs to be climbed / traversed in a minimum horizontal distance of 5 kms if the requirements of grades (between 3% - 4%) and respites (as per AASHTO Design Guide, 2011) are to be met and a geometrically viable route is to be found.

With this logic four routes were identified, one on the west side of the Sohal River, two in the Saggar Nala valley in the east and one on the same mountain as the current alignment.

These alternate routes are described, discussed and compared in the following pages.

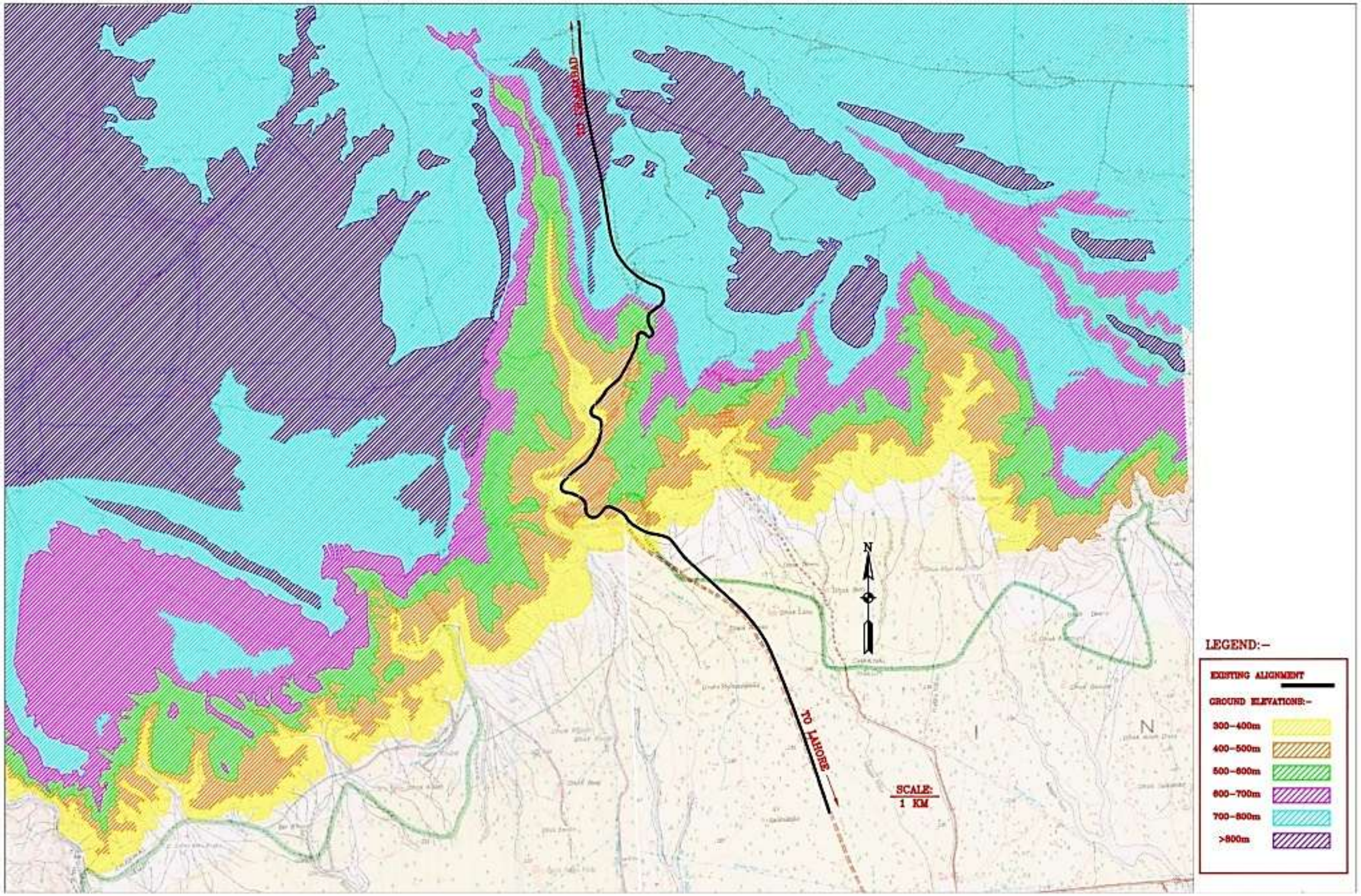

Figure 4.14 Contours of the area in Kalar Kahar Section Area of M2 (Survey of Pakistan, 2004)

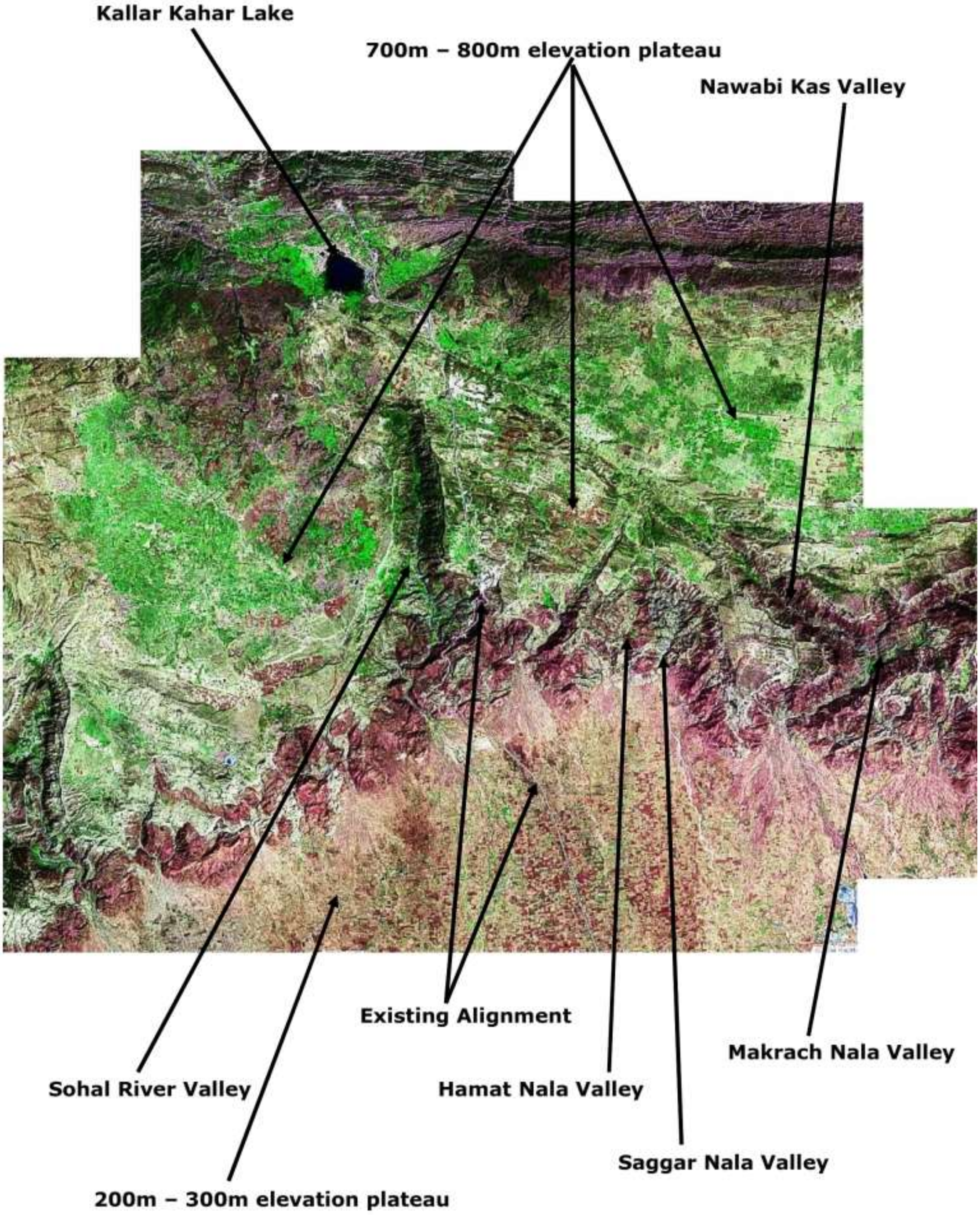

Figure 4.15 Satellite Imagery of the Salt Range Area (Google Imagery)

4.5 PROPOSAL FOR REALIGNMENT

The four alternate routes identified through the contour bands were studied in detail through the following means:

1. G. T. Sheets (1:50,000)
2. 2.5m resolution Satellite Imagery from Spot
3. Google Earth Satellite Imagery
4. Extensive site visits
5. G. P. S. Survey of the Routes
6. Digital Elevation Model

The four alternate routes are depicted over the contour bands in Figure 4.16.

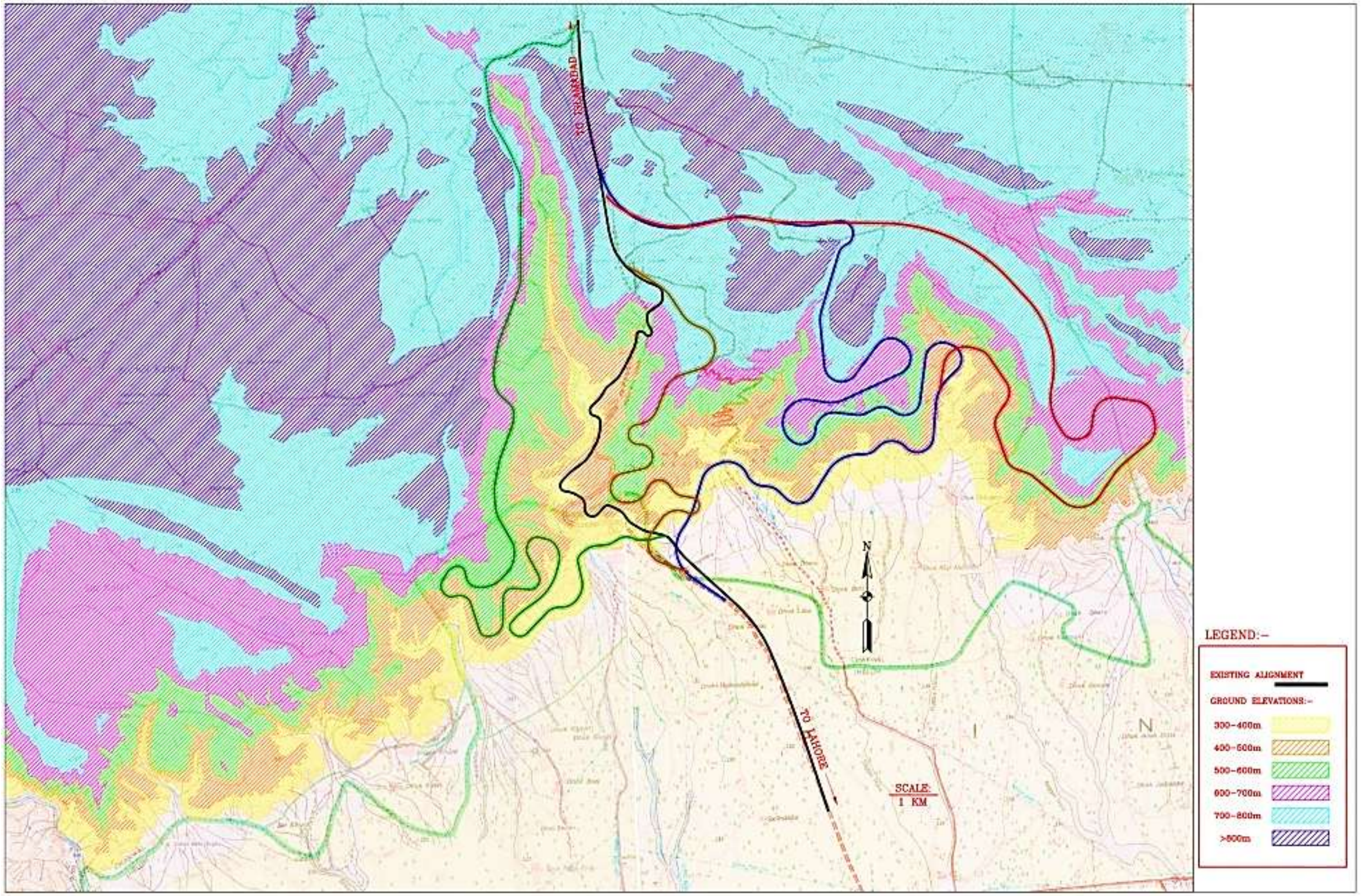

Figure 4.16 Proposed Alternate alignments for the Kalar Kahar Section (Survey of Pakistan, 2004)

4.6 ALTERNATE ALIGNMENT NO. 1

a) ROUTE DESCRIPTION

Near Km 221 this Alignment takes off to the east of the existing alignment, crosses the Hamat Nala, moves east along the foot of the hill to rise gradually along the contours, traverses through the Saggar Nala Valley to the north of Dhok Chappar, reaches the 700m contour north of Dhok Jindar, takes a loop west to move parallel to the Nawabi Kas valley, moves north of Waralla village and south of Choi village in the Ghuku valley to join the existing alignment north of Simbal village. The route is 33 kms long.

b) Topography

The first 6 kilometers of the alignment pass through relatively mild slopes. Between Km 6 and Km 16, the alignment traverses through relatively steep hill slopes often cut up by nala flows. At places complete hill sides have been eroded and problems may be encountered in placing the alignment between Km 12 and 16. From Km 16 onwards, the alignment traverses through rolling terrain in the 700+ contours till the alignment meets the existing motorway north of Simbal (Figure 4.18).

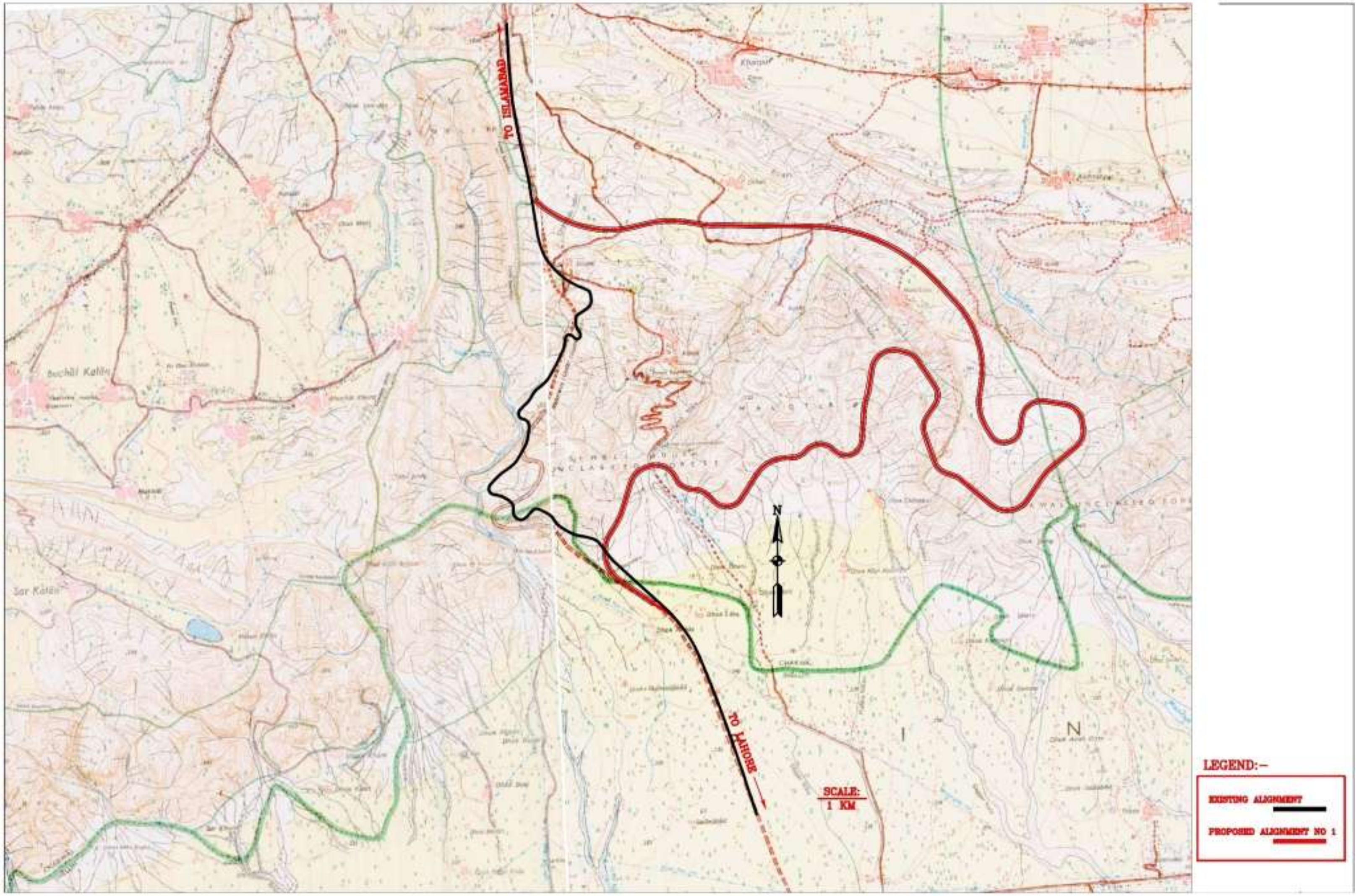

Figure 4.17 Alignment Plan of Proposed Alignment-1 (Survey of Pakistan, 2004)

Figure 4.18 A panoramic view of the Saggar Nala valley showing deep hill side cuts gypsy marls & shale in the lower contours and steep hillside slopes on the higher elevations (Alignment - 1)

c) Geology

The proposed alignment starts through quaternary deposits composed of alluvium at Pir Khara and colluvium in the adjoining hills.

Between Km 6 and 16, as the contours rise from 300 to 500, Gypsy Marl with distinctive pinkish red colour is encountered which is a mixture of calcium carbonate and clay with significant content of evaporite as gypsum. This formation is highly erodible due to its evaporite contents & soluble salts.

Shale is often thinly encountered in the above stretch. It varies from red shales coloured by iron oxides and gray to black shales coloured by carbonaceous materials. It has clayey composition and may contain quantities of silt, sand, organic material & carbonates.

Beyond Km 16, when the alignment reaches the 700m contour, the geology mostly consists of sandstones, dolomite and limestones.

d) Hydrology

Major streams along the alignment are Hamat Nala and Saggar Nala which traverse the alignment at Km 4 and 11, respectively. Few tributaries of Saggar Nala also cross the alignment between Km 4 and 11. Beyond Km 16, only minor streams are encountered except Chambah Nala crossing near Km 32. Inflows for all these nalas are from rainfall and they stay dry for rest of the year.

e) Structures

2 – 4 span Bridges will be required at a minimum of 6 locations along this route. 60 number of box culverts of various sizes and cell configuration are estimated to be required. Major retaining walls are expected to be provided in the Saggar Nala Valley north of Dhok Chappar due to steep side slope.

f) Plan & Profile

Preliminary Geometric Design of the Alignment was carried out using Eaglepoint software. Horizontal Plan on 1:4000 scale was plotted on underlying relevant G. T. Sheets to show the ground features. Vertical Profile of the Alignment based on GPS survey of the route was also generated. These Plan & Profile Drawings are enclosed in the Appendix-E.

g) Estimated Quantities & Cost

Rough cost estimate of the Alignment has been prepared based on Preliminary Plan & Profile generated on Eagle Point software. CSR 2014 rates (with 14% premium) have been used for costing purposes. Some estimates related to Bills 4 – 6 are based on judgement and experience on similar type of projects in identical terrain. Priced Bill of Quantities for Alignment 1 (for 3 types of cross-sections) thus obtained is reproduced as Table 4-2.

Table 4-2 Tentative BOQ & cost estimate for proposed alternative no. 1 (33.173 Km)

ALTERNATIVE NO. 1

ITEM #	ITEM DESCRIPTION	UNIT	RATE	BOQ FOR 2 LANES		BOQ FOR 3 LANES		BOQ FOR 6 LANES	
				QTY	AMOUNT	QTY	AMOUNT	QTY	AMOUNT
	BILL NO. 1								
101	CLEARING AND GRUBBING	SM	25.46	204,014	5,194,196	264,555	6,735,570	529,109	13,471,115
104	COMPACTION OF NATURAL GROUND	SM	27.68	204,014	5,647,108	264,555	7,322,882	529,109	14,645,737
108 a	FORM OF EMB FROM ROADWAY EXCAVATION IN COMMON MATERIAL	CM	398.68	1,802,331	718,553,323	2,083,926	830,819,618	3,314,460	1,321,408,913
108 bi	FORM OF EMB FROM ROADWAY EXCAVATION IN HARD ROCK MATERIAL	CM	1143.85	901,165	1,030,797,585	1,041,963	1,191,849,378	1,657,230	1,895,622,536
108 bii	FORM OF EMB FROM ROADWAY EXCAVATION IN MEDIUM ROCK MATERIAL	CM	1030.11	901,165	928,299,078	1,041,963	1,073,336,506	1,657,230	1,707,129,195
108 biii	FORM OF EMB FROM ROADWAY EXCAVATION IN SOFT ROCK MATERIAL	CM	928.42	901,165	836,659,609	1,041,963	967,379,288	1,657,230	1,538,605,477
108 c	FORM OF EMB FROM BORROW EXCAVATION IN COMMON MATERIAL	CM	447.49	3,449,258	1,543,508,462	3,621,027	1,620,373,372	4,371,636	1,956,263,394
					5,068,659,362		5,697,816,615		**8,447,146,366**
	BILLS NO. 2 & 3								
201	GRANULAR SUB-BASE	CM	1162.15	144,037	167,392,600	160,707	186,765,640	321,413	373,530,118
202	AGGREGATE BASE	CM	1455.27	90,005	130,981,576	131,173	190,892,132	262,345	381,782,808
203 a	ASPHALTIC BASE COURSE PLANT MIX (CLASS "A")	CM	17715.68	19,373	343,205,869	29,060	514,817,661	58,119	1,029,617,606
302 a	CUT-BACK ASPHALT FOR BITUMINOUS PRIME COAT	SM	122.01	264,721	32,298,609	385,802	47,071,702	771,604	94,143,404
303 a	CUT-BACK ASPHALT FOR BITUMINOUS TACK COAT	SM	48.87	242,163	11,834,506	363,244	17,751,734	726,489	35,503,517
304 c	TRIPLE SURFACE TREATMENT	SM	544.32	165,865	90,283,637	165,865	90,283,637	331,730	180,567,274
305 a	ASPHALTIC CONCRETE FOR WEARING COURSE (CLASS "A")	CM	18760.41	12,108	227,151,044	18,162	340,726,566	36,324	681,453,133
					1,003,147,841		**1,388,309,072**		**2,776,597,860**
	SUMMARY OF BOQ								
1	**ROAD WORKS (BILL NO. 1, 2 & 3)**				**6,071,807,203**		**7,086,125,687**		**11,223,744,226**
2	**STRUCTURES (BRIDGES, FLYOVERS, UNDERPASSES & CULVERTS)**				**960,000,000**		**1,200,000,000**		**2,000,000,000**
3	**DRAINAGE & EROSION WORKS**				**192,000,000**		**240,000,000**		**400,000,000**
4	**ANCILLARY WORKS**				**240,000,000**		**300,000,000**		**500,000,000**
5	**RETAINING STRUCTURES**				**240,000,000**		**300,000,000**		**500,000,000**
	TOTAL CONSTRUCTION COST (RS)				**7,703,807,203**		**9,126,125,687**		**14,623,744,226**

4.7 ALTERNATE ALIGNMENT NO. 2

a) Route Description

The alignment follows the same route as Alignment No. 1 till Km 11, where instead of moving east, it takes a loop to the west to climb the hill side between Hamat Nala and Saggar Nala through a series of wide hairpin bends, reaching the 700m contour south west of Malot. Here (at Km 22) it once again crosses Hamat Nala to climb north and takes a sharp turn at Km 25 towards west to meet the existing alignment north of Simbal village. The length of the alignment is 31 Kms.

b) Topography

The first 6 kilometers of the alignment pass through relatively mild slopes. Between Km 6 and Km 14, the alignment traverses through relatively steep hill slopes often cut up by nala flows. At a few places hill sides have excessive erosion which may cause problems for alignment between Km 6 and 14. Between Km 14 and 25, the alignment passes through relatively mild hill side. From Km 25 onwards, the alignment traverses through rolling terrain in the 700+ contours till the alignment meets the existing motorway north of Simbal (Figure 4.20).

c) Geology

The proposed alignment starts through quaternary deposits composed of alluvium at Pir Khara and colluvium in adjoining hills.

Between Km 6 and 14, as the contours rise from 300 to 600, Gypsy Marl with distinctive pinkish red colour is encountered which is a mixture of calcium carbonate and clay with significant content of evaporite as gypsum. This formation is highly erodible or soluble due to its evaporite contents & soluble salts

Shale is often thinly encountered in the above stretch. It varies from red shales coloured by iron oxides and gray to black shales coloured by carbonaceous materials. It has clayey composition and may contain quantities of silt, sand, organic material & carbonates.

Beyond Km 25, when the alignment reaches the 700m contour, the geology mostly consists of sandstones, dolomite and limestones.

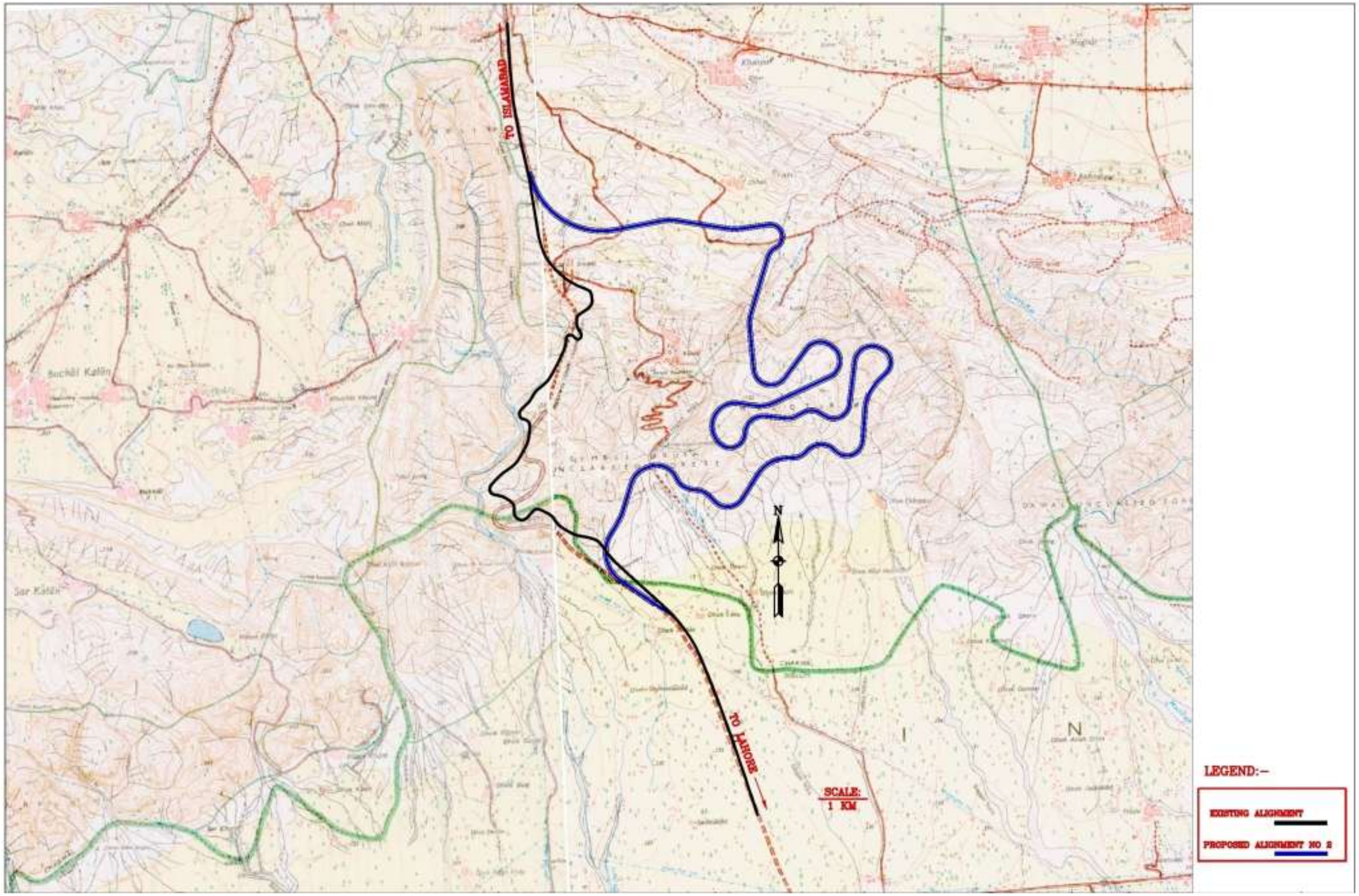

Figure 4.19 Alignment Map of Proposed Alternative-2 (Survey of Pakistan, 2004)

Figure 4.20 A panoramic view (from the Jhelum River Plain) of the hillside south of Malot between Hamat Nala (on the LHS) and Saggar Nala (on the RHS)

Existing Motorway passes on the extreme LHS of the photo from where Alignment No. 2 takes off and travels east along the hillside

d) Hydrology

Major stream along the alignment is Hamat Nala which traverses the alignment twice at Km 4 and 22. Few tributaries of Saggar Nala also cross the alignment between Km 4 and 11. Beyond Km 16, only minor streams are encountered except Chambah Nala crossing near Km 30. Inflows for all these nalas are from rainfall and they stay dry for rest of the year.

e) Structures

2 – 4 span Bridges will be required at a minimum of 4 locations along this route. 40 number of box culverts of various sizes and cell configuration are estimated to be required. Some retaining walls are expected to be provided in the Saggar Nala Valley north of Dhok Chappar due to steep side slopes or in order to accommodate the hairpin bends.

f) Plan & Profile

Preliminary Geometric Design of the Alignment was carried out using Eaglepoint software. Horizontal Plan on 1:4000 scale was plotted on underlying relevant G. T. Sheets to show the ground features. Vertical Profile of the Alignment based on GPS survey of the route was also generated. These Plan & Profile Drawings are enclosed in the Appendix-F.

g) Estimated Quantities & Cost

Rough cost estimate of the Alignment has been prepared based on Preliminary Plan & Profile generated on Eaglepoint software. CSR 2014 rates (with 14% premium) have been used for costing purposes. Some estimates related to Bills 4 – 6 are based on judgement and experience on similar type of projects in identical terrain. Priced Bill of Quantities for Alignment 2 thus obtained (for 3 different types of cross-sections) is reproduced as Table 4-3.

Table 4-3 Tentative BOQ & cost estimate for proposed alternative no. 2 (30.866 km)

ALTERNATIVE NO. 02

ITEM #	ITEM DESCRIPTION	UNIT	RATE	BOQ FOR 2 LANES		BOQ FOR 3 LANES		BOQ FOR 6 LANES	
				QTY	AMOUNT	QTY	AMOUNT	QTY	AMOUNT
	BILL NO. 1								
101	CLEARING AND GRUBBING	SM	25.46	189,826	4,832,970	246,156	6,267,132	492,313	12,534,289
104	COMPACTION OF NATURAL GROUND	SM	27.68	189,826	5,254,384	246,156	6,813,598	492,313	13,627,224
108 a	FORM OF EMB FROM ROADWAY EXCAVATION IN COMMON MATERIAL	CM	398.68	2,841,760	1,132,952,877	3,226,224	1,286,230,984	4,906,284	1,956,037,305
108 bi	FORM OF EMB FROM ROADWAY EXCAVATION IN HARD ROCK MATERIAL	CM	1143.85	1,420,880	1,625,273,588	1,613,112	1,845,158,161	2,453,142	2,806,026,477
108 bii	FORM OF EMB FROM ROADWAY EXCAVATION IN MEDIUM ROCK MATERIAL	CM	1030.11	1,420,880	1,463,662,697	1,613,112	1,661,682,802	2,453,142	2,527,006,106
108 biii	FORM OF EMB FROM ROADWAY EXCAVATION IN SOFT ROCK MATERIAL	CM	928.42	1,420,880	1,319,173,410	1,613,112	1,497,645,443	2,453,142	2,277,546,096
108 c	FORM OF EMB FROM BORROW EXCAVATION IN COMMON MATERIAL	CM	447.49	1,090,360	487,925,196	944,269	422,550,935	305,872	136,874,661
					6,039,075,121		6,726,349,056		**9,729,652,157**
	BILLS NO. 2 & 3								
201	GRANULAR SUB-BASE	CM	1162.15	134,020	155,751,343	149,530	173,776,290	299,061	347,553,741
202	AGGREGATE BASE	CM	1455.27	83,746	121,873,041	122,050	177,615,704	244,101	355,232,862
203 a	ASPHALTIC BASE COURSE PLANT MIX (CLASS "A")	CM	17715.68	18,026	319,342,848	27,039	479,014,272	54,077	958,010,827
302 a	CUT-BACK ASPHALT FOR BITUMINOUS PRIME COAT	SM	122.01	246,311	30,052,405	358,972	43,798,174	717,943	87,596,225
303 a	CUT-BACK ASPHALT FOR BITUMINOUS TACK COAT	SM	48.87	225,322	11,011,486	337,983	16,517,229	675,965	33,034,410
304 c	TRIPLE SURFACE TREATMENT	SM	544.32	154,330	84,004,906	154,330	84,004,906	308,660	168,009,811
305 a	ASPHALTIC CONCRETE FOR WEARING COURSE (CLASS "A")	CM	18760.41	11,266	211,354,779	16,899	317,032,169	33,798	634,064,337
					933,390,808		**1,291,758,742**		**2,583,502,214**
	SUMMARY OF BOQ								
1	**ROAD WORKS (BILL NO. 1, 2 & 3)**				**6,972,465,929**		**8,018,107,797**		**12,313,154,371**
2	**STRUCTURES (BRIDGES, FLYOVERS, UNDERPASSES & CULVERTS)**				**1,154,621,113**		**1,443,276,391**		**2,405,460,652**
3	**DRAINAGE & EROSION WORKS**				**206,182,342**		**257,727,927**		**429,546,545**
4	**ANCILLARY WORKS**				**206,182,342**		**257,727,927**		**429,546,545**
5	**RETAINING STRUCTURES**				**247,418,810**		**309,273,512**		**515,455,854**
	TOTAL CONSTRUCTION COST (RS)				**8,786,870,535**		**10,286,113,555**		**16,093,163,967**

4.8 ALTERNATE ALIGNMENT NO. 3

a) Route Description

Unlike Alignment Nos. 1 & 2, this route is on the western side of the existing motorway. Near Km 221 of the existing motorway, it turns west at Pir Khara to cross Sohal River through a major bridge. It then climbs through a series of hairpin bends south of Mor Jhang to gain elevation up to 500m. It moves north on the east of Mor Jhang and Sardhai to climb the 600m and 700m contours. It takes an eastwards loop east of Dhok Saiyidan and meets the existing motorway south of Khandoyah village. The route is 26 Kms in length.

b) Topography

The majority of this alignment passes through relatively treacherous topography with cut up hill sides at some locations while extremely steep side slopes at others.

Between Km 3 to 14 the terrain is excessively cut up and eroded due to water flow in alluvial deposits. Beyond Km 14 and up to Km 23, the hill side is extremely steep with high vertical ridges overhead through most of the route. After Km 23, the route passes through rolling terrain till the end (Figure 4.22 & Figure 4.23).

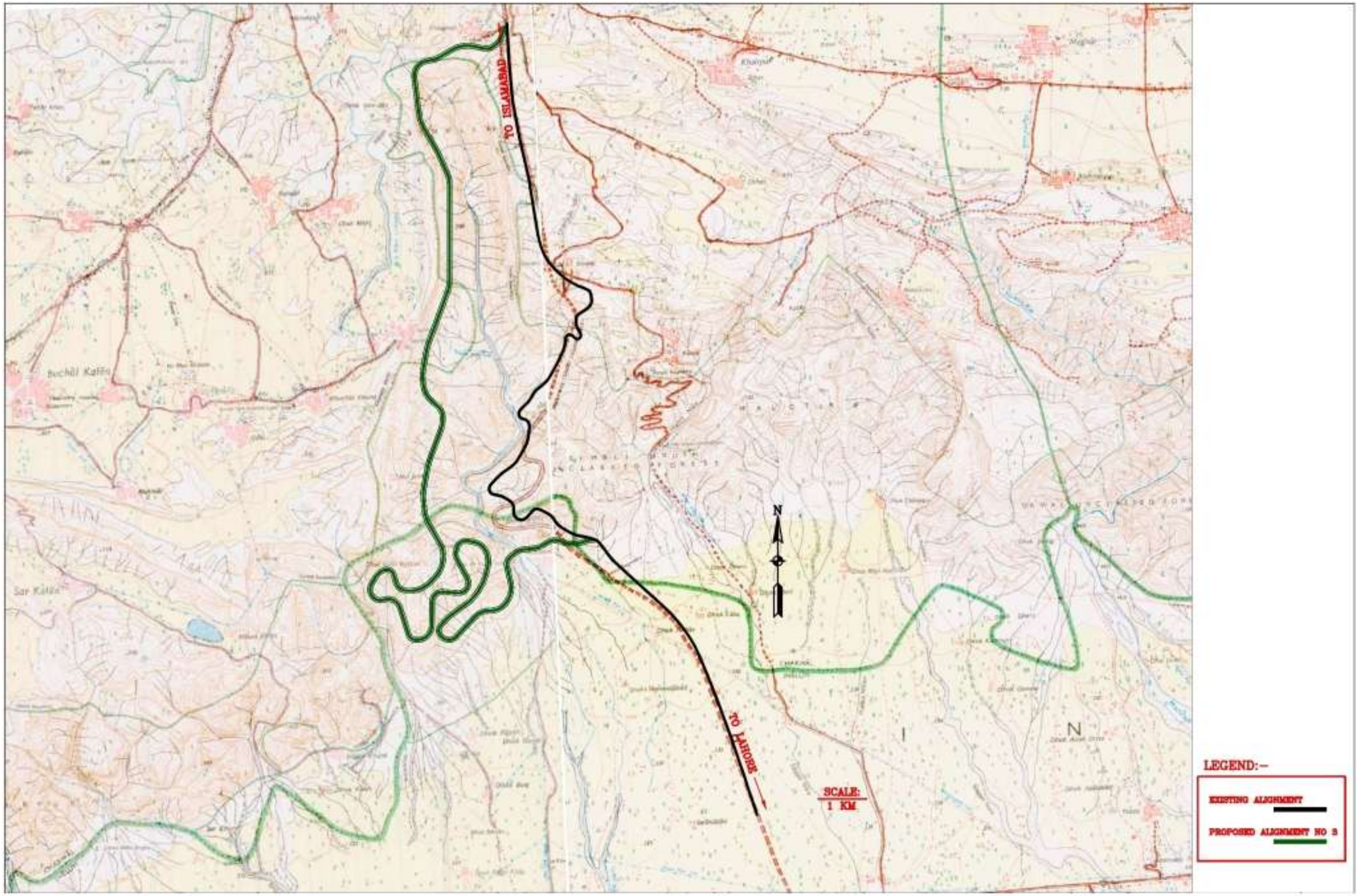

Figure 4.21 Alignment Map of Proposed Alternative-3 (Survey of Pakistan, 2004)

Figure 4.22 Vertical Cliffs and hillside slope east of Sardhai Village (Alignment # 3)

Figure 4.23 Vertical Cliffs and hillside slope as viewed from Mor Jhang Village (Alignment # 3)

c) Geology

The proposed alignment starts through quaternary deposits composed of alluvium at Pir Khara and colluvium in the hills to the west of Sohal River.

Between Km 3 and 14, as the contours rise from 300 to 500, Gypsy Marl with distinctive pinkish red colour is encountered which is a mixture of calcium carbonate and clay with significant content of evaporite as gypsum. This formation is highly erodible or soluble due to its evaporite contents & soluble salts causing deep fissures and ravines in the topography.

Shale is also encountered at places which varies from red shales coloured by iron oxides and gray to black shales coloured by carbonaceous materials. It has clayey composition and may contain large quantities of silt, sand, organic material and calcium carbonate.

Beyond Km 14, when the alignment reaches the 500m contour, the geology mostly consists of sandstones, dolomite and limestones.

d) Hydrology

Major stream along the alignment is Sohal River which traverses the alignment at Km 3. There is a major nala crossing near Km 23. A large number of seasonal streams are crossed in eroded area between Km 3 & Km 14. Inflows for all these nalas are from rainfall and they stay dry for rest of the year.

e) Structures

2 – 4 span Bridges will be required at a minimum of 2 locations along this route. 35 number of box culverts of various sizes and cell configuration are estimated to be required. Large retaining structures are expected to be provided in the step hill sides north of Mor Jhang. Erosion Protection and Nala Training works will be required between Km 3 and 14.

f) Plan & Profile

Preliminary Geometric Design of the Alignment was carried out using Eagle point software. Horizontal Plan on 1:4000 scale was plotted on underlying relevant G. T. Sheets to show the ground features. Vertical Profile of the Alignment based on GPS survey of the route was also generated. These Plan & Profile Drawings are enclosed in the Appendix-G pages (Figure 4.24).

Figure 4.24 Steep slopes on western side of Sohal River valley (Alignment # 3)

g) Estimated Quantities & Cost

Rough cost estimate of the Alignment has been prepared based on Preliminary Plan & Profile generated on Eagle Point software. CSR 2014 rates (with 14% premium) have been used for costing purposes. Some estimates related to Bills 4 – 6 are based on judgement and experience on similar type of projects in identical terrain. Priced Bill of Quantities for Alignment 3 thus obtained (with 3 different types of cross-sections) is reproduced as Table 4-4

Table 4-4 Tentative BOQ & cost estimate for proposed alternative no. 3 (26.032 Km)

ALTERNATIVE NO. 03

ITEM #	ITEM DESCRIPTION	UNIT	RATE	BOQ FOR 2 LANES		BOQ FOR 3 LANES		BOQ FOR 6 LANES	
				QTY	AMOUNT	QTY	AMOUNT	QTY	AMOUNT
	BILL NO. 1								
101	CLEARING AND GRUBBING	SM	25.46	160,097	4,076,070	207,605	5,285,623	415,210	10,571,247
104	COMPACTION OF NATURAL GROUND	SM	27.68	160,097	4,431,485	207,605	5,746,506	415,210	11,493,013
106 c	EXCAVATE SURPLUS COMMON MATERIAL	CM	324.4	472,346	153,229,042	613,929	199,158,568	1,232,627	399,864,199
106 di	EXCAVATE SURPLUS HARD ROCK MATERIAL	CM	941.25	236,173	222,297,836	306,964	288,929,865	613,313	577,280,861
106 dii	EXCAVATE SURPLUS MEDIUM ROCK MATERIAL	CM	799.12	236,173	188,730,568	306,964	245,301,072	613,313	490,110,685
106 diii	EXCAVATE SURPLUS SOFT ROCK MATERIAL	CM	674.03	236,173	159,187,687	306,964	206,902,945	613,313	413,391,361
108 a	FORM OF EMB FROM ROADWAY EXCAVATION IN COMMON MATERIAL	CM	398.68	1,649,900	657,782,132	1,827,604	728,629,163	2,604,145	1,038,220,529
108 bi	FORM OF EMB FROM ROADWAY EXCAVATION IN HARD ROCK MATERIAL	CM	1143.85	824,950	943,619,058	913,802	1,045,252,418	1,302,073	1,489,376,201
108 bii	FORM OF EMB FROM ROADWAY EXCAVATION IN MEDIUM ROCK MATERIAL	CM	1030.11	824,950	849,789,245	913,802	941,316,578	1,302,073	1,341,278,418
108 biii	FORM OF EMB FROM ROADWAY EXCAVATION IN SOFT ROCK MATERIAL	CM	928.42	824,950	765,900,079	913,802	848,392,053	1,302,073	1,208,870,615
					3,949,043,201		4,514,914,790		**6,980,457,128**
	BILLS NO. 2 & 3								
201	GRANULAR SUB-BASE	CM	1162.15	113,031	131,358,977	126,112	146,561,061	252,224	293,122,122
202	AGGREGATE BASE	CM	1455.27	70,630	102,785,720	102,936	149,799,673	205,871	299,597,890
203 a	ASPHALTIC BASE COURSE PLANT MIX (CLASS "A")	CM	17715.68	15,203	269,331,483	22,804	403,988,367	45,608	807,976,733
302 a	CUT-BACK ASPHALT FOR BITUMINOUS PRIME COAT	SM	122.01	207,735	25,345,747	302,752	36,938,772	605,504	73,877,543
303 a	CUT-BACK ASPHALT FOR BITUMINOUS TACK COAT	SM	48.87	190,734	9,321,171	285,050	13,930,394	570,101	27,860,836
304 a	SINGLE SURFACE TREATEMENT	SM	225.56	190,034	42,864,069	285,050	64,295,878	570,101	128,591,982
304 c	TRIPLE SURFACE TREATMENT	SM	544.32	130,160	70,848,691	130,160	70,848,691	260,320	141,697,382
305 a	ASPHALTIC CONCRETE FOR WEARING COURSE (CLASS "A")	CM	18760.41	9,502	178,261,416	14,253	267,392,124	28,505	534,765,487
307 a	DENSE GRADED HOT BIT-MAC	CM	13603.81	9,502	129,263,403	14,253	193,895,104	28,505	387,776,604
					959,380,676		**1,347,650,062**		**2,695,266,579**
	SUMMARY OF BOQ								
1	**ROAD WORKS (BILL NO. 1, 2 & 3)**				**4,908,423,878**		**5,862,564,853**		**9,675,723,707**
2	**STRUCTURES (BRIDGES, FLYOVERS, UNDERPASSES & CULVERTS)**				**1,402,039,923**		**1,752,549,903**		**2,920,916,506**
3	**DRAINAGE & EROSION WORKS**				**247,418,810**		**309,273,512**		**515,455,854**
4	**ANCILLARY WORKS**				**329,891,747**		**412,364,683**		**687,274,472**
5	**RETAINING STRUCTURES**				**247,418,810**		**309,273,512**		**515,455,854**
	TOTAL CONSTRUCTION COST (RS)				**7,135,193,167**		**8,646,026,464**		**14,314,826,392**

4.9 ALTERNATE ALIGNMENT NO. 4

a) Route Description

This alignment is an improved version of Alternate Alignment No. 3 proposed by Daewoo in their Alignment Study Report of 1992. It traverses the same mountain as the existing alignment of the Motorway on the eastern side.

The route takes a eastward loop near Km 221 on the existing motorway to start climbing the contours on the western side of the Hamat Nala valley. It turns sharply westwards towards the existing alignment and then moves north through a number of sharp hairpin bends. It passes west of Karoli village and south of Simbal village to meet the existing alignment.

The length of the route is 12 Kms.

b) Topography

The majority of this alignment passes through topography similar to the existing motorway between Pir Khara and Simbal Slide. Between Km 3 and Km 8, the route traverses steep slopes. After Km 8, the terrain is mostly rolling till it joins the existing motorway.

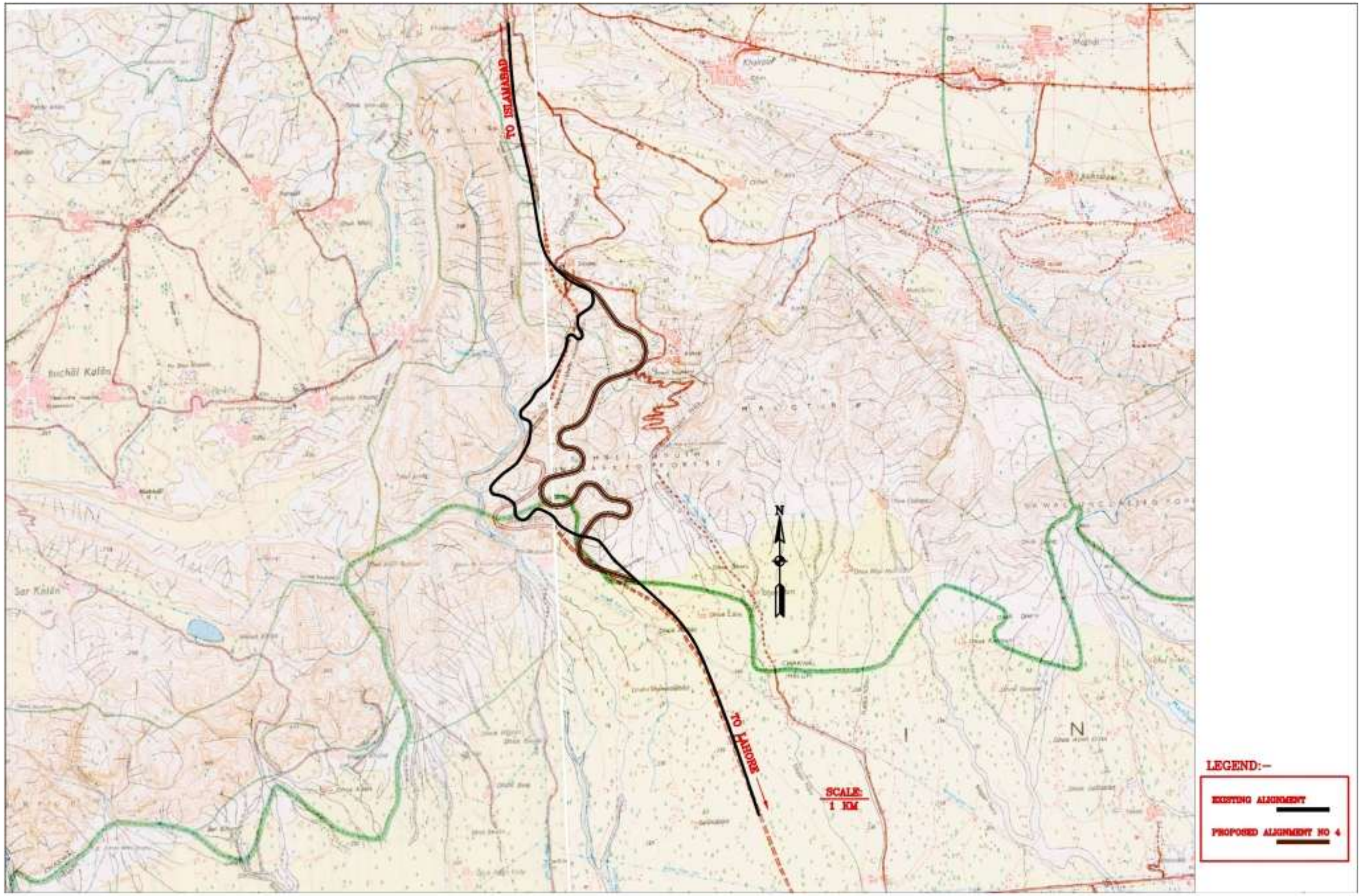

Figure 4.25 Alignment Map of Proposed Alternative-4 (Survey of Pakistan, 2004)

c) Geology

The proposed alignment starts through quaternary deposits composed of alluvium at Pir Khara and colluvium in the hills to the west of Hamat Nala.

Between Km 3 and 6, as the contours rise from 300 to 500, Gypsy Marl with distinctive pinkish red colour is encountered which is a mixture of calcium carbonate and clay with significant content of evaporite as gypsum. This formation is highly erodible or soluble due to its evaporite contents & soluble salts causing deep fissures and ravines in the topography.

Shale is also encountered at places which varies from red shales coloured by iron oxides and gray to black shales coloured by carbonaceous materials. It has clayey composition and may contain large quantities of silt, sand, organic material and calcium carbonate.

Beyond Km 6, when the alignment reaches the 500m contour, the geology mostly consists of sandstones, dolomite and limestones.

d) Hydrology

The alignment does not cross any major nala / river. A few dry / seasonal streams are crossed in the cut up / eroded area between Km 3 and Km 8. Inflows for all these nalas are from rainfall and they stay dry for rest of the year.

e) Structures

2 – 4 span Bridges will be required at a minimum of 2 locations along this route. 25 number of box culverts of various sizes and cell configuration are estimated to be required. Some retaining structures are expected to be provided for the hairpin bends between Km 3 and Km 8.

f) Plan & Profile

Preliminary Geometric Design of the Alignment was carried out using Eagle Point software. Horizontal Plan on 1:4000 scale was plotted on underlying relevant G. T. Sheets to show the ground features. Vertical Profile of the Alignment based on GPS survey of the route was also generated. These Plan & Profile Drawings are enclosed in the Appendix-H.

g) Estimated Quantities & Cost

Rough cost estimate of the Alignment has been prepared based on Preliminary Plan & Profile generated on Eagle Point software. CSR 2014 rates (with 14% premium) have been used for costing purposes. Some estimates related to Bills 4 – 6 are based on judgement and experience on similar type of projects in identical terrain. Priced Bill of Quantities for Alignment 4 thus obtained (with 3 different types of cross-sections) is reproduced as Table 4-5.

Table 4-5 Tentative BOQ & cost estimate for proposed alternative no. 4 (12.329 km)

ALTERNATIVE NO. 04

ITEM #	ITEM DESCRIPTION	UNIT	RATE	BOQ FOR 2 LANES		BOQ FOR 3 LANES		BOQ FOR 6 LANES	
				QTY	AMOUNT	QTY	AMOUNT	QTY	AMOUNT
	BILL NO. 1								
101	CLEARING AND GRUBBING	SM	25.46	75,823	1,930,454	98,324	2,503,329	196,648	5,006,658
103	STRIPPING	CM	240.66	204,013	49,097,769	264,555	63,667,806		-
104	COMPACTION OF NATURAL GROUND	SM	27.68	75,823	2,098,781	98,324	2,721,608	196,648	5,443,217
106 c	EXCAVATE SURPLUS COMMON MATERIAL	CM	324.4	1,102,132	357,531,621	1,272,783	412,890,805	2,018,502	654,802,049
106 di	EXCAVATE SURPLUS HARD ROCK MATERIAL	CM	941.25	551,066	518,690,873	636,391	599,003,029	1,009,251	949,957,504
106 dii	EXCAVATE SURPLUS MEDIUM ROCK MATERIAL	CM	799.12	551,066	440,367,862	636,391	508,552,776	1,009,251	806,512,659
106 diii	EXCAVATE SURPLUS SOFT ROCK MATERIAL	CM	674.03	551,066	371,435,016	636,391	428,946,626	1,009,251	680,265,452
108 a	FORM OF EMB FROM ROADWAY EXCAVATION IN COMMON MATERIAL	CM	398.68	1,244,659	496,220,650	1,353,754	539,714,645	1,830,483	729,776,962
108 bi	FORM OF EMB FROM ROADWAY EXCAVATION IN HARD ROCK MATERIAL	CM	1143.85	622,329	711,851,027	676,877	774,245,756	915,242	1,046,899,562
108 bii	FORM OF EMB FROM ROADWAY EXCAVATION IN MEDIUM ROCK MATERIAL	CM	1030.11	622,329	641,067,326	676,877	697,257,766	915,242	942,799,937
108 biii	FORM OF EMB FROM ROADWAY EXCAVATION IN SOFT ROCK MATERIAL	CM	928.42	622,329	577,782,690	676,877	628,426,144	915,242	849,728,978
					4,168,074,067		4,657,930,291		**6,671,192,976**
	BILLS NO. 2 & 3								
201	GRANULAR SUB-BASE	CM	1162.15	53,533	62,213,376	59,728	69,412,895	120,565	140,114,615
202	AGGREGATE BASE	CM	1455.27	33,451	48,680,237	48,751	70,945,868	97,503	141,893,191
203 a	ASPHALTIC BASE COURSE PLANT MIX (CLASS "A")	CM	17715.68	7,200	127,552,896	10,800	191,329,344	21,600	382,658,688
302 a	CUT-BACK ASPHALT FOR BITUMINOUS PRIME COAT	SM	122.01	98,385	12,003,954	143,386	17,494,526	286,773	34,989,174
303 a	CUT-BACK ASPHALT FOR BITUMINOUS TACK COAT	SM	48.87	90,002	4,398,398	135,003	6,597,597	270,005	13,195,144
304 c	TRIPLE SURFACE TREATMENT	SM	544.32	61,645	33,554,606	61,645	33,554,606	123,290	67,109,213
305 a	ASPHALTIC CONCRETE FOR WEARING COURSE (CLASS "A")	CM	18760.41	4,500	84,421,845	6,750	126,632,768	13,500	253,265,535
					372,825,312		**515,967,603**		**1,033,225,559**
	SUMMARY OF BOQ								
1	**ROAD WORKS (BILL NO. 1, 2 & 3)**				**4,540,899,379**		**5,173,897,895**		**7,704,418,536**
2	**STRUCTURES (BRIDGES, FLYOVERS, UNDERPASSES & CULVERTS)**				**1,072,148,176**		**1,340,185,220**		**2,233,642,034**
3	**DRAINAGE & EROSION WORKS**				**206,182,342**		**257,727,927**		**429,546,545**
4	**ANCILLARY WORKS**				**247,418,810**		**309,273,512**		**515,455,854**
5	**RETAINING STRUCTURES**				**226,800,576**		**283,500,720**		**472,501,199**
	TOTAL CONSTRUCTION COST (RS)				**6,293,449,282**		**7,364,585,274**		**11,355,564,168**

4.10 COMPARISON OF ALTERNATE ALIGNMENTS

Table 4-6: Comparison of Alternatives

Features		**Alignment No. 1**	**Alignment No. 2**	**Alignment No. 3**	**Alignment No. 4**
Topography		40% of the route passes through cut up / eroded hill sides and steep side slopes	15% of the route passes through cut up / eroded hill sides. Rest of the route passes through relatively mild slopes.	80% of the route passes through cut up / eroded hill sides and extremely steep side slopes	60% of the route passes through steep mountain sides
Length		33 Km	31 Km	26 Km	12 Km
Geology		Gypsy Marl & Shale encountered in about 10 kms stretch	Gypsy Marl & Shale encountered in about 6 kms stretch	Gypsy Marl & Shale encountered in about 11 kms stretch	Gypsy Marl & Shale encountered in about 4 kms stretch
Hydrology		2 major nala crossing	1 major nala crossing	1 river crossing	No major nala crossing
Construction		Problems expected in 6 kms stretch due to unstable hill sides	Problems expected in 2 kms stretch due to unstable hill sides	Problems expected in 80% of the length due to unstable hill sides and extra steep side slopes	Problems expected in 2 kms stretch due to unstable hill sides.
Geometric Design	Horizontal Plan	0 curves <300m radius	0 curves <300m radius	27 curves <300m radius	3 curves <300m radius
	Vertical Profile	Grade>3% 5 location Ave. Grade:	Grade>3%@ 5 location Ave. Grade:	Grade>3%@ 11 location Ave. Grade:	Grade>3%@ 11 location Ave. Grade:
Estimated Construction Cost 2-Lane 3-Lane 6-Lane		 Rs. 7.7 Billion Rs. 9.2 Billion Rs. 14.6 Billion	 Rs. 8.8 Billion Rs. 10.2 Billion Rs. 16.1 Billion	 Rs. 7.1 Billion Rs. 8.6 Billion Rs. 14.3 Billion	 Rs. 6.3 Billion Rs. 7.3 Billion Rs. 11.4 Billion
Merits		All V. grades <= 3% All H. curves > 325 m	All V. grades <= 3% All H. curves > 325 m		Add. length of only 2 km
Demerits		Add. length of 18 kms Tough terrain	Add. length of 15 kms	Add. length of 13 kms Extremely tough terrain	Steep Vertical Gradients Sharp Horizontal Bends

4.11 SUMMARY

Based on the comparison in the table above, Alignment 3 and 4 has the lowest cost but they are not feasible because of geometry. The alternative 3 and 4 have steep grades and sharp horizontal curves. Alignment number 1 and 2 have very much better geometry and they are much better with safety perspective. Alignment No. 2 traverses through relatively stable terrain with milder hill side slopes. Hence it has a lesser involvement of earthwork and a lower construction cost. Alignment No. 2, as presented in this report has very generous curve radii and grades along with regular repetition of respites (as per AASHTO guidelines). There is room for further improving the alignment and reducing the overall length (and hence costs) at the detailed design stage.

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The existing geometry of the Salt Range Area has been studied in detail. All the shortcomings in the design of the subject area are thoroughly studied and the improvements in the geometry are suggested. Moreover, alternatives of the existing route are studied in detail as already discussed in chapter 4. Four alignment options were studied. Comparison of these alignments based on several design parameters and cost was done so as to check the feasibility of best alternative.

In this chapter the conclusions have been drawn based upon the analysis performed in the chapter 4. The recommendations have thus been made accordingly to best fit the purpose of the research study. The recommendations about both, the improvement of existing alignment and the provision of alternate alignment have been provided based upon the analysis carried.

5.2 CONCLUSIONS

Following conclusions have been drawn from the study:

5.2.1 Improvement of Existing Alignment

In Chapter 4, existing alignment of M-2 has been described in the Salt Range Area and the constraints that are present in implementing any geometric improvements thereof.

This has been followed by Proposals to improve the existing grades and curves at three locations. These improvements aim to provide relief to road users over an overall length of 5.1 km (out of the total length of 10 km). Out of these, Proposals 1 & 3 relate to improvements which can be taken up immediately without drastically disrupting the existing traffic while Proposal 2 relates to a longer term improvement that can only be taken up if the traffic is diverted to an alternate route.

5.2.2 Alternate Alignment

The approach adopted in the research has been described. Four alignments proposed have been presented along with tentative plan and profiles, BOQ's and discussion on hydrology and geology of each option. In the end a comprehensive comparison of the four alternates has been made.

It is the author's view, any solution regarding re-alignment that makes compromises with respect to geometric standards of the finished road, is not worth considering since it would not provide any additional benefit to the current road user over the current alignment and would fail to attract Heavy Transport Vehicles to the Motorway Network. With this background, Alignments No. 3 & 4 can reasonably be eliminated from any assessment as both these alignments have high incidence of sharp curves and steep grades.

Among the remaining alternate routes, Alignment No. 2 traverses through relatively stable terrain with milder hill side slopes. Hence it has a lesser involvement of earthwork and a lower construction cost. Alignment No. 2, as presented in this report has very generous curve radii and grades along with regular repetition of respites (as per AASHTO guidelines). There is room for further improving the alignment and reducing the overall length (and hence costs) at the detailed design stage.

5.3 RECOMMENDATIONS

Based upon study of different organizations, analysis carried out in chapter 4 and conclusions of this research work, it is recommended that:

- Proposals 1 & 3, should be further studied and detailed design of any of these two proposal may be done so as to provide relief from steep grades at the start and end of Salt Range and to improve the black spot at km 229.

- Alignment No. 2 may be selected as the Alternate Route, for further study and detailed design.

- The re-aligned / alternate route should be used for all North-bound Traffic (HTV & LTV) only while the existing alignment (with proposed geometric & road safety improvements) be used for all South-bound Traffic (HTV & LTV).

5.4 FUTURE RECOMMENDATIONS

The alternative route proposed in this research may be further studied/deliberated in detailed design by the Concerned Government Authorities to attract more heavy traffic, to provide safe corridor for CPEC project and to generate more revenue.

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