



**RAWALPINDI DEVELOPMENT AUTHORITY (RDA)**

**TRANSACTION ADVISORY SERVICES FOR  
CONSTRUCTION OF RAWALPINDI RING ROAD PROJECT  
(Length = 65.3 km)**



**PRELIMINARY DESIGN REPORT  
(Volume III)**

## **Design Report**

This document has been prepared by Senior Engineers in Nespak and Financial Experts. The document covers project Introduction, Description, Alignment study, civil & allied works and Preliminary Design Reports.

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## **EXECUTIVE SUMMARY**

## **0. EXECUTIVE SUMMARY:**

### **0.1. INTRODUCTION:**

**Rawalpindi Development Authority (RDA)** was established in May 1989 under the Act of the Development of cities by the Punjab Government. Rawalpindi Development Authority (RDA) is a government sector corporation and authority responsible for providing Municipal and Town Services as well as improve, enhance and implement the growth plan in Rawalpindi City, a city in the Punjab, Pakistan. The aim of the Rawalpindi Development Authority (RDA) is facilitating and enabling provision and continuously improving metropolis-wide development works, facilities, services and incentives of acceptable and Modern World standards for Residential and Commercial outlets in Rawalpindi city. Rawalpindi Development Authority is spread over the Municipal Committee Rawalpindi and 64 other Revenue Estates of Rawalpindi, except Cantonment Board. The controlled area of Rawalpindi Development Authority is around 311 Sq. Km.

In recent years, traffic congestion had been observed on all highways, internal roads in the Rawalpindi city as well as in the capital city Islamabad. The traffic increased exponentially during few years are mainly due to increase in population, migration of people from small cities, lack of urban planning.

Rawalpindi Development Authority (RDA) and Government of the Punjab Province, through its vision for developing infrastructure projects to make Rawalpindi a world class city, prepared the proposal for development of the ring road. The Rawalpindi ring road after its construction will not only improve the traffic flow in the urban areas of the city but will also benefit city adjoining areas in terms of direct linkage to Motorway, trade route, time saving as well as socio economic activities, uplift of local community and surrounding areas.

### **0.2. OVERVIEW:**

Pakistan was previously facing inadequate transportation system few years ago. Currently, it has developed lot of Motorways as well as improved the network of National/Provincial Highways and many are under progress. Motorways are a network of multiple-lane, high-speed, controlled-access highways in Pakistan, which are owned, maintained, and operated federally by Pakistan's National Highway Authority. As of March 2020, 1973 km of motorways are operational, while an additional 1763 km are under construction or planned. Motorways are an important part of Pakistan's National trade Corridor and plays an important role from regional perspective, which aims to link Pakistan's three Arabian Sea ports (Karachi Port, Port Bin Qasim and Gwadar Port) to the rest of the country through its National Highways, Provincial roads, Ring roads and inter district road network.

CPEC Western corridor which is a priority phase of China Pakistan Economic Corridor (CPEC), consists of Motorway/Highway traversing between KKH, Thakot, Havelian, Islamabad, Dera Ismail Khan, Zhob, and Kuchlaak and connects Gwader. This Western corridor of Motorway has gained significance due to inauguration of Hakla D.I. Khan motorway, in which the major cities of Rawalpindi/ Islamabad being the economical hub will be connected to DI-Khan and will further proceed up to Gwader. This Motorway upon completion not only benefit the entire western cities of Pakistan in terms direct motorway access, trade activities, time saving, but will also uplift the provincial road network to International standards.

### **0.3. PROJECT ALIGNMENT:**

The proposed Rawalpindi Ring Road (RRR) alignment is traversing along the southern outer periphery of Rawalpindi city. Project road is limited to the Southern part because not much growth is apparent towards North and East of the city, mainly due to the presence of the hills and designated reserve forests in North-East part of the city. The alignment will be originated from N-5 near radio Pakistan transmitters, passes through well-known locations of Rawat–Chakbeli Road, Bahria town, Soan river, Adiala Road, Chakri Road, Motorway (M-2), Dhok Manewal, Hakla – DI Khan Motorway, Motorway (M-1), and will be terminated at G.T road (N-5) near Sangjani. Configuration of the project road is three-lane, dual carriageway facility with controlled access. The total length of the road will be sixty-five kilometers (65.3km). The alignment area consists of rolling/hilly terrain with thickly populated small towns, green fields/orchards on both sides.

### **0.4. SOCIO-ECONOMIC PROFILE OF THE PROJECT AREA:**

Roads make a crucial contribution to economic development, growth and bring important social benefits. They are of vital importance in order to make a nation grow and develop. In addition for providing access to employment, social, health and education services, roads and bridges network play a critical role. Road networks open up more areas and stimulate economic and social development. In short, for progress and development of any country, Roads/Bridges infrastructure plays an important role by providing efficient mobility of people and goods, especially when major portion of the freight transport is through roads.

Rawalpindi and Islamabad both combined are home to about 3.5 million people. Industries and manufacturing units initially located at the peripheries of the twin cities have been invaded by unplanned settlements thus a dilemma both for Islamabad at the center and Rawalpindi of the Punjab province. The twin cities have manufacturing industries and other units like oil refinery, NLC's staging facilities, the dry port, iron and steel rolling/manufacturing mills, textile mills, hosiery, tents and leather goods and numerous timber sawing units. Moreover the grains and fruit/ vegetable markets have also been surrounded by permanent settlements. The complexity stands compounded by intermingling of heavily

loaded slow moving goods traffic, cars, motor cycles and light commercial vehicles plying on the urban road network. Rawalpindi ring road corridor upon completion will impact several towns, villages and consequently accelerate urbanization.

Positive social impacts of project include employment opportunity, better transport facility and local marketing agricultural produce.

Negative impacts include change of land use, impact on existing lively hood opportunity that is loss of land, Pressure of existing infrastructure due to migration of labour and excluded heavy goods traffic.

#### **0.5. INVESTIGATION AND REPORTS:**

To conduct technical study, some of the Key study components are mentioned below:

- Traffic study is an elaborate investigation and meticulous analysis of the transportation system in a specific area, which is supported by an expansive collection of data. Usually, traffic studies are used to determine the required level of transportation facility in terms of Level of Service and geometric features.
- Topographic Survey is a vital element in the process of designing and constructing a safe and cost-effective roadway.
- Geometric design of road project is based on a set of design criteria that represents the best internationally accepted engineering practice. At the same time, the specific local site conditions and constraints will also be effectively considered in the application of these criteria.
- Soil Investigation is preformed to evaluate an area for the construction of a project and to ascertain the index and engineering properties of soil and rock encountered, soil and material survey is required to be performed.
- Pavement design process is a technique of developing a combination of top layers of different materials in most economical manner to cater for the total axle load over the design life of the pavement.
- Structure design is to formulate and finalize technical data, design assumptions, codes of practice, methods and procedures to be adopted in the structural design of various structures of the project.
- A cost estimate is necessary to give the stakeholders a reasonably accurate idea of the project cost to decide whether the work can be undertaken as proposed or needs to be curtailed or abandoned, depending upon the availability of funds and prospective direct and indirect benefits.

- The main objective of conducting a project economic analysis is not only assess the sustainability of investment projects but also to select projects that can contribute to a sustainable improvement in the welfare of project beneficiaries, and the country as a whole. Economic analysis is a tool for optimum allocation of resources that can lead to enhanced incomes for investment or consumption purposes. Therefore, it is best undertaken at the early stages of the project cycle to enable decision makers to make an informed decision on whether to undertake a particular investment and their corresponding costs.

# **CHAPTER-1**

## **INTRODUCTION**

## **1. INTRODUCTION**

### **1.1. BACK GROUND:**

The National Highway N5 is the main North – South arterial link which traverses through Rawalpindi city. Islamabad transportation network links the N5 through Islamabad Expressway on the Southern side near Rawat. Similarly, IJP road connects N5 near Koh-e-Noor Mills on the Northern side of Rawalpindi city within the urban area. Heavy loaded goods and transport travels through Rawalpindi city urban roads for destinations to Peshawar, Afghanistan, country's Northern areas, China and to the port city of Karachi. The presence of heavily loaded slow moving multi axle trucks which passes through the twin cities urban transportation system impede free movement thus resulting in severe injury to the roads with adverse effects on their performance. Moreover, congestion inflicts losses to the national exchequer in the forms of lost work hours, added fuel costs and expenses on frequent repairs of the damaged roads, and costs of accidents. Congestion is producing irritating level and resultantly damages to the twin cities transportation network.

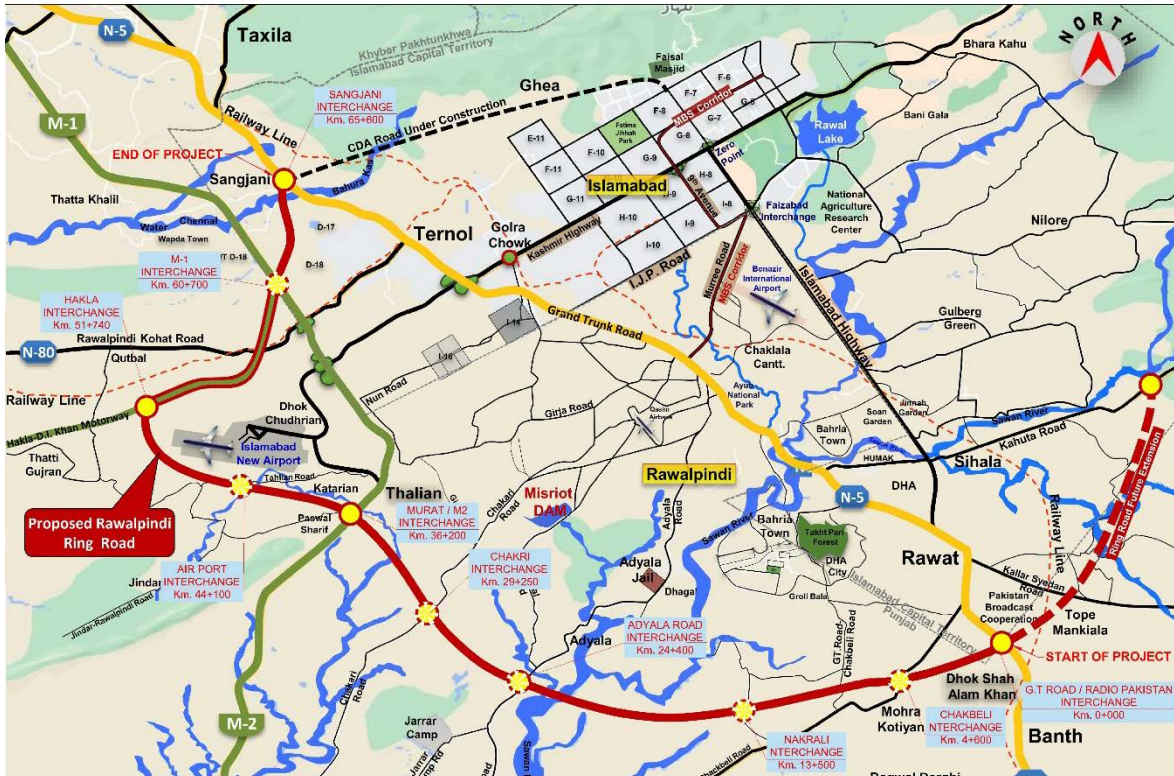
It was 1997 that Rawalpindi Development Authority (RDA) conceived a plan for provision of a Ring Road by linking National Highway N5 with Motorway M2 through a high speed multi-lane access controlled highway, The Rawalpindi Ring Road (RRR)) to bypass the twin cities. The aim as conceived was to deter the goods traffic from using the twin cities network, and to shift development and multi-faceted expansion in the vicinity of the proposed Rawalpindi Ring Road. Presently the Islamabad International Airport has already set a trend for move of both population and allied facilities to Rawalpindi city's South and South-West side.

### **1.2. PROJECT BRIEF:**

In recent years, traffic congestion had been observed on all highways, internal roads in the Rawalpindi city as well as in the capital city Islamabad. The traffic increased exponentially during few years are mainly due to increase in population, migration of people from small cities, lack of urban planning. Rawalpindi Development Authority (RDA) and Government of the Punjab Province is planning to upgrade the road infrastructure of Rawalpindi City by constructing Rawalpindi Ring Road project. The proposed project of Rawalpindi Ring Road (RRR) will facilitate to bypass traffic and provide alternative road to the local daily commuters. The RRR project will help to ease out the traffic congestion on the intercity roads of Islamabad and Rawalpindi. It will also provide access to airport, trade through motorway, and other land use.

Rawalpindi Development Authority intends to carry out the Preliminary Design, Traffic Studies, Commercial Feasibility Study and Bid Evaluation/Bid Comparative Analysis and subsequent construction for Rawalpindi Ring road project on Build-Operate-Transfer (BOT) Basis to add a new green field highway facility for the twin cities of Federal and Punjab

Province. Geographic location of project is shown in figure-1.1. Punjab Planning and Development (P&D) has appointed Rawalpindi Development Authority as the executing agency for Rawalpindi Ring Road. Consultancy Services for Feasibility Study of Rawalpindi Ring Road is assigned by RDA.



**Figure -1.1 Location Map of Project Alignment**

### **1.3. NEED OF THE PROJECT:**

The Rawalpindi Ring Road project focuses primarily on the linkage of G.T Road (N-5) near Radio Pakistan with major towns like Chakbeli, Bahria town, Adiala town, Chakri town, Motorway M-2, Capital Smart City, D.I.Khan Hakla motorway, Motorway M-1 and reconnected with GT Road N-5 at Sangjani. It will also give direct access to most economically developed cities and economic centers of GT Road (N-5) in South to North direction. Hence Rawalpindi Ring Road upon completion, will become a main artery of Pakistan economic system. The proposed facility will further facilitate the traffic in KPK, South Punjab and Baluchistan provinces.

### **1.4. SCOPE OF THE STUDY:**

The entire scope of services would, inter-alia, include the items mentioned in the TOR. The scope of consultancy services would demand a very high level of professional competence with optimal approach to meet all the objectives as it will require review of all available studies, data, records, information interaction with concerned agencies and identification of constraints besides carrying out necessary traffic surveys. In this regard the consultant

noted that the RDA has already carried out and finalized part of an alignment for the proposed ring road in Rawalpindi city (South side). The consultant shall also be fully responsible for the accuracy of the physical and ground details, such as alignment, grade, right of way details, abutting land use, along with existing features.

Rawalpindi Development Authority (RDA), Government of Punjab intends to develop a signal free, controlled access, Highway facility at Rawalpindi Southern periphery. This road will takeoff from GT Road N-5 at Radio Pakistan Interchange & will terminate N-5 at Sangjani Interchange. The road is equipped with state of the art modern facilities under Public Private Partnership (PPP) with approximate length of 65.3km and design speed of 120kph. The road includes Nine Interchanges (Four Interchanges will be constructed by Concessioner and five will be constructed in future). The proposed facility will ensure high speed connectivity of GT Road with Motorways and other parts of the country.

RDA has revived Consultancy Services for feasibility studies and preliminary design to NESPAK JV:

#### **1.5. SIGNIFICANCE OF PROJECT:**

The project's significance is to promote the smooth flow of traffic with in the twin cities of Rawalpindi and Islamabad as well as direct access from East to West side along with trade benefits through Pakistan Motorway Network. After construction with advanced facilities, shall provide an efficient intelligent corridor for domestic as well as International traffic. Thereby contribute to strengthening and balancing economic development in Pakistan. The corridor will largely contribute to the economic and social development of the region as well as monitory benefits to Punjab Government through tolling. In addition to that there will be substantial economic benefits in terms of anticipated savings in Vehicle Travel Time (VTT) and Vehicle Operating Cost (VOC).

#### **1.6. PROJECT OBJECTIVES:**

Objective includes:

- i. The main objective of project is to provide an access controlled high speed six lane toll road facility for efficient and safe transportation of passengers and goods, particularly the North and South bound heavy goods traffic presently using the National Highway N-5, The new facility will also attract additional passenger/ Cargo movements to and from the major industrial and economic hubs of the country.
- ii. The RRR will contribute towards the development of an environment, whereby the existing traffic and estimated traffic in years ahead, shall be catered for at an adequate level of service resulting in benefits to the economy.

- iii. It will strengthen the communication and connection between major economic cities in center and Southern Pakistan and promote economic development of small and medium cities along the alignment.
- iv. Construction of this project will open up a passage in Pakistan linking inland with the sea through Motorways, thus increasing the competitive strength of Pakistan goods in import and export and improving Pakistan foreign investment environment.
- v. With the completion of project, the fuel consumption of vehicles with in Rawalpindi will be significantly reduced. Due to increased traffic capacity and easing of traffic pressure on city urban routes and N-5, it will also reduce the travel distance between major cities.
- vi. The execution of project will have a positive social benefit and a great significance in promoting the economic development of Pakistan, as part of the programme for building the country's own Highways. Thereby stimulating the economic development of areas along the alignment.
- vii. It shall reduce the traffic congestion drastically, losses due to traffic accidents, increase traffic safety, improve running conditions on the existing relevant road network, and thereby enhancement of vehicles driving speed and reduction of the passengers travelling time.
- viii. The project is aimed to improve the road network function and increase the road traffic capacity in Rawalpindi city
- ix. This project will also improve the comprehensive transportation system.
- x. The project is devised to satisfy flood disaster relief requirements and would serve as a life passageway.
- xi. The project is to cater the requirements of National defense and serve as a strategic thoroughfare.
- xii. The project shall improve people's livelihood and the image of the government.

### **1.7. GENERAL APPROACH:**

The Consultants general approach is carrying out the feasibility study has been that of:

- a) Close liaison with the client.
- b) Minimum financial risks of the project by awareness and control of risks of the implementation plan and methods throughout the duration of the project.
- c) Maintaining strict quality control within the project.
- d) Application of modern technology during the study and design period as appropriate to assure flexibility and accuracy in planning, investigations, calculations, processing and reporting.

- e) Appropriate use of local information to facilitate adherence to local planning regulations and development plans.
- f) Profound respect for sacred places, heritage, and the environment in the project area.

## **CHAPTER-2**

# **PROJECT DESCRIPTION**

## **2. PROJECT DESCRIPTION:**

### **2.1. GENERAL:**

Feasibility study for the project was carried out by M/s Zeeruk International (Pvt.) Limited in Joint Venture with M/s Engineering General Consultants EGC (Pvt.) Limited, while ground validation and project outline/ preliminary design along with review was carried out by NESPAK. The alignment and corridor of the project is hence already defined and was initially proposed on the basis of feasibility studies, Satellite imagery and Google maps. The project has been included in the vision 2025 of the Punjab.

### **2.2. LOCATION OF PROJECT ROAD:**

The proposed Rawalpindi Ring Road (RRR) alignment is traversing along the southern outer periphery of Rawalpindi city. Project road is limited to the Southern part because not much growth is apparent towards North and East of the city, mainly due to the presence of the hills and designated reserve forests in North-East part of the city. The proposed road in general, is a new alignment primarily on rolling terrain.

### **2.3. ALIGNMENT FINALIZATION:**

A tentative alignment of the proposed Ring Road around Rawalpindi city was suggested by Rawalpindi Development Authority (RDA). After detailed discussion with stakeholders the study and detailed features of tentative alignment, the physical encumbrances and constraints that had developed with passage of time has formed the basis for fixing the modified project alignment. The base survey map/ physical topographic survey were imported to civil 3D software. The tentative alignment and the shifted obligatory was developed on the above base map to avoid all physical and nonphysical obstacles as far as possible. The developed alignment confirmed to 120 Km /hr. speed i.e. The required Geometric design standards for the project road are derived for a design speed of 120Km/hr. Based on the discuss constraint identified at site and the remedial measures the reviewed alignment was adjusted in the civil 3D software to arrive at finalized project alignment of 65.3km in length.

### **2.4. ALIGNMENT DETAILS:**

The project Rawalpindi Ring Road envisages construction of approximately 65.3 km long section of Road, dual carriageway, six lane, and access controlled facility with service track on either side of the main carriageway where required. The proposed road will be originated from G.T Road (N-5) near Radio Pakistan transmitters at km 0+000.

The major areas through which the proposed alignment is passing is enlisted below:

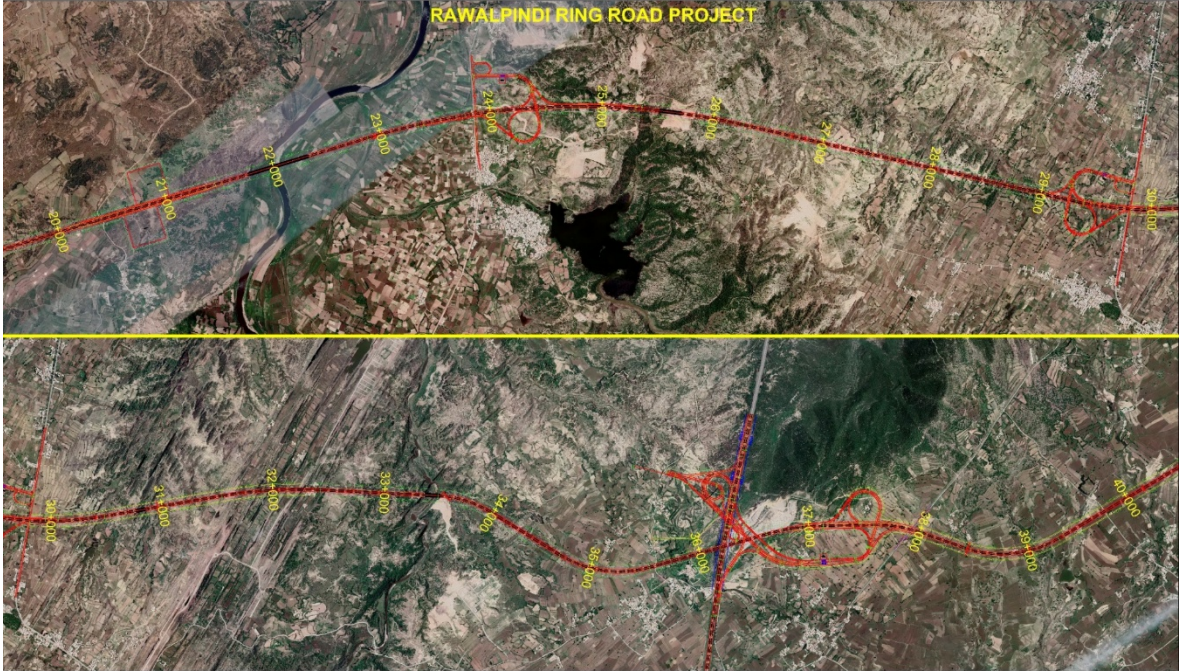
- Rawat – Chakbeli Road
- Bahria town
- Soan River
- Adiala Road
- Chakri Road
- Motorway (M-2)
- New Islamabad International Airport
- Hakla – DI Khan Motorway
- Motorway (M-1)

And will be terminated on G.T road (N-5) near Sangjani at km 65+300. Figure-2.1 to 2.4 shows the location of proposed Rawalpindi Ring road alignment with proposed interchanges.

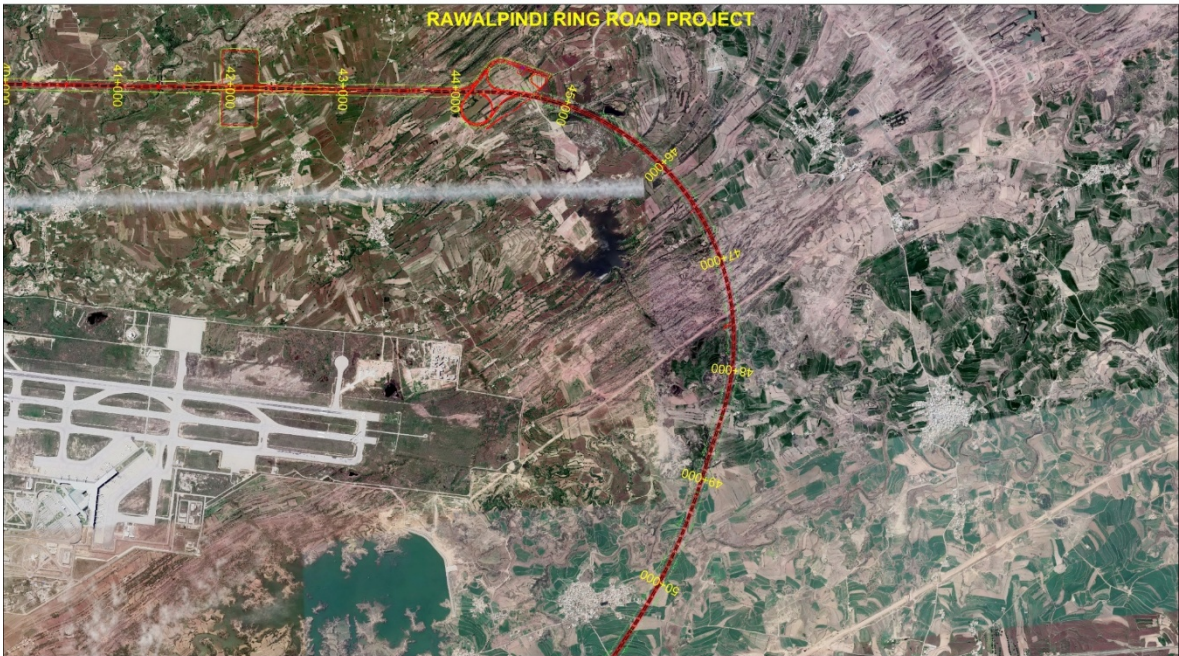
Apart from these, the alignment is also intersecting local katcha roads, pacca roads with black top at several locations. Two major river crossings and seven Nullahs are intersecting the alignment. The alignment area consists of rolling/hilly terrain with thickly populated small towns, green fields/orchards on both sides. The proposed alignment traverses entirely through the province of Punjab and runs parallel in most stretches and in close proximity to the Rawalpindi southern stretches.



**Figure-2.1**



**Figure-2.2**



**Figure-2.3**



**Figure-2.4**

**2.5. PROPOSED FEATURES:**

Sr. No.	Particulars	proposed
1	Road Length	65.3km
2	Interchanges	4 (Present) + 5 (Future)
2	Major Overpass/ Flyovers	30
3	River Bridges	2
4	Water/ Nullah Bridges	7
5	Underpasses	7
6	Cattle creep	17
7	Culverts	70 min
8	Utility ducts	24

Nine interchanges are proposed at major road locations along the ring road. Four interchanges are being constructed by the concessioner and five will be constructed in future. The vertical clearance at all major grade separators has been kept as minimum 5.3m in line with AASHTO guide lines. Refer structures design report and drawings for detailed studies.

## **CHAPTER-3**

# **ALIGNMENT STUDY**

### 3. ALIGNMENT STUDY:

#### 3.1. PROPOSED ALIGNMENT:

The proposed Rawalpindi Ring Road (RRR) alignment traverses through the southern outer periphery of Rawalpindi city from East to West direction. The major length of proposed alignment falls in province of Punjab and some part falls in Federal area. Figure-3.1 shows the layout plan of proposed Rawalpindi Ring road alignment with proposed interchanges.

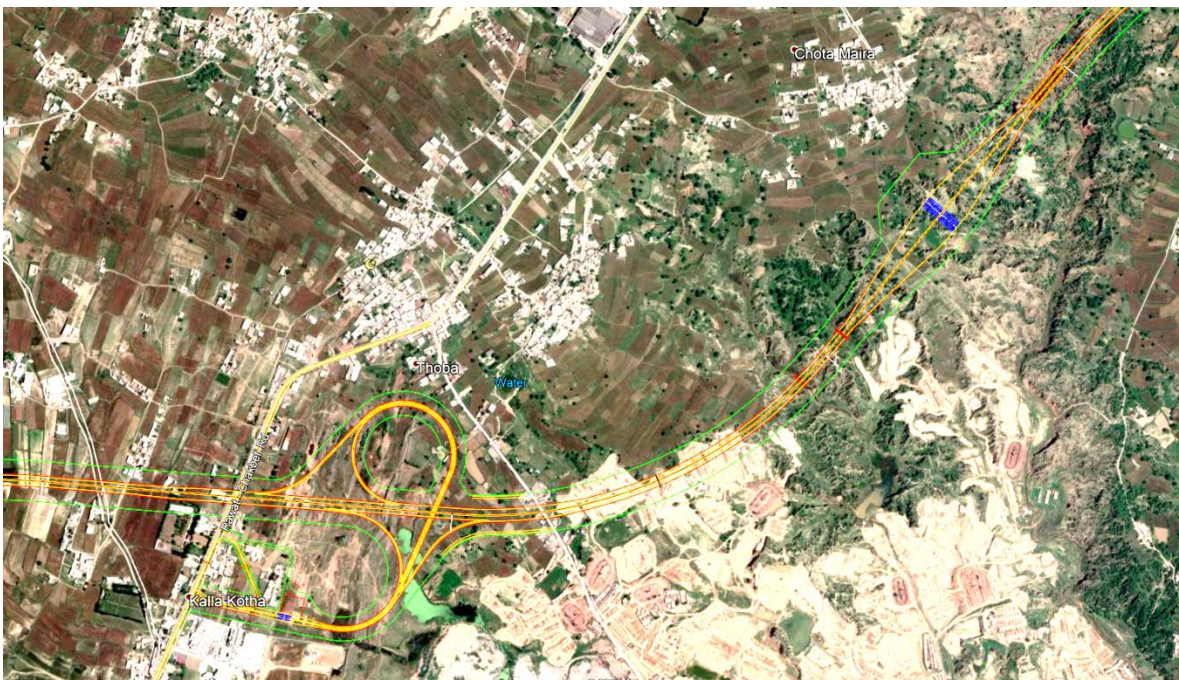
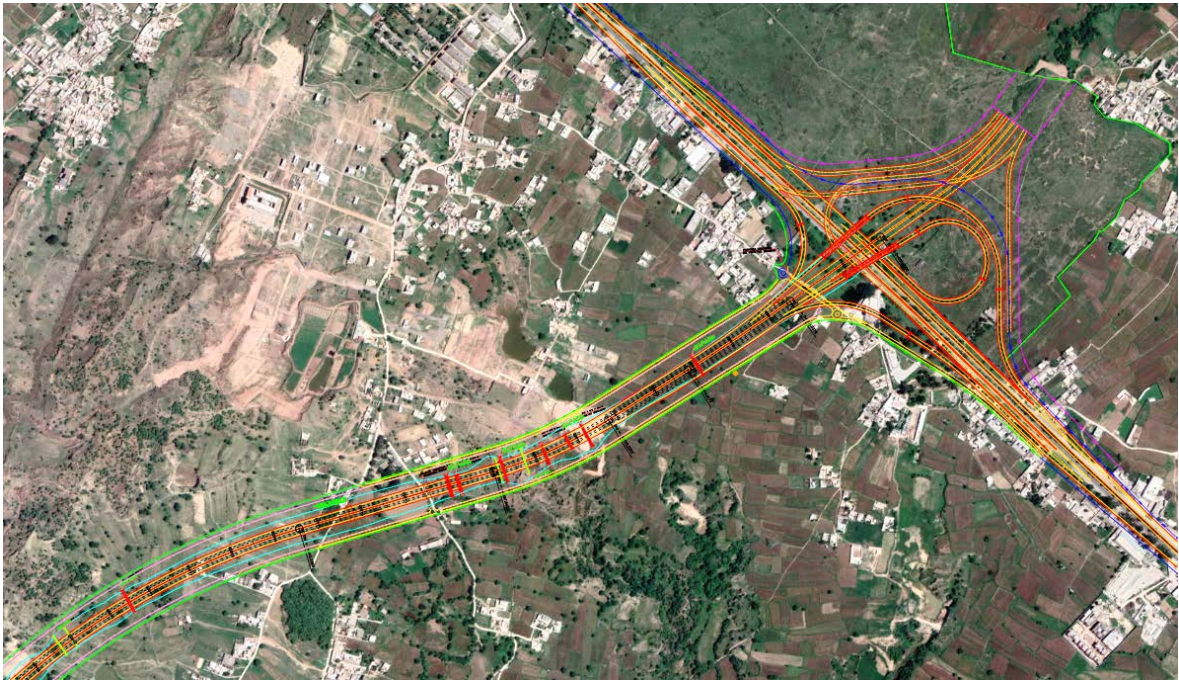


Figure-3.1

#### 3.2. ALIGNMENT REPORT (L=65.3 KM)

##### KM 0+000 TO KM 5+200

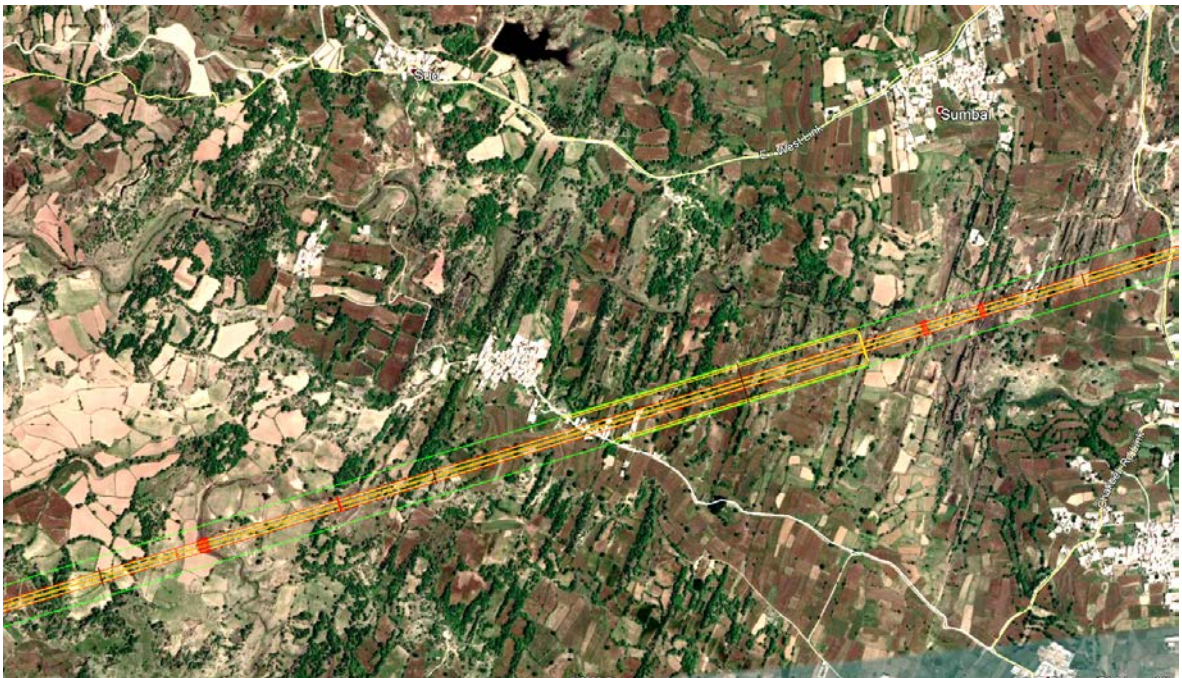
The proposed Ring Road takeoff from GT Road (N-5) at km 0+000 near Radio Pakistan through an interchange. The alignment proceeds in East to West direction and crosses the towns of Gohra upper and Gohra lower at km 1+300. It further proceeds through rolling stretches from km 2+200 to km 2+800 with a main toll plaza on both sides at km 3+000 and approaches Rawat Chakbeli road at km 5+200. At this location a semi cloverleaf interchange is provided with complete tolling facility on one side (Kala Kotha). This stretch of alignment passes through various Chaks and green farms on rolling areas with an elevation ranges between 500m. Refer figure-3.2 to 3.3.



**Figure-3.2 to 3.3**

**KM 5+200 TO KM 13+100**

From this location onward, the Alignment proceeds forward and crosses a town road at km 5+500, Jaba town road at km 7+000, Chakbeli link road at km 8+100, a town road at km 9+800 and approaches Adiala- Rawat link road at km 13+100. At this location a semi cloverleaf interchange is provided with complete tolling facility on one side (North). This stretch of alignment also passes through various Chaks and green farms on rolling areas. Refer figure-3.4 to 3.6.





**Figure-3.4 to 3.6**

**KM 13+100 TO KM 23+900**

The alignment further proceeds near the villages of Lilla and Kamalpur at km 14+500, Kamalpur road at km 15+600. At km 16+000 the alignment takes a right turn in North-West direction. The alignment crosses Chakbeli link road near Trahia and Chappar villages at km 17+200, the alignment proceeds and passes through proposed service area at km 20+600, crosses Soan River at km 22+000 and approaches Adiala road near Khasala Khurd at km 23+900. At this location a semi cloverleaf interchange in open land is provided with complete tolling facility on one side (South). Town of Adiala is 3km away from this location. This stretch of alignment passes through various Chaks and green farms on rolling areas ranges between elevations of 492m to 390m. Refer figure-3.7 to 3.10.





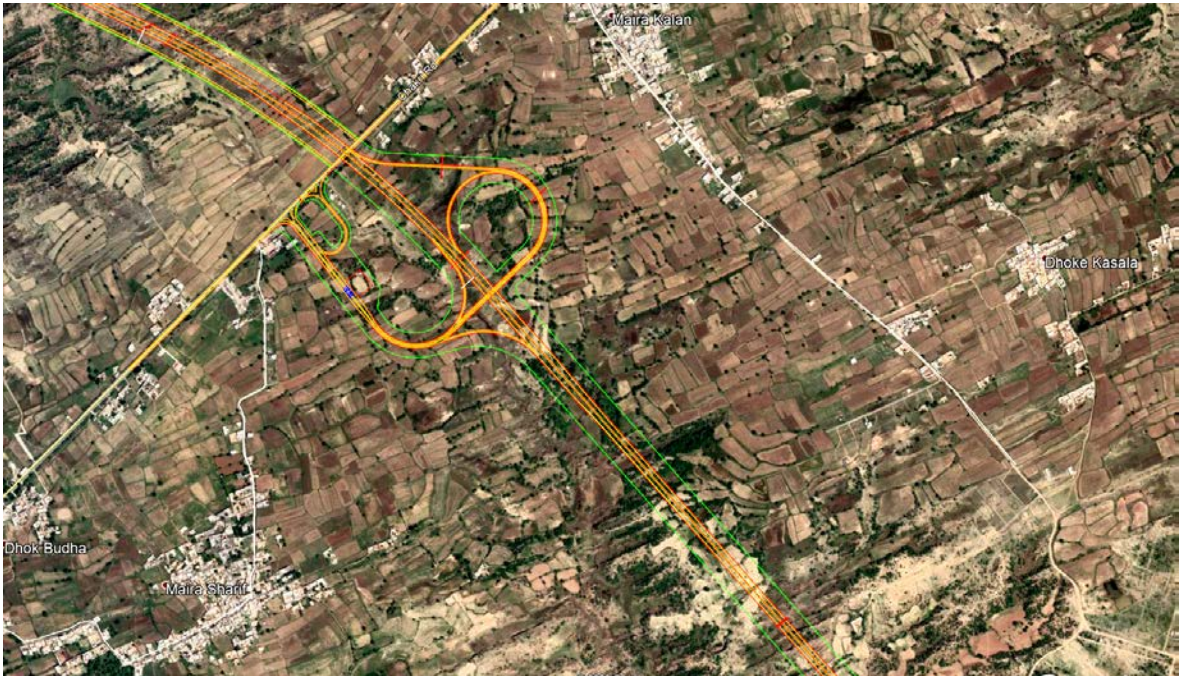


**Figure-3.7 to 3.10**

**KM 23+900 TO KM 29+800**

After crossing Adiala road, the alignment proceeds in North direction and approaches Chakri road at km 29+800. The alignment is proposed in between Maira Sharif and Maira Kalan villages. At this location a semi cloverleaf interchange in open land is provided with complete tolling facility on one side (South). This stretch of alignment also passes through various Chaks and green farms on rolling areas from low elevation of 390m to high elevation of 510m. Refer figure-3.11 to 3.12.



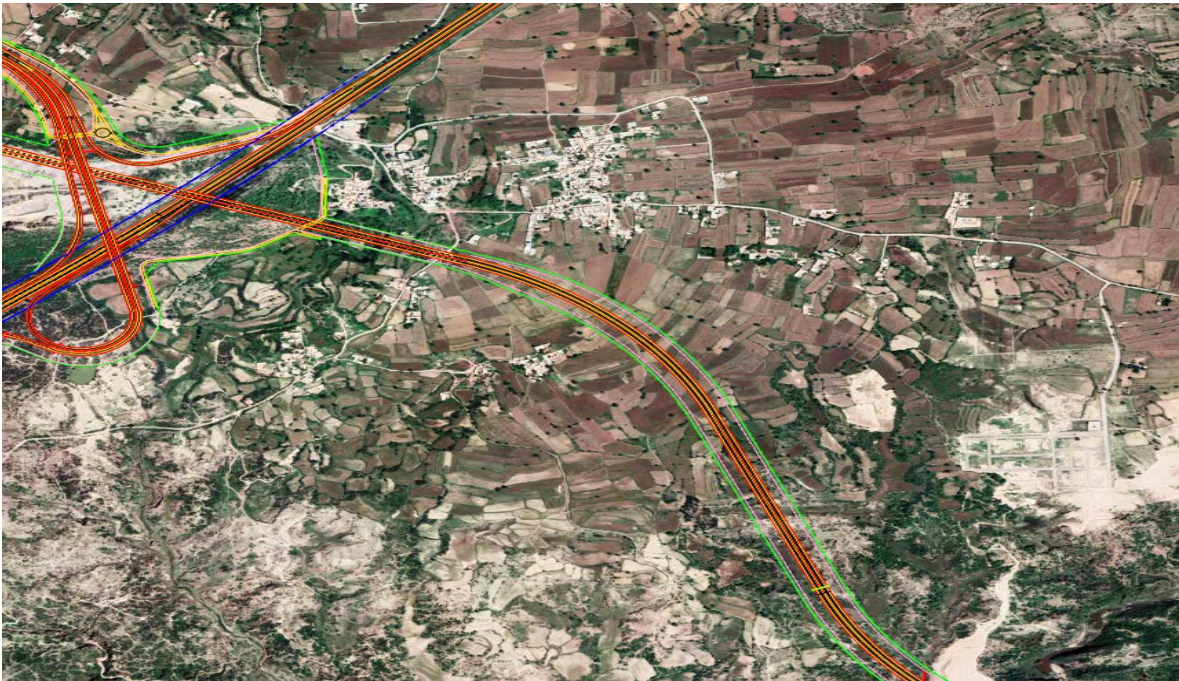


**Figure-3.11 to 3.12**

**KM 29+800 TO KM 23+200**

After crossing Chakri road, the alignment proceeds in North West direction and approaches Lahore-Islamabad Motorway (M-2) at km 36+200 near Murat. At this location a semi cloverleaf interchange in open land is provided with complete tolling facility on one side (North). This stretch of alignment also passes through various green farms on rolling areas ranges between elevation 430 and 550m. . Refer figure-3.13 to 3.14.

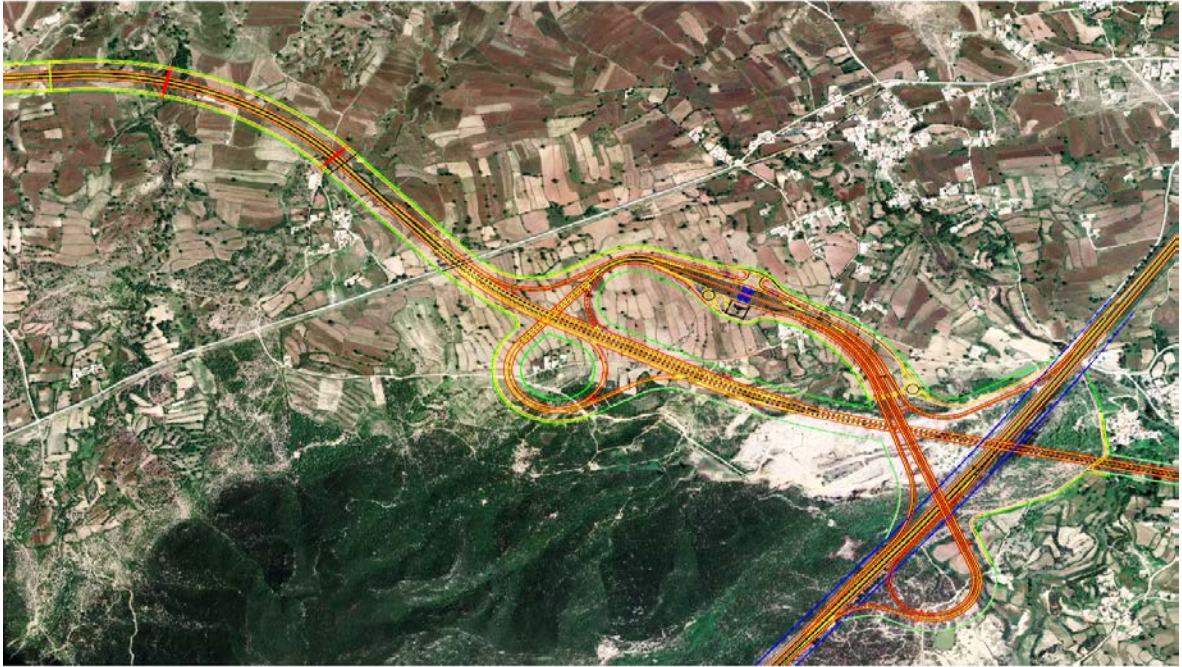




**Figure-3.13 to 3.14**

**KM 23+200 TO KM 44+700**

After motorway (M-2) crossing, the alignment proceed forward in West direction and crosses Paswal link road at km 37+900, Thalian link road at km 39+700, proposed service area at km 42+000, Dhok Dhullu link road at km 43+200 and approaches Dhok Manewali link road at km 44+700. At this location a semi cloverleaf interchange in open land is provided with complete tolling facility on one side (South). This stretch of alignment passes in parallel through southern side of new Islamabad International Airport with an offset of 2km length. The alignment passes through various green farms on rolling areas ranges between elevation 530 and 550m. . Refer figure-3.15 to 3.17.



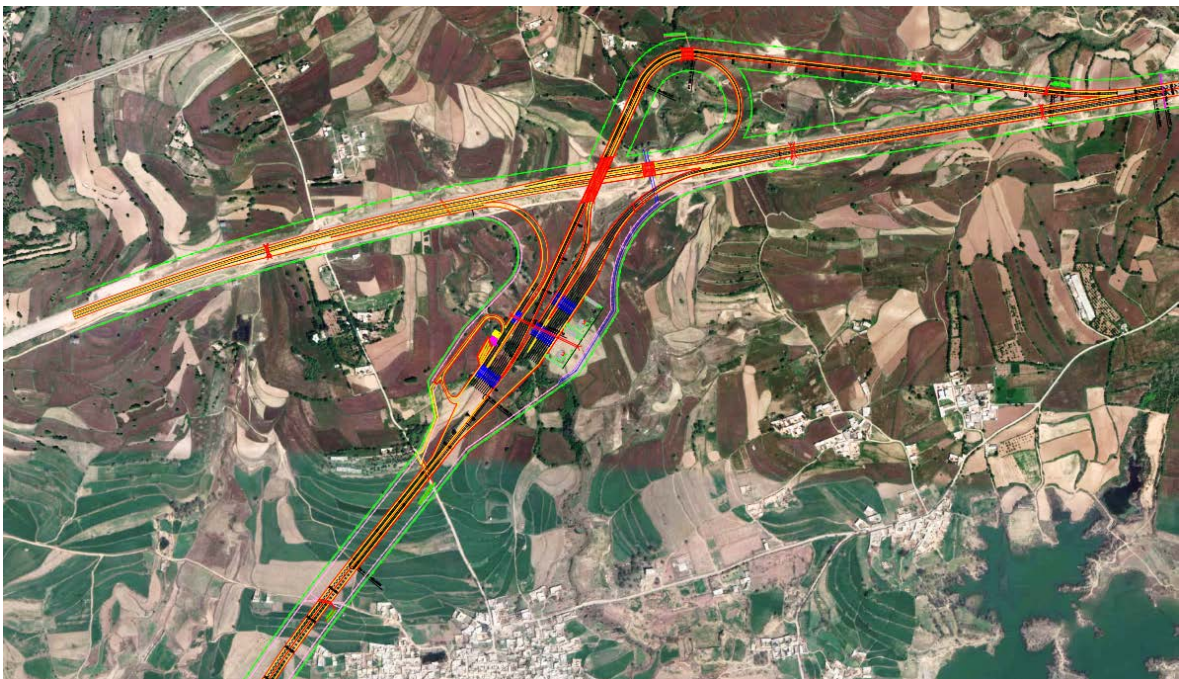


**Figure-3.15 to 3.17**

**KM 44+700 TO KM 51+700**

The alignment further proceeds and takes a sharp right turn in North direction over the new Islamabad International Airport. It crosses the Kaniyal-Mahlu link road at km 48+500, crosses Mahlu village very closely at km 50+400, crosses the proposed main toll plaza (both sides) at km 51+100 and merges with Hakla DIKhan motorway at km 51+700. At this location a semi cloverleaf interchange in open land is provided. This stretch of alignment also passes through various green farms on rolling areas ranges between elevation 500m and 530m. Refer figure-3.18 to 3.20.



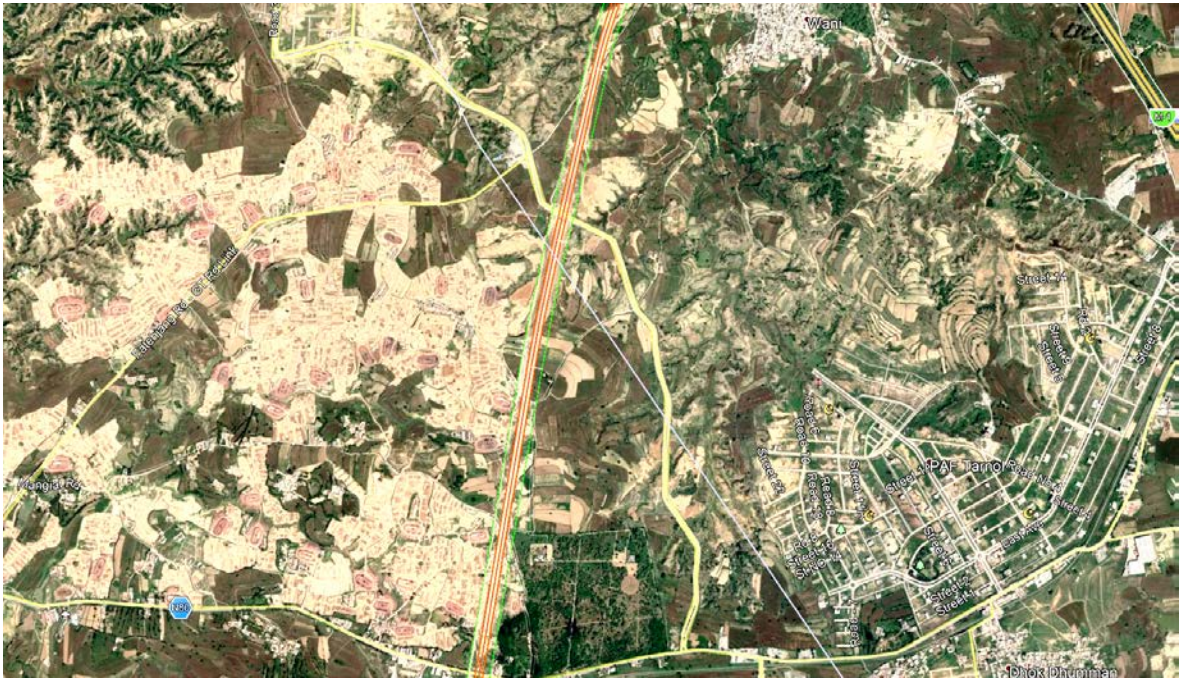
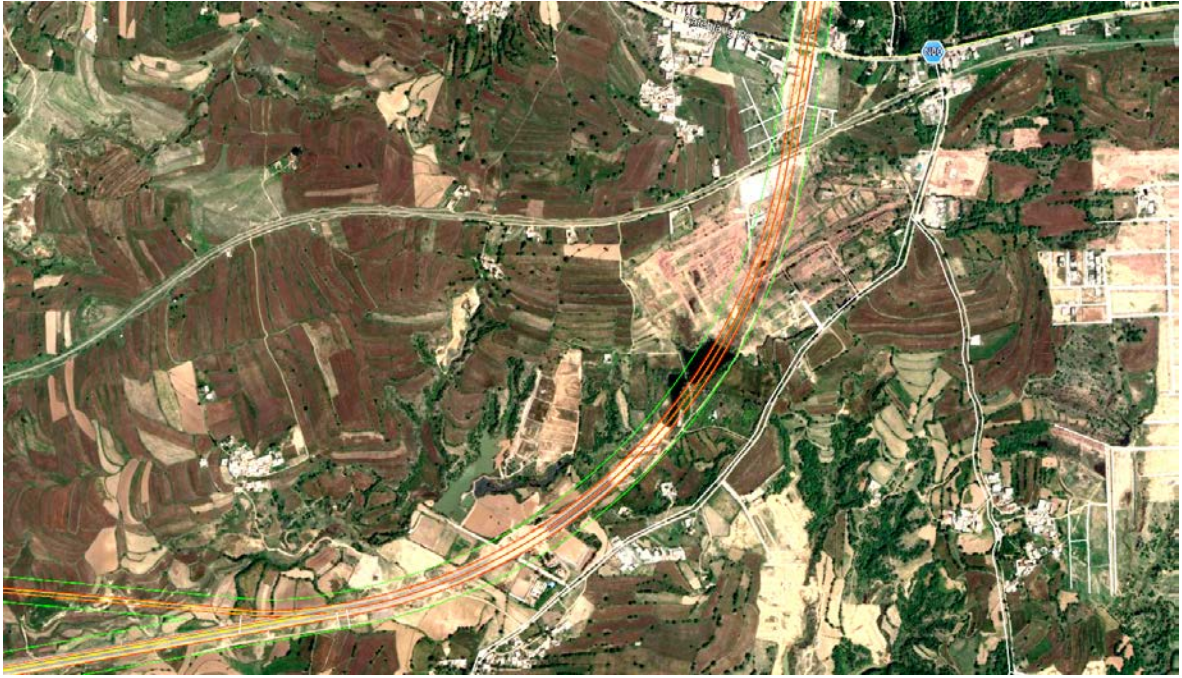


**Figure-3.18 to 3.20**

**KM 51+700 TO KM 60+800**

From Hakla DIKhan motorway onward, the alignment turns right in Eastern direction, soon after it turns left in North direction and crosses Fateh Jang road N-80 at km 55+600, Fateh Jang link road at km 57+700, passes through open land between Ministry of Commerce society and village Wani at km 59+000 and approaches Islamabad Peshawar motorway (M-1) at km 60+800. At this location a semi cloverleaf interchange in open land is available with complete main tolling facility on both sides. This stretch of alignment passes along Hakla DIKhan motorway on both sides from km 51+700 to km 60+800. The alignment passes

various green farms on rolling areas ranges between elevation 500m and 550m. Refer figure-3.21 to 3.23.

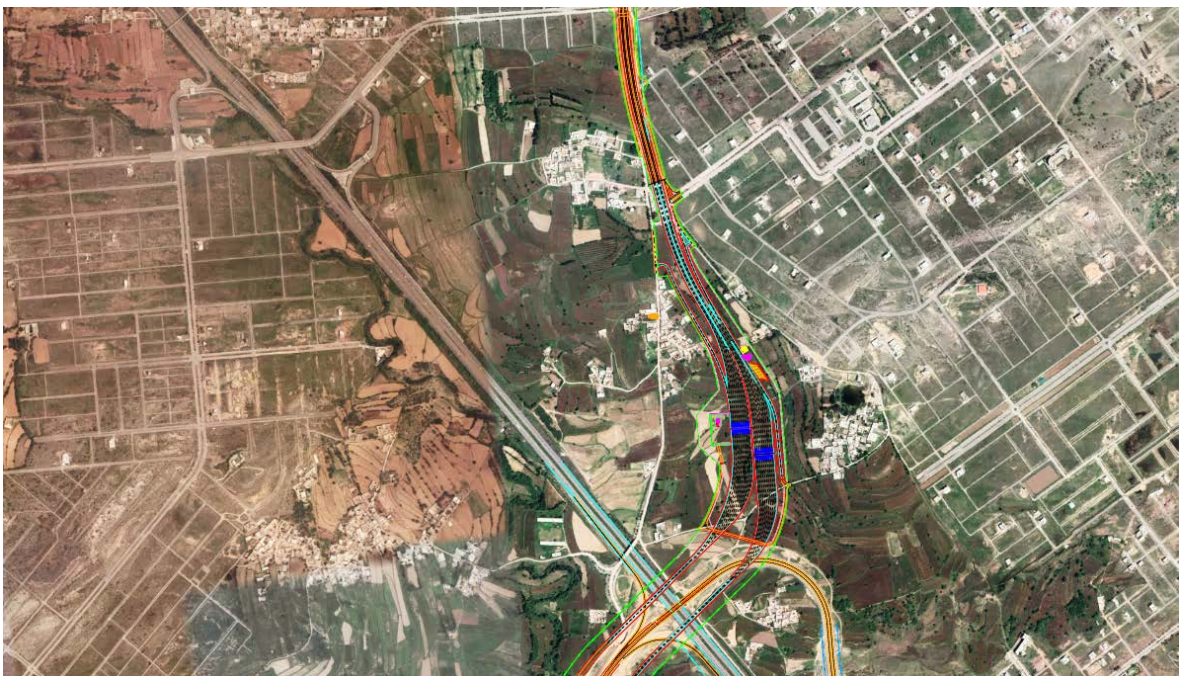


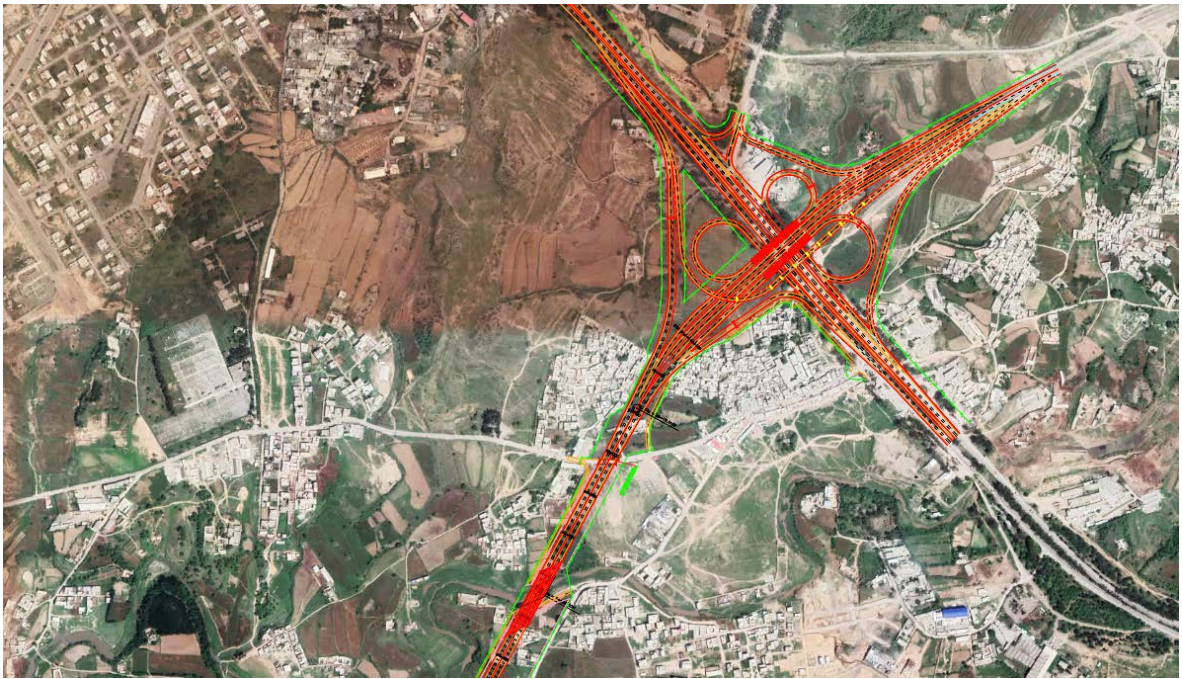


**Figure-3.21 to 3.23**

**KM 60+800 TO 65+300**

After motorway (M-1) crossing, the alignment turns left in North direction and passes left side of D-18 Islamabad (Engineering Cooperative society) and ends at Peshawar Road (N-5) at km 65+300 near Sangjani. At this location a semi cloverleaf interchange in open land is provided. This stretch of alignment passes through urban stretches of Islamabad with an elevation ranges between 500m and 530m. Alignment terminates at chainage 65+300. Refer figure-3.24 to 3.26.





**Figure-3.24 to 3.26**

## **CHAPTER-4**

# **CIVIL AND ALLIED WORKS**

## **4. CIVIL & ALLIED WORKS:**

Overall Construction of Rawalpindi Ring Road shall confirm to the following components:

### **4.1. ROAD COMPONENTS:**

Construction of Rawalpindi Ring road shall be a dual carriageway (three lane each side) with a design speed of 120 km/hr. Major components of road includes earthworks, pavement works, ancillary works with a New Jersey barrier as the median separator. Roadway will have an integral subgrade width of 32m. The standard lane width for a free way of approximately 3.60m shall be adopted with min. 1.0m asphaltic inner and 3.0m TST outer shoulder. The average embankment height shall be five (5) m with a side slope of 2:1 (min.) depending on the soil angle of repose. Road furniture comprising of lane markings, traffic signs, metallic Beam guardrails, Side Barriers and reflectors shall be provided. Typical section of Motorway is shown in geometric design report.

Improvement/upgrading/rehabilitation of exiting two lane road crossings through flyover/bridges between project start and end points is suggested to meet the Applicable Standards.

### **4.2. INTERCHANGES:**

In this project, nine (04 Present & 05 Future) Interchanges have been proposed for adjoining local road terminating points to tie with project road. Construction of Interchanges consists of flyover/overpasses crossing the main Ring road with single lane Loops and ramps for entry/ exit to and from the Ring road. Design speed at loops & ramps shall be of 60km/hr. At some Major road crossings, Ring road may overpass the cross roads. Major components includes earthworks, pavement works, ancillary works. The standard lane width for a Loop & Ramp shall be 3.60m with 1.0m asphaltic inner and 3.0m TST outer shoulder. The average embankment height shall be 5.0m with a side slope of 2:1 depending on the soil angle of repose. Road furniture comprising of lane markings, traffic signs, metallic Beam guardrails and reflectors shall be provided. Minimum capacity toll plaza with 3-4 entry and exit toll lanes shall be part of Interchange.

### **4.3. STRUCTURE COMPONENTS:**

Type of structures envisaged for construction under the project includes River bridges, Overpass Bridges, Nullah bridges (long and short), Interchange Flyover bridges, Subway, Cattle creep and culverts.

### **4.4. SERVICE ROAD:**

Provision of service roads in the urbanized stretches and rural villages to compensate farm to market roads (FMR) where ever required for the smooth connectivity of traffic. Service

Roads of 6.0m width are provided on both sides of main road at urban reaches as shown in the drawings. Apart from that Earthen track (both sides) will run throughout the entire length. The pavement structure for Service Roads are given in detailed cross sections. The layout plan shall be guiding for locations where service road is to be provided. Proposed length is estimated to be 30km (15km both sides).

#### **4.5. TOLL PLAZAS:**

Based on the traffic data and information derived from traffic studies, tolling system and tolling technology adopted and a study of the existing physical features including the availability of land, the possible toll plaza location has been finalized. Construction of four (4) main toll Plazas and five (5) future toll plazas at Interchanges duly equipped with ITS & Electronic Toll and Ticketing Management system located as per Layout plan. The layout of toll plaza is designed based on the forecast traffic such that the traffic will be subject to the minimum delay and inconvenience. Components include tolling booth, Construction of toll control building, Construction of residences for tolling staff. Tentative locations of Toll Plazas are shown in the Project Location Plan including Weigh stations. At all toll plazas, the main toll booth area shall be rigid pavement, which has been designed for 25 years. The design of rigid pavement shall withstand the cumulative effect of the axle load repetitions of different commercial vehicles for 25 years.

#### **4.6. WEIGH STATIONS:**

Weighing stations shall be located near toll plazas so that overloaded vehicles can be easily identified and suitably penalized / unloaded before being allowed to proceed further. The type of weighing system suitable for the project shall be brought out giving merits of each type of the state of the art and basis of recommendations for the chosen system. The suitable locations for weighing stations shall be selected and suitable design will be prepared in this regard.

#### **4.7. WAY SIDE AMENITIES:**

Service areas, maintenance yard including common facilities like petrol pump, first aid medical facilities, police office, restaurant, Masjid, vehicle parking etc. shall be included in the general layout for planning and design. For petrol stations, the guide lines issued by Ministry of Petroleum shall be followed.

#### **4.8. OTHER COMPONENTS:**

The suitable designs and layout for miscellaneous works including telecommunication facilities, Drainage and erosion protection works, Chutes, Land-Scaping/ green works, Intelligent Transport system (ITS), electrification works etc. and other allied works wherever appropriate shall be prepared to ensure construction of a modern freeway.

## **CHAPTER-5**

# **PRELIMINARY DESIGN REPORTS**

## **5. PRELIMINARY DESIGN REPORTS**

This section provides a detailed description of how the design study was carried out by the Expert Team deployed for the assignment. This report essentially aims at working out the best/optimum alignment and various technical improvements of the project corridor after considering environmental and social impacts, cost effectiveness and economic viability using International best practices including the use of state of the art techniques within the limited time frame. Site visits, data collection from site and data from various civil departments as well as indoor desk study are the main input for finalization of report.

Following reports have been prepared by the experts, based on the available relevant data/studies conducted for this assignment.

1. Geometric Design Report
2. Pavement Analysis & Design Report
3. Hydrology Report
4. Structural Design Report (Attached as Annexure-A)
5. ITS (Attached as Annexure-B)

## **6. GEOMETRIC DESIGN REPORT:**

### **6.1. GENERAL:**

The detailed design of this project road is based on a set of design criteria that represents the best internationally accepted engineering practice. At the same time, the specific local site conditions are effectively considered in the interpretation of these criteria. It is to be emphasized that engineering design is an integrated process of information collection, analysis, synthesis and evaluation. The ultimate objective of this process is achievement of the desired performance in the constructed facility. As such the design criteria should effectively represent the performance objectives, while satisfying the economic constraints. The stipulated design criteria are always subject to engineering judgment.

Geometric design of highway refers to the design of the visible dimension of such features as horizontal and vertical alignments, cross sections, intersections, interchanges. The main objective of geometric design is to produce a highway with safe, efficient, and economic traffic operations while maintaining esthetic and environment quality, geometric design is influenced by the vehicle, driver, and traffic characteristics.

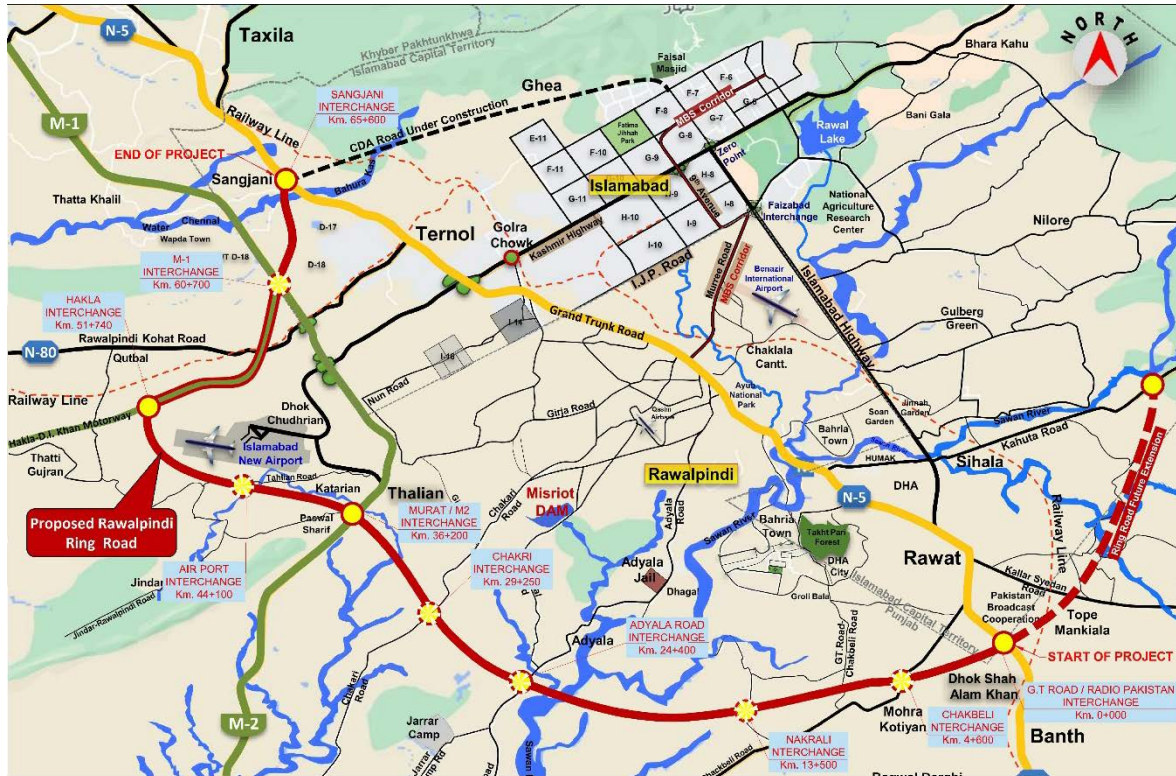
The geometric aspects of a highway include features that affect or relate to its operational quality and safety. These features, which are visible to the driver and affect driving performance, include elements of the roadways, ramps, and roadside. Roadways have features related to roadway curvature (horizontal and vertical alignment); intersections and interchanges; cross sections (e.g., number of lanes and lane width, presence of shoulders and curbs); channelization and medians; and other miscellaneous elements (e.g., driveways, bridges). Physical features of the roadside include: barriers (e.g., guide rails); obstacles (e.g., noise barriers, trees, signs); and other miscellaneous features (embankment slopes, ditches, etc.). Design standards describe the characteristics of the roadway geometry, such as lane width, radius of curves, and acceptable grade, as well as traffic control devices including signals, signage, and pavement markings. The establishment of design standards for roadways promotes safety and efficiency, since the standards are based on established research on the safety and performance implications of various design features. Uniform designs further promote safety by increasing the predictability of the driving environment, so that the road user knows what to expect in any given situation.

### **6.2. INTRODUCTION OF PROJECT:**

Rawalpindi Ring Road having a total length of 65.3km is to be a 6-Lane dual carriageway which includes Interchanges, Flyover, Overpasses, canal bridges, cattle creep, subways,

water course culverts, utility culverts & at-grade Service Roads on specified locations of urban and rural stretches with proper drainage system.

Layout map of project road is attached as figure-8.1.



**Figure-8.1 Layout Plan of project Alignment**

### 6.3. PROJECT FACILITIES:

The Project facilities and requirements shall conform to the minimum design requirements set out on the basis of which the Detailed Project drawings has been prepared. Preliminary Design drawings includes setting out data, Geometric Plan & Profile Data to lay down minimum design requirements of the Project. Functional parameters of the project which are given in the geometric design criteria are the minimum requirements and must be met while preparing detailed design. However, during final design and implementation stage, without reducing these functional parameters and/or due to unpredictable circumstances or any other practical reason, it is suggested to have an alternate/improved design for any component of the Project e.g. Interchange, Flyover, bridge structures, subways, cattle creep, road pavement structure, rigid pavement etc. Such alternate design, if approved by the Authority, may replace the relevant part of the design.

### 6.4. GEOMETRIC DESIGN ELEMENTS & STANDARDS:

Geometric design covering horizontal alignment, vertical profile, widening schemes, cross sectional elements of the highway, design standards for structure etc. The application of

design standards to a specific project often have to deal with a tradeoff to establish safety features within the frame of cost of structure of the projects. Road design is traditionally a manual technique in which the problem is considered separately in three views. i.e.

- a) Plan
- b) Longitudinal profile
- c) Cross section

#### **6.4.1. Horizontal Alignment:**

The alignment comprised of a variety of elements joined together to create a facility that serves the traffic in a safe and efficient manner. Each alignment element should harmonize the others to produce a consistent, safe efficient and responsible design. Horizontal alignment must afford at least the minimum stopping sight distance for the design speed at all points on the highway.

The major considerations in horizontal alignment are:

- a) Topography
- b) Type of facility
- c) Design speed
- d) Profile grade
- e) Subsurface conditions
- f) Existing highway and cultural development
- g) Likely future developments
- h) Right of way
- i) Safety standards
- j) Construction cost
- k) Environmental issues
- l) Geological features
- m) Drainage
- n) Economic aspects

The design of roadway should be based on an appropriate relationship between design speed and curvature on their joint relationships with super elevation and side friction.

#### **Design Speed:**

Speed reduces the visual field, restricts peripheral vision, and limits the time available for drivers to receive and process information. Design Speed is a selected speed based on the various geometric features of the roadway. Conversely the geometric design features

should correspond with the desired design speed. The selected design speed should be consistent with the speeds that drivers are likely to expect on a given highway facility.

Design Speed for the Rawalpindi Ring road project for main carriageway was taken 120 Kilometres per Hour. (Km/hr.)

### **Curve Radius:**

The minimum radius is a limiting value of curvature for a given design speed and is determined from the maximum rate of super elevation and the maximum side friction factor selected for design (limiting value of f).

The Design Consultant has studied the previous Geometry made by Consultant and has made improvements where required.

- a) Minimum radius at relevant design speed and maximum super elevation is taken as 756m.
- b) Absolute minimum curve radius at turnings/channelizing islands is taken as 22m.

### **Super Elevation:**

Super elevation is the banking of a roadway around a curve. The purpose of employing super elevation of the roadway cross section is to counter balance the centrifugal force, or outward pull of a vehicle traversing a horizontal curve. Side friction developed between the tires and the road surface also counter balances the outward pull of the vehicle. A combination of these two concepts allows a vehicle to negotiate curves safely at higher speeds. There are practical upper limits to the rate of super elevations on a horizontal curve. Super elevation is provided for all the horizontal curves with radius less than 4800m in order to counteract the effect of centrifugal force. The super elevation 'e' has been calculated from the formula:

$$E = (V)^2 / 225R$$

Where, V is the design speed, and R is the radius of curve in meter.

Maximum super elevation on the project is taken as 6% as per requirement.

### **Sight Distance**

Safe stopping site distance, both in Horizontal and vertical directions has been applied in design. The recommended sight distance is as follows:

<b>Design speed</b>	<b>S.S.T</b>	<b>O.S.D</b>
Highway 120km/hr.	250	1000
Loops and ramps 60km/hr.	85	300

### **Horizontal Design Control:**

The Horizontal alignment for the project road was designed in detail, keeping in view the objective of most feasible and reliable alignment throughout the entire length. The alignment goes through rolling/ hilly terrain of agriculture lands with urban areas. Nullahs, streams and water logged areas are frequently encountered in the alignment. In order to technically analyze the designed alignment, site visits, topographic survey, site photographs and Google Satellite Imagery were the governing factors used for our work. Keeping in view of all material/ documents/ studies/ preliminary design drawings provided supplemented with area reconnaissance and detailed topographic survey, design of in-route towns, Nespak worked all options with merits and demerits after ground assessment of salient features of the alignment. For items other than main road, Interchanges, subways, bridge and culverts, where tailor-made specifications are not available, the same shall be finalized during construction stage. All the horizontal curves for the detailed layout plan have been examined for radius. All the curves having radius less than desirable standards have been examined for feasibility of flattening with reference to land availability, connectivity to adjoining curves, affected length and other related factors.

The Horizontal alignment components in the design criteria are the minimum requirements to be maintained for Project road. Dimensions of different components are the minimum requirements and must be met while preparing detailed design based on preliminary design drawings and reports with cross-section. The Geometric Design Standards for the Project Facilities shall be as per Policy Design, 2018 AASHTO – Geometric Design of Highway & Streets.

### **6.4.2. Vertical Alignment:**

Topography of the land traversed has an influence on the alignment of roads and streets. Topography affects horizontal alignment, but has an even more pronounced effect on vertical alignment. The highways vertical alignment plays a significant role in highway safety, aesthetics and project costs. Vertical curves are normally parabolic. A simple vertical curve may be crest vertical curve or a sag vertical curve. The design of vertical alignments involves, to a large extent, complying with specific limiting criteria. These includes maximum and minimum grades, sight distance at vertical curves, vertical clearances and K values.

### **Gradient:**

Road and streets should be designed to encourage uniform operation throughout. Grades are important to facilitate the road users. The vertical alignment is provided for a smooth longitudinal profile. Grade changes have not been too frequent as to cause kinks and visual discontinuities in the profile. The desirable maximum ruling grade is taken as 3 % for this rolling area terrain. On embankments, level grades are not objectionable when the

pavement has sufficient camber to drain the storm water laterally. However, in cut sections, minimum gradient for drainage considerations is 0.3% with lined side drains.

### **Vertical Curves:**

Vertical curves are introduced for smooth transition at grade changes. Convex vertical curves are known as crest curves and concave vertical curves are sag curves. Both these curves are designed as square parabolas. The length of the vertical curves is controlled by sight distance requirements, but curves with greater length are aesthetically better and is provided where possible. For satisfactory appearance, the minimum curve length is as follows:

<b>Design speed</b>	<b>Minimum grade change requiring vertical curve</b>	<b>Minimum length of vertical curve (m)</b>
120Km/hr.	0.5	100

Due to changes in grade, vertical curves at the interchanges of the different grades is provided in the design so as to smoothen the vertical profile resulting in easing off the changes in the gradients for the fast moving vehicles.

### **K Value for Vertical Curves:**

The major control for safe operation on crest & a sag vertical curve is the provision of ample sight distances for the design speed which depends on rate of vertical curvature "K". For this project the "K" value for main carriageway, based on stopping sight distance is taken "95" for Crest vertical curve & "63" for Sag vertical curve. Both the Sag & Crest curves have been introduced as per AASHTO guide lines.

### **Vertical Design Control:**

The profile along the highway has been examined for gradient, stretches having gradient exceeding ruling standards examined for flattening and the profile improvements worked out accordingly. Similarly profile across the existing roads crossings examined carefully to control unnecessary fill and gradient by lowering profile accordingly.

### **6.4.3. Road Cross Section Elements:**

The cross section of the road within ROW may vary depending on the conceptual design regarding additional lanes/ service roads to be provided or not along the main carriageway. For Rawalpindi ring road project, road cross sections have been designed in accordance with typical cross section develop by consultants for different locations. Six different cross sections were prepared consisting of six lane highway with 0.6m central divider (NJB) for

design of highway cross section. These are further furnished for perusal. Road Cross Section elements for the project are taken as follows:

### **Right of Way (ROW)**

The right of way is governed by:

#### **Width of formation:**

It depends on the category of the highway and width of roadway and road margins.

#### **Height of embankment or depth of cutting:**

Is governed by the topography and vertical alignment

#### **Side slopes of embankment or cutting:**

It depends on the height of slope and soil type.

#### **Drainage system:**

Depends on its size, rainfall and topography.

#### **Sight distance considerations:**

On curves there is restriction to visibility on the inner side of the curve due to presence of some obstructions.

#### **Reserve land for future widening:**

Some land has to be acquired in advance anticipating future developments.

As per engineering design in Pakistan, in open areas the normal available land width ranges between 30 to 40m ROW. In urban areas the available land width ranges between 30 to 60m ROW. In case of Rawalpindi ring road the land requirement is more than the specified width as set in AASHTO Guide lines for freeways. In this project the land requirement is 110m or more to accommodate geometric design features and Interchanges.

#### **Lanes and Width of Carriage way:**

Width of carriageway consists of lane width and travelled way. Single Lane width for the Project is taken 3.60m, three (3) Lanes on either side for dual carriageway. The total travelled way is 10.80m on either side is provided.

#### **Shoulder Width**

Recommended Width of asphaltic inner shoulder is minimum 1.0m on both sides followed by 3.0m TST shoulders on both sides. The asphaltic shoulders shall be of the same composition as the main carriageway.

### Median Width:

As the road is proposed for 6 lane standard configuration, Central divider (NJB) for a width of 0.6m has been adopted.

### Cross Slope

On highways cross slope across the entire width of the travelled way is generally provided for surface drainage. In this project, the cross slope of main carriageway on either side taken as 2.0% and outer shoulder is taken as 4%.

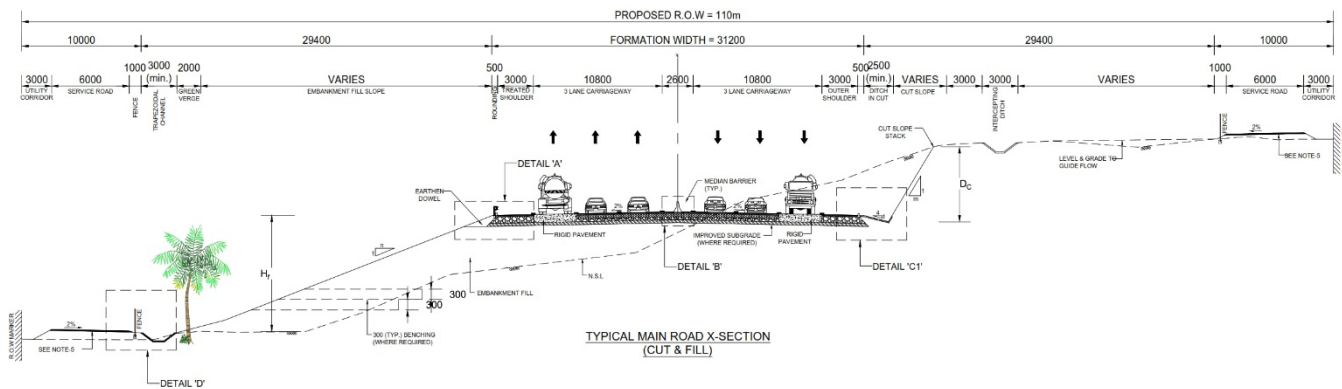
### Side Slopes

For cut and fill sections following side slopes are proposed

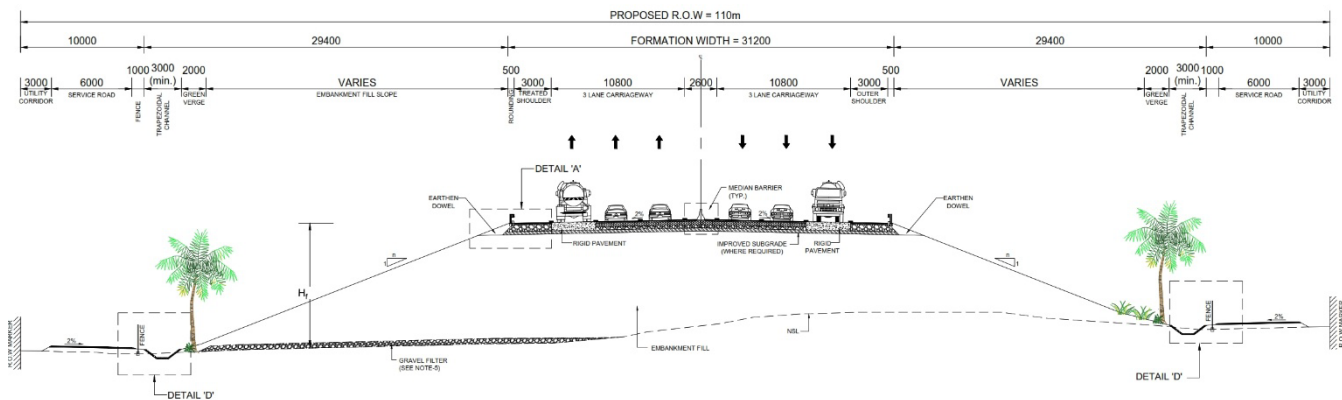
Fill height upto 3- 5m = 2H: 1V

For cut slopes =1H: 2V (min)

Following are the proposed typical sections recommended for Rawalpindi Ring Road.

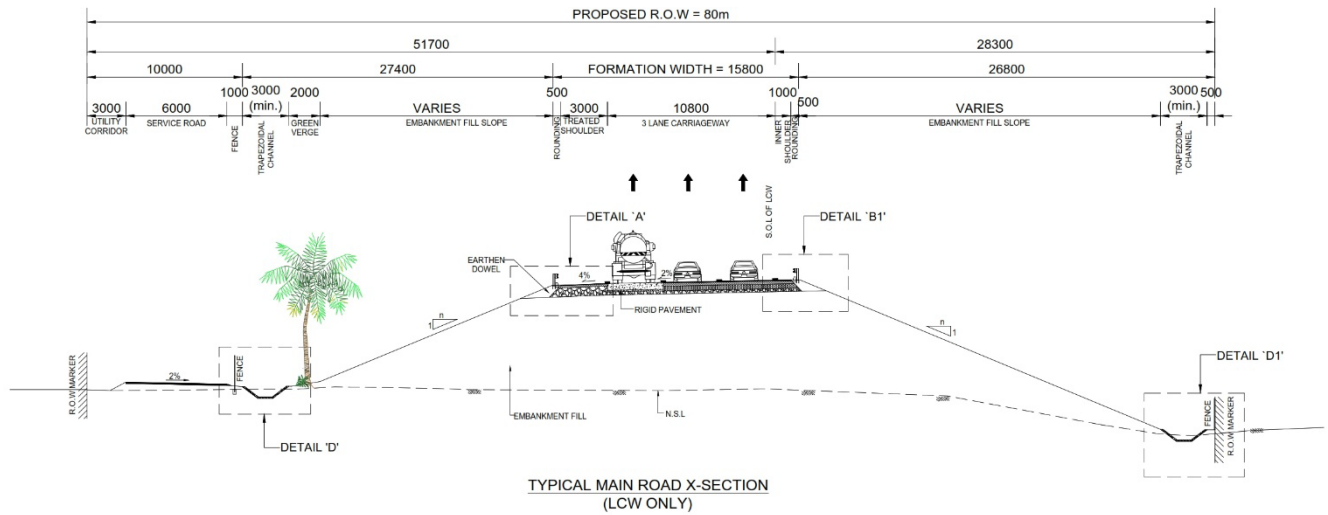


**Typical cross section of Rawalpindi Ring Road**

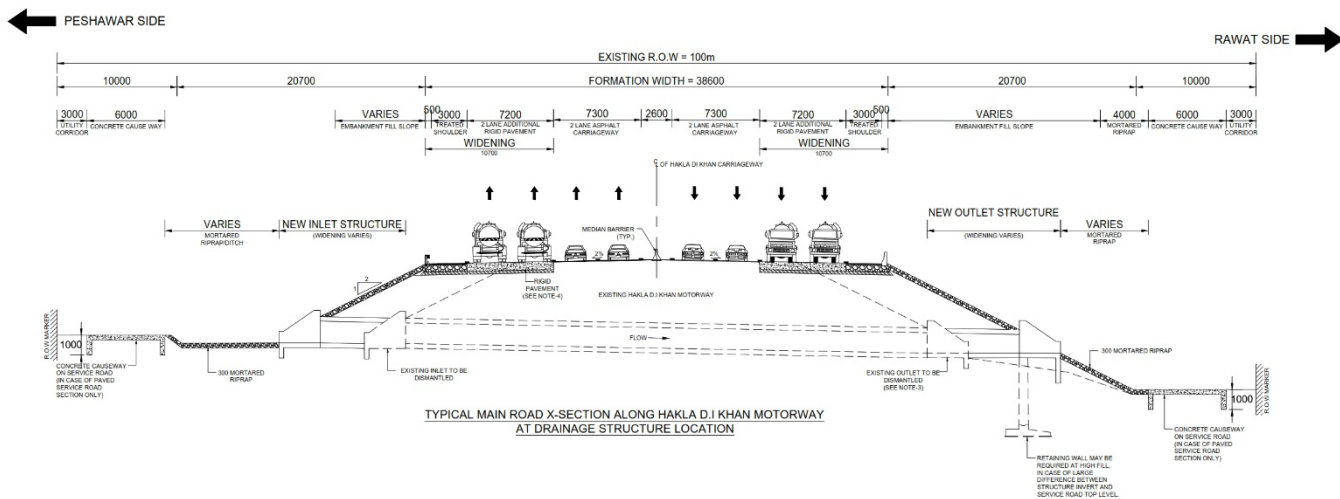


**Typical cross section in Fill**

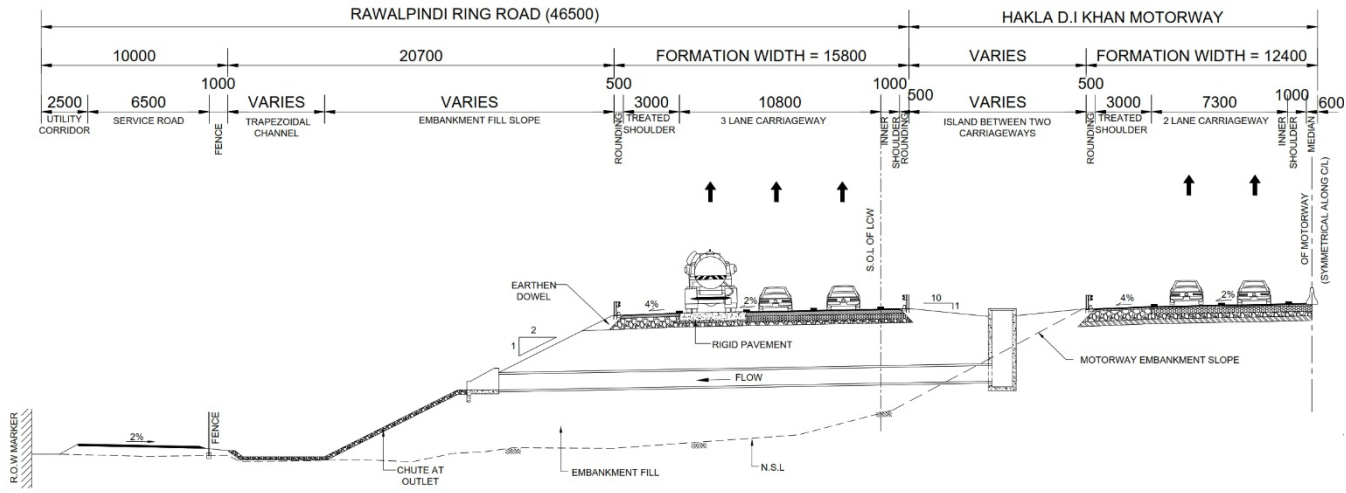




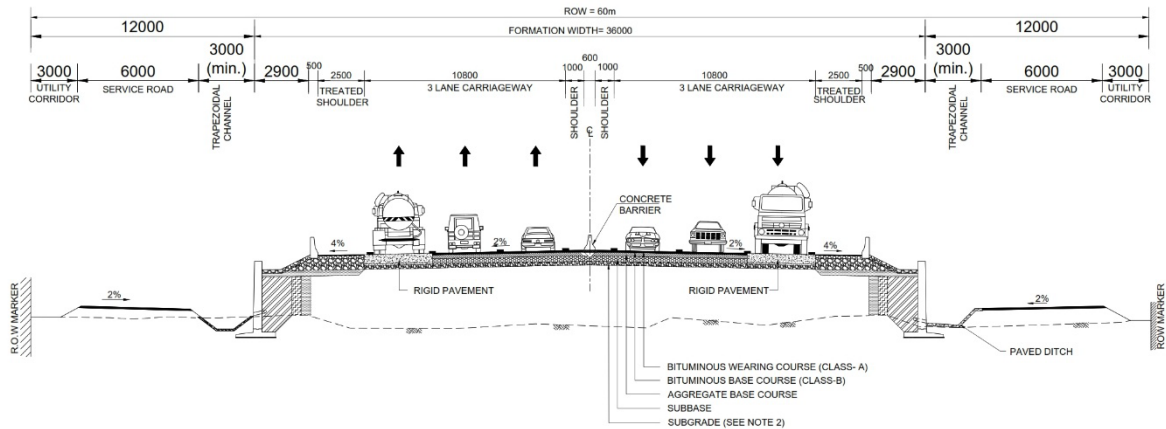
**Typical cross section of left carriage way only**



**Typical cross section along DI Khan -Hakla motorway at Drainage structure**



TYPICAL MAIN ROAD X-SECTION ALONG HAKLA D.I KHAN MOTORWAY  
(WHERE SANGJANI BOUND CARRIAGEWAY DIVERGES OUTWARDS)



TYPICAL CROSS SECTION FOR MAIN CARRIAGEWAY  
FROM M-1 TO SANGJANI

**Joint section of Rawalpindi Ring road from M-1 to Sangjani**

#### **6.4.4. Interchanges:**

Designing the geometry of Interchange involves balancing the needs of safety, capacity, operating performance and right of way constraints. An Interchange operates more safely when its geometry forces traffic to enter and circulate at slow speeds. Horizontal curvature and pavement widths are used to produce appropriate speed environment. Conversely, the capacity and safety of Interchanges can be negatively affected by low speed design elements. Geometric parameters for Interchange are governed by the maneuvering requirements of the largest vehicles expected to travel through the Interchange. The process of designing Interchange requires a considerable amount of iteration among geometric layout, operational analysis, and safety evaluation. Major adjustments in geometry can result in significant changes in the safety and operation performance. Thus the designer often needs to revise and refine the initial layout to enhance its capacity and safety. It is not possible to produce an optimal geometric design on the first attempt.

Before the details for the geometry are defined, three fundamental elements were determined in the primary design stage:

- The optimal Interchange size
- The optimal position
- The optimal alignment and arrangement of the approach legs.

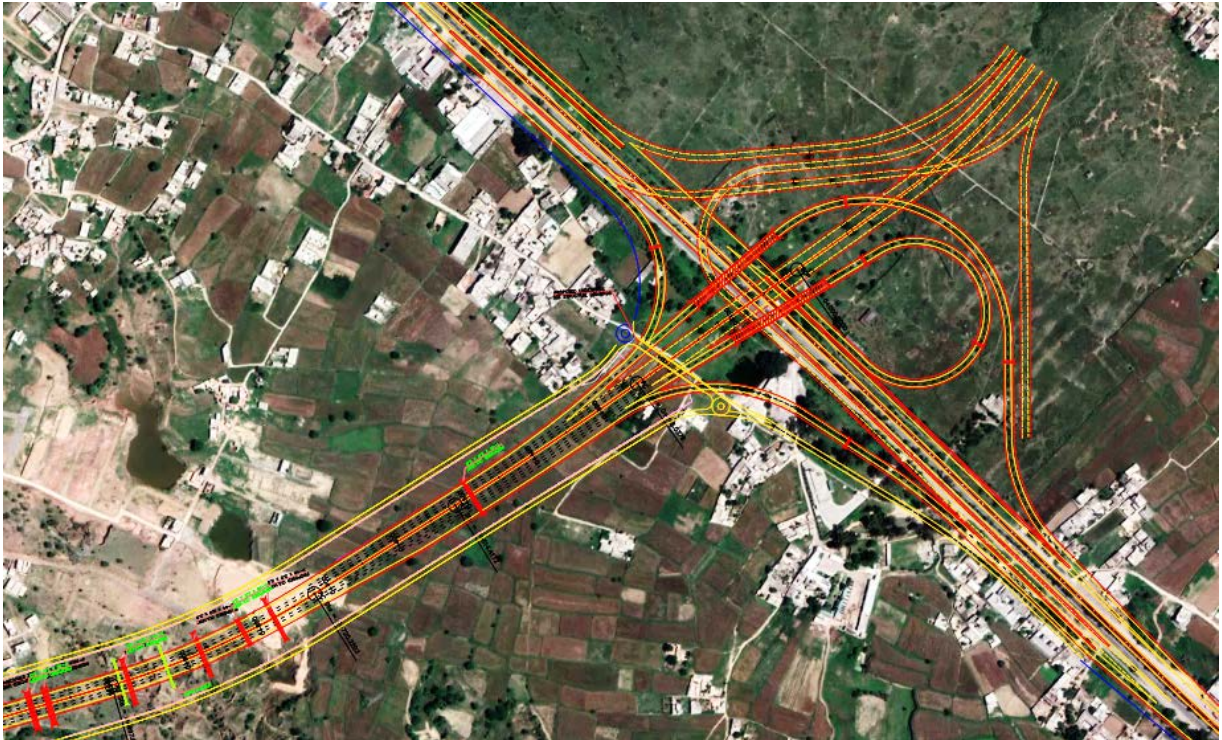
Below are design parameters that were applied for designing Interchange:

1. Design speed
2. Vehicle paths
3. Speed consistency
4. Design vehicle
5. Alignment of approaches and entries
6. Entry width
7. Length of conflicting leg of sight triangle
8. Pavement type
9. Vehicle path overlap

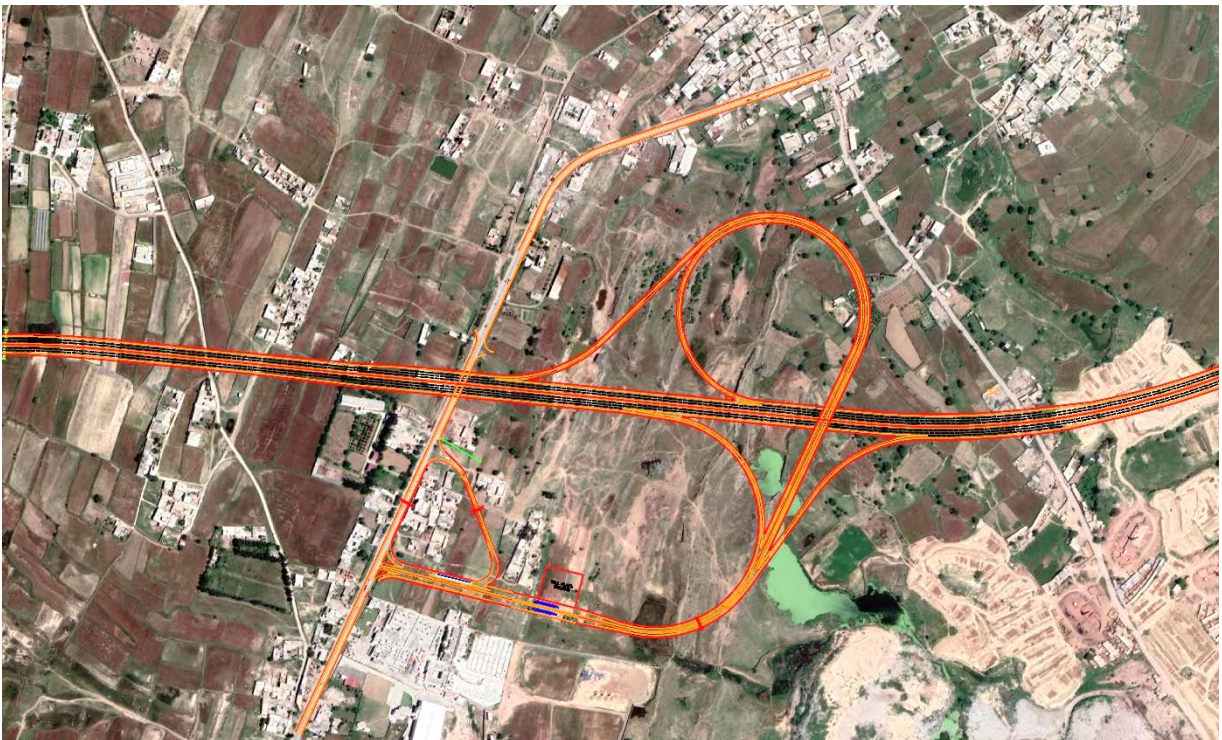
In this project, nine (04 Present & 05 Future) Interchanges have been proposed for adjoining local road terminating points to tie with project road. Interchange locations and Geometry marked on previous study was thoroughly examined and final location of improved Interchange has been finalized after analysis of traffic data. Adequately interchanges designed with channelization, all right turn and left turn (acceleration and deceleration) lanes (auxiliary) at major Interchanges for safe and smooth movement of traffic. All Interchanges are designed according to the AASHTO 2018 publication 'A Policy on the Geometric Design of Highway and Streets'. Geometric Design Criteria as given in the Preliminary Design

Report to be applied. The standards for loops & ramps design speed, radius and stopping sight distance for interchanges recommended are given below in table. Maximum vertical gradient of 3% is adopted for the design.

The recommended Geometry at various interchanges are shown on Google imagery.



**Interchange at Start Point near Radio Pakistan Transmitters (N5)**



**Partial Clover leaf interchange at Rawat Chakbeli Road crossing (Future)**



**Partial Clover leaf at Nakrali Interchange (Future)**



**Partial Clover leaf interchange at Adiala Road crossing (Future)**



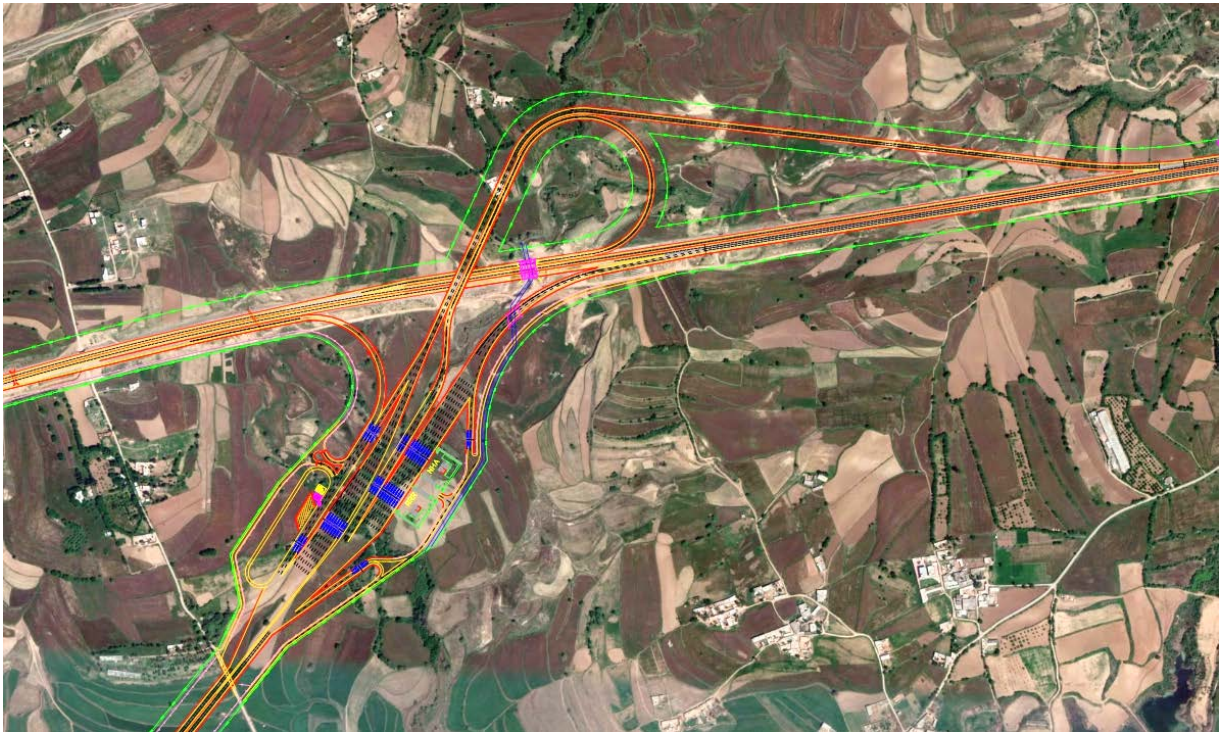
**Partial Clover leaf interchange Chakri Road crossing (Future)**



**Double Trumpet Interchange at Murat (M-2) crossing**



**Partial Clover leaf interchange proposed at PIA Road (Future)**



**Trumpet interchange proposed at DI-Hakla Motorway**



**Proposed Interchange at N-5 near Sangjani**

#### **6.4.5. Plan & Profile Design Drawings:**

##### **Plan View**

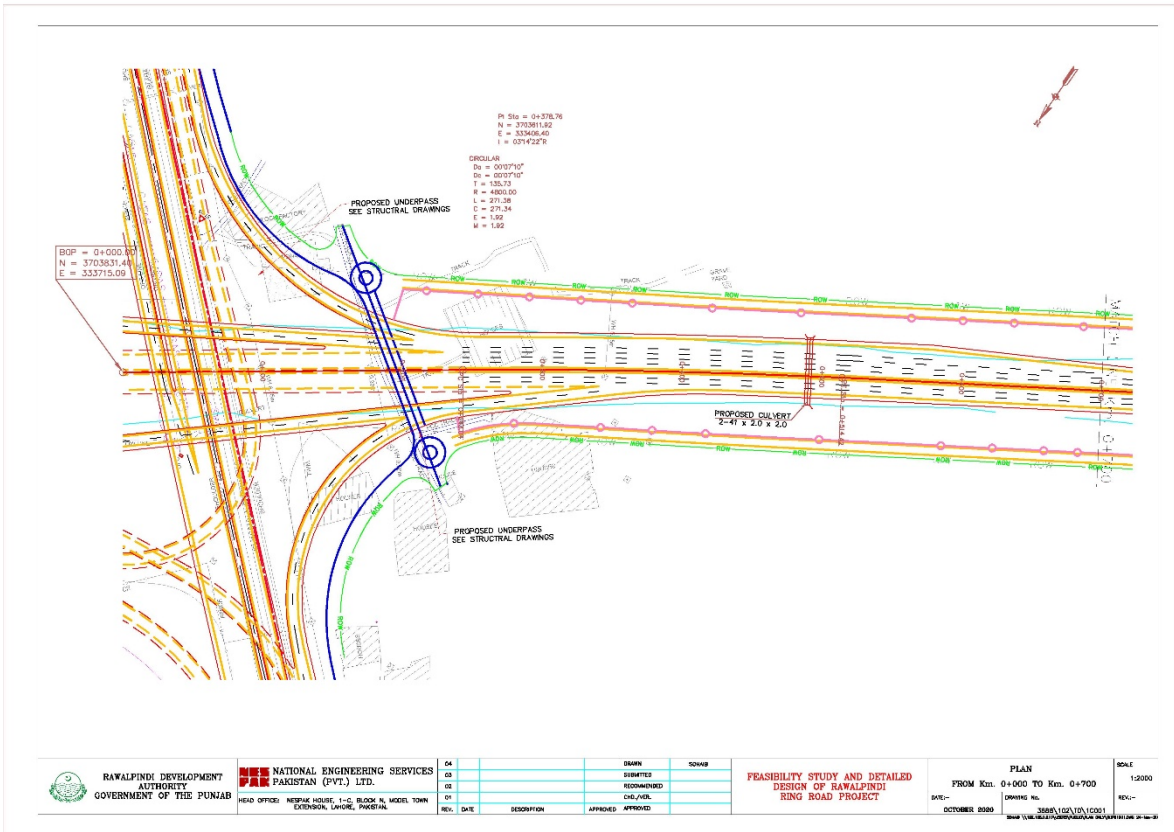
In plans, complete topography of the area (ROW), details of point of intersections and curve geometry (coordinates, deflection angle, radius, length of curve, tangent length, super elevation, etc. including PI, PC and PT chainage), chainage at every 25m, bridges, culverts etc. is provided.

##### **Profile View**

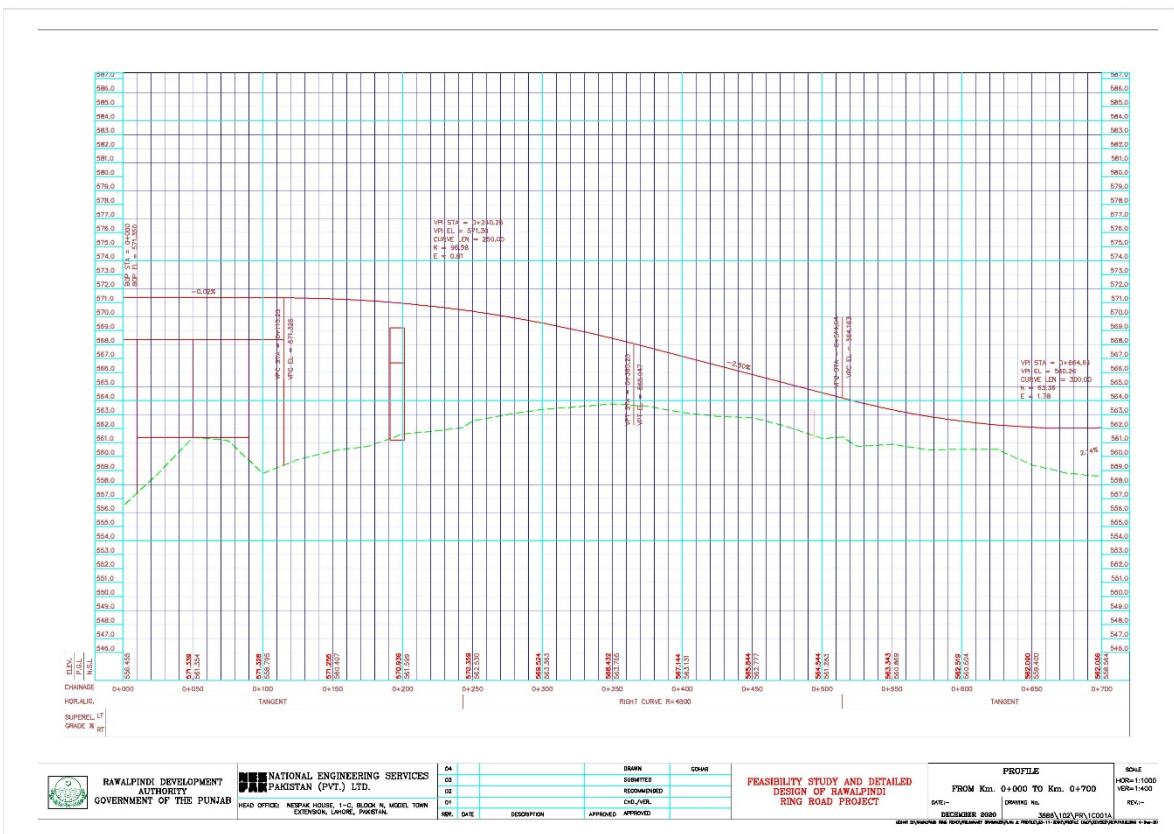
In Profile, chainage, existing ground/road level, finished road level (FRL), controlling factors, grade, embankment height, Insertion of vertical curves, Vertical Profile data, structures with height, bridges, culverts, etc. is provided.

Super-elevation, tangent run out and super-elevation runoff data is also provided in Plan & Profile drawings.

Following are some of the design sheets of plan and profile drawings extracted from the design folder of the project.



**Plan view**



**Profile view**

#### **6.4.6. Road Furniture:**

Road furniture such as traffic signs, pavement markings, cat eyes etc. on the Project Highway is provided as per specifications.

##### **Traffic Signs:**

A complete range of permanent retro-reflective Traffic signs for the safe and efficient movement of traffic. These signs are to be of Regulatory, Warning and Informatory types as per standards and placed on the roadside. The proposed signs and their location shall be approved as per standards. The overhead signs shall be placed on a structurally sound gantry or cantilever structure made of tubular structure or steel structure. These signs shall be of high intensity retro reflective sheeting. The height, lateral clearance and installation of the sign structures shall be as per Project Specifications. On kerbed road sections near Interchanges, the edges of the road signs shall be at least 600 mm away from the edge of the kerb, whereas on un-kerbed road sections the edge of the signs shall be at a distance of 2.5m from the edge of the carriageway. The design, placement, dimensions and lettering of boards shall be as per project Specifications. The design, location and materials to be used for road cat eyes and the colour, configuration, size and location of size of traffic signs shall be as per Project Specifications. Road cat eyes shall conform to the recommended practice.

##### **Road Markings:**

Road markings are of hot applied thermoplastic materials with glass reflectorizing beads as per relevant clauses of Project Specifications. Road markings shall be as per AASHTO or BS standards. These markings shall be applied to road centre lines, edge lines, continuity line, stop lines, give-way lines, diagonal/chevron markings, zebra crossing and at parking areas by means of an approved self-propelled machine which has a satisfactory cut-off valve capable of applying broken lines automatically.

##### **Traffic Safety Measures:**

Single faced New Jersey' type (NJB) shall be constructed at outer edge of both shoulders of project road if HFL is greater than 5m. Double faced NJBs shall be provided in the median. Details of these installations are shown in the detailed design drawings. NJB's installation shall have short transition flared section at the approach ends. Similarly 'W' beam guard rail steel type is provided on the high embankment section where the height of fill is more than 3.0m

## 6.5. Design Criteria:

Design criteria are basic to good geometric design and adhering to them will enhance the visual qualities of the roadway. In Pakistan most design parameters and criteria for road design are based on AASHTO guidelines.

The geometric design was carried out as per “A Policy on Geometric Design of Highways and Streets 2018” by AASHTO based on the following main parameters.

### **Roads Design Criteria:**

Table showing Salient features/ Technical Parameters and design criteria for Rawalpindi Ring Road:

<b>Sr. No.</b>	<b>Description</b>	<b>Main Carriageway</b>	<b>Interchanges</b>
1.	<b>Length of Project</b>	65.3 Km	
	Right of Way	110 m	As per design
	Design Vehicle	Truck Trailer 6 – axle	
2.	<b>Design Speed</b>	120 Kph	60 Kph
3.	<b>Road Cross-section</b>		
	Lane Width	3.60	3.60
	No. of Lanes	3 (each side)	One (1)
	Inner Shoulder	1.0 m	1.0 m
	Outer Shoulder	3.0 m	3.0 m
	Central median	(0.6) NJB	(0.6) NJB
4.	<b>Carriageway Cross Slope</b>		
	Main Carriageway	-2%	-2%
	Inner Shoulder	-2%	-2%
	Outer Shoulder	-4%	-4%
5.	<b>Horizontal Alignment</b>		
	Minimum Radius	756 m	123 m
	Minimum Radius with no super elevation	4770 m	1440 m
	Absolute minimum curve radius at turnings/ channelizing islands	-	22m
	Maximum super elevation	6%	6%

	Minimum stopping sight distance	250 m	85 m
	Acceleration length to entrance	350 m	150 m
	Deceleration length to exit	200 m	110m
6.	<b>Vertical Alignment</b>		
	Maximum Gradient	3%	3%
	Minimum Gradient	0.3%	0.3%
	“K” Value for Crest vertical curve	95	11
	“K” Value for Sag vertical curve	63	18
7.	<b>Pavement Lane Marking</b>		
	White Line	Between two lanes	
	Yellow Line	Roadway Edge/ Shoulder, Chevron	Roadway Edge/ Shoulder, Chevron
	Studs (White, yellow and green)	As Required	As Required
8.	<b>Vertical Clearance</b>		
	Roadway	5.3 m	
	Flyover/Overpass	5.3m	
	Railway	6.1 m	
	Subway	5.3 m	
	Cattle Creep/ Pedestrian	3.0 m	
9.	<b>Design Life</b>		
	Road pavement	10 Years	
	Bridges	100 Years	
	Electric & Electronic systems	25 years	
	Buildings	50 Years	
	Culverts	25 Years return period	
10.	<b>Structures loading</b>		
	Bridges	Class AA /70 Ton Tank as per West Pakistan Code of Pakistan for Highway Bridges	

	Culverts	1966 or Class A	
	<b>Structure System</b>	Class A / AA	
	Deck Slab		
	Girders	R.C.C	
	Median	Pre stressed	
		NJB/ Curb Type	

## 6.6. CODES AND STANDARDS

The codes and standards applicable for the design of the Project Facilities are given in the **(Detailed Project Report)** and listed below as a ready reference:

### **Geometrics:**

AASHTO 2018 publication 'A Policy on the Geometric Design of Highway and Streets'

### **Pavements:**

AASHTO Guide for Design of Pavement Structures, 1993

### **Road Signs:**

Manual of Uniform Traffic Control Devices for Streets and Highways by FHWA – 2003

### **Structures:**

BCP (2007)

Building Code of Pakistan

WPCPHB (1967)

West Pakistan Code of Practice for Highway Bridges

AASHTO (2017)

AASHTO LRFD Bridge Design Specification. American Association of State Highway and Transportation Officials.

(For the design of all structural members ASD combination for the calculating length of pile.)

ACI 318-08

Building Code Requirements for Reinforced Concrete - American Concrete Institute

ACI 301-02

Specifications for Structural Concrete - American Concrete Institute

ASTM A-615

-

Specifications for Deformed and Plain Billet Steel Bars for Concrete Reinforcement

		American Society of Testing Materials
ASTM C-150	-	Specifications for Portland Cement
ACI-350 R	-	Environmental Engineering Concrete Structures
ASTM C-33	-	Specifications for Concrete Aggregate
UBC 1997	-	Uniform Building Code of USA
ASTM C270		Standard Specification for Mortar for Unit Masonry

**Drainage:**

Water and Sanitation Agency (WASA), Design Criteria

**Electrical:**

CIBSE & CIE Standards

Road side design pertains to the design of area between the outside shoulder edge and ROW limits. It involves safe design of features like embankment slopes, cut slopes, road side clearances, road side drainage slopes, design of road signs, and luminaire with breakaway supports, road side barriers and bridge railings etc.

As per latest published version of "AASHTO Roadside Design Guide"

Design of road user facilitation requirements

Provision of Breakdown and accident response system. Provision of vehicle fitness checking system on applicable International standards. Provision of solar fog lighting system. Emergency call service along the Motorway. Fully automated 24/7 (Electronic toll collection system) Toll plazas. The automated vehicle detection system using video technology, automatic license plate reader using high resolutions high speed cameras. Weigh-in-Motion (WIM) station at every interchange. Lighting of Interchanges, major bridges, and critical areas, i.e. Toll plazas, weigh station and vicinity of Interchanges 5km either side or 10km at terminal points.

Any items of building works not covered by the project specifications shall conform to Punjab Building Department Specifications for Class 1 Building Works. For this purpose, building works shall be deemed to include ancillary facilities, landscape elements and/or any other works incidental to the building works.

# **CHAPTER 7**

## **PAVEMENT DESIGN REPORT**

## **7. PAVEMENT DESIGN REPORT**

This chapter of Design Report pertains to Pavement design of the Project.

### **7.1. PAVEMENT DESIGN ACTIVITIES**

Pavement design depends upon two basic parameters i.e. traffic and soil strength. The pavement design of RRR has been carried using AASHTO Guide for Design of Pavement Structures (1993). The AASHTO procedure uses Serviceability Indices, environment, drainage and reliability, Structural Numbers, layer thicknesses.

### **7.2. TRAFFIC STUDIES**

Traffic studies are intended to provide necessary input data for determination of the magnitude and pattern of the traffic load on the subject road through the design period. This entails collection, verification and analysis of the traffic data. From the collected data, the projected traffic for the design life of the subject project is determined. For details, refer Traffic Study Report.

### **7.3. DESIGN LIFE**

Design life is the number of years reckoned from the completion of pavement construction and application of traffic load until the time when major maintenance is required so that it can continue to carry traffic satisfactorily for further period.

For flexible pavement Design, a design period of **10** years has been adopted, taking base year as 2023 to calculate the traffic load and eventually carrying out pavement design. However, the ESALs have been calculated for 25 years from base year to work out the thickness requirement of unbound layers, in order to provide a foundation that can sustain 25 years structural life. For asphalt layers, stage construction is opted; the asphalt requirement for ten years design life is ascertained and shall be placed so that the pavement can perform satisfactorily for 10 years subject to adopting quality control measures during execution of the project.

For Rigid Pavement Design, A design period of **25** years has been taken. Therefore, ESALs have been evaluated for 25 years taking base year as 2023.

### **7.4. EQUIVALENT SINGLE AXLE LOAD**

In order to determine the cumulative axle load damage that a pavement will sustain during its design life, it is necessary to express the total number of heavy vehicles that will use the project road during the design period, in terms of the cumulative number of Equivalent Single Axle Load (ESALs).

#### **7.4.1. Equivalent Axle Load Factors**

The damage caused by vehicles to a road depends on the axle loads and wheel configuration of the vehicles. It is, therefore, important to determine the axle loads of heavy commercial vehicles in the projected traffic mix that is likely to use project road in future.

For pavement design purposes the damaging power of axles is related to a single axle of 8.16 tones (18000 lbs) using equivalence factors which have been derived from empirical studies.

Equivalent Axle Load Factors (EALF) are determined separately, for different types of axle configurations. The EALF obtained by NTRC Survey 1995 have been adopted.

#### **7.4.2. Calculation of Cumulative Equivalent Single Axle Loads (ESALs)**

In order to determine the cumulative ESALs over the design period the following procedure has been adopted:

- 1- AADT has been determined.
- 2- Direction Factor value is selected.
- 3- Annual traffic in design lane is determined.
- 4- Equivalent Axle Load Factors (EALF), for each class of vehicle i.e. Loaded and Empty has been used based on NTRC Axle Load Study (1995).
- 5- Equivalent Single Axle Load (ESALs) has been estimated for the entire design life.

#### **7.4.3. Total ESALs for the Design Life**

The pavement design procedure is based on the cumulative number of expected Equivalent Single Axle Loads during the design period. The projected Cumulative ESALs (loaded + empty) for the project have been computed over the design life of the project and mentioned in the Annexure.

#### **7.5. DESIGN CBR**

The pavement design is based on minimum soaked CBR 8% @ 95% M.D.D for Subgrade, as shown in typical cross sections attached in geometric design report and drawings.

#### **7.6. PAVEMENT DESIGN**

The pavement design process is the technique of developing a combination of top layers of different materials in most economical manner to cater for the total axle load over the design life of the pavement. In other words this is an art through which the stresses as induced in the top layers of a road due to movement of heavy wheel load are disseminated

and minimized to safe level through selection of different type and appropriate thickness of pavement layers.

The AASHTO Guide for Design of Pavement Structure 1993 has been used to compute the pavement thicknesses.

### **7.6.1. AASHTO Procedure for Flexible Pavement Design**

The AASHTO Guide for design Pavement Structures 1993 outlines this procedure for determination of flexible pavement thickness by solving AASHTO equations manually, by using different nomo-graphs or by using the computer software. For accuracy the computer program is preferred. Basically, the Structure Number (SN) required to be assigned to the proposed pavement structure for a given set of conditions is determined by solving the following numerical equation.

The required variable data to be substituted into this equation is:

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}[\Delta PSI/4.2-1.5]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$

- i. The estimated future traffic in terms of ESAL, for the design period,  $W_{18}$
- ii. The Reliability Level,  $R$
- iii. Standard Normal Deviate Value,  $Z_R$
- iv. The overall Standard Deviation,  $S_o$
- v. The roadbed soil Resilient Modulus,  $M_R$
- vi. The design serviceability loss,  $\Delta PSI = P_o - P_t$

The above General Design Variables have been discussed in the following paragraphs.

#### **7.6.1.1. Reliability (R)**

Design reliability refers to the degree of certainty that a given design alternative will last for the entire design period. A design reliability level of 90% has been adopted for pavement design of the project road.

#### **7.6.1.2. Standard Normal Deviation ( $Z_R$ )**

The standard normal deviation value of -1.282 corresponding to reliability (R) of 90% has been adopted in the design and is based on the recommended values of standard normal deviation ( $Z_R$ ) by AASHTO Guide 1993.

#### **7.6.1.3. Standard Deviation ( $S_o$ )**

The reliability factor is a function of the overall standard deviation that accounts for standard variation in materials and construction, the probable variation in the traffic prediction and the

normal variation in pavement performance for a given design traffic application. The recommended value of standard deviation for total variation in material properties and in traffic estimation for flexible pavement is 0.45 and has been adopted for pavement design.

#### **7.6.1.4. Performance Criteria**

The serviceability of a pavement is defined as its ability to serve the type of traffic that uses the facility. Initial and terminal serviceability indices have been established to compute the total change in serviceability that will be used in the design equations.

##### **A. Initial Serviceability Index ( $P_o$ )**

The initial serviceability index is a function of pavement design and construction quality. For flexible pavement design the typical value, as recommended by AASHTO Road Test, is 4.2 which has been adopted.

##### **B. Terminal Serviceability Index ( $P_t$ )**

The terminal serviceability index is the lowest index that will be tolerated before rehabilitation, resurfacing or reconstruction, becomes necessary and it generally varies with the importance or functional classification of the pavement. Recommended value of terminal serviceability index is 2.5.

#### **7.6.1.5. Resilient Modulus $M_R$**

The basis for material characterization in the AASHTO Guide 1993 is Elastic or Resilient Modulus (MR). The following correlation between CBR and MR has been used to determine resilient modulus of unbound layers, refer NCHRP (National Cooperative Highway Research Programme) and MEPDG (Mechanistic Empirical Pavement Design Guide);

$$M_R = 2555 (\text{CBR})^{0.64}$$

Where;

CBR = California Bearing Ratio in percentage.

$M_R$  = Resilient modulus in psi

#### **7.6.1.6. Computation of Required Pavement Thickness**

The structure number (SN) requirement as determined through adopting the design parameters as discussed above is balanced by providing adequate pavement structure. Under AASHTO design procedure the following equation provides the means for converting the structural number into actual thicknesses of surfacing, base and sub base materials:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

Where:

$a_1, a_2, a_3$  = layer coefficients representative of surface, base and sub base courses respectively

$D_1, D_2, D_3$  = actual thicknesses (in inches) of surface, base and sub base courses respectively

$m_2, m_3$  = drainage coefficients for base and sub base layers respectively

### 7.6.1.7. Layer Coefficients

In order to transform the structural number of different pavement layers into respected pavement layer thicknesses, following layer coefficients have been adopted (Refer Figure 2.5 ~ 2.7 of AASHTO Guide for Design of Pavement Structure).

Asphaltic Wearing Course, $a_1$	=	0.42 / inch (0.165/cm)
Asphaltic Base Course, $a_1$	=	0.42/ inch (0.165/cm)
Aggregate Base Course, $a_2$	=	0.13 / inch (0.051/cm)
Granular Sub base, $a_3$	=	0.12 / inch (0.047/cm)

### 7.6.2. AASHTO Procedure for Rigid Pavement Design

The AASHTO Guide for design of Pavement structures 1993 outlines this procedure for determination of rigid pavement thickness by solving AASHTO equations manually, by using different Nomo graphs or by using the computer software. For accuracy the computer program is preferred. In all options basically the Slab thickness (D) of the proposed pavement structure for a given set of conditions is determined by solving the following numerical equation

The required variable data to be substituted into this equation is:

$$\log_{10} W_{18} = Z_R \cdot S_o + 7.35 \cdot \log_{10}(D + 1) - 0.06 + \frac{\log_{10}[\Delta\text{PSI}/(4.5-1.5)]}{1 + \frac{1.624 \cdot 10^7}{(D+1)^{8.46}}} +$$

$$(4.22 - 0.32pt) * \log_{10} \left[ \frac{S'_c * C_d (D^{0.75} - 1.132)}{215.63 * J \left[ D^{0.75} - \frac{18.42}{\left(\frac{E_c}{k}\right)^{0.25}} \right]} \right]$$

- i. The estimated future traffic in term of ESAL, for the design period,  $W_{18}$
- ii. The Reliability Level, R
- iii. Standard Normal Deviate Value,  $Z_R$
- iv. The overall Standard Deviation,  $S_o$
- v. Concrete Elastic Modulus,  $E_c$

- vi. The design serviceability loss,  $\Delta PSI = P_o - P_t$
- vii. Concrete modulus of rupture,  $S'_c$
- viii. Load transfer coefficient,  $J$
- ix. Drainage coefficient,  $C_d$
- x. Modulus of Subgrade Reaction,  $k$

The above General Design Variables have been discussed in the following paragraphs.

#### **7.6.2.1. Reliability (R)**

Design reliability refers to the degree of certainty that a given design alternative will last for the entire design period. A design reliability level of 90% has been adopted for pavement design.

#### **7.6.2.2. Standard Deviation (So)**

The reliability factor is a function of the overall standard deviation that accounts for standard variation in materials and construction, the probable variation in the traffic prediction and the normal variation in pavement performance for a given design traffic application. The recommended value of standard deviation for total variation in material properties and in traffic estimation for rigid pavement is 0.35 and has been adopted for design of the rigid pavement.

#### **7.6.2.3. Standard Normal Deviation (Z<sub>R</sub>)**

The value corresponding to reliability (R) of 90% is -1.282 which has been adopted in the design based on the recommended values of standard normal deviation ( $Z_R$ ) by AASHTO Guide for design of pavement structures 1993.

#### **7.6.2.4. Performance Criteria**

The serviceability of a pavement is defined as its ability to serve the type of traffic that uses the facility. Initial and terminal serviceability indices have been established to compute the total change in serviceability that will be used in the design equations.

##### **A. Initial Serviceability Index (P<sub>o</sub>)**

The initial serviceability index is a function of pavement design and construction quality. For rigid pavement design typical value, as recommended by AASHTO Road Test, is 4.5 which has been adopted.

##### **B. Terminal Serviceability Index (P<sub>t</sub>)**

The terminal serviceability index is the lowest index that will be tolerated before rehabilitation, resurfacing or reconstruction, becomes necessary and it generally varies with

the importance or functional classification of the pavement. Recommended value of terminal serviceability index is 2.5 for the Rigid Pavement.

#### **7.6.2.5. Concrete Elastic Modulus ( $E_c$ )**

The basis for material characterization in the AASHTO Guide 1993 is Elastic Modulus ( $E_c$ ). Elastic Modulus of 3.6 MPa is used for the design of the rigid pavement. The following correlation between  $f'_c$  and  $E_c$  is recommended by American Concrete Institute (ACI):

$$E_c = 57000 \sqrt{f'_c}$$

Where;

$f'_c$  = 4000 psi at 28 days cylindrical concrete compression strength in psi

$E_c$  = Concrete Elastic Modulus in psi

#### **7.6.2.6. Modulus of Rupture**

The modulus of rupture required by the design procedure is the mean value determined after 28 days, using third-point loading (AASHTO T 97, ASTM C 78), calculated from the following correlation:

$$S'_c = 7.5 \sqrt{f'_c}$$

$f'_c$  = 4000 psi at 28 days cylindrical concrete compression strength in psi

$S_c$  = Concrete Modulus of Rupture in psi

#### **7.6.2.7. Load Transfer Co-efficient (J)**

The load transfer co-efficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer load across discontinuities, such as joints or cracks. The value of J recommended for a Jointed Plain Concrete Pavement (JPCP) or Jointed Reinforced Concrete Pavement (JRCP) with some type of load transfer device (such as dowel bars) at the joints is 3.2.

#### **7.6.2.8. Drainage Co-efficient ( $C_d$ )**

The treatment for the expected level of drainage for a rigid pavement is through the use of drainage coefficient,  $C_d$ , in the performance equation. (It has an effect similar to that of the load transfer coefficient, J). For good quality of drainage and up to 25% moisture level approaching saturation, the value of 1.00 is used for  $C_d$ .

#### **7.6.2.9. Effective Modulus of Subgrade Reaction (k)**

An effective modulus of subgrade reaction has been developed for rigid pavement. Since k is directly proportional to soil resilient modulus, the season length and season moduli have been used as input to estimate effective design k.

### **7.6.3. DESIGN THICKNESS**

#### **7.6.3.1. FLEXIBLE PAVEMENT:**

The minimum pavement thicknesses thus worked out, exploiting AASHTO approach for pavement design of the subject roads are as under subject to enforcement of Axle Load restrictions (refer Typical Cross-Sections for details):

#### **Main Carriageway**

##### **Pavement Section-I: N-5 near Radio Pakistan to DI Hakla & M-1 to N-5 Sangjani**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	180 mm
Base Course	300 mm
Granular Sub base	250 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

##### **Pavement Section-II: DI Hakla to M-1**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	190 mm
Base Course	300 mm
Granular Sub base	250 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

#### **Loops and Ramps**

##### **1. N-5 near Radio Pakistan Interchange and N-5 Sangjani Interchange**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	160 mm
Base Course	300 mm
Granular Sub base	200 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

##### **2. Murat Interchange**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	120 mm
Base Course	250 mm
Granular Sub base	200 mm

Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.

### **3. DI Hakla Interchange**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	150 mm
Base Course	300 mm
Granular Sub base	200 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

### **4. Toll Plaza near M-1 Motorway**

Asphalt Concrete Wearing Course	50 mm
Asphalt Concrete Base Course	130 mm
Base Course	250 mm
Granular Sub base	200 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

#### **7.6.3.2. RIGID PAVEMENT:**

The minimum pavement thicknesses thus worked out, using AASHTO approach for pavement design of the subject roads are as under subject to enforcement of Axle Load restrictions (refer X sections for details):

#### **Main Carriageway**

##### **Pavement Section-I: N-5 near Radio Pakistan to DI Hakla & M-1 to N-5 Sangjani**

Jointed Reinforced Concrete Pavement	490 mm
Lean Concrete	100 mm
Sub base Course	200 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

##### **Pavement Section-II: DI Hakla to M-1**

Jointed Reinforced Concrete Pavement	510 mm
Lean Concrete	100 mm
Sub base Course	200 mm
Subgrade shall have a minimum soaked CBR of 8 % @ 95% M.D.D.	

However, as directed the outer lane of main carriageway will be rigid.

# **CHAPTER 8**

## **HYDROLOGY REPORT**

## **8. HYDROLOGICAL & HYDRAULIC REPORT**

### **8.1. HYDROLOGICAL REPORT:**

#### **8.1.1. General:**

##### **8.1.1.1. Scope of Hydrological Studies:**

As per TORs, The scope of hydrological studies includes, review of previous studies, identification of the rivers, streams and Nullahs crossing the proposed road alignment and estimation of the design discharge against 25, 50 and 100 year return period. The report also includes the estimation procedure adopted for design flood discharges.

##### **8.1.1.2. Route Alignment and Water Channel Crossings the Proposed Alignment:**

The proposed Rawalpindi Ring Road (RRR) is a three-lane road with controlled access. The terrain along proposed RRR is plain and rolling. Agriculture land is found on both sides on flat area of the proposed road. The proposed alignment crosses a number of small and larger natural stream and rivers. The main natural streams are Soan River and Sill River. Soan River is a tributary of Indus River, carrying flood water from upland areas of Murree, Kahuta and Lei Nullah and falls into Indus River near Kalabagh. Sill River is a right bank tributary of Soan River. It collects flood water of Tarnol, Phamra and adjoining areas. These rivers /streams become flashy in monsoon/rainy season and sometimes flood water spills come out of the banks of the channels. The cross-drainage structures have been proposed on all crossing points of RRR to pass the flood. The proposed RRR alignment has been shown in Figure 8.1.

#### **8.1.2. Back Ground:**

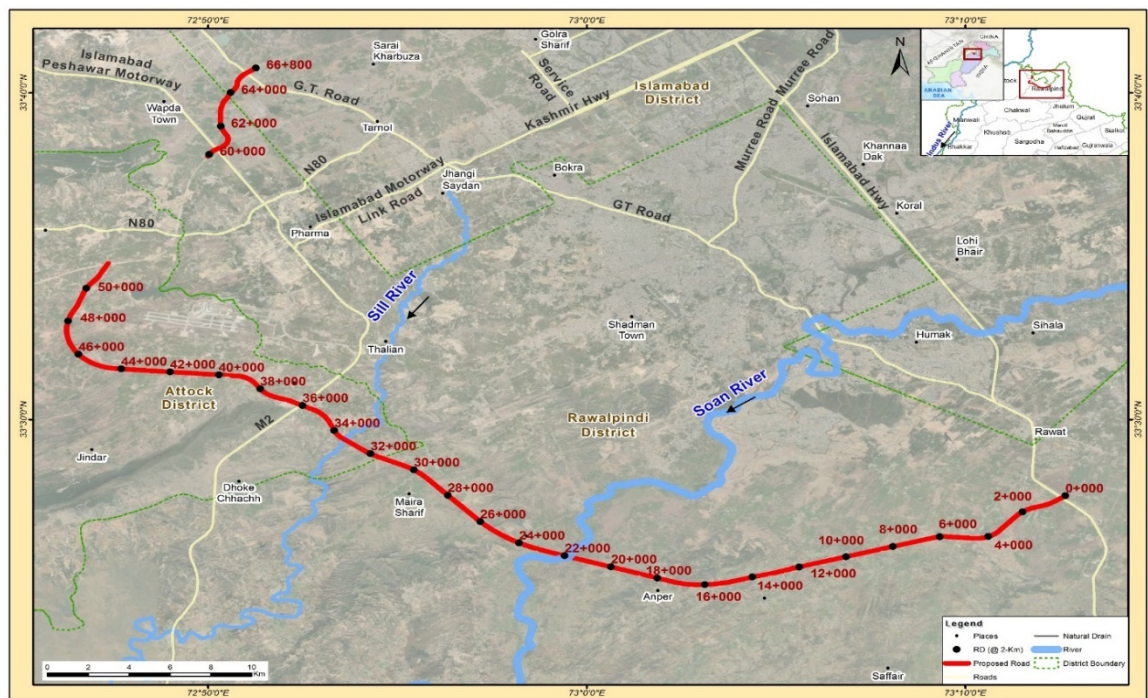
The scope of hydrological studies included the estimation of design discharges for 50-year and 100-year return periods at cross-drainage locations.

The design discharge of Soan River was estimated as 194,227 ft<sup>3</sup>/s (5,500 m<sup>3</sup>/s) using the proportionate to catchment area method. The flood frequency analysis was carried out at two locations i.e., at Rawalpindi (upstream) and at Makhad (downstream) gauges.

For ungauged catchments, discharges were estimated by rainfall-runoff analysis. Rational formula and SCS synthetic unit hydrograph method was used keeping in view the catchment areas. The design rainfalls were estimated as 210 mm, 245 mm and 275 mm for 25, 50 & 100-year return periods respectively.

The design parameters, catchment areas and discharge estimates has been reviewed critically. The observations are following:

1. Minimum eighty four (84) cross-drainage locations have been identified by the present study.
2. The catchment areas at various cross-drainage structures have also been checked using Digital Elevation Model (DEM) of Shuttle Radar Topographic Mission (SRTM) data and found differences; details have been provided in subsequent sections of the report. The major difference has been observed at Soan River where reported catchment at crossing is 3,675 km<sup>2</sup> instead of 2,052 km<sup>2</sup>, estimated in the present study; thereby overestimating the design discharge for Soan River.
3. Re-estimation of design discharges at cross-drainage structures is required, estimated by the Consultants.



**Figure-8.1. Project Area Map and Proposed Road Alignment**

### 8.1.3. Hydrological Analysis:

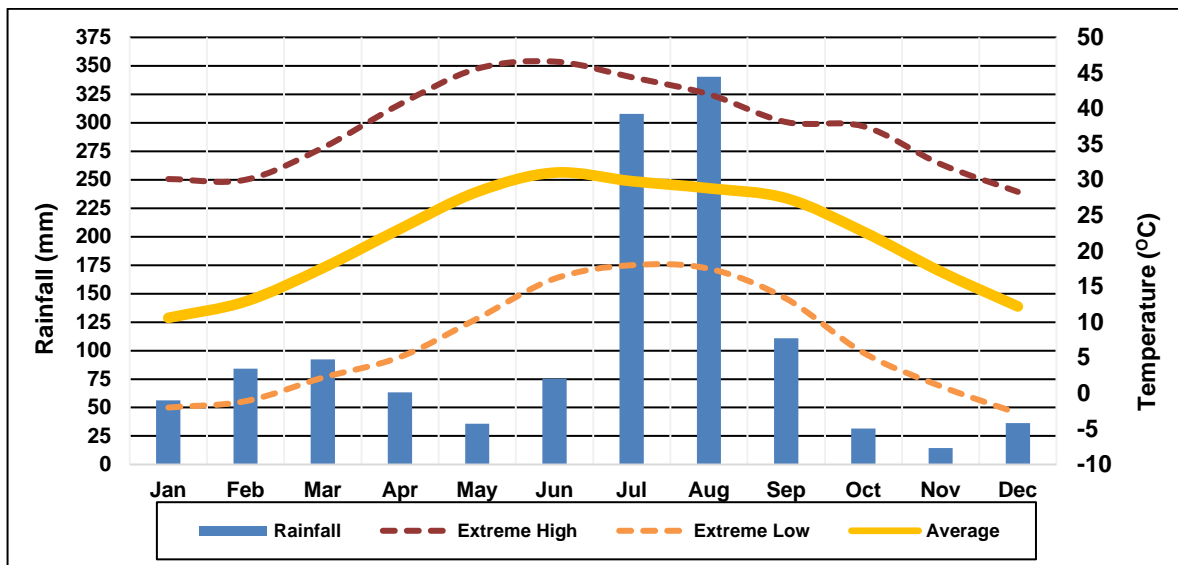
Hydrological studies have been carried out pertaining to the estimation of the discharges of the streams crossing the proposed RRR alignment.

#### 8.1.3.1. Climate of Rawalpindi:

Climate of Rawalpindi is humid subtropical. The summer season is long and hot and winter season is mild and wet. Rawalpindi experiences thunderstorms rain during Monsoon period (July to September). Islamabad Airport (previously called Chaklala Airport) rain gauging station is the nearest gauging station in the vicinity of the project area. This gauging station is maintained by Pakistan Meteorological Department (PMD).

The station provides a fair representative estimate for the climate parameters of the project site. Over the entire year, the temperature varies from 3°C to 38°C and rarely goes down to -2°C or above 46°C in winter and summer, respectively. The hot season usually lasts for 4 months, May to August, with an average daily high temperature remains above 36°C. June is the hottest month of the year. The cool season lasts for 3 months, from start of December to end of February, with an average daily high temperature below 19°C. January is the coldest month of the year. The maximum temperature 46.6 °C was recorded on June 23, 2005 and minimum -2 °C was recorded on January 21, 2008.

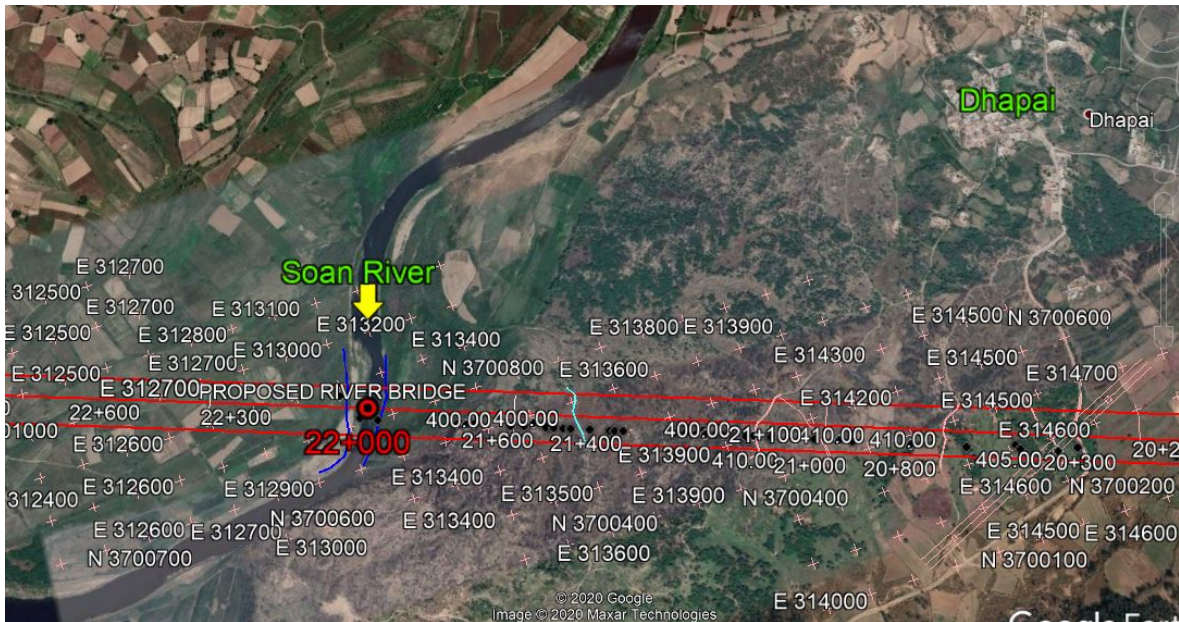
The average annual rainfall is 1,247 mm and maximum amount of rainfall is observed during the monsoon period. August is the month of heaviest rainfall with average rainfall 340 mm while the month of November receives the minimum rainfall in the year with an average rainfall of 14.4 mm. Almost 60% of the rainfall occurs during monsoon season (July – September). In order to carry out the hydrological studies, Islamabad Airport rain gauge station data has been used as it is the nearest gauging station Temperature and rainfall trends at Islamabad Airport gauging station are presented in Figure-8.2.



**Figure-8.2. Temperature and Rainfall Trends at Islamabad**

### 8.1.3.2. General Topography of the Area:

The proposed alignment falls in the Pothohar range. Geographically, the area mainly consists of hills, plateaus and dissected plains. The general topography of the area is undulated and somewhat mild around the ridge lines. The deskwork observations have also been validated using strip survey details and data. The sample cross verification of the digital data and strip survey is shown in Figure-8.3.



**Figure 8.3: Strip Survey and Data Acquisition checking on Soan River at RD 22+000 near Dhapai village**

### 8.1.3.3. Hydro-Meteorological Data Used:

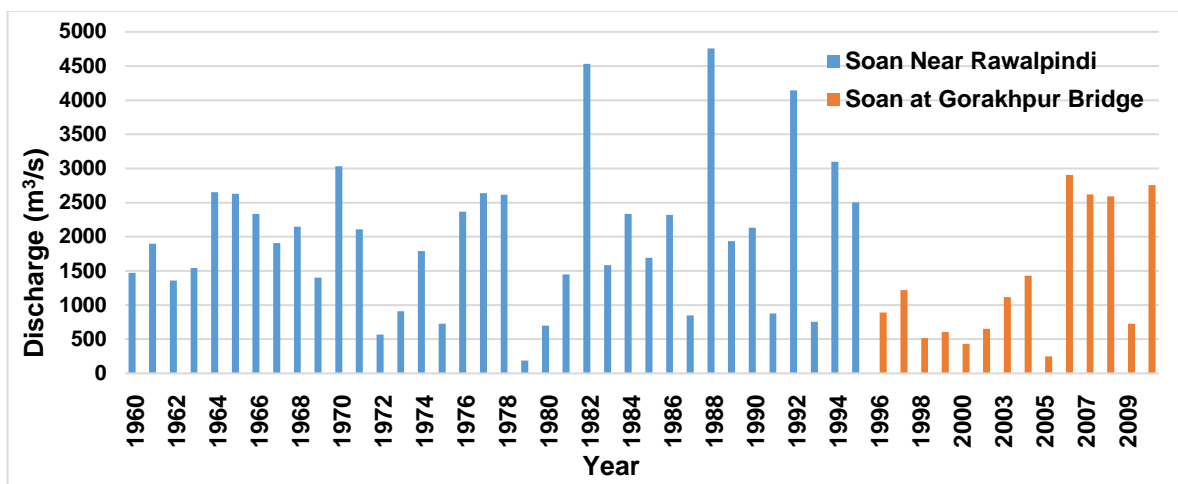
Hydro-meteorological data (Rainfall and Discharge) has been collected for the estimation of design discharges at the cross-drainage points along the proposed road alignment. For the gauged streams, design discharge has been estimated by flood frequency analyses of instantaneous annual peak discharges while for the ungauged streams, design discharge has been estimated using rainfall-runoff analyses. The inventory of stations, collected period of record and location of stations is given in Table-1.

Soan River is the only gauged stream crossing the proposed road. Soan River is gauged at various locations by Surface Water Hydrology (SWH) of WAPDA. The instantaneous annual peak discharges of at Rawalpindi and Gorakhpur bridges are shown Figure-8.4.

**Table-1: Inventory of the Collected Data**

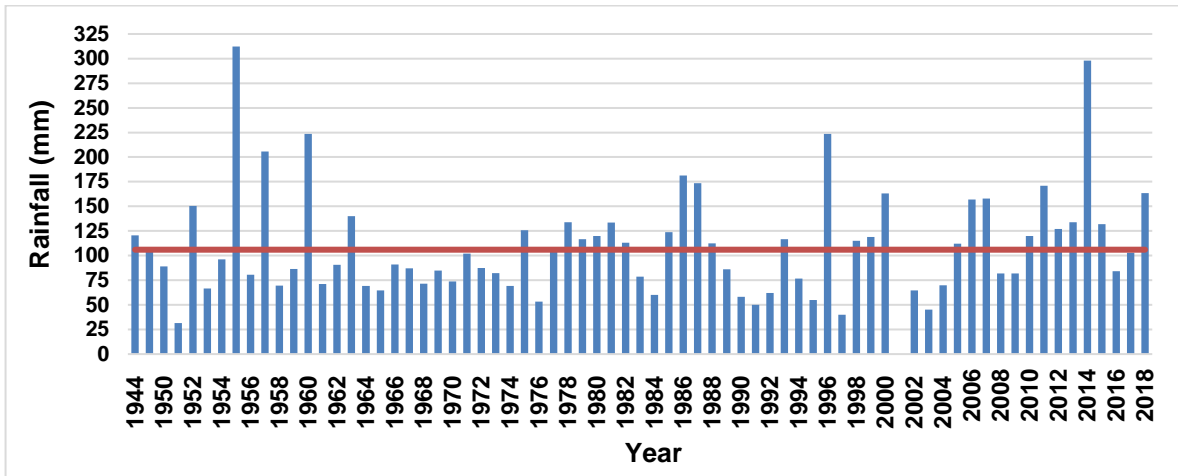
Sr No	Station Name	Latitude	Longitude	Period of Record	Years of Record	Type of Data	Operating Agency
<b>Stream Gauging Stations</b>							

1	Soan River near Rawalpindi	33° 33' 05"	73° 06' 05"	1960-1995	36	Instantaneous peak discharges	SWH
2	Soan River at Gorakhpur Bridge	33° 28' 6.71"	73° 1' 49.79"	1996-2010	14	Instantaneous peak discharges	SWH
<b>Rainfall Station</b>							
1	Islamabad	33° 37'	73° 06'	1944, 1948, 1950-2000, 2002-2018	70	One-Day annual Max. rainfall	PMD



**Figure 8.4: Instantaneous Peak Discharges of Soan River**

For all other cross-drainage points, one-day annual maximum rainfall data (1970 to 2018) of Islamabad Airport has been used for the estimation of design flood discharges. The rainfall data has been collected from Pakistan Meteorological Department (PMD). Perusal of the historic data shows that the maximum one-day rainfall of 312 mm was witnessed in 1955 while average annual one-day rainfall is 106 mm. Figure-8.5 shows the trends of annual maximum rainfalls observed at Islamabad Airport gauging station.



**Figure 8.5: 1-Day Annual Maximum Rainfalls at Islamabad**

#### **8.1.3.4. Catchment Parameters:**

A number of natural streams/Nullahs cross the existing road alignment. The catchment characteristics of the streams crossing the road have been determined using Digital Elevation Models (DEM) of Shuttle Radar Topography Mission (SRTM) having grid size of 30m x 30m, processed in ArcGIS. The same DEM has also been used for delineating catchment areas.

The catchment characteristics that have been investigated through the satellite imagery included catchment area, percent impervious, roughness coefficient, hydrologic conditions of area, soil cover, land use and treatments, soil type and extents. The slope and length of the streams have been determined by using (DEM). Map showing delineated catchment areas is provided in Figure-8.7.

#### **8.1.3.5. Estimation of Design Flood:**

Two methods have been utilized to estimate the flood for streams crossings the road alignment i.e., estimation of design discharges by flood frequency analysis and by rainfall-runoff analyses.

#### **A. Flood Frequency Analysis:**

Soan River is gauged, so the design discharges for Soan River have been estimated by flood frequency analyses of the instantaneous peak discharges. The catchment area of Soan River at proposed road crossing has been estimated as 2,052 km<sup>2</sup>. The River is gauged at upstream at Gorakhpur Bridge and near Rawalpindi having catchment areas 1,849 km<sup>2</sup> and 1,520 km<sup>2</sup>, respectively. The annual instantaneous peak discharges of both the stations have been transferred to the bridge site using Dicken's formula. The Dicken's formula is given below:

$$Q = CA^{3/4} \text{-----Equation 1}$$

Where;

Q = Discharge (m<sup>3</sup>/s)

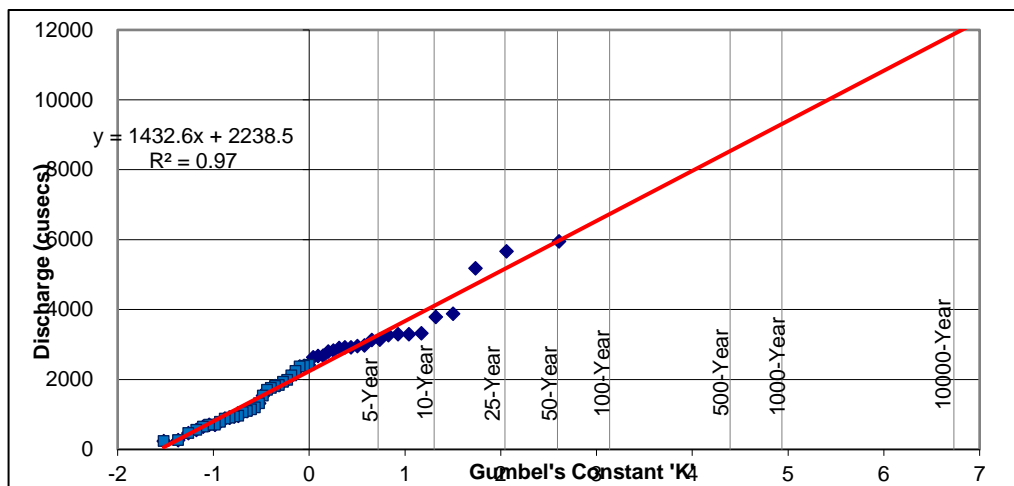
C = Constant

A = Catchment Area

The gauged data, transferred data and calculations of 'C' value for each value is given in Annex-1 of Annexure A. The transferred annual series further used in flood frequency analyses Gumbel's extreme value Type-I frequency distribution using Weibull's formula plotting position has been used. Results of the frequency analysis are given in Table 2 and regression line is presented in Figure-8.6.

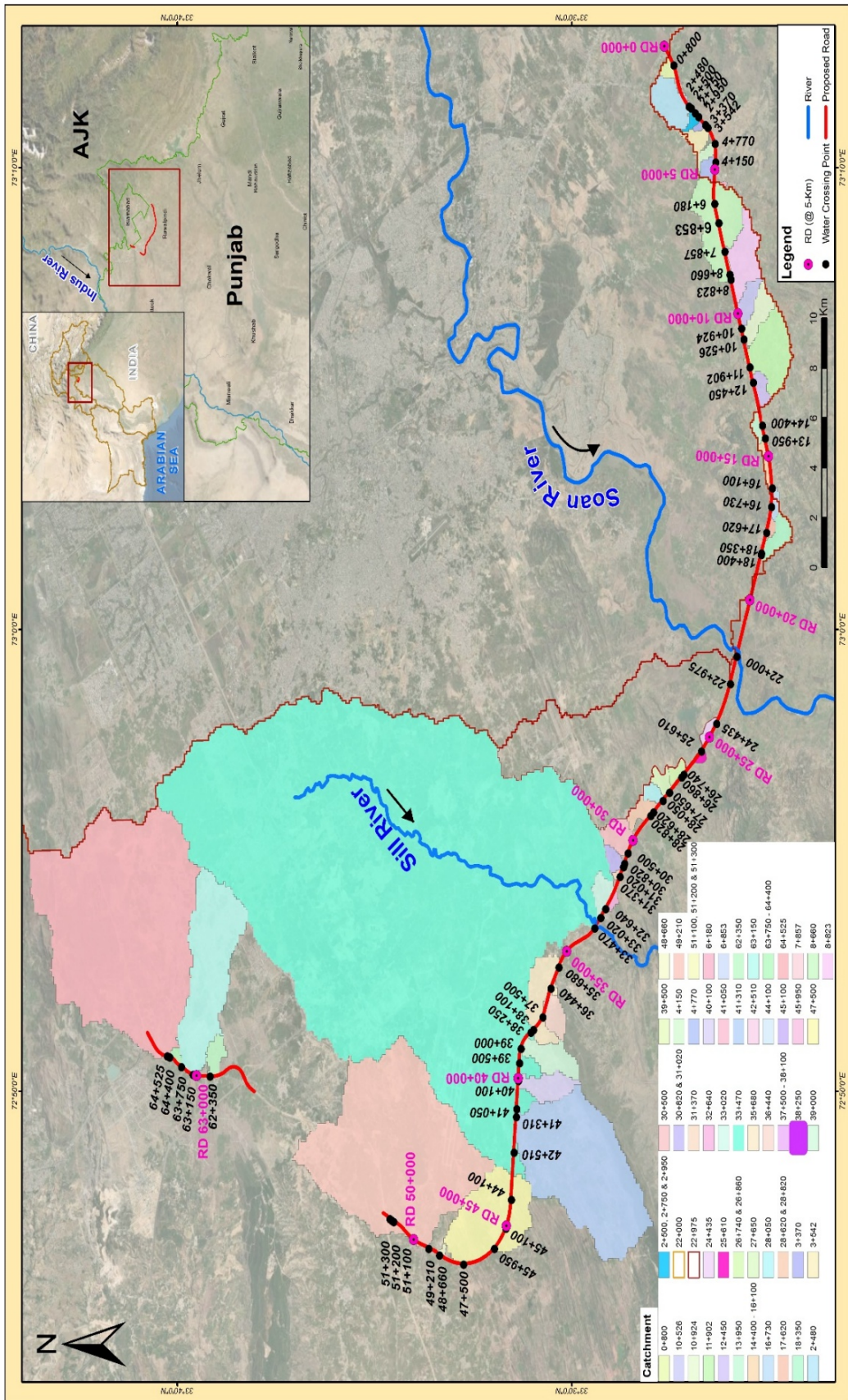
**Table 2: Results of Flood Frequency Analyses**

Return Period (year)	Design Discharges at Proposed Bridge Site (m <sup>3</sup> /s)	Design Discharges at Proposed Bridge Site (ft <sup>3</sup> /s)
2.33	2240	79,100
5	3269	115,450
10	4107	145,050
25	5167	182,450
50	5952	210,190
100	6731	237,700
500	8534	301,380



**Figure 8.6: Flood Frequency Analysis of Soan River at Bridge site**

Figure-8.7. Delineated Catchment area Map

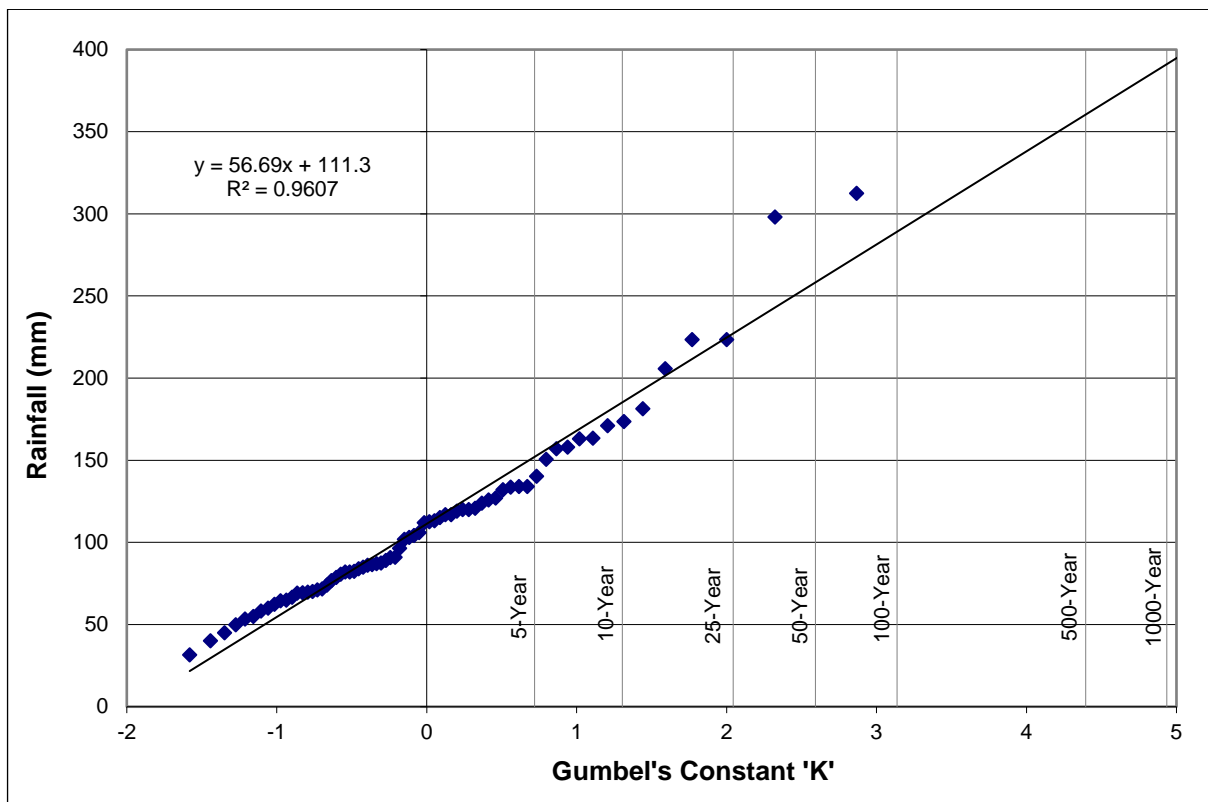


**B. Rainfall Frequency Analysis:**

Rainfall frequency analysis for 1-day annual maximum rainfall data of Islamabad Airport station has been carried out. Gumbel's extreme value Type-I frequency distribution using Weibull's formula plotting position has been used. Results of the frequency analysis are given in Table- 3 and regression line is presented in Figure-8.8.

**Table 3: Rainfall Depth against Various Return Periods**

Return Period (years)	Rainfall Depth (mm)	Rainfall Depth (in)
2.33	111	4.37
5	152	5.98
10	185	7.28
25	227	8.94
50	258	10.16
100	289	11.38



**Figure 8.8: Frequency fitting of 1-day Annual Maxima of Islamabad**

### **C. Flood Hydrograph Method:**

For the catchment areas greater than 1km<sup>2</sup>, the US Soil Conservation Services Unit Hydrograph Method (SCS-UH) has been used to estimate peak discharges. This method requires the following information about the catchment.

- Maximum 24-hour rainfall for the design return period
- Length of stream measured along the longest path travelled by storm water from head to the site
- Slope of stream from head to site
- Catchment area
- Antecedent soil moisture condition
- Soil group

### **Estimation of Curve Number (CN)**

The US-NRCS procedure consists of selecting a storm and computing the direct runoff by the use of curves founded on field studies of the amount of measured runoff from numerous soil cover combinations. The land use of the area has been visualized from the images of Google Earth and SOP maps.

US-NRCS divides soil types into four major hydrologic soil groups denoted by the letters “A” through “D”. “A” soils are those which have high infiltration capacity and subsequently low runoff rates. “D” soils are those with very low infiltration capacity and very high runoff rates.

Antecedent moisture conditions (AMC) at occurrence of design storm have significant effect over runoff magnitudes. For major rainfall events, the AMC-III condition is the critical soil moisture condition. According to (United States Soil Conservation Services) USSCS, if five days antecedent rainfall is less than 36 mm during growing season, then it is Antecedent Moisture Condition (AMC)-I condition, if it is greater than 53 mm, then it is called AMC-III condition, otherwise it is AMC-II condition. The AMC-III condition is most critical soil moisture condition and selected for the runoff estimation due to design rainfall. The curve no at AMC-II has been estimated as 70 and corresponding curve number for AMC-I and AMC-III are 51 and 85 respectively.

#### **D. Rational Method:**

For the catchments having area less than 1 km<sup>2</sup> rational method has been used to compute the floods. Rational method technique is described under:

$$Q = CIA$$

Where,

Q = Peak Discharge (Cusecs)

C= coefficient of discharge

I = Intensity of Rainfall (Inches/hour)

A = Catchment Area (Acres)

#### **i) Time of Concentration**

Time of concentration (T<sub>c</sub>) is the time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet. Kirpich formula has been used for computation of time of concentration which is given in equation 2.

$$T_c = \frac{L^{1.15}}{7700X(H)^{0.385}} \text{-----Equation 2}$$

Where

T<sub>c</sub> = Time of Concentration (hours)

L = Length of the longest stream (ft)

H = Fall in length L (ft)

#### **ii) Estimation of Runoff Coefficient (C)**

The runoff coefficient “C” is required for the estimation design discharges with rational formula. The ‘C’ coefficient for the project area has been estimated as 0.55.

#### **iii) Rainfall Intensity**

Rainfall intensity is defined as the ratio of the total amount of rain (rainfall depth) falling during a given period to the duration of the period It is expressed in depth units per unit time, usually as mm/hour or inch/hour. Intensity-Duration-frequency curve is given in Figure 8.9.

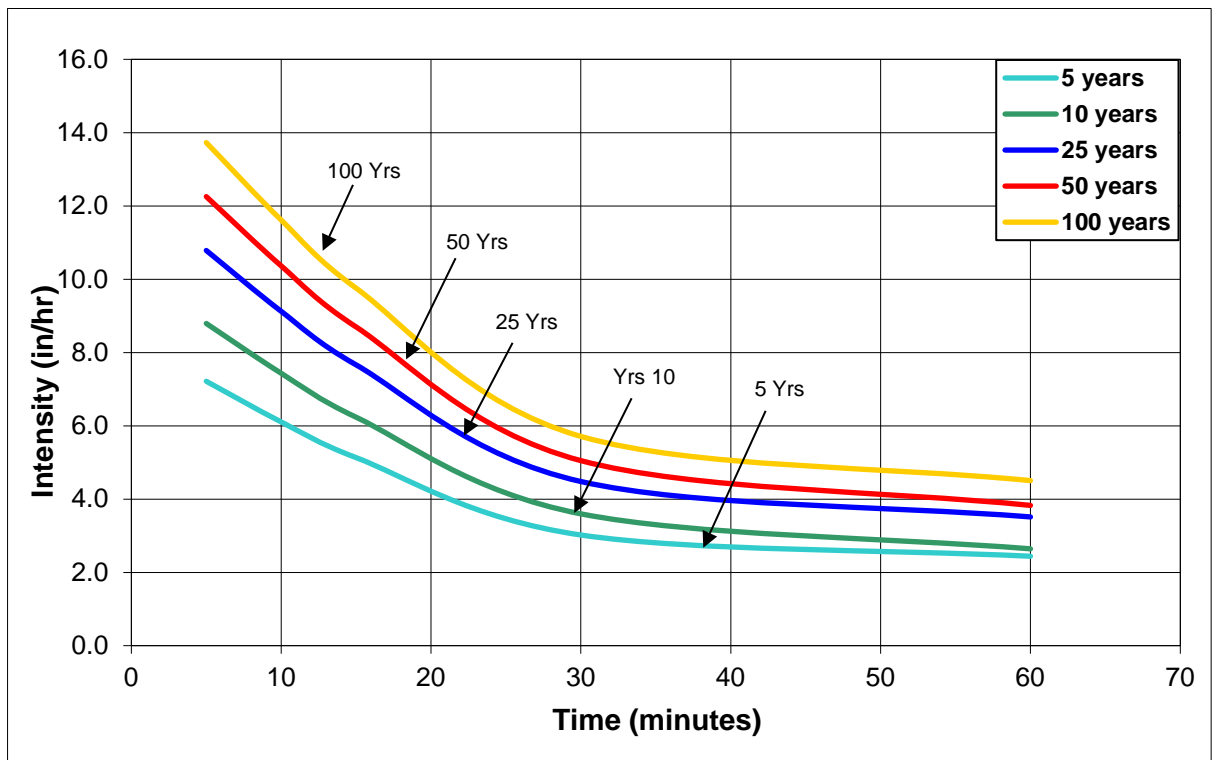


Figure 8.9: Intensity-Duration-Frequency Curves of Islamabad Airport Station

**8.1.3.6. Design Discharges for Drainage Crossings:**

The computed discharges for various return periods for natural crossings are given in Table-4. Design discharges at various cross-drainage structures are given in detailed drawings in Volume-3 of DPR.

**Table 4: Flood Estimations at Natural Drain Crossings for Various Return Periods**

Sr. No.	RD	Catchment Area		Peak Flood Discharges				
				5-year	10-year	25-year	50-year	100-year
		Km <sup>2</sup>	Acres	(ft <sup>3</sup> /Sec)				
1	0+800	0.34	84	310	375	460	525	585
2	2+480	2.28	563	1,027	1,323	1,697	1,974	2,248
3	2+500, 2+750 & 2+950	0.27	67	210	255	310	355	395
4	3+370	0.13	32	525	640	785	890	995
5	3+542	0.83	206	110	135	165	190	210
6	4+150	0.36	89	210	255	315	355	400
7	4+770	0.41	100	265	320	395	445	500
8	6+180	0.10	25	70	90	110	120	135
9	6+853	1.60	395	914	1,179	1,514	1,762	2,007
10	7+857	3.82	943	1,553	2,011	2,591	3,020	3,445
11	8+660	4.90	1,211	1,997	2,586	3,331	3,883	4,429
12	8+823	2.90	717	1,043	1,348	1,733	2,018	2,300
13	10+526	1.00	248	583	751	963	1,120	1,276
14	10+924	1.34	330	604	779	999	1,162	1,324
15	11+902	3.86	954	1,644	2,125	2,732	3,182	3,627
16	12+450	0.63	156	425	515	635	720	805

Sr. No.	RD	Catchment Area		Peak Flood Discharges				
				5-year	10-year	25-year	50-year	100-year
		Km <sup>2</sup>	Acres	(ft <sup>3</sup> /Sec)				
17	13+950	0.36	89	255	310	380	435	485
18	14+400 - 16+100	0.38	94	245	295	365	415	465
19	16+730	0.41	101	290	355	435	495	555
20	17+620	0.20	49	170	210	255	290	325
21	18+350	0.97	239	543	701	900	1,048	1,194
22	22+000 (Soan River)	2051.82	507,016	115,450	145,050	182,450	210,190	237,700
23	22+975	31.30	7,735	6,674	8,495	10,788	12,482	14,156
24	24+435	0.10	25	85	105	130	145	165
25	25+610	0.12	30	105	125	155	175	195
26	26+740 & 26+860	0.37	91	315	380	470	530	595
27	27+650	0.56	138	300	365	450	505	570
28	28+050	0.45	112	295	360	445	500	565
29	28+620 & 28+820	0.74	183	465	560	690	785	880
30	30+500	1.28	316	755	979	1,262	1,472	1,680
31	30+820 & 31+020	0.51	125	350	430	525	595	670
32	31+370	0.10	25	85	105	130	145	165
33	32+640	0.18	44	155	190	230	260	295
34	33+020	1.20	297	692	891	1,143	1,329	1,513
35	33+470 (Sill River)	210.74	52,076	26,163	33,519	42,820	49,706	56,526
36	35+680	4.23	1,046	1,524	1,968	2,530	2,946	3,358
37	36+440	1.19	294	647	837	1,076	1,254	1,429
38	37+500 - 38+100	0.60	148	515	625	770	875	980
39	38+250	0.10	25	85	105	130	145	165
40	39+000	2.09	516	1,028	1,332	1,716	2,000	2,281
41	39+500	0.60	148	360	435	535	610	685
42	40+100	1.92	473	960	1,243	1,601	1,866	2,129
43	41+050	0.50	124	320	390	480	545	610
44	41+310	21.22	5,243	5,202	6,620	8,404	9,721	11,024
45	42+510	0.36	89	210	255	315	355	400
46	44+100	0.88	217	460	555	685	775	870
47	45+100	1.08	268	636	818	1,049	1,220	1,388
48	45+950	0.14	35	120	145	180	205	230
49	47+500	8.44	2,086	2,967	3,838	4,939	5,755	6,562
50	48+660	0.10	25	85	105	130	145	165
51	49+210	36.38	8,989	8,693	11,065	14,050	16,255	18,434
52	51+100, 51+200 & 51+300	0.17	42	140	170	210	240	265
53	62+350	0.83	205	530	640	790	895	1,005
54	63+150	12.22	3,019	3,409	4,345	5,523	6,393	7,254
55	63+750 - 64+400	0.21	52	180	220	270	305	340
56	64+525	46.41	11,467	9,538	12,160	15,462	17,902	20,315

## **8.2. HYDRAULIC REPORT:**

Various streams, Nullahs and rivers cross the proposed route alignment of the Rawalpindi ring road (RRR). Bridges and culverts have been proposed for the crossings of perennial/non-perennial rivers & streams, on the basis of characteristics and topography of the area. Initially Google imagery were used to identify the locations of the drainage crossings. The identified locations were marked on the maps, and handed over to the surveyors for carrying out reconnaissance and strip surveys. The natural drainage pattern of the area is from north-east to south-west and the road alignment has been planned across the streams flowing around. The cross-drainage infrastructure has been planned to ensure safe and efficient disposal of flood water across the road alignment. The location of these streams has also been verified using satellite datasets and further hydraulic analyses have been performed for the design of cross drainage structures.

### **8.2.1. Design Methodology of Culverts**

Hydraulic analyses of culverts have been carried out by using HY-8 computer software, and the brief description of the methodology is given below:

#### **8.2.1.1. HY-8 Model Inputs**

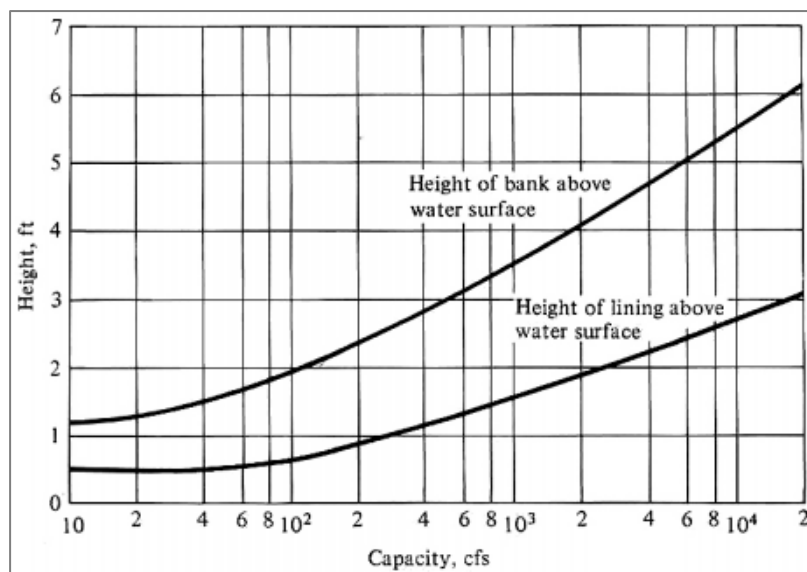
Followings are the input parameters:

- **Discharge:** The design discharge is taken as 25-years return period flood, whereas minimum discharge is assumed as nil, and the maximum discharge is taken as 50-years return period flood.
- **Tail Water Data:** The model requires manning's roughness coefficient (n), average bed slope and cross section on the downstream, for the computation of tail water level. The average bed slope of the nullah has been estimated from the strip survey and calibrated SRTM data, where available. The cross section at the downstream side of culverts was not available from the topographic survey; and is assumed as rectangular (as a conservative estimate) with bed width taken from strip survey and satellite data.
- **Roadway Data:** The roadway data is required as input in the model, which comprises width of proposed roads, road crown elevation and total carriage width. The size of culvert has been proposed to safely pass 25-years return period flood with adequate freeboard, and 50-years return period flood by partially encroaching the freeboard. Under both these conditions, the head water level will not approach the roadway. The culverts have been designed for open channel flow and sizes have been fixed to avoid pressure flow as it will cause heading up and inundation on the upstream side.
- **Culvert Data:** Concrete box type culverts have been proposed with manning's roughness coefficient of 0.016. The data required for the model comprised of type,

invert levels, culvert length, shape and size of culvert barrels along with inlet and outlet wing wall configurations.

### 8.2.1.2. Free Board

Freeboard for culverts is considered according to the recommendations of U.S. Bureau of Reclamation. Refer figure-8.10. The USBR has prepared curves for the average freeboard and bank heights, in relation to discharge capacities. The free board of the proposed structures has been adopted by considering the site topography and road profile and thus minimum height of culvert barrel has been fixed as 2.0 m. The aim of selecting this height to provide adequate waterway opening to address the choking issues and to allow movement of small machinery and manpower under the culvert for repair and maintenance purposes.



**Figure 8.10: Recommended Freeboard and Height of Bank of Lined Channels (U.S. Bureau of Reclamation)**

### 8.2.1.3. Hydraulic Modelling Results using HY-8 for Culverts

The list of crossings for culverts along with hydraulic design parameters, computed from HY-8 computer software are given in Table below:

**Table 5: Hydraulic Parameters of Proposed Culverts**

Sr. No.	Road RD	Design Discharge (25 Yr)	Barrel Width	Barrel Height	No. of Barrels	Inlet Invert level	Outlet Invert level	Headwater Level (HWL)	Outlet Flow Velocity (V)
			W	D		(m)	(m)	(m)	(m/s)
		ft <sup>3</sup> /sec	(m)	(m)		(m)	(m)	(m)	(m)
1	0+800	460	2	2	2	552.9	552.5	554.6	3.2
2	2+480	1697	2	3	7	518.4	518	520.1	3.1
3	2+500	310	2	2	2	516.1	515.8	517.5	2.8
4	2+750	310	2	2	2	526.6	526.3	528	2.8
5	2+950	310	2	2	2	531.6	531.2	533	2.8
6	3+370	785	2	2	4	529.4	529	530.9	3
7	3+542	165	2	2	1	523.4	523	524.8	2.9
8	4+150	315	2	2	2	533	532.6	534.3	2.8
9	4+770	395	2	2	2	539.6	539.3	541.2	3
10	6+180	110	2	2	1	538	537.7	539.1	1.9
11	6+853	1514	2	2	6	527.4	527	529.1	3.1
12	7+857	2591	3	2	7	514.1	513.8	516	2.5
13	8+660	3331	3	2	9	494.4	494	494.2	2.8
14	8+823	1733	3	2	5	492.9	492.6	494.7	3.2
15	10+526	963	2	2	4	498.2	497.8	500	3.2
16	10+924	999	3	2	3	469.1	468.7	470.8	3.1
17	11+902	2732	3	2	8	459.8	459.4	461.6	3.2
18	12+450	635	2	2	3	476.8	476.5	378.5	3.2
19	13+950	380	2	2	2	476.2	475.9	477.8	3
20	14+400	365	2	2	2	480.5	480.1	482	2.9
21	16+100	365	2	2	2	461.1	460.7	462.6	2.9
22	16+730	435	2	2	2	457.5	457.2	457.7	3.1
23	17+620	255	2	2	1	420.7	420.4	422.6	3.3
24	18+350	900	2	2	4	384.2	384	386	3.1
25	24+435	130	2	2	1	386.9	386.6	388.2	2.7
26	25+610	155	2	2	1	422	421.6	423.3	2.7
27	26+740	470	2	2	2	424.9	424.5	426.7	3.2
28	26+860	470	2	2	2	447.7	447.3	449.6	3.2
29	27+650	450	2	2	2	455.6	455.2	457.4	3.2
30	28+050	445	2	2	2	466.8	466.4	468.6	3.2
31	28+620	690	2	2	3	474.1	473.7	475.8	2.5
32	28+820	690	2	2	3	484.4	484	486.1	2.5

Sr. No.	Road RD	Design Discharge (25 Yr)	Barrel Width	Barrel Height	No. of Barrels	Inlet Invert level	Outlet Invert level	Headwater Level (HWL)	Outlet Flow Velocity (V)
			W	D		(m)	(m)	(m)	(m/s)
		ft <sup>3</sup> /sec	(m)	(m)		(m)	(m)	(m)	(m/s)
33	30+500	1262	2	2	5	473.5	473.1	475.4	2.3
34	30+820	525	2	2	3	466.5	466.2	468	1.9
35	31+020	525	2	2	3	471.3	470.9	472.8	1.9
36	31+370	130	2	2	1	483	482.6	484.2	2
37	32+640	230	2	2	1	453.5	453.2	455.2	3
38	33+020	1143	2	2	5	434.1	433.7	435.8	2.1
39	35+680	2530	3	2	8	486.5	486.1		
40	36+440	1076	2	2	1	488.3	488	490	2.5
41	37+500	770	2	2	4	527.7	527.4	529.3	2.4
42	38+100	770	2	2	4	532.1	531.8	533.7	2.7
43	38+250	130	2	2	1	0.4			
44	39+000	1716	3	2	6	515.6	515.3	517.4	3
45	39+500	535	2	2	2	524.7	524.3	526.3	2.6
46	40+100	1601	2	2	5	528.4	528	530.4	3.3
47	41+050	480	3	2	2	527.4	527	529	3
48	42+510	315	2	2	2	540	539.6	541.4	2.8
49	44+100	685	3	2	2	525.3	524.9	527	3.1
50	45+100	1049	2	2	4	517.1	516.7	518.7	3.1
51	45+950	180	2	2	1	519.3	519.2	520.9	2.2
52	48+660	130	2	2	1	495.2	495		
53	51+100	210	2	2	1	500.7	500.6	502.5	2.4
54	51+200	210	2	2	1	500.7	500.6	502.5	2.5
55	51+300	210	2	2	1	500.7	500.6	502.5	2.4
56	52+150		2	2	1				
57	52+180		2	2	1				
58	52+202		2	2	1				
59	63+750	270	2	2	2	500.5	500.1	501.7	2

### 8.2.2. Bridges over River Crossing:

The design of a new bridge across the river/Nullahs requires extensive hydraulic analyses prior to its on-site execution. The orientation of the bridge axis, waterway width, various flow parameters and fluvial behavior at the bridge location as well as along upstream and downstream reaches of the bridge are estimated from hydraulic analyses. Hydraulic analysis and design involved the following steps:

- i. Fixation of design discharge of the River;
- ii. Computation of the bridge length;
- iii. Determination of water levels and flow velocities at the bridge axis;
- iv. Computation of scour depth at the proposed bridge axis; and
- v. Design of protection works.

#### 8.2.2.1. Design Discharge at Bridge Crossings:

The bridge structures have been proposed to be provided at locations where discharge is higher than 5,000 cusec. The adopted design discharge value for each bridge is given in the Table-6 given below:

**Table 6: Design Discharges of Bridges over Natural Streams**

Sr. No.	Bridge RD	Drainage Area	Discharge	
		(Km <sup>2</sup> )	(m <sup>3</sup> /Sec)	(ft <sup>3</sup> /Sec)
1	22+000	2051.82	6,730	237,700
2	22+975	31.30	401	14,156
3	33+470	210.74	1,600	56,526
4	41+310	21.22	312	11,024
5	47+450	8.44	186	6,562
6	49+210	36.38	522	18,434
7	63+150	12.22	205	7,254
8	64+525	46.41	575	20,315

#### 8.2.2.2. Design of Bridges and Sizing Methodology:

Hydraulic design of these bridges has not been performed however, design discharges for the streams were computed and given in Table above.

The sizes of the two (02) bridges at Soan and Sill are given below:

**Table 7: Hydraulic Design Parameters of Bridges Over Natural Streams**

River Name	RD	Discharge (100 yr.)	Discharge (100 yr.)	Bay Width	Nos. of Spans	Freeboard (FB)
		(m <sup>3</sup> /sec)	(ft <sup>3</sup> /sec)	(m)	(Nos.)	(m)

Soan	22+000	67,047	237,700	25	17	1.0
Sill	33+470	1,601	56,526	20	5	1.0

### 8.2.2.3. Scour Depth Calculations:

Scour depth for the proposed structures is calculated using Lacey's formula. According to Lacey's Method:

$$R = 1.35[q^2/f]^{1/3} \quad (\text{in SI Units})$$

$$R = 0.9[q^2/f]^{1/3} \quad (\text{in FPS Units})$$

$q$  = Design discharge per meter width in  $m^3/s$  or  $ft^3/s$

$f$  = Lacey's silt factor depending upon bed material

$R$  = General Scour depth in meter or feet

The value of Lacey's silt factor depends on the  $D_{50}$  of the bed material which is determined from the borehole log of the stream bed. The equation used for calculation of " $f$ " is:

$$f = 1.76 (D_{50})^{0.5}$$

$D_{50}$  = Median grain size of bed material in millimeters

It is assumed that the river bed material at the proposed bridge location is Medium, and standard silt having an approximate value of  $D_{50}$  as 0.25 mm has been adopted the typical size of bed material and Lacey's silt factors are given in **Table 8**. The local depth of scour from HFL can be taken as  $xR$ , where  $x$  is safety factor which depends upon the type of structure and location of features. General values of  $x$  are given below in **Table 9**.

**Table 8: Lacey's Silt Factor for Various Materials**

Soil Type	$D_{50}$ (mm)	Lacey's Silt Factor
Large Boulders and Shingle	129.1 3	20.00
Boulders and shingle	72.64	15.00
Boulders and gravel	50.44	12.50

**Table 9: Safety Factor for Various Locations around Structures**

Location	X
Straight reach of channel	1.25
Mild bend of channel	1.50
Moderate bend of channel	1.75
Severe bend of channel	2.00
Upstream floor of structure	1.75
Downstream floor of structure	2.25

Medium boulders, shingle and sand	32.28	10.00	Transition from nose to straight of guide bank	1.75
Coarse gravel	26.15	9.00	Straight reach of guide bank	1.50
Gravel	7.28	4.75	Pier nose (Consultants recommendation)	2.00
Heavy sand	1.29	2.00		
Coarse sand	0.73	1.50		
Medium sand	0.51	1.25		
Standard silt / Fine sand	0.32	1.00		
Medium silt	0.16	0.70		
Fine silt	0.08	0.50		
Very fine silt	0.05	0.40		

The stone size has been computed by following a standard procedure and guide lines illustrated by Is bash curves in Hydraulic Design Criteria (HDC), based on average flow velocities. Density of the stone has been taken as 165 lbs./ft<sup>3</sup> (2,642 kg/m<sup>3</sup>).

### **8.2.3. Protection Works for Culverts:**

Cut-off walls have been proposed from erosion protection at the inlet and outlet of culverts. Stone protection (apron) is proposed on the upstream side and downstream side of the proposed structure. Wing walls have been proposed to maintain the approach velocity, and improve the inlet configuration. Concrete floor has been proposed on upstream and downstream of the culverts up to transition of wing walls, to cater high velocities. The calculated length of flexible protection is proposed to provide beyond the concrete floor. Safety factor (X) for scour depth calculation at upstream and downstream of the structure have been taken as 1.75 and 2.0. Length of the apron has been provided 1.5 times of scour depth on both upstream and downstream side of the structure, however cut off depths and length of concrete floors have been provided 1.0 x scour depths. Size of stone has been provided as per criteria given in bridge section.

### **8.2.4. Conclusions and Recommendations:**

- The layout of the cross-drainage structure locations is based on the available satellite imagery and is tentative. It must be confirmed and finalized as per site conditions at detailed design level.
- The Hydraulic analyses for the culverts have been performed on the limited available survey data. It is recommended that detailed survey must be carried out before final layout
- For bridge structures, the hydraulic data provided by the M/s Zeeruk has been used. The numerical modelling shall be performed with updated river/stream geometry at

the detailed design stage. Furthermore, physical models of Soan and Sill River shall be carried out at Irrigation Research Institute (IRI), Nandi Pur to confirm the numerical model results.

- The major crossings have been identified and addressed in the report. However, to cater local sheet flows, single/multiple cell culverts shall be provided as per site conditions.
- Geotechnical Investigations shall have to be performed at each structure location to compute mean particle diameter ( $D_{50}$ ) to estimate scour depth against each structure. The estimation of scour depth shall lead to compute upstream and downstream protections for each structure.

#### **8.2.5. References:**

1. Climatic Normals of Pakistan (1981-2010), Pakistan Meteorological Department.
2. Chow V. T., "Handbook of Applied Hydrology".
3. Kirpich Z. P., "Time of Concentration of Agricultural Watersheds", Civil Engineering Volume 10, No. 6 Pages 362, June 1940.
4. Open Channel Hydraulics by VEN T CHOW
5. Irrigation and Hydraulic Structures by SK Garg
6. Irrigation and Hydraulic structures by Dr Iqbal Ali
7. HEC-RAS User's and Reference Manual

# **CHAPTER 9**

## **STRUCTURE DESIGN REPORT**

## **9. STRUCTURE DESIGN REPORT**

Report is separately attached as **Annexure-A**.

## **CHAPTER 10 ITS REPORT**

## **10. ITS REPORT**

Report is separately attached as **Annexure-B**.

# **CHAPTER 11**

## **EIA APPROVAL**

## **11. EIA APPROVAL**

EIA Approval is separately attached as **Annexure-C**.