Study of Various factors affecting Hill Roads and their Environmental Impact Assessment

THESIS

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DOCTOR OF PHILOSOPHY

By

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CERTIFICATE

This to certify that the thesis entitled **"Study of Various factors affecting Hill Roads and their Environmental Impact Assessment** submitted by **VIRENDER SINGH PHOGAT** NO.**2016PHXP0501** for award of Ph.D. Degree of the Institute embodies the original work done by him under my supervision.

DATE: 19th July 2023

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(Virender Singh Phogat)

This research work is a milestone in study of various factors affecting hill roads and their Environmental Impact Assessment. The thesis is a holistic single document covering construction and operational phase studies and experiments. Study incorporated the construction data and effect on project area including increase of bed-load of River Kali and its streams along the route in Dharchula Project. The impacts on environment for both projects of road widening, and fresh alignment construction of hill road has been monitored, evaluated and analyzed with respects to multiple environmental parameters. The social impact of new hill road project on society is also studied in detail. Air pollution caused by equipment, machinery including generator sets in hill areas during construction phase has been studied for both Katra-Reasi road widening and Dharchula-Lipulekh pass. The objectives of the study have been achieved.

Further study analysed that the EIA team should supervise the complete construction work in this project and ensure that the excavation works are done with minimum temporary loss of vegetation. The optimisation of the cut and fill section reduces the impacts to a great extent. Excavation material is recommended to be used with advantage in the fill section. The dumping sites should be planned initially and rehabilitation of dumping sites should also be a part of the project's EIA. The planting of saplings should begin in the adjoining area even before the commencement of the project. The activities of the project should be conducted such that the nearby surface water sources are not polluted. Adequate drainage should be provided for the hilly roads and the drainage should be designed to reduce the speed of runoff water. Vehicles and equipment used for construction should be functional and tested for pollution norms regularly. Any spillage of material appropriately cleared, reduces the impact on the environment. Suitable waste management at construction sites and recycling of resources is crucial for a hill road project.

Research describes methodology for carrying out the environmental impact assessment of a hill road construction studying Road Dharchula to Lipulekh. The total muck generated during excavation and dumped on slopes was measured. The increase in bed load of River Kali is monitored at three monitoring stations at 40 km, 50 km, and 60 km respectively from Lipulekh Pass. Water pollution has been evaluated in this research for the complete duration of construction years. The river bed profiling was done and various parameters including flow

discharge, the active width, the slope, and the surface grain diameters D_{50} and D_{84} were measured. The study was carried out over three years for observing the construction sites, and sample collection was done during various seasons each year. During the formation cutting on a new alignment, EIA was carried out for muck generated and disposed off on the downhill slope, causing an increase in bedload of River Kali. Out of 19.98 Lac Cum of rock cutting, the small/ medium boulders were 12.94 lac Cum and 6.84 lac Cum was hard rock and 19.99 lac Cum was soft rock.

The study of project area of the road Ghatiabagarh to Lipulekh Pass identified the social impacts using questionnaire surveys from individuals of different professions, including the villagers, tourists, taxi drivers, travel booking agents, health workers, primary school teachers, amongst others along with field observation. In the present research National Science Foundation (NSF) Method, Battelle Environmental Evaluation System Method and Weighing and Scaling Checklist Method for assessment of social impacts have been used.

In the present thesis for ease of cost calculations construction activity is sub-grouped into various steps. Further cost for each activity per cubic meter or per square meter is analyzed as per present rate analysis and has been compared with respect to rates of year 2010, a decade earlier. The cost of construction of hill road has been estimated for one km stretch for Single Lane, Double Lane and four lane hill road construction. For estimation of culverts and bridges enroute which shall vary for each site and given geographical conditions the cost for one culvert (box type) and one bridge has been estimated. Depending upon number of culverts and bridges the cost estimation for any length of hill road can be estimated.

The construction activity on any hill road needs a work force which should be present in the area of construction site for longer durations or working seasons. Hence to keep the manpower fit and healthy the contaminants in water of hilly areas must be studied and various methods for treatment of water in hills for drinking purposes.

The study was conducted in three geographical regions ie. EIA of road widening of hill road at Katra-Reasi in State of Jammu & Kashmir, EIA and SIA of hill road construction on green field alignment from Dharchula to Lipulekh Pass in Uttarakhand, Study of cost of construction of Hill Road (Single Lane, Double Lane, and Four Lane) in Leh, Ladakh. The thesis is outcome of extensive research as described in the chapters ahead.

V	VOLT
kHz	Kilo Hertz
MHz	Mega Hertz
RO	REVERSE OSMOSIS
Ca^{2+}	CALCIUM
K^{+}	POTASSIUM
Mg^{2+}	MAGNESIUM
Na^{+}	SODIUM
Fe^{2+}	IRON
HCO_3^{-}	BICARBONATE
SO_4^{2-}	SULPHATE
F^{-}	FLOURIDE
CI^{-}	CHLORIDE
(l)	LITRES

AC	ASPHALT CONCRETE
AHP	ANALYTICAL HIERARCHY PROCESS
ANFIS	ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM
AQI	AIR QUALITY INDEX
A/U	AUTHORISED UNITS
AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
BRO	BORDER ROADS ORGANIZATION
BS	BHARAT STAGE
CO	CARBON MONOXIDE
CRIS	CUSTOMIZED RAINFALL INFORMATION SYSTEM
EIA	ENVIRONMENTAL IMPACT ASSESSMENT
GHG	GREEN HOUSE GAS
GSB	GRANULAR SUB-BASE
HSU	HARTRIDGE SMOKE UNIT
IMD	INDIAN METROLOGICAL DEPARTMENT
IPCC	INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
J&K	JAMMU AND KASHMIR
MCDM	MULTICRITERIA DECISION-MAKING METHODS

NSF	NATIONAL SCIENCE FOUNDATION
SAW	SIMPLE ADDITIVE WEIGHTS
SAW Method	SIMPLE ADDITIVE WEIGHTS METHOD
SIA	SOCIAL IMPACT ASSESSMENT
SWAT	SOIL WATER ASSESSMENT TOOL
SS	SUSPENDED SOLIDS
SSR	STANDARD SCHEDULE RATES OF MILITARY ENGINEERING SERVICES
DM	DECISION MAKERS
NHAI	NATIONAL HIGHWAY AUTHORITY OF INDIA
NHs	NATIONAL HIGHWAYS
SHs	STATE HIGHWAYS
MSL	MEAN SEA LEVEL
FC	FOREST CLEARANCE
ARCGIS	GEOGRAPHICAL INFORMATION SYSTEM SOFTWARE
HEC	*HYDROLOGIC ENGINEERING CENTRE'S*
RAS	*RIVER ANALYSIS SYSTEM*
IEA	INDIAN MINISTRY OF EXTERNAL AFFAIRS
BIM	BUILDING INFORMATION MODELING
MV	MARKET VARIATION

RA	REMOTE AREA
M&L	MATERIAL AND LABOUR
WQI	WATER QUALITY INDEX
NSF WQI	NATIONAL SANITATION FOUNDATION WATER QUALITY INDEX
INR/Rs	INDIAN NATIONAL RUPEES
FIG.	FIGURE
LDPE	LOW-DENSITY POLYETHYLENE
CM	CENTI METER
RBF	RIVER BANK FILTRATION
NOM	NATURAL ORGANIC MATTER
H.VERTICILATA	HYDRILLA VERTICILATA
Nf	NONOFILTRATION
RT-PCR	REVERSE TRANSCRIPTASE POLYMERASE CHAIN REACTION
EF-TU	RIBONUCLEIC ACIDS LIKE EF-TU
DEP	DIELECTROPHORETIC (DEP) PHENOMENA
DF	DIELECTROPHORETIC FILTRATION
UV	ULTRAVIOLET (UV) RADIATION

1 Chapter
Introduction

1.1 Introduction

India, a developing nation, has grown remarkably in all aspects, socially, economically, in agriculture, and the industrial evolution. The economic growth in the last few decades must be equally matched by logistics, mobility, and fully functional transport infrastructure. Connectivity and accessibility between major cities is a requirement-based achievement that contributes to the economic progress of the country, but rural India must be included in this idea of development. As per Survey of India (https://www.surveyofindia.gov.in/), India consists of 28 states and 8 union territories, which are divided into four regions: the Great Himalayas, the Ganga and Indus plains, the desert region, and the southern peninsula. The Himalayas consist of three practically parallel peaks interspersed with huge plateaus and valleys that span 2,400 kilometers and range in breadth from 240 to 320 kilometers. (https://knowindia.india.gov.in). India is a one-of-a-kind nation with hill roads in snow-covered mountains, motorways in plains, a desert, and a coastline, as well as every other possibility imaginable. The developed nations have all policy and peripherals in place whereas developing countries are evolving by hit and trial methods. India has various means of transportation to include land, air and sea. On one hand Indian railways take countries pax and freight load but road transport connects rural India to towns and cities constituting 85% pax load and 60 % freight load in the country. However, transport infrastructure is yet to come-up to satisfaction level in mountainous regions of India specially in Jammu & Kashmir, Uttarakhand due to limited technical resources and judicious usage. Several natural conditions such as steep mountainous geography across J&K (most of the J&K state is in hilly area) and Uttarakhand's prolonged monsoon season and snowfall in winters also complicates the challenge.

The hill roads are constructed in different ways. There are forest roads in mountains and thickly forested areas. They are usually dirt roads or at best-metaled roads. They are essential to preserve and safeguard forests and are completely controlled by forest departments of the state. There are national and state highways that crisscross the country sometimes passing through forests and hilly terrain and they usually are existing roads widened to accommodate increased traffic where they cut hills and forest to some extent. The Border Roads Organization (BRO) is under the Ministry of Defence, and they construct roads in tough terrain like Uttarakhand, Himachal Pradesh, Arunachal Pradesh, and in Jammu and Kashmir (J&K) etc. by working on challenging situation of precipitous mountains for accessing villages and for national security.

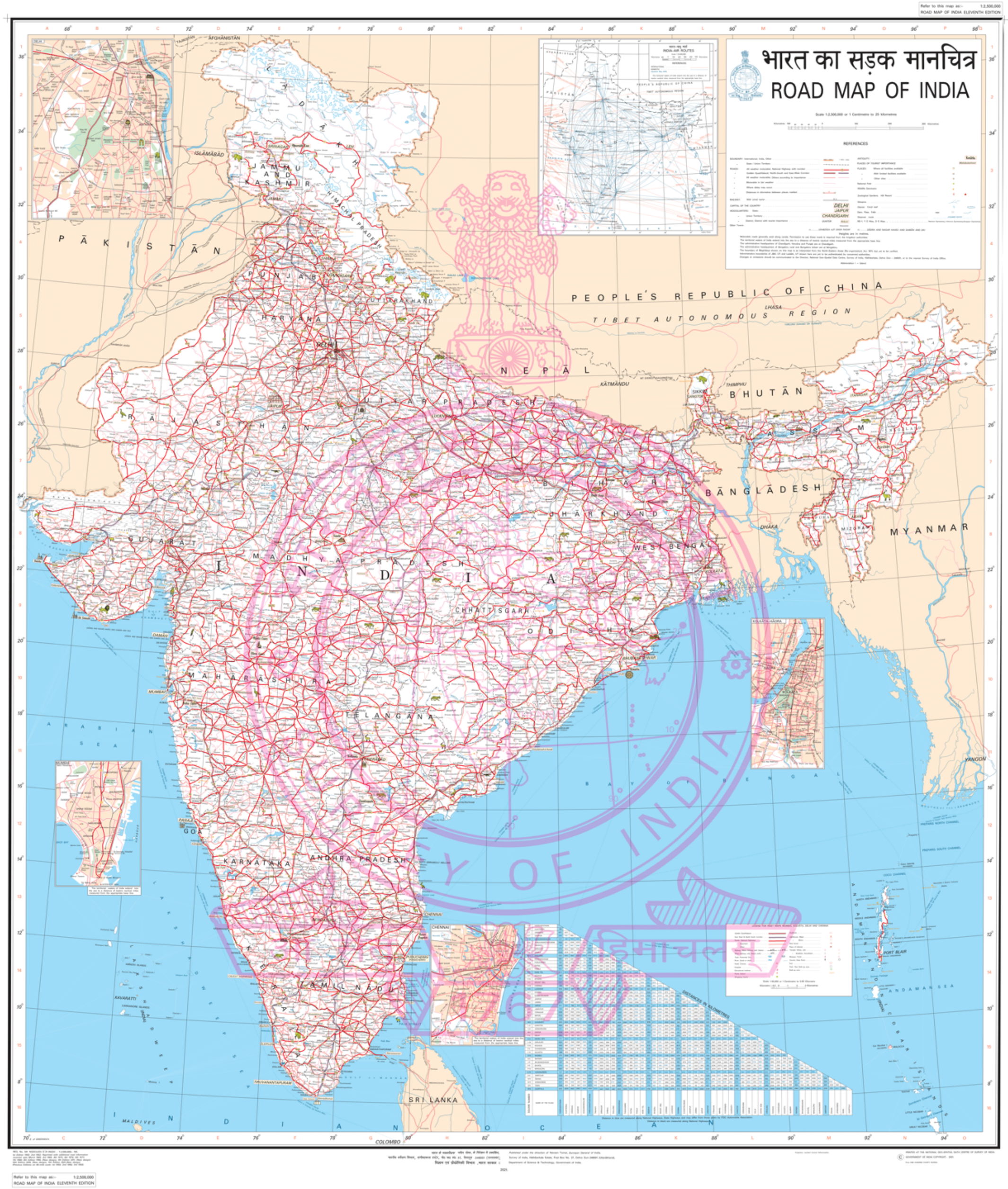

Figure 1.1: Road Map of India (Source: https://www.surveyofindia.gov.in/)

1.2 Purpose of The Work

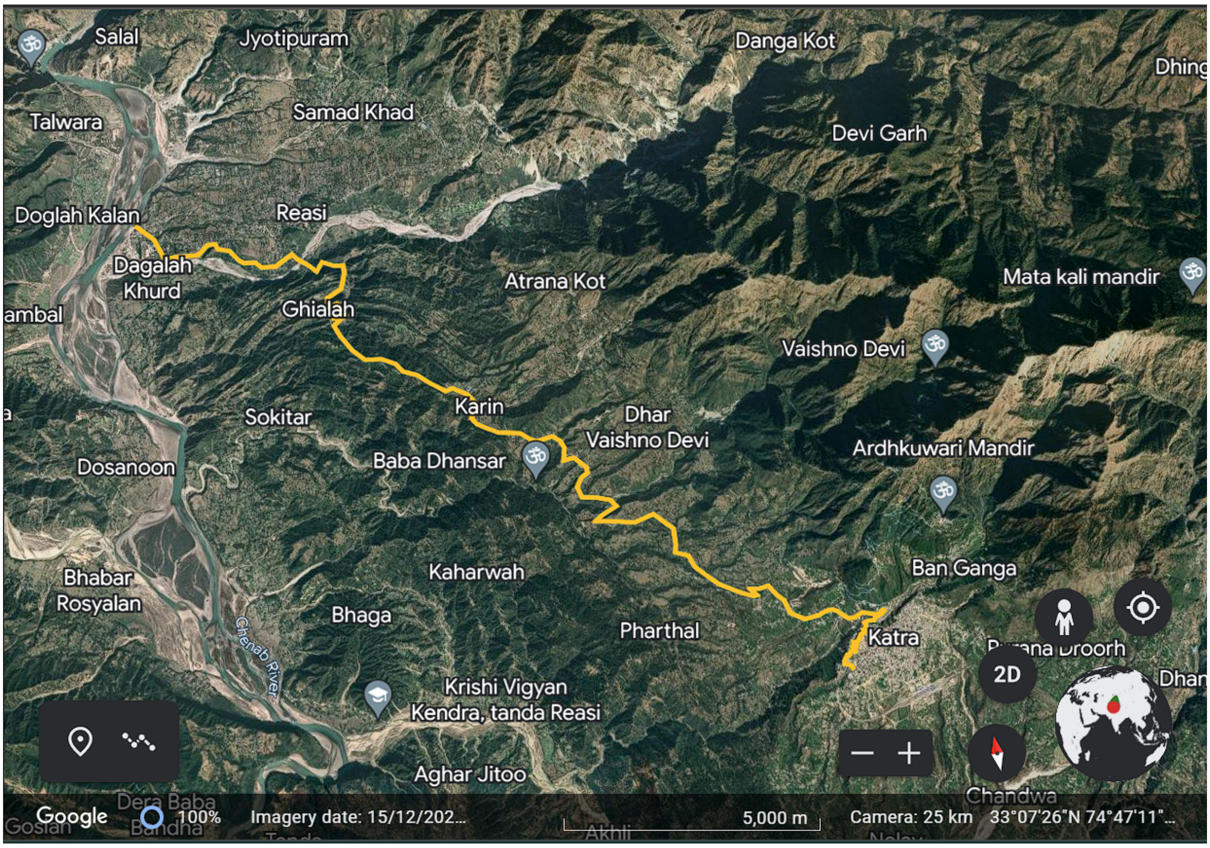

Figure 1.2: Image of the Proposed Study Area (Katra-Reasi Sector, J&K) (Source: https://earth.google.com)

The purpose of research was to extensively study various factors affecting hill roads and their Environmental Impact Assessment. The study has focused on two types of construction projects, i.e., Road widening project of 26 kilometers in J&K and Construction of a 76-kilometer fresh road on a virgin alignment. To understand the complexity of construction of hilly roads we need to understand number of operations such as earthworks, excavating, hauling, placing, and compacting. Earthworks are very important in context to the construction of hilly roads due to probability of landslide occurrences and non-availability of sufficient quantity of desired construction materials due to very high transportation cost. Moreover, the operations are manpower extensive and require expensive heavy equipment as well. In this study a road widening of 26 Km Katra-Reasi hilly road stretch and construction of 76 kilometers road Ghatiabagarh-Lipulekh both constructed by Border Roads Organization (BRO) were monitored during construction phase and later during operational phase. In the

Katra-Reasi road the existing width of pavement of 3.6m was widened to 10 m. The formation width was total 12 m including the 1.0 m wide shoulders along both sides of road serving as an emergency lane for vehicles. Study of Katra-Reasi road of 26 Km length identified various environmental impact assessment (EIA) parameters and further monitored the probable sites of soil erosion and evaluate effect of Muck on environment. On the road Ghatiabagarh-Lipulekh the project was monitored since beginning being a green-field alignment for soil excavated and disposal, type of equipment used, and hours run, effect of excavated soil on sediment transportation of River Kali. Social Impact assessment due to construction of Ghatiabagarh-Lipulekh road was carried out. An attempt has been made to standardize the cost of construction of hill road (single lane road, double lane road and four lane road) including cost of construction of culvert or bridges has been done for India and cost has been compared to cost incurred in year 2010. Further study analyzed water samples of River Shyok (at Nubra), River Indus (at Chumathang, Karu and Nimu), River Zanskar (at Chilling and Sangam), River Ganga (at Gangotri), River Kali (at Malpa, Najang and Mangti).

1.3 Objectives of the Work

Based on the past study and literature review various factors affecting hill roads and their environmental impact assessment need an in-depth study for various situations. Road widening project, construction of hill road on fresh alignment and construction of hill road on sub-zero/permafrost region have very typical and complex environmental impacts, which are not only varying due to terrain but in magnitude too. These complex factors dictated the selection of study areas in three different states with hill areas. Present study focusses upon road construction activity in three states, namely Jammu & Kashmir, Leh-Ladakh and Uttarakhand in India. Diversity in the study in different region/state would bring out the very essence of study being holistic. Different area, varying altitude, different set of construction activity, variation in the co-location of the river adjacent to road alignment, different soil strata and different duration of snowfall in the study areas make this study a prodigy. Accordingly, following objectives have been decided: -

a. Identification and assessment of potential environmental impacts of hill road construction.

b. Identification of conditions due to which water quality of stream may get affected due to muck generated during construction excavation and mitigation techniques to control the nuisances of Muck.
c. Assessment of impacts during operational years of hill road.
d. Analysis of cost-effectiveness and economic viability using Multicriteria tools.
e. Social impact assessment of hill road construction by National Science Foundation method (NSF method), Battelle method, Weighted Checklist method.
f. Estimation of cost of construction of hill road per Km in India.

1.4 Organization of the thesis

The study and analysis have always been the easier task compared to the most difficult task of arranging the work in the form of thesis. However, an effort has been made to keep thesis organised and systematic in following 8 chapters.

Chapter 1 gives outline framework of thesis and outline description of each chapter is mentioned in organization of the thesis. The gaps in research are identified. To study these gaps a research methodology has been devised. The objectives of present study are earmarked. Scope of study to have holistic approach is finalised.

Chapter 2 discusses literature review of the research carried out by many scientists and researchers from India and abroad in last 30 years in Hill Road construction projects. The EIA of hill road construction in developing countries is the key focus area.

Chapter 3 focusses on EIA of road widening project in J&K as a holistic process, considering all aspects of the environment which were impacted during the project execution and further in the operational phase. The study brings out various environmental issues and geological aspects to the forefront. The EIA including vehicular emissions in the operational phase due to road widening from existing 3.6 m to 10 m carriageway of 26 km stretch in Reasi District of Jammu & Kashmir has been studied. Impact on the environment including temperature, deforestation, rainfall, landslides, blasting, surface and groundwater, air pollution, soil pollution, habitat change, historical and socio environment have been studied.

Chapter 4 describes the fluvial process of River Kali in Uttarakhand state of India to estimate the fluvial sediment transported due to the construction of a greenfield alignment road. The study was conducted over three years for observing the construction sites, and sample collection was done during various seasons each year. During the formation phase, while cutting on a new alignment, EIA was carried out concerning muck generated and disposed of on downhill slope, causing an increase in bedload of River Kali.

Chapter 5 focusses on the social impact assessment (SIA) both in the short term and long-term arising due to the construction of 76 Km (Ghatiabagarh-Lipulekh) hill road at Dharchula district of Uttarakhand, India. In the present work National Science Foundation (NSF) Method, Battelle Environmental Evaluation System Method and Weighing and Scaling Checklist Method for assessment of social impacts have been used.

Chapter 6 covers how estimates are done deliberating upon calculation of cost of various activities during construction of hill road. The construction activity is sub-grouped into various steps for ease of cost calculations. Further cost for each activity per cubic meter or per square meter is analysed as per present rate analysis and has been compared with respect to rates of year 2010, a decade earlier. The cost of construction of hill road has been estimated for one km stretch for single lane, double lane and four lane hill road construction. For estimation of culverts and bridges en-route which shall vary for each site and given geographical conditions the cost for one culvert (box type) and one bridge has been estimated. Depending upon number of culverts and bridges the cost estimation for any length of hill road can be estimated.

Chapter 7 covers treatment of water in hills for drinking purposes. The construction activity on any hill road needs a work force which should be present in construction site for longer durations or working seasons. Hence to keep the manpower fit and healthy the contaminants in water of hilly areas are studied and various methods for treatment of water in hills for drinking purposes.

Chapter 8 summarises the salient points of the entire research work dealing with the impact assessment on hill roads along with the limitations and futuristic way ahead.

1.5 References

https://www.surveyofindia.gov.in/

https://knowindia.india.gov.in

1.6 Bibliographic Note

Parts of Chapters 3, 4, and 5 had already appeared in the following journal / conference papers:

[1] Phogat, V. S., Singhal, A., Mittal, R. K., & Singh, A. P. (2021). The impact of construction of hill roads on the environment, assessed using the multi-criteria approach. *International Journal of Environmental Studies*. https://doi.org/10.1080/00207233.2021.1905298

[2] Phogat, V. S., Singhal, A., Mittal, R. K., & Singh, A. P. (2021). Social Impact Assessment of Construction of Hill Road (Ghatiabagarh-Lipulekh Road Of 76 Km) on Green Field Alignment in Dharchula, India.*2nd International Conference On Civil And Environmental Engineering (ICCEE) 2022,E3S Web of Conferences 347, 04011 (2022*) https://doi.org/10.1051/e3sconf/202234704011.

2.1 Literature Review

This chapter deals with the review of work from other authors globally on environmental impact assessment of hill road construction in the past decades. The chapter is divided in 4 main components viz. (1) EIA of road construction activities (2) Gaps in the study (3) Research methodology (4) Scope of study. The third part is further divided in 6 phases for conducting the research. The road construction activity has increased multi-folds in previous decades to meet the emerging demand of increased population. Road construction activity has led to serious soil erosion which remains unaccounted for, especially in developing countries. The review of road construction work is very minimal for comprehensive land management decisions and monitoring strategies. All phases of road development including construction, usage by vehicles and maintenance affect physical and chemical soil conditions, water flow, and air and water quality, as well as flora and fauna. Integration of environmental considerations into all phases of transportation is an evolving process. The road development has become more complex and controversial due to increasing awareness of environmental issues. To reconcile the different goals of road development and environmental conservation, identification of the ecological effects of roads in the planning, design, construction, and maintenance of roads need evaluation (NRC, 2005).

In study on selection of equipment for hill road construction researchers have deliberated upon flow chart of construction activity and numerous variables affecting hill road construction. Various multicriteria techniques have been used in the study for selection of equipment (Phogat and Singh, 2013).

Studies have found causes of soil erosion in road projects. Further studies have interlinked the assessment methods and available control measures. (i) the linkages between specific activity of roads construction and soil erosion; (ii) prediction model of soil erosion; and measurement techniques (iii) mitigation / erosion control and rehabilitation techniques. Literature shows that road construction leads to disturbance/ removal of vegetation, profile modification of hill slope, relation between steep slopes and severe erosion. Studies carried out by Dawen et al. (2003) have estimated soil erosions induced by human activity to be nearly 60% of total erosion.

Studies have estimated global soil erosion potential at about 0- 38 mm/year. Developing countries of Southeast Asia were found to be the most seriously environmentally affected in the world (Yang et al., 2003).

Soil erosion occurs by various agents, particularly water, wind, and mass movement; hence construction activity and climate are key factors. Global rates of soil erosion exceed new soil formation by 10- and 20-fold due to construction activities. The increase in soil erosion to date is strongly linked with the clearance of natural vegetation. Construction activity along with climatic variation and extreme weather events, has created ideal conditions for soil erosion. The rainfall (amount, frequency, duration, and intensity), and wind (direction, strength, and frequency of high-intensity winds), coupled with drying-out of the soil influence soil erosion. However, erosion is site-specific, and different permutations of climatic conditions can increase or decrease it (Bullock, 2005). Studies have found that when using excavators, the forest area destroyed was 12.23% lower than when other equipment was used for excavation (Deforestation facts and information, 2022).

Gupta et al. (2014) studied adverse impacts on soil and land stability of construction and widening of National Highway in Jammu and Kashmir. Geological features exacerbate construction related destabilization and Instability of slopes tends to be most pronounced in hilly areas. In the rapidly weathering rocks creation of steep cuts removes basal support of slopes due to loading of unstable surfaces. Road construction activities like removal of vegetation, explosive blasting and rock cutting by vibrator / excavators and in operational phase inadequate drainage provisions and heavy traffic may lead to erosion and slope failures. Hydrology within and beyond the boundaries of the study area gets affected due to construction of drains, embankments and cut and fills. The hill road construction activity adversely affects water sources of springs and streams. The poor construction practices and improper disposal of debris have caused large scale soil erosion triggering massive landslides on NH-44 and enhanced sedimentation into small streams (Gupta et al., 2014).

The major impacts due to road construction are (i) Loss of vegetation and forest cover due to tree cutting (ii) Blasting and excavation triggered geological disturbances (iii) Natural slope disturbed by slope cutting operation induced disturbances causing soil erosion leading to landslides. (iv) Interruption of natural drainage and change in drainage pattern (v) Disturbance of water resources with blasting and discriminate disposal of fuel and lubricants from road construction machinery (vi) Siltation of water channels / reservoirs from excavated debris (vii) Effect on flora and fauna (viii) Air pollution due to dust from debris, road construction machinery, etc. (Bhutan, Pemashelpu HE Project, 2012).

Researchers brought out the criteria of sustainable design and construction of roads in hilly regions. Variation in criteria is likely to occur for every project due to its own uniqueness. The criteria for any road construction project are broadly classified as sustainable design and construction activities.

a. **Sustainable design: -** The focus areas are alignment selection and context sensitive design for sustainable design. The area of undeveloped land must remain least in alignment of any hill road. Alignment must factor in buffer between highway and high-quality area avoiding impact to environmental resources. The context sensitive design should have least impact on socio-economic resources. The highway features must be incorporated in hill roads utilising the visual enhancement. The design must reduce the heat effect during the operational life of road.

b. **Construction activities: -** National highways have increased from 70,934 km in the year 2010-11 to 1,14,158 km up to march, 2017. Total length of India's road network till march, 2017 was 58.98 lakh km (Basic Road Statistics of India 2016-17, 2019). The construction activities should focus on the following criteria i.e., to reduce construction waste management, air pollution, green-house gas emissions and dust during construction phase, mitigation techniques for voice & vibration control. Water management must include water consumption, water pollution control & temporary erosion and sediment control. Higher efficiency equipment and machinery reduced fossil fuel consumption and reduction in equipment emission is desired. Quality management system, environmental training on site and warranty by construction agency should be part of quality construction. Site maintenance must be focussed as part of construction maintenance. (Rooshdi et al., 2014).

Caliskan (2013b) in his research quantified percent damage to forests due to hill road construction. As per study, on steep terrain, 21% of trees were damaged by excavators and 33% of trees were damaged by bulldozers during forest road construction, and on very steep terrain, 27% of trees were damaged by excavators and 44% of trees were damaged by bulldozers during forest road construction. Research further determined that on steep terrain, when excavators were used, 12.23% less forest area was destroyed compared with when bulldozers were used and 16.13% less area was destroyed by excavators on very steep terrain. Study concluded that to reduce the environmental damage on the forest ecosystem, especially in steep terrains, hydraulic excavators should replace bulldozers in forest road construction activities. (Caliskan, 2013b).

The disposal of muck has direct impact on environment so it should be securely transported and dumped at pre-designated sites. When muck disposal plan is nonexistent or not well implemented may cause muck to be washed away into the main river causing negative impacts on the aquatic ecosystem of the river. Poor execution can lead to impacts on various aspects of environment. To prepare the land for muck disposal, clearing operations mandates trees cutting and vegetation clearance. Undergrowth perishes as a result of muck disposal. Lack of adequate stabilization at construction sites, the muck moves along with runoff and creates landslide like situations. Along with muck boulders/large stones enter the river/water body, affecting the fauna and aquatic biota. Studies suggest that muck disposal is done at low lying areas, which get filled up due to stacking of Muck. This can sometimes affect the natural drainage pattern of the area leading to accumulation of water or partial flooding of some area. (Phogat et al., 2021).

Industrial wastes produced in mineral associated industry should be gainfully utilized in highway construction to reduce the pollution and disposal problems. Fly ash, blast furnace slag, cement kiln dust, phosphor-gypsum, waste plastic bags, foundry sand and colliery sand if utilized in road construction will have positive impact on environment.

There is a direct loss of habitat and biota and other environmental effects resulting from the infrastructure development and road construction. The impacts may occur beyond the immediate vicinity of the road including changes in the hydrology of nearby river/streams. Mining for aggregates for the road generally takes place in a different area. Selection of mining area is very important to agree on the geographical boundary for an impact assessment.

Researchers studied the seasonal climatic effects both short- and long-term effect on roads, hills rock, slopes and vegetation. Study also claimed that this temperature variation can affect up to 70 m depth respective of the lithology. Studies carried out in permafrost region suggest that with no advection of heat, no accelerated warming the prediction of permafrost loss can be done for hilly roads condition (Batir et al., 2017).

Highway expansion is must to improve the quality of existing roads and enhance the connectivity between prime economic centres. The escalating traffic and need to bolster the economic capability of the area leads to the expansion of highways. The accession activity disturbs the ecosystem and induces myriad changes in the surrounding panorama. It affects both abiotic and biotic components, directly and indirectly. Researchers highlighted the impact on the environment and socio-economic conditions of the residents. Environment Impact Assessment of National Highways is imperative. Study reviews the influence of highway expansion on air, water and soil quality and the socio-economic conditions and health of the natives (Walia et al., 2017).

Study of landslide probability analysis was undertaken to evaluate the effect of land-sliding on closures of major mountain road networks at Guoshin Township in central Taiwan. Landslide causative factors and triggering factors were selected in a logistic regression scheme by the researchers. Study attempted to map landslide occurrence probability in the whole study area and along the road rout (Yang et al., 2012).

An attempt was made by Kim et al. to investigate greenhouse gas (GHG) emissions from onsite equipment usage. Their study was focussed on comparative analysis of the generation of GHGs by various equipment types used in different construction activities (Kim et al., 2012b).

In greenhouse gas emissions study researchers developed a framework that could estimate GHG emissions in asphalt pavement construction based on the limited information available in the feasibility study phase (Kim et al., 2012a). In another study seasonal deformation of unsurfaced roads was observed over several years and was studied using pavement deterioration models and finite-element analysis. These simulations and field measurements were used to study the effects of vehicle speed, load, suspension system, wheel torque, and wheel slip on rutting and washboard formation (Shoop et al., 2002).

A study in hill country of Nepal researchers focussed on a practical approach for the planning of rural road networks in hilly regions of developing countries. The research was focussed on the determination of obligatory points for the road network, which provides basic accessibility to settlements within a specified maximum walking time (Shrestha et al., 2017). In another study researchers studied the adverse impact of rainfall infiltration to asphalt concrete pavement (Hu et al., 2011). Another study reviewed the effects of various environmental factors on pavement performance (Ankit et al., 2011)

According to studies, temperature is an important climatic variable for flexible pavement design using a mechanistic-empirical approach. few studies attempted to seek potential temperature indices to correlate with distress predictions of flexible pavement. Researchers also aimed to explore the correlations between distress predictions and various potential temperature indices including total rutting, asphalt concrete rutting, thermal cracking, top-down cracking, bottom-up cracking, and the international roughness index (IRI) (Yang et al., 2017).

As per the American Association of State Highway and Transportation Officials (AASHTO) 1993, the mechanical properties of asphalt materials, such as the elastic modulus, are often measured at room temperature however, an asphalt concrete (AC) may experience a wide range of thermal regimes during the different climatic seasons. Study by Wright and Zheng, 1994 found that asphalt concrete becomes brittle when subjected to temperatures below −5°C.Temperature influences the performance of pavement, especially in the case of asphalt concrete (AC). The stiffness of AC is less at higher temperatures, making it susceptible to deformation. Low temperatures make the AC layer extremely brittle, and the surface becomes susceptible to cracking. As per AASHTO 1993, moisture variation also influenced the resilient modulus. The AASHTO design guide (AASHTO 1993) relies on physical properties to characterize pavement structure materials except the native soil (subgrade soil) (Maadani and Halim, 2017).

In another study Social impact was studied in six basic areas: (1) Beneficial development from the freeway construction; (2) effective and meaningful public communication; (3) reduction of harm during construction; (4) conservation of energy and material resources; (5) improvements to the visual quality of the freeway; and (6) social and economic benefits. (Yamanaka, 1983).

Permafrost soil due to its characteristics of low bearing capacity and instability, is not suitable for road construction (Ruan et al., 2014; Wang et al., 2014). The hill slope / inclination significantly impacts highway survey, construction, maintenance and operation. The inclination dictates maintenance and operation costs. The higher slope hill roads are more prone to geological disasters due to increased erosion intensity (Li et al., 2016).

In the permafrost the mean annual temperature of frozen soil is an important indicator. The soil with lower mean annual temperature will have greater cold storage capacity making frozen soil more stable. Frozen soil is easy to collapse and melt at higher mean annual temperature. Wang et al. estimated the average disease rate of the low temperature stable frozen soil zone as approximately 17% and the average disease rate of high temperature extremely unstable soil about 35% (Wang et al., 2016a,b). The high temperature permafrost is highly sensitive as severe disease rate increase to about 44%.

Ice content is another important parameter for permafrost. The higher ice content indicates higher soil porosity. At higher temperature increased soil deformation and thaw settlement disease occurs. The ice content of permafrost also indicates hill slope. The slopes lacking direct sun light have more ice content due to shade. Another researcher found in a study that increased ice content in permafrost negatively affects subgrade upto 80%, and the disease rate of pavement increases upto 120% (Xu, 2014).

Lack of design specialities and sophisticated equipment required for monitoring quality of construction, lack of data on soil conditions of permafrost during the previous years can cause manmade natural disasters on hill road highways. Permafrost may form continuous, broken and island type features and depending upon temperature soil may be classified as low temperature and high temperature permafrost soils. Salinity in permafrost has serious influence on soil features during construction stage. (Frolov, 2016)

Permafrost degradation is aggravated due to climate change and hill road construction activities (Heike et al., 2000; Thomas et al., 2003)

Along with highway transportation technology development, the material used for highway construction needs to be developed. Pavements in these regions need higher-grade asphalt concrete pavement (ACP) and cement concrete pavement (CCP). Researchers found that the thermal stability of embankments varies with pavement type. (Zhang et al., 2011).

Block-stone layers in hill roads in warm permafrost region are capable of adjusting heat dissipation in the sub surface soil. (Wang et al., 2020).

2.2 Gaps in Present Research

All research work has till now focused on place specific and parameter specific in construction of roads in India. There are various EIA studies specific to area or corridor developed more in the form of reports, but gap exists between construction planning, execution years, selection of equipment for the project, alignment and various technical considerations (Richardson, T. , 2005, Mareddy et al. 2017). The gap exists in base line data collection and monitoring and analysing it through the prism of researcher. There is a variety of erosion control measures for controlling road-related erosion although no study has demonstrated the method that is cost efficient and operational across different landscapes. This study may provide guidance in future research on hill road construction projects across the developing countries where sophisticated monitoring techniques are limited due to resource scarcity for assessing large areas. Present research encompasses study of various factors affecting hill roads and their Environmental Impact Assessment. Scope of research is vast to identify EIA parameters, monitor them and analyse to come up with approach to mitigate certain impacts of Muck on various environment factors including water quality, slope stability etc. Social impact assessment (SIA) also has been studied for hill road projects. Few more gaps are listed below, which are studied in this research:

a. Studies till now are area specific.
b. Implementation of EIA guidelines during road construction.
c. Rise in Temperature in the region due to road construction project.
d. Deforestation/change in vegetation due to road construction project.
e. Rainfall/Precipitation effect on road construction project.
f. Drainage.
g. Lack of data on landslides& mitigation techniques for reducing soil erosion.
h. Better ways to stabilise the muck.
i. Impact on surface/ground water.
j. Impact on air (decrease/ increase in air pollution).
k. Calculations of CO_2 emissions in the operational phase.
l. Habitat and ecology.
m. Impact on soil.
n. Effect of occasional snowfall on hill roads.

o. Impact on historic/cultural heritage and social environment.
p. Ethnic issues and security.
q. Lack of excavation data and disposal plan of muck generated in formation cutting of hill roads.
r. Effect of muck of road construction project on increase of bed-load transportation of river/stream.
s. Social impact assessment of hill road construction project using NSF method, Battelle method, and Checklist method.
t. Lack of standardization of cost estimation of construction of hill roads.

2.3 Research Methodology

Based on the objectives set for the present work and the background work reported in literature with the limitations, the methodology of research is proposed as follows:

❖ **Phase 1:**

During this phase a detailed literature survey on probable sites of soil erosion in the study area and their causes will be carried out. This entails data collection from Meteorological department & PWD from year of construction of road to till date for the following: -

a. Temperature variation over the years (^{O}C).

b. Rainfall data (mm).

c. Snowfall Data (Average number of days).

❖ **Phase 2:**

Measurement of muck generation due to road construction activity on the road stretch and disturbance to vegetation during construction phase. Following data shall be collected from Border Road organisation, Forest Department of J&K and Uttarakhand and GIS data from Civil Engineering Department of BITS, Pilani.

a. Quantum of soil excavated.
b. Disposal details of Muck, Quantity of earth dozed off/ transported to dumping sites

c. Vehicles and plant equipment with their duration employed during the construction of road
d. Data on Land slides
e. Maintenance carried out on this road stretch during this these years
f. Delineation of watersheds in project area
g. Variation in the strata year wise with the help of survey

❖ **Phase 3:**

This phase includes the analysis of muck disposal techniques, effect on slopes, soil erosion and water quality of streams/river in the valley. Various mitigation techniques and soil erosion control shall be studied.

❖ **Phase 4:**

Survey will be conducted in project area for collection of data various parameters, and it will be analysed with respect to guidelines and policy in vogue. Pollution check using an opacimeter during operation years shall be carried out. CO_2 emission for one year on project road shall be measured based on a survey of vehicular count. The water sample and soil sample monitoring season wise shall be done. Samples shall be analysed in lab for various constituents. Change / increase in bed-load transportation of River Kali during the construction years and operational years shall be evaluated. Effect of rainfall and snowfall on the constructed road and adjoining slopes and other seasonal variations during post construction phase shall be monitored.

❖ **Phase 5:**

Social impact assessment (SIA) shall be carried out by considering all criteria and survey shall be carried out in Dharchula town, villages and settlements connected by greenfield alignment and questionnaire feedback shall be evaluated. The NSF method, Battelle EES method and Checklist method shall be used to evaluate the social impact of project road.

❖ **Phase 6:**

Work will be concluded with the comparison between analytical and experimental results of the proposed study area. Estimation of cost of construction of hill road per km in India will be done. Based on the results obtained, the work will be compiled in thesis.

2.4 Scope of the present study

The present research aims to carryout study of various factors affecting hill roads and their Environmental Impact Assessment. Focus has been on Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) of project area during the construction years and operational years. Study incorporated the construction data and effect on project area including increase of bedload of river / streams along the route. The scope of EIA is unlimited beginning from the inception of project to the execution years and operational years culminating at the end of shelf life of a project. Present study has been inspired by the author's first-hand experience as head of execution team of road widening project of road Katra-Reasi from 3.6 meter to 12 meters. The study has two projects in two different geographical location, and one is road widening project in J&K and another a new road construction on greenfield alignment in Uttarakhand. The impacts on environment for both projects have been monitored, evaluated, and analysed with respects to multiple environmental parameters. The social impact of new hill road project on society is also studied in detail. Study shall form a foundation to conduct EIA and SIA in smooth manner for projects to be executed in future.

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3.1 Introduction

Hill roads in India are constructed in different ways. There are forest roads in mountainous and thickly forested areas. They are usually dirt roads or at best metalled roads. They are essential to preserve and safeguard forests and are completely controlled by the Forest Department of the state. There are national and state highways that crisscross the country sometimes passing through forests and hilly terrain. Occasionally, it is necessary to widen the existing roads by cutting into the hills and forest to accommodate increased traffic. The Border Roads Organization (BRO) in India is under the Ministry of Defence and they construct roads through difficult terrain like Uttarakhand, Himachal Pradesh, Arunachal Pradesh, and in Jammu and Kashmir (J&K) to establish the link with border villages. The road from Katra-Reasi in J&K (26 km) was widened by BRO from 2009 to 2012. This chapter attempts to quantify the Environmental Impact Assessment (EIA) of road construction through hilly terrain under different criteria. The project area lies in the district 'Reasi' which was created as the district in the Union Territory of J&K, India in 2007. It is predominantly a hilly district with variable climatic conditions ranging from sub-tropical to the semi temperate. Geographically, it is spread in the hilly and low-lying regions. The Chenab River and its tributaries flow through the district. Some small rivers/rivulets which flow in the project area are the Ans, Rudd, Plassu, Ban Ganga, Pai, and Anji. The district has a huge potential for micro and mini-hydro electricity generation as the Salal hydroelectric project of 690 MW is in the Reasi district. Reasi has many historical places of cultural and religious importance such as the following well-known shrines: Shri Mata Vaishno Devi Shrine, Shri Bawa Aghar Jitti Ji, Shri Shiv-Khori Shrine, Shri Baba Dhansar Ji, Shri Dera Baba Bhanda Bhadur Ji, Ziarat Baji Ismail Sahib Near Bharakh.

3.2 Background

Various EIA reports on road construction through hilly areas analyse the beneficial impacts with or without a project scenario. In principle, before any project begins, an evaluation needs to be carried out on the potential environmental impacts for its justification. The quarry or riverbed mining and muck disposal should as much as possibly follow the laws of the state mining department and optimum/ideal practices recommended in the Environmental Impact

Assessment (EIA) Manual (EIA Guidance Manual, 2010). The project report on the Narayanghat-Butwal road of Nepal in which the existing road was recommended to be upgraded to Highway Class II, 4-lane, 12 m formation width, 7 m carriageway width, and 2.5 m shoulders also considered the impacts by hilly road construction (*Environmental Impact Assessment NEP: SASEC Roads Improvement Project*, 2016). On hilly roads, landslides and slope stabilisation are critical issues. Retaining walls are often effectively used to prevent landslides in the hilly area by stabilising the fill slopes and cut slopes (IS 14458 (Part 1): Retaining Wall for Hill Area--Guidelines, Part 1: Selection of Type of Wall, 1998). The available literature recommends that earthwork and excavation should be undertaken in dry seasons to avoid erosion and silt runoff. From the initial construction cost considerations, it is always recommended to increase the extra width by filling, though requiring retaining walls costs much more than constructing the same width by cutting inside the hill. Similarly, the cost of a breast wall is several times more than a non-walled cut slope. Yet in consideration of maintenance cost, progressive slope instability, and environmental degradation from unprotected heavy excavations, the use of retaining walls on hilly roads and terraces appears to be more cost-effective. The most logical method consists of developing the formation width in half cutting and half filling so that the materials obtained from cutting are used in the filling. The excavation on the hillside is done to ensure a stable slope depending on the materials encountered. At places where there is a problem of retaining the hill slope, breast walls and gabion walls are constructed in natural slopes to retain the fill materials (Srinivasan et al., 2010).

The accumulation of water causes pore pressure leading to shear failure and mass movement of soil/landslides (Rashid et al., 2017). The construction and widening of the road include improvement in alignment, drainage, construction of new bridges, bridge approaches, traffic signs, retaining structures, junctions, and fresh alignment along certain stretches. In hilly areas, this is a herculean task both in terms of human and financial resources. But more importantly, the environmental impacts are tremendous and need a scientific approach to reduce and to mitigate such actions. In previous studies Multicriteria Decision-Making Methods (MCDM) have not been used to make decisions in the construction of hilly roads (Phogat and Singh, 2013). The various impacts though not observed in the short term may have much bigger effects in the long term. Hence, the Analytical Hierarchy Process (AHP) and Simple Additive Weights (SAW) methods of MCDM techniques have been applied in the decision making on the project.

3.3 The project area

The Katra-Reasi road connects Vaishno Devi Shrine at Katra to Reasi. Millions of pilgrim's travels on that road (Sharma & Raina, 2014). The road was considered for widening by Border Roads Organisation (BRO) and undertaken from 2009 to 2012 in two phases. The initial stretch of the road of 13 km starting from Katra was widened from 2009–2010. The next 13 km was widened from 2011–2012. This required alignment, land acquisition, forest clearance, earthwork, cutting of hill strata, dozing (bulldozer work) and hauling of debris from road stretch to dumping site. The complete distance was split into five different stretches based on varying terrains as shown in Figure 3.1.

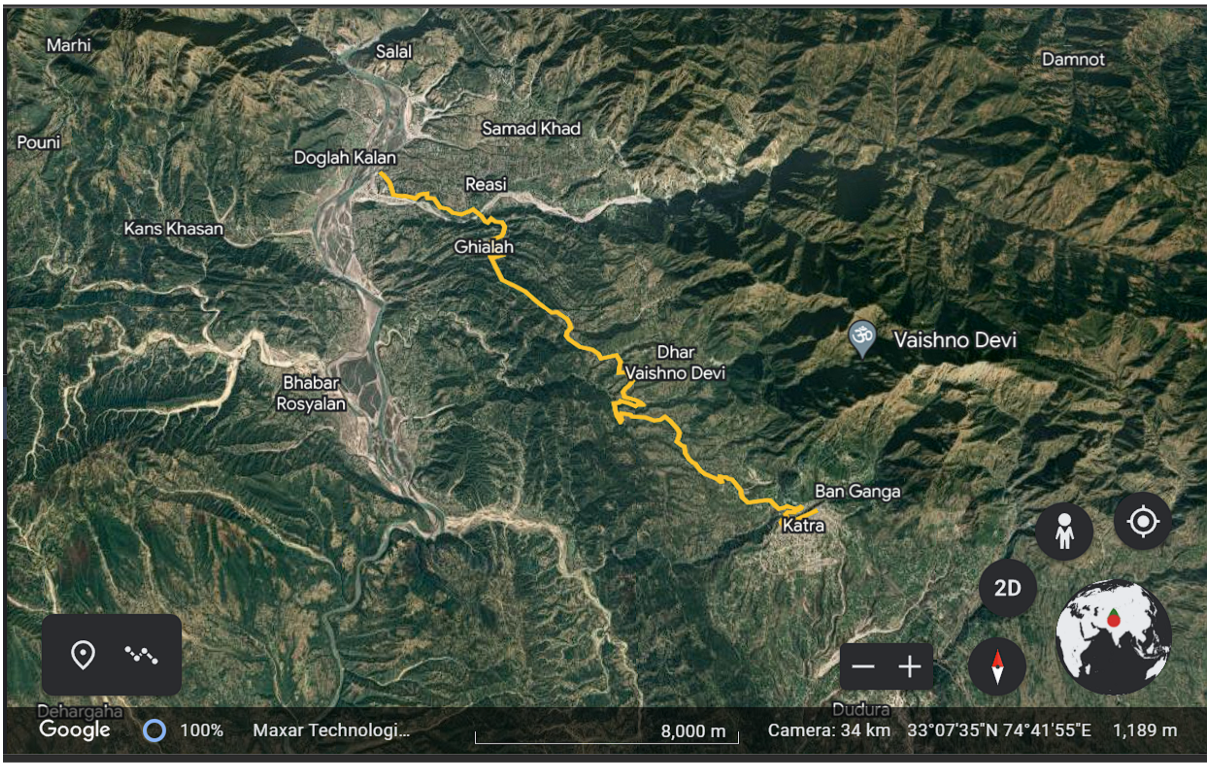

Figure 3.1 Google Map Showing the Project Area Ariel View of 26 Km Road (Source: https://earth.google.com)

The first stretch which commences from Katra Y junction and takes a hairpin turn near the railway tunnel and crosses Rivulet Ban Ganga is characterised by very steep mountainous areas. Rock drilling was done to widen the road and the stones and aggregates so produced were used in the sub-base course of various fill sections of that stretch of road. The drilling operation was very difficult and dangerous as muck, rock and boulders fell on the rock drilling equipment. This stretch took extensive resources in terms of time, manpower, and finances.

The sides of the road were protected by a breast wall running for almost 900 m on both sides of road with suitable drains on each side as shown in Figure 3.2.

Figure 3.2 Box cut at km 1 near railway tunnel (Source: Author's Field Survey)

The initial stretch required a dedicated team who coordinated well with railway authorities as the rail link from Katra to Udhampur passes over the road and the tunnel work was simultaneously under progress. The peculiar environmental problem was the disposal of the soil being dug out from the widening and tunnelling. The aggregates were tested at the lab at Katra detachment. The existing width of the pavement of 3.6 m was proposed to be widened to 10 m. It was proposed to provide 1.0 m wide shoulders on both sides of the road to serve as an emergency lane for vehicles leading to a total of 12 m wide formation width. In certain stretches, the widening was done up to 15 m to provide breast wall and construction of drain on the hillside. The formation work was executed using the following equipment: D80 and BD50 dozer, Bamford (JCB) machines, rock breakers, wheel loaders and tippers.

Most of the work in the second stretch included intensive excavation, hauling, and dozing operations. The breast wall stretched for about 2.4 km and the retaining wall was only constructed as and when required. The stone used in the retaining and breast walls was from the tunnelling waste and the excavations in Phase One area. The slope was gradual except for a 'Z' bend at the initial stretch (of the length 800 m) and a 'V' bend at the end which was almost 1.8 km in length and required a rock breaker.

In the third phase, the road extended from milestone Kilometre 10 to milestone Kilometre 15 from Katra as shown in Figure 3.3.

Figure 3.3 Dozer clearing a slope on hill side (Source: Author's Field Survey)

In the road stretch from Village Kotli Manotrian to Village Karin, excavation and hauling were extensively carried out and a stretch of 1 km was found to be over the hard rock which was cleared by a rock breaker. Fill sections are usually recommended because they are more stable along sloping sections than cut sections as shown in Figure 3.4.

Figure 3.4 A Retaining Wall Being Constructed to Avoid Cut Section (Source: Author's Field Survey)

The road stretch in the fourth phase was typically over areas with the hill on one side and the valley on the other side (see Figure 3.5). The movement on the road stretch was restricted and it was difficult to halt the passage of daily traffic for long periods. Accordingly, the work was done during off-peak hours to provide a smooth flow of daily traffic.

Figure 3.5 View of deforestation caused by dozer (Source: Author's Field Survey)

From Village Ghialah onward the task was herculean as it was over hard rock and high gradient. In the last stretch, i.e., fifth phase, the two-kilometre stretch from Village Ghilah took almost two years as it was passing through hard rock (Figure 3.6).

Figure 3.6 A Rock Breaker Operating on Last Stretch (Source: Author's Field Survey)

The EIA on the road widening project has been performed in this study in an integrated manner by taking into consideration all key criteria (factors) that influence the quality of the environment both during the project execution and later in the operational phases. The study brings out various environmental issues and geological features as discussed in the next sections.

3.4 Potential impacts of the construction project

After a thorough survey and study of the project, the key factors which have been influencing the environment have been identified. These factors are given below:

- **a.** Environmental setup and ecology of the project influence corridor.
    - i. Physical Environment
    - ii. Geological Environment
- **b.** Weather Analysis
    - i. Temperature Variations
    - ii. Average Monthly Rainfall
    - iii. Hail
    - iv. Sunshine /Cloud cover and Fog Conditions
    - v. Wind Velocity
- **c.** Rise in Temperature in the region.
- **d.** Deforestation/change in vegetation.
- **e.** Rainfall/Precipitation.
- **f.** Drainage.
- **g.** Land Slides.
    - i. Impact on Surface and Groundwater
    - ii. Impact on Air Quality
- **h.** Habitat and ecology.
- **i.** Impact on soil.
- **j.** Impact on historic/cultural heritage and social environment.
- **k.** Ethnic issues and security.
- **l.** Safety while driving.

The salient points corresponding these key parameters have been explained in the subsequent sections.

3.4.1 Environmental setup and ecology of the project influence corridor

a. **Physical Environment** The project road passes from Katra to Reasi in Reasi District in union territory of Jammu and Kashmir in India. In the project area alignment of road is along the series of ridges. The district is also rich in its flora and has a tremendous potential of horticulture fruits. i.e., Citrus, Quince, Mango, guava, apricot etc.
b. **Geological Environment** Traversing from Katra to Reasi the project road passes through the ridge line of sandstone and shale / mudstone. At certain places the rock strata are bare but due to soil deposition certain stretch has soil cover and along the road some agriculture activity is being practiced.

3.4.2 The Weather Analysis

3.4.2.1 Temperature Variations

The temperature data from Year 1950 to year 2020 was accessed from Customized Rainfall Information System (CRIS) available online at http://city.imd.gov.in. (Sample Data sheet for Katra and Jammu attached as Annexure '1'). The complete weather analysis was carried out for available meteorological data. In the project area the temperature was in the range of a maximum 32.3 ^{0}C and minimum 11.4 ^{0}C from Year 1980 to Year 2000. (Figure 3.7). However, from year 1980 to 2016 the temperature variation was found negligible. After completion of road widening project, the traffic in the study area increased from the year 2017 onwards. The study of temperature variation in the year 2017 to 2020 showed an increase in mean monthly temperature range by 1^{0}C (Figure 3.8). The variation in annual temperature is around 20.9 °C. The temperature data was taken from IMD station, Katra which is in the project area itself. The temperature dataset was further analyzed with nearest IMD station, Jammu to ensure consistency and to rectify any source of error.

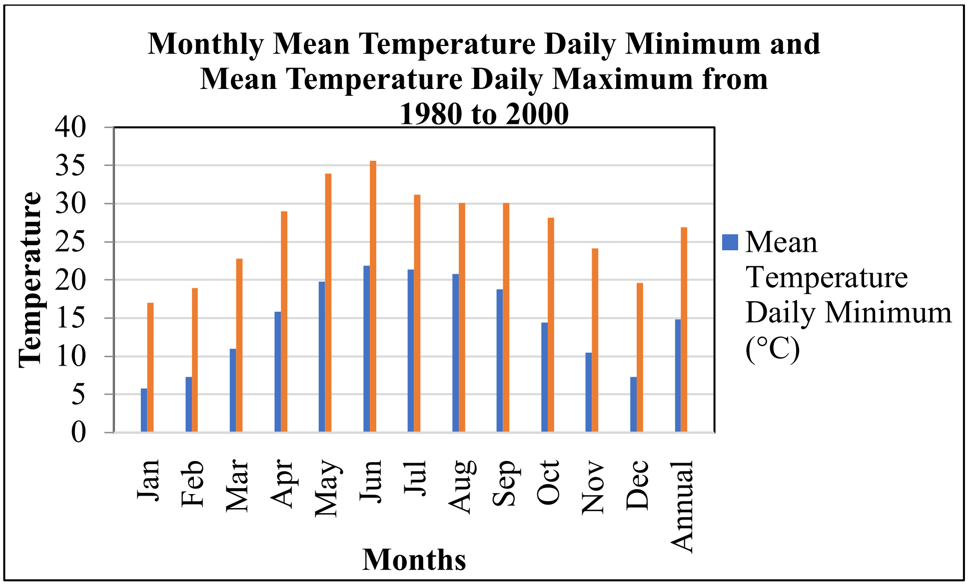

Figure 3.7 Average temperature of Reasi, Jammu year 1980 to year 2000 (Source: http://city.imd.gov.in)

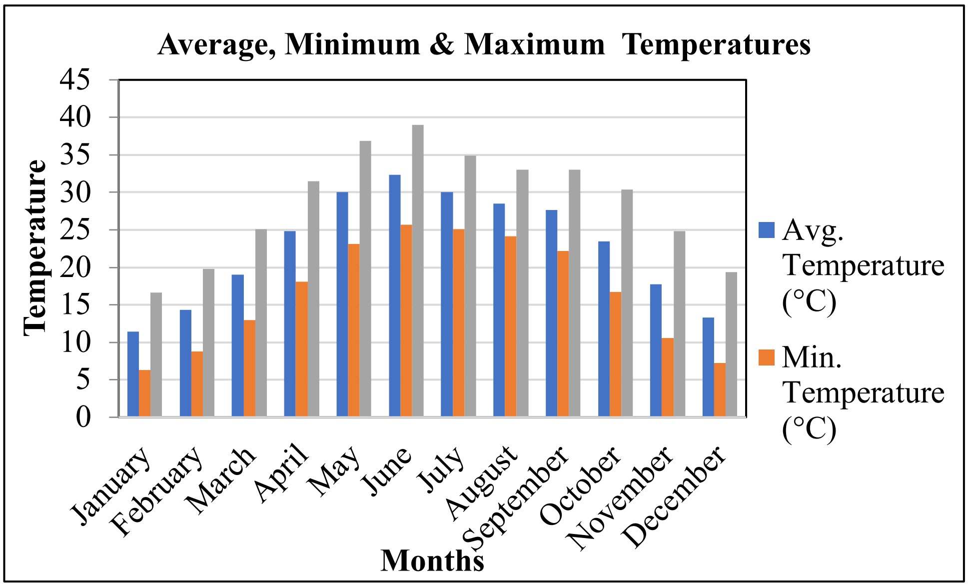

Figure 3.8 Average temperature Reasi, Jammu for year 2017 to year 2020 (Source: https://city.imd.gov.in)

3.4.2.2 Average Monthly Rainfall

The Average Annual Rainfall for Jammu and Kashmir was found to be 1205.3 mm. The least amount of rainfall occurs in November. The average in month of November is 13 mm. In August, the precipitation reaches its peak, with an average of 350 mm. The variation in the precipitation between the driest and wettest months is 337 mm. Figure 3.9 shows mean number of rainy days during each month of Year 1980 to Year 2020.

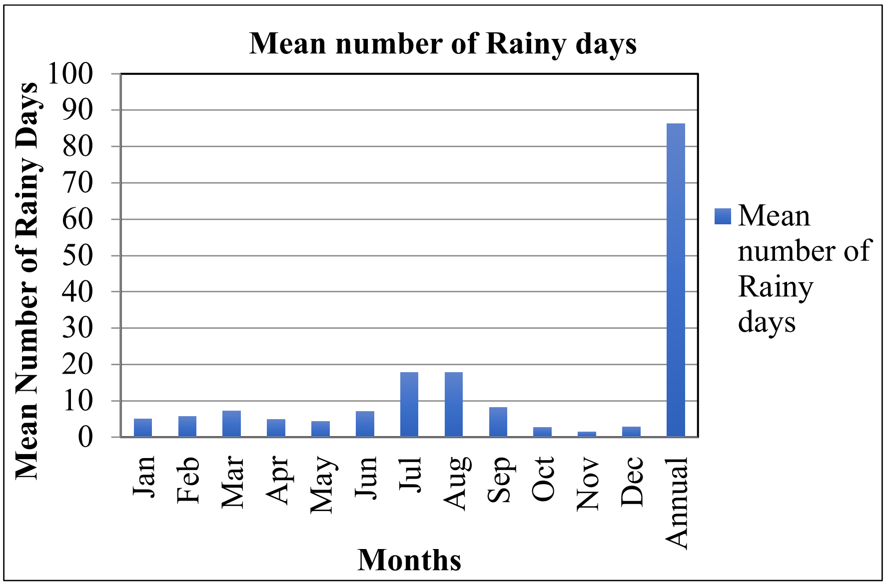

Figure 3.9 Mean number of rainy days from year 2017 to 2020 (Source: https://city.imd.gov.in)

3.4.2.3 Hail

The highest hail was observed in the month of March and followed by month of May. During rest of the year, it was measured at an average of 0.1 mm to 0.3 mm

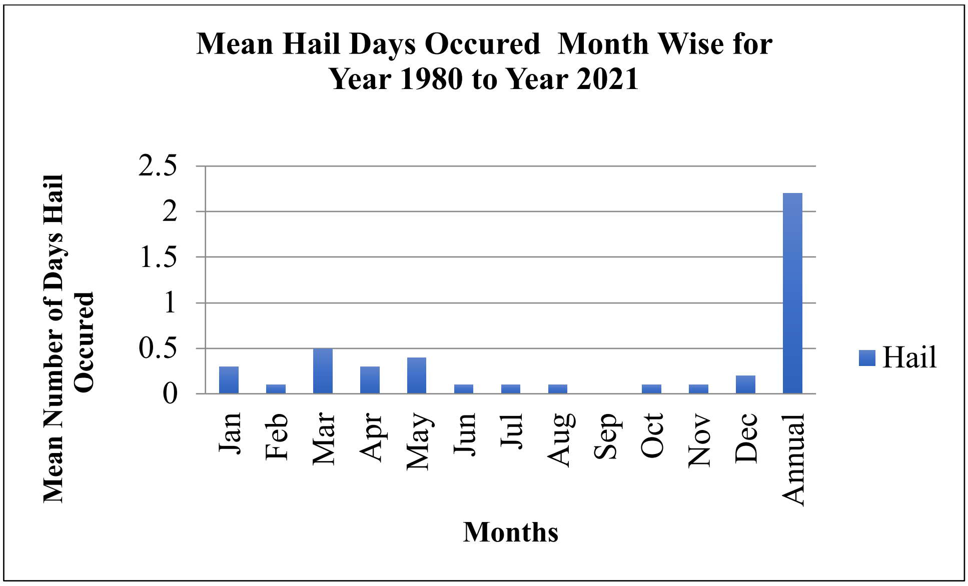

Figure 3.10 Average hail month wise from year 1980 to 2021 (Source: http://city.imd.gov.in)

3.4.2.4 Sunshine /Cloud cover and Fog Conditions

Based on observations of data collected over the years, it was observed that project area is marked by over 240 days of sunshine in the year and rest of the period was covered by clouds of varying extent though general visibility was found to be excellent for over 330 days in a year. Thick cloud cover and fog conditions were observed generally in winter season from mid of December to January end, each year. During winters the visibility also reduced during the day (Figure 3.11).

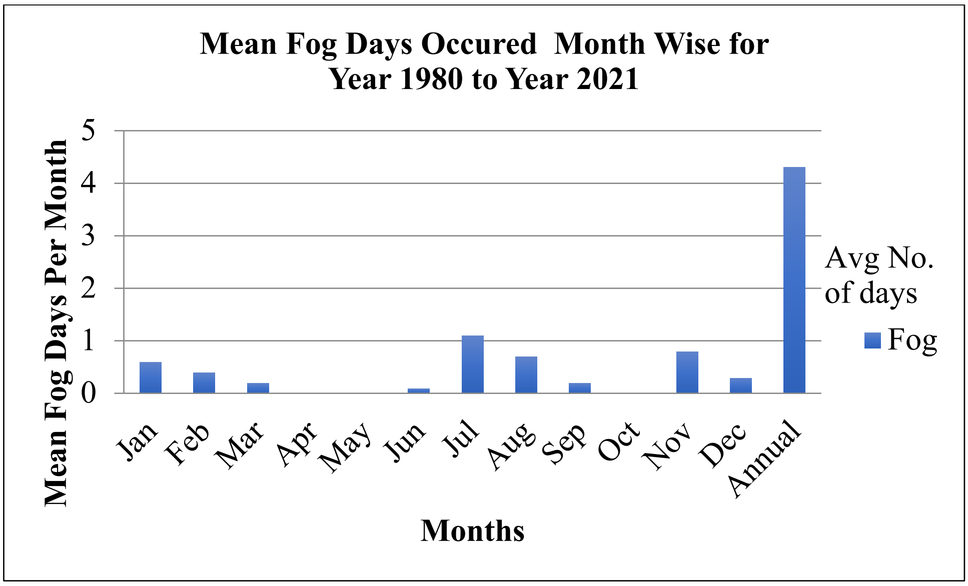

Figure 3.11 Average Fog Month Wise from Year 1980 to 2021 (Source: http://city.imd.gov.in)

3.4.2.5 Wind Velocity

Wind velocity has been 3.2 to 9.7 kph throughout the project area (monitored using automatic anemometer).

3.5 Rise in Temperature

The Inter-governmental Panel on Climate Change (IPCC) Special Report by the United Nations Environment Program highlighted concern at a temperature rise of 1.5°C globally which needs appropriate mitigation methods (IPCC Special Report on Global Warming, 2018). According to the data of the Indian Metrological Department (IMD), the mean temperature rose over by 1°C over the past eight years after the execution of the project (*Katra, Jammu and Kashmir and Https://www.Worldweatheronline.Com/Katra-Weather/Jammu-and-Kashmir/in.Aspx - Wikipedia*,) . This temperature rise is mainly owing to the increase in the number of visitors coming to Vaishno Devi Shrine and related construction activity in Katra Town. The pavement damage results from variation in temperature as expansion and contraction occurs (Rashid et al., 2013). Although the minimal shift in temperature does not cause damage to the pavement, it has been observed that the sudden variation of temperature causes transverse cracks in it. Changes in temperature that cause freezing and thawing during the winter season have impacted asphalt binding materials to a considerable extent.

3.6 Deforestation/ Change in Vegetation

The study of project site recommends that earthwork and excavation should be undertaken in dry seasons to avoid erosion and silt runoff (Phogat et al., 2022). The quarry or riverbed mining and muck disposal should, as much as possible, follow the laws of the state mining department and optimum/ideal practices recommended in the EIA Manual (Srinivasan et al., 2010). It is necessary to protect the environment and minimize erosion and landslides. In the project area, the vegetation which got disturbed during the execution of the project was (12 m minus 3.75 m existing of road) * 26,000 m = 2,14,500 m^2. The foliage loss from destruction during the dozing operations was temporary. The foliage has regained its original status. The middle portion includes the tributary of the Chenab which was selected as the source of Granular Subbase (GSB) material for the complete road stretch. Moreover, the area adjacent to the tributary was selected as a dumping site for excess muck, i.e., waste materials generated during operations of dozers. Excess quantity of muck was also used as fill material in an area of 800 m × 600 m protected with a 2 metre thickness wall made of riverbed material, stones, boulders, and wire mesh. The muck was filled all around the retaining walls and an adjacent perennial water source was used to develop the ecological/ environmental park in the area. Blasting was also employed at certain sites to avoid loss of time by use of a rock breaker. The project validated previous studies on the use of various forms of equipment and the percentage of damage caused to the forests. About 21% of trees were damaged by excavators and 33% of trees were damaged by bulldozers on very steep terrain. This confirmed an earlier study which showed that when using excavators, the forest area destroyed was 12.23% lower than when other equipment was used (*Deforestation Facts and Information*, 2022).

3.7 Rainfall / Precipitation

The rainfall during the period of execution caused some serious damage as shown in Figure 3.12 (Gupta, 2014). Surface water, drained off from the muck dozed off at the site, polluted the downstream surface water sources. The turbidity observed in stream water was very high. The pollution of the surface water sources was higher during the years of construction. Later, it subsided with the full recovery of vegetation on the valley side.

The flexible pavement is maintained every year to avoid any damage from moisture seeping after rainfall. The seal coat on the top layer was found to be of paramount importance in addition to suitable transverse slope/camber and the drainage along the pavement. Moisture that seeps in causes ravelling, cracks, stripping and rutting of the road. The wearing course rapidly fails as the bond breaks between the pavement's aggregate and the asphalt binder.

Figure 3.12 A Fresh Cut Slope Caved in due to Rains (Source: Author's Field Survey)

3.8 Drainage

The drainage if inadequate will erode embankments and adversely affect the pavement by the reduction in pavement subgrade strength as illustrated in Fig 3.13. The loss of slope stability will occur due to increase in moisture content in various layers of pavement.

Figure 3.13 A Temporary Drain on Hill Side During the Construction to Take Out Rainwater (Source: Author's Field Survey)

During the rainy season, the road surface may get inundated which if not drained adequately will cause potholes as seen in Fig 3.14. The freeze-thaw action takes place during winters due to snowfall. The roadside drain, cross drainage works, and catch water drains do contribute to slope stability.

Figure 3.14 The Potholes Caused Due to Lack of Drainage (Source: Author's Field Survey)

3.9 Land Slides

The evolution of the Himalayas has taken place over 26 million years, and it continues. Mass landslides occur so frequently that most slopes remain unstable. Heavy rainfall coupled with snowfall results in a deep weathering profile. The accumulation of water causes pressure leading to shear failure and mass movement of soil/landslides (Sur et al., 2021). The normal clearance of vegetation had very little negative impact on the environment but large-scale excavation on hill spurs owing to road construction had a major impact on the geophysical nature of the area (Hearn & Shakya, 2017). The landslides were limited as the contemporary topographical processes reflected stable slopes. Figure 3.15 shows a land slide caused by rainwater. Figure 3.16 shows the retaining wall being constructed to stabilise the road. At another location near milestone Kilometre 18 a retaining wall was made to widen the road. The higher gradient of slopes also caused landslides. Over eight years' period, the vegetation has reverted to its normal conditions as observed before the start of construction.

Figure 3.15 Landslide at milestone km 18 During Rainy Season (Source: Author's Field Survey)

Figure 3.16 The Retaining Wall Being Constructed at km 18 (Source: Author's Field Survey)

3.10 Impact on Surface and Groundwater

Surface water sources were polluted mainly by the waste generated during the clearance of vegetation. Pollution from leakage of oil from vehicles/equipment was minimal (Seutloali &Beckedahl,2015). Soil erosion was high during the years of construction as shown in the groundwater reports in the financial year-wise sample testing details for Reasi district, Jammu and Kashmir by the Ministry of Jal Shakti, Government of India (Sanitation & Ministry of Jal Shakti, 2020, https://ejalshakti.gov.in/). The disposal of sediments on the sides of nearby streams reflected the level of erosion and removal of soil cover in the area of construction. The impact on surface/groundwater sources was temporary during the construction years.

During the operational period of the road, surface water sources were polluted by plastic and other non-biodegradable products dumped or thrown out by road users which in due course affected the groundwater during rainy season. Tourism has potential adverse impacts on the environment as it increases the pressure on natural resources (e.g. harming plantation, wildlife and habitats, pollution to water bodies by wastes dumping, and associated loss of biodiversity) (Caliskan, 2013a). It was observed that there was an increase in turbidity in the water bodies, and in the concentrations of heavy metals and salinity and a decrease in the dissolved oxygen content of surface water in the affected areas (Sample Ground Water Report attached at Annexure 2).

3.11 Impact on Air Quality

Air pollution is mainly caused by the increase of harmful chemicals and particles in the air beyond the acceptable ranges. Main air pollutants are benzene, carbon monoxide (CO), nitrogen dioxide, naphthalene, formaldehyde, trichloroethylene, tetrachloroethylene, PM_{10} (particulate matter 10 micrometres or less in diameter), $PM_{2.5}$ (particulate matter 2.5 micrometres or less in diameter) (Pinguelli-Rosa & Kahn-Ribeiro, 2001). During construction, the sources of air pollution were from the exhaust gases generated from the necessary equipment, but these had little effect on people in the nearby villages along the road. Dust pollution, however, was predominant within 100 m of the dozing and excavation sites leading to a higher air quality index (AQI) along the road stretch (Singh et al., 2017). The road was still open to traffic.

3.11.1 Calculation of CO_2 emission per year for the 26 km road stretch

During the operation phase, the air pollution was predominantly high from vehicular emissions. Table 3.1 summarizes the values. The calculations for CO_2 emission were based on the fuel consumed by various vehicles as per the average mileage of 100 vehicles of each type from the physical survey. The parameters used in the calculations were 2.68 kg and 2.31 kg of CO_2 per litre of diesel and petrol respectively (Pinguelli-Rosa & Kahn-Ribeiro, 2001). All the two-wheelers were running on petrol. The other vehicles were considered as diesel operated. From Table 3.1, it is estimated that about 587000 kg (5.87 lakh kg) of CO_2 were emitted in one year along this single stretch of 26 km which shall increase by a hundred percent. For the calculations, the two-wheelers have been considered running on petrol, rest of all vehicles are considered diesel based. Remedial actions must include plantation of maximum trees in the highly sensitive zone- near to Katra city and near the railway tunnel, near Reasi city including Chenab River distributary up to 200 m on each side. In low sensitive zone i.e., the rest of the road stretch plantation up to 60 m on each side of the road should be done.

Table 3.1 Calculation of CO2 Emission in kg for one year

Type of Vehicle	Per day (no.)	Per Month (no.)	No. of Vehicles Per Year	Mileage on stretch kilometre/ litre	Fuel in Litres (l) consumed in the stretch in one year (litres)	Emission of CO_2 (kg)
Car/Jeep	80	2400	28800	13 kmpL	57600	154368
Bus	30	900	10800	3 kmpL	97200	260496
Minibus	18	540	6480	6 kmpL	29155	78135
Trucks	40	1200	14400	3 kmpL	25920	69465
Tempo/Auto Rickshaw	8	240	2880	26 kmpL	2880	7718
Two-Wheelers	42	1260	15120	52 kmpL	7560	17464

Type of Vehicle	Per day (no.)	Per Month (no.)	No. of Vehicles Per Year	Mileage on stretch kilometre/ litre	Fuel in Litres (l) consumed in the stretch in one year (litres)	Emission of CO_2 (kg)
Total				As measured during pollution check of vehicles during study.	220315	587646

3.11.2 Hartridge Smoke Unit % (HSU %)

a. Within the next 6 years with traffic estimated to double by year 2027 even after issuance of Bharat Stage (BS) VI emission standards for all major on-road vehicle categories in India. According to the Ministry of Roads Transport and Highways, the emission from internal combustion (diesel) engines when subjected to a free acceleration test is measured (AIS-137, Part-5, https://morth.nic.in/ais.). If the density of smoke emitted by the vehicle is less than 65 Hartridge Smoke Unit (HSU), then the vehicle is a non-polluting vehicle.

b. A reading of zero HSU means smoke is invisible; and 100 HSU means smoke is thick and opaque. Smoke tests were carried out to measure the thickness of smoke emitted by the exhausts of the vehicles using an opacimeter. The light absorption coefficient (k) value of the emission as measured by the opacimeter was used to determine the thickness of the smoke. When the vehicle's exhaust emitted black smoke, it showed a higher k value. During the research, 300 diesel vehicles were tested for pollution in the operational phase using a Diesel Smoke Metre (Make Namtech SM-054 & GA 954) on selected sections of the road. Table 3.2 gives out sample data of pollution check for few diesel vehicles and Table 3.3 summarises the values. The samples were collected from 144 cars, 18 three-wheelers, 90 trucks, 30 light commercial vehicles, and 18 buses.

From Table 3.3, the average readings of HSU were 34.01% for cars, 23.39% for three-wheelers, 34.2% for trucks, 35.46% for light commercial vehicles and 41.59% for buses. Similarly, the average values of light absorption coefficient (k) for these vehicles were observed as 1.004 for cars, 0.623 for three-wheelers, 1.009 for trucks, 1.047 for light commercial vehicles, and 1.258 for buses.

The results show that the HSUs of buses are the highest, followed by light commercial vehicles, heavy commercial trucks and cars, and three-wheelers in that order. The study also observed that the age and make of the vehicles had negligible impact on HSU (%) and light absorption coefficient (k) values.

(Sample Data sheet for Pollution Check conducted by author during research is attached as Annexure '3').

Table 3.2 Sample Data of Pollution Check Conducted During Research Work by Author

RPM min	RPM max	Temp	RPM	HSU%	K value	Mean HSU%	Mean K value
750	3110	48	3080	48.33	1.57	43.61	1.33
			3100	41.94	1.26		
			3130	40.57	1.21		
670	3580	62	3530	21.41	0.56	22.95	0.61
			3540	23.25	0.62		
			3540	24.18	0.64		
650	2410	67	2450	54.06	1.81	50.25	1.62
			2360	49.62	1.59		
			2450	47.07	1.48		
970	3840	46	3840	17.5	0.45	20.49	0.53
			3850	25.02	0.67		
			3800	18.95	0.49		
580	2370	74	2340	29.04	0.8	31	0.86
			2340	33	0.93		
			2350	30.97	0.86		
940	3260	63	3230	39.85	1.18	36.23	1.05
			3240	34.98	1		
			3260	33.87	0.96		

RPM min	RPM max	Temp	RPM	HSU%	K value	Mean HSU%	Mean K value
740	2280	65	2300	46.79	1.47	45.83	1.43
			2300	43.41	1.32		
			2270	47.28	1.49		
720	2960	62	2950	28.82	0.79	24.89	0.67
			2980	22.24	0.58		
			2960	23.6	0.63		
930	3540	61	3520	35.01	1	36.39	1.05
			3510	39.46	1.17		
			3510	34.71	0.99		
630	2090	74	2040	18.28	0.47	19.39	0.5
			2120	20.55	0.53		
			2100	19.35	0.5		
690	4880	50	4890	22.02	0.58	20.23	0.53
			4870	21.38	0.56		
			4850	17.28	0.44		
710	4450	79	4450	24.77	0.66	27.61	0.75
			4430	29.68	0.82		
			4450	28.38	0.78		
570	2380	45	2390	54.84	1.85	53.82	1.8
			2360	49.6	1.59		
			2330	57.01	1.96		
720	4100	74	4130	30.14	0.83	31.73	0.89
			4090	32.53	0.92		
			4090	32.53	0.92		
710	3840	56	3810	15.48	0.39	16.35	0.42
			3850	18.94	0.49		
			3800	14.63	0.37		
580	3170	43	3200	19.3	0.5	19.66	0.51
			3210	17.22	0.44		
			3180	22.45	0.59		
600	2280	66	2310	44.99	1.39	47.26	1.49
			2310	50.71	1.65		
			2310	46.07	1.44		
580	3540	63	3580	37.62	1.1	39.08	1.15
			3500	36.75	1.07		
			3530	42.86	1.3		

RPM min	RPM max	Temp	RPM	HSU%	K value	Mean HSU%	Mean K value
550	3230	52	3260	22.3	0.59	21.44	0.56
			3270	22.47	0.59		
			3200	19.54	0.51		
850	3310	42	3280	20.39	0.53	19.1	0.49
			3320	16.2	0.41		
			3320	20.72	0.54		
800	3000	43	2990	17.44	0.45	15.43	0.39
			2980	14.48	0.36		
			2980	14.37	0.36		
590	3180	54	3170	21.95	0.58	25.11	0.67
			3210	25.76	0.69		
			3170	27.62	0.75		
930	2090	56	2100	30.65	0.85	29.6	0.82
			2080	28.21	0.77		
			2100	29.93	0.83		
780	4290	41	4300	53.04	1.76	51.05	1.66
			4320	50.46	1.63		
			4250	49.65	1.6		
720	2540	41	2570	38.63	1.14	36.35	1.05
			2510	33.03	0.93		
			2530	37.4	1.09		
570	2140	40	2150	40.19	1.2	38.45	1.13
			2180	38.26	1.12		
			2160	36.89	1.07		
650	2850	78	2830	28.22	0.77	29.94	0.83
			2830	31.12	0.87		
			2850	30.47	0.85		
690	4770	61	4780	22.48	0.59	21.56	0.56
			4810	20.93	0.55		
			4720	21.27	0.56		
650	4320	43	4350	40.75	1.22	42.73	1.3
			4270	44.6	1.37		
			4320	42.85	1.3		
700	4790	56	4770	23.17	0.61	24.51	0.65
			4830	25.29	0.68		
			4750	25.08	0.67		

RPM min	RPM max	Temp	RPM	HSU%	K value	Mean HSU%	Mean K value
590	2920	62	2920	39.24	1.16	37.49	1.09
			2950	36.44	1.05		
			2880	36.8	1.07		
620	2220	58	2210	50.42	1.63	48.44	1.54
			2190	48.02	1.52		
			2220	46.88	1.47		
950	3970	69	3950	29.19	0.8	31.01	0.86
			3930	33.79	0.96		
			3960	30.06	0.83		
870	4640	73	4640	47.32	1.49	45.13	1.4
			4610	45.32	1.4		
			4680	42.74	1.3		
830	3160	50	3190	49.87	1.61	51.1	1.66
			3180	52.28	1.72		
			3130	51.16	1.67		
600	3020	53	3020	26.22	0.71	26.56	0.72
			2990	23.96	0.64		
			2990	29.49	0.81		
830	3160	50	3190	49.87	1.61	51.1	1.66
			3180	52.28	1.72		
			3130	51.16	1.67		
810	2880	70	2910	44.48	1.37	42.93	1.3
			2900	41.57	1.26		
			2890	42.75	1.3		
770	3330	75	3320	47.21	1.49	46.49	1.45
			3340	45.16	1.4		
			3330	47.1	1.48		
610	4610	41	4630	30.64	0.85	30.93	0.86
			4610	33.9	0.96		
			4610	28.26	0.77		
830	2610	48	2610	36.54	1.06	38.93	1.15
			2620	41.16	1.23		
			2640	39.1	1.15		
910	4710	66	4710	41.89	1.26	45.37	1.41
			4660	46.82	1.47		
			4700	47.4	1.49		

RPM min	RPM max	Temp	RPM	HSU%	K value	Mean HSU%	Mean K value
920	4080	48	4090	37.64	1.1	38.92	1.15
			4120	39.3	1.16		
			4100	39.81	1.18		
600	4480	73	4450	30.56	0.85	28.69	0.79
			4510	28.92	0.79		
			4450	26.59	0.72		
840	2550	60	2540	33.45	0.95	28.12	0.77
			2510	26.32	0.71		
			2500	24.59	0.66		
780	3790	43	3780	30.47	0.85	31.4	0.88
			3780	28.33	0.77		
			3810	35.39	1.02		
630	4600	48	4620	23.91	0.64	25.34	0.68
			4600	25.06	0.67		
			4590	27.05	0.73		
680	3610	58	3560	40.98	1.23	36.52	1.06
			3560	33.05	0.93		
			3640	35.54	1.02		

Table 3.3 Calculation of Average HSU (%) and Light Absorption Coefficient (K) Values for a Sample of 300 Vehicles using an Opacimeter (Source: Author's Field survey)

Type of Vehicle	RPM min	RPM max	Temp (oC)	Mean value of RPM	Mean value of HSU (%)	Mean value of light absorption coefficient (k)
Car	370.21	1656.88	29.21	1653.96	34.01	1.00
Three-Wheelers	645.00	3950.00	51.50	3935.00	23.39	0.62
Truck	698.00	3351.33	54.53	3350.44	34.22	1.01
Light commercial vehicles	733.33	3668.33	62.33	3669.44	35.46	1.05

Buses	656.67	3190.00	43.67	3193.33	41.60	1.26
Mean of all types of vehicles	726.88	3394.38	57.29	3390.63	33.89	1.00

3.12 Habitat and Ecology

The area is covered with conifer forest (Pine trees genus Pinus/ Pinaceae) and is habitat to various species including Cervidae (deers), monkies, Semnopithecus (langurs), Serpentes (snakes), Feliscatus (cats) etc.

The habitat has been divided into segments due to the road passing through the forest. More so forest has been split into two zones and segregating water bodies where all species ventured (Navin Gupta, 2014). The damage to fragmented habitat can be reduced by creating local rainwater harvesting in upper slopes which shall further develop thick vegetation near to sources of water.

3.13 Impact on the Soil

Road cut soil embankment has a higher soil loss rate, 16 times more than the fill slopes. The steep slopes, low vegetation cover, and loose colluvium increase the rate of soil erosion (Seutloali & Beckedahl, 2015). The soil quality certainly changed due to the removal of the top surface layer (humus). The excavation/filling and compaction of various layers on the road stretch required a huge quantity of material. The material extracted from the quarries and dumping on the road stretch as subbase and base course caused a massive movement of material. However, soil pollution was very meagre and localized due to various dumpsites used during excavation. Waste generated during construction included debris and construction waste, packing waste, waste spares from equipment, waste charcoal, oils and greases, and waste generated by manpower executing the task of road construction.

3.14 Impact on historic/cultural heritage and social environment

The road connects the holy shrine of Mata Vaishno Devi and further Shiv Khori another pilgrimage place. This has enhanced tourism due to the importance of archaeological and cultural lineage. On the socio front, it has a positive impact. Value of land adjoining the road has increased many folds. Better Road condition has enhanced tourism. Employment opportunities have increased. Many individuals have been gainfully employed in the transportation sector.

3.15 Ethnic Issues and Security

The social conflict between the road labour, migrants and the locals did come upon occasions but was amicably resolved with the help of the local administration. The explosive was used for hard rock was safeguarded and used in utmost security and supervision to avoid any mishap or threat to the community.

3.16 Safety While Driving

The study analysed the road accidents across Katra-Reasi road during 2010-2014 after collecting data from local police stations and other sources. It has been observed that with the increase in road width, number of accidents on the road have slightly increased with highest numbers during the construction time as shown in Table 3.4. The main causes for such accidents are due to over speeding, and lack of drivers' discipline.The complete set of data for number of accidents collected by author during research is attached in Appendix 'A').

Table 3.4 Data as per Road Safety Committee Meeting in April 2017 (Source: J&K Government website of District Reasi DC office, Jammu & Kashmir)

S. No.	Year	Total accidents	Death	Injury
1	2010	170	38	438
2	2011	168	47	329
3	2012	222	35	335
4	2013	218	33	355
5	2014	197	29	279

3.17 Multi-criteria Approach to Quantify the Impacts

This case study deals with a real-life problem of assessment of the impact of construction by incorporating multiple attributes in the analysis. The application of the MCDM method is carried out under the assumption that the study group has sufficient knowledge about impact assessment of environment by construction activity of hill roads. Such information makes the study group's intentions to focus on various criteria i.e., the environmental impacts while taking a decision involving higher financial stakes.

It is important to understand what are the different ways by which an individual (e.g., policy maker, implementing agency or even end user) can keep a balance among different alternatives available to him/her.

In the present study, an attempt has been made to assess the impact of satisfaction level of the decision maker for the construction of a two-lane highway by taking into consideration of the four alternatives, (i) impact on the environment (ii) impact on travel time, (iii) impact on economic resources, (iv) impact of duration of execution phase.

These alternatives have been assessed and prioritized under the framework of 14 criteria. Several approaches exist in the literature to address the multiple attribute decision-making process (Phogat and Singh, 2013).

In this study, Simple Additive Weights Method (SAW) and Analytical Hierarchy Process (AHP) methods have been applied which is demonstrated in subsequent paragraphs.

a. Application of Analytical Hierarchy Process (AHP): The AHP is extremely powerful and flexible decision-making process which assists users in setting priorities and take most appropriate decision considering qualitative and quantitative aspects.

b. In AHP synthesis of result is done by reducing complex decisions to a series of one-on-one comparisons. This way decision maker (DM) arrives at best decision with clear rationale.

c. AHP was developed by Dr Thomas Saaty, a professor at the Wharton School of Business. It is widely used and highly regarded decision-making theory. Dr Saaty along with Dr Ernest Forman, a professor of management science at George Washington University cofounded AHP software "Expert Choice".

d. The decision maker first makes pair wise comparison judgements throughout the hierarchy to consider sub-objectives and objectives and then achieving goal by best alternative course of action. It can predict likely outcome and facilitate group decision making. It can be utilised to allocate resources, select alternatives, carry out cost analysis or benefit comparisons and plan projected and desired futures.

e. Using AHP, the relative weights have been evaluated by performing pairwise comparisons among all fourteen criteria for the present case study (Cheung et al., 2001; Fong & Choi, 2000). Table 3.5 represents the relative weights of different criteria evaluated by the AHP (Decision Makers Committee entrusted with Project Management) (Peurifoy et al., 2018; A. P. et al. Singh,2017; M. V. S. Phogat & Singh, 2013; Ricketts et al., 2004; Saaty & Katz, 1990.).

f. The slope stability directly affects environment by soil erosion, increased sediment transportation in surface water runoff. The impact on travel time do not occur due to slope stability directly but has impact on economic resources and increases the duration of execution phase as well. Rise in temperature occurs due to equipment run during the construction phase is nominal and mainly due to traffic movement in operational phase.

g. Traffic movement on road increases with improvement in quality of road. For road widening the deforestation as criterion has impact on environment including resettlement and shifting of population adjacent to road and impact on habitat of animal species due to traffic movement.

h. An increased soil erosion on slopes is also considered as a sub-criterion of rainfall and landslides.

i. Drainage also creates impact on environment, increased cost of repairs as impact on economic resources if provided inadequately and impact on duration of execution by decreasing slope stability.

j. The air pollution and CO_2 emissions are concern for the environmentalist world-wide.

Based on the prominent potential environmental impacts, 14 criteria were selected with help of experts,

Table 3.5 Evaluation of relative weights for various environmental factors using AHP

Criterion	Weightage
Slope Stability	0.10
Rise in Temperature	0.10
Deforestation	0.0500

Criterion	Weightage
Rainfall/Precipitation	0.2000
Landslides	0.0200
Drainage	0.1000
Impact on surface water	0.0200
(Air pollution + or -)	0.0200
CO_2 Emissions	0.0500
Impact on soil	0.0100
Impact on cultural Heritage	0.0200
Impact on social environment	0.0400
Ethnic issues and security	0.0200
Safety while driving	0.2500

3.18 Application of SAW method

By the SAW method, the evaluation vectors for the four alternatives that were the focus were assigned with respect to fourteen criteria (Peurifoy et al., 2018; Saaty & Katz, 1990.). The evaluation vector matrix shows the alternative systems versus criteria array for EIA studies. It summarises the input evaluation matrix for the computation of the score of all four alternatives which is equal to the weighted sum of its cardinal evaluation/preference ratings. All the criteria considered were estimated quantitatively (Peurifoy et al., 2018; Fong & Choi, 2000; Ricketts et al., 2004). Some of the criteria may also be estimated subjectively, according to the impact levels of the different alternatives on the environment and considering the results of discussions with local decision-makers and stakeholders such as Border Roads Organisation (BRO), Public Health Department, and Forest Department. It is assumed that the 'true ideal point' is not known so that the approach of 'displaced ideal' is used. The ideal point is defined by the 'best' value in Table 3.6. At the opposite end of the best value, the 'worst value' of the criterion function is introduced.

Table 3.6 Defining ideal point by the 'best' value for various environmental factors using SAW

Criterion	Impact on Environment	Impact on Travel Time	Impact on Economic Resources	Impact on Duration of Execution Phase
Slope Stability	1.00	0.00	0.60	1.00
Rise in Temperature	1.00	0.00	0.63	0.81
Deforestation	0.68	0.62	0.00	1.00
Rainfall/Precipitation	1.00	0.43	0.06	0.00
Landslides	1.00	0.68	0.27	0.00
Drainage	1.00	0.44	0.00	1.00
Impact on surface water	1.00	0.83	0.00	1.00
(Air pollution + or -)	0.00	0.14	1.00	0.57
CO2 Emissions	0.45	0.00	0.36	1.00
Impact on soil	0.08	0.83	0.00	1.00
Impact on cultural Heritage	0.10	1.00	0.90	0.00
Impact on social environment	0.40	1.00	0.00	0.00
Ethnic issues and security	0.13	1.00	0.17	0.00
Safety while driving	1.00	0.90	0.00	0.27

The weights for each criterion have been evaluated from AHP after discussions with the Decision Makers (DMs) (Phogat & Singh, 2013). The score of alternative j using each criterion 'i' for all 'i' and 'j' has been obtained and the sum of the weighted score for each option was computed using the SAW method.

The ranking has been provided for all alternatives based on the descending value of the sum of the weighted score (Saaty & Katz, 1990). Table 3.7 summarises the results obtained by the SAW method of MCDM.

3.19 Results and Discussion

The results of the analysis in Table 3.7 clearly show that the impact on environment is ranked first and that on economic resources is ranked last. The sequence of most preferred to least preferred is Impact on Environment (Ranking 1), Impact on travel time (Ranking 2), Impact on duration of Execution phase (Ranking 3) and Impact on Economic Resources (Ranking 4).

Safety while driving has the highest impact on the environment. The impact of rainfall on the environment was measured at 24%. The rise in traffic and increased construction activity in and around town has caused a rise in temperature with an impact on the environment of 12%. Drainage, slope stability, and landslides have an impact of 12%, 8%, and 3%, respectively, on the environment. Impact from CO2 emission was measured at 3%. The results obtained by the SAW method of MCDM are appended in Table 3.7.

Table 3.7 Evaluation Matrix for different Alternatives Vs Criteria

Criterion	Impact on Environment	Impact on Travel Time	Impact on Economic Resources	Impact on Duration of Execution Phase
Slope Stability	0.069	0.000	0.023	0.100
Rise in Temperature	0.100	0.022	0.000	0.061
Deforestation	0.034	0.031	0.000	0.050
Rainfall/Precipitation	0.200	0.086	0.012	0.000
Landslides	0.020	0.014	0.005	0.000
Drainage	0.100	0.044	0.000	0.100
Impact on surface water	0.020	0.017	0.000	0.020
(Air pollution + or -)	0.001	0.012	0.000	0.020
CO_2 Emissions	0.023	0.000	0.018	0.050
Impact on soil	0.001	0.008	0.000	0.010
Impact on cultural Heritage	0.002	0.020	0.018	0.000
Impact on social environment	0.016	0.040	0.000	0.000
Ethnic issues and security	0.003	0.020	0.003	0.000
Safety while driving	0.250	0.225	0.000	0.067
Total Score	0.838	0.539	0.080	0.478
Ranking	1.000	2.000	4.000	3.000

The pie chart in Figure 3.17 illustrates the impact on the environment observed (as %) during the study.

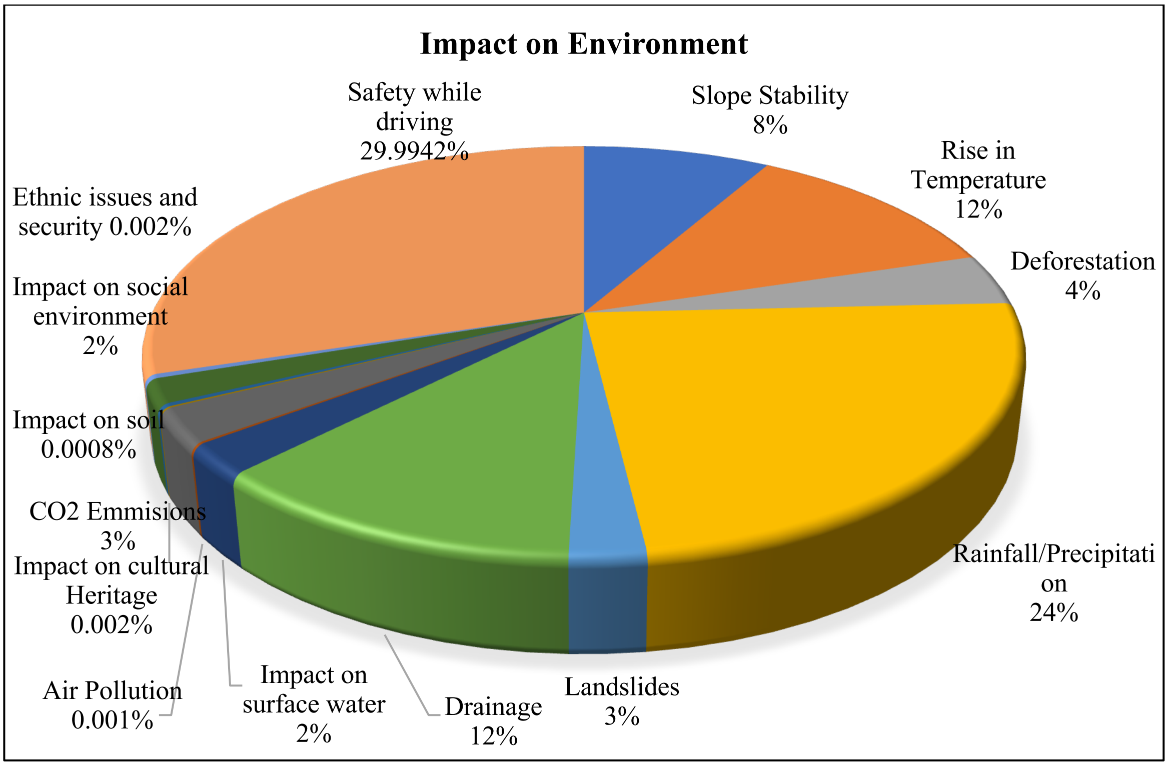

Figure 3.17 Pie Chart Showing Impact of Various Environmental Factors Due to Construction of Hill Road

3.20 Conclusions

The MCDM model presented in this chapter allows for the systematic evaluation of both qualitative and quantitative factors affecting decisions as well as a mechanism for the overall integrative evaluation of criteria. During the study, the priority of objectives was verified by the timely completion of the project. The choice for decision-making criteria will vary with the case, depending upon altitude, terrain, task, time of completion of project and cost. The MCDM tools have been proved to be very precise and comprehensive for taking decisions where bias should be avoided. Apart from decision-making about EIA parameters using MCDM tools the study also concerned other issues. Avoiding excavation during the rainy season reduced pollution of surface water in adjacent river stream.

The surface water hydrology was least altered because of minimal soil erosion and limited increased sediments in surface water. The landscape was disfigured to the least extent by road embankments during widening projects. The ecology and sensitive areas subject to human interference needed immediate EIA mitigation techniques. The project also caused dislocation and involuntary settlement of certain people whose houses were acquired in widening the road.

Retaining walls were immediately supported with plantation on slopes. Slopes in other stretches were adequately stabilised with subsequent plantation. Mitigation techniques for soil erosion were used by choice of natural biodegradable substances in construction. Suitable passage for wildlife and protection of flora and fauna by avoiding the sensitive area during the planning stage and driving without speeding (i.e., within the permissible speed limit) on the road stretch ensures safety of both human lives and wildlife. The results of the opacimeter test of diesel vehicles show that HSUs of buses are the highest, followed by light commercial vehicles, heavy commercial trucks, and cars; and three- wheelers have the least score. The results also show that the make and age of the vehicles had negligible impact on HSU and k values.

3.21 Recommendations

It is recommended that the EIA team should supervise the complete construction work in this project and ensure that the excavation works are done with minimum temporary loss of vegetation. The optimisation of the cut and fill section reduces the impacts to a great extent. Excavation material is recommended to be used with advantage in the fill section. The dumping sites should be planned initially, and rehabilitation of dumping sites should also be a part of the project's EIA. The planting of saplings should begin in the adjoining area even before the commencement of the project. The activities of the project should be conducted such that the nearby surface water sources are not polluted. Adequate drainage should be provided for the hilly roads and the drainage should be designed to reduce the speed of runoff water. Vehicles and equipment used for construction should be functional and tested for pollution norms regularly. Any spillage of material appropriately cleared reduces the impact on the environment. Suitable waste management at construction sites and recycling of resources is crucial for a hill road project.

3.22 References

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4 Chapter
Assessment of Sediment Load in River Kali due to Construction of Ghatiabagarh-Lipulekh Road Stretch in Hilly Terrain of Dharchula, India

4.1 Introduction

India has a pervasive and diverse network of roads connecting various states. The construction of hill roads has been taking place rapidly in India. Multiple agencies, such as the National Highway Authority of India (NHAI), Border Roads Organization (BRO), and various private construction companies, have been employed to achieve the country's desired road construction objectives. This chapter deals with assessing sediment load in river Kali mainly due to the construction of the Ghatiabagarh-Lipulekh road stretch located in Hilly Terrain in Dharchula, India. The road is constructed by the Border Roads Organization under quite challenging terrain and connects Lipulekh to New Delhi via Dharchula. The road has strategic importance for pilgrimage travel and tourism and is a lifeline for the people, especially in Kailash Mansarovar. It runs parallel to Nepal's international border (India Road Maps, 2021).

Keeping in view of the importance of this road stretch, a large number of construction and maintenance activities have been taking place in this road stretch along river Kali. As a result, a significant amount of suspended sediments (e.g., sand, gravel, cobbles, and boulders) are added to the river, forming ripples, dunes, fractal-shaped erosion, and silting of sediment dams down-stream (Basic Road Statistics of India 2016-17, (2019).; Connell et al., 2017; Zalasiewicz et al., 2008). For effective river management and environmental protection, the information of suspended sediment load is very crucial (Melesse et al., 2011).

Related studies in Kaligandaki basin of Nepal indicate that upstream regions known as High Himalayan region contribute 73% of the total estimated sediment load and 27% is contributed from Middle and High Mountain regions (*Sediment Transport - Wikipedia*). In another study by researchers in Malaysia, adaptive neuro-fuzzy inference system (ANFIS), regression model, and the GEP approach was used to predict suspended load in three Malaysian rivers: Muda River, Langat River, and Kurau River.

Studies conducted by researchers in the Jinsha River Basin (JRB) have found that hydrological and geomorphological processes in upper mountainous catchments are affected substantially by climate change and human activities. The study quantified the effects of construction of cascade dams on decreasing sediment load (Wiberg and Smith, 1989).

The climate variations cause higher precipitation and snow melting on glacier which in turn increases discharge and added sediment load in river (Sharmeen and Willgoose, 2006). In another related study researchers attempted to predict monthly flow and sediment load in Jajrood River, Iran using artificial intelligence techniques namely Artificial Neural Network(ANN), Adaptive Neuro-Fuzzy Interference Systems (ANFIS), Group Method of Data Handling (GMDH), and Least Square Support Vector Machines (LS-SVM) (Recking et al., 2008).

These sediments settle at the riverbed and change the river's ecosystems and affect land use patterns in the region. As there is no available evidence of any study on the impact of sediments in this particular river stretch, this study attempts to assess how the road construction in this hilly region has impacted the river due to increased sediment yield/soil erosion carried by runoff along steep gradients during rainfall.

There are three ways by which the grains can move, i.e., lifting of the grain, sliding of the grain up and out of its position on the bed: In this case, drag forces in the direction of most effortless movement must exceed the combined frictional and gravitation force in the opposite direction and thirdly by rotation of the grain about a pivot point formed by neighbouring grains, in this case, the moment of the fluid forces must exceed the moment of the gravitational force (Dupré et al., 2004; Recking, 2013).

When the bed shear stress exceeds a critical value, sediments are transported in bedload and suspended load (Recking, 2010). The channel's ability to entrain and transport sediment depends on the balance between the gravitational forces acting to settle particles on the bed and drag forces that work to either suspend them in the flow or push them downstream (*Google Earth*). A. Recking checked simple equations to predict the bedload transport rate with bed surface material diameters D50 and D84. The analysis was performed with 7636-bed load transport values from the flume, and f4 river reaches. A. Recking developed a new model that is less time-consuming. The parameters required are the flow discharge, the active width, the slope, and the surface grain diameters D50 and D84 (Dupré et al., 2004).

The problem of determining the bedload and suspended sediment in a stream system resulting from rainfall on an area of hill road construction site may be divided into three phases. The first phase is detaching soil particles and their movement from the construction area. The second phase is the transport of particles over the exposed surface directly dependent on slope length and gradient, generally referred to as the overland transport process. The last phase is the stream transport process which includes suspended sediments and bedload of stream.

4.2 Study Area

The movement of sediment is a natural part of the hydrologic system. The alignment of hill roads and their proximity to streams/rivers is considered one of the major sources of sediment in streams. This chapter describes how the hill road construction is held responsible for the increase in suspended sediment yield and bedload of River Kali measured through turbidity of the samples. Investigation of the effect of proximity of road site along the slopes of river Kali, various construction activities and effect of rainfall on the muck generated, gradient along the alignment and type of soil has been studied in detail.

The project road takes off at Dharchula, crossing River Dhauli Ganga, and runs parallel to River Kali (Uttarakhand District Census Handbook, Government of India, 2011). The total length of the road is 76 km. The project road traverses through the Tawaghat, Mangti, Chandra, and Kalapani to Lipukesh, falling in the district Pithoragarh of Uttrakhand State; the stretch of the project road passes through hilly terrain having a general height of 1000 m to 5200 m above mean sea level (MSL) (*Ministry of Road Transport & Highways, Government of India*). There are no settlements, and the road is a greenfield alignment constructed to improve pilgrims' journey speed and riding quality (Dey et al., 2019). The alignment does consider various watersheds and snowfall in the area.

The study observed the fluvial process of River Kali at three monitoring stations, Malpa, Najang, and Mangti, to estimate the fluvial sediment transported due to the construction of a greenfield alignment road. The project Environmental Impact Assessment (EIA) commenced well before environmental clearance (EC), forest clearance (FC), wildlife clearance.

The watershed area was calculated with the help of ArcGIS (Geographical Information system software), as shown in Table 4.1. Polygon 3 in Figure 4.2 shows the total catchment area for monitoring station Mangti. Ground survey aided by ArcGIS has selected all three monitoring stations. The significance of watershed delineation was to study the increase in bedload of

River Kali only due to formation cutting; hence the monitoring station selection done with the help of ArcGIS rules out inconsistencies that may occur during site selection for data collection.

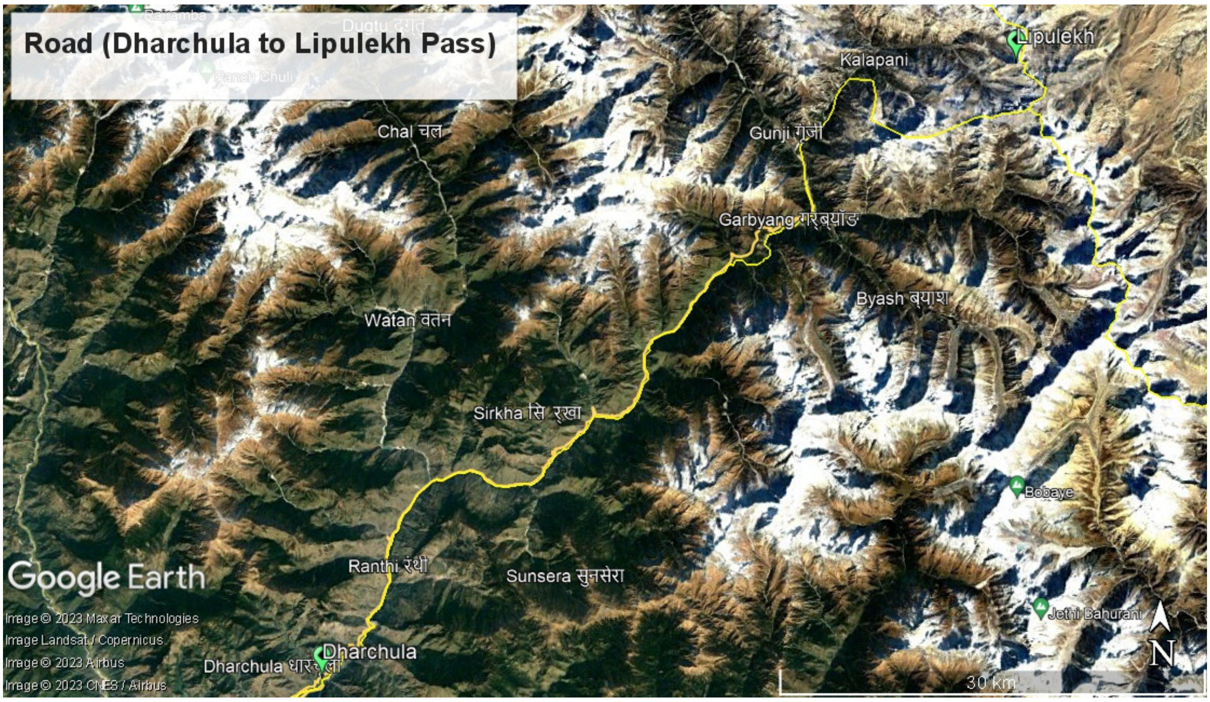


Figure 4.1 Google Earth Showing Study Area (Source: https://earth.google.com)

The study was exclusively focused on the mainstream of River Kali and avoided minor streams merging in the river because the bed load contribution from other streams was negligible.

Table 4.1 Total Area of the Watershed in the Project

Watershed	Watershed Perimeter (m)	Shape Area (km^2)
Watershed 1	243703.38	1069.54
Watershed 2	293301.60	1421.63
Watershed 3	149142.29	493.16

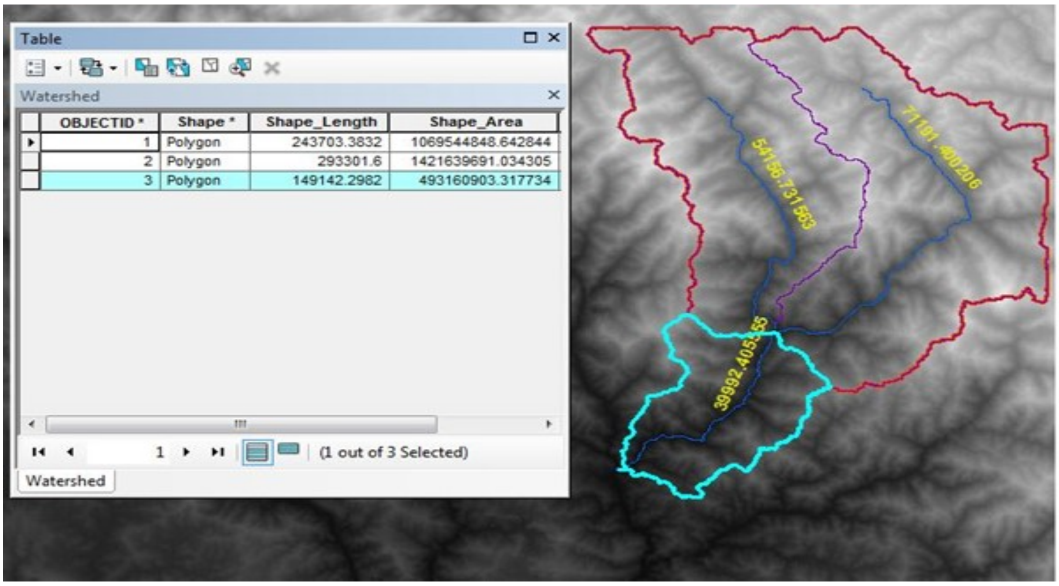


Figure 4.2 Total Area of the Watershed in the Study Area

4.3 Methodology

Figure 4.3 describes the research methodology for carrying out the environmental impact assessment of a hill road construction. The total muck generated during excavation and dumped on slopes was measured. The increase in bedload of River Kali is monitored at three monitoring stations, namely Malpa, Najang, and Mangti, located at 40km, 50 km, and 60 km, respectively, from Lipulekh Pass. The occurrence of sediments was measured in the form of turbidity during the complete duration of construction years. The river bed profiling was done, and various parameters, including flow discharge, the active width, the slope, and the surface grain diameters D_{50} and D_{84}, were measured. The samples were collected from the river bed at monitoring sites during various seasons for three years.

The generation of muck was studied due to formation cutting on a new alignment of the road as seen in Figure 4.4 and Figure 4.5, and its disposal sites located at three selected sites were examined. It has been observed that the generated muck has been disposed of on the downhill slope, which is the main cause of the increase in sediment load at river bed.

As described in Figure 4.5, sediments in the river bed are dependent on muck generation, which is a function of the type of construction equipment used and the number of hours runs for each equipment on the construction site. Excavated soil is either dozed off at the site itself or ferried to the dumping site at a selected low-lying area. Rainfall is another important parameter that dictates surface runoff and soil erosion. At last, when the surface runoff forms part of the adjacent stream, the bedload is a function of river bed profile, including flow discharge, active width of the stream, the slope of stream embankment, and grain size of runoff sediments. These parameters were measured at the construction sites and monitoring stations, as discussed in Figure 4.3. The log of equipment used for formation cutting and hours run was maintained, and soil samples at regular intervals collected from the site were tested. Based on activities held during the construction process and material balance statistics, it has been found that out of 19.98 Lac cum of rock cutting, the small/ medium boulders were 12.94 lac cum and 6.84 lac cum was hard rock, and 19.99 lac cum was soft rock (from the record perused of various equipment run logbooks).

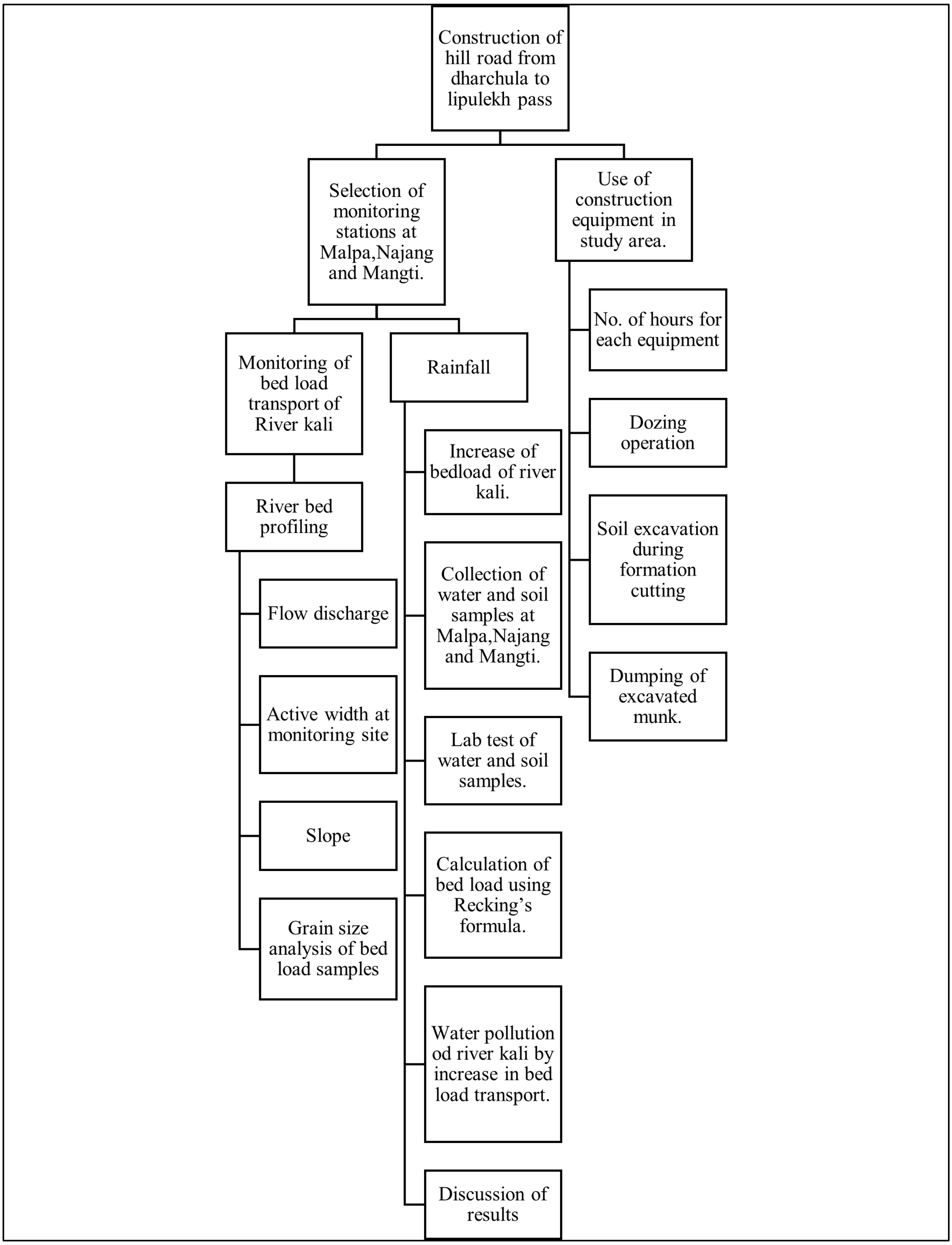


Figure 4.3 Flowchart showing research methodology

Figure 4.4 Rock breaker utilized in formation (Source: Author's Field Survey)

Figure 4.5 Air Compressor Utilized to Drill Holes for Blasting and Excavator Creating Trace Cut (Source: Author's Field Survey)

The water quality was also monitored and analysed to assess the impacts of developmental activities on the river water quality. The water quality samples were collected from three monitoring points. Various samples collected during the winter, summer, and rainy seasons were tested at the Civil Engineering lab of Birla Institute of Technology, Pilani, India. Table 4.2 shows the weighted average of various parameters at three monitoring stations. The study observed that TDS and turbidity directly reflect the increase in bedload.

Table 4.2 Analysis of Water Quality of River Kali During Years of Construction

Monitoring Station	Malpa	Najang	Mangti
Hardness (mg/L)	2.4	2.6	2.3
Chloride (mg/L)	1.7	2	1.5
pH	7.5	7.2	7
Turbidity (NTU)	174	145	164
Ca (mg/L)	1	0.6	0.4
Fe (mg/L)	0	0	0
Fluorides (mg/L)	0.1	0.1	0.3
Residual Cl (mg/L)	0	0	0
Dissolved Oxygen (mg/L)	7.5	7.3	7
TDS (mg/L)	105	94	89
Salinity (mg/L)	0.0695	0.1301	0.0257

Stream load is of three types, namely dissolved load, suspended load, and bedload. The study found that bedload and suspended load together form a total load of a stream. Wash load does not settle under typical flow conditions; hence wash load is excluded from analysis in the present study.

When mobilized, bedload particles remain near-continual contact with the bed, moving by either of three actions, including rolling, sliding, or saltation (hopping) along the river bed, as shown in Figure 4.6. The magnitude and turbidity of flow dictate bedload material, mainly coarser size fractions such as gravel bedload transport functions based on mixed grain size models using three-dimensional flow momentum equations (Recking, 2012). The sediment mobilization theory has an unreliable prediction of bedload transport in either flumes or rivers due to the inherent complexities of flow and sediment interactions at multiple scales (*Bedload - an Overview | ScienceDirect Topics*).

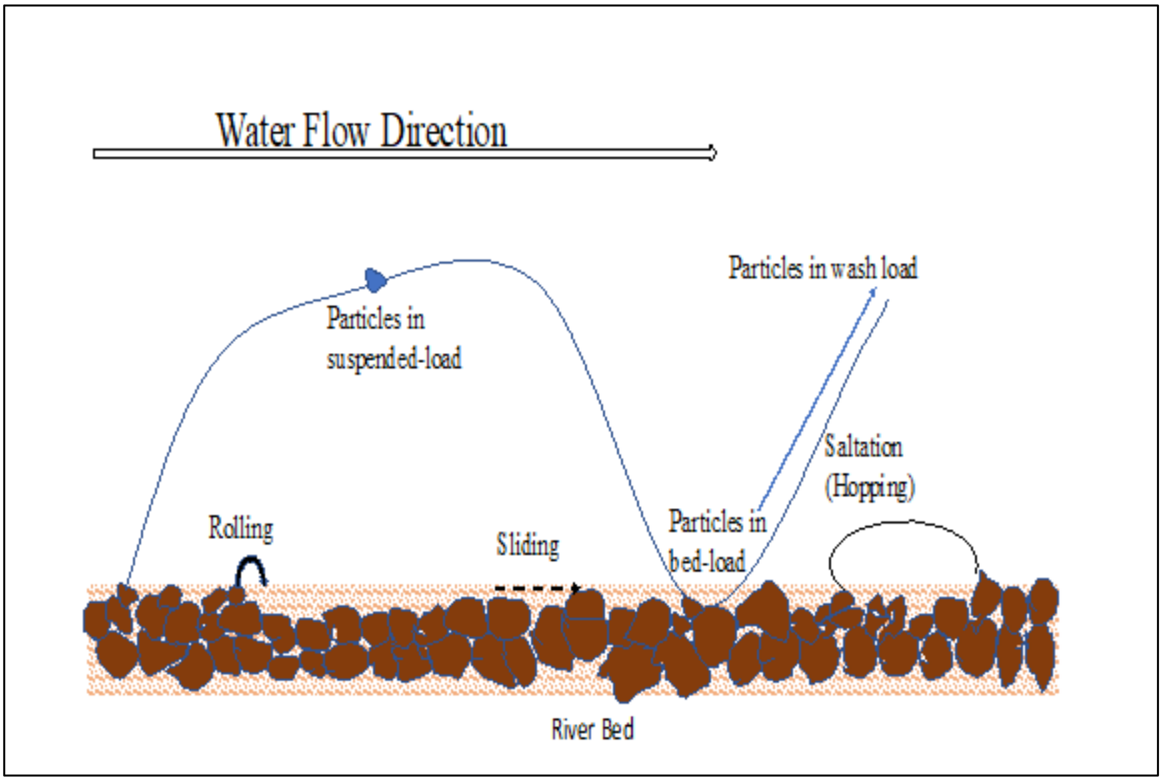


Figure 4.6 Three Modes of Particle Transported as Bed Load

When mobilized, bedload particles remain near-continual contact with the bed, moving by either of three actions, including rolling, sliding, or saltation (hopping) along the river bed, as shown in Figure 4.6. The magnitude and turbidity of flow dictate bedload material, mainly coarser size fractions such as gravel bedload transport functions based on mixed grain size models using three-dimensional flow momentum equations (Recking, 2012). The sediment mobilization theory has an unreliable prediction of bedload transport in either flumes or rivers due to the inherent complexities of flow and sediment interactions at multiple scales (*Bedload - an Overview | ScienceDirect Topics*). The bedload transport models are either based on calculations of excess shear stress or the difference between the bed shear stress provided by a flow and the critical bed shear stress required to mobilize sediment. In maximum studies, individual grain mobility ignores grain size distribution, bed shear stress, degree of bed armoring, and bed morphology (U.S.Army Engineers). The US Hydrologic Engineering Centre's River Analysis System (HEC-RAS) software can simulate one-dimensional longitudinal sediment transport under mobile channel bed conditions (Tsai et al., 2010). Recent research focuses on the calculation of bedload based on measured data of suspended load by considering average velocity profile and average concentration profile for an irrigation channel by modifying the Einstein method (Rheinheimer & Yarnell, 2017). The study of erosion and deposition of bedforms during a flood event can vary from measured sediment transport rates based on particle size alone (Haschenburger, 2019). As per previous studies, bedload is approximately proportional to the mechanical power (work per time) dissipated in a river or stream at high flows. The curving or meandering of channels is an outcome of the physical results of particle transport (Drake et al., 1988).

The study further observed that increased erosion on the outer bends caused scouring and meandering effects during the rainy season. Due to particles' movement, both suspended sediment and bedload, an outward extension of the curves occurs, which is a granular phenomenon (Recking, 2013). Grain's motion is due to slide and roll activity resulting in traction, hopping, and stream bed, resulting in saltation (Chatanantavet et al., 2013). The suspended grains are maintained in the water column by upward-directed turbulent eddies. The occurrence of micro-leaps smaller than the grain diameter creates the ballistic saltation trajectories a step further from rolling and sliding (Meinshausen et al., 2009). The bed load calculations using the Bagnold approach, Samaga et al. approach, Meyer-Peter equation, and Van-Rijn's equation showed divergence from the measured bed load. Results of measured data and prediction of bedload using Recking's model are accurate for three monitoring stations in this study.

4.4 Collection of Bed Load From Stream Bed

4.4.1 Bedload prediction using Recking's model

The required input data for the computation of bedload transport rates are the river width (W), which may be discharge dependent, the slope (either energy slope or the bed slope when the flow is considered nearly uniform), and bedload grain sizes d_{16}& d_{84}[10]. The Recking model, as used in this study, is given equation (4.1), (4.2) and (4.3) (Recking, 2012)

$$\Phi = 14 \, \tau_{84}^{*2.5} \Big/ \left\{1 + \left(\tau_m^* / \tau_{84}^*\right)^4\right\} \tag{4.1}$$

Where,

$\tau_m^* = (5S + 0.06)\left(d_{84}/d_{16}\right)^{4.4\sqrt{S}-1.5}$ τ_m^* is dimensionless shear stress due to mobile particles.

τ^*_{84} is dimensionless shear stress due to a percentage finer than 84% fine particles and can be expressed as $\tau^*_{84} = \frac{SR}{d_{84}(s-1)}$.

S is relative density and density of sediment is 2650 Kg per cubic meter.

The modified form of these dimensionless parameters is as below;

$$\tau^*_m = 0.041 * \left(\frac{D_{84}}{D_{16}}\right)^{-1.18887} \tau^*_{84} = \frac{0.91630}{D_{84}} \quad \text{(For Cross-Section 1)} \tag{4.2}$$

$$\tau^*_m = 0.041 * \left(\frac{D_{84}}{D_{16}}\right)^{-1.18887} \tau^*_{84} = \frac{0.94457}{D_{84}} \quad \text{(For Cross-Section 2)} \tag{4.3}$$

4.4.2 Grain Size Analysis

The bedload samples were collected at various points, including Malpa, Najang, and Mangti, during the winter, summer, and rainy seasons. Sieve analysis was done for a total of 90 samples. Each season total of ten samples at each monitoring station was collected at an interval of 100 meters approximately to arrive at a weighted average grain size, as shown in Table 4.3, Table 4.4 & Table 4.5

Table 4.3 Grain Size Analysis Bedload at Malpa, River kali During years of Construction (Source: Sample Tested at Bits Pilani Lab)

Grain Size Distribution at Malpa					
Sieve size (mm)	**Retained Weight on sieve size (g)**	**%age of weight retained**	**%Cumulative weight retained**	**%age Finer by weight**	**Remarks**
10	47	1.3016	1.3016	98.6984	D_{90} = 2.6mm
4.75	145	4.0155	5.3171	94.6829	D_{84} =1.9 mm
2.36	207	5.7325	11.0496	88.9504	D_{50} =0.32 mm
1.18	380	10.5234	21.573	78.427	D_{16} =0.13 mm
0.5	453	12.545	34.118	65.882	
0.3	563	15.5912	49.7092	50.2908	
0.15	851	23.5669	73.2761	26.7239	
0.075	965	26.7239	100	0	
Total Weight	1000	100			

Table 4.4 Grain Size Analysis Bedload at Najang, River kali During years of Construction (Source: Sample Tested at Bits Pilani Lab)

Grain Size Distribution at Najang					
Sieve size (mm)	**Retained Weight on sieve size (g)**	**%age of weight retained**	**%Cumulative weight retained**	**%age Finer by weight**	**Remarks**
10	29	0.691	0.691	99.309	$D_{90} = 2.9$ mm
4.75	151	3.5978	4.2888	95.7112	$D_{84} = 1.8$ mm
2.36	239	5.6945	9.9833	90.0167	$D_{50} = 0.35$ mm
1.18	509	12.1277	22.111	77.889	$D_{16} = 0.13$ mm
0.5	621	14.7963	36.9073	63.0927	
0.3	774	18.4417	55.3491	44.6509	
0.15	906	21.5868	76.9359	23.0641	
0.075	968	23.0641	100	0	
Total Weight	1000	100			

Table 4.5 Grain Size Analysis Bedload at Mangti, River kali During years of Construction (Source: Sample Tested at Bits Pilani Lab)

Grain Size Distribution at Mangti					
Sieve size (mm)	**Retained Weight on sieve size (g)**	**%age of weight retained**	**%Cumulative weight retained**	**%age Finer by weight**	**Remarks**
10	38.5	1.913	1.913	98.087	
4.75	76.5	3.8012	5.7143	94.2857	D_{90}= 2.8 mm
2.36	94.5	4.6957	10.4099	89.5901	D_{84}= 1.0 mm
1.18	150	7.4534	17.8634	82.1366	D_{50}=0.17 mm
0.5	174	8.646	26.5093	73.4907	D_{16}=0.09 mm
0.3	207	10.2857	36.795	63.205	
0.15	379	18.8323	55.6273	44.3727	
0.075	893	44.3727	100	0	
Total Weight	1000	100			

The grain size distribution for Malpa is D_{90}=2.6mm, D_{84}=1.9mm, D_{50}=0.32mm, and D_{16}=0.13mm. For Najang, grain size distribution is D_{90}=2.9mm, D_{84}=1.8mm, D_{50}=0.35mm, and D_{16}=0.13mm. The grain size distribution for Mangti is D_{90}=2.8mm, D_{84}=1.0mm, D_{50}=0.17mm and D_{16}=0.09mm.

The river bed profile has been shown in table 4.6, 4.7 and 4.8 for Malpa, Najang and Mangti respectively. These are the three locations where data was collected.

Table 4.6 River Kali Bed Profile at Malpa. (Source: Author's Field Survey)

Cross-Section Data (Malpa); Total Width 48m	
Distance from left bank (m)	**Depth (m)**
0	0
5	-1.5
12	-3
24	-3.8
36	-2.8
41	-1.2
48	0

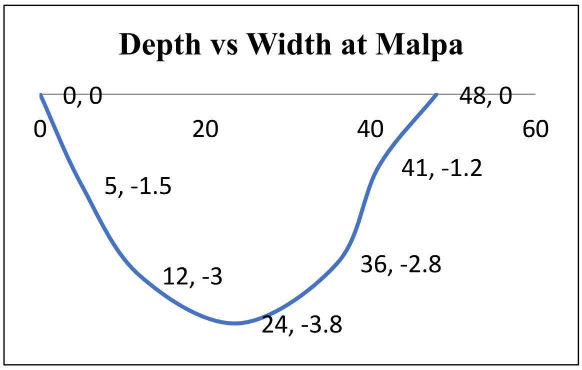


Table 4.7 River Kali Bed Profile at Najang (Source: Author's Field Survey)

Cross-Section Data (Najang); Total Width 30m	
Distance from left bank (m)	**Depth (m)**
0	0
5	-2
10	-4
15	-5
20	-3.8
25	-2.1
30	0

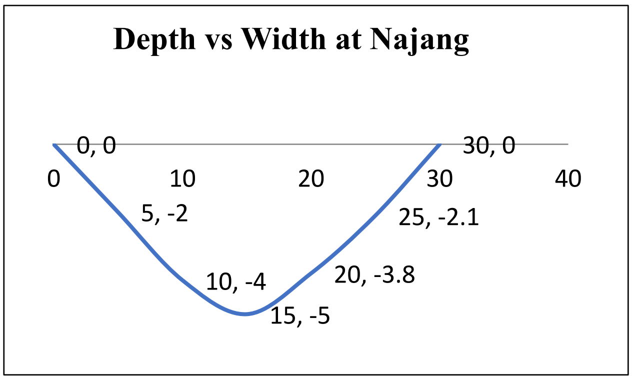
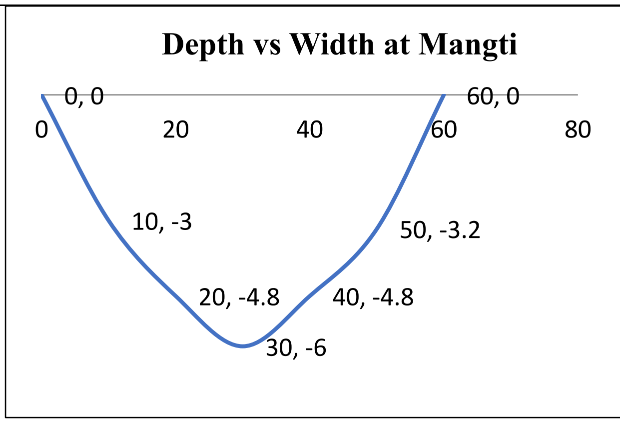


Table 4.8 River Kali Bed Profile at Mangti (Source: Author's Field Survey).

Cross-Section Data (Mangti); Total Width 60m	
Distance from left bank (m)	**Depth (m)**
0	0
10	-3
20	-4.8
30	-6
40	-4.8
50	-3.2
60	0



4.5 Results and Discussion

The study focused on the observation and analysis of bedload particles generated during the construction of hill roads. The bedload consisted of particles ranging in size from 0.5 mm to over 10 mm. The findings revealed important insights into the composition and transportation of bedload in relation to various environmental factors.

The average size of bedload particles measuring 1.18 mm and above accounted for 22% of the total sample material. In contrast, suspended particles with diameters less than 0.1 mm constituted an average of 24% of the entire sample material. Larger particles exceeding 10 mm in diameter were relatively scarce, comprising approximately 2% of the bedload. It is important to note that these observations were made during average flows.

During high flow periods, the bedload composition exhibited significant variations, including the presence of large particles and even rock content from the excavation site. This underscores the influence of flow conditions on bedload transportation and the potential impact of construction activities on stream ecosystems.

The calculated bedload values for three specific monitoring stations, namely Malpa, Najang, and Mangti, were determined to be 0.0594841 tonnes/day, 0.0588199 tonnes/day, and 1.58733 tonnes/day, respectively. These values provide crucial information for assessing the pollution load generated by hill road construction at specific locations. Engineers can utilize this data to guide decision-making processes, including the selection of road alignments and locations.

The predicted bedload values can also serve practical purposes such as designing the capacity of dumping sites, planning suitable drainage systems, and implementing slope stabilization measures. Furthermore, these predicted values can be used as a baseline for evaluating the effectiveness of sediment control measures implemented in highway construction areas.

The construction of hill roads often exposes steeper slopes to rainfall, resulting in increased runoff velocities and subsequently higher bedload transport in adjacent streams. The overall bedload and suspended sediment yield are influenced by several environmental factors, including the area of the exposed construction site affected by rainfall, the presence of additional streams along the route, the bed profile, and the width of the river.

It is worth noting that attempts to mitigate the increased bedload and resulting water pollution through measures such as increased plantations have proven unsuccessful due to the challenging conditions at higher altitudes and inclement weather. Moreover, such mitigation techniques are often not economically feasible in these environments.

The study emphasizes the importance of minimizing excavation and earthwork during the implementation phase of hill road construction to preserve the environment. Safer and more effective alternatives, such as the use of elevated hill roads, should be considered to minimize the negative environmental impacts associated with conventional road construction.

In conclusion, this study provides valuable insights into bedload generation and transportation during hill road construction. The findings can be applied in various ways, including assessing pollution sources, guiding engineering decisions, designing infrastructure, and evaluating sediment control measures. By considering the environmental factors and implementing sustainable practices, it is possible to reduce the ecological impact of road construction activities in hilly regions.

4.6 Conclusion and future scope

Effective sediment management is essential for both newly proposed and existing highway/road projects and other developmental infrastructure projects in the hilly regions due to its geologic and climatic conditions. Therefore, it is essential to adapt proper grassland and watershed management to control sedimentation and excess erosion from anthropogenic activities. An increased sediment load can increase the operation and maintenance costs and decrease the infrastructure facilities' useful life. In the hilly region, especially Ghatiabagarh-Lipulekh Road Stretch in Dharchula, hydrologic models such as Soil Water Assessment Tool (SWAT) should be applied to predict hydrologic regime and resulting sedimentation in the rivers so that high-risk areas can be identified and sediments in the river can be controlled. This study with available limited sediment concentration data is an attempt to understand the current status of sediment load. Due to the difficult geologic and climatic conditions, getting observations through sediment concentration gauges is quite difficult. However, we must capture sufficient sedimentation data to formulate hydrological models in the coming times. Better data would certainly help develop efficient watershed management plans that can be used to develop appropriate management strategies/scenarios that would address the increasing life of infrastructure and mitigate climate change impacts.

Also, an engineer must establish the location of alignment of hill road in the catchment area for minimum disturbance to slopes, least earthwork/excavation reducing bedload of streams by increasing the distance from a stream. Increased distance from streams to the construction site would usually reduce the bedload but would increase the cost of construction of hill roads with increased instability and enhanced chances of landslides in the construction area. Hence, an optimum balance has to be achieved in the economy, and environmental impacts caused.

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5 Chapter
Social Impact Assessment of Construction of Hill Road (Ghatiabagarh-Lipulekh Road Of 76 Km) on Green Field Alignment in Dharchula, India

5.1 Introduction

India is the fastest-growing economy in Asia (Gurung, S.K, 2021), with diverse terrain, weather, seasons varying with every state. The hill roads form a very intrinsic part of development in a country with a large population of 1.3 billion people. Uttarakhand, the 27th state of India, was created on 09th November 2000, being carved out from Uttar Pradesh with Himachal Pradesh on its Northwest and Uttar Pradesh on the south. This hilly state is located on the foothills of Himalayan Ranges and has international boundaries in the North with Tibet (China) and in the east with Nepal. The region between Dharchula and Lipulekh has dense forests, rivers on lower reaches, snow-clad mountains, and glaciers as shown in figure 5.1. The affinity of the pilgrims is the most revered for sacred temples at Badrinath, Kedarnath, Gangotri, and Yamunotri which results in thousands of people visiting these destinations every year (Department of Tourism, Government Of Uttarakhand, India, 2020). Apart from the scenic beauty, the pilgrims and tourists cherish the Kailash-Mansarover journey. Hence the Road from Pithoragarh to Lipulekh pass is one such creation for Kailash-Mansarovar, which has its pilgrimage importance apart from strategic value for the nation. Thus, this road is a lifeline for Kailash-Mansarovar journey and runs parallel to Nepal's international border *(List of Expressways India, 2021).*

Dharchula in Pithoragarh, Uttarakhand, is a small and remote town in the Himalayan Mountains through which the ancient trade flourished and now for pilgrimage and tourism. The hill-town has a breath-taking scenic view and a tourist destination connecting Narayan Ashram, Mansarovar Lake, Chikrila dam, River Kali, and Om-mountain. Thousands of pilgrims come to take a holy bath in the freezing waters of Mansarovar Lake (Noronha, G, The Economic Times, 10 December,2020). The Badrinath, Gangotri, Kedarnath, and Yamunotri, collectively known as most revered four pilgrim-destinations (Char-Dhams). Traditionally, sequence of route followed for these destinations is Yamunotri followed by Gangotri and further to Kedarnath and Badrinath at the end (from west to east as a ritual). Each place is devoted to a specific deity. Belief is that a bath in the Yamuna's waters at Yamunotri, dedicated to the Yamuna in Rawai Valley, provides protection the devotee from fatal mishaps resulting in untimely death. Gangotri shrine is dedicated to the Ganga, is also known as Bhagirathi because of belief that ancient King Bhagirath brought her from heaven to the earth. Shiva's temple at Kedarnath in north, an immensely prayed Jyotirlinga, is at the glacier which is at origin of the river Mandakini. Badrinath is on the banks of the river Alaknanda and dedicated to Vishnu. It is believed in mythology that Vishnu meditated at Badrinath, Lakshmi as badri tree (in the form of a berry), the badri tree offered shade during meditation (Department of Tourism, Government Of Uttarakhand, India, 2021).

According to the Vedas, universe was formed by Vishnu and during this formation the Himalaya’s peaks are the Golden Lotus's petals. Shiva sits in meditation on Mount Kailash, creating the spiritual force protecting the earth. As per Rigveda, the Himalayan range including, Mount Kailash, formed 30 million years ago. Mount Kailash is also known as Kang Rimpoche, meaning Precious Jewel which is situated in Tibet. The four river’s origin is the vicinity of Mount Kailash, flow in four directions River Indus towards the north, the river Karnali towards the south, the river Yarlung Tsangpo towards the east, River Sutlej towards the west. Kailash Mansarovar has huge pilgrim followers for centuries. Uttarakhand's Lipulekh Pass leads to Kailas-Mansarovar.

Due to India's border dispute with China in 1962, Indians were not allowed to visit Kailas–Mansarovar from 1962 to 1980. In 1981, the Indian Ministry of External Affairs (IEA) resolved the issue with the China’s government only for conduct of trips to Kailash-Mansarovar through the Lipulekh pass. Kailas-Mansarovar is 865 kilometres from Delhi. Pilgrims have a parikarma (walk of 43 kilometres around Mount Kailas). The Kailas-Mansarovar route is from Dharchula via Tawaghat – Lipulekh pass – Darma and Joharvalley (District Pithoragarh, Government of Uttarakhand, India, 2021). Pilgrims from India can visit Kailash-Mansarovar through any of the three routes — via Sikkim, Uttarakhand or, Kathmandu in Nepal. Route via Sikkim and Kathmandu are extremely long and arduous. Uttarakhand's new road route to reach Kailash-Mansarovar will cut short an arduous trek of five days.

The Kailash-Mansarovar Road is a greenfield alignment along the river Kali, at international border between India and Nepal. The Uttarakhand route has components. First stretch is 107.6 kilometre from Pithoragarh to Tawaghat, the second stretch is 19.5 kilometre from Tawaghat to Ghatiabagarh, the third stretch of 80 km from Ghatiabagarh to Lipulekh Pass at the India Nepal China border. First two stretches existed earlier but the third stretch till the India’s Lipulekh pass used to take five days to cover on foot. The Border Roads Organisation (BRO) built a new road on the third stretch to allow vehicles. It has so far completed 76 km of the 80 km road, cutting travel time to just two days by car. The road access is till Lipulekh Pass, a tri-junction of India, Nepal and China as shown in Figure 5.1.

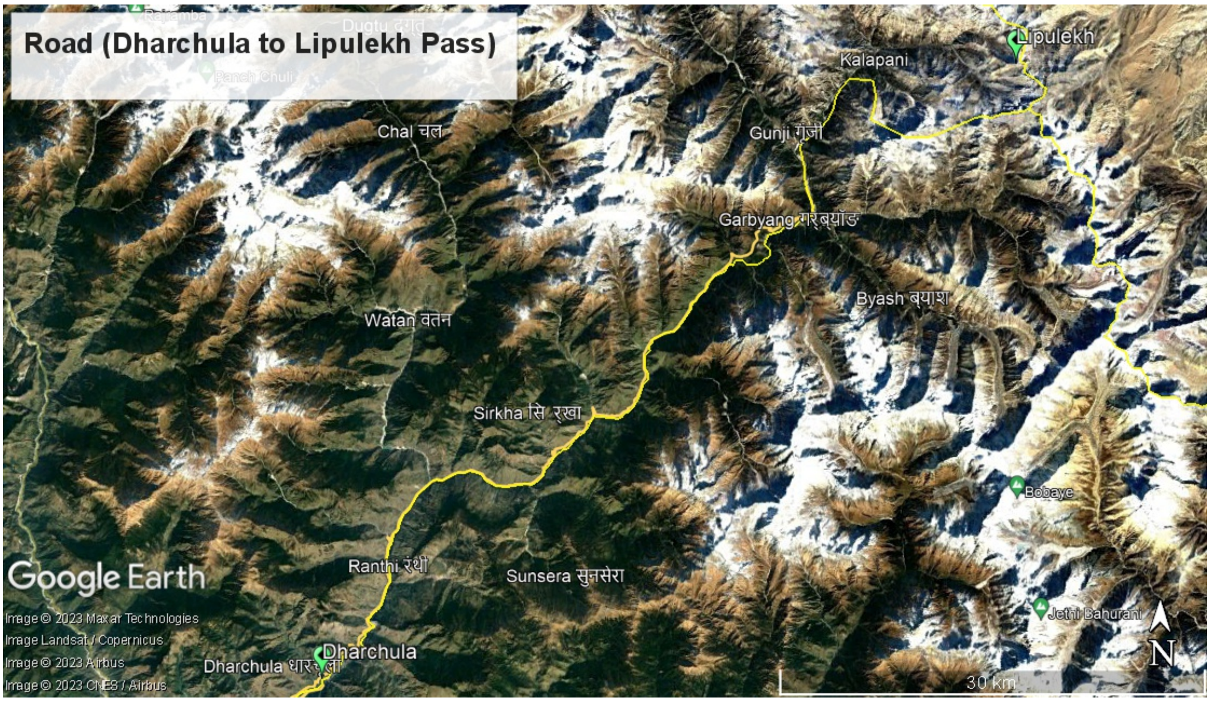

Figure 5.1 Route from Dharchula to Lipulekh Pass (A Trijunction of International Border India, China, and Nepal, Source: https://earth.google.com)

5.2 Completion of Hill Road Project

Defence Minister Rajnath Singh inaugurated the road connecting Dharchula to Lipulekh Pass at the India-Nepal-China border, 17,000 feet above sea level. The BRO achieved road connectivity from Dharchula to Lipulekh pass (international border), known as Kailash-Mansarovar Yatra Route. The last 4 km of the road till Lipulekh Pass shall be completed by year 2021 (summer season). Construction faced many challenges posed by high altitude terrain, steep mountains having hard rock component, sub-zero temperatures, very short working season and, harsh weather (Dutta, A.N, ThePrint, 08 May, 2020). The Dharchula-Lipulekh road is a greenfield alignment and further extended pilgrimage road Pithoragarh-Tawaghat-Ghatiabagarh. The 80 km road starts from Ghatiabagarh and terminates at Lipulekh Pass, the shortest route for Indians to Kailash-Mansarovar. Due to high altitude pilgrims must acclimatize by taking first night halt at Gunji and the second stage acclimatization at the Lipulekh pass. Beyond Indian territory, which is a five-kilometre trek, in Tibet, a 97 km road exists (Gurung, S.K, The Economic Times, 08 May, 2021). The present study analyses the social impacts of the construction of Ghatiabagarh-Lipulekh Road of 76 Km. Construction of road infrastructure kickstarts a process of the interlinked chain of development. It includes changing ecosystems, land productivity, demography changes, shifting of settlements, and urbanization evolution. Construction of roads induces benefits such as connectivity of rural India to townships, enhancement of education, health, and development of trade and commerce. Development of the hinterland hinges on the improved and efficient road network. All-round development, safe travel, reduced vehicle operating cost, reduced fuel consumption, a faster and comfortable journey from Dharchula to Lipulekh are immediate benefits of this road construction. The survey during the studies on road safety shows that traffic accidents can be averted and reduced to minimum by creation of a positive roadside environment. Andrey, in his survey of traffic accidents involving bad weather in Canada, observed that probability of crashes increases by 75% during rainfall, and that of a personal injury increases by 45% (Andrey, 2001).

5.3 Social Impacts

The road has strategic significance connecting national capital with the international border at Lipulekh pass as well as connectivity to Kailash-Mansarovar which makes pilgrim's journey very comfortable and reduce travel expenses while visiting the holy abode of Shiva. High altitude and harsh terrain made old trek route very precarious. By construction of the new road, a light vehicle can reach up to 76 km (4 km short of the international border), reducing the five-day trek to only two days of road travel. For return journey on this route thus saves six days (three days on each side journey). Lipulekh Pass is the shortest route, only 20 % of road travel distance as compared to two other approaches. The maximum of the road distance travelled for pilgrimage is on the Indian side. Only 5 Km of the trek to the international border and parikrama of 43 km must have on foot; hence there is no air travel involved. The old, aged pilgrims can also fulfil their wish of the holy pilgrimage, and in case of any natural calamity during Yatra, air evacuation by helicopters is possible. Two other routes available to undertake the Kailash-Mansarovar journey via Sikkim or Kathmandu are detours and very long. For the Sikkim route first a flight to Bagdogra from Delhi followed by further 1665 kilometre of road travel followed by 43 kilometres of parikrama on foot is to travel. Out of total journey distance of 1665 kilometre, only 175 kilometre is travelled in India. The third route involves a flight to

Kathmandu from Delhi followed by road travel of 1940 km or two flights & one helicopter sorties of 755 kilometre or a road journey from Nepal 840 kilometre. The distance is excluding 43-kilometre parikarma. The Dharchula-Lipulekh road alignment is along the Kali River, providing connectivity to border villages and remotely located security forces (Singh, M. The New Indian Express, 08 May, 2020). The author surveyed forty-two villages/settlements connected to this road via foot track. All villages have been divided into five zones for ease of survey, namely Gunji, Malpa, Pungla, Tawaghat, and Dharchula in the year 2021 as shown in Table 5.1.

Table 5.1 Village Surveyed Along Road Ghatiabagarh- Lipulekh in 2021

Ser. No.	Zone	Villages
1	Dharchula	Dharchula town, Dharchula. Dehat, Mohati, Bangabagar, Lasku, Dhumpanera, Lasku, Lairekhet, Jaijhul, Galati, Rantoli, Chhapri
2	Tawaghat	Tawaghat, Khela, Garguwa, Syankuri, Chandakot, Huti, Jumma, Ranti, Bhramdev VDC
3	Pungla	Pungla, Rung, Sirkha, Sirdang, PunlaBhataka, ChhalanaChhilason, Himkhola, SagriDhakdhauna, Gumkana, TyongiPangu, Dhar Pangu
4	Malpa	Malpa, Salagar, Bungbung, Bhudhi, Garbyang
5	Gunji	Gunji, Nabi, Napalachuchu, Chhangru,

The study of project area of the road Ghatiabagarh to Lipulekh Pass identified the social impacts using questionnaire surveys from individuals of different professions, including the villagers, tourists, taxi drivers, travel booking agents, health workers, primary school teachers, amongst others along with field observation. The questionnaire form (attached as Appendix 'B') was attempted by total one hundred twenty-four individuals during the survey. To evaluate the social impact, questionnaire, community consultation, interview of village headman of various settlements and meetings with local population were means of collecting data about potential social impacts of the project. The SIA usually relies on expert judgement which is primarily objective based and lack participation from local community (Anciaes et al., 2017). Various criteria were nominated considering all aspects of rural life in India's interior hilly regions. The comprehensive list of criteria must include economic development, agriculture development, health, education, social resources and cultural aspect and sites of culture and national significance (Momtaz & Kabir, 2018). Geurs et al. described the impacts including effects on well-being, preferences, behaviour, individual perception, perception of groups and society in general (Geurs et al., 2009). Oiamo et al. found traffic noise and air pollution influence on environment and health quality of life (Oiamo et al., 2015).

In the present research National Science Foundation (NSF) Method, Battelle Environmental Evaluation System Method and Weighing and Scaling Checklist Method for assessment of social impacts have been used. The NSF method calculates weighted linear sum of sub-indices and weighted product aggregate function by providing weights to different parameters under consideration. The Q value is an indicator of extent of good or bad, the social impact when analysed in relation to each parameter. Q= 100 is considered as very good and Q=1 very bad. Weighted Quality Impact (WQI) interpretation was done as follows.

Table 5.2 Social Impact Assessment Using National Science Foundation (NSF) Method for Road Ghatiabagarh-Lipulekh

Social Impact Index Range	Social Impact Rating
90-100	Excellent
70-89	Good
50-69	Medium
25-49	Bad
0-24	Very Bad

The weightage for various social criteria decided upon by panel of experts is shown in Figure 5.2.

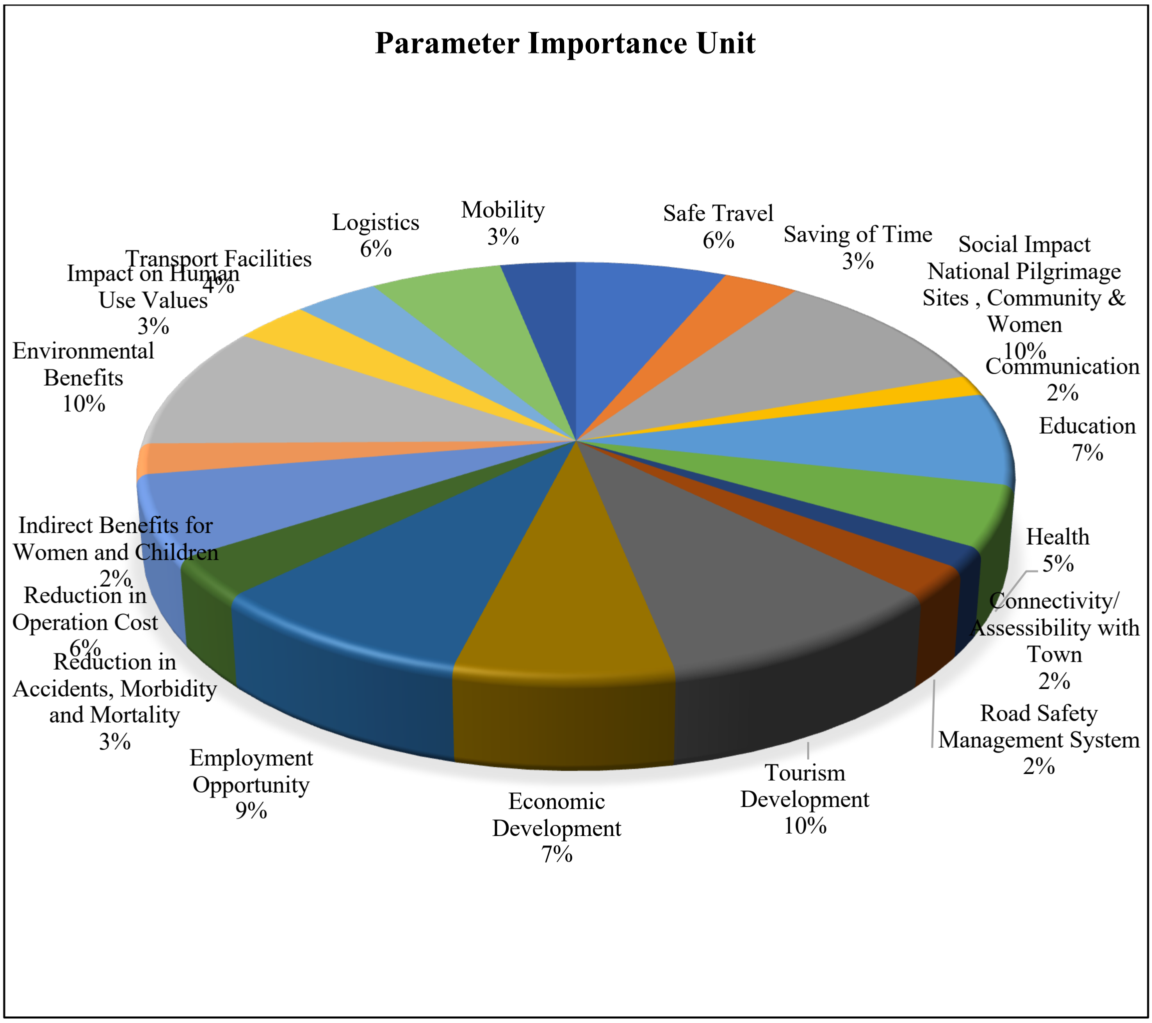

Figure 5.2 Weights Assigned to Various Criteria Under Consideration for National Science Foundation (NSF) Method for Road Ghatibagarh – Lipulekh

5.4 Results and Discussion

5.4.1 NSF Method

As per NSF method social impact for national pilgrim sites, environmental benefits, tourism development have an 'Excellent' rating. Safe travel, education, economic development, and employment opportunities have 'Good' social impact rating. Transport facilities, reduction in cost, health, saving of time have 'Medium' social impact. Overall impact is considerably positive. Fig 5.3 presents a pictorial insight to social impact assessment by NSF method. NSF method is a initiative of US government, however this can be seamlessly utilized in Indian context to ensure the comparison with other SIA methods used in the study.

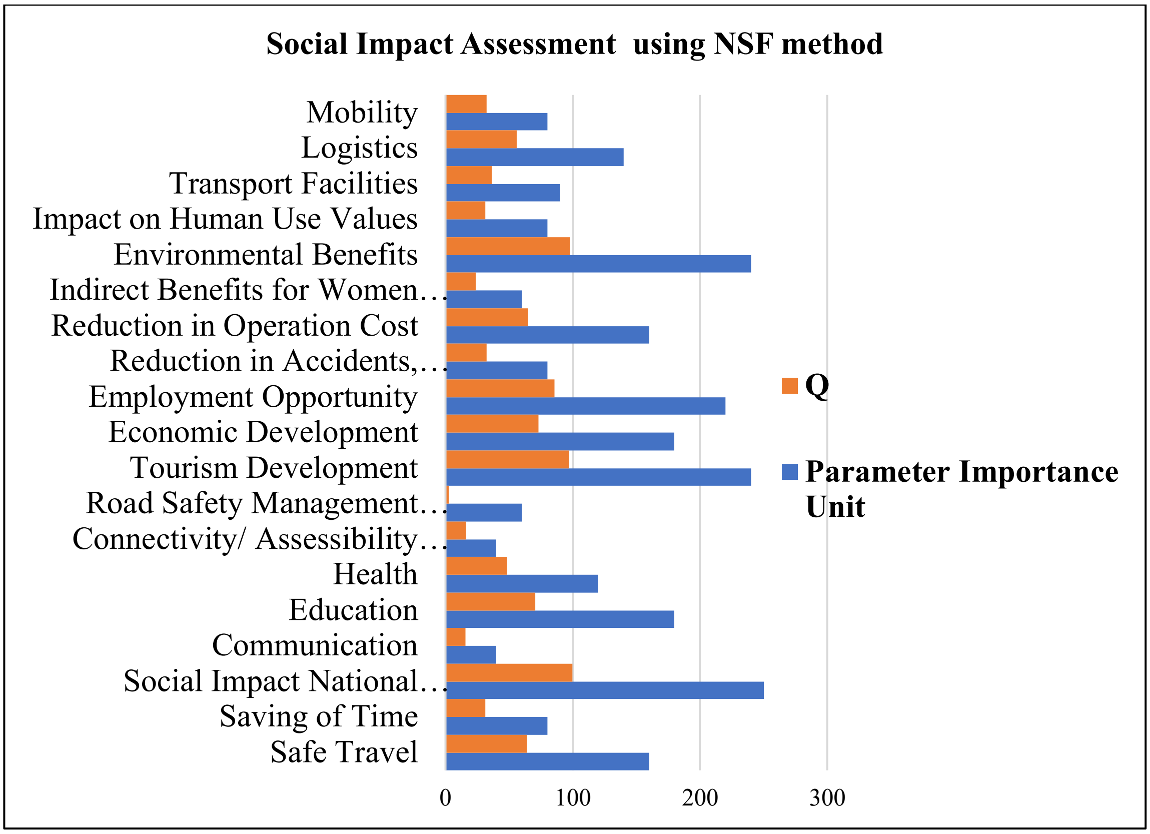

Figure 5.3 Social Impact Assessment for Road Ghatibagarh – Lipulekh by National Science Foundation (NSF) Method

5.4.2 Battelle Environmental Evaluation System Method

The SIA is calculated for the project using Battelle Environmental Evaluation System Method (BEES) which evaluates and compares parameters pairwise based on ranking. In Battelle method initial ranking is vital. After ranking as per ranked priority first parameter is compared with second, second with third, and so on. Subjectivity in ranking process is pivotal to the assessment process by BEES (Goyal & Deshpande, 2001).

$$\sum_{i=1}^{m} EIU = \sum_{i=1}^{m} (EQ_i)_1 \, {}^{P}/_{U_i} - \sum_{i=1}^{m} (EQ_i)_2 \, {}^{P}/_{U_i} \quad \text{-------------- (5.1)}$$

where EIU= Social Impact Unit

$(EQ_i)_1 = Social\ Quality\ Indicator$ i $with\ project\ conditions$

$(EQ_i)_{12} = Social\ Quality\ Indicator$ i $without\ project\ conditions$

$P/U_i = Parameter\ importance\ unit/Relative\ weight\ of\ indicator\ i$

m = Total no. of environmental indicators

Table 5.3 Social Impact Assessment Using Battelle Environmental Evaluation System for Road Ghatibagarh-Lipulekh

Parameters	Parameter Importance Unit	Social Quality without the Project	Social Quality with the Project
Safe Travel	160	0.01	1
Saving of Time	80	0.01	1
Social Impact National Pilgrimage Sites, Community & Women	250	0.02	1.9
Communication	40	0.01	0.6
Education	180	0.02	1
Health	120	0.006	0.6
Connectivity/ Accessibility with Town	40	0.001	0.4
Road Safety Management System	60	0.001	0.5
Tourism Development	240	0.001	0.5
Economic Development	180	0.001	0.6
Employment Opportunity	220	0.02	0.8
Reduction in Accidents, Morbidity and Mortality	80	0.001	0.6
Reduction in Operation Cost	160	0.002	0.8
Indirect Benefits for Women and Children	60	0.001	1
Environmental Benefits	240	0.99	0.75
Impact on Human Use Values	80	0.001	0.6
Transport Facilities	90	0.001	0.8

Parameters	Parameter Importance Unit	Social Quality without the Project	Social Quality with the Project
Logistics	140	0.001	0.7
Mobility	80	0.001	0.8

$$\sum_{i=1}^{m} EIU = 15.84$$

5.4.3 Checklist Method

The subjectivity in ranking is expert opinion oriented hence the checklist method was applied for structured assessment and evaluation of identified impacts. Factors were weighed as per the importance by the help of a panel of experts, as shown in Table 5.4.

Table 5.4 Social Impact Assessment of Construction of Hill Road Using Checklist Method

S. No	Project Benefits Social Factors	Sub-Criteria	Positive impact very likely	Positive impact possible	No impact	Negative impact possible	Negative impact very likely	No judgement possible at present
1.	Safe Travel		1	-	-	-	-	-
2.	Saving of time		1	-	-	-	-	-
3	Social impact	3-1 Community/Population change	-	-	-	-	-	0.1
		3-2 Income amenity	-	0.42	-	-	-	-
		3-3 Human migration	-	-	-	-	-	0.4
		3-4 Resettlement	-	-	-	-	-	0.5
		3-5 Women's role	-	0.4	-	-	-	-
		3-6 Minority groups	-	-	0.1	-	-	-

S. No	Project Benefits Social Factors	Sub-Criteria	Positive impact very likely	Positive impact possible	No impact	Negative impact possible	Negative impact very likely	No judgement possible at present
		3-7 Sites of value	1	-	-	-	-	-
		3-8 Regional effects	-	0.02	-	-	-	-
		3-9 User involvement	-	0.5	-	-	-	-
		3-10 Recreation	-	0.01	-	-	-	-
4	Communication		0.6	-	-	-	-	-
5(a)	Education	Students can approach School/College	0.8	-	-	-	-	-
5(b)		School/College development in Remote areas	0.2	-	-	-	-	-
6(a)	Health	6-1 Water & sanitation	-	0.1	-	-	-	-
6(b)		6-2 Habitation	-	-	-	0.4	-	-
6(c)		6-3 Health services	-	0.2	-	-	-	-
6(d)		6-4 Nutrition	-	0.1	-	-	-	-
6(e)		6-5 Relocation effect	-	-	-	-	0.6	-
6(f)		6-6 Disease ecology	-	-	-	-	0.2	-
6(g)		6-7 Disease hosts	-	-	-	-	0.1	-
6(h)		6-8 Disease control	-	0.2	-	-	-	-
6(i)		6-9 Other hazards	-	-	-	-	0.4	-

S. No	Project Benefits Social Factors	Sub-Criteria	Positive impact very likely	Positive impact possible	No impact	Negative impact possible	Negative impact very likely	No judgement possible at present
							Increase in Use of Plastic	
7	Connectivity/Accessibility with towns		0.4	-	-	-	-	-
8(a)	Road safety management system	Driver's comfort	0.5	-	-	-	-	-
8(b)		Increase in Traffic	-	-	-	-	0.5	-
9	Tourism Development	-	0.8	-	-	-	-	-
10	Economic Development		0.6	-	-	-	-	-
11	Employment Opportunity		-	0.8	-	-	-	-
12	Reductions in Accidents, Morbidity and Mortality		0.6	-	-	-	-	-
13	Reductions in Operation Cost		-	0.8	-	-	-	-
14(a)	Indirect Benefits	Pre-Birth care of Pregnant women	0.6	-	-	-	-	-
14(b)		Childhood Awareness and development	0.4	-	-	-	-	-
15	Environmental Benefits	-	0.75	-	-	-	-	-
16	Impact on Human Use Values	-	0.6	-	-	-	-	-
17	Transport Facilities (Car, Cabs, Buses)	-	0.8	-	-	-	-	-
18	Logistics	-	0.7	-	-	-	-	-
19	Mobility	-	0.8	-	-	-	-	-

S. No	Project Benefits Social Factors	Sub-Criteria	Positive impact very likely	Positive impact possible	No impact	Negative impact possible	Negative impact very likely	No judgement possible at present
20	Total Impact	-	12.15	3.55	0.1	0.4	1.8	1

A total of 19 criteria, including various sub-criteria, were evaluated with utmost importance graded as one mark and least 0, and evaluation followed an interval of 0.01. Out of a total score of 19 points, the checklist method found a positive social impact to be 16.05.

Table 5.5 Social Impact Assessment Using Weighing and Scaling Checklist Method

Social Impact	Very High	Possible	No impact	Negative impact possible	Negative impact very likely	No judgment possible at present
Assessment Score	12.5	3.55	0.1	0.4	1.88	1

5.5 Conclusion

The strategic importance of road overlay all social impacts and magnitude of this factor for any road cannot be quantified hence excluded from assessment in present study. The project road has increased the women’s participation in society, as per NSF method 23.9%, Battelle method 60% and Checklist method 40% respectively. The imparting of education accessibility is estimated to increase by 70.8% as per NSF method, 72% as per Battelle method and 80 % as per Checklist method. The project road shall also indirectly benefit the educator development program of primary school teachers by 20%. Education impact shall be clearly noticed in next census. Project road has changed the perceived public opinion and public engagement of society. Local population’s access to science and technology has increased by 16 % as per NSF method and Battelle method whereas 40% as per Checklist method. Health related impact is 48.5% as per NSF method, 72% as Battelle method and 60 % as per Checklist method for villagers including the elderlies and persons with disabilities. Increased mobility and transport facilities have impacted perceived well-being of society by 32% and 36% as well. Employment opportunities during construction phase was limited to labour requirements but connectivity has increased so development of diverse workforce by combination of academic, tourism, industry and communication is enhanced by 80%. The study team gleaned specific insights from analysis shown in Table 5.6.

NSF method has holistic approach clearly giving outcome for each social impact parameter while the Checklist method was found to be subjective. Battelle method too has an inherent advantage of comparing social impact situation with and without project. The study further substantiated the outcome of Battelle method and Checklist method have almost similar results, assessment scores being 15.8 and 16.05 respectively. Social impact study has very vast domain, but the road will enhance connectivity and will benefit the Indian pilgrims on the Kailash Mansarover journey too. The construction of this hill road has made travel very safe. Education, health, and indirect impact have long-term benefits, but even short-term social effects on society have been tremendous. It has given connectivity to almost fifty villages and settlements.

Table 5.6 Comparison of Attributes of NSF, BEES and Checklist Method

Attribute	**NSF method**	**Battelle method**	**Checklist method**
Subjectivity in selection of criteria	Holistic	Inclusive	Subjective
Initial ranking of criteria	Not Required	Required	Not Required
Weight assignment to criteria	Yes	Yes	No
Weight assignment process	Well defined	Well defined	Survey and feedback interaction based
Comparison Matrix	Array	Array	(n x n) matrix, very exhaustive
Reliability of weights	More	More	Less
Possibility of study of Impacts without project	Yes	Yes	No

The migration from villages to Dharchula town for health and education has started. As per the villagers' interview during the survey, some resettlements are likely to come up near the road head as job avenue of shops for food and refreshments for tourists has occurred. Usage of plastic for the packaging of food items and refreshments by tourists has increased the use of plastic in the region. Due to the absence of proper waste disposal facilities, the current trend allows the travelers on the road to dump the plastic on roadsides creating garbage of 300 kilograms per month during tourist season and has 4% negative impact, which in the long run will affect the pollution of River Kali. The study envisages social road safety education should form part of the curriculum to impact the behaviour of drivers apart from enforcing traffic laws on over-speeding, lane discipline, and overtaking.

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6 Chapter
Cost of Construction of Hill Road by Minimising Adverse Environmental Impacts (Estimation for Green Field Alignment in Leh Ladakh Region), India

6.1 Introduction

The cost estimation of a hill road construction has numerous variables involved. These variables have been studied across the world, but these are particularly country / region specific. The traffic quantum and purpose of road governs the variables and further impacts cost of construction. The road can be divided for study as flexible pavements and rigid pavements.

The traffic-based study can divide the roads as single roads, double lane, urban roads, and expressways. Single lane roads are generally last mile connectivity connecting villages and rural India to the nearest town or highways. The traffic is very low, and load is generally of light vehicles and light commercial vehicles. Double lane roads are generally the roads within small towns and connecting small towns to other small towns. These are designed for commercial purpose and are capable of handling heavier loads. Urban roads and expressways are multiple lane roads enabling traffic at higher speed and higher loads.

During planning and feasibility studies cost estimation of highway project must be done with highest level of accuracy. However, during conceptual phase to derive cost of construction of hill road is very difficult.

Lack of preliminary information, lack of database, and lack of proper method for cost estimation increase the level of difficulty for cost calculations. (Sodikov, 2005).

Another research highlighted that the mode of road construction varies with the geographical feature of the earth such as plain land, mountain terrain, steep and hilly region. It was further noticed that easier and more accessible to construct a road in plain region as compared to the hilly region. Their review paper presented the road construction mode in the hilly region as well as their problem and solution with reference to the segment of NH-13 from Sagalee to Midpu (Doimukh). (Takar et al., 2019).

Research shows that in commercial building sector the Building Information Modelling (BIM) is having a profound effect on construction industry project delivery and processes. Studies show that the use of BIM is rising rapidly especially among the contractor community. (McGraw Hill Construction, 2012).

In India the engineering of hill roads is always a daunting task, due to unstable strata of the young fold Himalayan Mountains. Geologically rocks in Himalayan ranges are in formative stage and inherently very weak like highly weathered or fractured sedimentary formations such as sand rocks, siltstones, clay stones. (Singh et al., 2019).

In construction of rural roads, the sustainability at minimum cost is the main criterion. However conventional geometric design and specifications tend to recommend better technology and more materials which normally result in higher cost of construction. (Tiwari and Trivedi, 2016).

Sanyal (1985) studied effects of road construction on hills and its ecology with some suggestions to prevent further deterioration of the situation, giving due considerations to the habits and socio-economic customs of the hill people without minimizing the importance of further development of roads in these hills.

6.1.1 Relevance

India has 28 states and 8 union territories comprising of four regions, Great Himalayan mountains, Ganga and Indus plains, the desert region, and the southern peninsula. The Himalayas has three almost parallel ranges interspersed with large plateaus and valleys extending over 2,400 km with a varying width of 240 to 320 km. (https://knowindia.india.gov.in). Each state is following own method of cost calculation for hill road construction. It is imperative to standardise the cost calculation across the country for construction of hill roads of single lane, double lane and four lane roads including cost calculation for culverts and bridges in high altitude areas.

This chapter focuses on standardization of cost calculation method for construction of hill roads of single lane, double lane, and four lane roads with cost calculation method for culverts and bridges in high altitude. The study further compares the cost of construction of roads in year 2010 and year 2021.

6.2 Cost Variables

The cost of construction of various roads depends on numerous variables as discussed in Table 6.1. The variables are interlinked intangibles which affect cost of construction directly or indirectly. Table 6.1 tabulates all the cost variables for a hill road construction.

Table 6.1 Cost Variables affecting the Economics of Hill Road Construction in Hill Roads

S.No.	Cost Variable	Remarks
1.	Terrain	The terrain may be classified as lower hilly region and upper hilly region. The lower hilly region has more peculiar effects of heavy rainfall and runoff related erosion. The upper hilly region is affected by snowfall and consequent affects.
2.	Type of rock	The rock type and content are classified as igneous/volcanic (granite), metamorphic rocks and sedimentary rocks. Further rocks may be igneous, metamorphic, or sedimentary subclassified as basalt, granite, sandstone, marble, limestone, slate, schist, gneiss, intrusive rocks, diorite rock, conglomerate rock, gabbro, pumice, quartzite, obsidian, rhyolite, andesite, coal, chert, breccia.
3.	Altitude	With increase in altitude, the oxygen level drops hence creating difficulty for the man and machines to operate at optimum level.
4.	Induction space	The induction space available will dictate "How many places can the construction activity can commence simultaneously.
5.	Availability of equipment / machinery	The latest and efficient equipment including excavators, drills, dozers, and explosives
6.	Working season	The working season is estimated at 180 days for Leh region ie. May to October. All construction activity ceases with commencement of snowfall.
7.	Manpower / Labour available	The labour inducted from plains need acclimatization for three weeks before commencement of construction activity. The local manpower is scanty because region is sparsely populated.
8.	Width of road	Width of road will dictate the quantum of excavation and rock drilling required. This will further affect muck disposal plan.
9.	Load Factor	The load factor will affect planning parameters and technical specification of various layers of road.
10.	Traffic Handling capacity	Each road is designed for specific traffic handling capacity.

S.No.	Cost Variable	Remarks
11.	Weather conditions	The weather conditions are very important for construction phase and the service life of the road.
12.	Technical Specifications	All variables discussed above need to be factored in for finalization of technical specification. The construction cost economics shall be based on technical specification primarily.

6.3 Calculation of cost of construction

The construction activity is sub-grouped into various steps for ease of cost calculations. Further cost for each activity per cubic meter or per square meter is analysed as per present rate analysis and has been compared with respect to rates of year 2010, a decade earlier. The cost of construction of hill road has been estimated for one Km stretch for Single Lane, Double Lane, and four lane hill road construction. For estimation of culverts and bridges en-route which shall vary for each site and given geographical conditions the cost for one culvert (box type) and one bridge has been estimated. Depending upon number of culverts and bridges the cost estimation for any length of hill road can be estimated.

Market variation (MV) is calculated in percentage increase in rates for all activities with each year passing by as compared to rates finalised in base year. In this study the base year is taken as 2010 when rates were finalised. Next revision of rates has been done in year 2020. For all intermediary years MV needs to be added for cost calculations. Remote area (RA) percentage is added to the cost based on lack of availability of contractors in execution, lack of equipment and machinery and high altitude and tough terrain. As shown in figure 6.1 proposed retaining wall increased the cost of construction. M&L is material and labour for any given task. Site clearance and site development is the first step to construction activity of road. Table 6.2 gives an estimated expenditure for the site clearance and development.

Figure 6.1 Study of retaining wall on a hill road along River Indus at Leh, Ladakh

Table 6.2 Estimated Expenditure for site clearance and site development

S. No.	Description of work	Brief description of work	A/U	Quantity	Rate (Rs)	Amount (Rs)
1	2	3	4	5	6	7
1(a)	Site clearance	Surface excavation 30 cm deep and averaging 15 cm and getting out soft/loose soil.	Sqm	1378.35	15.9	21915.8
		Removing excavated material for a distance beyond 500m and maximum total distance 1.5Km	Cum	206.75	161.4	33369.9
Total						55285.6
Add MV 47% +15% Remote area = 62% on SSR 2010						34277.1
G Total Rs						89562.7
Say Rs						89600
1	2	3	4	5	6	7
1(b)	Site Development	Forming embankments including raising (or lowering) earth spreading in layers not exceeding 30 cm thick watering ramming/rolling and finishing to required size shape etc not exceeding 1.5m height from base.	Cum	1000	50.7	50700
Total (Rs)						50700
		Add MV +RA (47 MV+15 RA) = 62% on SSR 2010				31434
(In Rupees)					G/Total Rs	82134
Say Rs					82100	
*** A/U: Authorized unit; MV: Market variation; RA: Remote area; SSR: Standard schedule of rates**						

6.4 Costing for Four Lane Hill Road

The cost of four lane road with a 1.5 m wide divider has been calculated for the year 2010 and year 2021. Table 6.3 brings out cost analysis for length of 1 Km of four lane road. The altitude while arriving at this cost is 3657m (12000ft) to 4876.8m (16000ft). Above that altitude snow clearance would also needs to be factored in with a working season of four months in a year.

Table 6.3 Cost Analysis for Four Lane Road with 1.5m wide divider (Source: Military Engineering Services)

S. No.	Brief description of Work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks (SSR Code)	SSR Rate 2020	Amount (Rs)
	Four Lane Road with 1.5 m wide divider	10		RM				
			14 m Wide					
1	Excavation over area and excavating 1.5 m deep and getting out in soft / loose soil	Cum	42	77.4	3250.8	3004	258.5	10857
2	M&L for Rolling and consolidating formation surface in cutting to the required gradient and camber including filling in depression and hollows water, levelling etc complete using power roller exceeding 8 tonne & not exceeding 12 tonne capacity.	Sqm	14	8	112	20027	26	364
3	M&L for Soling (or subbase) with broken boulders or quarried stone, interstices filled surface formed and rolled and consolidated to required gradient and camber (200 mm spread thick)	Sqm	14	1203.6	16850.4	20001	3694.1	51717.4

S. No.	Brief description of Work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks (SSR Code)	SSR Rate 2020	Amount (Rs)
4	M&L 150 mm thick (compacted thickness) WBM, with coarse aggregate limestone, sandstone, flint, or quartzite of grading (63 to 40 mm size) spread, rolled, and consolidated to gradient and camber required.	Sqm	14	1645	23030	20010	1712.5	23975
5	M&L Preparing surface by brushing with wire brushes for removing caked mud etc, sweeping with brooms and finally fanning the cleaned with gunny bags to remove all loose dirt etc for unsurfaced WBM surface and applying tack coat with bituminous primer 10 kg per 10 sqm with paving bitumen.	Sqm	14	538.7	7541.8	2,001,520,016	873.1	12223.4
6	M&L 50mm thick Premix bituminous macadam laid/rolled and compacted to required gradient and camber (consolidated thickness 75 mm or less)	cum	7	4163.1	29141.7	20066	8915.7	62409.9
7	Applying evenly priming/tack coat with paving bitumen @ 5Kg per 10 Sqm.	Sqm	14	214.5	3003	20016, 20017	263	3682
8	M&L Bituminous premix semi dense asphaltic concrete 40mm consolidated with 5.5% binder content by weight of total mix rolled and compacted to required camber and complete.	Sqm	14	1533.4	21467.6	20072	2545.3	35634.2
9	M&L painting lines, dashes, arrows, letters etc, on roads pavements and the like not exceeding 10cm wide with road marking paint white or golden yellow.	RM	2	19.6	39.2	17052	62	124

S. No .	Brief description of Work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks (SSR Code)	SSR Rate 2020	Amount (Rs)
10	Removing excavated materials to a distance exceeding 250 m and not exceeding 500 m depositing were directed	Cu m	21	149.4	3137.4	3031	324	6804
11	Removing excavated materials to a distance exceeding 1.50 Km and not exceeding 5.00 Km and depositing where as directed.	Cu m	21	208.3	4374.3	3033	433.6	9105.6
	Divider (1.50 m) WIDE	RM	10					0
1	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	Cu m	4.5	77.4	348.3	3004	258.5	1163.25
2	M&L precast cement concrete M-25 grade using 20mm graded stone aggregate as in kerb stone of size 20 cm x 45 cm with plain faces including chamfers, weathering, throating etc and setting in cement mortar 1:4 complete	Cu m	0.9	4021.6	3619.44	4030	9158.7	8242.83
3	M&L earth filling in, including spreading, levelling, watering and well ramming in layers not exceeding 25 cm	cum	4.4	523.9	2305.16	20007	799.3	3516.92
4	M & L Laying of grass over earth filing complete all as directed by Engineer in charge.	sqm	11	500	5500	Assessed	925	10175
	Total Rs				123721.1			239995
	Add (15% RA) on SSR -2010 Items			118221	18558.15		7%MV+RA 15% on SSR -2020	34472.9
Grand Total (Rupees)			**Total cost for 10 RM**		**142279.3**	**274467.43**		
			Total cost for 1 RM		**14227.9**	**27446.74**		
			Total cost for 1000 RM		**14227925**	**27446742.5**		

S. No.	Brief description of Work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks (SSR Code)	SSR Rate 2020	Amount (Rs)
			Total cost for 1000 RM		14227925	27446700		

6.5 Cost of Construction of Two-Lane Hill Road

For an altitude of 12000 ft to 16000 ft the cost of two-lane road for a stretch of one Km has been calculated as follows. Working Season also adds to the construction cost as contractors' equipment and machinery remains committed for multiple working seasons. In Table 6.4 cost of two-lane road per Km constructed in hill region is calculated.

Table 6.4 Cost of Construction of Two-Lane Hill Road
(Source: Military Engineering Services)

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
	Two Lane Road	10		RM				
1	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	Cum	21	77.4	1625.4	3004	258.5	5428.5
2	Rolling and consolidating formation surface in cutting to the required gradient and camber including filling in depression and hollows water, levelling etc complete using power roller exceeding 8 tonne & not exceeding 12 tonne capacity.	Sqm	7	8	56	20027	26	182
3	Soling (or subbase) with broken boulders or quarried stone, interstices filled surface formed and rolled and consolidated to required gradient and camber (150 mm spread thick)	Sqm	7	1203.6	8425.2	20001	3694.1	25858.7

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
4	M&L 150 mm thick (compacted thickness) WBM, with coarse aggregate limestone, sandstone, flint, or quartzite of grading (63 to 40 mm size) spread, rolled and consolidated to gradient and camber required.	Sqm	7	1645	11515	20010	1712.5	11987.5
5	M&L Preparing surface by brushing with wire brushes for removing caked mud etc, sweeping with brooms and finally fanning the cleaned with gunny bags to remove all loose dirt etc for unsurfaced WBM surface and applying tack coat with bituminous primer 10 kg per 10 sqm with paving bitumen.	Sqm	7	538.7	3770.9	20015,20016	873.1	6111.7
6	M&L 50mm thick Premix bituminous macadam laid/rolled and compacted to required gradient and camber (consolidated thickness 75 mm or less)	cum	3.5	4163.1	14570.85	20066	8915.7	31204.95
7	Applying evenly priming/tack coat with paving bitumen @ 5Kg per 10 Sqm.	Sqm	7	214.5	1501.5	20016, 20017	263	1841
8	M&L Bituminous premix semi dense asphaltic concrete 40mm consolidated with 5.5% binder content by weight of total mix rolled and compacted to required camber and complete.	Sqm	7	1533.4	10733.8	20072	2545.3	17817.1
9	M&L painting lines, dashes, arrows, letters etc, on roads pavements and the like not exceeding 10cm wide with road marking paint white or golden yellow.	RM	2	19.6	39.2	17052	62	124
10	Removing excavated materials to a distance exceeding 250 m and not exceeding 500 m depositing were directed	Cum	10.5	149.4	1568.7	3031	324	3402

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
11	Removing excavated materials to a distance exceeding 1.50 Km and not exceeding 5.00 Km and depositing where as directed	Cum	10.5	208.3	2187.15	3033	433.6	4552.8
	Total Rs				**55993.7**			**108510.25**
	Add (15% RA) on SSR -2010 Items				**8399.05**		MV+RA 15%	**16276.54**
(In Rs)		**Total Cost 10.0 RM**			**64392.75**			**124786.79**
		Total Cost 1.0 RM			**6439.25**			**12478.68**
		Total Cost 1000.0 RM			**6439275**			**12478679**

6.6 Cost of Construction of Single Lane Road

Based on the less traffic and sparsely populated areas certain road connecting small villages only need single lane road. Cost of construction for 1 Km stretch of single lane road has been calculated for year 2010 and present year 2021 as shown in Table 6.5.

Table 6.5 Cost of construction of single lane hill road (Source: Military Engineering Services)

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
	<u>**Single Lane Road**</u>	10.00 RM						
1	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	Cum	16.5	77.4	1277.1	3004	258.5	4265.25
2	Rolling and consolidating formation surface in cutting to the required gradient and camber including filling in depression and hollows water, levelling etc complete using power roller exceeding 8 tonne & not exceeding 12 tonne capacity.	Sqm	5.5	8	44	20027	26	143

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
3	Soling (or sub base) with broken boulders or quarried stone, interstices filled surface formed and rolled and consolidated to required gradient and camber (150 mm spread thick)	Sqm	5.5	1203.6	6619.8	20001	3694.1	20317.55
4	M&L 150 mm thick (compacted thickness) WBM, with coarse aggregate limestone, sandstone, flint or quartzite of grading (63 to 40 mm size) spread, rolled and consolidated to gradient and camber required.	Sqm	5.5	1645	9047.5	20010	1712.5	9418.75
5	M&L Preparing surface by brushing with wire brushes for removing caked mud etc, sweeping with brooms and finally fanning the cleaned with gunny bags to remove all loose dirt etc for unsurfaced WBM surface and applying tack coat with bituminous primer 10 kg per 10 sqm with paving bitumen.	Sqm	5.5	538.7	2962.85	#########	873.1	4802.05
6	M&L 50mm thick Premix bituminous macadam laid/rolled and compacted to required gradient and camber (consolidated thickness 75 mm or less)	cum	1.88	4163.1	7805.81	20066	8915.7	16716.94
7	Applying evenly priming/tack coat with paving bitumen @ 5Kg per 10 Sqm.	Sqm	5.5	214.5	1179.75	20016, 20017	263	1446.5

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Code	SSR Rate 2020	Amount (Rs)
8	M&L Bituminous premix semi dense asphaltic concrete 40mm consolidated with 5.5% binder content by weight of total mix rolled and compacted to required camber and complete.	Sqm	5.5	1533.4	8433.7	20072	2545.3	13999.15
9	M&L precast PCC block masonry (type B1 1:2:4 (20mm graded aggregate, setting in cement mortar .1:6) with solid block exceeding 10 cm in width and setting in mortar, edging width equal to the width of the PCC block laid dry on end vertically	Cum	0.26	3959	1047.16	4030	9079	2401.4
10	M&L painting lines, dashes, arrows, letters etc, on roads pavements and the like not exceeding 10cm wide with road marking paint white or golden yellow.	RM	2	19.6	39.2	17052	62	124
11	Removing excavated materials to a distance exceeding 250 m and not exceeding 500 m depositing were directed	Cum	8.25	149.4	1232.55	3031	324	2673
12	Removing excavated materials to a distance exceeding 1.50 Km and not exceeding 5.00 Km and depositing where as directed	Cum	8.25	208.3	1718.48	3033	433.6	3577.2
	Total Rs				41407.89			79884.78
	Add (15% RA) on SSR -2010 Items				6211.18		7%MV+RA 15%	11982.72
Total Cost 10.0 RM					**47619.1**			**91867.5**
Total Cost 1.0 RM					**4761.9**			**9186.75**
Total Cost 1000.0 RM					**4761910**			**9186750.1**
Say Rs					**4761910**			**9186800**

6.7 Cost of Construction of Box Type Culvert on a Road

The hill road construction and its construction cost will remain incomplete without proper planning of culverts and bridges as per requirement. Hence for the research only cost for one culvert has been calculated in Table 6.6.

Table 6.6 Cost of Construction of Box type Culvert for a road width of 14 m (Source: Military Engineering Services)

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
	FOR BOX TYPE CULVERTS ON ROAD		For One culvert of size=1200x1200, Type A					
				(L=14.0 M, B=1.2 M, D=1.2 M				
1	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	Cum	104.47	77.4	8085.98	3004	258.5	27005.5
2	Add to item 03004 for each additional 1.5 m or part thereof in depth beyond the first 1.5 m loose /soft soil.	Cum	34.82	125.1	4355.98	3005	158.7	5525.93
3	M&L returning, filling in including spreading levelling watering and well ramming in layer not exceeding 25 cm in soft/loose soil complete.	Cum	73.38	41.7	3059.95	3009	139.1	10207.16
4	Removing excavated materials to a distance not exceeding 50 m and depositing where directed at level not exceeding 1.5m above the starting point.	Sqm	65.91	96.1	6333.95	3029	320.4	21117.56
5	M&L for Cement concrete in foundation, filling, and mass concrete (PCC 1:3:6)	Cum	6.25	2579	108214.84	4025	5862	36637.5

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
6	M&L for Walls, retaining walls, basement walls, ballast walls and the like; any thickness; above topof footing; including attached Pilasters and buttress M-30 extra for water retaining structure.	Cum	41.96	4199	176190.04	04054,04066	8421.42	353362.78
7	M&L for Form work to sides of concrete foundation footing bases of column raft and raft beams, side and soffits (if any) of foundation and plinth beams and similar work vertical or to batter rough finished surfaces of concrete flat.	Sqm	41.96	134.2	13873.6	7004	316.72	13289.57
8	Form work to faces of walls, retaining walls, abutment parapets and staircase railing and similar work including attached pilaster buttress etc vertical or to batter fair finished flat.	Sqm	103.38	200	20676	7005	493.55	51023.2
9	Mild steel TMT bars, 10 mm dia and over, cut to length, bent to shape required including cranking, bending spirally for hoping for columns, hooking and binding with and including mild steel wire(annealed) not less than 0.9 mm dia complete	kg	2824.9	48.6	137290.14	10034	82.6	233336.74
10	Ditto but 6 mm to 8 mm dia	kg	300	49.1	14730	10035	84.55	25365
				TOTAL	**492810.47**			**776870.94**
Add (15% RA) =15%					**73921.57**		MV+RA 15%	**116530.64**
Total					**566732.05**			**893401.59**

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
Total cost for one culvert					566732.05			893400
Total cost for 01 culvert					1566732	C/o to summary		893400

6.8 Cost of Construction of Box Type Culvert for a Length of 24 m

For a four-lane road culvert length of 24 m approximately is needed. Number of culverts will be dependent on number of river-lets, streams and drains encountered on the aligned road. Hence, for the research only cost for one culvert has been calculated in Table 6.7.

Table 6.7 Cost of Construction of Box type Culvert for a road width of 24m (Source: Military Engineering Services)

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount	Remarks	SSR Rate 2020	Amount
					(Rupees)	SSR Code		(Rupees)
			For one culvert					
				(L=24.0 M, B=1.2 M, D=1.2 M)				
1	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	Cum	170.47	77.4	13194.38	3004	258.5	44066.5
2	Add to item 03004 for each additional 1.5 m or part thereof in depth beyond the first 1.5 m loose /soft soil.	Cum	56.82	125.1	7108.18	3005	158.7	9017.33
3	M&L returning, filling in including spreading levelling watering and well ramming in layer not exceeding 25 cm in soft/loose soil complete.	Cum	125.18	41.7	5220.01	3009	139.1	17412.54
4	Removing excavated materials to a distance not exceeding 50 m and depositing where directed at level not exceeding 1.5m above the starting point.	Sqm	102.11	96.1	9812.77	3029	320.4	32716.04
5	Cement concrete in foundation, filling and mass concrete (PCC 1:3:6)	Cum	9.85	2579	155152.64	4025	5862	57740.7

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rupees)	Remarks SSR Code	SSR Rate 2020	Amount (Rupees)
6	Walls, retaining walls, basement walls, ballast walls and the like; any thickness; above topof footing; including attached Pilasters and buttress M 30 extra for water retaining structure.	Cum	60.16	4199	39302.64	04054, 04066	8421.42	506632.63
7	Form work to sides of concrete foundation footing bases of column raft and raft beams, side, and soffits (if any) of foundation and plinth beams and similar work vertical or to batter rough finished surfaces of concrete flat.	Sqm	9.36	134.2	19778.4	7004	316.72	2964.5
8	Form work to faces of walls, retaining walls, abutment parapets and staircase railing and similar work including attached pilaster buttress etc vertical or to batter fair finished flat.	Sqm	147.38	200	29476	7005	493.55	72739.4
9	Mild steel TMT bars, 10 mm dia and over, cut to length, bent to shape required including cranking, bending spirally for hoping for columns, hooking and binding with and including mild steel wire(annealed) not less than 0.9 mm dia complete	KG	5032.13	48.6	244561.52	10034	82.6	415653.94
10	Ditto but 6 mm to 8 mm dia	KG	300	49.1	14730	10035	84.55	25365
				TOTAL	**523606.53**			**1158943.6**
Add (15% RA)=15%					**78540.98**		7%MV+RA 15%	**173841.54**
Total					**602147.5**			**1332785.1**
Total cost for 01 culvert					**602148**			**1332800**

6.9 Cost of Construction of Bridge Length 15.5 m and Width 20 m

At certain stretch of road either water flow across road is tremendous and a culvert would not be able to pass the water across the road and at certain places the along with water big boulders and rubble coming in the streams need suitable passage. Hence at places requirement of construction of bridge needs to be addressed. Table 6.8 shows cost of construction of one such bridge.

Table 6.8 Cost of Construction of Bridge for a road width of 20m (Source: Military Engineering Services)

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
	Bridge			**L-15.5 m & W=20.0 m**				
1	Surface dressing not exceeding 150 mm deep hard/dense soil.	sqm	559	10	5590	3011	26.9	15037.1
2	Excavation over area not exceeding 1.5 m deep and getting out in soft/loose soil	cum	540.51	77	41619.27	3004	258.5	139721.84
3	Excavation over area not exceeding 1.5 m deep and getting out each additional 1.5 m or part thereof in depth beyond the first 1.5 m soft/loose soil.	cum	540.51	47.7	25782.33	3005	158.7	85778.94
4	Excavation in trenches not exceeding 1.5 m wide and not exceeding 1.5 m deep for foundation and getting out in hard/dense soil.	cum	396.37	115.2	45661.82	3006	383.7	152087.17
5	M&L PCC 1:3:6 type C-2 cement concrete in foundation, filling, and mass concrete.	cum	36.03	2263.3	81546.7	4011	4727.2	170321.02
6	M&L RCC M 30 Design mix (20 mm graded aggregate) in foundation footing, plinth beams base of column under reamed piles and mass concrete.	cum	202.83	3649.2	740167.24	4053	6532	1324885.56
7	M&L RCC M 30 Design mix (20 mm graded aggregate) inwalls, retaining wall, basement walls, ballast walls and the like any thickness above top of footing including attached pilasters and buttress (add 15% for RMC as per para for 4.2.1 of SSR part I).	cum	169.66	4133.5	701289.61	4054	8240.42	1398069.66

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
8	Rough finished surfaces of concrete formwork to sides of concrete foundation footing bases of columns, raft and footing beams sides and soffits (if any) of foundation and plinth beams and similar works.	sqm	37.75	134.2	5066.05	7004	316.72	11956.18
9	Rough finished surfaces of concrete formwork to faces f walls retaining wall abutment parapet and staircase railing and similar work including attached piles, buttress etc.	sqm	714.4	200	142880	7005	493.55	352592.12
10	M&L RCC M25 Design mix (20 mm graded aggregate) in slabs supported on walls, beams and column in floors, roofs, landing, balconies, canopies ,deck slabs and in shelves and the like.	cum	124	3770	467480	4055	7388.4	916161.6
11	Formwork to soffits of roof slabs, floor slab landing etc & similar work not exceeding 200mm thick with rough flat finished surfaces of concrete horizontal or sloping.	sqm	310	211.5	65565	7006	495.26	153530.6
12	M&L returning, filling in including spreading levelling watering and well ramming in layer not exceeding 25 cm.	cum	1138.49	41.7	47475.03	3009	139.1	158363.96
13	M&L for rendering 20mm thick in cm 1:4 on cement concrete or brick work including finished even and smooth surface using without extra cement with wpc (WPC shall be separately).	sqm	171.36	151.2	25909.63	14001, 14004, 14005	362.56	62128.28
14	WPC on external wall (integral water proofing compound).	kg	34.8	35.3	1228.44	4099	46.1	1604.28

S. No.	Brief description of work	A/U	Qty	SSR Rate 2010	Amount (Rs)	Remarks SSR Codes	SSR Rate 2020	Amount (Rs)
15	M&L mild steel bars TMT bars 10mm dia and over cut to length bent to shape required including cranking bending spirally for hooping for column hooking ends and binding with and including mild steel wire (annealed) not less than 0.9 mm dia or securing with.	kg	53613.21	48.6	2605602.01	10034	82.6	4428451.15
16	Ditto but 6 to 8 mm dia	kg	500	49.1	24550	10035	84.55	42275
17	Removing excavated material to a distance exceeding 250 m and notexceeding 500 m depositing were directed etc.	Cum	1164.87	208.3	242642.42	3029	320.4	373224.35
Total Rs					**5270055.55**			**9786188.79**
Add 15% RA on SSR -2010 Items					**790508.35**		7%MV+RA 15%	**1467928.32**
Total					**6060563.9**			**11254117.1**
Cost for one Bridge					**6060564**			**11254100**
Cost for one Bridge					**6060564**			**11254100**

6.10 Cost of Construction of Highways as per Ministry of Road and Transport

The cost of developing two lane highway in the year 2018 was Rs 11-12 crore and for four lane highway was approx. Rs 30 crore. Presently in year 2022 cost has gone up by 30 %. As per Ministry NHAI has initiated discussions with the Indian Institutes of Technology (IITs) for research and development to bring down the cost of road construction with improved quality. IITs will do a comprehensive study on the alternative environment friendly methods for road and highway constructions and simultaneously maintaining the quality.

Table 6.9 Comparative Changes in Cost of Construction from year 2010 to year 2022

S. No.	Type of Construction	Cost of Construction in Year 2010 (Rs)	Cost of Construction in Year 2021/22 (Rs)	Percentage Change
1		49400	80100	**62%**

S. No.	Type of Construction	Cost of Construction in Year 2010	Cost of Construction in Year 2021/22	Percentage Change
		(Rs)		
	Site Clearance per Square meter			
2	Four Lane Road per km with 1.5m wide divider	14227925	27446700	**92.90%**
3	Two Lane Hill Road per km	6439275	12478678.75	**93.80%**
4	Single Lane Hill Road	4761910	9186800	**92.90%**
5	Box Type culvert (1200m x 1200m) for 14 m wide road	566732	893400	**57.64%**
6	Box Type culvert (1200m x 1200m) for 24 m wide road	602148	1332800	**121.3% (increase in cost of steel)**
7	Bridge L 15.5m W 20.0 m for 24 m wide road	6060564	11254100	**85.7% (increase in cost of steel)**

6.11 Link between cost of construction and environmental impacts

The construction economics heavily rely upon the environment of the hill road to be constructed. Overpasses, tunnels, and additional culverts increase the cost of construction. In one such example the road from Haridwar to Dehradun passes through elephant corridor hence complete stretch needs guardrails to shield the traffic from sudden movement of animals on road. Such infrastructure needs to be planned to depend upon animal movement pattern avoiding road kills. The cost of safety barriers along the hill roads with steep slope on valley side to protects vehicles from careening would add on to the cost of project. More turnings and zigzag need additional road furniture for adequate safety and road information. The loose strata needs most breastwork and deeper excavation on hill sides so as to avoid maintenance cost due to landslides during operational years. Due to construction of hill roads, hillslopes concentrate water flows, which therefore build channels higher on slopes than if roads were not present.

This process results in smaller, more elongated first-order drainage basins and a channel network with a longer total length. Streams carve channels, convey materials and sediments, and alter the landscape due to the external forces of gravity and resistance. Consequently, water runoff and sediment output are the primary physical mechanisms by which hill roads affect streams and other aquatic systems, and the resulting effects get noticed after decades. Drainage basin area modulate the impact of stream network length on erosion and sedimentation. Increased road runoff can increase erosion rates, decrease percolation and aquifer recharge rates, modify channel shape, and increase stream discharge rate. Water runs off very impervious road surfaces quickly, particularly during storms and snowmelt. Overall, the cost of hill roads is governed directly and indirectly by environmental factors of the region.

6.12 Conclusion

The cost of construction is dependent on multiple variables as discussed in this chapter. However, the chapter gives an insight into cost calculation of hill roads. This would standardize the cost calculation method and assist the engineers in planning the construction of hill roads across the country. These cost calculation techniques will be applicable to all developing countries in Asia, only additional factor to be considered for other countries in variation in the currency rates as compared to Indian rupee (INR).

6.13 References

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7.1 Introduction

Due to construction of hill roads muck, dust, other contaminants pollute the surface water. At the same time the construction activity on any hill road needs a work force which should be present in the area of construction site for longer durations or working seasons. Hence to keep the manpower fit and healthy, the contaminants in water of hilly areas and various methods for treatment of water in hills for drinking purposes must be studied.

Water is one of the most important natural resources required for life to exist on Earth. About 78% of the earth's surface is covered with water. Out of that 78%, only 3% is fresh water and of that 3% only about 1% is fit to be used for domestic purposes. With limited water left for use and the rising problem of water pollution, the treatment of water has become inevitable to avoid any harmful effects to the human body. Nowadays, due to increasing population and development, the demand for good quality water has increased rapidly (Khadse et al., 2011).

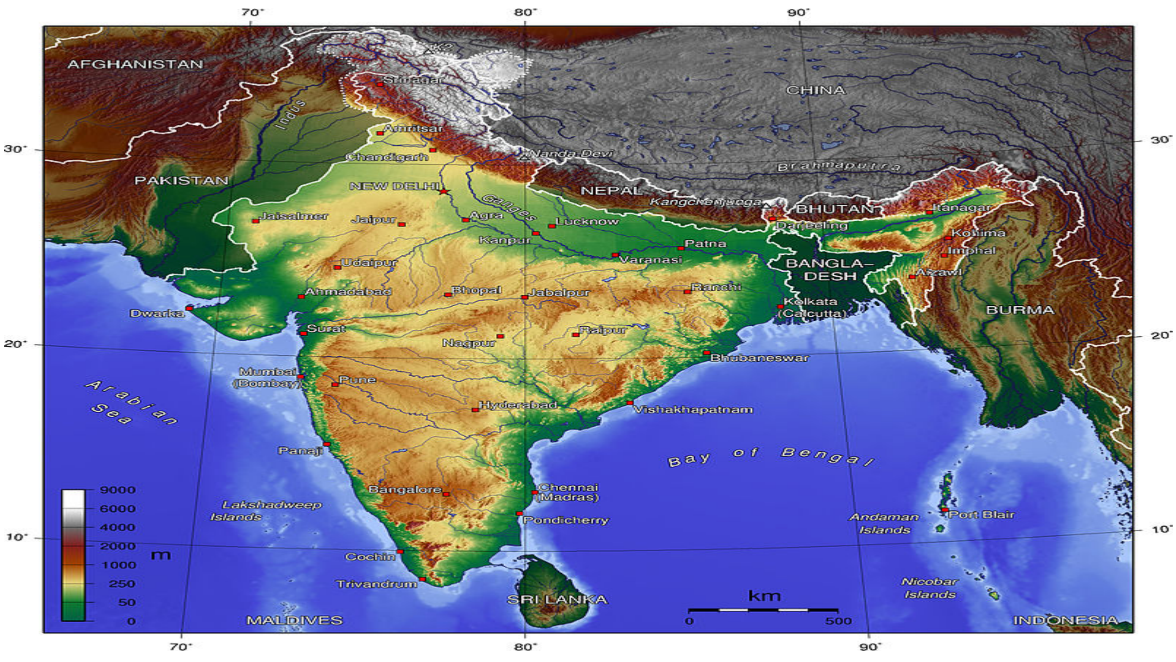

Figure 7.1 Elevation Map of India

India has also a lot of hilly areas, especially in the northern region near the Himalayan Range. Fig. 7.1 (http://www.maps-of-the-world.net/maps/maps-of-asia/maps-of-india/large-topographical-map-of-india.jpg) shows the hilly region in India. These hilly areas have different problems regarding potable water as compared to the rest of the country. With a major portion of the country's population residing in these areas, it is a necessity to provide them with clean and pure drinking water after special treatment.

In hilly areas, the major source of water is rainwater and water from natural springs (Jain et al., 2010). Due to the sloping topography and a lot of deforestation in these areas, the water usually runs off quickly, creating a shortage of usable water, including drinking water. The sloping topography has always been an issue, but in recent years, deforestation has been one of the biggest concerns due to manmade activities and can be easily avoided but is still done for personal needs. To add to that, there are several factors that affect the quality of water in hilly areas. These include the presence of heavy metals, sediments from surrounding hills, presence of different ions like F^-, Ca^+, SO_4^{2-}, Na^+, etc., presence of radiation, bacteria and biological wastes are some of the contaminants that affect water of hilly areas. These contaminants lead to the requirement of special treatment of water in these areas, otherwise it may affect the body of those consuming the water. The major problems faced regarding water in hilly areas is the storage and cheap treatment of water to supply for drinking purpose as a major portion of water in these areas is runoff. These problems need to be addressed and solved in the most economical way possible. The best way to ensure safe drinking water in these areas is by harvesting and then treating the water.

7.2 Areas of Study

This chapter studies the condition of water in hilly areas and provides ways to treat it. As elaborated in section 7.11 and 7.12 of this chapter, water samples were collected from various Rivers of Ladakh, Uttarakhand and Uttarkashi during three different seasons namely winter (from December to January), summer (from April to June) and rainy season (from July to September). Approximately 15 Samples at each monitoring station for River Indus at Chumathang, Karu and Nimu and River Zanskar at Chilling and Sangam and River Shyok at Nubra (Hunder) and River Kali at Najang, Mangti and Malpa and River Ganga at Gangotri were collected and tested at Environmental Engineering Lab at BITS Pilani, Pilani Campus. The conclusions and techniques discussed further are based on the studies made in these areas.

The areas studied are Leh (Ladakh), Gangotri, Uttarakhand, rivulets of River Chenab (Jammu Kashmir). The hilly areas of India are shown in Figure. 7.1 (http://www.maps-of-the-world.net/maps/maps-of-asia/maps-of-india/large-topographical-map-of-india.jpg).

7.3 Impurities

The water in hilly areas has some impurities that are different from those found in normal water in the rest of the country. Different areas in the hilly region have different impurities in the water. These impurities render water undrinkable and unusable. These impurities may affect a person not only physically but also mentally. The major impurities found in hilly areas are discussed in following sections.

7.3.1 Ions

There are some cations and anions that are frequently found above permissible levels in the water of hilly areas. In the Kangra district of Himachal Pradesh, the groundwater contains excess of HCO_3^-, SO_4^{2-} and Cl^- anions and Ca^{2+}, Mg^{2+}, K^+ and Na^+ cations (Dev and Bali 2018). In the Jammu Shiwaliks, Mg^{2+} and Fe^{2+} cations and HCO_3^- and SO_4^{2-} anions are found above permissible limits (Romshoo et al 2017). In the Doda district of Jammu and Kashmir, studies were conducted, and it was found that the water there had an excess of Flouride (F^-) ion. The excess of Flouride ion causes diseases like Dental Fluorosis and chronic kidney damage to name a few (Khandare et al 2017). The excess of different cations and anions in drinking water causes different diseases in the human body.

7.3.2 Bacterial Contamination

Bacterial contamination may be found in water adjacent to populated areas on the banks of river. Bacterial contamination not only causes different diseases but also imparts colour and odour to the water. So, the water is neither potable nor palatable. In the two areas of Uttarakhand, Garhwal and Kumaon, the fecal and total coliform levels were quite high in raw water and treatment was required to bring it down to acceptable limits (Tyagi et al., 2015). In another study, it was found that the total coliform and fecal coliform levels increased from source to point of use, indicating bad supply network which requires constant maintenance (Khadse et al., 2012). The Dal Lake in Kashmir has water which is unfit for consumption under the presence of coliform bacteria due to the direct inflow of the untreated sewage in the lake from the houseboats and from the settlements within and along the lake periphery (Khanday et al., 2018). Bacterial contamination affects the human health due to enteric pathogens. The pathogens cause different diseases in human beings like typhoid, cholera, bacillary diarrhea, and polio (Tyagi et al., 2015). Bacterial growth also causes aesthetic deterioration of the taste and odour of water, bio-corrosion of pipes and fittings, and nitrification processes (Sousi et al., 2018). Therefore, it is important to treat the water before drinking.

7.4 Water Quality Index

When analysing the water of the river Chenab and its tributaries in Jammu Kashmir, Water Quality Index (WQI) was used. The National Sanitation Foundation Water Quality Index (NSF WQI) was developed by selecting parameters rigorously, developing a common scale and assigning weights to the parameters. It provides a number like a grade that express the overall water quality at a certain location and time based on several water quality parameters (Khadse et al., 2016).

$$NSFWQI = \sum W_i I_i \text{ ------------------(7.1)}$$

The WQI of Chenab and most of its tributaries was 70-82 which shows that they have good water quality, and their water is fit for consumption. The only stream which had unsafe water was the Bicheleri stream which had a WQI of 61-67, which is medium. The water of Bicheleri stream is not fit for direct consumption but it can become potable after standard treatment (Khadse et al., 2016).

7.5 Storage of Water

The major source of water in hilly areas is rainfall, in addition to groundwater and natural water springs. Due to the uneven sloped surface of hilly regions, most of the rainfall water becomes runoff resulting in a shortage of water, both for drinking and domestic use. The best way to ensure drinking water is to store rainwater / spring water efficiently, because rainwater is used for irrigation and runoff from rooftops maybe used for domestic use (Kumar, 1996). This stored water can then be treated for different contaminants and supplied to the people for drinking purposes.

7.6 Farm Ponds

The government of Uttarakhand has come up with a very efficient and cheap way to collect and store water which helps in the production of not only drinking water, but also water for irrigation and domestic use. They construct Farm Ponds to collect and use water from natural springs, runoff from rooftops and surface runoff. Out of these, the collection of spring water helps to solve the problem for drinking water. The pond is also very cost effective. It costs about ₹ 150/- per cubic meter water stored (Kumar, 1996). As it is very economical, farm ponds can be constructed easily which is very helpful in storing water at a small scale, providing water not only for drinking but also for irrigation and domestic purposes. A typical Farm Pond is shown in Figure. 7.2.

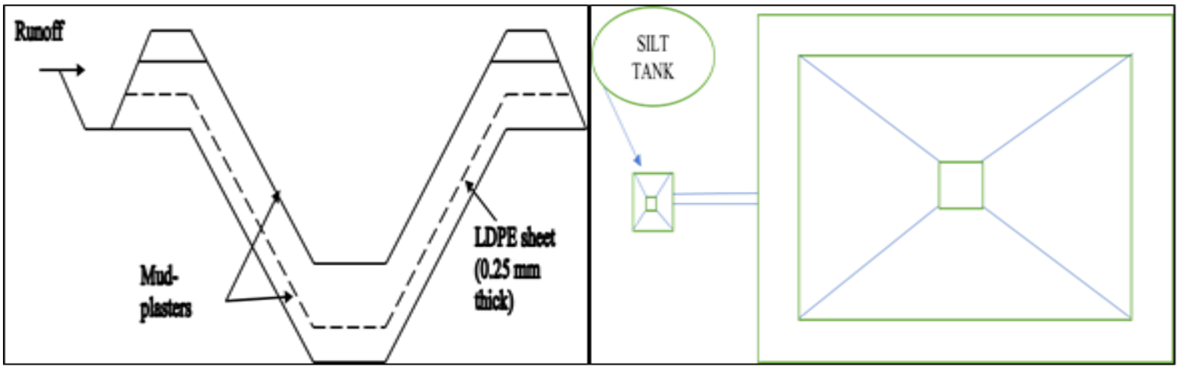

Figure 7.2 A typical farm pond sketch with side and top view

7.7 Design of Farm Pond

To construct a Farm Pond or a dug-out pond a 1:1 side sloped truncated reverse pyramid-shaped pit is dug. To avoid the upward movement of the bottom soil because of the buoyant force, the depth of the pond is restricted to 1 to 1.5 meters only. If there is availability of stones in the vicinity of pond location, then the pond can be stone pitched all around the surface and the depth of the pond can be increased to 2 meters. A 0.25mm thick single piece of Low-Density Polyethylene (LDPE) sheet of required size is placed buried ends on all sides and with properly folded corners. To properly stick the sheet to the surfaces, before placing the sheets, the pond was plastered with 5cm thick mud plaster on the inner surfaces. Another 10 cm layer of mud mixture of soil and chopped dry pine needle or wheat straw (4:1) is placed on the sides and a 15cm thick layer is placed at the bottom. When harvesting the surface runoff, a small slit retention trench is dug at the point of entry of the pond to settle down the suspended particles and debris along with overload runoff and the main pond may get relatively clean runoff water. The size of the pond is 1x0.5x0.5 meters. When the runoff from rooftops or water springs is harvested, the slit retention trench may be avoided. To minimize the evaporation losses from the pond, a small quantity of burnt engine oil can be spread on the surface of the water or polyethylene granules of about 3mm size can be broadcasted. Closed brick-cemented tanks can be used to store the runoff from roof-tops and the flows from water springs as they are relatively free from dust or foreign materials. This stored water can be used for drinking, domestic uses and cattle feeding after proper treatment or filtration. The construction of a Farm Pond is shown in Figure. 7.3 (Kumar, 1996).

Figure 7.3 A typical Farm Pond

7.8 Treatment Methods

7.8.1 Uttaranchal Koop

Uttarakhand has problems of freshwater due to slope factor, management issues, urban conglomeration, deforestation, and other environmental problems. In the rainy season, there is an excess of suspended and dissolved solids in the water. The major source of drinking water in this area are small rivers and rivulets. To tap the water from these sources, stone/gravel walls are created manually but they get easily washed away or damaged during heavy rains causing problems related to drinking water leaving the infiltration well ineffective. Jal Sansthan of Uttarakhand has innovated Uttaranchal koop to solve this problem. Uttaranchal Koop is a valuable device which taps the sub-surface flow of a stream through saturated strata. It is a hollow cylindrical Steel pipe with radial perforated pipes, connected with welded outlet socket in the middle of a vertical cylinder. The water is obtained from the bottom of the streams. The device is placed over the impermeable strata of streams tapping the entire alluvial field. After placing the Koop, the space-graded filter media envelops the Koop up to the natural bed level of the stream.

Figure 7.4 Uttaranchal Koop (Outlet and Inlet) (Source: http://ujsmis.uk.gov.in)

The base flow of the stream rises inside the cylindrical pipe through its open end and perforated radial pipes due to hydrostatic pressure of the submerged surface and maintains a static level in the cylindrical pipe. The outlet socket, placed almost at the middle of the Koop, is connected to the 'gravity-main' of the water supply scheme. The gravity main starts drawing water from the Koop. The static level of the well is maintained through hydrostatic pressure; thus, a continuous flow is ensured. It is very advantageous as it has less construction cost, negligible maintenance cost, better earthquake resistance, less chances of getting damaged during monsoon, the water obtained has lower turbidity, less suspended particles and coliform is easily removed (Sharma, 2014). Figure 7.4 (http://ujsmis.uk.gov.in/Photos.aspx?id=images/img-2.jpg&nm=a2) shows the Uttaranchal Koop device. Such cost effective and innovative devices are needed for use in hills.

7.8.2 River Bank Filtration

Generally proper treatment of surface water is required to make it fit for consumption. Direct consumption of surface water causes harm to the human body as it contains many contaminants. When surface water flows through aquifer material, its quality changes due to natural attenuation processes like sorption, oxidation, hydrolysis, filtration, acid-base reaction, reduction, biochemical reactions, hydrolysis, etc., which is the reason why riverbank filtration is efficient in filtering potential contaminants (Dash et al., 2010).River bank filtration is a very cheap and effective technique which results in the production of potable water. Study observed that at various places in Leh, Jammu and Kashmir and Uttarakhand River bank firltration is the final step in the production of drinking water. Chlorination of water reduces bacterial contamination but is ineffective in removing turbidity, faecal coliform, etc. This is the advantage of Bank Filtration as it removes turbidity, certain bacteria and coliform (Dash et al., 2008). A typical River Bank Filtration (RBF) process is shown in Figure 7.5.In RBF, river water passes through the riverbed sediments or alluvial aquifer, which comprises layers of sand and gravel that also contain underground water. The riverbed acts as a natural filter and removes surface water contaminants by physical, chemical, and biological processes. The physical processes include advection, dispersion, transport and dilution. The mechanical processes include the trapping of particles like particulate organic matter and pathogens in pores resulting in filtration. Filtration, sorption-desorption, solution precipitation, redox reaction, complexation, acid-base reaction, hydrolysis, etc., form the physiochemical processes. The degradation of organic matter for metabolic processes of these organisms and mineralization of secondary substrates form the biological processes (Tyagi et al., 2013). RBF has been proven to be effective in the removal of various contaminants of the surface water. For example, it is helpful in removing turbidity, salinity, pesticides and pharmaceuticals, taste and odour causing compounds, and natural organic matter (NOM). When filtration time and flow path length are enough, it is also effective at reducing the parasites Giardia and Cryptosporidium (Dash et al., 2010). RBF is widely utilised throughout the world to create drinkable water. To mention a few, these nations include the United States of America, Austria, Serbia, Germany, the Slovak Republic, Hungary, and the Netherlands (Ronghang et al., 2018). Haridwar, Uttarakhand, India, has an RBF that is highly effective at removing impurities from groundwater to give potable water to the general people, supplying more over 35 percent of Haridwar's drinking water (Dash et al., 2010). This technology is recommended for usage in hilly regions of India to alleviate the drinking water problem because it is inexpensive and highly effective.

Another cheap material is rice husk which can be used in sedimentation process of drinking water as shown in Figure 7.6

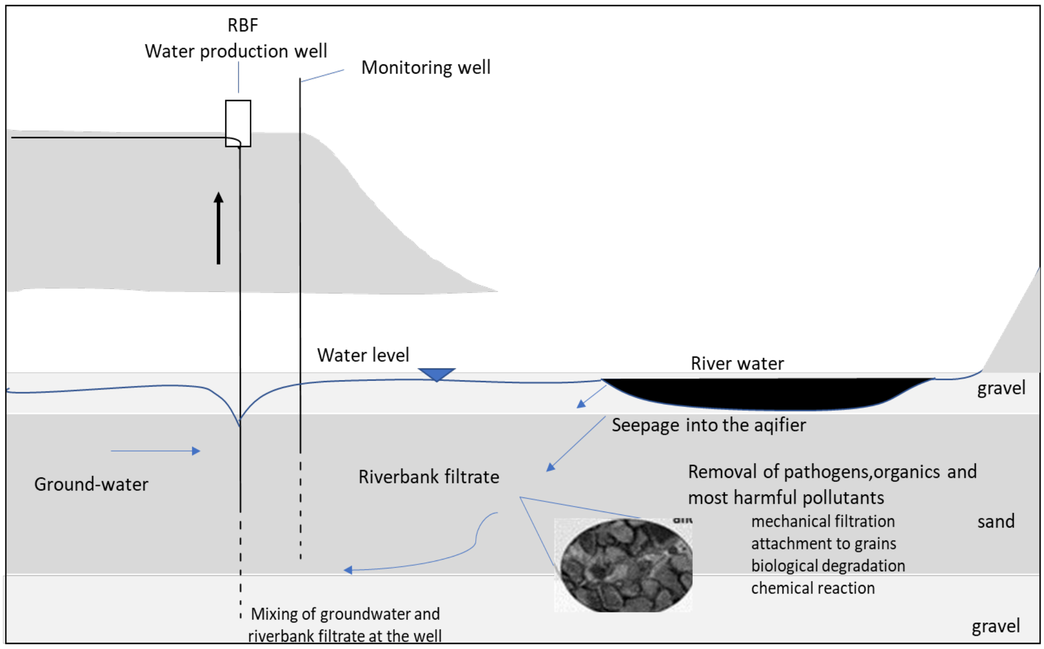

Figure 7.5 Mechanism of Riverbank Filtration

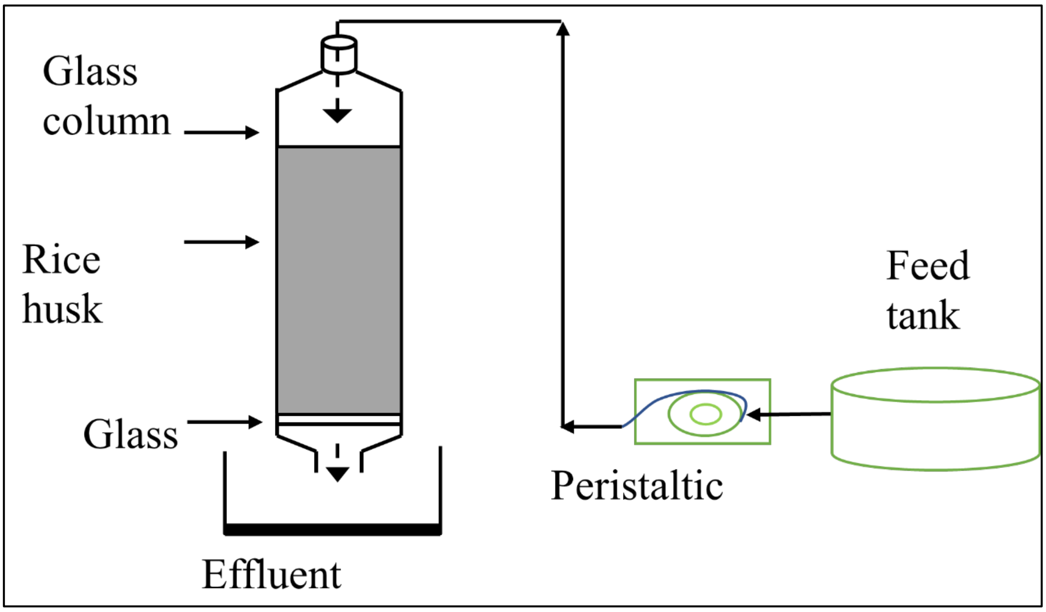

Figure 7.6 Fixed Bed Column Setup

7.8.3 Removal of Bacterial Contamination

Untreated water almost everywhere shows bacterial contamination. The detection of bacteria in drinking water is a major issue as most of the methods may detect dead bacteria showing false results. For this reason, Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) is an efficient method to detect bacterial contamination in drinking water. The use of hydrophobic filters can enhance the detection performance. The detection time can be reduced significantly by the use of less stable Ribonucleic acids like *EF-Tu* (Molaee et al., 2015).

Coliform bacteria can be removed by conventional water treatment like chemical addition, coagulation, flocculation, sedimentation, filtration and disinfection (usually using chlorine). It has been found that these conventional processes do not gurantee in terms of separation efficiency. In recent years, nanotechnology has been frequently used to match the increasing need of potable water. When cylindrical propylene water filters are coated with nano silverparticle layer, they were able to remove *E. coli* contamination even upto a 100%, with the optimum bacterial load and flow rate (Heidarpour et al., 2011 and Moustafa, 2017). This technology has a lot of potential in the use of removing bacterial contamination from water to solve the problem of potable water as it removes 100% bacteria.

A new technique of removal of certain bacteria is Dielectrophoretic (DEP) phenomena. The motion of a particle due to the unbalanced force present in a non_uniform electric field pulls the particle electrostatically along slope of electric field which produces an unbalanced electrostatic force on the charge in a particle referred as DEP. This mechanism has non-linear dependence on electric field and is able to perform microorganism concentration as well as separation in water monitoring systems. This method is used to remove bacteria such as *Escheria coli, Staphylococcus aureus* and *Vibrio cholerae* from water. For the removal of these bacteria, the highest efficiency of Dielectrophoretic Filtration (DF) was observed at 20 V and around 500 kHz to 2 MHz frequency (Sankaranarayanan et al., 2016).

Another method for the removal of bacteria is the use of Ultraviolet (UV) radiation. In this method, the water to be treated is passed through germicidal UV light configured in a low-pressure lamp. When water passes the ultraviolet purifier, the exposure of UV light to the bacteria damages their genetic composition killing them. One of the disadvantages of this process is that it does not contribute in the removal of dissolved chemicals and particulate matter (Sharma and Bhattacharya, 2017).

The combination of ultrasound and chemical disinfectant is a good way to remove bacteria from water. Ultrasound is the cyclic sound pressure wait a frequency more than the upper limit of human hearing. The cellular structure of bacteria is damaged by the mechanical vibrations of the waves. The chemical disinfectant is required because there is a possibility of regrowth of microorganisms (Sharma and Bhattacharya, 2017).

The use of various types of disinfectants is very effective in the removal of bacteria from water. For example, ozone makes an effective disinfectant. The way in which ozone works is that it oxidizes the organics in the bacterial membrane, weakening the cell wall and leading to cellular rupture, thus exposing the organism to external environment causing almost immediate death of the cell. Another disinfectant which is most commonly used is chlorine and its compounds, like chloramine or chlorine oxide (Sharma and Bhattacharya, 2017).

$$Cl_2 + H_2O \rightarrow HOCl + HCl \tag{7.2}$$

$$HOCl \rightarrow HCl + [O] \tag{7.3}$$

Usually bleaching powder is used in place of chlorine.

$$Ca(OCl)Cl + H_2O \rightarrow Ca(OH)_2 + Cl_2 \tag{7.4}$$

$$Cl_2 + H_2O \rightarrow HOCl + HCl \tag{7.5}$$

$$HOCl \rightarrow HCl + [O] \tag{7.6}$$

7.8.4 Removal of Ions

The presence of some cations and anions in drinking water above permissible levels causes various health problems and it is better to treat the water and bring them down to the permissible levels before supply. In the process of distillation, principle of difference in volatility in the mixture is used. Distillation is mostly done along with the use of carbon filters. Although distilled water is safe, it is unhealthy due to the absence of essential minerals (Sharma and Bhattacharya, 2017). Chloride and Flouride can also be removed by the use of activated carbon which works on the principle of adsorption. Almost all kinds of ions can be removed by the process of Reverse Osmosis (RO). It works on the principle that under isothermal operating condition, the tendency for material transport is always in the direction of lower chemical potential (Sharma and Bhattacharya, 2017). In case of RO, water with high mineral concentration enters directly into sewage output. So, use of these devices should be done only in areas with salty water or with high nitrate concentration (Malakootian et al., 2017). Figure 7.7 shows the working of osmosis and reverse osmosis (Sharma and Bhattacharya, 2017).

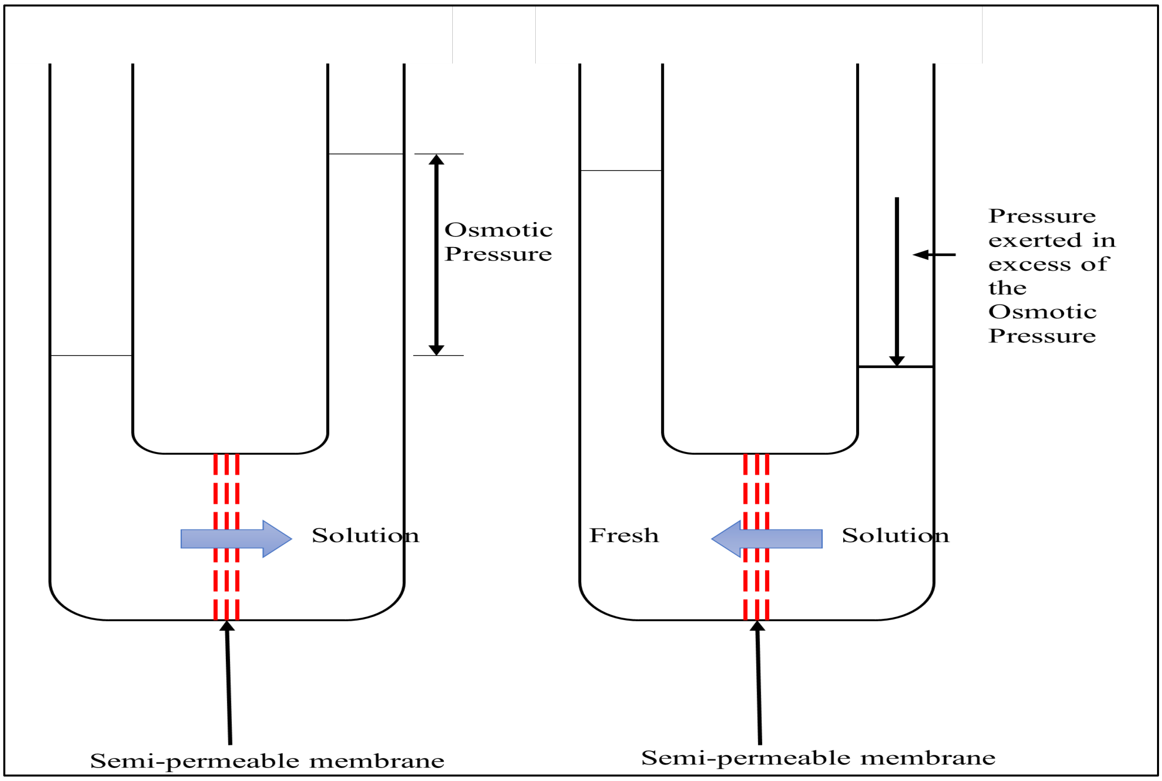

Figure 7.7 Schematic Diagram of Osmosis and Reverse Osmosis (Sharma and Bhattacharya, 2017)

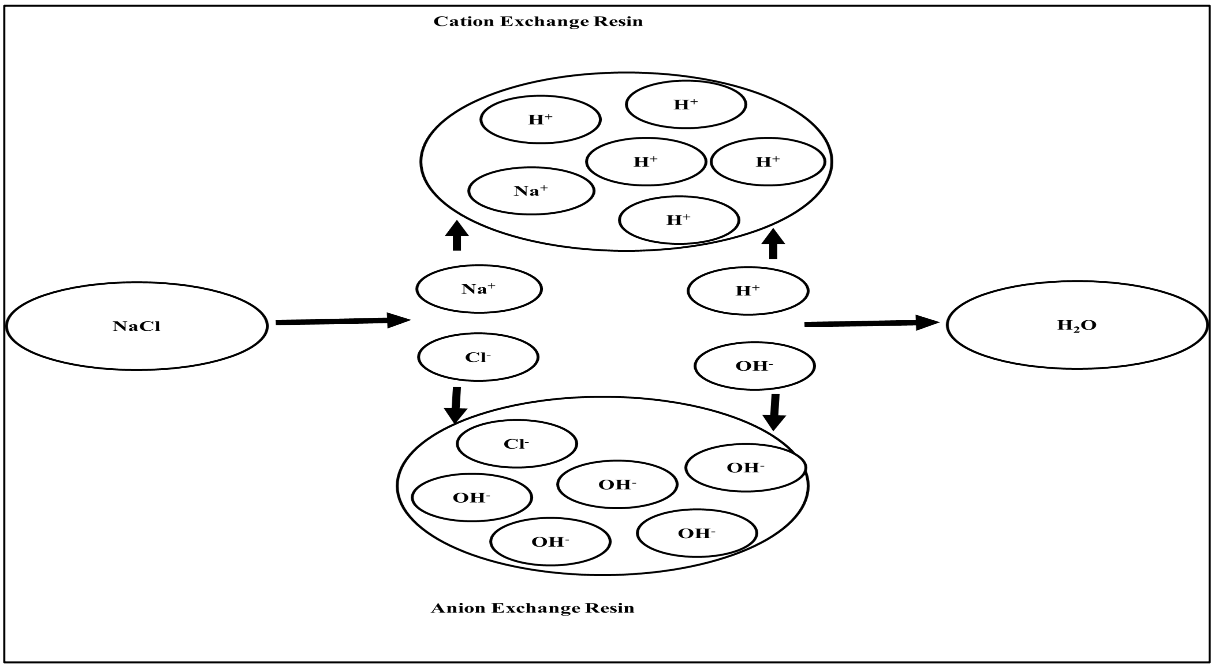

Figure 7.8 Behavior of Cation and Exchange Resin

For example, a cation exchange resin exchanges cations like Ca^{2+} and Mg^{2+} with Na^+ in general. Although this results in an increase in the Na^+ concentration in the solution, but it results in the removal of harmful cations. It is a very simple and low cost technique which results in easy water purification (Sharma and Bhattacharya, 2017). Figure 7.8 shows the schematic diagram of the behaviour of a cation and anion exchange resin (Sharma and Bhattacharya, 2017).

7.9 Testing of Water Samples

Water samples were collected from various Rivers of Ladakh, Uttarakhand and Uttarkashi during three different seasons namely winter (from December to January), summer (from April to June) and rainy season (from July to September). Samples from River Indus at Chumathang, Karu and Nimu and River Zanskar at Chilling and Sangam and River Shyok at Nubra (Hunder) and River Kali at Najang, Mangti and Malpa and River Ganga at Gangotri were collected and tested at Environmental Engineering Lab at BITS Pilani, Pilani Campus.

Table 7.1 Water Sample from River Indus at Chumathang, Ladakh

Samples from River Indus at Chumathang, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.5	6.6	6.8	6.5-8.5
BOD (mg/L)	3.6	3.5	3.5	4
TDS (mg/L)	670	740	816.6	2000
SS (mg/L)	40.8	62	96	-
Hardness (mg/L)	250	264	286	600
DO (mg/L)	6.6	5.8	6.2	-
Turbidity (NTU)	96	242	2730	5
Fe (mg/L)	0.4	0.4	0.4	0.3
SO_4^{--} (mg/L)	122.3	126.2	128.4	400

Table 7.2 Water Sample from River Indus at Karu, Ladakh

Samples from River Indus at Karu, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.4	6.6	6.8	6.5-8.5
BOD (mg/L)	3.6	3.5	3.5	4
TDS (mg/L)	676	778	840	2000
SS (mg/L)	42.6	66	98	-
Hardness (mg/L)	248	266	296	600
DO (mg/L)	6.8	6.4	6.2	-
Turbidity (NTU)	98	246	2786	5
Fe (mg/L)	0.38	0.39	0.4	0.3
SO_4^{--} (mg/L)	124	126	129	400

Table 7.3 Water Sample from River Indus at Nimu, Ladakh

Samples from River Indus at Nimu, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.4	6.6	6.9	6.5-8.5
BOD (mg/L)	3.6	3.4	3.4	4
TDS (mg/L)	724	778	882	2000

Samples from River Indus at Nimu, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
SS (mg/L)	48	76	108	-
Hardness (mg/L)	262	294	312	600
DO (mg/L)	6.4	6.2	5.8	-
Turbidity (NTU)	84	226	2986	5
Fe (mg/L)	0.39	0.39	0.4	0.3
SO_4^{--} (mg/L)	124	126	129	400

Table 7.4 Water Sample from River Zanskar at Chilling, Ladakh

Samples from River Zanskar at Chilling, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.2	6.6	6.7	6.5-8.5
BOD (mg/L)	2.4	2.2	2.2	4
TDS (mg/L)	446	659	975	2000
SS (mg/L)	44	69	106	-
Hardness (mg/L)	128	238	338	600
DO (mg/L)	5.2	5.8	5.9	-
Turbidity (NTU)	68	1162	2877	5
Fe (mg/L)	0.36	0.36	0.39	0.3
SO_4^{--} (mg/L)	121.6	122.4	122.4	400

Table 7.5 Water Sample from River Zanskar at Sangam, Ladakh

Samples from River Zanskar at Sangam, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.2	6.6	6.7	6.5-8.5
BOD (mg/L)	2.4	2.2	2.2	4
TDS (mg/L)	448	683	1012	2000
SS (mg/L)	42	66	118	-
Hardness (mg/L)	127	243	336	600
DO (mg/L)	5.4	6	6	-
Turbidity (NTU)	108	1246	3149	5
Fe (mg/L)	0.37	0.37	0.38	0.3
SO_4^{--} (mg/L)	122.3	122.6	126.1	400

Table 7.6 Water Sample from River Shyok at Nubra (Hunder), Ladakh

Samples from River Shyok at Nubra (Hunder), Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.4	6.3	6.4	6.5-8.5
BOD (mg/L)	2.8	2.7	2.7	4
TDS (mg/L)	398	677	984	2000
SS (mg/L)	40	72	124	-
Hardness (mg/L)	226	248	252	600
DO (mg/L)	6.4	6.4	6.8	-
Turbidity (NTU)	134	1712	3307	5
Fe (mg/L)	0.3	0.32	0.32	0.3
SO_4^{--} (mg/L)	120.6	120.4	121.3	400

Table 7.7 Water Sample from River Kali at Malpa, Uttarakhand

Samples from River Kali at Malpa, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	7.5	7.5	7.6	6.5-8.5
BOD (mg/L)	3.9	3.7	3.7	4
TDS (mg/L)	105	106	108	2000
SS (mg/L)	33	34	38	-

Samples from River Kali at Malpa, Ladakh				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
Hardness (mg/L)	208	226	272	600
DO (mg/L)	7.5	7.5	7.5	-
Turbidity (NTU)	174	176	176	5
Fe (mg/L)	0	0	0	0.3
SO_4^{--} (mg/L)	0.1	0.1	0.1	400

Table 7.8 Water Sample from River Kali at Najang, Uttarakhand

Samples from River Kali at Najang, Uttrakhand				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	7.1	7.2	7.2	6.5-8.5
BOD (mg/L)	3.8	3.6	3.7	4
TDS (mg/L)	94	94	96	2000
SS (mg/L)	56	58	66	-
Hardness (mg/L)	260	262	276	600
DO (mg/L)	7.3	7.3	7.3	-
Turbidity (NTU)	145	146	148	5
Fe (mg/L)	0	0	0	0.3
SO_4^{--} (mg/L)	0.1	0.1	0.1	400

Table 7.9 Water Sample from River Kali at Mangti, Uttarakhand

Samples from River Kali at Mangti, Uttarakhand				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	7	7	7.2	6.5-8.5
BOD (mg/L)	3.8	3.7	3.7	4
TDS (mg/L)	89	89	90	2000
SS (mg/L)	32	33	33	-
Hardness (mg/L)	230	228	232	600
DO (mg/L)	7	7	7	-
Turbidity (NTU)	164	168	194	5
Fe (mg/L)	0	0	0	0.3
SO_4^{--} (mg/L)	0.1	0.1	0.1	400

Table 7.10 Water Sample from River Ganga at Gangotri, Uttarkashi

Samples from River Ganga at Gangotri Glacier				
Sample Collection Season	**Winter Season**	**Summer Season**	**Rainy Season**	**Permissible Limits**
pH	6.5	6.6	6.8	6.5-8.5
BOD (mg/L)	2.4	2.4	2.3	4
TDS (mg/L)	248	256	448	2000
SS (mg/L)	36	36	38	-
Hardness (mg/L)	106	108	108	600
DO (mg/L)	6.4	6.6	6.6	-
Turbidity (NTU)	120	1446	2876	5
Fe (mg/L)	0	0	0	0.3
SO_4^{--} (mg/L)	0	0	0	400

7.10 Discussion

Analysis of water samples of various rivers for different seasons bring out that during winters when 80 % of river is frozen, the water can be directly used for drinking after few hours of sedimentation. However studies have further revealed that turbidity and suspended solids are major concern for utilisation of river water for drinking purposes during summer and rainy season. The ice on glacier melts and increases the turbidity as increase of flow was observed varying from 86% to 176% as compared to winter flow in each river. Maximum increase of flow was observed in River Shyok at 176% followed by River Zanskar, River Kali, River Ganga and River Indus being least at 86%. Studies further reviewed various papers regarding the quality of water in the hilly areas and the contaminants found in it in this chapter. The vast areas referred to in this chapter cover a majority of the hilly portion in India, ranging from Jammu and Kashmir in North to Manipur in North East. Therefore, it can be safely said that the results obtained here can be generally applied to a major portion of the hilly areas in India. Not only have we listed the impurities found in the water of hilly areas, but we have also discussed some new, cheap and efficient ways as well as some conventional ways to ensure that these impurities are removed efficiently and economically.

The presence of bacterial contamination, like total coliform and faecal coliform, is a very big cause of diseases in human beings in general. The accurate detection of bacteria in water can be done by the use of Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) along with hydrophobic filters and less stable Ribonucleic acids. Coliform bacteria can be removed by chemical addition, coagulation, flocculation, sedimentation, filtration and disinfection with chlorine, which are all conventional methods. It can also be removed by the use of nanotechnology where the propylene water filters are coated with nano silverparticle layer. Use of Ultraviolet radiation is another method to remove bacteria from water. Bacteria can also be removed by the technique of combination of ultrasound and chemical disinfectant. The use of chemical disinfectants like bleaching powder, chlorine and ozone is most common for bacterial removal from water. A new method of removal of bacteria from water is Dielectrophoretic process. Dielectrophoretic Filtration at 20 V and 500 kHz to 2 MHz frequency has high efficiency for the removal of bacteria like *Escheria coli, Staphylococcus aureus* and *Vibrio cholerae* from water.

The water of the river Chenab and its tributaries was analysed using the National Sanitation Foundation Water Quality Index (NSF WQI). It was found that all of its tributaries except Bicheleri stream had good water quality which was fit for consumption. Bicheleri stream had medium water quality which had to be treated before consumption.

One of the major problems in hilly areas regarding water is its storage. The concept of Farm Pond is discussed to solve this problem. Farm Ponds are truncated reverse pyramid-shaped pit to store water which can be later used for drinking, irrigation as well as domestic purposes. It is a very efficient and cost effective technique which costs about ₹ 150/- per cubic meter water stored.

Uttaranchal Koop is a very innovative technique developed by the Jal Sansthan of Uttarakhand to treat water in a very efficient way so that it can be potable at a small scale. It is a device that taps the sub-surface flow of a stream through saturated strata. It costs very less and provides water which has lower turbidity, lesser suspended particles and easy removal of coliform.

River Bank Filtration (RBF) is a widely used method to treat water in a natural way. In RBF, the surface water contaminants are removed by physical, chemical and biological processes as the river water passes through the riverbed sediments, which comprises of layers of sand and gravel and which acts as a natural filter. RBF is widely used in USA, Austria, Serbia, Germany, Slovak Republic, Hungary and Netherlands. In India, RBF is used in Haridwar, Uttarakhand.

7.11 Conclusion

The hilly areas have different problems regarding drinking water and therefore they require special attention and different techniques to solve the problem of potable water. The demand of potable water is increasing with increase in population and development. Most of the water in hilly areas becomes runoff and there is a need to find new ways to harvest water which can be treated and used for drinking. The concept of Farm Pond is a very cheap and efficient way of doing that. The use of innovative techniques such as the Uttaranchal Koop and River Bank Filtration have led to providing more potable water. These techniques are cheap and have shown positive results and they should be used in other hilly areas in India as well. The water of hilly areas has a lot of heavy metals, bacterial contamination and ionic contamination. Newer and more innovative methods should be proposed so as to remove these contaminations in a cheaper and more efficient way. Overall, the water in the hilly areas of India is safe for drinking after treatment.

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8.1 Introduction

The present study aimed EIA of hill road construction and SIA of project area during the construction years and operational years. The scope of EIA is unlimited beginning from the inception of project to the execution years and operational years culminating at the end of shelf life of a project. Present study has been inspired by the author's first-hand experience as head of execution team of road widening project of road Katra-Reasi from 3.6 meter to 12 meters and mentorship by **Dr Anupam Singhal** and **Dr Ajit Pratap Singh** during the ME years.

8.2 Conclusion

This research work is a milestone in study of EIA of hill road construction. The thesis is a holistic single document covering construction and operational phase studies and experiments. Study incorporated the construction data and effect on project area including increase of bedload of River Kali and its streams along the route in Dharchula Project. The impacts on environment for both projects have been monitored, evaluated, and analysed with respects to multiple environmental parameters. The social impact of new hill road project on society is also studied in detail. Air pollution caused by equipment, machinery including generator sets in hill areas during construction phase has been studied for both Katra-Reasi road widening and Dharchula-Lipulekh pass.

8.2.1 Chapter – 3

In Chapter 3 the research was carried out on Katra Reasi road widening project and EIA was studied in detail during the construction phase and operational phase. In depth study carried out from year 2010 to 2021 has given elaborate results and conclusion. The MCDM model presented in Chapter 3 allows for the systematic evaluation of both qualitative and quantitative factors affecting decisions as well as a mechanism for the overall integrative evaluation of criteria. During the study, the priority of objectives was verified by the timely completion of the project. The choice for decision-making criteria will vary with the case, depending upon altitude, terrain, task, time of completion of project and cost. The MCDM tools have been proved to be very precise and comprehensive for taking decisions where bias should be avoided. Apart from decision-making about EIA parameters using MCDM tools the study also concerned other issues. Avoiding excavation during the rainy season reduced pollution of surface water in adjacent river stream. The surface water hydrology was least altered because of minimal soil erosion and limited increased sediments in surface water. The landscape was disfigured to the least extent by road embankments during widening projects. The ecology and sensitive areas subject to human interference needed immediate EIA mitigation techniques. The project also caused dislocation and involuntary settlement of certain people whose houses were acquired in widening the road. Retaining walls were immediately supported with plantation on slopes. Slopes in other stretches were adequately stabilised with subsequent plantation. Mitigation techniques for soil erosion were used by choice of natural biodegradable substances in construction. Suitable passage for wildlife and protection of flora and fauna by avoiding the sensitive area during the planning stage and driving without speeding (i.e., within the permissible speed limit) on the road stretch ensures safety of both human lives and wildlife. The results of the opacimeter test of diesel vehicles show that HSUs of buses are the highest, followed by light commercial vehicles, heavy commercial trucks, and cars; and three- wheelers have the least score. The results also show that the make and age of the vehicles had negligible impact on HSU and k values

8.2.2 Chapter - 4

In Chapter 4 the research carried out on construction of green field alignment road from Dharchula to Lipulekh pass in Uttarakhand studied the impact of construction activity on the increase in bed load of adjacent flowing River Kali. The study observed bedload consisted of particles in the size category of 0.5 mm to more than 10 mm. The average size of bedload particles of 1.18 mm and above was 22% of total sample material, suspended particles with diameters less than 0.1 mm were found to be average 24% of entire sample material, particles above 10 mm diameter were approximately 2%. These were observations during average flows; however, bedload at times of high flow included large particles, including rock content from the excavation site. The bed load calculated for Malpa, Najang, and Mangti was 0.0594841 tonnes/day, 0.0588199 tonnes/day, and 1.58733 tonnes/day. The water samples collected at these monitoring stations showed turbidity at 174, 145, and 164, respectively. The TDS decreased as the water flowed downstream at 40, 50, and 60 Km from the construction site. The excavated material enhanced bed load transportation during rainfall by 14 %. The bed load during the rainy season for Malpa, Najang, and Mangti was 0.068 tonnes/day, 0.06696 tonnes/day, and 1.70564 tonnes/day, respectively. The other environmental factors such as the addition of streams en-route, the bed profile, and the river's width contributed to variation in bedload transportation.

8.2.3 Chapter - 5

In Chapter 5 the social impact assessment of hill road construction was studied for road Dharchula to Lipulekh pass. Research analysed that the strategic importance of road overlay all social impacts and magnitude of this factor for any road cannot be quantified hence excluded from assessment in present study.

a. The project road has increased the women's participation in society, as per NSF method 23.9%, Battelle method 60% and Checklist method 40% respectively.

b. The imparting of education accessibility is estimated to increase by 70.8% as per NSF method, 72% as per Battelle method and 80 % as per Checklist method.

c. The project road shall also indirectly benefit the educator development program of primary school teachers by 20%. Education impact shall be clearly noticed in next census.

d. Project road has changed the perceived public opinion and public engagement of society.

e. Local population's access to science and technology has increased by 16 % as per NSF method and Battelle method whereas 40% as per Checklist method.

f. Health related impact is 48.5% as per NSF method, 72% as Battelle method and 60 % as per Checklist method for villagers including the elderlies and persons with disabilities.

g. Increased mobility and transport facilities have impacted perceived well-being of society by 32% and 36% as well.

h. Employment opportunities during construction phase was limited to labour requirements but connectivity has increased so development of diverse workforce by combination of academic, tourism, industry and communication is enhanced by 80%.

i. NSF method has holistic approach clearly giving outcome for each social impact parameter while the Checklist method was found to be subjective. Battelle method too has an inherent advantage of comparing social impact situation with and without project.

j. The study further substantiated the outcome of Battelle method and Checklist method have almost similar results, assessment scores being 15.8 and 16.05 respectively.

k. Social impact study has very vast domain, but the road will enhance connectivity and will benefit the Indian pilgrims on the Kailash Mansarover journey too.

l. The construction of this hill road has made travel very safe.

m. Education, health, and indirect impact have long-term benefits, but even short-term social effects on society have been tremendous.

n. It has given connectivity to almost fifty villages and settlements. The migration from villages to Dharchula town for health and education has started.

o. As per the villagers' interview during the survey, some resettlements are likely to come up near the road head as job avenue of shops for food and refreshments for tourists has occurred.

p. Usage of plastic for the packaging of food items and refreshments by tourists has increased the use of plastic in the region. Due to the absence of proper waste disposal facilities, the current trend allows the travellers on the road to dump the plastic on roadsides creating garbage of 300 kilograms per month during tourist season and has 4% negative impact, which in the long run will affect the pollution of River Kali.

q. The study envisages social road safety education should form part of the curriculum to impact the behaviour of drivers apart from enforcing traffic laws on over-speeding, lane discipline, and overtaking.

8.2.4 Chapter - 6

In chapter 6 research found that the cost of construction is dependent on multiple variables. However, the chapter gives an insight into cost calculation of hill roads. This would standardise the cost calculation method and assist the engineers in planning the construction of hill roads. Research covers how estimates are done deliberating upon calculation of cost of various activities during construction of hill road. The construction activity is sub-grouped into various steps for ease of cost calculations. Further cost for each activity per cubic meter or per square meter is analysed as per present rate analysis and has been compared with respect to rates of year 2010, a decade earlier. The cost of construction of hill road has been estimated for one km stretch for Single Lane, Double Lane, and four lane hill road construction. For estimation of culverts and bridges en-route which shall vary for each site and given geographical conditions the cost for one culvert (box type) and one bridge has been estimated. Depending upon number of culverts and bridges the cost estimation for any length of hill road can be estimated.

8.2.5 Chapter - 7

In chapter 7 the research focused on the problem of drinking water needed by the manpower employed in hill road construction activity. The hilly areas have different problems regarding drinking water and therefore they require special attention and different techniques to solve the problem of potable water. The demand of potable water is increasing with increase in population and development. Most of the water in hilly areas becomes runoff and there is a need to find new ways to harvest water which can be treated and used for drinking. The concept of Farm Pond is a very cheap and efficient way of doing that. The use of innovative techniques such as the Uttaranchal Koop and River Bank Filtration have led to providing more potable water. These techniques are cheap and have shown positive results and they should be used in other hilly areas in India as well. The water of hilly areas has a lot of turbudity, bacterial contamination and other contaminants. Overall, the water in the hilly areas of India is safe for drinking after treatment.

8.3 Limitations

Study shall form a foundation to conduct EIA and SIA in smooth manner for projects to be executed in future. At present the limitations are awareness to EIA and lack of will to cater for EIA effectively in any road construction project. In developing nations, the EIA forms part of mandatory reports needed for approval of projects. The EIA must be integrated in all construction projects from planning to execution and operational phase.

a. Biggest limitation is that the EIA is only restricted to DPR (Detailed Project Report) in many projects. It is recommended that the EIA team playing proactive role should supervise the complete construction work in this project and ensure that the excavation works are done with minimum temporary loss of vegetation. The optimisation of the cut and fill section reduces the impacts to a great extent. Excavation material is recommended to be used with advantage in the fill section.

b. Lack of planning of the dumping sites initially has huge environmental impact. Rehabilitation of dumping sites should also be a part of the project's EIA. The planting of saplings should begin in the adjoining area even before the commencement of the project.

c. Study of construction of road Dharchula to Lipulekh pass and road widening project at Katra Reasi bring forward the constraints in hill region. The activities of the project should be conducted such that the nearby surface water sources are not polluted. Adequate drainage should be provided for the hilly roads and the drainage should be designed to reduce the speed of runoff water.

d. The increased bedload creates water pollution, but at that altitude and inclement weather, the mitigation techniques are minimal and not economical hence experiments carried out by attempting to increase plantation were not successful. Thus, the study suggests that during the implementation phase of hill road construction, the emphasis must be to reduce the excavation/earthwork to minimal. To conserve the environment, the use of elevated hill road shall be safer and effective.

e. Vehicles and equipment used for construction should be functional and tested for pollution norms regularly. Any spillage of material appropriately cleared reduces the impact on the environment. Suitable waste management at construction sites and recycling of resources is crucial for a hill road project.

f. For drinking water on construction sites newer and more innovative methods should be proposed so as to remove these contaminations from runoff water in a cheaper and more efficient way.

g. This research is limited to study, experiments, and survey by research scholar himself.

h. Research work needs funding either from government or from private institutions. Limitation of funding will be restricting factor for researchers.

8.4 Scope for Further Work

a. The research can be further expanded to include the Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) of hill road construction in northeastern states. This would provide a comprehensive understanding of the environmental and social implications of road construction activities in this region.

b. Additionally, the research can be extended to investigate the specific challenges and impacts of hill road construction in permafrost regions such as Ladakh. Understanding the unique characteristics of permafrost and its interaction with road construction would contribute to the development of appropriate engineering and environmental management strategies.

c. Furthermore, the research has the potential to delve into the hill road construction projects undertaken by the National Highway Authority of India (NHAI). Analyzing the NHAI's practices, policies, and their impact on the environment would provide valuable insights for sustainable road development in hilly areas.

d. A significant area of future research could focus on studying air pollution in greater detail during the construction phase of hill roads. Specifically, investigating the emissions from equipment, machinery, and generator sets operating in hill areas would contribute to understanding and mitigating the adverse effects on air quality.

e. While the current research has examined multiple environmental parameters and social aspects, there is scope for specialization and in-depth study of individual parameters. This would involve dedicating research efforts to explore the specific impacts of hill road construction on air, water, land, and social aspects separately, providing detailed insights into each area.

f. Based on the field data collected, a promising direction for future research would be to conduct sediment transport modeling. Researchers can develop laboratory-scale models to simulate sediment transport in similar terrain, validating the simulation against the field data. This approach would enable a more comprehensive understanding of sediment movement and its implications on water quality and ecosystem health across entire watersheds.

In conclusion, the research holds promising avenues for further exploration and expansion. By incorporating elements such as EIA and SIA, studying specific regions and organizations, investigating air pollution in detail, specializing in individual parameters, and conducting sediment transport modeling, researchers can contribute to a deeper understanding of the environmental impacts of hill road construction and develop effective strategies for sustainable development in hilly areas.

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OFFICE OF THE DEPUTY COMMISSIONER REASI

Minutes of meeting

A meeting of the Road Safety Committee was held on 10-04-2017 under the chairmanship of the undersigned and the following Officers/Officials/Private Transport Union Members, participated in the meeting.

1. Sr. Superintendent of Police, Reasi
2. Addl. Deputy Commissioner, Reasi
3. Chief Medical Officer, Reasi.
4. Assistant Regional Transport Officer, Reasi.
5. District Information Officer, Reasi
6. XEN, PWD (R&B), Div. Katra
7. XEN ,PMGSY, Div. Reasi
8. District Officer, SPCB, Reasi
9. OIC - 364/RMPL (GREF)
10. Tehsildar, Pouni
11. DTI, Reasi.
12. Manger, Bus Stand
13. President, (Transport Union), Reasi
14. President, Auto Union, Reasi

The following issues were discussed threadbare and decisions taken thereof:-

Assistant Regional Transport Officer, Reasi has provided the year wise information /details of road accidents, which occurred during the years mentioned below in the District Reasi.

S.No.	Year	Total Accident	Death	Injury
1.	2010	170	38	438
2.	2011	168	47	329
3.	2012	222	35	335
4.	2013	218	33	355
5.	2014	197	29	279

Questionnaire

1. **Safe Travel**
   - **a.** Is road adequately marked with various signs? [Ideal/Adequate/Just Sufficient/Barely Marked/No Marking]
   - **b.** Are highway guardrails provided on the complete road stretch? [Ideal/Adequate/Just Sufficient/Barely Provided/No Guardrails]
   - **c.** Does this hill road cater for Highway design consideration specific to Human factors (Reaction time, Visual Acuity, Car following behaviour)? [Yes/ No]
   - **d.** Does road cater for vehicular turning radius and other technical parameters including gradient requirements of hill slope? [Yes/ No]
   - **e.** Does this road have appropriate roadway for traffic requirements & traffic service level? [Yes/ No]
   - **f.** Does this road provide safe, efficient, and fast movement of traffic? [Yes/ No]
2. **Saving of Time**
   - **a.** Does construction of road Ghatibagarh-Lipulekh 76 Km stretch reduce travel time? [1 day/ 2 days/ 3 days]
   - **b.** Is any other shorter diversion route available? [Yes/ No]
3. **Social Impact**
   - **a.** Has any change in population / community noticed since construction of road? [Yes/ No]
   - **b.** Has construction of road Ghatibagarh-Lipulekh 76 Km stretch provided job avenues and affected income amenity? [Very much/ Limited impact/ No Impact/ Negative Impact]
   - **c.** Has construction of road Ghatibagarh-Lipulekh 76 Km stretch given rise to migration of population?
     - i. Incoming Population [Yes / No/ No Judgement possible]
     - ii. Outgoing Population [Yes / No / No Judgement possible]
   - **d.** Has construction of road Ghatibagarh-Lipulekh 76 Km stretch forced any settlement to shift due to alignment? [Yes / No/ No Judgement possible]

e. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch increased Women's Role in existing population? [Very much/ Limited impact/ No Impact/ Negative Impact]

f. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch caused any effect on minority groups? [Very much/ Limited impact/ No Impact/ Negative Impact]

g. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch increased accessibility to the sites of value? [Yes / No/ No Judgement possible]

h. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch caused any regional effects? [Very much/ Limited impact/ No Impact/ Negative Impact]

i. Does construction of road Ghatibagarh-Lipulekh 76 Km stretch have any impact on user involvement? [Very much/ Limited impact/ No Impact/ Negative Impact]

j. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch increased recreation facility? [Yes/ No]

4. Does construction of road Ghatibagarh-Lipulekh 76 Km stretch have any impact on Communication in the area? [Very much/ Limited impact/ No Impact/ Negative Impact]

5. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch impacted education in District Dharchula?

a. More students from area have approached school / College in Dharchula &Pithoragarh? [Yes/ No]

b. Teachers at primary schools and Block development program teams have approached the villagers? [Yes/ No]

6. Health

a. Has the construction of road caused any changes to water & sanitation in villages? [Yes/ No]

b. Has the construction of road Ghatibagarh-Lipulekh 76 Km stretch caused any changes to habitat of any known species? [Very much/ Limited impact/ No Impact/ Negative Impact]

c. Has the construction of road had any impact on health services? [Very much/ Limited impact/ No Impact/ Negative Impact]

d. Has the construction of road had any impact on nutrition of villagers? [Very much/ Limited impact/ No Impact/ Negative Impact]

e. Has the construction of road has caused relocation of villages / settlements? [Very much/ Limited impact/ No Impact/ Negative Impact]

f. Has the construction of road had any impact on disease ecology of villagers? [Very much/ Limited impact/ No Impact/ Negative Impact]

g. Has the construction of road had any impact on disease hosts? [Very much/ Limited impact/ No Impact/ Negative Impact]

h. Has road construction helped in disease control amongst villagers? [Very much/ Limited impact/ No Impact/ Negative Impact]

i. Have any other hazards come to your notice due to construction of road? [Very much/ Limited impact/ No Impact/ Negative Impact]

7. Has the connectivity / accessibility with Dharchula and Pithoragarh increased? [High connectivity/Adequate / Less than adequate/ Connectivity lacking]

8. Road Safety Management System

a. How is the driver's comfort while driving on the road stretch? [10/9/8/7/6/5/4/3/2/1/0/-1/-2/-3/-4/-5]

b. Has construction of this stretch of road caused increase in traffic on the road? [Very much/ Limited impact/ No Impact/ Negative Impact]

9. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch increased tourism in the Dharchula district? [Very much/ Limited impact/ No Impact/ Negative Impact]

10. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch increased economic development in the town including any industry in the Dharchula district? [Very much/ Limited impact/ No Impact/ Negative Impact]

11. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch enhanced employment opportunity in Dharchula? [Very much/ Limited impact/ No Impact/ Negative Impact]

12. Is there any change noticed in the area in number of accidents, morbidity, and mortality? [Very much/ Limited impact/ No Impact/ Negative Impact]

13. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch caused reduction in operation cost of movement in the area? [Yes/No]

14. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch caused any indirect benefits?

a. Pre-birth care amongst pregnant women [Very much/ Adequate/ No benefit/ Negative Impact]

b. Is there increase in Childhood awareness and development activity by block development authorities [Yes/No]

15. Are there any benefits to environment by construction of this road stretch? [Yes/No]

16. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch impacted day to day life of villagers? [Yes/No]

17. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch enhanced the transport facility in the Dharchula district? [Very much/ Limited impact/ No Impact/ Negative Impact]

18. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch enhanced the logistic facility in the Dharchula district? [Very much/ Limited impact/ No Impact/ Negative Impact]

19. Has construction of road Ghatibagarh-Lipulekh 76 Km stretch impacted mobility in the Dharchula district? [Very much/ Limited impact/ No Impact/ Negative Impact]

20. Any Other Comment/ Feedback you wish to provide?

Figure C1: A retaining wall on a snow-clad hill road under construction

Figure C2: Commencement of snowfall on upper reaches

Figure C3: Research scholar at highest motorable pass at Khardungla for research. Altitude of 18360 ft.

Figure C4: Dozer Marks on the road after snow clearance

Figure C5: Commencement of snowfall on upper reaches

Figure C6: Temperature measurement during data collection at 1300 hrs during research work (-4°C)

Figure C7: Altitude measurement during research work (5327.9 m). Studying the inclement weather at higher reaches of Himalayas and its impact on roads.

Figure C8: Study of impact of snow on hill road of Himalayas

Figure C9: Study of landslides on rural hill roads in Uttarakhand

Figure C10: Studying effect of landslides on flaura and fauna due to vegetation and trees getting uprooted on rural hill roads in Uttarakhand

Figure C11: Study of EIA on rural hill roads in Uttarakhand

Figure C12: Study of flora and fauna on rural hill roads in Uttarakhand

Figure C13: Study of EIA of formation cutting after one working season at a hill road in Uttarakhand

Figure C14: Study of EIA of a gravel hill road in Uttarakhand

Figure C15: Study of landslides induced by unstable strata on slopes of hill road in Uttarakhand

Figure C16: Study of formation cutting of hill road in Uttarakhand

Figure C17: Landslide triggered by rains on a hill road in Uttarakhand

Figure C18: Study of EIA due to fresh laying of AC pavement on a hill road at Leh, Ladakh at an altitude of 16000 ft.

Figure C19: Study of EIA including impact on river due to a hill road construction at Leh, Ladakh at an altitude of 16000 ft.

Figure C20: Scouring of hill road along River Indus at Leh, Ladakh.

Figure C21: Study of landslide due to rains on a hill road along River Indus in Ladakh.

Figure C22: Study of weather on a hill road in Ladakh.

Figure C23: EIA of hill road during winters when complete area is covered in snow and temperature has dropped below -24°C.

Figure C24: Water Sample Collection during winters from River Zanskar when River has partially frozen.

Figure C25: Water Sample Collection during winters from River Shyok at Nubra Valley, River has partially frozen.

Figure C26: Water Sample Collection during summers from River Indus at Karu, Leh.

Figure C27: Water Sample Collection during summer from River Indus at Nimu

Figure C28: Water Sample Collection during summer from River Ganga at Gangotri

Figure C29: Water Sample Collection during winter season from River Ganga at Gangotri

Figure C30: Water Sample Collection during rainy season from River Ganga at Gangotri.

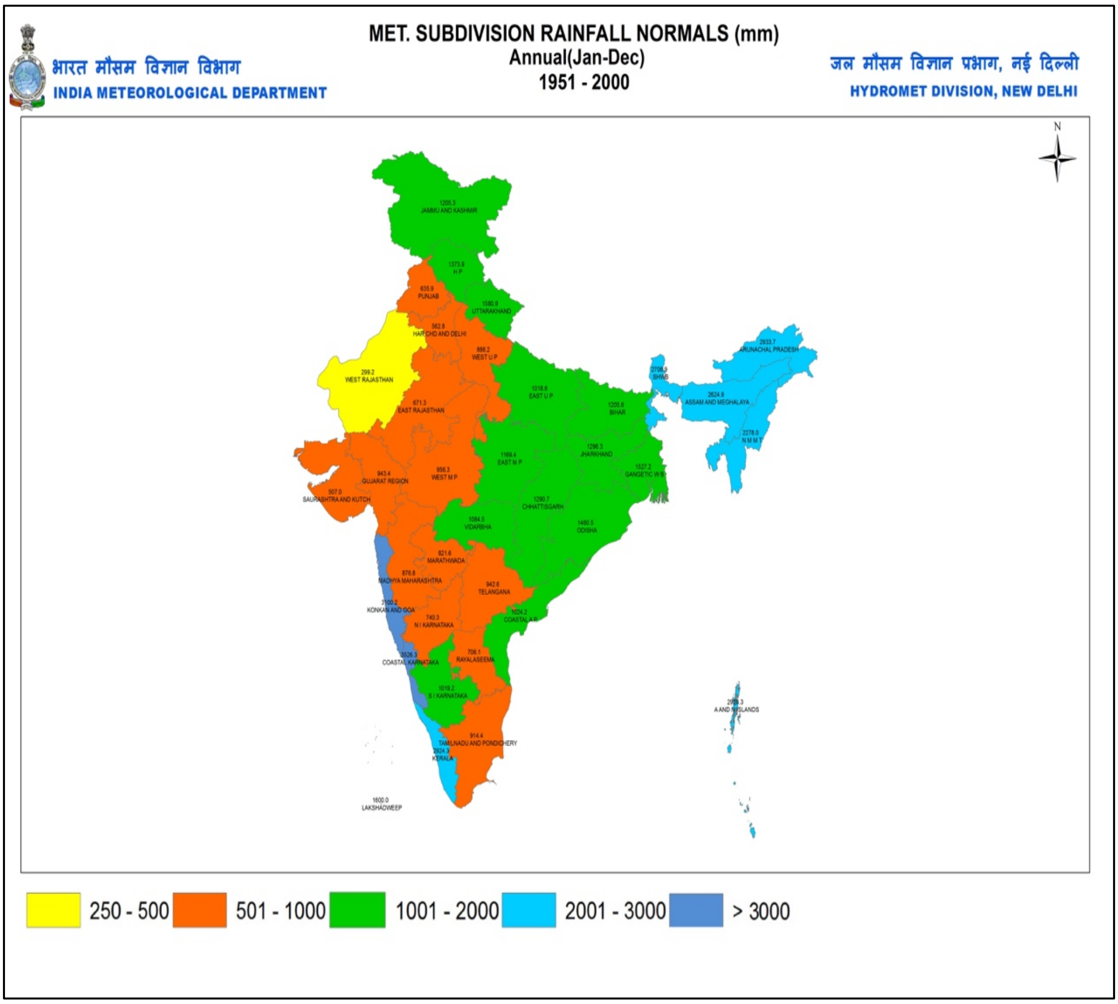
Figure C31: River Indus frozen at upper reaches during winter season.

Figure C32: River Indus partially frozen at Nimu during winter season.

Figure C33: River Indus during summer season at Nimu.

Figure C34: River Zanskar at Sangam during Rainy season.

Refer Para 3.4.2 (a) of Chapter-3



Customized Rainfall Information System (CRIS) Hydromet Division

India Meteorological Department Ministry of Earth Sciences New Delhi-110003

State: - Jammu & Kashmir District:- Reasi

Table 1: Customized Rainfall Information System (CRIS)

YEAR	JAN		FEB		MAR		APR		MAY
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F
2012	156.5	54	101.2	9	34	-60	91.9	111	15.5
2013	74	-27	222	139	56.9	-33	33.5	-23	55.3
2014	99	-2	104.6	12	232.5	175	101	132	23.8
2015	25.4	-75	207.7	123	559.9	562	181.7	318	52.5
2016	15.8	-84	30.7	-67	176.5	109	22.4	-49	88.5

KATRA
EXTREME WEATHER EVENTS IN THE MONTH OF FEBRUARY

YEAR	TEMPERATURE (ºC)		RAINFALL (mm)	
	Highest maximum(date)	Lowest minimum(date)	24 hour highest(date)	Monthly total
2017	24.7/28	7.1/09	65.2/05	87.2
2016	26.2/19	6.4/12	23.3/20	30.7
2015	24.8/23	6.2/05	47.7/03	207.7
2014	21.4/21	4.6/16	24.8/08	98.6
2013	21.7/12	4.8/07	39.9/04	222
2012	23.2/27	3.4/09	36.8/13	101.2
2011	21.4/02	5.3/27	48.8/08	177.1
2010	26.2/28	4.8/10	62.1/09	111.9
2009	23.2/04	8.0/11	20.6/11	45.9
2008	26.8/29	2.6/08	14.3/03	58.2
ALL TIME RECORD	28.8(11/1993)	-1.0(22/1984)	169.2(19/2003)	349.9/2005

CLIMATOLOGICAL TABLE

PERIOD:1980-2000

Month	Mean temperature (°C)		Mean total rainfall(mm)	Mean number of rainy days	Mean number of days with			
	Daily minimum	Daily maximum			HAIL	Thunder	FOG	SQUALL
JAN	5.8	17	101	5.2	0.3	1.6	0.6	0
FEB	7.3	18.9	131.6	5.8	0.1	1.8	0.4	0
MAR	11	22.8	155.7	7.3	0.5	3.7	0.2	0
APR	15.8	29	95.7	4.9	0.3	3.5	0	0
MAY	19.8	33.9	59.2	4.4	0.4	4.8	0	0
JUN	21.9	35.6	118.6	7.1	0.1	4.7	0.1	0
JUL	21.4	31.2	630.2	17.9	0.1	7.5	1.1	0
AUG	20.8	30.1	648.8	17.9	0.1	5.1	0.7	0
SEP	18.8	30.1	209	8.3	0	4	0.2	0
OCT	14.4	28.2	38.6	2.8	0.1	1.9	0	0
NOV	10.5	24.1	28.8	1.6	0.1	0.6	0.8	0
DEC	7.3	19.6	73.3	3	0.2	0.7	0.3	0
ANNUAL	14.8	26.9	2290.9	86.3	0.2	39.8	4.3	0

JAMMU

Extreme weather events in the month of February

YEAR	TEMPERATURE (°C)		RAINFALL(mm)	
	Highest maximum(date)	Lowest minimum(date)	24 hour highest(date)	Monthly total
2017	28.6/20	6.5/10	35.4/05	55.3
2016	26.8/29	6.6/04	12.1/20	15.9
2015	26.9/22	6.0/05	40.2/03	135.3
2014	23.0/24	4.9/12	14.7/14	40.7
2013	24.0/02	5.4/06	27.2/22	145.2
2012	25.3/29	3.2/08	17.7/13	39.9
2011	25.3/05	6.9/21	20.6/14	97.5
2010	29.5/27	5.3/03	17.0/09	31.7
2009	26.7/21	8.1/08	25.2/11	45.4
2008	27.5/29	3.1/13	8.8/05	25
All Time Record	31.7 22/1947	1.1 01/1929	123.6 12/1991	202.2 1914

CLIMATOLOGICAL TABLE

PERIOD:1971-2000

Month	Mean temperature (°C)		Mean total rainfall(mm)	Mean number of rainy days	Mean number of days with			
	Daily minimum	Daily maximum			HAIL	Thunder	FOG	SQUALL
Jan	7.8	18.9	52.4	3.1	0.3	1.2	1.4	0
Feb	9.8	21.6	79	4.2	0.3	2.6	0.3	0
Mar	13.9	25.9	74.9	4.8	0.4	4.8	0	0
Apr	18.9	32	47.1	3.2	0.4	5.9	0	0.1
May	23.3	37.2	34.8	3.2	0.5	6.8	0	0.1
Jun	26	38.7	87.3	5.3	0.3	9.3	0	0.1
Jul	25.3	34	371.5	12.5	0.1	11.8	0.1	0
Aug	24.8	33.1	370.2	13.1	0.1	11.4	0.1	0
Sep	23.1	33.1	140.9	6.1	0.1	7.3	0	0
Oct	18.1	31.2	25.1	1.8	0.1	2.6	0	0
Nov	13	26.6	10.1	1.1	0.1	1.3	0	0
Dec	9	21.2	38.3	2.3	0.1	1.1	1.4	0
Annual	17.7	29.6	1331.6	60.6	2.7	66.1	3.3	0.2

Refer Para 3.10 of Chapter 3

Status of water testing laboratories in Jammu province (as on 30/11/2016)

S.no	Divisions	Name of Sub. Division	Status of building (Complete/Under Construction)	Fully Equipped/awaiting equipments	Status as on today(Functional/Non – Functional)	Target 2017-2018
1	PHE City Div – I Jammu	Sub.Div.Dhonthly	Tendering under process	…	Non-Functional	3
		Sub.Div.Bakisnagar	Tendering under process	…	Non-Functional	
		Sub.Div.Sitlee	Building complete	Fully equipped	**Fully functional**	
		Sub.Div.Muthi	Tendering under process	…	Non-Functional	
2	PHE City Div – II Jammu	Sub.Div.Gandhinagar	Tenders invited	…	Non-Functional	2
		Sub.Div.Kunjwani	Tenders invited	…	Non-Functional	
		Sub.Div.Narwal	Building complete	Fully equipped	**Fully functional**	
3	PHE Rural Div. Jammu	Sub.Div.Bishnah	Building complete	Fully equipped	**Fully functional**	3
		Sub.Div.Kandi-Ist	Work under execution	…	Non-Functional	
		Sub.Div.Kandi-IIst	Work under execution	…	Non-Functional	
		Sub.Div.Kandi-IIIrd	Tendering under process	…	Non-Functional	
4	PHE Div, Akhanoor	Sub.Div.Akhnoor	Building complete	Fully equipped	**Fully functional**	1
		Sub.Div.Khour	Building complete	Awaiting equipments	Non-Functional	
		Sub.Div.Bhalwal	Work under execution	…	Non-Functional	
5	PHE Div, Samba	Sub.Div.Samba	Building complete	Fully equipped	**Fully functional**	2
		Sub.Div.Vijaypur	Const. upto plinth level	…	Non-Functional	
		Sub.Div.Baribrahmana	Tendering under process	…	Non-Functional	
6		Sub.Div.Kathua	Building complete	Fully equipped	**Fully functional**	2

	PHE Div, Kathua	Sub.Div.Harinagar	Tenders floated	…	Non-Functional	
		Sub.Div.Basholi	Building complete	Fully equipped	**Fully functional**	
		Sub.Div.Billawar	Building complete	Fully equipped	**Fully functional**	
		Sub.Div.Bani	Tenders floated	…	Non-Functional	
7	PHE Div, Udhampur	Sub.Div.(HQ)Udhampur	Building complete	Fully equipped	**Fully functional**	0
		Sub.Div.Chennai	Building complete	Fully equipped	**Fully functional**	
		Sub.Div.Ramnagar	Building complete	Fully equipped	Non-Functional(no staff)	
8	PHE Div, Reasi	Sub.Div.Reasi	Building complete	Fully equipped	**Fully functional**	1

Table-1 District-wise break-up of active Ground Water Monitoring Wells in J&K State (as on January 2016)							
S.No	REGION	DISTRICT	Total No of Monitoring wells	Number of Active Ground Water Monitoring Wells			
				May-15	Aug-15	Nov-15	Jan-16
1	KASHMIR REGION	ANANTNAG	1	1	1	1	
2		BANDIPORA	2	1	2	2	
3		BARMULLA	7	6	7	6	
4		BUDGAM	2	1	2	2	
5		KUPWARA	11	9	10	10	
6		PULWAMA	4	1	3	3	
7		SRINAGAR	3	3	0		
	Total		**30**	**30**	**30**	**30**	
8	JAMMU REGION	JAMMU	89	84	87	86	86
9		KATHUA	33	31	32	33	33
10		RAJAURI	38	35	38	37	36
11		REASI	9	9	9	8	9
12		SAMBA	40	35	39	40	38
13		UDHAMPUR	22	20	22	22	22
	Total		**231**	**214**	**227**	**226**	**224**
	TOTAL J&K		**261**	**244**	**257**	**256**	**224**

WATER QUALITY BRANCH, PHE DEPARTMENT, JAMMU

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
1	Colour	5 Hazen Unit	Colour in drinking water may be due to the presence of coloured organic substances; the presence of metals such as iron, manganese, and copper; or the presence of highly coloured industrial wastes. Although the presence of colour in drinking water may be indirectly linked to health, its primary importance in drinking water is **aesthetic**.

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
2	Turbidity	5 NTU	Turbidity is a concern for both health and aesthetic reasons. In these waters, the particulate matter that creates turbidity can contain toxins, harbour microorganisms, and interfere with disinfection. In addition, organic matter in the Water can react with disinfectants such as chlorine to create by-products. **These by-products may cause adverse health effects.**
3	pH	6.5-8.5	pH of water below 6.5 is acidic and above 8.5 is alkaline in nature. Because pH is related to a variety of other parameters, it is not possible to determine whether pH has a direct relationship with human health. Insofar as pH affects the unit processes in water treatment that contribute to the removal of viruses, bacteria and other harmful organisms, it could be argued that **pH has an indirect effect on health.**
4	Total Dissolved Solids	2000 mg/lit	Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The presence of dissolved solids in water **may affect its taste**. Water with extremely low TDS concentrations may also be unacceptable because of its flat insipid taste. Certain components of TDS such as chlorides, sulphates, magnesium, calcium and carbonates also affect corrosion or encrustation in water distribution systems. **High TDS levels (above 500 mg/L) result in excessive scaling in water pipes, water heaters, boilers and household appliances such as tea kettles and steam irons. Such scaling can shorten the service life of these appliances.**

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
5	Total Hardness	600 mg/lit	The principal natural sources of hardness in water aresedimentary rocks and seepage and runoff from soils. Thecations that are the major contributors to hardness - calcium and magnesium- are not of direct public health concern**. In areas with hard water, household pipes can become clogged with scale; hard waters also cause incrustations on kitchen utensils and increase soap consumption.** Hard water is thus both a nuisance and an economic burden to the consumer. Hard water causes **excessive soap consumption**; soft water may result in corrosion of water pipes.
6	Ammonia	0.5 mg/lit	Ammonia is very soluble in water, Ammonia is present in most waters as a result of the biological degradation of nitrogenous organic matter, although it may also reach groundwater and surface waters from industrial waste discharges. Ingestion of massive doses of ammonium chloride by human adults (52-105g over three days) resulted in **headache, insomnia, nausea, diarrhoea and a failure in glucose tolerance.** A dose of 6-8 g daily for 6-9 days resulted in increased urinary output of renal ammonia and urinary magnesium, calcium and phosphate. **There seems to be little risk from ammonia in drinking water at the levels normally encountered.**
7	Residual Chorine	0.2 mg/lit	Most drinking water treatment plants use chlorine as a disinfectant. The use of chlorine in the treatment of drinking water has virtually eliminated waterborne diseases, because chlorine can kill or inactivate most microorganisms commonly

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
			50 mg/L) over a short period of time, **Long-term consumption increases risk for cancer and other health effects.**
8	Fluoride	1.5 mg/lit	**Dental fluorosis** is the most common effect of fluoride. **Skeletal fluorosis** is the most serious adverse health effect clearly associated with prolonged exposure to high levels of fluoride in drinking water. Skeletal fluorosis can occur at very high exposure levels.
9	Arsenic	0.05 mg/lit	Arsenic is classified as a human **carcinogen**. Early clinical symptoms of acute arsenic intoxication include **abdominal pain and vomiting, diarrhoea, pain to the extremities and muscles, and weakness with flushing of the skin.** These symptoms are often followed by numbness and tingling of the extremities and muscular cramping. Signs of chronic arsenicalism include pigmentation and development of keratoses, peripheral neuropathy, **skin cancer, peripheral vascular disease, hypertensive heart disease, cancer of internal organs (bladder, kidney, liver, and lung), alterations in gastrointestinal function** (non-cirrhotic hypertension), and an increased risk of mortality resulting from diabetes, have been observed in populations ingesting arsenic-contaminated drinking water.

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
10	Iron	0.3 mg/lit	Iron is the fourth most abundant clement in the carth's crust and the most abundant heavy metal. At concentrations above 0.3 mg/L, iron can **stain laundry and plumbing fixtures** and produce undesirable tastes in beverages. The precipitation of excessive iron imparts an objectionable reddish-brown colour to water.
11	Nitrate	45 mg/lit	Short-term effects: Excessive levels of nitrate in drinking water have caused **serious illness and sometimes death**. The serious illness in infants is due to the conversion of nitrate to nitrite by the body, which can interfere with the oxygen-carrying capacity of the Childs blood, this can be an acute condition in which health deteriorates rapidly over a period of days. Symptoms include shortness of breath and blueness of the skin. **(Blue Baby Syndrome).** Long-term Nitrates and nitrites have the] potential to cause diuresis, increased starchy deposits and **haemorrhaging of the spleen.**
12	Sulphate	400 mg/lit	Sulphur is a non-metallic element. It is one of the least toxic anions. Studies have shown that drinking water containing sulphates at 3000 mg/L experienced no adverse effects other than diarrhoea. Cattle can tolerate concentrations of sodium sulphate in their drinking water up to 2610 ppm for periods up to 90 days with no signs of toxicity except for changes in methane-globin and sulphaemoglobin level. **May also cause gastrointestinal irritation.**

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
13	Selenium	0.01 mg/lit	It is established that selenium is an essential element in human nutrition, It is unclear whether or not gelenium can be considered a carcinogen. Studies have indicated that selenium might have anti-carcinogenic properties. ingestion of large amounts of selenium has been corrected with a variety of **clinical disorders** in humans
14	Zinc	15 mg/lit	Zinc is an essential element for all living things, including man General symptoms of zine deficiency in humans include retarded growth, hypogonadism, anorexia, **mental lethargy, shin changes, and night blindness.** Water containing zine at concentrations more than 5.0 mg/L has an **undesirable astringent taste** and may be opalescent and develop a **greasy film on boiling.**
15	Mercury	0.001 mg/lit	Mercury is a dense, silver-white metal that melts at -38.9°C Mercury is a toxic element and serves no beneficial physiological function in man, As a result of industrial and agricultural applications, high levels of mercury may occur in localized areas of the environment. The two major responses to mercury poisoning involve neurological and renal disturbances. Acute lethal toxic doses by ingestion of any form of mercury will result in the terminal signs and symptoms, which consist of **shock, cardiovascular collapse, acute renal failure, and severe gastrointestinal damage.**

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
16	Lead	0.01 mg/lit	Lead is the most common of the heavy elements. Lead is present in tap water as a result of dissolution from natural sources or from household plumbing systems containing lead in pipes, solder or service connections to homes. The amount of lead from the plumbing system that may be dissolved depends upon several factors, including the acidity (pH), water sounds and standing time of the water. Exposure of pregnant women to lead also increases the risk of pre-term delivery, Lead has been classified in Group lIB--possibly **carcinogenic** to humans.
17	Cynide	0.05 mg/lit	Cyanide **in toxic and highly lethal** to humans, Single oral doses of 50 to 200 mg cyanide have produced fatalities in humans.
18	Copper	1.5 mg/lit	Copper occurs in nature as the rental and in minerals, in humans, acute copper toxicity has usually been associated with accidental consumption; symptoms include a **metallic taste in the mouth, nausea, vomiting, epigastric pain, diarrhoea, jaundice, haemolysis, haemoglobinuria, haematuria, and oliguria.** In severe cases, the stool and saliva may appear green or blue; in the terminal phases, anuria, hypotension, and coma precede death.
19	E-Coli Coliforms	NIL	E. coli is a type of faecal coliform bacteria commonly found in the intestines of animals and humans. The presence of E, coli in water is a strong indication of recent sewage or animal waste contamination. Infection often causes gastrointestinal illness, skin, ear, respiratory, eye, neurologic, and wound infections.

S.NO	Parameters	Maximum Permissible Limit as per IS 10500-2012	Effect if Limit Exceeds
			The most commonly reported symptom are stomach cramp, diarrhoea, nausea, vomiting, and low-grade fever.

Ministry of Drinking Water & Sanitation
National Rural Drinking Water Program

Format E4-Water Quality Laboratory Details (2016-2017)-All Sources.

S.No.	State	District	Village	Location/Source & Main Scheme Name	Type of Source	Laboratory Name	Testing Date	Below Permissible limit [Mg/L] (mandatory*)	Above Permissible limit [Mg/L] (Emerging other**)	Below Permissible limit [Mg/L] (Emerging other**)
1	Jammu and Kashmir	REASI	AGGAR BALLIAN	MARI Spring Local, **Scheme Name**: AGGAR BALLIAN NRD WP H240000390	215 Delivery Point	District HW Lab REASI	01/03/2017	Arsenic-0.010 Nitrate-45.00 Fluoride-1.100 Iron-0.300 Chloride-324.00 PH-6.70 TDS-1326.00 Alkanity-359.00		Turbidity-3.00 Sulphates-235.00 Calcium-125.00 Magnesium-49.00 Manganese-0.200 Copper-0.060 Hardness-365.00 Residual Chlorine-0.400 Aluminium-0.050

***Mandatory Parameters are Alkalinity, Arsenic, Chloride, Fluoride, Iron, Nitrate, pH, and TDS (Salinity).**
****Other than Mandatory Parameters.**

Ministry of Drinking Water & Sanitation
National Rural Drinking Water Program

Format E4-Water Quality Laboratory Details (2017-2018)-All Sources.

S.No.	State	District	Village	Location/Source & Main Scheme Name	Type of Source	Testing Date	Below Permissible limit [Mg/L] (mandatory*)	Above Permissible limit [Mg/L] (Emerging other**)	Below Permissible limit [Mg/L] (Emerging other**)
1	Jammu and Kashmir	REASI	AGGAR BALLIAN	MARI Spring Local, **Scheme Name**: AGGAR BALLIAN NRD WP H240000390	Delivery Point	02/04/2018	Arsenic-0.020 Nitrate-45.00 Fluoride-1.200 Iron-0.300 Chloride-460.00 PH-7.70 TDS-1326.00 Alkanity-400.00		E-Col-0.000 Turbidity-3.00 Sulphates-235.00 Calcium-125.00 Magnesium-49.00 Manganese-0.200 Copper-0.060 Hardness-365.00

									Residual Chlorine-0.400 Aluminium -0.050

***Mandatory Parameters are Alkalinity, Arsenic, Chloride, Fluoride, Iron, Nitrate, pH, and TDS (Salinity).**

****Other than Mandatory Parameters.**

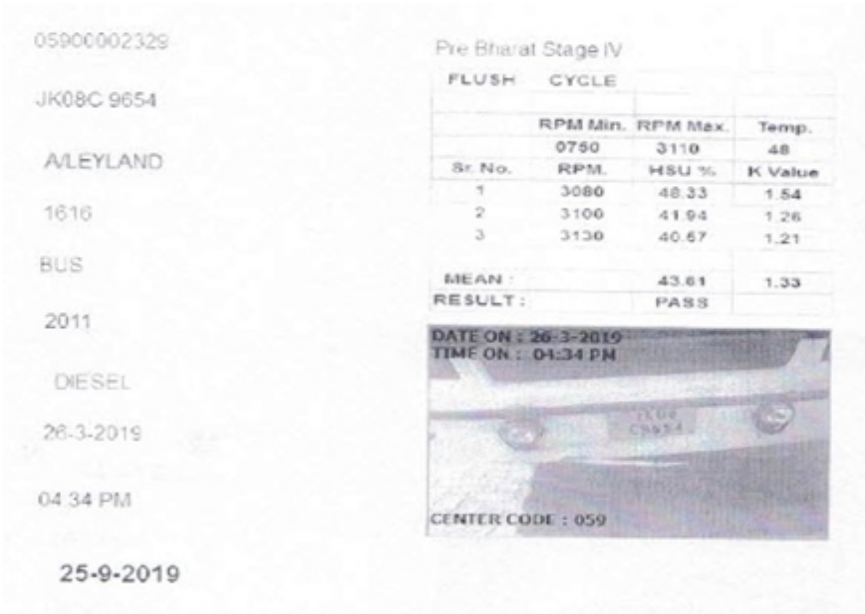
Ministry of Drinking Water & Sanitation
National Rural Drinking Water Programme

Format E4-Water Quality Laboratory Details (2016-2017)-All Sources.

S.No.	State	District	Village	Location/Source & Main Scheme Name	Type of Source	Testing Date	Below Permissible limit [Mg/L] (mandatory*)	Above Permissible limit [Mg/L] (Emerging other**)	Below Permissible limit [Mg/L] (Emerging other**)
1	Jammu and Kashmir	REASI	AGGAR BALLIAN	MARI Spring Local, **Scheme Name**: AGGAR BALLIAN NRD WP H240000390	Delivery Point	01/03/2017	Arsenic-0.010 Nitrate-45.00 Fluoride-1.100 Iron-0.300 Chloride-324.00 PH-6.70 TDS-1326.00 Alkanity-359.00		Turbidity-3.00 Sulphates-235.00 Calcium-125.00 Magnesium-49.00 Manganese-0.200 Copper-0.060 Hardness-365.00 Residual Chlorine-0.400 Aluminium-0.050

***Mandatory Parameters are Alkalinity, Arsenic, Chloride, Fluoride, Iron, Nitrate, pH, and TDS (Salinity).**
****Other than Mandatory Parameters.**

(Annexure '3' , Refer Para 3.11 sub-para b (ii) of Chapter-3).



05900002329

JK08C 9654

A/LEYLAND

1616

BUS

2011

DIESEL

26-3-2019

04.34 PM

25-9-2019

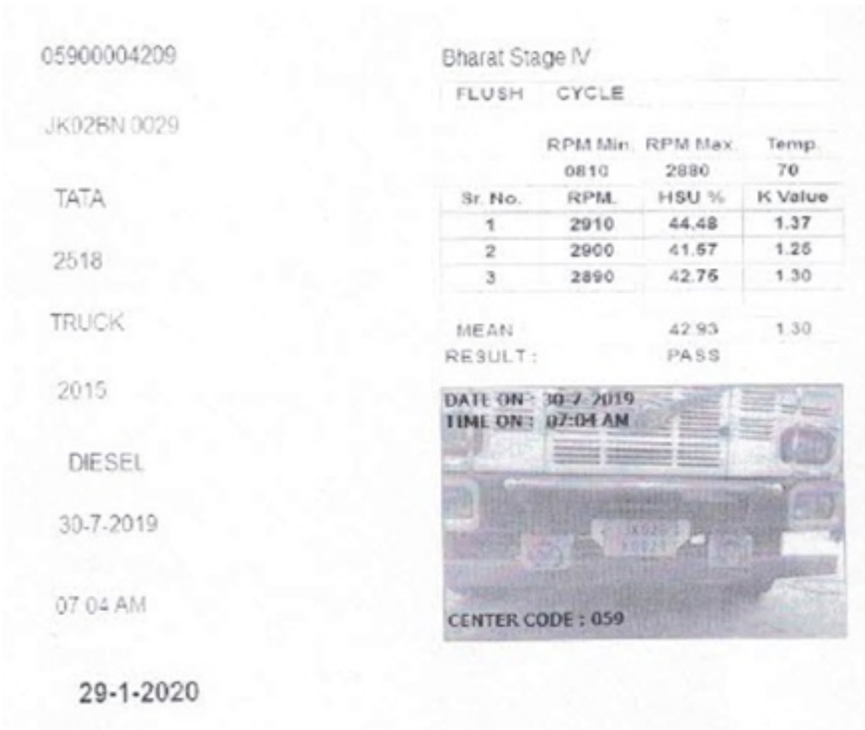
Pre Bharat Stage IV

FLUSH CYCLE

	RPM Min.	RPM Max.	Temp.
	0750	3110	48
Sr. No.	RPM.	HSU %	K Value
1	3080	48.33	1.54
2	3100	41.94	1.26
3	3130	40.67	1.21
MEAN :		43.61	1.33
RESULT :		PASS	

DATE ON : 26-3-2019
TIME ON : 04:34 PM
CENTER CODE : 059

Figure A.1(a): A typical sample of pollution check of Bus using …



05900004209

JK02BN 0029

TATA

2518

TRUCK

2015

DIESEL

30-7-2019

07.04 AM

29-1-2020

Bharat Stage IV

FLUSH CYCLE

	RPM Min.	RPM Max.	Temp.
	0810	2880	70
Sr. No.	RPM.	HSU %	K Value
1	2910	44.48	1.37
2	2900	41.57	1.25
3	2890	42.75	1.30
MEAN		42.93	1.30
RESULT :		PASS	

DATE ON : 30-7-2019
TIME ON : 07:04 AM
CENTER CODE : 059

Figure A.1(b): A typical sample of pollution check of Truck using …

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