

## PROJECT INFORMATION

|                                     |                                                                                                                                                                                                                                         |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name of the Project                 | Feasibility Study of Water Transport along Koshi, Gandaki and Bheri River Basins                                                                                                                                                        |
| Project Executing Agency            | Government of Nepal<br>Ministry of Physical Planning & Works<br>Water Transport Development Project<br>Singha Durbar, Kathmandu<br>Tel:977-1- 4211564                                                                                   |
| Name of the JV Consultant           | EastConsult P. Ltd.<br>Basundhara, Kathmandu<br>Tel: 4356196/4383785<br>And<br>ECoCoDE Nepal P. Ltd.<br>Kupandole, Lalitpur, Nepal<br>Tel: 977-1-5011116<br>Email: <a href="mailto:ecocodenepal@ntc.net.np">ecocodenepal@ntc.net.np</a> |
| Project Commencement Date           | July 13 <sup>th</sup> , 2011                                                                                                                                                                                                            |
| Expected Date of Project Completion | April, 2012                                                                                                                                                                                                                             |

## ACKNOWLEDGEMENT

Water Transport Development Project (WTDP), Ministry of Physical Planning and Works (MoPPW) has taken initiation for the 'Feasibility Study of Water Transport along Koshi, Gandaki and Bheri River basins'. The job was entrusted to the EastConsult and ECoCoDE Nepal Pvt. Ltd JV. This report is prepared at the concluding stage of the study as Final Report. It contains the general conclusion, findings and recommendations of the study. It highlights the possible water corridors along the Koshi, Gandaki and Bheri River basins.

The consultants' JV would like to express its appreciation to the officials from WTDP, Ministry of Physical Planning and Works. The Project Chief Mr. Hari Om Shrivastava and Engineer Suresh Neupane are highly grateful for the support.

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The consultants' JV is highly indebted to Himalayan River Fun Rafting Agency, Thamel for its technical support during field study of river basins.

Finally, the project team would like to express thanks to all staffs and colleagues of EastConsult and ECoCoDE Nepal Pvt Ltd for their anxious support for this study.

Team Leader

EastConsult / ECoCoDE Nepal Pvt. Ltd. JV  
Feasibility Study of Water Transport along Koshi, Gandaki and Bheri River Basins  
Apr, 2012

## ABBREVIATIONS

|         |                                                                                 |
|---------|---------------------------------------------------------------------------------|
| CBS     | Central Bureau of Statistics                                                    |
| CITES   | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| DMG     | Department of Mines and Geology                                                 |
| DoR     | Department of Road                                                              |
| ECoCoDE | Engineering Consultancy for Constructive Development Efforts in Nepal           |
| ER      | Earthen Road                                                                    |
| FRN     | Feeder Road Measure                                                             |
| FRO     | Feeder Road Minor                                                               |
| GR      | Gravel Road                                                                     |
| GoN     | Government of Nepal                                                             |
| HEP     | Hydro Electric Power                                                            |
| IWT     | Inland Water Transport                                                          |
| JV      | Joint Venture                                                                   |
| LOA     | Length Over All                                                                 |
| MRE     | Mountaineering Risk Engineering                                                 |
| MoAC    | Ministry of Agriculture and Cooperatives                                        |
| MOPPW   | Ministry of Physical Planning and Works                                         |
| MT      | Motorized Traffic                                                               |
| NMT     | Non-Motorized Traffic                                                           |
| VDC     | Village Development Committee                                                   |
| WTDP    | Water Transport Development Project                                             |

## SALIENT FEATURES

1. Project Name: Feasibility study of water transport along Koshi, Gandaki and Bheri River Basins

2. Location: Koshi, Gandaki and Bheri Basin

3. Proposed Waterway:

|           | Koshi Basin(173 km)            | Gandaki Basin(185 km)     | Bheri Basin(123 km)         |
|-----------|--------------------------------|---------------------------|-----------------------------|
| Section 1 | Koshi Barrage – Chatara (K-BC) | Devghat – Ramdi (G-DR)    | Chisapani – Ghatgaun (B-CG) |
| Section 2 | Chatara – Tribeni (K-CT)       | Deghat – Mugling(G-DM)    | Ghatgaun – Taranga (B-GT)   |
| Section 3 | Tribeni – Saune (K-TS)         | Mugling – Fishlin (G-MF)  | Taranga – Kamalpur (B-TK)   |
| Section 4 | Saune – Ghurmi (K-SG)          | Mirmi – Seti Beni (G-MrS) | Kamalpur– Botechaur (B-KB)  |

4. Influence Area under Proposed Waterway

|                 | Koshi Basin (173 km)                                                            | Gandaki Basin (185 km)                                                          | Bheri Basin (123 km)                                       |
|-----------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------|
| No. of District | 7                                                                               | 8                                                                               | 2                                                          |
| No. of VDC      | 50                                                                              | 52                                                                              | 24                                                         |
| Population      | 0.5 Million                                                                     | 1.2 Million                                                                     | 0.2 Million                                                |
| Road            | 1. E-W Highway<br>2. Dharan-Chatara<br>3. Diktal-Gaighat<br>4. Mid Hill Highway | 1. Prithivi Highway<br>2. Siddharatha Highway<br>3. Mugling-Narayanghat Highway | 1. Ratna Highway<br>2. Botechaur-Chinchu<br>3. E-W Highway |

5. Project technical parameters:

| Section | River        | Length, km | Avg Depth, m     | Avg Velocity, m/s | Avg Gradient |
|---------|--------------|------------|------------------|-------------------|--------------|
| K-BC    | Saptakoshi   | 47.05      | 3.87             | 1.2               | 1 in 1681    |
| K-CT    | Saptakoshi   | 8.72       | 8.64             | 1.4               | 1 in 872     |
| K-TS    | Sunkoshi     | 48.47      | 9.70             | 1.7               | 1 in 591     |
| K-SG    | Sunkoshi     | 69.12      | 16.90            | 2.1               | 1 in 452     |
| G-DR    | Kali Gandaki | 130.425    | 16.20            | 1.5               | 1 in 662     |
| G-DM    | Trishuli     | 32.638     | 6.75             | 1.4               | 1 in 859     |
| G-MF    | Trishuli     | 16.6       | 5.47             | 2.2               | 1 in 426     |
| G-MrS   | Kali Gandaki | 5          | Existing service |                   |              |
| B-CG    | Karnali      | 15.59      | 6.60             | 1.2               | 1 in 708     |
| B-GT    | Bheri        | 36.99      | 3.74             | 1.5               | 1 in 355     |
| B-TK    | Bheri        | 19.804     | 4.04             | 1.3               | 1 in 440     |
| B-KB    | Bheri        | 50.51      | 3.18             | 1.2               | 1 in 446     |

6. Observation in Proposed Waterway Basin

| Basin           | Koshi | Gandaki | Bheri |
|-----------------|-------|---------|-------|
| No. of Rapids   | 72    | 75      | 55    |
| Bridge          | 12    | 27      | 12    |
| Gauging Station | 3     | 3       | 3     |

| Basin               | Koshi                              | Gandaki               | Bheri                                   |
|---------------------|------------------------------------|-----------------------|-----------------------------------------|
| Ropeway             | 1                                  | 6                     | 1                                       |
| Under Construction  | 2 Motor Bridge                     | 2 Motor Bridge        | 1 Suspension Bridge                     |
| Future Work         | Multi Project Koshi High Dam 269 m | Promotion for Rafting | Diversion for Irrigation from Botechaur |
| Existing WT Service | Yes                                | Yes                   | No                                      |

## 7. Infrastructure required

| Basin   | Main Terminal Building | Intermediate Terminal Building | Access Road, km |
|---------|------------------------|--------------------------------|-----------------|
| Koshi   | 2                      | 3                              | 3               |
| Gandaki | 2                      | 3                              | 2               |
| Bheri   | 2                      | 2                              | 2               |

## 8. Economic Analysis

| Section                | Service                                     | NPV     | IRR    | B/C    | Remark                                  |
|------------------------|---------------------------------------------|---------|--------|--------|-----------------------------------------|
| K-BC                   | Proposed Waterway for Recreational          | -11.37  | 2.63%  | 0.44   | Unfeasible                              |
| K-CT –Simle            | Existing Waterway                           | -432.36 | 900%   | -34.98 | Feasible due to high willingness to pay |
| K-TS                   | Proposed Waterway for Public Transportation | 157.4   | 86.38% | 10.69  | Feasible                                |
| K-SG                   | Technically Not Feasible                    |         |        |        |                                         |
| K-Dolalghat to Chatara | Existing Rafting Route                      | 41.06   | 36%    | 3.53   | Feasible for Tourism                    |
| G-DR                   | Existing Rafting Route                      | 15.33   | 19.68% | 1.75   | Feasible for Tourism                    |
| G-Devghat to Aptar     | Proposed Waterway for Public Transportation | 14.82   | 19.7%  | 1.72   | Feasible                                |
| G-DM                   | Proposed Waterway for Recreational          | 38.12   | 24.28% | 2.31   | Feasible                                |
| G-MF                   | Existing Rafting Route                      | -8.75   | 6.39%  | 0.57   | Unfeasible for Jet Boat                 |
| G-MrS                  | Existing Waterway                           | 18.06   | 21.3%  | 1.88   | Feasible                                |
| B-CG                   | Proposed Waterway for Recreational          | 91.27   | 49.56% | 5.44   | Feasible                                |
| B-GT                   | Proposed Waterway for Public Transportation | 4.43    | 14.05% | 1.22   | Feasible                                |
| B-TK                   | Proposed Waterway for Public Transportation | 3.73    | 14.1%  | 1.18   | Feasible                                |
| B-KB                   | Not Feasible due to no willingness to pay   |         |        |        |                                         |

## EXECUTIVE SUMMARY

Nepal is very rich in terms of its water resources. Tremendous hydropower potential of Himalayan Rivers could be a major strength of future economy. The objective of the project is to study the Feasibility of water transport along the Koshi, Gandaki and Bheri River Basins and upgrading the existing motor boat services which are providing service at some location. The Detail Feasibility study is to be prepared considering the upgrading existing water transport with safety and give assess to remote people and it's future reliability and scope in transporting the rural agricultural product to the markets and access to the services. The study duely considered the technical as well as financial aspects of existing water transport services. In desk study, collecting all data, maps and information relevant to water transport and reviewing them for use in the proposed project.

The Koshi, Gandaki, and Bheri River basins were major objects of the study. The particular sections of above mentioned basins were assigned for conducting the study. The study length carried out along the Koshi, Gandaki and Bheri River Basins was 175 km, 150 km and 125 km respectively. The major alignment studied along Koshi was Ghurmi-Koshi Barrage. The Gandaki basin was divided into two alignments i.e. Trisuli (Fisling-Devghat) and Kali Gandaki (Ramdi-Devghat). Similarly, Bheri River Basin considered from Botechaur to Chisapani.

The major challenges were encountered during the field observation of river sections. The entire river corridors under consideration were thoroughly observed for water flow patter (speed) and depth was measured. The field team was supported by the Rafting Company.

Technical feasibility study encompasses the selection of water transport routes, river corridor survey, hydrological study, environmental study and other relevant analysis of all the river basins. Based on these studies and analysis, consultant recommended the most effective sustainable system of water transportsections. Furthermore, design and estimates of the transport system following the standard codes of practices, norms and guidelines were carried out.

The financial study of proposed water transport systems were carried out on the basis of economical data collected during field study. The cost of infrastructure development, initial price of appropriate vessel, operation and maintenance cost were calculated. The economic benefit from the invest ment was considered by the fare collection, revenue generation and over all impact to the regional economy. The NPV, BC ratio and IRR were also calculated to the proposed routes of water transport.

The Final Report consists of main Report, Maps, drawings and Annexes. The main report consists of the following chapters:

- General: this chapter incorpores the basic information on the project assignment.
- Methodology: in this chapter, the overall procedure of the study is contained.
- Water transport: the history, present status and basic engineering characteristics were described in this chapter.
- Existing Water Transport Systems in Nepal: this chapter includes the existing practices of water transport in Nepal. Mainly, the recreational mode of water transport such as Rafting and sightseeing are very usual for Koshi, Gandaki and Bheri River basins.
- Traffic demand analysis and traffic estimation: the basic concepts for the traffic demand analysis and forecsting techniques are described in this chapter.
- Detail Study of river basins were placed in the separate three chapters.

The last chapter of the study concludes the results of project assignment and recommendations are pointed out.

## VOLUME INFORMATION

|            |   |                                                                                    |
|------------|---|------------------------------------------------------------------------------------|
| Volume I   | : | Main Report                                                                        |
| Volume II  | : | Annex I Maps and Drawings                                                          |
| Volume III | : | Annex II Data and Findings<br>Annex III Calculation Sheets<br>Annex IV Photographs |

## CONTENTS

|                                                                                   |    |
|-----------------------------------------------------------------------------------|----|
| 1. General.....                                                                   | 14 |
| 1.1 Background.....                                                               | 14 |
| 1.2 Objective.....                                                                | 14 |
| 1.3 Scope of Work .....                                                           | 14 |
| 1.3.1 Desk study .....                                                            | 14 |
| 1.3.2 Detailed Engineering Study and Survey .....                                 | 14 |
| 1.3.3 Technical Feasibility study .....                                           | 14 |
| 1.3.4 Water Transport route Selection.....                                        | 15 |
| 1.3.5 River corridor Survey .....                                                 | 15 |
| 1.3.6 Hydrological Study.....                                                     | 15 |
| 1.3.7 Consideration on Environment Protection .....                               | 16 |
| 1.3.8 Other information .....                                                     | 16 |
| 1.3.9 Analysis of Data, Conclusion and Recommendation of Design Parameters .....  | 16 |
| 1.3.10 Design and estimates .....                                                 | 16 |
| 1.3.11 Use of Standard Design(s) and software .....                               | 16 |
| 1.4 Limitation of the WT Project Study .....                                      | 16 |
| 2. Methodology and Procedure.....                                                 | 17 |
| 2.1 Phase – I: Desk Study .....                                                   | 17 |
| 2.2 Phase – II: Field Work .....                                                  | 18 |
| 2.2.1 Field Verification .....                                                    | 18 |
| 2.2.2 Socio-economic Studies of Influence Area .....                              | 18 |
| 2.2.3 Traffic Studies of Influenced Area.....                                     | 19 |
| 2.2.4 Environmental Studies.....                                                  | 19 |
| 2.2.5 Studies on Property Acquisition.....                                        | 19 |
| 2.2.6 Geological/Geo-morphological, Hydrological and Meteorological Studies ..... | 19 |
| 2.2.7 Engineering Studies.....                                                    | 20 |
| 2.3 Phase-III Office Works.....                                                   | 20 |
| 2.3.1 Engineering Design .....                                                    | 20 |
| 2.3.2 Cost Estimate .....                                                         | 21 |
| 2.3.3 Economic Analysis.....                                                      | 21 |
| 2.4 Procedure of Primary Data Collection .....                                    | 22 |
| 2.5 Introduction to Echo-Sounder .....                                            | 22 |
| 2.5.1 Principle of Operation .....                                                | 23 |
| 2.5.2 Working Procedure .....                                                     | 24 |
| 3. Water Transport .....                                                          | 25 |
| 3.1 Introduction .....                                                            | 25 |
| 3.2 History of Water Transport.....                                               | 26 |
| 3.3 Modern Status of Water Transport .....                                        | 27 |

|       |                                                                            |    |
|-------|----------------------------------------------------------------------------|----|
| 3.4   | Chronology of water Transport in Nepal .....                               | 28 |
| 3.5   | Brief Status of Water Transport in Nepal .....                             | 29 |
| 3.6   | Review of Basic Design Criteria .....                                      | 30 |
| 3.6.1 | Elements of the Inland Water Transport .....                               | 30 |
| 3.6.2 | Depth of River .....                                                       | 31 |
| 3.6.3 | Width, Alignment and Current Velocity .....                                | 32 |
| 3.6.4 | Terminal Facilities .....                                                  | 33 |
| 3.7   | Classification of Rivers .....                                             | 33 |
| 4.    | Existing Water Transport Services In Nepal .....                           | 35 |
| 4.1   | Koshi River: Chatara – Tribeni – Simle (Arun river) .....                  | 35 |
| 4.2   | Gandaki Basin – Mirmi- Setibeni (Syanja, Parbat and Gulmi districts) ..... | 36 |
| 4.3   | Recreational water transport: Rafting .....                                | 37 |
| 4.4   | Recreational water transport: Boating .....                                | 38 |
| 4.5   | River Crossing: shortest route for local travel .....                      | 39 |
| 4.6   | Critical Issues in the Existing Water Transport .....                      | 39 |
| 5.    | Traffic Demand Analysis .....                                              | 40 |
| 5.1   | Introduction .....                                                         | 40 |
| 5.2   | Normal Traffic .....                                                       | 40 |
| 5.3   | Diverted Traffic .....                                                     | 41 |
| 5.4   | Development Traffic .....                                                  | 41 |
| 5.5   | Generated Traffic .....                                                    | 41 |
| 5.6   | Traffic Growth and Forecasting .....                                       | 42 |
| 6.    | Water Transport Study in Koshi Basin .....                                 | 43 |
| 6.1   | Introduction .....                                                         | 43 |
| 6.2   | Study of Proposed Waterway Corridor .....                                  | 44 |
| 6.3   | Influence Area .....                                                       | 44 |
| 6.4   | Socio Economic Study of Proposed Waterway Corridor .....                   | 44 |
| 6.5   | Hydrology Study of Proposed Waterway Corridor .....                        | 51 |
| 6.5.1 | Hydrology .....                                                            | 51 |
| 6.5.2 | DHM data for Koshi Basin Proposed Waterway Analysis .....                  | 51 |
| 6.5.3 | Field Investigation for Koshi Basin for Proposed Waterway .....            | 53 |
| 6.6   | Geological and Environmental Study of Proposed Waterway Corridor .....     | 55 |
| 6.6.1 | Geological Features in Proposed waterway .....                             | 55 |
| 6.6.2 | Environmental Features in Proposed waterway .....                          | 56 |
| 6.7   | Existing Water Transport Senario .....                                     | 57 |
| 6.7.1 | Adventure/Recreational Purpose .....                                       | 57 |
| 6.7.2 | Public Transportation .....                                                | 57 |
| 6.8   | Traffic Study of Proposed Waterway Corridor .....                          | 58 |
| 6.9   | Engineering Characteristics of the Proposed Waterway Section .....         | 58 |
| 6.9.1 | Section: Koshi Barrage to Chatara (0+000 – 49+050) .....                   | 58 |

|       |                                                                        |    |
|-------|------------------------------------------------------------------------|----|
| 6.9.2 | Section: Chatara to Tribeni (0+000 – 8+750) .....                      | 59 |
| 6.9.3 | Section: Tribeni – Saune (0+000 – 47+165).....                         | 59 |
| 6.9.4 | Section: Saune – Ghurmi (0+000 – 69+120).....                          | 59 |
| 7.    | Water Transport Study in Gandaki Basin .....                           | 60 |
| 7.1   | Study of Proposed Waterway Corridor .....                              | 60 |
| 7.2   | Influence Area.....                                                    | 61 |
| 7.3   | Socio Economic Study of Proposed Waterway Corridor .....               | 61 |
| 7.4   | Hydrology Study of Proposed Waterway Corridor .....                    | 68 |
| 7.4.1 | Hydrology.....                                                         | 68 |
| 7.4.2 | DHM data for Gandaki Basin Proposed Waterway Analysis .....            | 68 |
| 7.4.3 | Field Investigation for Gandaki Basin proposed Waterway .....          | 71 |
| 7.5   | Geological and Environmental Study of Proposed Waterway Corridor ..... | 72 |
| 7.5.1 | Geological Features in Proposed waterway .....                         | 72 |
| 7.5.2 | Environmental Features in Proposed waterway .....                      | 73 |
| 7.6   | Existing Water Transport Senerio.....                                  | 75 |
| 7.6.1 | Adventure/Recreational Purpose .....                                   | 75 |
| 7.6.2 | Public Transportation .....                                            | 76 |
| 7.7   | Traffic Study of Proposed Waterway Corridor .....                      | 76 |
| 7.8   | Engineering Characteristics of the Proposed Waterway Section .....     | 76 |
| 7.8.1 | Section: Devghat - Ramdi (0+000 – 130+425) .....                       | 76 |
| 7.8.2 | Section: Devghat - Mugling (0+000 – 32+638).....                       | 77 |
| 7.8.3 | Section: Mugling - Fishlin (0+000 – 16+600).....                       | 77 |
| 8.    | Water Transport Study in Bheri Basin .....                             | 78 |
| 8.1   | Study of Proposed Waterway Corridor .....                              | 78 |
| 8.2   | Influence Area.....                                                    | 79 |
| 8.3   | Socio Economic Study of Proposed Waterway Corridor .....               | 79 |
| 8.4   | Hydrology Study of Proposed Waterway Corridor .....                    | 83 |
| 8.4.1 | Hydrology.....                                                         | 83 |
| 8.4.2 | DHM data for Gandaki Basin Proposed Waterway Analysis .....            | 83 |
| 8.4.3 | Field Investigation for Bheri Basin proposed Waterway .....            | 86 |
| 8.5   | Geological and Environmental Study of Proposed Waterway Corridor ..... | 87 |
| 8.5.1 | Geological Features in Proposed waterway .....                         | 87 |
| 8.5.2 | Environmental Features in Proposed waterway .....                      | 88 |
| 8.6   | Existing Water Transport Senerio.....                                  | 90 |
| 8.6.1 | Adventure / Recreational purpose .....                                 | 90 |
| 8.7   | Traffic Study of Proposed Waterway Corridor .....                      | 91 |
| 8.8   | Engineering Characteristics of the Proposed Waterway Section .....     | 91 |
| 8.8.1 | Section: Chisapani - Ghatgaun (0+000 – 15+590) .....                   | 91 |
| 8.8.2 | Section: Ghatgaun - Taranga (0+000 – 36+990).....                      | 91 |
| 8.8.3 | Section: Taranga - Kamalpur (0+000 – 19+804) .....                     | 91 |

|        |                                                |     |
|--------|------------------------------------------------|-----|
| 8.8.4  | Section: Kamalpur - Botechaur (0+000 – 50+510) | 92  |
| 9.     | Proposed Interventions for Water Transport     | 93  |
| 9.1    | Selection of Vessel                            | 93  |
| 9.2    | Improvement of Waterways                       | 94  |
| 9.2.1  | Boulder removing                               | 94  |
| 9.2.2  | Hard rock cutting                              | 97  |
| 9.3    | Legislation and Institutional Policy Framework | 97  |
| 9.3.1  | Context of National Transport Policy-2058      | 98  |
| 9.3.2  | Water transport Policy issues                  | 98  |
| 9.4    | Environmental Assessment of Project Area       | 99  |
| 10.    | Water Transport and Intermodal Connectivity    | 100 |
| 10.1   | Methodology of Modeling and programming        | 100 |
| 10.2   | Koshi Basin                                    | 100 |
| 10.3   | Gandaki River Basin                            | 101 |
| 10.4   | Bheri River Basin                              | 102 |
| 11.    | Cost Estimates                                 | 103 |
| 12.    | Economic Analysis                              | 105 |
| 12.1   | Approach of the economic analysis              | 105 |
| 12.1.1 | Analysis Parameters                            | 105 |
| 12.1.2 | Economic Indicators                            | 105 |
| 12.1.3 | Evaluation                                     | 105 |
| 12.2   | Maintenance Cost                               | 106 |
| 12.2.1 | Economic maintenance Cost                      | 106 |
| 12.3   | Road User Cost                                 | 106 |
| 12.3.1 | Transport Cost                                 | 106 |
| 12.3.2 | Value of Time                                  | 106 |
| 12.4   | Benefit Analysis                               | 107 |
| 12.4.1 | Road Users' Benefit                            | 107 |
| 12.4.2 | Producer's Surplus Benefits                    | 107 |
| 12.5   | Results                                        | 107 |
| 13.    | Conclusion and Recommendation                  | 109 |
| 13.1   | Conclusions                                    | 109 |
| 13.2   | Recommendation                                 | 110 |

### List of Tables

|            |                                                                                    |    |
|------------|------------------------------------------------------------------------------------|----|
| Table 3-1  | Values of $C_{min}$                                                                | 32 |
| Figure 3-2 | Scheme of minimum depth ( $h_{pmin}$ ) of the river for the displacement of vessel | 32 |
| Table 6-1  | Core Zone of influence VDC for Proposed Waterway                                   | 44 |
| Table 6-2  | Population in Core zone of Influence Area                                          | 45 |

|                                                                                                                     |    |
|---------------------------------------------------------------------------------------------------------------------|----|
| Table 6-3 Landuse Pattern in umbral zone of influence area of Proposed Waterway .....                               | 46 |
| Table 6-4 Cereal Crops statistic in Koshi River umbral zone of influence area .....                                 | 47 |
| Table 6-5 Cash Crops statistic in Koshi River umbral zone of influence area .....                                   | 47 |
| Table 6-6 Some Major Crops statistic in Koshi River umbral zone of influence area .....                             | 48 |
| Table 6-7 Minerals found in Koshi River umbral zone of influence area.....                                          | 48 |
| Table 6-8 Market Places in various districts lying in Koshi River umbral zone of influence area.....                | 48 |
| Table 6-9 Tourism Area in Koshi River umbral zone of influence area.....                                            | 49 |
| Table 6-10 Total Hydro Power status in Koshi River influence area.....                                              | 49 |
| Table 6-11 Health statistics in the Koshi River influence area .....                                                | 50 |
| Table 6-12 Statistics of accessibility in the Koshi River influence area .....                                      | 50 |
| Table 6-13 Agricultural Road in Koshi River influence area.....                                                     | 50 |
| Table 6-14 Hydrological Station in Koshi Basin Proposed Waterway.....                                               | 51 |
| Table 6-15 Average Discharge over the year on Sunkoshi River at Khamphughat.....                                    | 51 |
| Table 6-16 Average Discharge over the year on Sunkoshi River at Hamphuhwar .....                                    | 52 |
| Table 6-17 Average Discharge over the year on Saptakoshi River at Chatara .....                                     | 53 |
| Table 6-18 Summary of Rapids .....                                                                                  | 54 |
| Table 6-19 Summary of Identified Civil Structure.....                                                               | 54 |
| Table 6-20 Land Use Type of of Koshi Watershed .....                                                                | 56 |
| Table 7-1 Core Zone of influence VDC in Gandaki River Corridor .....                                                | 61 |
| Table 7-2 Population in core zone of Influenced along Gandaki River Corridor .....                                  | 62 |
| Table 7-3 Landuse Pattern in Gandaki River umbral zone of influence area.....                                       | 62 |
| Table 7-4 Cereal Crops statistics in Gandaki River umbral zone of influence area .....                              | 63 |
| Table 7-5 Cash Crops statistics in Gandaki River influence area.....                                                | 64 |
| Table 7-6 Some Major Crops statistics in Gandaki River influence area .....                                         | 64 |
| Table 7-7 Minerals found in Gandaki River umbral zone of influence area .....                                       | 64 |
| Table 7-8 Market Places in various districts lying in Gandaki and Trishuli River umbral zone of influence area..... | 65 |
| Table 7-9 Tourism Area in Gandaki and Trishuli River umbral zone of influence area.....                             | 65 |
| Table 7-10 Total Hydro Power status in Gandaki and Trishuli River umbral zone of influence area .....               | 66 |
| Table 7-11 Health statistics in the Gandaki and Trishuli River umbral zone of influence area .....                  | 67 |
| Table 7-12 Statistics of accessibility in the Gandaki and Trishuli River umbral zone of influence area.....         | 67 |
| Table 7-13 Agricultural Road in Gandaki and Trishuli River umbral zone of influence area .....                      | 67 |
| Table 7-14 Hydrological Station in Gandaki Basin Proposed Waterway .....                                            | 68 |
| Table 7-15 Average Discharge over the year on Kali Gandaki River at Ansing.....                                     | 68 |
| Table 7-16 Average Discharge over the year on Sunkoshi River at Kotagaun.....                                       | 69 |
| Table 7-17 Average Discharge over the year on Trishuli River at Kalikhola.....                                      | 70 |
| Table 7-18 Average Discharge over the year on Trishuli River at Kalikhola.....                                      | 70 |

|                                                                                                       |     |
|-------------------------------------------------------------------------------------------------------|-----|
| Table 7-19 Hydrograph of Narayani River at Devghat .....                                              | 71  |
| Table 7-20 Summary of Rapids .....                                                                    | 72  |
| Table 7-21 Summary of Identified Civil Structure.....                                                 | 72  |
| Table 7-22 Land Use Type of Gandaki Basin .....                                                       | 74  |
| Table 8-1 Direct influence VDC in Bheri River Corridor .....                                          | 79  |
| Table 8-2 Population in core zone of Influenced in Bheri River Corridor .....                         | 80  |
| Table 8-3 Landuse Pattern in Bheri River umbral zone of influence area.....                           | 80  |
| Table 8-4 Cereal Crops statistic in Bheri River umbral zone of influence area.....                    | 81  |
| Table 8-5 Cash Crops statistic in Bheri River umbral zone of influence area.....                      | 81  |
| Table 8-6 Some Major Crops statistic in Bheri River umbral zone of influence area .....               | 81  |
| Table 8-7 Minerals found in Bheri River umbral zone of influence area .....                           | 81  |
| Table 8-8 Market Places in various districts lying in Bheri River umbral zone of influence area ..... | 81  |
| Table 8-9 Tourism Area in Bheri River umbral zone of influence area .....                             | 82  |
| Table 8-10 Total Hydro Power status in Bheri River umbral zone of influence area.....                 | 82  |
| Table 8-11 Health statistics in the Bheri River Umbral zone of influence area .....                   | 82  |
| Table 8-12 Statistics of accessibility in the Bheri River umbral zone of influence area .....         | 83  |
| Table 8-13 Agricultural Road in Bheri River umbral zone of influence area .....                       | 83  |
| Table 8-14 Hydrological Station in Bheri Basin Proposed Waterway .....                                | 84  |
| Table 8-15 Average Discharge over the year in Bheri River at Samaijighat .....                        | 84  |
| Table 8-16 Average Discharge over the year on Bheri River at Jamu.....                                | 85  |
| Table 8-17 Average Discharge over the year in Karnali River at Chisapani .....                        | 85  |
| Table 8-18 Summary of Rapids .....                                                                    | 87  |
| Table 8-19 Summary of Identified Civil Structure.....                                                 | 87  |
| Table 8-20 Land Use Type of Bheri Watershed.....                                                      | 88  |
| Table 8-21 Fish species in Bheri River .....                                                          | 90  |
| Table 11-1 No. of Infrastructure to construct in proposed waterway.....                               | 103 |
| Table 11-2 Purposed Terminal Station in Proposed waterway.....                                        | 103 |
| Table 11-3 Summary of the boulder removal for the proposed waterway .....                             | 103 |
| Table 11-4 Cost Estimates for Economic Analysis .....                                                 | 104 |
| Table 12-1 Summary of Economic Analysis for Proposed Waterway.....                                    | 108 |

## 1. GENERAL

## 1.1 Background

In the context of hydro-power potential, Nepal is the second richest country in the world about 2.27 percent of the world natural resource. The major sources of water are glaciers, snowmelt from Himalayas, rainfall and ground water. It is estimated that there are altogether 6,000 rivers (including rivulets and tributaries) having about 45,000 Kms length. Koshi, Gandaki and Karnali are the main river systems getting major part of their water from the snow, glaciers and small tributaries. Other important rivers are Babai, Kamala, Narayani, Bagmati, Rapti, Seti and Mahakali. It has many numbers of perennial and non perennial rivers. Traditionally, the huge hydro-power potential has been used for the hydro-electric and irrigation purpose.

Recently, the GoN (MoPPW) is seeking the possibilities the use of river-systems for the navigational purpose. The hilly and mountainous terrain is not favourable for the land transport and it costs is very high along the weak geological hilly regions. Furthermore, the possibilities of the development of remote areas and river valleys are the challenges of the circumstance. Village settlements and towns along these river-basins are potential generators of economic development. The reliable transport along the river basin could be better solution for the travel demand management. Proposed project will seek the viability the river navigation for the freight as well as passenger transport.

For this purpose, Water Transport Project has awarded the assignment to EASTConsult and ECoCoDE Nepal Pvt Ltd JV. The proposed feasibility study will cover the river basins of Koshi, Gandaki and Bheri River. The total preliminary length of these basins is estimated as 450 km.

Contract Agreement for the study was signed between MoPPW and JV of EASTConsult and ECoCoDE Nepal Pvt. Ltd. on July 13th, 2011 in Nepal. Study was commenced from the date of agreement, with a completion period of 6 months.

## 1.2 Objective

Objective of this job is to study the Feasibility of water transport along the Koshi, Gandaki and Bheri River Basins and upgrading the existing motor boat services which are providing service at some location. The Feasibility study is to be prepared considering the upgrading existing water transport with safety and give assess to remote people and its future reliability and scope in transporting the rural agricultural product and providing the services.

## 1.3 Scope of Work

Following particular tasks were included in the scope of assignment.

## 1.3.1 Desk study

Desk study of this project was carried out for general information on the existing water transport systems, river basin and socio-economic status of the region for the Koshi, Gandaki and Bheri River Basins. Relevant maps, literatures as well as related study reports were collected.

## 1.3.2 Detailed Engineering Study and Survey

Detailed engineering study includes the following sub-topics:

## 1.3.3 Technical Feasibility study

The technical feasibility study includes the review of the available data, collection and analysis of field data, to be used in the study of water transport along Koshi, Gandaki and Bheri River Basins. The analysis was conducted to decide upon the technical feasibility of the River Transport. A cost comparison of different types of water transport is also included in this topic.

In this study the following points related to the river and its catchment area were considered:

- ❖ Topography
- ❖ Nature of flow, maximum and minimum discharge and it's depth at critical points
- ❖ Nature and structure of local as well as regional geology

#### 1.3.4 Water Transport route Selection

The most suitable routes for the water Transport were assessed on the above characteristics along the Koshi, Gandaki and Bheri River as well as the catchment area were also were selected. The selected route were indicated in the map and critical obstruction were highlighted graphically.

#### 1.3.5 River corridor Survey

In the Koshi, Gandaki and Bheri River Basin the following sub subject matters were studied

- a. The feasibility study includes overview of required infrastructure, shipping and boating service, safety practices, legislation and intuitional and policy frame work governing the sub-sector.
- b. Review the demand for all economically feasible roots of water transport system along the proposed site of koshi, Gandaki and Bheri river basin and determination the beneficiaries for willingness to pay for the services
- c. Consideration of River alignment for profile, cross sections at narrow/critical locations
- d. Study and reportingof the Major settlement along the river corridor contributing to the route
- e. Expected volume of goods and passenger transport
- f. Study of existing system of water transport including its merit and drawbacks and recommending appropriate improvement for the same.
- g. Modeling of future demand over 10-30 years with market share scenarios linked to the identification of key route /supply hypotheses including completion of visual survey and survey of people's view about traveling by water.
- h. Detail measurement of critical obstructions along the river transport pathway, its tentative quantity and cost for clearing them
- i. Identifying the issues and problems experienced by small boat operators traveling in open waters over large distances under risk. Propose Network or system that allows operators to arrive safely at their destinations and possible protected location that facilitate the exchange for goods and passengers.

#### 1.3.6 Hydrological Study

For determination of all design data the consultant carried out detailed hydrometrical study of all the river Basins under consideration, which includes the following:

- a. Catchment area of the river Basin.
- b. Length of the river from origin up to Last station.
- c. Possibility of change of catchment
- d. Nature, size and quantities of debris carried by the river
- e. Intensity, duration and distribution of rain in the catchment
- f. Vegetation, cultivation etc. of the catchment.
- g. Existence of reservoir's, Lakes etc. in the catchment.
- h. Existing bridge or other hydraulic structures across the river in the vicinity of the proposed river transport with their obstruction and clear height details as much as possible.
- i. General slope of the river from the critical point (origin) of the river up to possible downstream of the River.
- j. Cross sections at critical locations
- k. Bed slope of the river at stations points

- l. Maximum discharge calculated by established formulas with different return periods and the peak discharge observed over a period of 100 years.
- m. Velocity and depth of flow at the time of survey.
- n. Shifting of the river in the past at proposed River Transport route and in its vicinity.
- o. Other information required for river control, design, construction and maintenance of the water transport.

#### 1.3.7 Consideration on Environment Protection

The consultant duly considered the environmental issues along the river corridors. The mitigation measures to minimize the damages by choosing River transport system. The GoN environmental policies, Environmental Protection Act and Environmental Protections Rules are review for the development of water transport system.

#### 1.3.8 Other information

The study includes the information of availability of construction materials like, sand gravel boulders, timber, etc. with their engineering properties, quantities and lead up to site. Quarry site of materials with their available quantities are graphically illustrated for the proposed routes of water transport.

#### 1.3.9 Analysis of Data, Conclusion and Recommendation of Design Parameters

Based upon the above mentioned studies and investigations the consultants shall make the best use of their technical know-how and professional skill to arrive at and recommend the most cost effective sustainable system of water transport.

#### 1.3.10 Design and estimates

Based on the collected information and results of the discussions mentioned above the consultant finalized the engineering design of the transport system as per the the standard codes of practice, norms and guidelines.

#### 1.3.11 Use of Standard Design(s) and software

Depending upon the site condition and other factors the Consultants used the Standard Design and software of the part(s) of the system. This matter will be discussed and finalized during the presentation of the Draft Report.

### 1.4 Limitation of the WT Project Study

The study has to extract primary data and that has to be accurate. But maintaining accuracy is impossible due to various factors

- The study in the big rivers are itself challenging where the accurate data collection are impossible in the presence of river current.
- The flow of the river varies throughout the year dramatically, during monsoon (July-October) it is considered as high water and other season it is consider as low water. The field study has been conducted from November to December which is considered as low water period.
- The GPS used in the field study has its limitation due to which co-ordinate and elevation marked can be in error. The actual causes of poor reading of GPS may be due to low signal strength in dell areas.
- The Echo Sounder which was used in the field study requires minimum 2m depth to display the sounding depth, so limitation of the sounding device also effect the data extracted.
- The data extracted from local peoples are also biasing with each other
- Rapid change in environment due to landslides, floods, etc can affect the data extracted, so precision of extracted data can be absence after few periods.
- While collecting the primary data from the field, the assumption is made of sailing the rafting boat from the most depth part of the river. Generally, when a River Bends, the outside of the bend is usually deeper water, while the inside of the turn will be shallower water.

## 2. METHODOLOGY AND PROCEDURE

The feasibility study of water transport along Koshi, Gandaki and Bheri River Basins is conducted as per the following methodology mentioned in this chapter. The whole methodology can be separated into three phases

- Phase – I : Desk Study
- Phase – II : Field Work
- Phase – III : Office Work

The overall methodology is shown in Figure of this document.

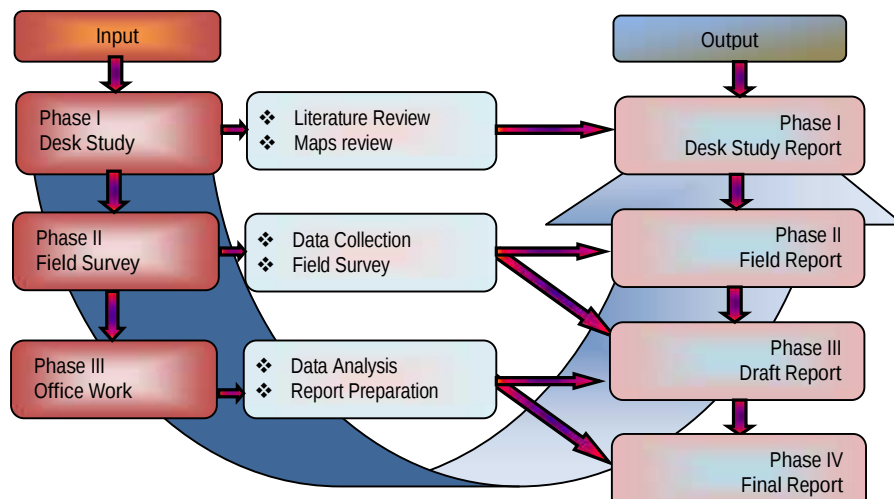


Figure 2-1 Overall Methodology

### 2.1 Phase – I: Desk Study

In this phase, at first and foremost job will be the collection of relevant materials from different concerned authorities. The main materials to be collected are:

- ❖ Topographic maps
- ❖ District maps
- ❖ Aerial photos
- ❖ Geological maps
- ❖ Hazard maps
- ❖ Map of earthquake zoning
- ❖ Political map
- ❖ Land use maps
- ❖ Catchment area map
- ❖ Hydrological and meteorological data
- ❖ Reconnaissance reports or related documents if any
- ❖ District maps, statistics of the road and other transport facilities in the district
- ❖ Socio-economic status of the affected areas

- ❖ Roads/ river Network Study of DOR, MRE.
- ❖ Road and other transport mode Standard and other relevant DOR publications

Some maps or aerial photographs restricted for general use were received from DOR or ministry, or through concerned department with the help of client. After having collected the maps and other required materials, a team consisting of Team Leader, engineering geologist/geo-technical engineer, hydrologist, sociologist/transport economist and environmental engineer conducted preliminary study at the consultant's office. First of all the consultant's team studied the, status of the locality of all river networks in Nepal and found the proposed river basins. River corridors were mainly studied for the proposed water transport system. The administrative boundaries of all the adjacent villages and settlements were noted down for the further study of the water transport routes. To enhance the accuracy and detail information consultant referred aerial photographs and google maps. Appropriate formats for the collection of field information were developed and discussed with client. After the completion of the Desk study consultant submitted the inception report of the project. Series of formal and informal meetings were held with client and other relevant professionals for the sharpening of the field methodology of the project. After having subsequent comments and feedback from Ministry, the team scheduled the field survey.

The desk study included the socio-economic study of districts and villages along the river corridors.

## 2.2 Phase – II: Field Work

Field survey for water transport study was conducted for all the river basins under consideration. The field schedule of consultants' team and checklist for information collection was approved by the client. Consultant followed the activities as below:

### 2.2.1 Field Verification

Based on the outcome of the desk study and feedback on desk study report by the concerned in-charge of the Ministry, the study team verified the existing topographic maps of river corridors and updated information on the topographic maps. Local people have been gathered to collect socioeconomic aspects and need for water transport system for the particular river basin.

Sociologist will focus on collecting information related to socio-economy and traffic flow of the influence area. Highway engineer along with the hydrologist, environmental engineer, civil engineer and geologist will focus on engineering part of the study.

### 2.2.2 Socio-economic Studies of Influence Area

Main tasks of the sociologist will be to collect information regarding the following:

- Demography: (influenced population; their economic activities; structure of population; nature of migration and outside influx etc.)
- Landuse pattern: (wild life sanctuary; forest; production and surplus in influenced area; settlement patterns etc.)
- Trade, industry and commerce existing and planned: (Local produces and other resources; export & import; major and cottage industries; market development; tourism potential; major development works etc.)
- Health existing and planned: (hospital; health post; ayurvedic clinic etc.)
- Education: existing and planned: (Primary schools; secondary schools; high schools; colleges; other educational institution)

- Transport and communication network: existing and planned (trail network and bridges; air transport; water transport; ropeways; road network; telecommunication, postal service; and other communication facilities etc.)
- Administrative facilities: (government offices, cooperatives; banks; police station etc.)

### 2.2.3 Traffic Studies of Influenced Area

In order to determine the existing and future traffic flow the sociologist / highway engineer observed the existing conditions of traffic flow in the particular river basins or its catchment areas. He carried out traffic counts and origin destination surveys or other surveys as consider necessary to determine the present and future nature of traffic, volume of goods, animal and pedestrian movements (motorized as well as non-motorized traffic) within the influenced area ( in the case of existing route).

In broad terms, the consultant tried to identify, describe and quantify existing and probable future traffic generating sources, based on the probable future development of the influence area on relevant factors, such as;

- Population growth and changes in population distribution.
- Regional economic growth
- Development of agriculture, forestry, mineral and other resources.
- Anticipated domestic trade in agriculture and non-agriculture commodities. A second traffic forecast should be made assuming that an appropriate accelerated development program within the zone of influence is undertaken by the Government.

### 2.2.4 Environmental Studies

Environmentalist and geologist conducted the possible impact on ecology, environment and geo-system, forest area, possible encroachment by human and cattle and any other factors which will affect the quality of life and positive and negative impact in the influenced area due to the project. The team took deep concerns of following issues:

- Possible impact on Ecology, Environment and Geo-system in the vicinity of the river corridor after the development of proposed facility of water transport.
- Disturbance to the geo-system and possibility for triggering the landslide and other instabilities.
- Any other social and environmental factors which affect the quality of life in the influence area.
- Positive & negative impact on the area due to the development of water transport system.
- Identify and recommend mitigation methods to be incorporated in detailed design stage.

### 2.2.5 Studies on Property Acquisition

Studies on legal aspect of land acquisition, temporary and permanent acquisition of land and property, displacement and rehabilitation aspect, compensation etc. was also studied by the sociologist.

### 2.2.6 Geological/Geo-morphological, Hydrological and Meteorological Studies

Highway engineer along with the geologist, hydrologist conducted the field observation along the river corridors to assess the geology, geomorphology, natural hazard and hydrology of the streams in the alignment. Existing situation on field regarding the geological formation, type of rocks, its dip, strike, seepage flow etc. were observed in order to decide the stability of the transport route (Any Civil structures if any). Geological information were collected and regional Geological map was updated including the highlighting the hazard section.

### 2.2.7 Engineering Studies

The technical team at first verified the information collected during the desk study phase and make necessary changes in the topographic map and other secondary data on particular river basins. After conducting the field studies the changes in the study area (new settlements, river meandering, landslides, drainage name, district demarcation etc.) will be located in the map. Natural hazard areas and landslide zones were marked on the map. The approximate dimension of protection works needed in these areas were measured in the site and noted. Volume of river training works required will also be measured and noted.

Photographs of the distinct features such as overall view, landslide area, other geological hazard areas, river crossings, distinct soil type, road intersections, existing trail and bridges, existing water transport means like Boat, feri etc, were taken and included in the report.

For the study of water flow characteristics, the field team took assistance of the Rafting Company. The technical team sailed the whole length of the river corridors to distinguish the rapid sections and still water sections. During the sailing over the river surface team noted down the critical sections: rapids, poor geology, narrow sections, and shallow sections with the help of GPS instrument.

The same team measured the water velocity at various critical section of the rivers. The team measured the water depths with the help of Echo sounder.

## 2.3 Phase-III Office Works

### 2.3.1 Engineering Design

The table works comprise of plotting of field data, preparing drawings, design, and interpretation of field data and reporting. The stepwise procedure of the table works is narrated below:

- After completion of the survey work, all the team members including surveyors and overseers will discuss in the office, prepare necessary drawings, sketches and reports for discussion with the client. The suggestions, feedback of the Engineer In-Charge will be incorporated in the drawings and reports.
- Prior to proceeding with the design and drawings the team will discuss and maintain a close liaison with the Engineer-in-charge of the Ministry.
- Based on the preliminary discussion with the Engineer-in-charge and interaction within the team, the Highway Engineer took responsibility for the design work. Other professional like geologist, environmental engineer, hydrologist prepared the necessary documents, reports and assist the design engineer (Both highway engineer and structural engineer) by providing feedback and suggestions in designing any particular structure.
- When the design works are complete or underway, all the design procedures, norms, codes followed during the designed will be explicated with the Engineer-in-Charge. Based on his/her suggestions and comments, further design work will be done.
- The team leader will routinely report to the Engineer-in-Charge about the work progress on weekly basis.
- The drawings prepared are:
  - Location map of river basins
  - Alignment map showing alignment with kilo-meterage, name of points, districts, zones, regional demarcations, rivers, land use, markets, grid lines etc.
  - Map showing linkage of the route with surrounding network of rivers,
  - Plan and L - section of the route in the standard scales
  - Cross - sections of at each suitable chainage in 1: 100

- Map showing land use pattern
- Reference charts of all intersection points, BMs and other reference points
- Hydrological, meteorological and geological maps of the route

### 2.3.2 Cost Estimate

The cost estimates of this project mainly related to the cost of infrastructure construction, and vessel price. Preliminary cost estimate of each water transport sections was estimated based upon the typical construction cost of particular physical facility for the promotion of water transport.

Maintenance cost of operation of water transport system was estimated estimated based on the periodic maintenance of vessel and infrastructure.

Operating cost of water transport system is included fuel consumption, crew salary, depreciation of initial investment and government tax.

After estimating all the costs for each service a comparison will be made between different service sections. Comparison will be made between existing road transport and proposed water transport. While recommending the most feasible alignment in terms of construction cost, comparison has to be made with the operating cost as well as to determine the period during which the extra construction cost will be compensated.

### 2.3.3 Economic Analysis

Economics of the route construction will be analyzed based on the three settings:

- a. that the proposed water transport route project is not undertaken and that existing trends continue;
- b. That the proposed water transport route is undertaken and that existing trends continue and GoN plans are carried out;
- c. That the proposed project is undertaken and that appropriate accelerated development programmed, particularly for agriculture and forestry, setting of new industries, converting city into metro city and establishment of port are undertaken.

The economic analysis for the three settings of alternative alignments will include:

- a. Estimated future transport cost savings including vehicular and porters and pack animals, where appropriate.
- b. Estimate of other economic benefits such as increase in the net value of agriculture and forestry production, the future trends in road maintenance, time savings, reduction in road accidents and other developments and social benefits such as industrial expansion, improvement in existing facilities with regard to communication, recreation and education.
- c. comparison of the expected cost of construction and maintenance with the benefit estimate in (a) and (b) indicating the benefit cost ratio;
- d. Evaluation of the sensitivity of the rates of return to possible variations in the main factors used in the economic evaluation.

On the basis of the study of alternative solutions, the recommendation of the optimum economic program for construction of the proposed water transport route has prepared. Lastly, the consultant specified whether the proposed water transport route project should be undertaken by the ministry or by the local agencies i.e. the proposed water transport route is district level or local road.

## 2.4 Procedure of Primary Data Collection

According to the schedule submitted to the employee of the project, the field study was planned as phase II after the submission of the Inception report. The field study was conducted during two months in November and December. The field survey was completed in four stages.

1. Trisuli River (Fishlin – Devghat 50 Km)
2. Kali Gandaki River (Ramdi – Devghat 130 Km)
3. Sunkoshi River (Ghurmi – Koshi Barrage 173 Km)
4. Bheri River (Bhotechaur – Chisapani 123 Km)

The objective of dividing the field study into the four different segments is that the study has been conducted with the help of the rafting boat navigating from upper to lower reach. Thus, the study has to be assigned in four different rivers. Trisuli River has been selected at first for field investigation taking consideration of easy access and other conveniences.

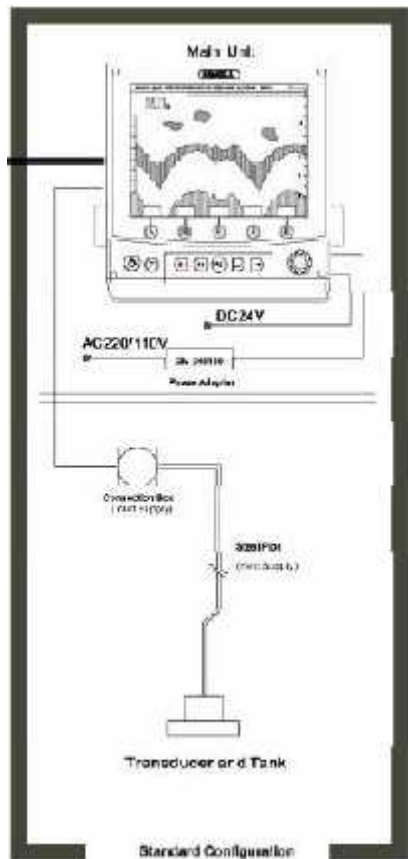
The field study has been conducted after the submission inception report, the preparation of maps, format of data collection sheet and other management works. The five members team has been formulated for waterway corridor survey, among them one team leader, 3 engineers and 1 overseer. The equipment that has been used for the waterway corridor survey are listed below,

| SN | Instruments                                                  | Quantity |
|----|--------------------------------------------------------------|----------|
| 1  | Echo Sounder (Display LCD, Battery 24v, Transducer, Charger) | 1 No.    |
| 2  | Garmin GPS                                                   | 1 No.    |
| 3  | Sony Digital Camera                                          | 1 No.    |
| 4  | Fibre Tape 50 m                                              | 1 No.    |
| 5  | Stop Watch                                                   | 1 No.    |
| 6  | Stationary Items                                             | 4 Sets   |

The strategy of collecting the data by the team was made as ease as possible. The hydrological, geological, environmental social and traffic data has to be collected. With the help the prepared questionnaire, the team has collected socio-economic data and by available traffic post and toll bars related data has been extracted. When the team is in the water they are totally bounded with limitations of collecting data, small mistakes can create accident. Thus, one member will handle Echo sounder, one member will handle GPS, one member will take photographs and other two will book the data as well as refer references with observation of environmental and geological features.

## 2.5 Introduction to Echo-Sounder

For the survey of waterway in various rivers NINGLU DS2008 Echo Sounder has been used. It is navigation sounder with a large, high resolution graphic LCD. The echo sounder graphics is continuously shown on the LCD along with complete navigational details. The bed depth has been recorded with the help of this machine. The main parts are: Display LCD, Transducer, 24 V Battery, Charger and Connecting Wires.



Photograph 2-1 Ninglu DS2008 Echo Sounder and its standard configuration

### 2.5.1 Principle of Operation

The DS2008 sends ultrasonic pulses which can be transmitted and received by the transducer from the surface and records the time until the echo returns from the bottom. By making full use of the properties of ultrasonic waves which travel at about 1500 m/sec and plus the depth of sea gauge, the correct marine depth can be measured.

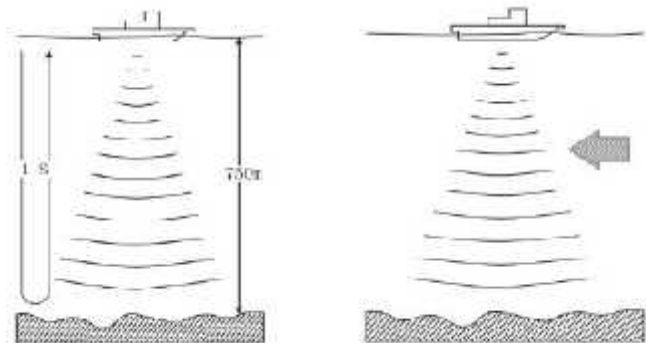


Figure 2-2 Principle of Operation

Data from the surface to the bottom is sectionally detected from the narrow side as is shown in the above figure. Being based on the principle that water is an excellent medium for the transmission of sound waves and will bounce off a reflecting layer traveling at about 1500 m/sec, the reflection is detected by the transducer, amplified and transformed into a picture of a slice of the ocean which can be displayed on a LCD screen.

Transducer plays a role of receiving sensor and transmitting sensor and its receiving time is related to the depth range. The shallower the range is, the less the returned time is. By making use of transmitting and receiving time to pick up the reflected echoes the display of fish school or other floating objects and the sea bottom can be seen on the screen.

## 2.5.2 Working Procedure

The procedures of measuring depth in the rivers are

- a. Setup the Echo-Sounding Machine as in photograph 2-1.
- b. Mount the display LCD in such a place where the splash from waves couldnot reach to it.
- c. Dip the Transducer in the river for about 10 cm.
- d. Turn on the Echo-Sounding Machine and burger sound will noticed.
- e. By pressing button C the sound will be turn off.
- f. Select the setting by pressing button F  
Our Configuration during field study, TVG 10, Gain 10, Pic 1/1, Level 7 and Draft 0.1
- g. After configuring setting, depth is taken for vertical control.
- h. The GPS is used for horizontal control by marking waypoints.
- i. The GPS points and Sounding depth in metre are recorded parallely.

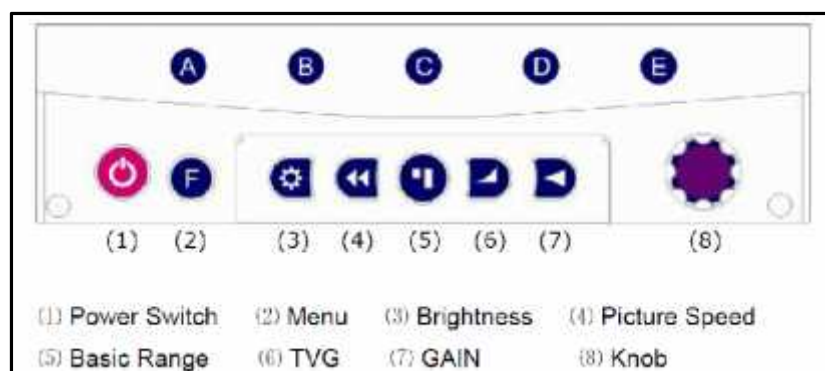


Figure 2-3 Operating Panel of Ninglu DS2008 Echo Sounder

### 3. WATER TRANSPORT

#### 3.1 Introduction

Water transport refers to movement of goods and passengers on waterways by using various means like boats, steamers, launches, ships, etc. With the help of these means goods and passengers are carried to different places, both within as well as outside the country. Within the country, rivers and canals facilitate the movement of boats, launches, etc. Since the goods and passengers move inside the country, this type of transport is called inland water transport. When the different means of transport are used to carry goods and passengers on the sea route it is termed as ocean transport. Let us know further about these two types of water transport.

##### a. Inland water transport

Inland water transport use boats, launches, barges, streamers, etc., to carry goods and passengers on river and canal routes. These routes are called inland waterways and are used in domestic or home trade to carry bulky goods. Passenger transport through waterways is not so popular in our country. Inland water transport system exists only in few states like West Bengal, Andhra Pradesh, Assam, Tamil Nadu, etc.

##### b. Ocean transport

Ocean transport refers to movement of goods and passengers with the help of ships through sea or ocean waterways. It plays an important role in the development of international trade. It is also used for transporting goods and passengers in the coastal areas. Ocean transport has its fixed route, which links almost all the countries of the world. Sea transport may be of the following two types.

- i. Coastal Shipping - In this transport, ships ply between the main ports of a country. This helps in home trade, and also in carrying passengers within the country.
- ii. Overseas shipping - In this transport, ships ply between different countries separated by sea or ocean. It is mainly used for promotion and development of international trade. It is economical means of transport to carry heavy machines and goods in bulk. Overseas transport is carried out on fixed routes, which connect almost all the countries. In ocean transport, different types of ships are used to carry passengers and goods. These may be classified as under.
  - a. Liners - A liner is a passenger or cargo vessel, which belongs to a regular shipping company. These ships ply over a fixed route according to a prescribed schedule or timetable.
  - b. Tramps - A tramp is a cargo ship, which does not make regular trips but plies whenever cargo is offered to it. It does not follow a fixed route or a prescribed timetable like that of liners.

Advantages of water transport:

- a. It is a relatively economical mode of transport for bulky and heavy goods.
- b. It is a safe mode of transport with respect to occurrence of accidents.
- c. The cost of maintaining and constructing routes is very low as most of them are naturally made.
- d. It promotes international trade.

Different Means Water Transport

- a. Inland transport: Jet Boats, Steamers, Barges, Launches
- b. Ocean transport: Ships, Tankers, Submarines

### 3.2 History of Water Transport

Humans have always lived near water. We use it to drink, cook, bathe in, water crops, and for travel. Long ago people realized that they could travel faster and more easily on the rivers and over the sea than on land. On barges and ships, people could carry much more than they could with wagons and animals. With sails, boats could use the power of the wind to move, instead of rowing.

The Ancient Egyptians used ships and barges on the Nile River to travel and to carry cargo from one end of their empire to the other. "Cargo" means the things being carried by the ship. When people travel or move cargo by water, they are using water transportation. The Egyptians may have used water transportation on the Nile River to move some of the enormous stones they used to build the Great Pyramids.

Another ancient people, The Phoenicians, were famous sailors. They were known for trading, or buying and selling things, among the countries of their ancient world. The Phoenicians are also known because they were the first people to use an alphabet, instead of pictures, to write.

The Vikings were a group of famous shipbuilders and sailors from Northern Europe. They were explorers, traders, and conquerors. They settled in many of the lands that they conquered. It is believed that they were the first Europeans to travel to North America.

At first, early sailors could only go where the rivers and ocean were naturally deep enough. But, water transportation became so important to people that they started to dig waterways of their own. A waterway is like a highway for boats. Rivers are natural waterways; a canal is a man-made waterway. The Egyptians, the Romans, and the ancient Chinese all built canals to connect the sea to their cities and to connect the cities to the countryside.

#### Water Transportation in American History

Native Americans used the natural waterways, like rivers, lakes, and oceans, for travel and trade, too. Native Americans used canoes, kayaks, and rafts for water transportation. Later, the settlers used rivers to explore, settle, and trade in North America.

Many rivers were important to the early settlers, but one of the most important and most famous is the Mississippi River. On it, people, their animals, and freight could travel from the upper Midwest to the Gulf of Mexico. The long river was shallow in many places, so the boats and rafts that traveled on the Mississippi had to be shallow draft. Mark Twain wrote about the great Mississippi River in the many adventures of Tom Sawyer and Huckleberry Finn.



Figure 3-1 The Ancient Egyptians were the earliest shippers



Figure 3-1 Ancient Boats



Ancient Chinese Canal



Figure 3-2 Stern-Wheeler on the Mississippi River, early 1800's



Figure 3-3 View of Erie Canal by John William Hill, 1829. Packet boat on the Erie Canal

Early Americans built many canals, mostly in the northeastern states. One of the most famous canals built was the Erie Canal. It was 363 miles long, and went from Albany, New York to Buffalo, New York. On the Erie Canal, people, food, and supplies could travel back and forth between the towns and Atlantic Ocean ports in the Northeast United States and the Great Plains. Horses walked beside the canal on a road, called the tow path, and pulled along flat-bottomed boats and barges, called packets.

Canal building continued in earnest in the Northeast United States through the late 19th century. For a long time, the Erie Canal was a very busy waterway. But it and most of the other old canals were not used as much after railroads were built across the country. While most of the old canals in this country are no longer used, many of them have been cleaned up and turned into parks by people interested in saving the canal history of the United States.

### 3.3 Modern Status of Water Transport



Figure 3-4 Panama Canal connect the Atlantic Ocean with the Pacific Ocean

Today, people in the different parts of the world can use barges and ships, trucks or airplanes for travel or moving cargo. Many natural waterways have been deepened for the big barges and ships used today. The rivers are used to move supplies and products between cities on the interior of the country to the port cities on the coasts. Panama Canal is one of the important modern water transportation infrastructures that cut through a narrow piece of land between North and South America, called the Isthmus of Panama. It is a shortcut for ships going from one side to the other. It is a coastal waterway. The Tenn-Tom waterway in Northern Mississippi is one of the modern canal inland waterway in United States connects the Tennessee River to the Tombigbee River. Completed in 1984, just one month after President Ronald Reagan's re-election, the US\$2-billion waterway

project included 10 locks and dams, a 175-foot-deep (53.1-meter-deep) canal connecting the Tennessee River with the Tombigbee River watershed, and 234 miles (377 km) of navigation channels. In China, navigable inland waterways total more than 100,000 km and there are a large number of inland port facilities with berths for large vessels. IWT accounts for almost 10% of the freight tonnage, two-thirds of it being carried on the Yangtze (including coal, steel, cement, containers and LPG). Many steel mills, located along the Yangtze, use barges. Downstream carries barges up to 10,000 tons capacity. Barges move on the river for more than 3000 km. A shift in priorities is reflected in the construction of the three Gorges Dam 590 km long reservoir, which will involve locks for barges to traverse. Navigability of the river upstream and downstream may actual improve with the controlled flow of water. The river Brahmaputra is one of the National Waterway of India. Two Government-owned organizations (Central Inland Waterways Corporation and Directorate of Inland Waterways, Assam) operate water transport services on the river Brahmaputra and Barak on a commercial basis. These services are used for the transportation of passengers and goods alike. To many places in the hinterlands, waterway is the only mode of transport.



Photograph 3-1 Tow on the Tennessee-Tombigbee Waterway



Photograph 3-2 Yangtze River, China

### 3.4 Chronology of water Transport in Nepal

The history of water transport in Nepal begins after the successful Expedition of Mt. Everest by Sir Edmund Hillary in 1953. The New Zealand habitated Hillary and Joe Hamilton built the concept of Ocean to Sky expedition in 1968. The Ocean to Sky expedition was to travel from 0 MSL to 8848 MSL via Mouth of Ganges to Source. During the expedition, the Sherpa from the expedition team has to lost life in Sunkoshi and the expedition couldnot complete.

In the document of J.M. Delaix the challenges and the possibilities of water transport is discussed where the information of establishment of International Development Enterprises in 1988 is also mentioned to accomplish the water transport project in Arun River. Later in 1990, Dr. Paul Polak and his team brought the jet boat in Nepal to navigate in Arun river.

In 1998 INDO-Nepal Border (Narayanghat to Valmiki Nagar) of 87 km length waterway study was conducted by JV of NEPECON, Everest Consultant & Rites. In 2006, Team of Jet Boaters from New Zealand came for white river expedition in Nepal and they declared Nepal was declared the “holy grail of jet boating”. In 2010, Saptakoshi Sunkoshi Investigation for Navigation by Rites (Tribeni to Kursela 275 km) where they have been focused in river training of the lateral shifting of Saptakoshi and forwarded unfeasibility of waterway for connecting to India National waterway.

Under MoPPW, the Arun and Tamar river waterway has also been studied in 2011. In Arun, the length of 45 km from Chatraghat to Leguwaghat has been studied by Development Consult. In Tamar, the length of 45 km from Mulghat to Majhitar has been studied by Sitara Consult.

### 3.5 Brief Status of Water Transport in Nepal

Since, Nepal has many rivers where navigations are possible. People living near the river corridor are using the navigation facilities by country boats and some motorized water boats which are all done by local initiatives and private agency.

Currently, water transport is available in Koshi river from Chataraghat to Simle Via Tribeni of about 12 km, recreational purpose motor boat in Kulekhani Dam of about 7 km and through local initiatives of Parbat in Kali Gandaki from Mirmi to Seti Beni about 4.5 km. Sumnima Water Transport and Nepal River Transport has been operating jet boat service on the Chataraghat-Simle section but unfortunately, in high water season of Sept. 2011 Sumnima water Transport was washed up in rapid near Barahakshetra.

Nepal River Transport is also preparing to operate boat service on the Arun River linking Tumlingtar with Chatara and they had travelled to Tumlingtar in 1 hr 36 min from Chatraghat. Sumnima Water Transport had earlier been approved to operate transport service on the Arun River. However, the project was dropped following protests from the local residents. Nepal River Transport has now promised to issue shares to the locals affected by the waterway project.

From this fact it can be known that water transport in Nepal is at initial stage.



Photograph 3-3 Nepal River Transport Jet Boat, Chatra



Photograph 3-4 Mirmi to Seti Beni in Kali Gandaki River



Photograph 3-5 Kulekhani Dam Motor Boat for Recreational purpose



Photograph 3-6 Single Engine Jet Boat, Chatra

### 3.6 Review of Basic Design Criteria

#### 3.6.1 Elements of the Inland Water Transport

As all transport system, the IWT is also constituted by some basic elements and the level of interrelation among all of them will determine the level of the reached result. Considering the transport of cargo, there are some elements that constitute the IWT: vehicles, terminals and ways.

##### 1. Vehicles: vessels

The waterway vehicles are composed of a technology totally different from the others, because in this case the vessels displace by a fluid way, the water. Basically there are three types of waterway vehicles classified in accordance with the type of object to be carried: vessel for people, vessel for cargo and finally the mix vessel, this one carries both people and cargo.

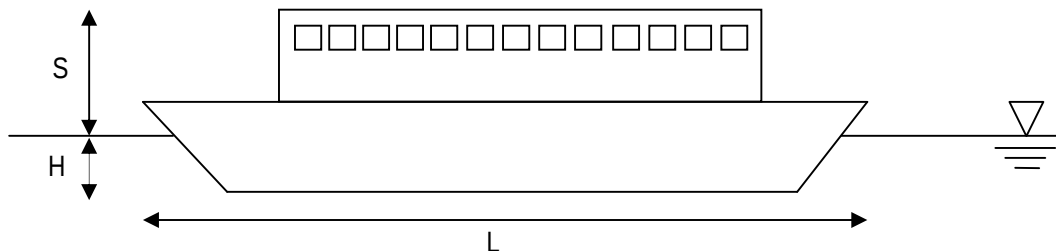


Figure 3-5 Layout of the Vessel

- Length of the vessels (L)
- Width of the vessels (B)
- Draft of the vessels (H)
- Height of the super-structure of vessels (S)

##### 2. Terminals

An inland water port is an intermodal transport centre in which transport by waterway may be the mode, and which produces the greatest community economic impact. Moreover, the facilities within an inland water port, which are located on the waterfront for the purpose of loading and unloading passenger boats and barges, are the terminals. The chief requirements of a port are obvious ones:

- ❖ Vessels must be able to reach the port, so the passage must have sufficient depth and width and must be suitably marked to aid navigation.
- ❖ Vessels regarding harbor must be able to anchor while waiting for a berth to discharge or take on passenger, cargo, fuel and supplies.
- ❖ Finally, the port must possess suitable wharves, backed by appropriate facilities for handling and storing the components passing through the port and for servicing the ships.

In fact, it is not possible to specify rigid minimum requirements for port facilities. In general, each port must be built to the needs of its commerce.

### 3. Ways: Rivers

The way in the IWT is easily identified as the rivers, which have already been formed; however in many cases, rivers in their natural state are not ideal passageways or waterways. Rapids and sandbars offer formidable barriers that could be passed with the utmost labour. Isolated rocks, fallen trees, and other obstructions may be considered as hazard as well. The river to be considered as waterway in order to serve to the traffic of vessels has to hold appropriated features to the navigation, such as: depth of river, current velocity, minimum width and favourable alignment of the river. Such conditions are considered as requirements of navigable rivers.

The simple fact of existence of rivers it does not mean that there is navigation, e. g., it is common for rivers in their natural state to hold barriers to the traffic of vessels and this way they need some intervention to achieve the navigability. In some cases the navigability can be reached just by regulating the flow in storage reservoirs, dredging, banks stabilization or snag removal. On the other hand, some rivers in their natural situation provide appropriated conditions for displacement of vessels, in those cases it is necessary to analyse what type of vessel may be used and the amount of the passenger or cargo to be carried. Thus, there are no criteria of navigability and in the final analysis, economic criteria control. Therefore, there are the physical factors with an influence of the costs of waterborne transport: depth of water, width and alignment of river, locking time, current velocity and the terminal facilities. All of them are defined in accordance with the vessel pattern to be used. Such criteria are considered in the classic requirements of navigable rivers.

#### 3.6.2 Depth of River

The depth of the water in the river must be sufficient to a safe displacement of determined vessel; the barges cannot be loaded further so that their draft exceeds this minimum depth ( $h_{pmin}$ ). The  $h_{pmin}$  is the minimum distance that has to be reached between the draft of the vessel and the bottom of the river. The  $h_{pmin}$  has to be equal to the depth of the rivers minus the draft of the vessel and minus the “squat” – slight depression in the surface of water that happens by the moving of vessel. The equation (1) expresses the definition of  $h_{pmin}$

$$h_p = h - H - S_q \dots\dots\dots \text{Equation (1)}$$

|       |            |                                                                                  |
|-------|------------|----------------------------------------------------------------------------------|
| Where | $h_{pmin}$ | Minimum distance between the draft of the vessel and the bottom of the river (m) |
|       | $h$        | Depth of the river (m)                                                           |
|       | $H$        | Draft of the vessel (m)                                                          |
|       | $S_q$      | Squat (m)                                                                        |

In addition, based on experimental data, an empiric formulation to solve the problem about the forecast of the “squat” is defined as

$$Sq = \frac{h}{H \cdot 0.0298 \cdot \left[ \frac{V}{\sqrt{gh}} \right]^{2.2} \cdot \left( \frac{H}{h} \right)^{-2.9} \cdot k}$$

$$\text{Where, } k = \frac{3.1}{\left( \frac{W}{B} \right)^{0.5}} \text{ when } \frac{W}{B} < 9.91$$

$$k_b = 1 \text{ when } \frac{W}{B} \geq 9.91$$

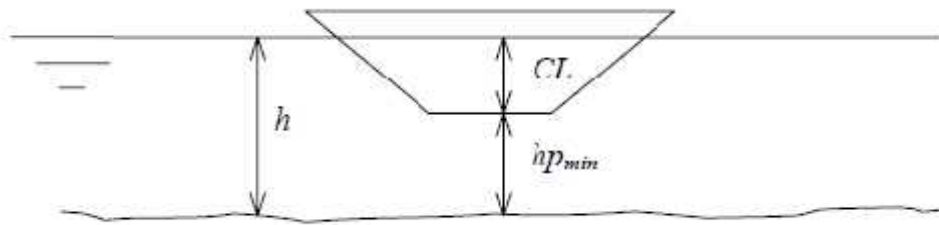
|       |   |                                                   |
|-------|---|---------------------------------------------------|
| Where | h | depth of the river (m)                            |
|       | H | Draft of the vessel (m)                           |
|       | V | Speed of the vessel (m/s)                         |
|       | G | Acceleration of the gravity, 9.81m/s <sup>2</sup> |
|       | W | Width of the river (m)                            |
|       | B | Breadth of the vessel (m)                         |

However,  $h_{pmin}$  must be greater than or equal to  $C_{min}$  ( $h_{pmin} \geq C$ ), where  $C_{min}$  is the minimum distance between the draft of the vessel and the bottom of the river for vessel displacing in cruise speed. The Table 36 shows the values of  $C_{min}$ , in accordance with Brazilian National Standards Organization in Portuguese "Associação Brasileira de Normas Técnicas (ABNT)" for rivers with different types of bottom.

Table 3-1 Values of  $C_{min}$ 

| Type of Bottom | $C_{min}(m)$ |
|----------------|--------------|
| Oozy           | 0.30         |
| Sandy          | 0.50         |
| Rocky          | 1.00         |

Another formulation about the  $h_{pmin}$  has been proposed in Brazil, where it has been defined as a minimum height of the water, which allows the traffic of the vessels at a low speed in the critical part of the route, during the season that the minor level of the water took place. Thus, specifically for the rivers of the Amazon basin with sandy bottom, it has been defined  $h_{pmin} = 0.50m$ . The Figure 3-2 shows the scheme of minimum depth ( $h_{pmin}$ ) of the rivers at Amazon Region for the displacement of vessel.

Figure 3-2 Scheme of minimum depth ( $h_{pmin}$ ) of the river for the displacement of vessel

### 3.6.3 Width, Alignment and Current Velocity

The vessels and the transit time depend of the alignment, width, and current velocity. The width of a channel required for navigation, although a matter of less importance than the depth, yet requires consideration. It is

difficult to maneuver a long vessels or heavily loaded barges in a channel not wider than the vessel itself. Eg. A minimum width of 91.44m is the goal of present navigable channel of the Mississippi River, on the other hand, for a cargo of 1500 tons register, this would require a channel about 70m wide. A highly irregular alignment also increases the “circuits”, or length in excess of airline distance, which the barge tow must travel. The speed of most barge tows in still water is around 6mph or 9ft/sec. Current velocities on the order of 3ft/sec or 4ft/sec represent a substantial reduction in the speed for tows bound upstream or more specifically in the ton miles moved per horsepower-hour.

#### 3.6.4 Terminal Facilities

Terminal facilities are an important factor in the economics of navigation projects. Since charges for vessels continue while it is at a terminal, facilities that permit rapid passenger and cargo transfer effectively reduce lost time and decrease cost. In fact, it should be noted the difficulty in estimate the exactly criteria to determine the navigability of rivers in general, perhaps this happens in reason of the absence of great studies and researches about such matter.

### 3.7 Classification of Rivers

The International Scale of River Difficulty is a standardized scale used to rate the safety of a stretch of river, or a single (sometimes whitewater) rapid. The grade reflects the technical difficulty and skill level required associated with the section of river. The scale is of use to various water sports and activities, such as rafting, river boarding, white water canoeing, and white water kayaking.

Whitewater is formed in a rapid, when a river's gradient increases enough to disturb its laminar flow and create turbulence, i.e. form a bubbly, or aerated and unstable current; the frothy water appears white.

There are six levels each referred to as "Grade" or "Class" followed by a number. The scale is not linear, nor is it fixed. For instance, there can be hard grade twos, easy grade threes, and so on. The grade of a river may change with the level of flow. Often a river or rapid will be given a numerical grade, and then a plus (+) or minus (-) to indicate if it is in the higher or lower end of the difficulty level. Also note that while a river section may be given an overall grading, it may contain sections above that grade, often noted as features, or conversely, it may contain sections of lower graded water as well. Details of portages may be given if these pose specific challenges.

|                      |                                                                                                                                                                                         |                                                                                       |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Class I: Easy        | Waves small; passages clear; no serious obstacles.                                                                                                                                      |  |
| Class II: Medium     | Rapids of moderate difficulty with passages clear. Requires experience plus suitable outfit and boat.                                                                                   |  |
| Class III: Difficult | Waves numerous, high, irregular; rocks; eddies; rapids with passages clear though narrow, requiring expertise in maneuvering; scouting usually needed. Requires good operator and boat. |  |

Class IV: Very difficult

Long rapids; waves high, irregular; dangerous rocks; boiling eddies; best passages difficult to scout; scouting mandatory first time; powerful and precise maneuvering required. Demands expert boatman and excellent boat and good quality equipment.



Class V: Extremely difficult

Exceedingly difficult, long and violent rapids, following each other almost without interruption; riverbed extremely obstructed; big drops; violent current; very steep gradient; close study essential but often difficult. Requires best person, boat, and outfit suited to the situation. All possible precautions must be taken.



Class VI : Unraftable

Formerly classified as unrunnable by any craft. This classification has now been redefined as "unraftable" due to people having recently kayaked multiple Class VI around the world.



#### 4. EXISTING WATER TRANSPORT SERVICES IN NEPAL

The history of water transport in Nepal is not so long. Some initiations were carried out to study the suitability of water transport along the river basins. However, studies were limited to the report production and the projects were not realized. Presently, the context of water transport can be characterized as:

- Lack of detail study for water transport projects form the public domain,
- The river hydrology seems to be main obstruction to carryout projects,
- Weak Geology i.e River bed and side slopes are very sensitive for any interventions for may created long term hazard to the locality which may be unfavourable for water transport,
- Local initiations were started in some places with most advantageous mode of transport to the operators as well as users.

In such adverse situations there are some good examples of existing water transport systems in Gandaki and Koshi River Basins.

##### 4.1 Koshi River: Chatara – Tribeni – Simle (Arun river)

The rafting is for the tourism, adventure purpose. For the public transportation, the Jet boat service provided by the Nepal River Transport in Chatara is operating from Chatara to Simle via Tribeni in Saptakoshi forwarding to lower stretch of Arun River for 5 years. The length of the operation is about 12 km which takes 12-15 minutes to complete the journey. According to the Nepal River Transport operator, they make about 24 trips in a day carrying 20 passengers in a trip with life jackets for safety and they are charging Rs. 250 per person with 10 kg luggage. They have tried to increase their route towards Sunkoshi and Arun River, but due to the rapids near Ekuwakhola (K-TS 4+000) it couldnot move towards Ghurmi in Sunkoshi and during high water of June taking risk, they can move upto Tumlingtar in 1 hr 36 min from Chatara which length is about 60 km. Before, there was other jet boat service provider i.e. Sumnima water transport, Chatara but in rapids of high water it has been washed up a year ago.

In the increment in the water transport traffic, Nepal River Transport has brought another big jet boat carrying 40 passengers from Narayanghat Municipality in a lease but it couldnot be operated due to the failure of the engine.

|                          |                                               |
|--------------------------|-----------------------------------------------|
| Operator:                | Nepal River Transport Pvt. Ltd.               |
| Service Started:         | 2062                                          |
| Operation Length:        | 12 Km                                         |
| Travel time:             | 15 min.( Walking time 6-8 hrs)                |
| Vessel type:             | Single Engine Jet Boat (American Manufacture) |
| No. of Vessel Operation: | one                                           |
| Passenger Number:        | Up-stream 20 persons /Down stream 50 persons  |
| Fare rate:               | Rs. 250 per passenger                         |
| Frequency:               | 12 updowns (24 trips)                         |
| Operating months:        | October –June (8 months)                      |
| Opearting staff          | 5 persons                                     |
| Fuel (Diesel)            | 35 lts. Per trip                              |



Figure 4-1 Boats under maintenance in Koshi Basin

#### 4.2 Gandaki Basin – Mirmi- Setibeni (Syanja, Parbat and Gulmi districts)

This water transport service was started on upstream side of the the Dam-site of Kaligandaki Hydropower Project. The water reservoir formed has been utilized as the very favourable and economical mode of water transport. The basic technical and socioeconomic parameters can be highlighted in the table below.

For the public transportation, the propellor boat service provided by the Streamer Service in Mirmi is operating from Mirmi to SetiBeni in upper Kali Gandaki i.e. upstream of Kali Gandaki Hydropower Dam. Due to the dam, ponding of water makes feasible for navigation in the length of 4.5 km which takes 30 minutes to complete the journey. According to the streamer operator, 1 trip is Mirmi - SetiBeni – Mirmi where they use 8 streamers out of 10 in a day with 1 trip per day carrying more than 80 passengers and charging Rs. 50 per person and 0.5 paisa per kg of goods. They have to pay the tax to the District office annually. The motor boats are made locally using the bus engine and body work has been made locally. The passenger boarding or terminal station infrastructure has not built. The passenger traffic seems to be high enough since every boat departing every  $1\frac{1}{2}$  hour is fully loaded by passenger and goods. After the questionnaire with local people, passenger and operator, we found that the water transport in this area operating for short route has highly benefited the contiguous as well as shadow area people. The people before walking take 3-4 hours to reach SetiBeni and after the initiation of the WT in Kali Gandaki, the fruitful utilization of natural resource has been sensed by the benefited people.

|                             |                                                                            |
|-----------------------------|----------------------------------------------------------------------------|
| Service started from:       | 2060                                                                       |
| Travel distance:            | 5 km                                                                       |
| Vessel type:                | Bus engine locally made propeller type of propulsion                       |
| Operation and legal status: | Vessels are Registered at DDC by paying total revenue of Rs. One lakh p.a. |
| Travel time:                | 30 min                                                                     |
| Vessel capacity:            | Small boat 50 persons /Big boat 70 persons                                 |
| Number of operating vessel: | 8 boats (each boat serving one trip per day)                               |
| Fare per trip:              | Rs. 50 per pax/ Rs. 0,50 per Kg.                                           |
| Fuel consumption:           | 12 ltr. Per trip                                                           |
| Size of the Vessel:         | 35 ft.X8 ft.                                                               |
| Speed:                      | 9 – 20 km/hr                                                               |
| Draft:                      | 1 – 2.5 m.                                                                 |



Dam site of Kaligandaki Hydropower Project



Boats operating for water transport



Freight service



Passenger service

Figure 4-2 Water transport at Mirmi - Setibeni

#### 4.3 Recreational water transport: Rafting

Tourism industries are one of the prominent sectors of Nepalese economy. Himalayan Rivers could be the centre of adventure for worldwide tourism. The recreational water transport could play a vital role for the promotion of tourism in Nepal. 'White Water Rafting' is very famous along the Himalayan river in Nepal. The white water rafting has been started in late 1960's by two French in Sunkoshi. In 1976, the first Commercial River rafting company named Himalaya River Expedition was launched and experienced river guide, Mike Yager of America was brought to manage the company and to train Nepalese guides. From this phase to present, rafting in Nepal has really taken off and Nepal is known as one of the world's premier river running destinations.

Koshi Basin is worldwide famous for rafting specially along Sunkoshi and Tamor Rivers, feeder branches for Koshi River.

Sunkoshi River (River of Gold) is one of the prominent rivers for the white water rafting in the world. The electrifying and nerve thrilling rapids of Class 4-5 with inspiring source of natural beauty can be found in the Sunkoshiriver adventure. The rafting agency has marked the starting point Dohalghat and end point Chatara which length is about 272 km and they have scheduled the rafting trip for about 9 days / 8 Nights. For the access to Dohalghat, the Araniko Highway is used and from Chatara, Dharan-Chatara of 16 km road is used for connecting with Eastern Highways. According to the rafting agency, the best month for rafting in this river is in May, September and October where the discharge of the river start to increase and decrease.

Trishuli River is Nepal's most popular rafting river. It has impressive gorges and some moderate white water. The difficulty grade of the river is 3-4. The rafting agency has marked the starting point Baireni and end point

Narayanghat which length is about 106 km and they have scheduled the rafting trip for about 4 days / 3 Nights. For the access to Baireni, the Prithivi Highway is used. According to the rafting agency, the best month for rafting in this river is in March to May and October to December where the discharge of the river starts to increase and decrease.

Kali Gandaki River is divided into Upper and Lower Kali Gandaki since 2001 after the built of the dam in Mirmi. The upper Kali Gandaki has difficulty grade of IV and lower Kali Gandaki has difficulty grade of II, The upper Kali Gandaki trip starts from Beni to Mirmi which takes 2-3 days to complete the journey of 60 km and the lower Kali Gandaki trip starts from Ramdi to Narayanghat which takes 4-5 days to complete the journey of 130 km. According to the rafting agency, the best month for rafting in upper Kali Gandaki is in March to May and October to December and for rafting in lower Kali Gandaki is in February to April and October to December.

Bheri River is one of the most scenic rivers in Nepal with golden cliffs, green jungle, crystal clear green water, white beaches, excellent fishing, good bird watching, coupled with sparkling rapids of moderate difficulty which has attracted the expedition in the river. The rafting agency has marked the starting point Devisthal and end point Chisapani which length is about 142 km and they have scheduled the rafting trip for about 5-6 days. According to the rafting agency, the best month for rafting in this river is in February to May and October to November, when the discharge of the river start to increase and decrease.



Figure 4-3 Bheri River Basin: Scene of natural beauty

#### 4.4 Recreational water transport: Boating

Water body can be taken as the prime natural matter for recreation. The boating for sightseeing is very popular for domestic as well as international tourists in Nepal. Many private entrepreneurs have engaged in tourism service for boating in different places of the country. The dam-site of Kulekhani Hydropower Project is famous for boating cum natural sightseeing. It may help to the local economy as well as the shortest travel route to cross the water body.



Figure 4-4 Boating service in Marpha, Kulekhani

#### 4.5 River Crossing: shortest route for local travel

The rivers create major physical obstruction to the village accessibility in Nepal. However, it could be a better solution for improving accessibility in remote areas in the country. Government has taken major role for the construction trail bridges and other relevant infrastructure. It creates fixed facility for the access to the market and other services. However, boat service for the river crossing could solve the problem in very simple way. From the very beginning of the human civilization as well as these days boat technology is serving us very effectively. In the context of Nepal, the geographical constraints and river hydrology are not very suitable for passenger transport. However, people using local technology for crossing rivers by the use of boats is familiar.

#### 4.6 Critical Issues in the Existing Water Transport

Since, Nepal's topography is the most challenging in any civil infrastructure development. Beside this challenge, there are other many challenges and issues identified in the existing water transport services. The list of challenges with its remediation have been tabulated below:

| Challenges & Issues       | Remediation                                                     |
|---------------------------|-----------------------------------------------------------------|
| Boat & Pilot Registration | Policy Formulation                                              |
| Insurance & Security      | Policy Formulation                                              |
| Maintenance & Experts     | Providing Training in Jet Boats or Mechanics of Water Transport |
| Custom Discount           | Policy Formulation                                              |

## 5. TRAFFIC DEMAND ANALYSIS

### 5.1 Introduction

The traffic survey for the existing and proposed water transport facilities was conducted by the consultant. The basic concepts of economic growth rate, traffic growth factors, population, and production industries of the region were taken as the primary models for the traffic demand analysis. The existing road transport services are very influential to the forecast of water transport services. Therefore, road traffic is taken as the first choice for the general trips of the region

The Consultant undertook:

- Traffic count surveys and;
- Origin-Destination (O-D) surveys.

in order to establish the base year traffic along the proposed waterways. Traffic surveys were carried out along the sections of the Koshi, Gandaki and Bheri River basins. O-D surveys were undertaken to confirm estimates of traffic which could be expected to divert onto the proposed waterways of respective sections of river basins. Before establishing the traffic forecast models following concepts needs to be explained.

### 5.2 Normal Traffic

Normal traffic is the traffic that would pass along the existing facility (water ways or roads), or alignment, if no investment in the proposed project took place.

During the field study and survey, two major factors were noted down which have strong influences on the normal traffic along the foot trails along the river corridors. The first factor is seasonal variation and second is the existing road facility.

The major factor i. e. 'seasonal variation' affects to the local travel as well as regional travel patterns. The annual travel pattern of the rural areas along the river corridor can be distinguished as:

- Rainy season: The season may prolong from June to September. The intra-village as well as inter-village and regional trips are limited to the minimum number. Major part of population is engaged for crop production activities and at the same time the water-body (rivers and stream create barriers to the easy movement of the people.
- Festival season: It prolong for about two months October and November. During the season the trips are more than that of average annual.
- Winter travel season: the season is taken as the earning or season of trade for rural population. Farmers in the villages during season are engaged mainly construction, cash crops and other business.
- Summer season: during summer season village trips are generally for the preparation of rainy season and the trips are limited to the pre crop activities.

The consultant mainly conducted the traffic study during the after festival season. Therefore, the number of trips counted can be considered as the average for annual conversion. Different water transport corridors were taken for the traffic count. The traffic counts were pedestrian and porter count. The existing road traffic along the waterway also considered for the traffic forecast.

At present, the pedestrian, animal back or porters along the village trails and tracks are only the composition of existing traffic. The rate of economic growth of the particular village would direct reflect the growth of such traffic pattern. The Consultant undertook traffic counts and O-D surveys to identify the levels of economic growth and the future potential of tourism as well as other industries.

### 5.3 Diverted Traffic

Diverted traffic is the traffic that changes from other routes or transport modes to the proposed project. Diverted traffic occurs because the proposed transport project would reduce road user costs (vehicle operating costs and road user time costs). When a new facility is constructed there may be a change in traffic composition when traffic diverts. However, for the analysis of the proposed water ways it is assumed that there is no change in composition when freight and passenger traffic divert to waterways from existing roads.

At the first, the proposed waterways may create shortest path to the regional or local market than the existing road transport. Secondly, the proposed waterways may improve the accessibility to the local production centers such as farms for cash crops, mines such as stone quarry.

### 5.4 Development Traffic

The traffic representing the increase in traffic due to the improvement on adjacent land which would have taken place had not the new or improved transport facility been constructed. The tourist flow due to the promotion of some attraction centers can be taken as the development traffic for the particular waterways.

### 5.5 Generated Traffic

Generated traffic is traffic that is induced in response to an investment in a transport project. Generated traffic does not exist prior to the investment. It is induced because the proposed new, or improved, facility enables lower user costs for passengers and freight. The reductions in transport cost and travel time for freight and passengers are the main causal factors for generated traffic. Levels of generated traffic are usually proportional to the reduction in VOC and travel time. The focus of this project is to enhance water transport mode for local villages and market centers improve the existing access, specifically by investing in some infrastructure development and promoting the local entrepreneurs to operate the water transport vessels such as mechanized boats.

These initiations or strategy to improve the water transport would be expected to reduce traveler's costs, travel times and hence passenger fares and freight rates if there is competition between transport operators. It may also encourage a public attraction towards the new intervention of water transport as a part of recreational trips.

There are two ways to forecast generated traffic. Where sufficient data and time is available a traffic demand model is first calibrated on the basis of population, agricultural production, industrial production and services sector revenue or service sector employment, using location matrices, development nodes and probable transport routes. The model is then validated using historical time series data and traffic counts that relate the identified causal factors that result in traffic with the actual traffic counted on existing roads. A validated traffic model can then be used to forecast diverted and generated traffic that will occur after a proposed transport investment.

Where it is not possible to use a traffic demand model, the recommended procedure<sup>1</sup> is to forecast generated traffic using a demand relationship based on the price elasticity of demand (PED) for transport which measures the response of traffic to a change in transport costs.

When the PED for transport is not known it is usually assumed to be  $-1.0^2$  for new roads, that is, a 1% decrease in transport costs would result in a 1% increase in traffic. However, Nepal is a poor country. Rural incomes per head and discretionary spending are very low. Thus it is expected that PEDs for transport for roads through rural

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<sup>1</sup>HDM-4 Applications Guide, Part D Data Management, page D5-7

<sup>2</sup>Price elasticities of demand are usually negative when calculated but referred to as absolute numbers when analyzing change in demand

areas will be less than 1.0. This analysis has used a PED of 0.1 for motorized transport and 0.1 for non-motorized traffic for calculating generated traffic.

The generated traffic is calculated only from the levels of normal traffic. However, it is noted that because both proposed waterway are shortest and they have limitation for the services in rainy or high flood seasons.

## 5.6 Traffic Growth and Forecasting

To assess the expected growth in normal traffic on transport projects, the Consultant reviewed the growth of GDP for Nepal, the relationship between GDP growth and traffic growth in Nepal, traffic growth rates used by previous studies and the standard traffic growth rates used by Department of Roads (DOR) for motorized and non-motorized traffic for road project evaluation in Nepal.

The Consultant used following growth rates (% pa) to forecast Normal Traffic:

| Year        | Traffic Growth Rates |     |
|-------------|----------------------|-----|
|             | MT                   | NMT |
| 2012 – 2022 | 8                    | 6   |
| 2022 – 2032 | 6                    | 5   |

These are similar to and consistent with the growth rates used by DOR for the road maintenance planning projects.

During 1990's the average traffic growth rate on DOR roads was just over 8% pa for both motorized and non-motorized traffic. Real GDP growth averaged 4.9% pa for the ten years 1990 – 2000 but declined in 2002/03 as the ceasefire with the Maoist insurgents ended. Economic growth started to re-emerge in 2006 onwards.

The ADB<sup>3</sup> forecasts that GDP growth in 2003/04 will be 4% but will accelerate in 2004/05 to 5%pa. This rate is forecast to continue if the insurgency problems can be overcome. The forecast traffic growth rate, 8% pa for 15 years then dropping to 6% pa, is considered prudent and consistent with expected growth of motorized traffic.

While there is evidence to suggest that non-motorized traffic will also grow at about 8% pa, it is likely that when project roads are upgraded there will be a shift from rickshaws and bullock carts to buses and trucks as the improved roads encourage better bus services and trucks are able to access the area. Thus a 6% pa growth rate dropping to 5% pa is consistent with the expected growth in non-motorized traffic on project roads.

The growth rates listed above are used for traffic forecasts with and without the proposed improvements for each project road.

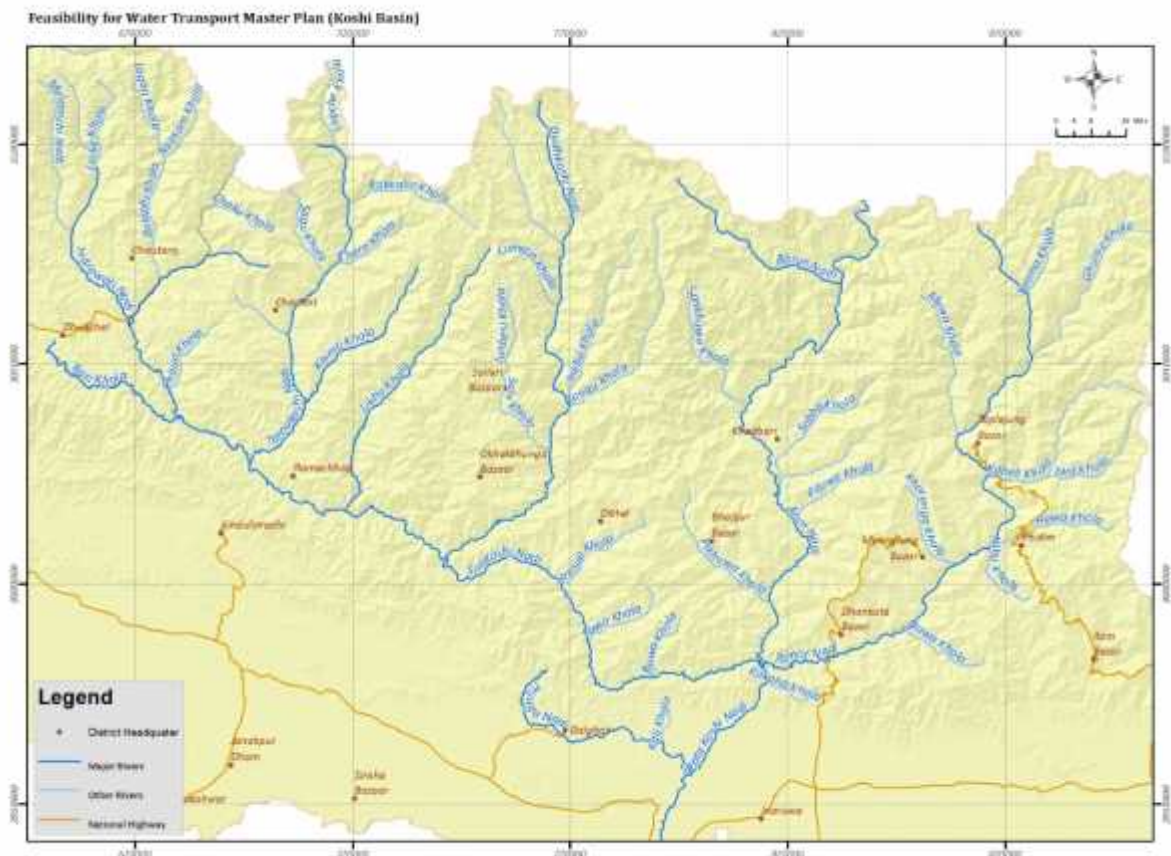
Traffic count results for particular river sections are shown in the study chapter of the respective basin.

<sup>3</sup>ADB "Outlook"

## 6. WATER TRANSPORT STUDY IN KOSHI BASIN

### 6.1 Introduction

Koshi River lies in the eastern part of Nepal and it is one of the biggest rivers of in the Nepal where seven big rivers are merged. They are Arun, Tamar, Dhudh Koshi, Bhoté Koshi, Sun Koshi, Tama Koshi and Indrawati. Thus, it is also named as Saptakoshi in southern part of Nepal. The Bhotekoshi, Sunkoshi, Indrawati, Tamakoshi, Dudhkoshi, Arun and Tamar merges at various places as Barabise (Sindhupalchowk), Dolalghat (Kavrepalnchowk), Pakarbas (Ramechap), Bahunidada (Khotang), Tribeni – Chhintang (Dhankuta). Its catchment area is about 28,140 sq km in Nepal but for Koshi Barrage its catchment area is about 61,788 sq km and its average discharge is about 2166 cubic meter per second (76,500 cusec). During floods, it increases to as much as 18 times the average. The greatest recorded flood in Koshi Barrage was 24,200 cumec (850,000 cusec) on 24 August 1954. According to the Global Mapper Software, the total length of the Saptakoshi River is about 950 km.



Map 6-1 Koshi River and its tributaries

## 6.2 Study of Proposed Waterway Corridor

The only mode of surface transport available in Nepal is Road, which apart from being a costly option, is beset with other strategic problems. Water transport study will provide an alternative mode to Nepal for its intermodal trade. WT mode is expected to be economical, environmentally friendly, safe, better manageable and direct with road to function as a complementary mode. Hence, the mode envisages spurring developmental activities along the proposed waterway, both contiguous and shadow area. Here, all the data are collected in the reference to the proposed waterway and it is divided into 4 sections in the Koshi Basin.

|                     |                                      |           |
|---------------------|--------------------------------------|-----------|
| Proposed Waterways: | Section 1: Chataraghat-Koshi Barrage | 47.05 km  |
|                     | Section 2: Chatra ghat – Tribeni     | 8.72 km   |
|                     | Section 3: Tribeni - Simhawati Saune | 48.47 km  |
|                     | Section 4: Simhawati Saune – Ghurmi  | 69.12 km  |
|                     | Total                                | 173.36 km |

## 6.3 Influence Area

Here the data of different factors like (demographic, Land use pattern, Agriculture etc) are collected on the basis of core zone of influence and umbral zone of influence. The core zone of influence refers to the population who are inhabited along the river corridor, whereas umbral zone of influence area refers to the all the VDC in the district who can access the intermodal facilities. (Refer Annex I)

Here, the VDC which are influenced by Sunkoshi River among seven rivers namely Bhotekoshi, Sunkoshi, Indrawati, Tamakoshi, Dudhkoshi, Arun and Tamar are listed. There are 7 districts and 50 VDC out of 17 districts and 285 VDC in the Koshi river corridor.

Table 6-1 Core Zone of influence VDC for Proposed Waterway

| District    | VDC                                                                                                                                                                                |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Okhaldhunga | Toksel, Thakle                                                                                                                                                                     |
| Khotang     | Bhaunidada, Dikuwa, Chyasimitar, Darchim, Chhitun, Rajapani, Batase, Lichkiramche, Baraha Pokhari, Suntale, Phaktan, Pauwasera, Devasthan                                          |
| Udayapur    | Lekhani, Sorun Chhabise, Rupatar, Thanagaun, Basbote, Tamlida, Balamta, Jante, Laphagau, Aptar, Khanbu, Simhawati Saune, Sidhipur, Chaudandi, Katunje Babala, Mainamaini, Tokshila |
| Bhojpur     | Pancha, Dummana, Hasanpur                                                                                                                                                          |
| Dhankuta    | Chintang, Ahale                                                                                                                                                                    |
| Sunsari     | Barahakshetra, Mahendranagar, Prakashpur, Madhuban, Paschim Kusaha, Shripur Jabadi, Haripur                                                                                        |
| Saptari     | Odara, Pipal (Purba), Jagatpur, Badagama, Bairawa, Bhardaha                                                                                                                        |

(Source: District Development Profile of Nepal 2010/11)

## 6.4 Socio Economic Study of Proposed Waterway Corridor

The general study of the Socio-Economy aspect of the project has been carried. The project has been focused on vulnerable groups along the proposed waterway. Vulnerable groups refer to the indigenous people as well as poor and dalits groups. In Nepal the indigenous population is popularly known as Janajatis which is also recognized by the government and constitutes about 37.2 percent (8.4 million) of Nepal's total population. The water transport development project covers Eastern, Central and Western part of Nepal. There are mostly indigenous people habitats along the proposed waterway.

In context of Nepal, Highways and Airports are the major infrastructure in the mode of transportation. Lack of adequate transportation infrastructure, especially in rural areas, results in significant limitations for communities. These limitations occur in terms of access to socio-economic and cultural centers such as schools, clinics, markets and other business centers. Limited access to schools hamper educational access for learners, lack of access to clinics hamper health development and limited access and mobility to markets and other business centers places limits on trade opportunities, and subsequently also limits the potential opportunity for earning an income and a subsequent improvement in the day-to-day living standard. The result is a poor socio-economic development standard.

The socio-economic data on the influence area are compiled and presented on the following sub-topics.

#### i. Population

Here, the total population in Koshi river corridor is taken out from the VDC of specified district who were directly influenced by the project. According to Census 2001 demographic statistics, it occupies about 5.12% of the total population of Nepal. In the reference to the latest population census (2001 AD), the following data is collected.

Table 6-2 Population in Core zone of Influence Area

| S.N | District    | Total Directly Influenced Population |                |
|-----|-------------|--------------------------------------|----------------|
|     |             | 2001 Census                          | 2011 Projected |
| 1   | Okhaldhunga | 38524                                | 43288          |
| 2   | Khotang     | 58231                                | 62390          |
| 3   | Udayapur    | 82136                                | 106798         |
| 4   | Bhojpur     | 58082                                | 59317          |
| 5   | Dhankuta    | 91837                                | 104442         |
| 6   | Sunsari     | 85641                                | 156484         |
| 7   | Saptari     | 56974                                | 69774          |

Source: District Development Profile of Nepal 2010/11

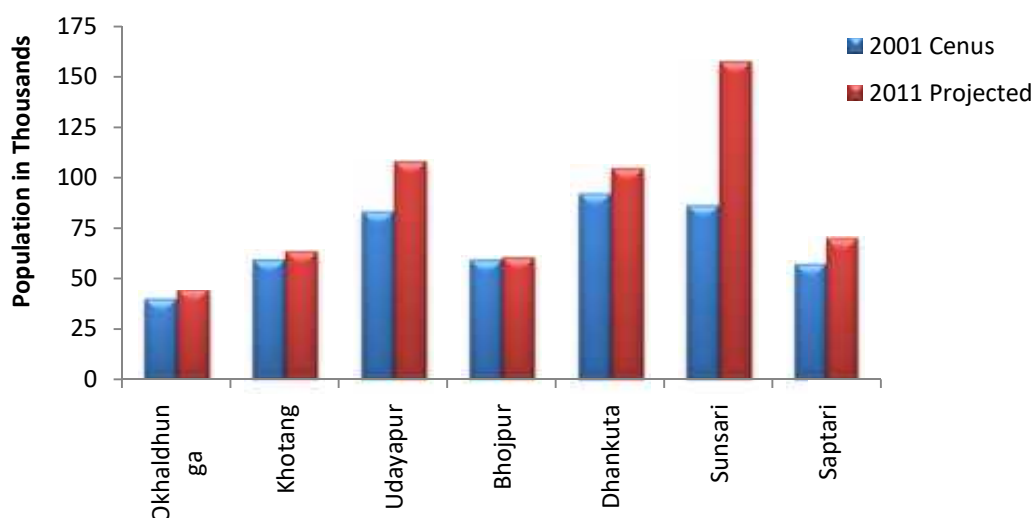


Chart 6-1 Population distribution in Proposed Waterway

## ii. Land use Pattern:

The plain and river intersection area of the influence area is mainly covers by cultivated land and residential pattern. Hilly area with steep slope is only covered by the forest. This forest is main habitat for wildlife. Wide range of birds and animals can be found in these forests. In certain section of forest has been converted to wildlife conservation area. Most of the settlements in the area are located in lower altitude and along the river valley. The steep slopes in the hilly area are terraced for the agricultural production. The market and settlements are scattered near water courses and relatively plain land. Land use pattern in Koshi River influence area are given below and the given area is in Hectare,

Table 6-3 Landuse Pattern in umbral zone of influence area of Proposed Waterway

| S.N | District    | Agriculture |                 | Pasture | Forest | Other | Total  |
|-----|-------------|-------------|-----------------|---------|--------|-------|--------|
|     |             | Cultivation | Non Cultivation |         |        |       |        |
| 1   | Okhaldhunga | 29825       | 19012           | 10911   | 47347  | 1407  | 108502 |
| 2   | Khotang     | 47233       | 24089           | 7445    | 79554  | 2543  | 160864 |
| 3   | Udayapur    | 3506        | 17328           | 2892    | 138917 | 8967  | 203169 |
| 4   | Bhojpur     | 43087       | 22647           | 6004    | 77887  | 1369  | 150994 |
| 5   | Dhankuta    | 33105       | 13711           | 4067    | 36383  | 2754  | 90020  |
| 6   | Sunsari     | 74541       | 7403            | 4912    | 23204  | 17016 | 127076 |
| 7   | Saptari     | 79796       | 6589            | 2649    | 3418   | 12706 | 135929 |

Source: District Development Profile of Nepal 2010/11

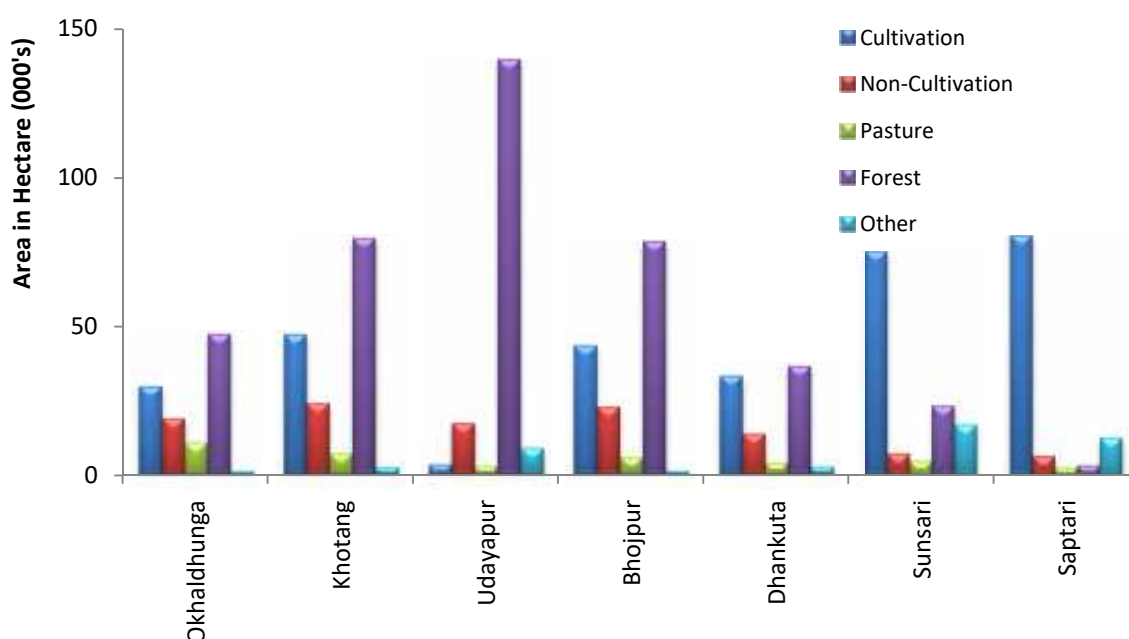


Chart 6-2 Land use pattern in Koshi River umbral zone of influence area

## iii. Economic Activities:

In reference to the District profile 2010/11, the major source of income and employment in the Koshi river corridor are agriculture, tourism, civil services, fishery, porters, etc

## Agriculture

Agriculture is the major sector of Nepalese economy. It provides employment opportunities to 66 percent of the total population and contributes about 36 percent in the GDP. Therefore, the development of agriculture sector is the key for the development of national economy.

The places where the production of cereal crops, cash crops, major crops, fruits, vegetables, pulses etc in the Koshi River influence area are summarized. The maximum production capacity of Cereal crops like paddy in Saptari, Wheat in Sunsari, Millet and Barley in Khotang and Mazie in Dhankuta. The maximum production of cash crops like OilSeed, Sugarcane and Tobacco in Sunsari and Potato in Saptari. The maximum production of Major crops like Cardamon in Khotang, Ginger in Bhojpur, Garlic in Sunsari, Chilli and Turmeric in Saptari. The maximum production of pulses like Lentil and Grass pea in Sunsari, Pigeon Pea in Saptari, Horse gram in Khotang, The maximum production of fruits like mango, Banana in Sunsari, Papaya and Jackfruit in Saptari. The maximum production of vegetables is in Saptari.

According to the agriculture statistics (2009/10) of different types of crops production in various areas of Koshi River influence area are tabulated where Area in Ha and Production in Mt.

Table 6-4 Cereal Crops statistic in Koshi River umbral zone of influence area

| DISTRICT    | Paddy   |         | Maize  |         | Millet |        | Wheat  |         | Barley |       |
|-------------|---------|---------|--------|---------|--------|--------|--------|---------|--------|-------|
|             | Area    | Prod    | Area   | Prod    | Area   | Prod   | Area   | Prod    | Area   | Prod  |
| Okhaldhunga | 5130    | 10850   | 12097  | 22985   | 8785   | 12299  | 2807   | 3519    | 115    | 138   |
| Khotang     | 12279   | 22642   | 22950  | 49060   | 14375  | 14513  | 3500   | 5147    | 500    | 400   |
| Udayapur    | 14050   | 39340   | 16900  | 38025   | 2572   | 3458   | 4800   | 10950   | 38     | 37    |
| Bhojpur     | 15300   | 35600   | 21000  | 42600   | 5136   | 5236   | 2510   | 3867    | 30     | 40    |
| Dhankuta    | 8650    | 23530   | 18875  | 54750   | 8080   | 9091   | 2723   | 4901    | 10     | 10    |
| Sunsari     | 49991   | 133950  | 7500   | 19600   | 1250   | 1260   | 17000  | 44400   | -      | -     |
| Saptari     | 59903   | 150724  | 4000   | 8000    | 250    | 250    | 15000  | 35080   | -      | -     |
| NEPAL       | 1481289 | 4023823 | 875660 | 1855184 | 268473 | 299523 | 731131 | 1556539 | 26600  | 27587 |

Table 6-5 Cash Crops statistic in Koshi River umbral zone of influence area

| DISTRICT    | Oil Seed |        | Potato |         | Tobacco |      | Sugarcane |         |
|-------------|----------|--------|--------|---------|---------|------|-----------|---------|
|             | Area     | Prod   | Area   | Prod    | Area    | Prod | Area      | Prod    |
| Okhaldhunga | 476      | 250    | 2905   | 31238   | 0       | 0    | 5         | 40      |
| Khotang     | 1050     | 743    | 5800   | 89750   | 0       | 0    | 8         | 144     |
| Udayapur    | 5100     | 2996   | 760    | 7546    | 14      | 11   | 14        | 224     |
| Bhojpur     | 267      | 187    | 3000   | 32100   | 0       | 0    | 0         | 0       |
| Dhankuta    | 1050     | 813    | 2025   | 33412   | 0       | 0    | 41        | 800     |
| Sunsari     | 8500     | 7013   | 2750   | 40673   | 97      | 88   | 3000      | 168000  |
| Saptari     | 5900     | 3230   | 5550   | 88245   | 78      | 68   | 60        | 2500    |
| NEPAL       | 198540   | 155050 | 185342 | 2517696 | 2534    | 2491 | 58310     | 2495098 |

Table 6-6 Some Major Crops statistic in Koshi River umbral zone of influence area

| Districts   | Caradom<br>Area | Caradom<br>Prod | Ginger<br>Area | Ginger<br>Prod | Garlic<br>Area | Garlic<br>Prod | Turmeric<br>Area | Turmeric<br>Prod | Chilli<br>Area | Chilli<br>Prod |
|-------------|-----------------|-----------------|----------------|----------------|----------------|----------------|------------------|------------------|----------------|----------------|
| Okhaldhunga | 90              | 80              | 42             | 377            | 25             | 100            | 28               | 199              | 36             | 54             |
| Khotang     | 500             | 300             | 5              | 40             | 30             | 240            | 23               | 211              | 25             | 125            |
| Udayapur    | 17              | 9               | 58             | 742            | 40             | 420            | 54               | 373              | 31             | 59             |
| Bhojpur     | 315             | 179             | 235            | 2963           | 18             | 130            | 6                | 48               | 4              | 15             |
| Dhankuta    | 280             | 175             | 170            | 1825           | 14             | 84             | 16               | 24               | 49             | 255            |
| Sunsari     | 0               | 0               | 200            | 2400           | 125            | 938            | 110              | 830              | 100            | 450            |
| Saptari     | 0               | 0               | 120            | 733            | 110            | 781            | 265              | 2033             | 265            | 663            |
| NEPAL       | 11766           | 5232            | 18042          | 210790         | 5381           | 39483          | 4161             | 37926            | 6394           | 26712          |

Reference: www.moac.gov.np

### Minerals

The influence area of Koshi water Transport Project can be sensed in the logistic of mineral products from its minning area. Here, the lists of different places are tabulated according to the type of minerals found in the Koshi River influence area.

Table 6-7 Minerals found in Koshi River umbral zone of influence area

| Minerals           | Places                                                              |
|--------------------|---------------------------------------------------------------------|
| Copper             | Bhojpur (Chhirling Khola), Dhankuta, Okhaldhunga, Udayapur (Kurule) |
| Phosporite         | Sunsari (Barahachhetra)                                             |
| Magnesite          | Udayapur (Kampughat)                                                |
| Quartzites         | Dhankuta                                                            |
| Coal (low quality) | Sunsari (Barachhetra), Udayapur (Kampughat)                         |

Source: www.dmg.gov.np

### Market Places

The Project has influenced in the business areas. These business areas are the attraction of trip generation, so there can be intramodal or intermodal movement.

Table 6-8 Market Places in various districts lying in Koshi River umbral zone of influence area

| District    | Market Places                                                                                       |
|-------------|-----------------------------------------------------------------------------------------------------|
| Okhaldhunga | Okhaldhunga Bazar, Kottuke, Manebhanjyang, Rumjatar, Rampur                                         |
| Khotang     | Diktal market, Aiselukhark, Syalgaulda, Chisapani, Ratanchha, Khotang market                        |
| Udayapur    | Gaighat, Katari, Beltar                                                                             |
| Bhojpur     | Bhojpur market, Digla market, Ghotetar, Daba market, Chyagre market, Manedada, Chamche market, Kote |
| Dhankuta    | Dhankutta, Pakhribas, Hile, Sidhuwa, Bhedetar, Utarpani, Jitpur, Dadabajar                          |
| Sunsari     | Dharan, Itahari, Inarwa, Duhabi, Khanar, Jhumka, Mahendranagar, Harinagar                           |
| Saptari     | Phattepur, Kanchanpur, Kalyanpur, Rajbiraj, Hanumannagar                                            |

(Source:www.cbs.gov.np)

### Tourism

As we know that the tourism is about travelling, so when the inland navigation will be possible along the Koshi river corridor, tourist can feel the experience of navigation from plain areas passing through deep gorges formed by the Koshi River. We can also found that the various travel agencies are organizing the package of the rafting

adventures in Koshi River corridor namely Sunkoshi, Bhotekoshi, Arun, Tamar and Tamakoshi. Thus, the possibility of tourism industry in the following places of Koshi River influence area,

Table 6-9 Tourism Area in Koshi River umbral zone of influence area

| District    | Places                                                                                                                                                         |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Okhaldhunga | Rampurjar, Rumjatar, Chisngkhu gadi, Gauraban, Kakani, Bilandu, Pokalee, Ratmate                                                                               |
| Khotang     | Barahapokhari, Haleshi Mahadevsthan, Tyamke Dada and Simle Dada                                                                                                |
| Udayapur    | Rautaha Pokhari (Rautaha), Jhile Pokhari (Iname), Chaudandi                                                                                                    |
| Bhojpur     | Tyamke, Selme, Suntale, Dikla, Maiyurdada, Hatuwa gadi, Salpapakhari, Hansapokhari                                                                             |
| Dhankuta    | Bhedetar, Panchakanya Sahid Smriti park, Dhwoje dada, Hile, Pakhribas                                                                                          |
| Sunsari     | Barahachhetra Mandir, Dantakali Mandir, Pindeswor Mandir, Budhasubba Mandir, Shivajatta, Pachakanya Mandir, Ramdhuni, Bisnupadhuka, Bhedetar, Koshi Tappu, etc |
| Saptari     | Masjit, Baudha Stup (Hariharpur), Barmajhiya Bazar, Chandradevi Pokhari, Kanakpatti Parkhal, Manjuranee Khata, Sambhunath Mandir, Chhinnamasta Bhagabati       |

Source: [www.cbs.gov.np](http://www.cbs.gov.np)

#### iv. Utility Services

##### Irrigation

Koshi river has also contributed in irrigation mainly two canals are branched: The Eastern Canal and the Western Canal which are taking off from the barrage and have been designed for a discharge capacity of 455 cubic metres per second (16,100 cu ft/s) to irrigate 6,125 square kilometers (1,514,000 acres) and 210 cubic metres per second (7,400 cu ft/s) to irrigate 3,566.1 square kilometers (881,200 acres) respectively.

##### Electricity

Nepal has a total estimated potential of 83,290 MW out of which economically exploitable potential is 42,140 MW. The Koshi river basin contributes 2235 MW of this potential (360 MW from small schemes and 1875 MW from major schemes) and the economically exploitable potential is assessed as 10,860 MW (includes the Saptakoshi Multipurpose Project of 3300MW). Here, the list of Hydropower status in Koshi River influence area is tabulated below.

Table 6-10 Total Hydro Power status in Koshi River influence area

| S.N | Hydro Project in Koshi River influence area                  | MW      |
|-----|--------------------------------------------------------------|---------|
| 1   | Application for Survey License for Generation (Below 1 MW)   | 20.325  |
| 2   | Application for Survey License for Generation (1 to 25 MW)   | 13.82   |
| 3   | Application for Survey License for Generation (25 to 100 MW) | 47.4    |
| 4   | Application for Survey License for Generation (Above 100 MW) | 300     |
| 5   | Survey License for Generation (Below 1 MW)                   | 4.4     |
| 6   | Survey License for Generation (1 to 25 MW)                   | 2.5     |
| 7   | Survey License for Generation (25 to 100 MW)                 | 0       |
| 8   | Survey License for Generation (Above 100 MW)                 | 120     |
| 9   | GoN Reserved Survey License for Generation                   | 509.4   |
| 10  | Construction License for Generation                          | 0       |
| 11  | Operating Power Plants                                       | 164.215 |

Source: [www.nea.org.np](http://www.nea.org.np)

## v. Health

Mostly, urban areas of Nepal are facilitated with the health facilities. The people living in remote areas along corridor of Koshi can be benefited in health sector. Since, Sunsari district is linked with Koshi River which has the biggest hospital of Nepal, i.e. BPKHIS. Here, the statistics of health facilities along the koshi river corridor which is influenced by the project are tabulated.

Table 6-11 Health statistics in the Koshi River influence area

| S.N | District    | Hospitals | PHCC / HC | HP | SHP | PHC Out reach Clinic | EPI Clinic | FCHV | NGO/INGO & Private Sector |
|-----|-------------|-----------|-----------|----|-----|----------------------|------------|------|---------------------------|
| 1   | Okhaldhunga | 1         | 2         | 9  | 45  | 168                  | 168        | 745  | 3                         |
| 2   | Khotang     | 1         | 2         | 8  | 65  | 240                  | 235        | 933  | 0                         |
| 3   | Udayapur    | 1         | 2         | 9  | 35  | 167                  | 210        | 450  | 11                        |
| 4   | Bhojpur     | 1         | 3         | 9  | 51  | 196                  | 192        | 567  | 1                         |
| 6   | Dhankuta    | 1         | 2         | 11 | 24  | 132                  | 151        | 315  | 3                         |
| 7   | Sunsari     | 1         | 5         | 7  | 40  | 256                  | 303        | 1035 | 10                        |
| 8   | Saptari     | 1         | 4         | 9  | 103 | 420                  | 480        | 1078 | 2                         |

Source: District Development Profile of Nepal 2010/11

## vi. Transport

The project of water transport has possibility to link E/W highway in terai region and Madhya Pahadi Lokmarg. The E/W highway can be linked in Koshi Barrage and Madhya Pahadi Rajmarga can be linked in Ghurmi (Udayapur) and Leguwa (Dhankuta). There is also possibility to link with Arniko highway in Dolalghat, Karvepalanchok. The constructing track route of Saune (Udayapur) to Diktel (Khotang) can also be linked by this project. Here, the data of Transport facilities along the Koshi River corridor which is influenced by the project.

Table 6-12 Statistics of accessibility in the Koshi River influence area

| District    | Types of Road |       |       |        | Road Category |        |      |     |    |     | Pop. Influence Per Km (Nos) | Road Density (Km / Km <sup>2</sup> ) | Airport |
|-------------|---------------|-------|-------|--------|---------------|--------|------|-----|----|-----|-----------------------------|--------------------------------------|---------|
|             | BT            | GR    | ER    | Total  | NH            | FRN    | FR O | M H | PR | M R |                             |                                      |         |
| Okhaldhunga | 0             | 0     | 47    | 47     | 0             | 41     | 0    | 6   | 0  | 0   | 3334                        | 4                                    | 1       |
| Khotang     | 0             | 0     | 71    | 71     | 0             | 11     | 0    | 60  | 0  | 0   | 0                           | 4                                    | 2       |
| Udayapur    | 77.36         | 32.5  | 70    | 179.86 | 49.86         | 130    | 0    | 0   | 0  |     | 1600                        | 9                                    |         |
| Bhojpur     | 0             | 0     | 50    | 50     | 0             | 0      | 0    | 50  | 0  | 0   | 0                           | 3                                    | 1       |
| Dhankuta    | 61.27         | 30.41 | 40.46 | 132.14 | 48.27         | 57.87  | 0    | 26  | 0  | 0   | 1260                        | 15                                   |         |
| Sunsari     | 112.33        | 68.7  | 10    | 191.03 | 89.03         | 80     | 0    | 0   | 22 | 0   | 3275                        | 15                                   |         |
| Saptari     | 135           | 45.5  | 59    | 239.5  | 71.15         | 150.35 | 0    | 0   | 18 | 0   | 2381                        | 18                                   | 1       |

Source: District Development Profile of Nepal 2010/11

Table 6-13 Agricultural Road in Koshi River influence area

| District    | Total Km | Completed  |             | Transportation Operating (KM) |
|-------------|----------|------------|-------------|-------------------------------|
|             |          | Dusty Road | Gravel Road |                               |
| Okhaldhunga | 30.23    | 9          | 0           | 9                             |
| Khotang     | 15       | -          | -           | 0                             |
| Udayapur    | 152.5    | 69.25      | 21.25       | 49.25                         |
| Bhojpur     | 128      | 0          | 0           | 0                             |
| Dhankuta    | 7        | 90         | 7           | 44                            |
| Sunsari     | 127      | 108        | 95          | 98                            |
| Saptari     | 292.47   | 209.32     | 79.7        | 147.27                        |

Source: District Development Profile of Nepal 2010/11

## 6.5 Hydrology Study of Proposed Waterway Corridor

### 6.5.1 Hydrology

Water transport is based on the hydrological characteristics which are mainly precipitation, base flow, high flood level. To determine the waterway design, the detailed hydrological and metrological data from river and DHM has been collected. The collection of the data for Koshi Basin from Ghurmi – Koshi Barrage Proposed waterway of 173.5 km has been carried during the month of December, 2011.

The hydrological study is concentrated in determining the obstruction for the Proposed waterway and location of the terminal station with respect to high flood level. The depth of the river with its critical and narrow section has been surveyed result in plotting of profile of bed level with respect to water surface level. Here, Critical section refers to those sections along the Proposed waterway which may affect in the maneuverity of the vessels due to bends, sandbars, boulder deposition, rapids etc.

### 6.5.2 DHM data for Koshi Basin Proposed Waterway Analysis

To study the availability of navigational discharge during different seasons in a year it is required to analyze the historical discharge data on the waterway under consideration for development. The discharge data has been collected from Department of Hydrology and Metrology (DHM), Babar Mahal and analyzed to establish low discharge and to study the availability of water for navigation.

In the length of 173.5 km of proposed waterway in Koshi basin, there are three gauging stations at Kamphughat, Hamchuwar and Chatraghat. The details of these stations are given in table6-14,

Table 6-14 Hydrological Station in Koshi Basin Proposed Waterway

| River      | Gauging Site | Station No. | Lat.     | Long.    | Elevation (m) | Area (km <sup>2</sup> ) | Records (From-To) | Remarks |
|------------|--------------|-------------|----------|----------|---------------|-------------------------|-------------------|---------|
| Sunkoshi   | Kamphughat   | 680         | 26 52 28 | 86 49 10 | 200           | 17600                   | 1966-1985         | Good    |
| Sunkoshi   | Hampchuwar   | 681         | 26 55 15 | 87 08 45 | 150           | 18700                   | 1991-2010         | Good    |
| Saptakoshi | Chatara      | 695         | 26 52 00 | 87 09 30 | 140           | 54100                   | 1977-2010         | Good    |

Source: DHM, BabarMahal

#### Kamphughat

The mean monthly discharge at Kampughat for the years 1976-1985 are furnished in table,

Table 6-15Average Discharge over the year on Sunkoshi River at Khamphughat

| Year | Jan | Feb | Mar | Apr | May | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|-----|-----|-----|------|------|------|------|------|-----|-----|
| 1976 | 216 | 176 | 147 | 155 | 237 | 1049 | 2198 | 2713 | 1977 | 771  | 372 | 234 |
| 1977 | 174 | 148 | 132 | 167 | 206 | 508  | 2198 | 2864 | 1629 | 816  | 364 | 209 |
| 1978 | 156 | 123 | 123 | 150 | 408 | 1354 | 2845 | 3205 | 1814 | 1102 | 395 | 217 |
| 1979 | 165 | 168 | 138 | 153 | 203 | 545  | 2644 | 3104 | 2005 | 839  | 403 | 255 |
| 1980 | 187 | 159 | 150 | 155 | 192 | 865  | 3443 | 3717 | 2545 | 923  | 413 | 279 |
| 1981 | 219 | 189 | 169 | 185 | 253 | 760  | 3053 | 3726 | 2116 | 705  | 344 | 233 |
| 1982 | 189 | 167 | 156 | 179 | 188 | 711  | 2368 | 2943 | 1704 | 550  | 357 | 271 |
| 1983 | 209 | 175 | 167 | 172 | 280 | 419  | 1969 | 2316 | 2014 | 1021 | 379 | 257 |
| 1984 | 203 | 170 | 145 | 136 | 230 | 748  | 2757 | 2028 | 2633 | 777  | 367 | 270 |
| 1985 | 219 | 194 | 181 | 177 | 218 | 607  | 2812 | 2459 | 2776 | 1238 | 482 | 228 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during February-March of about 123 cumecs in the year 1978 and high flow are noticed during August of about 3726 cumecs in the year 1981.

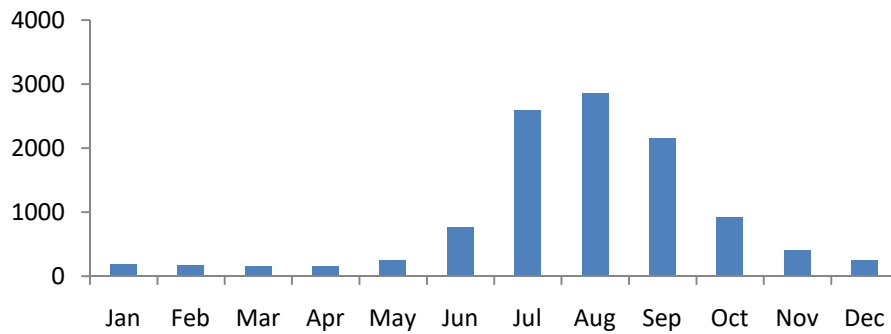


Chart 6-3 Hydrograph of Sunkoshi River at Khamphughat

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Sunkoshi at Khamphughat. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 4000 cumecs from lean season to flood season, the river rises by about 10.18 m.

Hampchuwar

The mean monthly discharge at Hampchuwar for the years 1998-2007 are furnished in table,

Table 6-16 Average Discharge over the year on Sunkoshi River at Hampchuwar

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul  | Aug  | Sept | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|------|------|------|-----|-----|-----|
| 1998 | 174 | 163 | 140 | 181 | 318 | 773 | 2170 | 3140 | 1430 | 611 | 322 | 233 |
| 1999 | 175 | 145 | 127 | 140 | 282 | 719 | 1970 | 2240 | 1670 | 992 | 373 | 266 |
| 2000 | 212 | 173 | 147 | 165 | 265 | 799 | 2040 | 2750 | 1620 | 466 | 286 | 184 |
| 2001 | 151 | 125 | 109 | 110 | 209 | 694 | 1310 | 2420 | 1380 | 636 | 277 | 184 |
| 2002 | 141 | 122 | 111 | 124 | 216 | 502 | 2340 | 2980 | 1180 | 553 | 321 | 237 |
| 2003 | 190 | 180 | 169 | 190 | 202 | 754 | 2230 | 2260 | 1900 | 673 | 305 | 223 |
| 2004 | 181 | 153 | 147 | 146 | 219 | 530 | 2070 | 1970 | 1280 | 673 | 314 | 221 |
| 2005 | 172 | 147 | 141 | 128 | 246 | 534 | 1710 | 2580 | 1250 | 697 | 398 | 291 |
| 2006 | 219 | 190 | 184 | 209 | 356 | 973 | 1940 | 1770 | 1440 | 673 | 383 | 260 |
| 2007 | 451 | 513 | 464 | 474 | 567 | 902 | 1830 | 1810 | 1440 | 840 | 616 | 492 |

Note: All discharge in Cumecs

Source: DHM, Babar Mahal

The table indicates that the low discharge are generally observed during March of about 109 cumecs in the year 2001 and high flow are noticed during August of about 3140 cumecs in the year 1998.

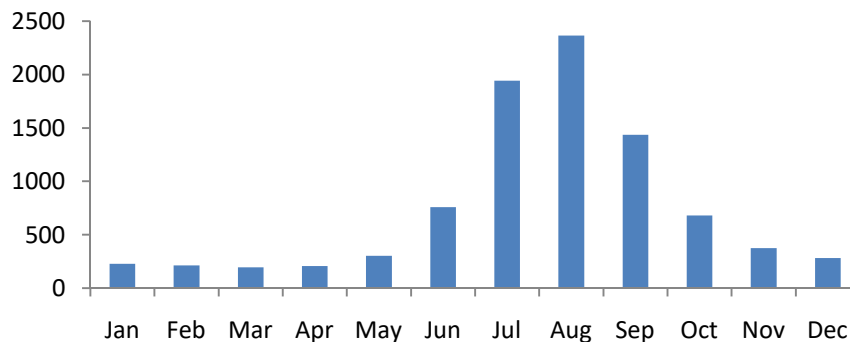


Chart 6-4 Hydrograph of Sunkoshi River at Hampchuwar

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Sunkoshi at Hampchuwar. The river experiences lowest low water during March and the

river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 2500 cumecs from lean season to flood season, the river rises by about 12.9 m.

#### Chatara

The mean monthly discharge at Chatara for the years 2000-2009 are furnished in table,

Table 6-17 Average Discharge over the year on Saptakoshi River at Chatara

| Year | Jan | Feb | Mar | Apr | May  | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|-----|-----|------|------|------|------|------|------|-----|-----|
| 2000 | 402 | 328 | 308 | 491 | 1060 | 3040 | 5240 | 6420 | 4470 | 1460 | 687 | 435 |
| 2001 | 312 | 260 | 248 | 326 | 830  | 2470 | 3530 | 5790 | 3880 | 2260 | 742 | 414 |
| 2002 | 284 | 240 | 231 | 334 | 722  | 1900 | 5300 | 5620 | 2820 | 1300 | 670 | 421 |
| 2003 | 306 | 282 | 268 | 418 | 485  | 2580 | 6180 | 5800 | 5300 | 1610 | 772 | 522 |
| 2004 | 409 | 344 | 346 | 437 | 795  | 1580 | 3800 | 3870 | 2960 | 1640 | 755 | 503 |
| 2005 | 395 | 339 | 350 | 379 | 569  | 1170 | 3050 | 4060 | 2190 | 1270 | 681 | 459 |
| 2006 | 347 | 310 | 291 | 349 | 635  | 2080 | 3350 | 3080 | 2820 | 1330 | 688 | 472 |
| 2007 | 354 | 382 | 398 | 518 | 696  | 1620 | 3740 | 3720 | 3980 | 1590 | 817 | 530 |
| 2008 | 386 | 321 | 333 | 414 | 588  | 1970 | 3640 | 4650 | 2720 | 1260 | 689 | 468 |
| 2009 | 351 | 297 | 280 | 383 | 570  | 972  | 2690 | 3770 | 2250 | 1180 | 614 | 417 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 231 cumecs in the year 2002 and high flow are noticed during August of about 6240 cumecs in the year 2000.

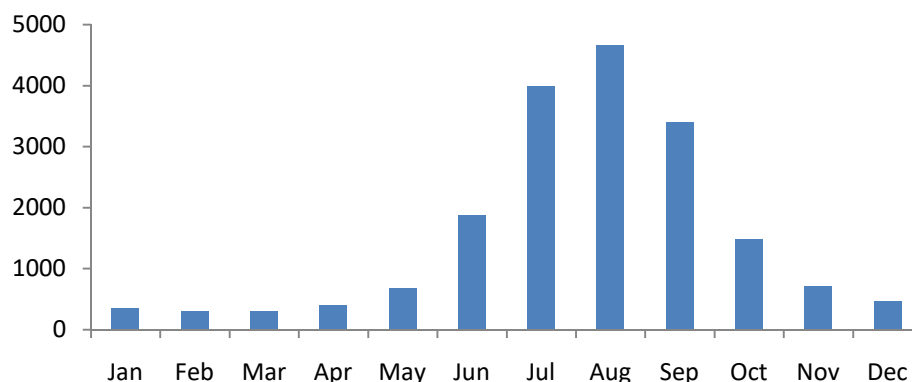


Chart 6-5 Hydrograph of Saptakoshi River at Chatara

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Saptakoshi at Chatara. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 5000 cumecs from lean season to flood season, the river rises by about 7.28m.

#### 6.5.3 Field Investigation for Koshi Basin for Proposed Waterway

Hydrographic survey was conducted on December for Proposed waterway in Koshi Basin. The survey was done using rafting boat from Ghurmi to Koshi Barrage. The elevation difference of 273 m has been observed in 173km proposed waterway. The hydrographic survey in these stretches, the position and sounding depth has been recorded by using EchoSounder and GPS. All the conspicuous objects nearby banks were obtained with the help of GPS and noted on the survey book.

#### i. Profile of River surface and its bed level

The data from the DHM is the secondary data to analyze the water level w.r.t discharge. The primary data collected from hydrographic survey has been used to plot the profile of river surface and its bed level. The elevation difference of Koshi Barrage to Ghurmiis about 273 m; the gradient above Tribeni to Saune seems to be medium and high gradient above Saune. This can be visualized in the data and drawing of profile of the bed level and water surface level of Proposed waterway which has been attached in Annex.

#### ii. Identification of obstruction in proposed waterway

The upper reach of the proposed waterway has been identified as the class III-IV grade where numerous rapids with holes and critical bend with eddy formation. Rapids are the high current area formed due to the excessive boulders deposition at its bed level. The converging of tributaries, bends and landslide area are mainly places of rapid formation. If the boulders deposition are excess, then the formation of rapid with shallow depth in downstream and dam phenomenon in upstream creating still section with maximum depth.

The lower reach of the proposed waterway in Koshi basin is found to be quite still and carry enormous sediments. The river morphological reason for sediment transportation is due to the high gradient of the river, bed scouring phenomenon occurs. The width of Saptakoshi River is spreaded approx 4 km but at low water lots of sandbars and bifurcation are formed.

During field investigation some of the possible obstruction for proposed waterway in Koshi basin has been detected which are Rapids, Bends, Bifurcation and Sandbars. But among these, rapid is the most crucial in our study. The summary of identified rapids has been tabulated below:

Table 6-18 Summary of Rapids

| Section | No. of Rapids |
|---------|---------------|
| K-BC    | 0             |
| K-CT    | 5             |
| K-TS    | 24            |
| K-SG    | 43            |
| Total   | 72            |

The details of the rapids have been attached in the Annex.

#### iii. Identification of Infrastructure in Proposed waterway

The infrastructures which are on operation, obsoleted or under construction have been identified along the proposed waterway in Koshi basin. The summarized data has been tabulated below:

Table 6-19 Summary of Identified Civil Structure

| Type of Structure                 | Numbers |
|-----------------------------------|---------|
| Tread Bridge                      | 11      |
| Motor Bridge                      | 1       |
| Under Construction Motor Bridge   | 3       |
| Ropeway                           | 1       |
| Boat Service (Country & Jet Boat) | 3       |
| Ferry Service                     | 2       |
| Transmission Line                 | 2       |
| Gauging Station                   | 3       |
| Irrigation Works                  | 1       |
| Hydropower Plant                  | 1       |

The details of the identified civil infrastructures have been attached in the Annex

## 6.6 Geological and Environmental Study of Proposed Waterway Corridor

### 6.6.1 Geological Features in Proposed waterway

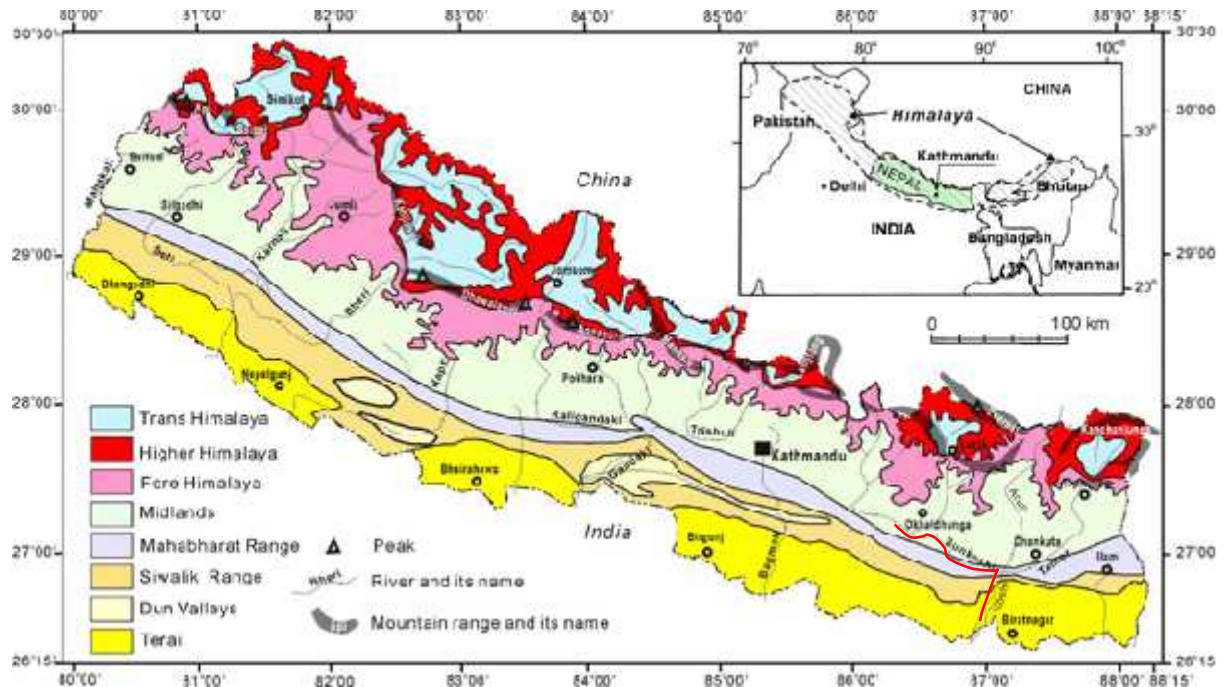


Figure 6-1 Physiographic map of Nepal

Physiographically, the proposed waterway of 173km passes from Terai, Siwalik, Lesser Himalaya zone (Mahabharat and Midlands) and parallel to the MBT.

Terai Zone, the southern tectonics division of Nepal, represents the northern edge of Indo-Gangentic alluvial basin. This plain is made up of alluvium of Pleistocene to recent age (1.8 million years to the present with an avg. thickness of about 1500m).

Siwalik zone also called Churia Hills consists of fluvial sedimentary rocks of Neogene to quaternary age (14 to 1 million years) which elevation ranges from 200 m -700 m above sea level. This zone is bounded to the north by MBT and to south by MFT. Rocks of this zone are divided stratigraphically into 3 parts. The lower Siwalik consists of fine grained mudstone, siltstone and shale. The middle Siwalik is marked by thick multistoried stone beds cycle of finding upward sequences is normally observed. The upper Siwalik is characterized by very coarse grained rocks such as boulder conglomerates.

Lesser Himalayan Zone is boarded to the south by MBT and north by MCT. Lesser Himalaya zone consists of mainly of unfossiliferous sedimentary and various degree of metamorphism such as shale, sandstone, limestone dolomites, slates, phylites, schist and quartzite ranging in age from pre-cambrian (as old as 1800 million years) to Eocene (about 40 million yrs) which elevation range below 4000 m. In our site area, it is characterized by development of extensive thrust sheets of crystalline rocks of Higher Himalaya (Gneisses and Schist) that have traveled southward to cover below the low grade metamorphic rocks (Nuwakot Complex) of lesser Himalaya.

Geological reason for the excessive transportation of sediments in the Koshi basin is due to lower Siwalik which consists of mudstone and siltstone. The huge landslides are found in Lesser Himalaya zone (Harkapur and Durchim). The proposed waterway passes parallel to the MBT which indicates the vicinity surrounding are geologically fragile and need be very aware while selection of site for infrastructures.

### 6.6.2 Environmental Features in Proposed waterway

The baseline information of the existing physical and biological environment of the proposed waterway project is described as below:

#### i. Climate

The study area lies in the tropical and sub-tropical region. Air temperature measured is lowest in January 2-40C and highest in May and June 35-400C. The mean annual rainfall for Koshi basin is around 2800 mm.

#### Topography and Land Use

The proposed koshi waterway is located in the terai and low hill physiographic region. The elevation of the proposed koshi waterway ranges from 74m to 360m. The major land use types within the Koshi watershed are cultivated land (29.91%), forest (33.12%), bush (9.83%), barren land (18.25 %) and grazing land (4.05%). The land use types of Koshi watershed is given in the table below and the map is shown in Annex.....

Table 6-20 Land Use Type of of Koshi Watershed

| Landuse Type | Percentage (%) |
|--------------|----------------|
| Built up     | 0.003          |
| Cliff        | 0.07           |
| Cultivation  | 29.91          |
| Forest       | 33.12          |
| Orchard      | 0.01           |
| Nursery      | 0.001          |
| Grass        | 4.05           |
| Bush         | 9.83           |
| Barren Land  | 18.25          |
| Sand         | 0.03           |
| River/Stream | 0.33           |
| Snow/Glacier | 3.30           |
| Pond/Lake    | 1.11           |

Source: Department of Survey, 1995

#### ii. Biological Environment

##### Natural Forests and Tree Vegetation

The major tree species in the proposed surrounding waterway area are Sal (*Shorea robusta*), Saj/Asna (*Terminalia alata*), Sisam (*Dalbergia sissoo*), Simal (*Bombax ceiba*), Aanp (*Magnifera indica*), Kadam (*Anthocephalus chinensis*), Khayer (*Acacia catechu*), Jamun (*Syzygium cumini*), Bet (*Calamus acanthospathus*), Pipal (*Ficus religiosa*), Amala (*Phyllanthus emblica*), Bhalayo (*Semecarpus anacardium*), Kusum (*Karhamus tinctorius*), Chandmaruwa (*Rauvolfia serpentina*), Harro (*Terminalia chebula*), Barro (*Terminalia bellirica*), Mauwa (*Engelhardia spicata*), Bhorla (*Bauhinia vahlii*), Satisal (*Dalbergia latifolia*), Bijaysal (*Pterocarpus marsupium*), Siris (*Albigia* spp.), Tatari (*Dillenia pentagyna*) and Bayer (*Zizyphus mauritiana*). Major shrub and herb species found in the study area are *Murraya exotica*, *Indigofera pulchella*, *Nyctanthes arbor-tristis*, *Barleria cristata*, *Cassia tora*, *Cassia odoratissima*, *Careya arborea*, *Justicia adhatoda*, *Clerodendrum infortunatum*, *Colebrookea oppositifolia*, *Holoptile integrifolia*, *Holmskioldia sanguinea*, *Jasminum pubescens*, *Woodfordia fruticosa*, *Phoenix humilis*, *Kurilo* (*Asparagus racemosus*), Bayar (*Zizyphus mauritiana*) etc.

## Terrestrial Wildlife and Aquatic Animals

The water transport way passes through the KoshiTappu Wildlife Reserve (KTWR), a rich Nepalese wildlife natural reservation famous for wild water buffaloes (*Bubalus bubalis*). Other major wild mammals found in the study area are Bandel (*Sus scrofa cristatus*), Syal (*Canis aureus*), Rato Bandar (*Macaca mulatta*) and Chituwa (*Panthera pardus*).

Among the herpetofauna, turtles, crocodiles (*Crocodylus palustris*), toad (Asian toad and marble toad), lizards (Cashmir rock agama, Asian house gecko, common keeled grass skin), snakes (Asiatic rock python, Olive keel back water snake, common krait, Cobra, banded krait) have been reported in the proposed waterway area.

Major species of birds are Kalij (*Lophura leucomelana*), Kaag (*Corvus splendens*), Bhangera (*Passer domesticus*), Suga (*Psittacula* spp.), Dangree (*Acridotheres fuscus*), Mayur (*Pavocristatus*), Maina (*Gracula religiosa*), Jureli (*Pycnonotus* spp.), ChibeChara (*Dicrurus aeneus*), PhusreeDhanesh (*Ocyrops birostris*), ThuloDhanesh (*Buceros bicornis*), Nyauli (*Megalaima zeylanica*), Kuthurke (*Megalaima lineata*), Dhukur (*Streptopelia* spp. & *Chalcophaps* spp.) and Chil (*Hieraaetus kienerii*).

In the Koshi river basin forest, agriculture lands and aquatic environment interact, which results in a complex ecological network with a substantial impact on the fish fauna of the river. Koshi River provides the habitat for ninety-six species of fish, 11 species are very common. Fishes such as Setala, Bam, Garela, Chadke, Asala, Sahar, and Bhaichari are common according to the local respondents near the river.

## 6.7 Existing Water Transport Scenario

In Context of Nepal, Water transport is mainly for promotion of tourism industry rather than public transportation. The promotion of the tourism industry in water transport is done by white water rafting. The white water rafting has been started in late 1960's by two French in Sunkoshi. In 1976, the first Commercial River rafting company named Himalaya River Expedition was launched and experienced river guide, Mike Yager of America was brought to manage the company and to train Nepalese guides. From this phase to present, rafting in Nepal has really taken off and Nepal is known as one of the world's premier river running destinations.

In Koshi Basin, under the proposed waterway there are two types of existing Water Transport; Adventure / Recreational purpose and Public Transportation purpose.

### 6.7.1 Adventure/Recreational Purpose

Sunkoshi River (River of Gold) is one of the prominent rivers for the white water rafting in the world. The electrifying and nerve thrilling rapids of Class 4-5 with inspiring source of natural beauty can be found in the Sunkoshi river adventure. The rafting agency has marked the starting point Dohalghat and end point Chatara which length is about 272 km and they have scheduled the rafting trip for about 9 days / 8 Nights. For the access to Dohalghat, the Araniko Highway is used and from Chatara, Dharan-Chatara of 16 km road is used for connecting with Eastern Highways. According to the rafting agency, the best month for rafting in this river is in May, September and October where the discharge of the river start to increase and decrease.

### 6.7.2 Public Transportation

The rafting is for the tourism, adventure purpose. For the public transportation, the Jet boat service provided by the Nepal River Transport in Chatara is operating from Chatara to Simle via Tribeni in Saptakoshi forwarding to lower stretch of Arun River for 5 years. The length of the operation is about 12 km which takes 12-15 minutes to complete the journey. According to the Nepal River Transport operator, they make about 24 trips in a day carrying 20 passengers in a trip with life jackets for safety and they are charging Rs. 250 per person with 10 kg luggage. They have tried to increase their route towards Sunkoshi and Arun River, but due to the rapids near Ekuwa khola (K-TS 4+000) it could not move towards Ghurmi in Sunkoshi and during high water of June taking risk, they can

move upto Tumlingtar in 1 hr 36 min from Chatara which length is about 60 km. Before, there was other jet boat service provider i.e. Sumnima water transport, Chatara but in rapids of high water it has been washed up a year ago.

In the increment in the water transport traffic, Nepal River Transport has brought another big jet boat carrying 40 passengers from Narayanghat Municipality in a lease but it couldnot be operated due to the failure of the engine.

## 6.8 Traffic Study of Proposed Waterway Corridor

According above chapter, the Traffic description for particular waterway,

| Section | Type of service                      | Vessel Capacity                                                                         | Frequency/day | no. of passengers/day | No. of Vessel | Remarks                                     |
|---------|--------------------------------------|-----------------------------------------------------------------------------------------|---------------|-----------------------|---------------|---------------------------------------------|
| K-BC    | Recreational                         | Motor boat proposed for sightseeing                                                     |               |                       |               | Proposed recreational service               |
| K-CT    | Passenger cum Freight                | 25                                                                                      | 24            | 600                   | One           | existing full capacity operation            |
| K-TS    | Recreational cum passenger transport | Improvement of access to Bojpur & Khotang supply of agro products and Timber to Ghatara |               |                       |               | Proposed recreational cum passenger service |
| K-SG    | Recreation                           | Religious recreational transport to Halesi Mahadev                                      |               |                       |               | only Recreational                           |

According above chapter, the Traffic count for particular waterway,

| Section | Type of service                  | Vessel Capacity, Passenger | trips/day | no. of passengers/day | No. of Vessel | Remarks                                     |
|---------|----------------------------------|----------------------------|-----------|-----------------------|---------------|---------------------------------------------|
| K-BC    | Recreational (Motor Boat)        | 80                         | 2         | 160                   | One           | Proposed motor baot for sight seeing        |
| K-CT    | Passenger cum Freight (Jet Boat) | 25                         | 24        | 600                   | One           | existing full capacity operation            |
| K-TS    | Proposed Jet Boat                | 20                         | 2         | 40                    | Two           | Proposed recreational cum passenger service |
| K-SG    | Recreation Rafting               | 8                          | 50        | 400                   |               | for whole tourist season (three monthgs)    |

## 6.9 Engineering Characteristics of the Proposed Waterway Section

### 6.9.1 Section: Koshi Barrage to Chatara (0+000 – 49+050)

This section is the lowest reach of the Koshi basin where several rivers has converged to contribute the average discharge of 1590 cumec (DHM, 2010). The barrage area has been trained by the river training works and above the training works, the river channel has been spreaded widely for about 4 km. The several meandering of the river from one bank to another bank can be seen. There exists one deepest channel and other secondary channel either become dry or very shallow during lean period. The islands with vegetation (Koshi Tapu Wildlife Reserve area) are more or less stable and sandy islands (sand bars) are unstable and change their location frequently. In this section, the river seems to be still with few small rapids but overabundanceof suspended load (Silt content). The major settlements areMadhuban, Prakashpur, Chakraghati and Chatara. During the hydrographic survey, the deepest channel has been followed and observed more likely uniform depth with steady flow than upper reach section. The average gradient of the section is about 1 in 1681 with average velocity of 1.2 m/s and average depth of 3.87 m.

#### 6.9.2 Section: Chatara to Tribeni (0+000 – 8+750)

This section seems to be transversely stable due to a narrow gorge with hills on either side confining the river. The width of the river in this section is wide enough for about 120 m. This section exists few rapids of class II which are found little technical in the reference to the rafting guide and existing boat pilots. Here, technical refers to the river behavior evaluation by experience like river current analysis, wave timing, etc. The left bank has cultivated land with BMS, forest area and few landslide areas and right bank has earthen road to connect Barhakshetra religious place and found to be unstable slope due to track opening. This track has been linked up from the Dharan-Chatara road. The ferry service has been operated few years ago. The Saptakoshi Multi project of 269 m High Dam lies under this section just below Tribeni. The confluence area of Tamar, Arun and other converging river in the Proposed waterway has deposited the boulders in the bed level thus shallow depth with rapids have been identified in that area. The average gradient of the section is about 1 in 872 with average velocity of 1.4 m/s and average depth of 8.64 m.

#### 6.9.3 Section: Tribeni – Saune (0+000 – 47+165)

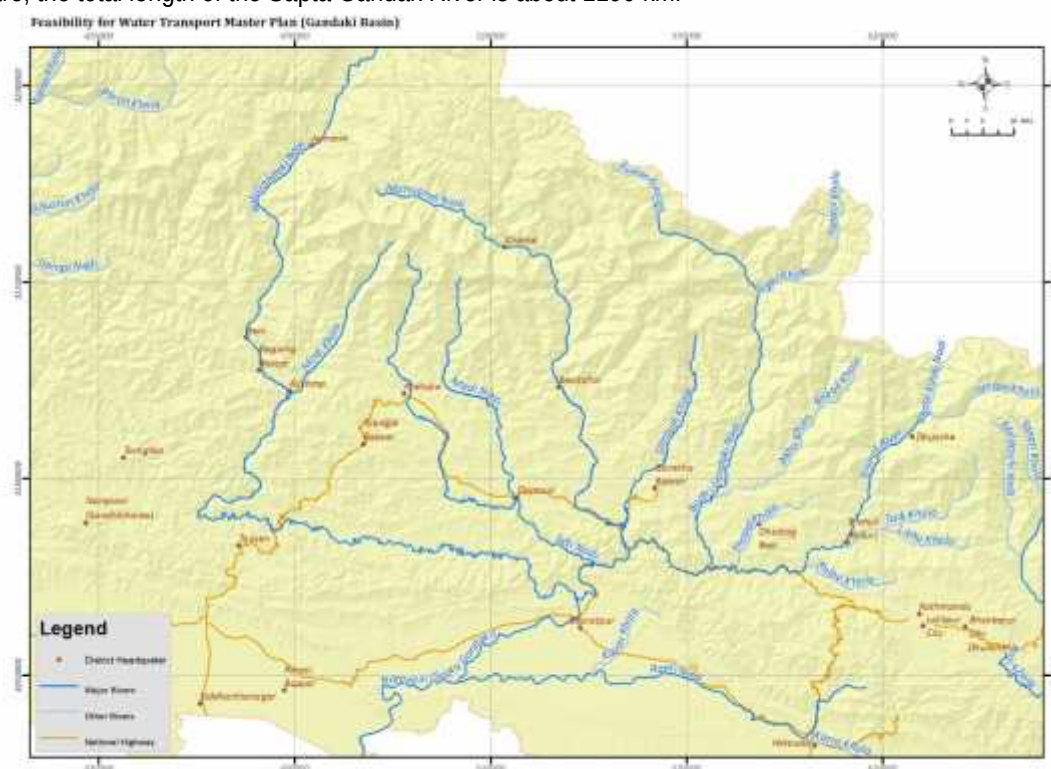
This section also passes through the narrow gorge with hills on either side confining the river to the width for about 96 m. The five major rivers (Bhotekoshi, Indrawati, Tamakoshi, Dudhkoshi and Sunkoshi) converge to contribute the discharge of 843 cumec (DHM, 2008). The both banks have cultivated land with BMS and maximum forest area where Bamboo and Khayar has been observed. The people living in this section especially export bamboos and khayar to India via Koshi River. The right bank seems few earthen roads but in left bank many earthen roads have been constructed to link the place like Beltar, Rampur and Gaighat. The major settlements are Hambhupa, Gogatar, Jogepathar, Ranitar, Sikhintar and Saune. This section exists several rapids of class III where Rapid no. 67 Chainage (2+720) of class IV named as Big Dipper has been found as critical. There are many landslide areas with steep hills. The average gradient of the section is about 1 in 591 with average velocity of 1.7 m/s and average depth of 9.7 m.

#### 6.9.4 Section: Saune – Ghurmi (0+000 – 69+120)

This section also passes through the narrow gorge with hills on either side confining the river to the width for about 81 m. The both banks have few cultivated lands with BMS and maximum forest area of sal. This section exists numerous rapids of class III and IV. The electricity has been found in this section from chainage 11+000 to 26+000 and in this same chainage the Diktal-Gaighat road is also under construction. The Mid Hill highway will pass from Harkapur and Ghurmi crossing via Sunkoshi River. The slopes of the hills seem to be stable but in newly road construction area, it seems to be unstable. The huge landslides can be observed with boulder deposition in river corridor. The landslides of Durchim and Harkapur are the huge landslides which have blocked the Sunkoshi River for few hours. We can observe the most dangerous rapids as its result. The major settlements are Rasuwaghat, Phoksintar, Chanaute, Bhadareghat, Regmitar, Kunai, Khurleghat, Chiptar, Harkapur and Ghurmi. The average gradient of the section is about 1 in 452 with average velocity of 2.2 m/s and average depth of 16.9 m.

## 7. WATER TRANSPORT STUDY IN GANDAKI BASIN

Gandaki River lies in central part of Nepal and formed by merging seven big rivers. They are Daraudi, Seti, Madi, Kali, Marsyandi, Budhi, and Trisuli. In Southern part of Nepal it is called as Narayani River. The river Daraudi, Seti, Madi, Kali, Marsyandi, Budi and Trisuli merges in various places as Devghat (Tanahu), Abukhaireni (Tanahu), Salang (Dhading), Byas (Tanahu) and Deurali (Gorkha). Its catchment area is about 46,300 sq km and its average discharge is about 1760 cubic meter per second. According to the previous studies, it was found that the navigation in Gandaki River is feasible only in the lower reaches. Considering these references, this project will study the feasibility of water transport in Gandaki River of about 150 km. According to the Global Mapper Software, the total length of the Sapta Gandak River is about 1190 km.



Map 7-1 Gandaki River and its Tributaries

### 7.1 Study of Proposed Waterway Corridor

The only mode of surface transport available in Nepal is Road, which apart from being a costly option, is beset with other strategic problems. Water transport study will provide an alternative mode to Nepal for its intermodal trade. WT mode is expected to be economical, environmentally friendly, safe, better manageable and direct with road to function as a complementary mode. Hence, the mode envisages spurring developmental activities along the proposed waterway, both contiguous and shadow area. Here, all the data are collected in the reference to the proposed waterway and it is divided into 4 sections in the Gandaki Basin.

|                    |                              |            |
|--------------------|------------------------------|------------|
| Proposed Waterways | Section 1: Devghat – Ramdi   | 130.425 km |
|                    | Section 2: Devghat - Mugling | 32.638 km  |
|                    | Section 3: Mugling – Fishlin | 16.6 km    |
|                    | Section 4: Mirmi – Seti Beni | 5 km       |
|                    | Total                        | 184.663 km |

## 7.2 Influence Area

Here the data of different factors like (demographic, Landuse pattern, Agriculture etc) are collected on the basis of core zone of Influence and umbral zone of Influence. The core zone of influence refers to the population who are inhabited along the river corridor, whereas umbral zone of influence area refers to the all the VDC in the district who can access the intermodal facilities.

Here, the VDC which are directly influenced by Kali Gandaki and Trisuli River among seven rivers namely Daraudi, Seti, Madi, Kali, Marsyandi, Budhi, and Trisuli are listed. There are 8 districts and 52 VDC out of 17 districts and 309 VDC in the Gandaki river corridor.

Table 7-1 Core Zone of influence VDC in Gandaki River Corridor

| District    | VDC                                                                                                                                  |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------|
| Parbat      | Saligram                                                                                                                             |
| Gulmi       | Arbeni, Harmichaur                                                                                                                   |
| Syangja     | Pidikhola, Nibuwa Kharka, Shri Krishna Gandaki, Malunga, Jagatradevi, Tulsi Bhanjyang, Pakwadi, Kuwakot, Chapakot, Rantnapur, Sakhar |
| Palpa       | Kanichhap, Pipaldada, Hungi, Heklan, Gejha, Khaliban, Rampur, Darchha, Gaidakot, Bakamalan                                           |
| Tanahu      | Gajarkot, Sundahara Ghiring, Bhagawatipur, Ramjhakot, Bhirkot, Baidi, Kota, Devghat, Abhukhareni, Chimkeshawari                      |
| Gorkha      | Manakamana, Taklung, Makaising, Bhumilichok                                                                                          |
| Nawalparasi | Rakuwa, Dedgaun, Mithukaram, Bhartipur, Upllo Arkhala, Bulingar, Dadajhahari Tadi, Kotthar, Ratanpur, Gaidakot                       |
| Chitwan     | Darechok, Chadi Bhanjyang, Kalibas, Bharatpur NP                                                                                     |

Source: District Development Profile of Nepal 2010/11

## 7.3 Socio Economic Study of Proposed Waterway Corridor

The general study of the Socio-Economy aspect of the project has been carried. The project has been focused to vulnerable groups along the proposed waterway. Vulnerable groups refer to the indigenous people as well as poor and dalits groups. In Nepal the indigenous population is popularly known as Janajatis which is also recognized by the government and constitutes about 37.2 percent (8.4 million) of Nepal's total population. The water transport development project covers Eastern, Central and Western part of Nepal. There are mostly indigenous people habitats along the proposed waterway.

In context of Nepal, Highways and Airports are the major infrastructure in the mode of transportation. Lack of adequate transportation infrastructure, especially in rural areas, results in significant limitations for communities. These limitations occur in terms of access to socio-economic and cultural centers such as schools, clinics, markets and other business centers. Limited access to schools hamper educational access for learners, lack of access to clinics hamper health development and limited access and mobility to markets and other business centers places limits on trade opportunities, and subsequently also limits the potential opportunity for earning an income and a subsequent improvement in the day-to-day living standard. The result is a poor socio-economic development standard.

The socio-economic data on the influence area are compiled and presented on the following sub-topics.

### i. Population

Here, the total population in Gandaki and Trisuli river Proposed waterway corridor is taken out from the VDC of specified district who were directly influenced by the project. According to Census 2001 demographic statistics, it occupies 8.05% of the total population of Nepal. In the reference to the latest population census (2001 AD), the following demographic data is collected.

Table 7-2 Population in core zone of Influenced along Gandaki River Corridor

| S.N | District    | Total Directly Influenced Population |                |
|-----|-------------|--------------------------------------|----------------|
|     |             | 2001 Census                          | 2011 Projected |
| 1   | Parbat      | 53390                                | 58701          |
| 2   | Gulmi       | 31026                                | 34518          |
| 3   | Syangja     | 78314                                | 84663          |
| 4   | Palpa       | 62750                                | 71314          |
| 5   | Tanahu      | 227210                               | 267185         |
| 6   | Nawalparasi | 198499                               | 256136         |
| 7   | Chitwan     | 293835                               | 391279         |
| 8   | Gorkha      | 207793                               | 237098         |

Source: District Development Profile of Nepal 2010/11

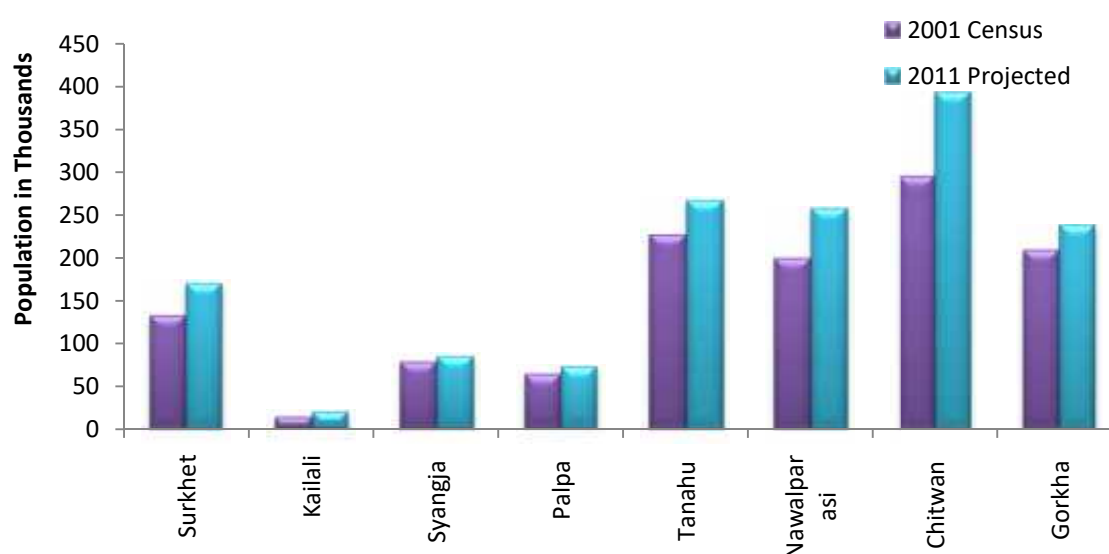


Chart 7-1 Population distribution along Purposed Waterway

## ii. Land use Pattern:

Land use pattern in proposed waterway corridor influence area are given below where area in Hectare,

Table 7-3 Land use Pattern in Gandaki River umbral zone of influence area

| S.N | District    | Agriculture |                 | Pasture | Forest | Other  | Total  |
|-----|-------------|-------------|-----------------|---------|--------|--------|--------|
|     |             | Cultivation | Non Cultivation |         |        |        |        |
| 1   | Parbat      | 19244       | 10766           | 49077   | 84453  | 66466  | 230006 |
| 2   | Gulmi       | 31468       | 22710           | 11964   | 41664  | 1113   | 107919 |
| 3   | Syangja     | 37718       | 22300           | 10265   | 31691  | 1713   | 103687 |
| 4   | Palpa       | 36567       | 20605           | 6998    | 71172  | 1253   | 35795  |
| 5   | Tanahu      | 40309       | 25791           | 2586    | 85362  | 2829   | 156877 |
| 6   | Nawalparasi | 60175       | 9968            | 4296    | 114900 | 12275  | 201614 |
| 7   | Chitwan     | 46814       | 8465            | 10417   | 142422 | 11336  | 219456 |
| 8   | Gorkha      | 41482       | 13057           | 58990   | 112535 | 125406 | 361470 |

Source: District Development Profile of Nepal 2010/11

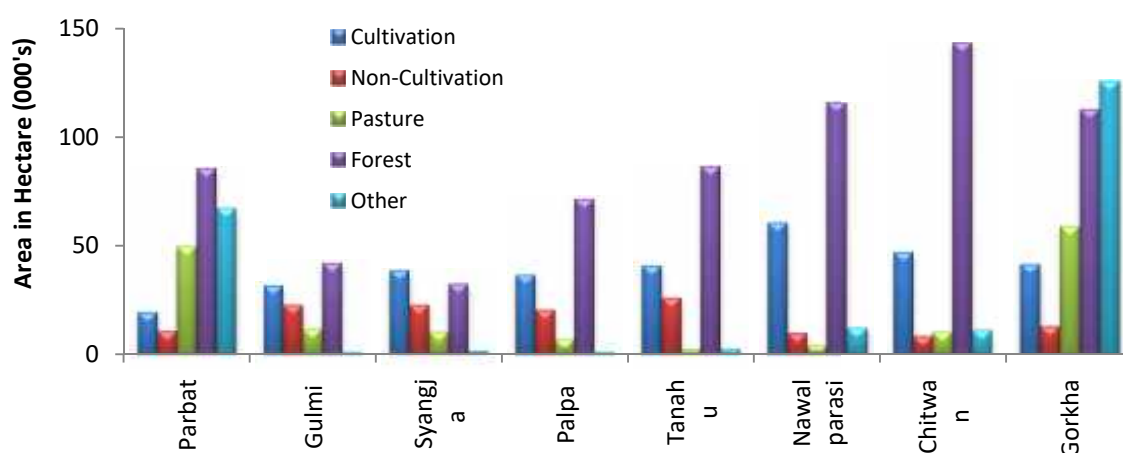


Chart 7-2 Landuse Pattern in Gandaki River Influence area

### iii. Economic Activities :

In reference to the District profile 2010/11, the major source of income and employment in the Gandaki River corridor are agriculture, tourism, civil services, fishery, porters, etc

#### Agriculture:

Agriculture is the major sector of Nepalese economy. It provides employment opportunities to 66 percent of the total population and contributes about 36 percent in the GDP. Therefore, the development of agriculture sector is key for the development of national economy.

The places where the production of cereal crops, cash crops, major crops, fruits, vegetables, pulses etc in the Gandaki River influence area are summarized. The maximum production of Cereal crops like paddy and Wheat in Nawalparasi, Millet and Barley in Baglung and Mazie in Syangja. The maximum production of cash crops like OilSeed in Chitwan, Potato in Palpa, Tobbaco and sugarcane in Nawalparasi. The maximum production of Major crops like Cardamon in Palpa, Ginger in Nawalparasi, Garlic, Chilli and Turmeric in Tanahu. The maximum production of pulses like Lentil and Grass pea in Chitwan, Chicken Pea, Horse gram and Pigeon Pea in Nawalparasi, Black gram in Gorkha. The maximum production of fruits like mango in Chitwan, Banana, Papaya and Guava in Nawalparasi. The maximum production of vegetables is in Chitwan.

According to the agriculture statistics (2009/10) of different types of crops grown in various areas of Gandaki River influence area are tabulated where Area in Ha and Production in Mt.

Table 7-4 Cereal Crops statistics in Gandaki River umbral zone of influence area

| DISTRICT    | PADDY   |         | MAIZE  |         | MILLET |        | WHEAT  |         | BARLEY |       |
|-------------|---------|---------|--------|---------|--------|--------|--------|---------|--------|-------|
|             | Area    | Prod    | Area   | Prod    | Area   | Prod   | Area   | Prod    | Area   | Prod  |
| Parbat      | 9021    | 22150   | 14180  | 34037   | 8890   | 9190   | 2915   | 6734    | 198    | 176   |
| Gulmi       | 9958    | 24753   | 21034  | 39864   | 2915   | 3971   | 8098   | 15791   | 380    | 589   |
| Syangja     | 17550   | 51589   | 30800  | 88300   | 16800  | 19341  | 6430   | 12860   | 200    | 120   |
| Palpa       | 8575    | 21009   | 20210  | 43729   | 2540   | 2590   | 6235   | 13405   | 30     | 49    |
| Tanahu      | 18850   | 45552   | 22150  | 57147   | 6700   | 7289   | 1905   | 3429    | 6      | 6     |
| Nawalparasi | 44590   | 138749  | 9400   | 23520   | 500    | 550    | 18800  | 46360   | 88     | 88    |
| Chitwan     | 29605   | 85406   | 18050  | 46060   | 1810   | 1868   | 9010   | 23200   | 250    | 300   |
| Gorkha      | 17785   | 43996   | 19350  | 41602   | 11679  | 12679  | 4155   | 7230    | 105    | 105   |
| NEPAL       | 1481289 | 4023823 | 875660 | 1855184 | 268473 | 299523 | 731131 | 1556539 | 26600  | 27587 |

Table 7-5 Cash Crops statistics in Gandaki River influence area

| DISTRICT    | Oil Seed |        | Potato |         | Tobacco |       | Sugarcane |         |
|-------------|----------|--------|--------|---------|---------|-------|-----------|---------|
|             | Area     | Prod.  | Area   | Prod.   | Area    | Prod. | Area      | Prod.   |
| Parbat      | 332      | 244    | 1510   | 21136   |         |       | 10        | 176     |
| Gulmi       | 529      | 582    | 440    | 3600    | 0       | 0     | 55        | 753     |
| Syangja     | 272      | 212    | 805    | 12547   | 0       | 0     | 17        | 211     |
| Palpa       | 910      | 774    | 705    | 6627    |         |       | 56        | 863     |
| Tanahu      | 668      | 423    | 769    | 6536    | 0       | 0     | 38        | 683     |
| Nawalparasi | 6475     | 4311   | 1100   | 12711   | 6       | 5     | 7523      | 328750  |
| Gorkha      | 607      | 592    | 2460   | 26519   | 0       | 0     | 58        | 845     |
| NEPAL       | 198540   | 155050 | 185342 | 2517696 | 2534    | 2491  | 58310     | 2495098 |

Table 7-6 Some Major Crops statistics in Gandaki River influence area

| Districts   | Caradom |       | Ginger |        | Garlic |       | Turmeric |       | Chilli |       |
|-------------|---------|-------|--------|--------|--------|-------|----------|-------|--------|-------|
|             | Area    | Prod. | Area   | Prod.  | Area   | Prod. | Area     | Prod. | Area   | Prod. |
| Parbat      | 2.03    | 1.3   | 35     | 420    | 28     | 195   | 20       | 187   | 23     | 58    |
| Gulmi       | 0       | 0     | 282    | 2185   | 24     | 175   | 19       | 165   | 20     | 88    |
| Syangja     | 6       | 3     | 537    | 5047   | 55     | 440   | 70       | 630   | 25     | 150   |
| Palpa       | 0       | 0     | 1235   | 12226  | 65     | 434   | 63       | 506   | 30     | 120   |
| Tanahu      | 0       | 0     | 520    | 6301   | 160    | 909   | 162      | 1629  | 80     | 264   |
| Nawalparasi | 0       | 0.00  | 1290   | 13126  | 50     | 325   | 45       | 530   | 65     | 234   |
| Chitwan     | 0       | 0     | 158    | 1393   | 97     | 593   | 58       | 338   | 125    | 200   |
| Gorkha      | 45      | 14    | 111    | 1048   | 38     | 190   | 28       | 196   | 42     | 88    |
| NEPAL       | 11766   | 5232  | 18042  | 210790 | 5381   | 39483 | 4161     | 37926 | 6394   | 26712 |

Reference: www.moac.gov.np

## Minerals

The influence area of proposed waterway can be sensed in the logistic of mineral products from its minning area. Here, the lists of different places are tabulated according to the type of minerals found in the Gandaki and Trisuli River influence area.

Table 7-7 Minerals found in Gandaki River umbral zone of influence area

| Minerals      | Places                                                |
|---------------|-------------------------------------------------------|
| Iron          | Chitwan (Jirbang), Parbat, Tanahun                    |
| Copper        | Gulmi (Mulkhani), Tanahun (Bhutkhola), Gorkha (Gyazi) |
| Zinc and Lead | Parbat (Dhuwakot)                                     |
| Cobalt        | Gulmi (Netadarling, Tamghas)                          |
| Magnesite     | Palpa                                                 |
| Quartzites    | Parbat, Syangja                                       |
| Slate         | Parbat, Tanahun                                       |
| Coal          | Palpa                                                 |

Source: www.dmg.gov.np

## Market Places

The Project will influence in the business areas. These business areas are the attraction of trip generation, so there can be intramodal or intermodal transportation. Here, the list of market places are tabulated according to the district,

Table 7-8 Market Places in various districts lying in Gandaki and Trishuli River umbral zone of influence area

| District    | Market Places                                                                                                                                                                                                                                                                                                                                                                          |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parbat      | Kusma bajar, Majhaphat, Baribenee, Dhairing Milanchok, Nagliwang Pharse, Tilaharee Dimuwa, Deupur Patichaur, Ramja, Debisthan, Bachha, Pangrang, Lunkhu, Deuralee, Hubas, Tribeni, Seteebeni, Bahakee, Raneepani                                                                                                                                                                       |
| Gulmi       | Tamghas, Ridi, Baletaksar, Bami taksar, Arungga, Shantipur, Gaidakot, Birbas Lumchha, Shreenga, Purkotdaha, Simaltaree, Majuwa                                                                                                                                                                                                                                                         |
| Syangja     | Walling, Syangja Bazar                                                                                                                                                                                                                                                                                                                                                                 |
| Palpa       | Tansen                                                                                                                                                                                                                                                                                                                                                                                 |
| Tanahu      | Damauli, Khireneetar, Bhimad, Duleghuda, Kokre, Dhorphirdi, Abukhireni, Bimalnagar, Dumre, Chandrabatee, Sepa, Bagaicha, Bhansar, Turrure, Purkot, Bandipur                                                                                                                                                                                                                            |
| Nawalparasi | Gaidakot Bajar, Beldeeya Bajar, Soranammur Market, RajharBajar, Dumkaulee Bajar, Daldale Bajar, Pragatinagar Bajar, Kawasoti Bajar, Dandabajar, Chormara Bajar, Arunkhola Bajar, Dumsibas, Daunne bajar, Bardaghat Bajar, Bhutaha Bajar, Bhumahi Bajar, Ramnagar Bajar, Sunwal Bajar, Swathee Bajar, Bilaspur Bajar, Maheshpur Bajar, Gopijang Bajar, Belatadee Bajar, Basabasai Bajar |
| Chitwan     | Narayanghat                                                                                                                                                                                                                                                                                                                                                                            |
| Gorkha      | Gorkha Bazar                                                                                                                                                                                                                                                                                                                                                                           |

Source: www.cbs.gov.np

### Tourism

As we know that the tourism is about travelling, so when the inland navigation will be possible along the Gandaki river corridor, tourist can feel the experience of navigation from plain areas passing through deep gorges formed by the Gandaki River. We can also found that the various travel agencies are organizing the package of the rafting adventures in Gandaki River corridor namely Trisuli, Kali Gandaki, Marsyangdi and Seti River. Thus, the possibility of tourism industry in the following places of Gandaki River influence area,

Table 7-9 Tourism Area in Gandaki and Trisuli River umbral zone of influence area

| District    | Places                                                                                                                                                                                                                                                                                                                             |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parbat      | Jalbihar, Phodhara view(Pang), Gupteswar Gupha (Kusma), Chaubise Rajya Durbar (Paikot), Golryang/Khadakare, Seti Beni, Mahashila (Lankhu), Shiv Mandir (Khaniyaghat), Dhuwakot Gadi, Durlungkot and sansarkot                                                                                                                      |
| Gulmi       | Aamchaur, Bastu bichitra, Purtighat, Saleemedaha kurgah, Hopure Lake                                                                                                                                                                                                                                                               |
| Syangja     | Sirubari, Panchaseghas, Dahare Deurali and chuli, Panchakoshi, Chandisthan, Chhaya area, Chihan Dada, Girekot, Garausur, Aalamdevi                                                                                                                                                                                                 |
| Palpa       | Tansen Durbar (Tansen ), Bhairab Mandir (Bhairabsthan), Risi Mandir (Ridi), Ranighat durbar(Rani Mahal), Argalee Durbar(Argalee), Ramdee, Prabhas, Satyawati Tal, Madi, Ghorbanda, Madan Pokhari, Rimeeghat Lake                                                                                                                   |
| Tanahu      | Chhabdi Barahi, Shiv Panchayan mandir, Ekala Mandir, Dhor Barahi, Thanimai, Chhimkeswaree, Bandipur Khadakamai mandir, Devghat, Ghasi kuwa, Tanahusur Durbar, Manung kot, Kotdurbar, Chhimkeswari Lake, Thaprek, Bhimad, Byas Gupha, Sidha Gupha (Bimalnagar), Parsar Gupha, Millennium Gupha (Phirphire), Sidha Gupha (Bhanumati) |
| Nawalparasi | Ramgram stup, Tribeni Dham, Palhibhagabati Mandir, Sitamani, Jaldebi Ghat, Nagbaba Mandir, Ramjaki Mandir, Balpuri Kut, Madras baba, Shiva Mandir, Daunne Devi, Kailash Asram, Barda Goriya Kut, Maulakalika Mandir, Rudrapurgadi, Sikraulighat, Pitaujighat, Miterighat, Narayanghat, Mausam                                      |
| Chitwan     | Royal Chitwan National Park                                                                                                                                                                                                                                                                                                        |
| Gorkha      | Gorkha Durbar                                                                                                                                                                                                                                                                                                                      |

Source: www.cbs.gov.np

### iv. Utility Services :

#### Irrigation

The Gandak Project at Valmikinagar (Bhainsalaton), intercepts water of a catchment (37,410 sqkm – 90% area is in Nepal) which lies partly in Nepal and partly in India. An Agreement between His Majesty's Government of Nepal and the Government of India on the Gandak Irrigation and Power Project, signed at Kathmandu on 4 December 1959; which came in force upon signature (somewhat modified in 1964), to construct the project

comprising a barrage, canal head regulators and other appurtenant works about 33 m (100 ft) below the existing Triveni Canal Head Regulator and of taking out canal systems for purposes development of irrigation and power for Nepal and India. Some modification was subsequently made in this agreement in 1964 for the protection of Nepal's riparian rights. Basically there is an agreed share of water for 'western Canal System including a power station in Nepal and Eastern canal System. As a part of this bilateral agreement, the Gandak Barrage, a part of Gandak Project, has been built (1968/69.) over the Gandak river for providing irrigation to Nepal, U.P. and Bihar. The irrigation potential of this project is 11,510 km<sup>2</sup>, spread in the district of West Champaran, East Champaran, Muzaffarpur, Samastipur, Saran, Siwan & Gopalganj. The Eastern Gandak Canal Project was taken up in 1960 and Main Canal system was completed in 1975 for flow irrigation in Nepal for the gross commanded area estimated to be 103,500 acres (419 km<sup>2</sup>).

### Electricity

In Nepal, Sapta Gandaki alone has a huge hydropower potential of 20,650 MW (economic exploitable potential is 5,270 MW) out of a total estimated potential of 83,290 MW (economically exploitable potential is 42,140 MW). The country has so far been able to generate only around 600 MW of hydropower out of which the Gandak basin projects contribute more than 44% - 266 MW. The Hydropower projects built are the Trisuli at Nuwakot (21 MW), Devighat at Nuwakot (14 MW), Pokhra (1MW) and Western Gandak HEP, at Nawalparasi (15) MW, - financed by the Govt. of India - , Marsyangdi at Tanahu (69 MW), Kali Gandaki at Syanja (144 MW) and Syange 2 MW. Middle Marsyangdi HE Project (70 MW) at Lamjung is under final stage of construction. Several major projects are on the anvil for implementation in the near future. With Govt. of Nepal now according priority to private-sector participation in a multi-pronged approach, the pace of Hydropower development will get accelerated.

Here, the list of Hydropower status in Gandaki River umbral influence area is tabulated below.

Table 7-10 Total Hydro Power status in Gandaki and Trishuli River umbral zone of influence area

| S.N | Hydro Project in Gandaki WT influence area                   | MW      |
|-----|--------------------------------------------------------------|---------|
| 1   | Application for Survey License for Generation (Below 1 MW)   | 13.217  |
| 2   | Application for Survey License for Generation (1 to 25 MW)   | 85.73   |
| 3   | Application for Survey License for Generation (25 to 100 MW) | 1104.97 |
| 4   | Application for Survey License for Generation (Above 100 MW) | 2895    |
| 5   | Survey License for Generation (Below 1 MW)                   | 12.634  |
| 6   | Survey License for Generation (1 to 25 MW)                   | 60.913  |
| 7   | Survey License for Generation (25 to 100 MW)                 | 75      |
| 8   | Survey License for Generation (Above 100 MW)                 | 518     |
| 9   | GoN Reserved Survey License for Generation                   | 5       |
| 10  | Construction License for Generation                          | 133.1   |
| 11  | Operating Power Plants                                       | 380.17  |

Source: www.nea.org.np

### v. Health

The main hospitals in this project area are found in the municipality's area only like Bharatpur, Tamghas and district headquarter areas. Here, the statistics of health facilities along the Gandaki and Trishuli river corridor which is influenced by the project are tabulated.

Table 7-11 Health statistics in the Gandaki and Trishuli River umbral zone of influence area

| S.N | District    | Hospitals | PHCC / HC | HP | SHP | PHC Out reach Clinic | EPI Clinic | FCHV | NGO/INGO & Private Sector |
|-----|-------------|-----------|-----------|----|-----|----------------------|------------|------|---------------------------|
| 1   | Parbat      | 1         | 2         | 10 | 42  | 175                  | 165        | 495  | 0                         |
| 2   | Gulmi       | 1         | 4         | 12 | 64  | 325                  | 311        | 975  | 0                         |
| 3   | Syangja     | 1         | 3         | 10 | 54  | 192                  | 216        | 612  | 2                         |
| 4   | Palpa       | 2         | 3         | 9  | 53  | 214                  | 249        | 615  | 3                         |
| 5   | Tanahu      | 2         | 2         | 12 | 31  | 143                  | 215        | 423  | 4                         |
| 6   | Nawalparasi | 1         | 5         | 8  | 63  | 230                  | 345        | 713  | 33                        |
| 7   | Chitwan     | 1         | 4         | 6  | 31  | 125                  | 237        | 405  | 55                        |
| 8   | Gorkha      | 2         | 3         | 10 | 55  | 286                  | 250        | 621  | 4                         |

Source: District Development Profile of Nepal 2010/11

## vi. Transport

The project of water transport has possibility to link Highways and Feeder Roads. The E/W highway can be linked in Narayanghat (Bharatpur). As many highways and feeder road in this project area is along the river route, there can be possibility of mode choice for the freight and passenger movement. The Siddhartha highway can be linked via Kali Gandaki River route in Ramdi (Palpa and Syangja Border). The Prithivi highway can be linked in Mugling via Trisuli River which has been chosen as the section of Proposed Mid-Hill Highway. Here, the data of Transport facilities along the Gandaki River corridor which is influenced by the project.

Table 7-12 Statistics of accessibility in the Gandaki and Trishuli River umbral zone of influence area

| District    | Types of Road |       |      |        | Road Category |        |      |    |    | Pop. Influence Per Km (Nos) | Road Density (Km / Km <sup>2</sup> ) | Air port |
|-------------|---------------|-------|------|--------|---------------|--------|------|----|----|-----------------------------|--------------------------------------|----------|
|             | BT            | GR    | ER   | Total  | NH            | FRN    | FRO  | MH | PR |                             |                                      |          |
| Parbat      | 24.11         | 0     | 13   | 37.11  | 0             | 24.11  | 13   | 0  | 0  | 4253                        | 8                                    |          |
| Gulmi       | 40.34         | 4.2   | 66   | 110.54 | 0             | 101.54 | 9    | 0  | 0  | 2684                        | 10                                   |          |
| Syangja     | 97.94         | 3     | 37   | 137.94 | 78.94         | 59     | 0    | 0  | 0  | 2300                        | 12                                   |          |
| Palpa       | 94.59         | 4     | 30   | 128.59 | 58.93         | 69.66  | 0    | 0  | 0  | 2088                        | 9                                    |          |
| Tanahu      | 105.16        | 14.25 | 13   | 32.41  | 71.25         | 61.16  | 0    | 0  | 0  | 23.81                       | 9                                    |          |
| Nawalparasi | 127.28        | 41.05 | 24   | 192.33 | 98.33         | 69     | 11   | 0  | 14 | 2927                        | 9                                    |          |
| Chitwan     | 130.39        | 50    | 10   | 90.39  | 88.9          | 40.49  | 0    | 0  | 61 | 2479                        | 9                                    | 2        |
| Gorkha      | 23.84         | 0.4   | 64.1 | 88.34  | 0             | 63.84  | 24.5 | 0  | 0  | 32.62                       | 2                                    | 1        |

Source: District Development Profile of Nepal 2010/11

Table 7-13 Agricultural Road in Gandaki and Trishuli River umbral zone of influence area

| District    | Total Km | Completed  |             | Transportation Running Part (KM) |
|-------------|----------|------------|-------------|----------------------------------|
|             |          | Dusty Road | Gravel Road |                                  |
| Parbat      | 343.9    | 204.85     | 3.5         | 158.35                           |
| Gulmi       | 241      | 96         | 5           | 89                               |
| Syangja     | 663      | 564        | 17          | 564                              |
| Palpa       | 294      | 152.5      | 10          | 137                              |
| Tanahu      | 413.8    | 286        | 67          | 302                              |
| Nawalparasi | 163.69   | 95.09      | 29.85       | 104.59                           |
| Chitwan     | 172.2    | 172.9      | 78.5        | 76                               |
| Gorkha      | 413.1    | 134.57     | 1           | 120.57                           |

Source: District Development Profile of Nepal 2010/11

## 7.4 Hydrology Study of Proposed Waterway Corridor

### 7.4.1 Hydrology

Water transport is based on the hydrological characteristics which are mainly precipitation, base flow, high flood level. To determine the waterway design, the detailed hydrological and metrological data from river and DHM has been collected. The collection of the data for Gandaki Basin from Kali Gandaki and Trishuli Proposed waterway of 180 km has been carried during the month of November, 2011.

The hydrological study is concentrated in determining the obstruction for the proposed waterway and location of the terminal station with respect to high flood level. The depth of the river with its critical and narrow section has been surveyed result in plotting of profile of bed level with respect to water surface level. Here, Critical section refers to those sections along the proposed waterway which may affect in the maneuverability of the vessels due to bends, sandbars, boulder deposition, rapids etc.

### 7.4.2 DHM data for Gandaki Basin Proposed Waterway Analysis

To study the availability of navigational discharge during different seasons in a year it is required to analyze the historical discharge data on the waterway under consideration for development. The discharge data has been collected from Department of Hydrology and Metrology (DHM), Babar Mahal and analyzed to establish low discharge and to study the availability of water for navigation.

In the length of 180 km of proposed waterway in Gandaki basin, there are four gauging stations at Ansing, Kotagaun, Kalikhola and Devghat. The details of these stations are given in table 5-14,

Table 7-14 Hydrological Station in Gandaki Basin Proposed Waterway

| River        | Gauging Site | Station No. | Lat.     | Long.    | Elevation (m) | Area (km <sup>2</sup> ) | Records (From-To) | Remarks |
|--------------|--------------|-------------|----------|----------|---------------|-------------------------|-------------------|---------|
| Kali Gandaki | Ansing       | 419.1       | 27 53 05 | 83 47 42 | 351           | 10020                   | 1996 - 2006       | Good    |
| Kali Gandaki | Kotagaun     | 420         | 27 45 00 | 84 20 50 | 198           | 11400                   | 1964 - 2006       | Good    |
| Trishuli     | Kalikhola    | 449.91      | 27 50 08 | 84 33 12 | 220           | 16760                   | 1994 - 2006       | Good    |
| Narayani     | Devghat      | 450         | 27 42 30 | 84 25 50 | 180           | 31100                   | 1963 - 2006       | Good    |

Source: DHM, BabarMahal

### Ansing

The mean monthly discharge at Ansing for the years 2001 - 2010 are furnished in table,

Table 7-15 Average Discharge over the year on Kali Gandaki River at Ansing

| Year | Jan  | Feb  | Mar  | Apr  | May  | Jun | Jul  | Aug  | Sept | Oct | Nov | Dec  |
|------|------|------|------|------|------|-----|------|------|------|-----|-----|------|
| 2001 | 105  | 91   | 82.6 | 84.9 | 145  | 500 | 1230 | 1830 | 913  | 312 | 179 | 115  |
| 2002 | 97   | 87.8 | 82.2 | 96.1 | 167  | 347 | 1260 | 1240 | 618  | 270 | 138 | 105  |
| 2003 | 86.8 | 75.6 | 76.1 | 90.6 | 109  | 418 | 1240 | 1390 | 1120 | 368 | 172 | 110  |
| 2004 | 94.3 | 74.6 | 74.6 | 75.5 | 107  | 261 | 880  | 929  | 756  | 424 | 158 | 114  |
| 2005 | 90.8 | 78.3 | 76.2 | 78.2 | 95.9 | 206 | 1010 | 989  | 573  | 371 | 185 | 119  |
| 2006 | 91.1 | 77.2 | 69.2 | 73.5 | 155  | 320 | 862  | 767  | 629  | 283 | 143 | 97.3 |
| 2007 | 75.8 | 79.5 | 83.3 | 98   | 118  | 306 | 1140 | 1230 | 1160 | 459 | 210 | 123  |
| 2008 | 101  | 80.6 | 80.8 | 97   | 118  | 509 | 921  | 1540 | 758  | 310 | 164 | 121  |
| 2009 | 84.3 | 77   | 68.8 | 75.6 | 104  | 186 | 895  | 1310 | 607  | 595 | 190 | 121  |
| 2010 | 90.8 | 79.3 | 75.7 | 85   | 91.3 | 195 | 1020 | 1200 | 1380 | 305 | 141 | 94.8 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 68.8 cumecs in the year 2009 and high flow are noticed during August of about 1830 cumecs in the year 2001.

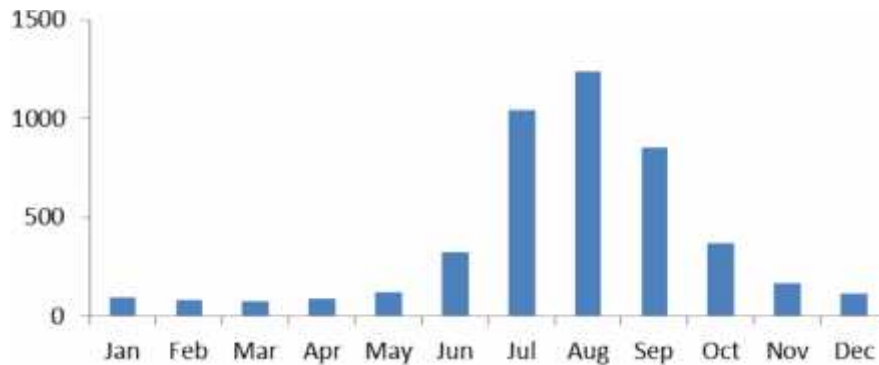


Chart 7-3 Hydrograph of Kali Gandaki River at Ansing

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Sunkoshi at Ansing. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 1400 cumecs from lean season to flood season, the river rises by about 7.9 m.

#### Kotagaun

The mean monthly discharge at Kotagaun for the years 1999-2008 are furnished in table,

Table 7-16 Average Discharge over the year on Sunkoshi River at Kotagaun

| Year | Jan | Feb  | Mar  | Apr  | May | Jun | Jul  | Aug  | Sept | Oct | Nov | Dec |
|------|-----|------|------|------|-----|-----|------|------|------|-----|-----|-----|
| 1999 | 117 | 92.9 | 77.4 | 94.5 | ... | ... | 1290 | 1840 | 1120 | 547 | 229 | 142 |
| 2000 | 108 | 88.6 | 75.3 | 103  | 183 | 814 | ...  | ...  | 1320 | 350 | 206 | 135 |
| 2001 | 104 | 88.5 | 75.3 | 77.7 | 146 | 428 | 1120 | 1940 | 1040 | 308 | 197 | 137 |
| 2002 | 113 | ...  | ...  | 118  | 186 | 303 | 1080 | 1180 | 596  | 295 | 191 | 120 |
| 2003 | ... | ...  | 91.8 | 105  | 123 | 437 | 1310 | 1520 | 1240 | 429 | 232 | 156 |
| 2004 | 124 | 111  | 104  | 108  | 132 | 281 | 910  | 919  | 737  | 430 | 218 | 149 |
| 2005 | 122 | 109  | 101  | 100  | 137 | 219 | 935  | 1010 | 560  | 397 | 227 | 149 |
| 2006 | 119 | 106  | 96.8 | 105  | 185 | 340 | 799  | 768  | 638  | 286 | 172 | 127 |
| 2007 | 315 | 306  | 259  | 284  | 291 | 538 | 1170 | 1010 | 851  | 448 | 296 | 241 |
| 2008 | 222 | 211  | 195  | 205  | 220 | 558 | 754  | 1330 | ...  | 320 | 240 | 204 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 75.3 cumecs in the year 2000 and 2001 and high flow are noticed during August of about 1940 cumecs in the year 2001.

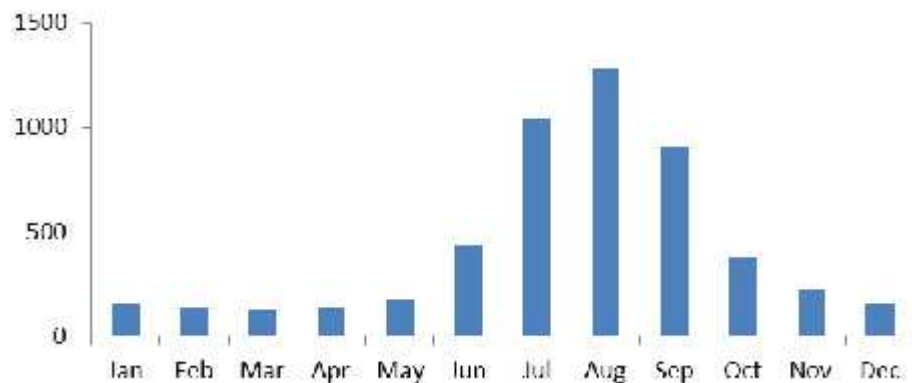


Chart 7-4 Hydrograph of Kali Gandaki River at Kotagaun

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Kali Gandaki at Kotagaun. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 1300 cumecs from lean season to flood season, the river rises by about 9.2 m.

#### Kalikhola

The mean monthly discharge at Kalikhola for the years 1999-2008 are furnished in table,

Table 7-17 Average Discharge over the year on Trishuli River at Kalikhola

| Year | Jan | Feb | Mar  | Apr | May | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|------|-----|-----|------|------|------|------|------|-----|-----|
| 1999 | 161 | 131 | 115  | 173 | 376 | 1020 | 3380 | 3000 | 2210 | 1050 | 416 | 247 |
| 2000 | 172 | 138 | 128  | 184 | 445 | 1590 | 2680 | 3630 | 2440 | 631  | 332 | 205 |
| 2001 | 172 | 126 | 98.7 | 121 | 247 | 767  | 1650 | 2200 | 1300 | 613  | 333 | 228 |
| 2002 | 178 | 155 | 137  | 221 | 471 | 969  | 2730 | 3010 | 1500 | 607  | 319 | 220 |
| 2003 | 175 | 155 | 150  | 201 | 226 | 887  | 3260 | 3720 | 2770 | 708  | 359 | 214 |
| 2004 | 170 | 151 | 142  | 174 | 385 | 1140 | 3140 | 3620 | 1930 | 1020 | 371 | 244 |
| 2005 | 176 | 146 | 138  | 160 | 276 | 669  | 2440 | 3150 | 1400 | 665  | 385 | 232 |
| 2006 | 172 | 142 | 135  | 158 | 424 | 1010 | 2430 | 2360 | 1940 | 649  | 345 | 239 |
| 2007 | 517 | 572 | 542  | 710 | 694 | 1310 | 2280 | 2470 | 1640 | 816  | 607 | 497 |
| 2008 | 536 | 492 | 464  | 515 | 523 | 1650 | 2450 | 3160 | 957  | 707  | 579 | 558 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 98.7 cumecs in the year 2001 and high flow are noticed during August of about 3720 cumecs in the year 2003.

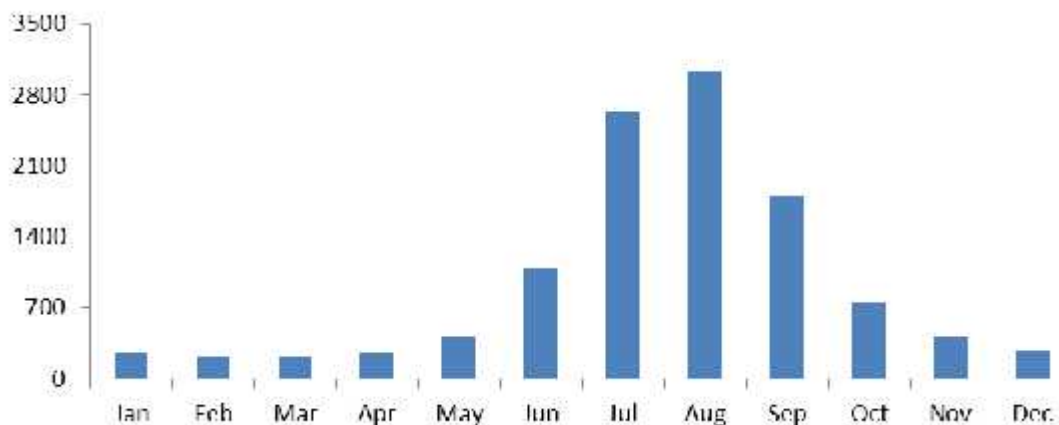


Chart 7-5 Hydrograph of Trishuli River at Kalikhola

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Trishuli at Kalikhola. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 3500 cumecs from lean season to flood season, the river rises by about 12.4 m.

#### Devghat

The mean monthly discharge at Devghat for the years 2001-2010 are furnished in table,

Table 7-18 Average Discharge over the year on Trishuli River at Kalikhola

| Year | Jan | Feb | Mar | Apr | May | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|-----|-----|-----|------|------|------|------|------|-----|-----|
| 2001 | 355 | 305 | 242 | 277 | 619 | 2100 | 3890 | 5490 | 3540 | 1470 | 776 | 506 |
| 2002 | 347 | 288 | 264 | 358 | 757 | 1640 | 4520 | 4710 | 2460 | 1170 | 604 | 393 |

| Year | Jan | Feb | Mar | Apr | May | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|-----|-----|-----|------|------|------|------|------|-----|-----|
| 2003 | 299 | 307 | 266 | 337 | 439 | 1520 | 4970 | 4640 | 3990 | 1430 | 751 | 491 |
| 2004 | 377 | 294 | 289 | 359 | 646 | 1670 | 3920 | 3980 | 2990 | 1630 | 724 | 464 |
| 2005 | 360 | 277 | 251 | 290 | 508 | 1070 | 3720 | 4230 | 2210 | 1300 | 726 | 410 |
| 2006 | 293 | 248 | 219 | 255 | 714 | 1530 | 3390 | 3180 | 2690 | 1080 | 556 | 369 |
| 2007 | 270 | 294 | 273 | 350 | 465 | 1570 | 4110 | 4370 | 4490 | 1720 | 741 | 456 |
| 2008 | 344 | 277 | 254 | 304 | 450 | 2190 | 3760 | 5580 | 2590 | 1200 | 616 | 401 |
| 2009 | 299 | 233 | 197 | 278 | 406 | 772  | 2790 | 4220 | 2270 | 1560 | 647 | 407 |
| 2010 | 303 | 251 | 226 | 293 | 391 | 912  | 3800 | 5050 | 4580 | 1310 | 671 | 405 |

Note: All discharge in Cumecs

Source:DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 197 cumecs in the year 2009 and high flow are noticed during August of about 5580 cumecs in the year 2008.

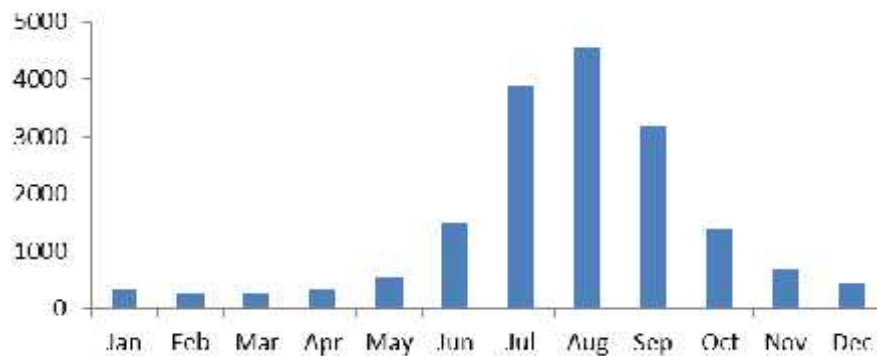


Table 7-19 Hydrograph of Narayani River at Devghat

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Narayani at Devghat. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 5000 cumecs from lean season to flood season, the river rises by about 8.64 m.

#### 7.4.3 Field Investigation for Gandaki Basin proposed Waterway

Hydrographic survey was conducted on November for proposed waterway in Gandaki Basin. The survey was done using rafting boat in two phases, first from Fishling to Devghat in Trishuli and another from Ramdi to Devghat in Kali Gandaki River. The elevation difference of 77 m and 197 m has been observed in 50 km and 130 km proposed waterway respectively. The hydrographic survey in these stretches, the position and sounding depth has been recorded by using EchoSounder and GPS. All the conspicuous objects nearby banks were obtained with the help of GPS and noted on the survey book.

##### i. Profile of River surface and its bed level

The data from the DHM is the secondary data to analyze the water level w.r.t discharge. The primary data collected from hydrographic survey has been used to plot the profile of river surface and its bed level. In Trishuli River, the gradient above Devghat (0+000) to Gaighat (16+000) seems to be medium and high gradient above Gaighat. In Kali Gandaki River, the gradient throughout the length of 130 km seems to be medium except in between Aptar (16+000) to Khalte (26+000). This can be visualized in the data and drawing of profile of the bed level and water surface level of Proposed waterway which has been attached in Annex.

##### ii. Identification of obstruction in proposed waterway

The upper reach of the proposed waterway in both Trishuli and Kali Gandaki rivers have been identified as the class III where numerous rapids with holes can be found. Rapids are the high current area formed due to the excessive boulders deposition at its bed level. The converging of tributaries, bends and landslide area are mainly

places of rapid formation. If the boulders deposition are excess, then the formation of rapid with shallow depth in downstream and dam phenomenon in upstream creating still section with maximum depth.

The lower reach of the proposed waterway in Gandakii basin is found to be quite still. The Kali Gandaki River flowing from west to south and the Trishuli River from North to South meet at Devghat. The width of river is fairly wide enough before converging at Devghat.

During field investigation some of the possible obstruction for proposed waterway in Gandaki basin has been detected which are Rapids, Bends, Bifurcation and Sandbars. But among these, rapid is the most crucial in our study. The summary of identified rapids has been tabulated below:

Table 7-20 Summary of Rapids

| Section | No. of Rapids |
|---------|---------------|
| G-DR    | 46            |
| G-DM    | 18            |
| G-MF    | 11            |
| G-MrS   | 0             |
| Total   | 75            |

The details of the rapids have been attached in the Annex.

### iii. Identification of Civil Infrastructure in Proposed waterway

The infrastructures which are on operation, obsolete or under construction have been identified along the proposed waterway in Gandaki basin. The summarized data has been tabulated below:

Table 7-21 Summary of Identified Civil Structure

| Type of Structure               | Numbers |
|---------------------------------|---------|
| Tread Bridge                    | 25      |
| Motor Bridge                    | 2       |
| Under Construction Motor Bridge | 2       |
| Ropeway                         | 6       |
| Transmission Line               | 7       |
| Gauging Station                 | 3       |
| Utility Works                   | 2       |

The details of the identified civil infrastructures have been attached in the Annex

## 7.5 Geological and Environmental Study of Proposed Waterway Corridor

### 7.5.1 Geological Features in Proposed waterway

Physiographically, the proposed waterway of 180 km passes from Siwalik to Lesser Himalaya zone (Mahabharat and Midlands) and crosses the MBT near Devghat.

Siwalik zone also called Churia Hills consists of fluvial sedimentary rocks of Neogene to quaternary age (14 to 1 million years) which elevation ranges from 200 m -700 m above sea level. This zone is bounded to the north by MBT and to south by MFT. Rocks of this zone are divided stratigraphically into 3 parts. The lower Siwalik consists of fine grained mudstone, siltstone and shale. The middle Siwalik is marked by thick multistoried stone beds cycle of finding upward sequences is normally observed. The upper Siwalik is characterized by very coarse grained rocks such as boulder conglomerates.

Lesser Himalayan Zone is boarded to the south by MBT and north by MCT. Lesser Himalaya zone consists of mainly of unfossiliferous sedimentary and various degree of metamorphism such as shale, sandstone, limestone dolomites, slates, phylites, schist and quartzite ranging in age from pre-cambrian (as old as 1800 million years) to Eocene (about 40 million yrs) which elevation range below 4000 m.

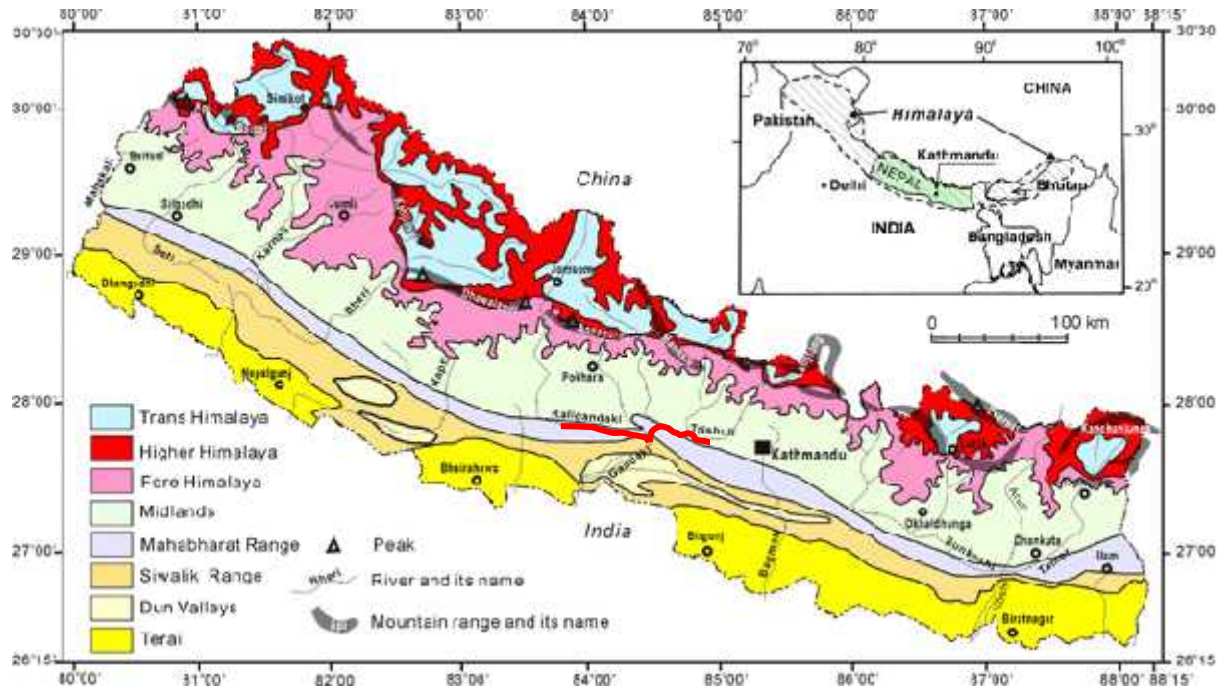


Figure 7-1 Physiographic map of Nepal

Geologically, the purposed waterway in Kali Gandaki and Trisuli River are found more stable in comparison to Koshi Basin. There are few landslides in lesser Himalaya zone. The braiding of the Kali Gandaki River is found to be excessive due to the less gradient. The Trishuli River has high gradient in upper reach with stable rocky slopes but at lower reach near Devghat, huge conglomerate boulders are seen near the bank.

#### 7.5.2 Environmental Features in Proposed waterway

The baseline information of the existing physical and biological environment of the proposed Kaligandaki and Trisuli waterway project is described as below:

##### i. Physical Environment

###### Climate

The study area lies in the sub-tropical region. The temperature ranges 9°C in winter and to 40.1° C in summer in adjoining metrological station of Rampur, Chitwan. Mean annual rainfall for Gandaki basin is around 3200 mm. The Gandaki river basin has an average outflow of 50.7 billion m<sup>3</sup>/year.

###### Topography and Land Use

The proposed Kaligandaki and Trisuli waterway are located in the low hill physiographic region. The elevation of the proposed kaligandaki waterway ranges from 189m to 247m and that of trisuli waterway ranges from 189m to 278m. The major land use types within the Gandaki watershed are cultivated land (24.7%), forest (35.1%), bush (6.2%), barren land (19.1 %) and grazing land (10.2%). The land use types of Gandaki watershed is given in the table below and the map is shown in Annex.

Table 7-22 Land Use Type of Gandaki Basin

| Landuse Type | Percentage (%) |
|--------------|----------------|
| Built up     | 0.01           |
| Cliff        | 0.2            |
| Cultivation  | 24.7           |
| Forest       | 35.1           |
| Orchard      | 0.01           |
| Nursery      | 0.01           |
| Grass        | 10.2           |
| Bush         | 6.2            |
| Barren Land  | 19.1           |
| Sand         | 1.6            |
| River/Stream | 0.5            |
| Snow/Glacier | 2.2            |
| Pond/Lake    | 0.1            |

Source: Department of Survey, 1995

## ii. Biological Environment

A rich bio-diversity is observed in the proposed area consisting of significant composition of flora and fauna. The dense forest of the Proposal area provides excellent habitats for wildlife. Some endangered species of wild animals were also found inhabiting the water transport area.

### Natural Forests and Tree Vegetation

The dominant tree species along the water transport corridor is Sal (*Shorea robusta*). The other major species include Sisam (*Dalbergiasisoo*), Simal (*Bombaxceiba*), Aanp (*Magnifera indica*), Kadam (*Anthocephalus chinensis*), Khayer (*Acacia catechu*), Jamun (*Syzygium cumini*), Bet (*Calamus acanthospathus*), Pipal (*Ficus religiosa*), Amala (*Phyllanthus emblica*), Bhalayo (*Semecarpus anacardium*), Kusum (*Karhamustinctorius*), Asana (*Terminalia alata*), Chandmaruwa (*Rauvolfia serpentina*), Harro (*Terminalia chebula*), Barro (*Terminalia bellirica*), Mauwa (*Engelhardtia spicata*), Bhorla (*Bauhinia vahlii*), Satisal (*Dalbergia latifolia*), Bijaysal (*Pterocarpus marsupium*), Siris (*Albigia* spp.), Tatari (*Dillenia pentagyna*) and Bayer (*Zizyphus mauritiana*).

### Terrestrial Wildlife and Aquatic Animals

The major wild mammals found in the study area are Bagh (*Panthera tigris*), Bandel (*Sus scrofa cristatus*), Syal (*Canis aureus*), Rato Bandar (*Macaca mulatta*), Chituwa (*Panthera pardus*), Jarayo (*Cervus unicolor*), Chital (*Axis axis*), and Bhalu (*Urusus* spp.), Ghoral (*Naemorhedus goral*), Arna (*Bubalus bubalis*), Gaurigai (*Bos gaurus*), Nilgai Biral (*Felis chaus*).

Major species of birds documented either from field observations or from secondary information are Kalij (*Lophura leucomelana*), Kaag (*Corvus splendens*), Bhangera (*Passer domesticus*), Suga (*Psittacula* spp.), Dangree (*Acridotheres fuscus*), Mayur (*Pavocristatus*), Maina (*Gracula religiosa*), Jureli (*Pycnonotus* spp.), Chibe Chara (*Dicrurus aeneus*), Phusree Dhanesh (*Ocyrops birostris*), Thulo Dhanesh (*Buceros bicornis*), Pangree Dhanesh (*Anthraceroceros birostris*), Nyauli (*Megalaima zeylanica*), Kuthurke (*Megalaima lineata*), Dhukur (*Streptopelia* spp. & *Chalcophaps* spp.), Karangkurung (*Anthropoides virgo*), Chil (*Hieraaetus kienerii*), Kharmujur (*Choriotis nigriceps*), Luiche (*Gallus gallus*) and Haleso (*Treron* spp.).

Kaliz and Dhukur are hunted for meat. Suga, Dhukur, Dangree and Bhangera are reputed to be major crop raiders.

Among the herpeto fauna, Chheparo, Ajingar (*Python molurus*), Dhaman (*Ptyasmucosus*), Karet, and AndaKhaneSarpa (*Elachistodonwestermanni*) have been reported. The Kaligandaki and Trisuliriver provides the habitat for fishes such as Setala, Bam, Garela, Chadke, Asala, Sahar, and Bhaichari according to the local respondents near these rivers.

#### Protected and Endangered Species of Flora and Fauna

Satishal, Bijayasal, Chadmaruwa, Sal, Simal and Khayer are protected species according to Forest Act (1983). Out of the mammals reported in the area, Gaurigai, Arna, Salak, and Bagh, are protected species according to the National Park and Wildlife Conservation Act (1963). Ghoral, Gaurigai, Bagh, and Chituwa, have been included in CITES - I category. Rato Bandar and Ban Biralo in CITES-II and Syal&Arna in CITES-III category.

Out of birds reported in the Project area, Thulodhanesh, and KharMujur are protected species according to the National Park and Wildlife Conservation Act (1963). ThuloDhanesh, and Kharmujur have been included in CITES-I category, Phusree Dhanesh in CITES-II category. Maina, Suga&Dhukur in CITES-III category.

Out of the reptiles, Ajinger is the protected species according to the National Park and Wildlife Conservation Act (1963). Ajingar has been included in the CITES-I category and AndakhaneSarpa and Dhaman in the CITES-II category.

### 7.6 Existing Water Transport Senerio

In Context of Nepal, Water transport is mainly for promotion of tourism industry rather than public transportation. The promotion of the tourism industry in water transport is done by white water rafting. The white water rafting has been started in late 1960's by two French in Sunkoshi. In 1976, the first Commercial River rafting company named Himalaya River Expedition was launched and experienced river guide, Mike Yager of America was brought to manage the company and to train Nepalese guides. From this phase to present, rafting in Nepal has really taken off and Nepal is known as one of the world's premier river running destinations.

In Gandaki Basin, under the proposed waterway there are two types of existing Water Transport; Adventure / Recreational purpose and Public Transportation purpose.

#### 7.6.1 Adventure/Recreational Purpose

Trishuli River is Nepal's most popular rafting river. It has impressive gorges and some moderate white water. The difficulty grade of the river is 3-4. The rafting agency has marked the starting point Baireni and end point Narayanghat which length is about 106 km and they have scheduled the rafting trip for about 4 days / 3 Nights. For the access to Baireni, the PrithiviHighway is used. According to the rafting agency, the best month for rafting in this river is in March to May and October to December where the discharge of the river starts to increase and decrease.

Kali Gandaki River is divided into Upper and Lower Kali Gandaki since 2001 after the built of the dam in Mirmi. The upper Kali Gandaki has difficulty grade of IV and lower Kali Gandaki has difficulty grade of II, The upper Kali Gandaki trip starts from Beni to Mirmi which takes 2-3 days to complete the journey of 60 km and the lower Kali Gandaki trip starts from Ramdi to Narayanghat which takes 4-5 days to complete the journey of 130 km. According to the rafting agency, the best month for rafting in upper Kali Gandaki is in March to May and October to December and for rafting in lower Kali Gandaki is in February to April and October to December.

### 7.6.2 Public Transportation

For the public transportation, the propellor boat service provided by the StreamerService in Mirmi is operating from Mirmi to Seti Beni in upper Kali Gandaki i.e. upstream of Kali Gandaki Hydropower Dam. Due to the dam, ponding of water makes feasible for navigation in the length of 4.5 km which takes 30 minutes to complete the journey. According to the streamer operator, 1 trip is Mirmi - Seti Beni – Mirmi where they use 8 streamers out of 10 in a day with 1 trip per day carrying more than 80 passengers and charging Rs. 50 per person and 0.5 paisa per kg of goods. They have to pay the tax to the District office annually. The motor boats are made locally using the bus engine and body work has been made locally. The passenger boarding or terminal station infrastructure has not built. The passenger traffic seems to be high enough since every boat departing every  $1\frac{1}{2}$  hour is fully loaded by passenger and goods. After the questionnaire with local people, passenger and operator, we found that the water transport in this area operating for short route has highly benefited the contiguous as well as shadow area people. The people before walking take 3-4 hours to reach Seti Beni and after the initiation of the WT in Kali Gandaki, the fruitful utilization of natural resource has been sensed by the benefited people.

### 7.7 Traffic Study of Proposed Waterway Corridor

According above chapter, the Traffic description for particular waterway,

| Section | Type of service                  | Vessel Capacity                                       | Frequency/day | no. of passengers/day | No. of Vessel | remarks                      |
|---------|----------------------------------|-------------------------------------------------------|---------------|-----------------------|---------------|------------------------------|
| G-DM    | Recreational                     | Only Recreational / Rafting existing parallel highway |               |                       |               | Existing service             |
| G-MF    | Recreational                     | only Recreational/rafting existing parallel highway   |               |                       |               |                              |
| G-DR    | Recreational / Passenger service | only Recreational/rafting existing parallel highway   |               |                       |               |                              |
| G-MrS   | Passenger service                | 80                                                    | 8             | 640                   | 10            | Motor boat local manufacture |

According above chapter, the Traffic count for particular waterway,

| Section | Type of service                        | Vessel Capacity | trips/day | no. of passengers/day | No. of Vessel | remarks                             |
|---------|----------------------------------------|-----------------|-----------|-----------------------|---------------|-------------------------------------|
| G-DM    | Proposed Jetboat for sightseing        | 25              | 4         | 100                   |               | tourist season (proposed)           |
| G-MF    | Rafting                                | 8               | 10        | 80                    |               | Tourist season                      |
| G-DR    | Passenger service<br>Proposed Jet Boat | 25              | 6         | 150                   | 2             |                                     |
| G-DR    | Recreational                           | 8               | 5         | 40                    |               | Tourist season (8 months operation) |
| G-MrS   | Passenger service                      | 80              | 8         | 640                   | 10            | Motor boat local manufacture        |

### 7.8 Engineering Characteristics of the Proposed Waterway Section

#### 7.8.1 Section: Devghat - Ramdi (0+000 – 130+425)

The section lies in the Kali Gandaki River where deep gorges are formed by the Kali Gandaki River with mild gradient throughout the length of the purposed waterway. The section seems to be slightly challenging between Aptar (16+000) to Khalte (26+000) due to increase in gradient and high braiding river pattern can seen. The both bank have dense forest with cultivation land mixed with BMS. The major settlements are Kota, Khalte,

Paschimthar, Gajarkot, Gadyaulitar, Rampur, Lamachaur and Ramdi. The numerous tracks are opened in left bank than in right bank. The section is contiguous with the Siddhartha Highway at Ramdi. During the hydrographic survey, the deepest area of about 53 m has been detected in Khasuwatar of Nawalparasi at chainage of 44+200. The average discharge of Kali Gandaki according to Kotagaun gauging station is 443 cumec (DHM, 2008). The average gradient of the section is about 1 in 662 with average velocity of 1.5 m/s and average depth of 16.2 m.

#### 7.8.2 Section: Devghat - Mugling (0+000 – 32+638)

This section lies in Trishuli River which is the main tributaries of Kali Gandaki River. The section gradient is mild till Gaighat (16+000) but increase in gradient above Gaighat. The class of the river is graded as 2-3 in this section. In the chainage of 6+000 above Devghat, the bend of the river is acute. The huge conglomerate boulders are placed near the bank of the river. The strong rapids can be found above Gaighat. The slopes of the contiguous hills are stable enough. The left bank have mostly steep slopes with forest and less cultivated land and right bank has Narayanghat - Mugling Highway aligned parallel to the section. The section ends at Mugling linking Prithivi Highway. During the hydrographic survey, the deepest area of about 43 m has been detected in Bhorle of Chitwan at chainage of 17+250. The average discharge of Trishuli River according to Kalikhola gauging station is 914 cumec (DHM, 2008). The average gradient of the section is about 1 in 859 with average velocity of 1.4 m/s and average depth of 6.75 m.

#### 7.8.3 Section: Mugling - Fishlin (0+000 – 16+600)

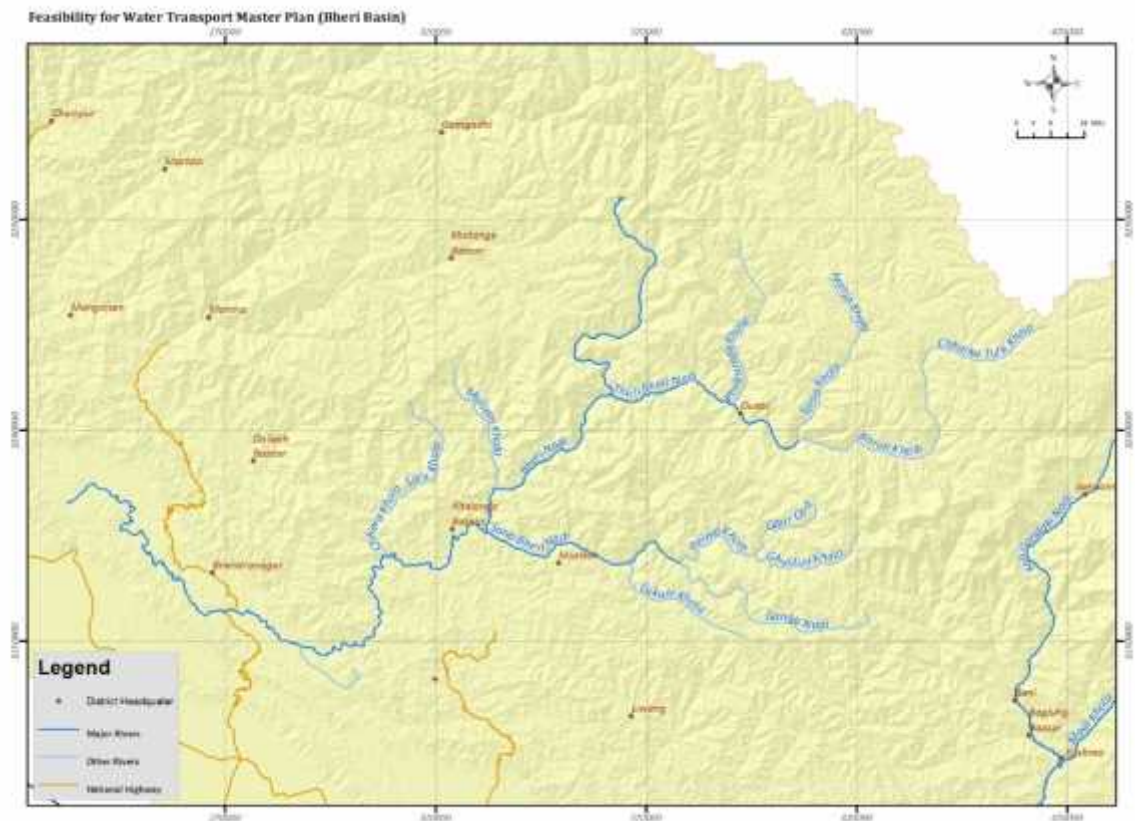
This section continues from Mugling and follows Trishuli. The scattered huge boulders forming critical rapid in Mugling area after the confluence of Marsyandi River can be observed. This section passes through the narrow gorge with hills on either side confining the river to the width for about 75 m. The both bank have steep rocky slopes with dense forest and few cultivated land. Few landslide areas are observed. This section exist several rapids of class 3-4 and renowned for rafting. The gravity ropeways are observed for the transportation of agricultural products from villages to the market places via Prithivi Highway. This section also runs parallel to the Prithivi Highway from start to end in right bank. The cable car of Manakamana is located in this section. The average gradient of the section is about 1 in 426 with average velocity of 2.2 m/s and average depth of 5.47 m.

## 8. WATER TRANSPORT STUDY IN BHERI BASIN

Bheri River lies in Western part of Nepal and it is merged with Karnali river which is the longest river of Nepal. It is a major tributary of the Karnali River draining from the western Dhaulagiri range in western Nepal which merges with Karnali in Sugarkhal (Kailali). Bheri River There are mainly two rivers amalgamating to form the Bheri River namely Thulo Bheri and Sano Bheri. The Thulo Bheri merge at Kalika (Dolpa) and Sano Bheri merge at Purtimkada (Rukum). The total catchment area of Karnali basin is about 42854 sq. km and the Bheri basin lie under the catchment occupying about 13669 sq. km. According to the Global Mapper Software, the length of Bheri River is about 285 km.

The Bheri River is a mature river that cuts a wide valley as it flows west to join the Karnali just before it cuts through the Chure Hills, disgorges onto plains of the Terai and flows into Royal Bardia National Park.

Thirty years ago, the whole of this area was wild pristine jungle, roamed by one of the last nomadic hunting tribes in Nepal, the Raute. There are still a few members of the Raute tribe living by the river and although some of the jungle has been cleared for farming, for the majority of the time cliffs, forest and wildlife will be seen.



Map 8-1 Bheri River and its Tributaries

### 8.1 Study of Proposed Waterway Corridor

The only mode of surface transport available in Nepal is Road, which apart from being a costly option, is beset with other strategic problems. Water transport study will provide an alternative mode to Nepal for its intermodal trade. WT mode is expected to be economical, environmentally friendly, safe, better manageable and direct with road to function as a complementary mode. Hence, the mode envisages spurring developmental activities along the proposed waterway, both contiguous and shadow area. Here, all the data is collected in the reference to the proposed waterway and it is divided into 4 sections in the Bheri Basin.

|                     |                                       |           |
|---------------------|---------------------------------------|-----------|
| Proposed Waterways: | Section 1: Karnali Bridge to GhatGaun | 15.59 km  |
|                     | Section 2: GhatGaun to Taranga        | 36.99 km  |
|                     | Section 3: Taranga to Kamalpur        | 19.80 km  |
|                     | Section 4: Kamalpur to Bhotechaur     | 50.51 km  |
|                     | Total                                 | 122.89 km |

## 8.2 Influence Area

Here the data of different factors like (demographic, Landuse pattern, Agriculture etc) are collected on the basis of core zone of Influence and umbral zone of Influence. The core zone of influence refers to the population who are inhabited along the river corridor, whereas umbral zone of influence area refers to the all the VDC in the district who can access the intermodal facilities.

Here, the VDC which are influenced by identified alignment is listed. There are 2 districts and 24 VDC out of 6 districts and 52 VDC in the Bheri River corridor.

Table 8-1 Direct influence VDC in Bheri River Corridor

| S.N | District | VDC                                                                                                                                                                                                                                          |
|-----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Surkhet  | Sahare, Ghumkhahare, Mehelkuna, Dahachaur, Gumi, Maintada, Lekhparsa, Dasarathpur, Ramghat, Kafalkot, Satakhani, Latikoili, Lekhparajul, Lekhgaun, Uttarganga, Kunathari, Hariharpur, Taranga, Tatopani, Pokharikanda, Babiyachaur, Ghatgaun |
| 2   | Kailali  | Sugarkhal, Baliya                                                                                                                                                                                                                            |

Source: District Development Profile of Nepal 2010/11

## 8.3 Socio Economic Study of Proposed Waterway Corridor

The general study of the Socio-Economy aspect of the project has been carried. The project has been focused to vulnerable groups along the proposed waterway. Vulnerable groups refer to the indigenous people as well as poor and dalits groups. In Nepal the indigenous population is popularly known as Janajatis which is also recognized by the government and constitutes about 37.2 percent (8.4 million) of Nepal's total population. The water transport development project covers Eastern, Central and Western part of Nepal. There are mostly indigenous people habitats along the proposed waterway.

In context of Nepal, Highways and Airports are the major infrastructure in the mode of transportation. Lack of adequate transportation infrastructure, especially in rural areas, results in significant limitations for communities. These limitations occur in terms of access to socio-economic and cultural centers such as schools, clinics, markets and other business centers. Limited access to schools hamper educational access for learners, lack of access to clinics hamper health development and limited access and mobility to markets and other business centers places limits on trade opportunities, and subsequently also limits the potential opportunity for earning an income and a subsequent improvement in the day-to-day living standard. The result is a poor socio-economic development standard.

The socio-economic data on the influence area are compiled and presented on the following sub-topics.

### i. Population

Here, the total population in Bheri river corridor is taken out from the VDC of specified district who were directly influenced by the project. According to Census 2001 demographic statistics, it occupies 1.09% of the total population of Nepal. In the reference to the latest population census (2001 AD), the following data is collected.

Table 8-2 Population in core zone of Influenced in Bheri River Corridor

| S.N | District | Total Directly Influenced Population |                |
|-----|----------|--------------------------------------|----------------|
|     |          | 2001 Census                          | 2011 Projected |
| 1   | Surkhet  | 133495                               | 170600         |
| 2   | Kailali  | 12762                                | 18833          |

Source: District Development Profile of Nepal 2010/11

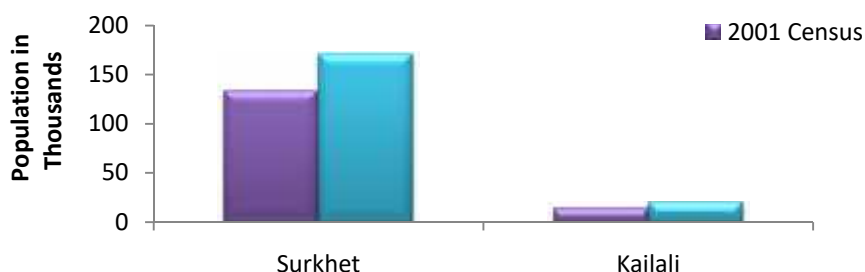


Chart 8-1 Population distribution along Bheri River Corridor

## ii. Land use Pattern:

Land use pattern in various influence area by Bheri river Project are given below and the given where area is in Hectare,

Table 8-3 Landuse Pattern in Bheri River umbral zone of influence area

| S.N | District | Agriculture |                 | Pasture | Forest | Other | Total  |
|-----|----------|-------------|-----------------|---------|--------|-------|--------|
|     |          | Cultivation | Non Cultivation |         |        |       |        |
| 1   | Surkhet  | 36175       | 16025           | 14398   | 177855 | 4563  | 249016 |
| 2   | Kailali  | 69667       | 11113           | 4837    | 23109  | 8081  | 324791 |

Source: District Development Profile of Nepal 2010/11

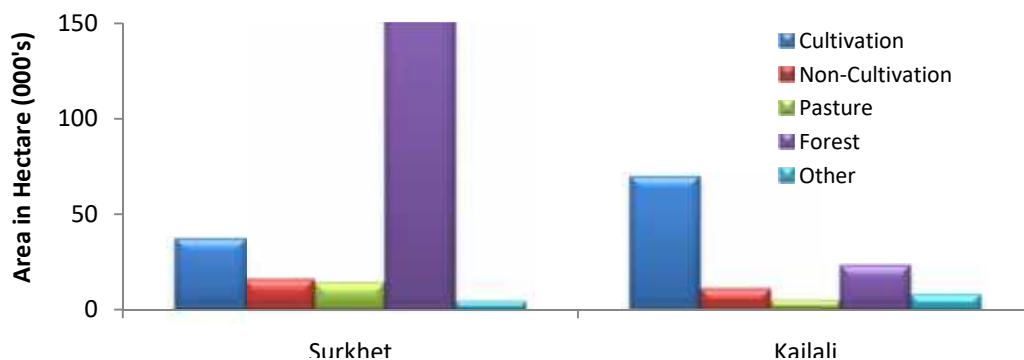


Chart 8-2 Landuse Pattern in Bheri River umbral zone of Influence area

## iii. Economic Activities :

In reference to the District profile 2010/11, the major source of income and employment in the Bheri river corridor are agriculture, tourism, civil services, fishery, porters, etc

## Agriculture

Agriculture is the major sector of Nepalese economy. It provides employment opportunities to 66 percent of the total population and contributes about 36 percent in the GDP. Therefore, the development of agriculture sector is key for the development of national economy.

The places where the production of cereal crops, cash crops, major crops, fruits, vegetables, pulses etc in the Bheri River influence area are summarized. The maximum production of Cereal crops like Mazie and Barley in Surkhet. The maximum production of cash crops like OilSeed, Potato, Tobbaco in Kailali, Sugarcane in Surkhet. The maximum production of Major crops like Garlic and Chilli in Kailali. The maximum production of pulses like Lentil, Pigeon Pea and Horse gram in Kailali, Chicken Pea and Black gram in Surkhet, The maximum production of fruits like mango and Jack Fruit in Surkhet, Banana, Guava and Papaya in Kailali. The maximum production of vegetables is in Kailali.

According to the agriculture statistics (2009/10) of different types of crops grown in various areas of Bheri River influence area are tabulated where Area in Ha and Production in Mt.

Table 8-4 Cereal Crops statistic in Bheri River umbral zone of influence area

| DISTRICT    | PADDY   |         | MAIZE  |         | MILLET |        | WHEAT  |         | BARLEY |       |
|-------------|---------|---------|--------|---------|--------|--------|--------|---------|--------|-------|
|             | Area    | Prod    | Area   | Prod    | Area   | Prod   | Area   | Prod    | Area   | Prod  |
| Surkhet     | 13800   | 44160   | 16100  | 42665   | 2095   | 2703   | 16255  | 30761   | 1030   | 1349  |
| Kailali     | 58500   | 146400  | 16500  | 28500   | 300    | 310    | 35000  | 63000   | 550    | 660   |
| N E P A L : | 1481289 | 4023823 | 875660 | 1855184 | 268473 | 299523 | 731131 | 1556539 | 26600  | 27587 |

Table 8-5 Cash Crops statistic in Bheri River umbral zone of influence area

| District | Oil Seed |        | Potato |         | Tobacco |       | Sugarcane |         |
|----------|----------|--------|--------|---------|---------|-------|-----------|---------|
|          | Area     | Prod.  | Area   | Prod.   | Area    | Prod. | Area      | Prod.   |
| Surkhet  | 4200     | 3808   | 1095   | 19359   |         |       |           |         |
| Kailali  | 20000    | 14000  | 6000   | 108000  | 15      | 10    | 205       | 8225    |
| NEPAL    | 198540   | 155050 | 185342 | 2517696 | 2534    | 2491  | 58310     | 2495098 |

Table 8-6 Some Major Crops statistic in Bheri River umbral zone of influence area

| Districts | Caradom |       | Ginger |        | Garlic |       | Turmeric |       | Chilli |       |
|-----------|---------|-------|--------|--------|--------|-------|----------|-------|--------|-------|
|           | Area    | Prod. | Area   | Prod.  | Area   | Prod. | Area     | Prod. | Area   | Prod. |
| Surkhet   | 6       | 4     | 530    | 6489   | 118    | 708   | 72       | 870   | 94     | 565   |
| Kailali   | 0       | 0     | 500    | 6500   | 120    | 850   | 82       | 985   | 500    | 2750  |
| NEPAL     | 11766   | 5232  | 18042  | 210790 | 5381   | 39483 | 4161     | 37926 | 6394   | 26712 |

Reference: www.moac.gov.np

## Minerals

The influence of Bheri water Transport Project can be sensed in the logistic of mineral products from its minning area.

Table 8-7 Minerals found in Bheri River umbral zone of influence area

| Minerals | Places  |
|----------|---------|
| Iron     | Surkhet |

Source: www.dmg.gov.np

## Market Places

The Project will influence in the business areas. Since these business areas are the attraction of trip generation, so there can be intramodal or intermodal transportation.

Table 8-8 Market Places in various districts lying in Bheri River umbral zone of influence area

| District | Market Places                                                                                          |
|----------|--------------------------------------------------------------------------------------------------------|
| Surkhet  | Birendranagar Market, Chhinchu Market, Ramghat Market, Badidachaur Market, Babiyaachaur, Ghuthu Market |

| District | Market Places     |
|----------|-------------------|
| Kailali  | Dhangadi, Tikapur |

Source: www.cbs.gov.np

#### Tourism

As we know that the tourism is about travelling, so when the inland navigation will be possible along the Bheri river corridor, tourist can feel the experience of navigation from plain areas passing through deep gorges formed by the Bheri River. We can also found that the various travel agencies are organizing the package of the rafting adventures in Bheri River. Thus, the possibility of tourism industry in the following places of Bheri River influence area,

Table 8-9 Tourism Area in Bheri River umbral zone of influence area

| District | Places                                             |
|----------|----------------------------------------------------|
| Surkhet  | Kakre Bihar, Bulbule Udhan                         |
| Kailali  | Tikapur, Ghodaghodi, Chisapani, Godabari, Dhangadi |

Source: www.cbs.gov.np

#### iv. Utility Services :

The Bheri-Babai Multipurpose Project is an inter-Basin water transfer project prioritised for the development of irrigation in Bardia District. The intake of the Bheri-Babai (BR-1) diversion scheme lies on the Bheri River 45 km upstream of the confluence with the Karnali River. The tailrace outlet is located in the Babai River 20 km upstream of the existing Babai irrigation project diversion weir. The Bheri-Babai project aims to generate electricity and supply additional water to the Babai Irrigation Scheme in the Terai by diverting 40 m<sup>3</sup>/s of water from the Bheri River into the Babai River. The project is yet to undergo a feasibility study. Here, the list of Hydropower status in Bheri River influence area is tabulated below.

Table 8-10 Total Hydro Power status in Bheri River umbral zone of influence area

| S.N | Hydro Project in Bheri WT influence area                     | MW    |
|-----|--------------------------------------------------------------|-------|
| 1   | Application for Survey License for Generation (1 to 25 MW)   | 3     |
| 2   | Application for Survey License for Generation (25 to 100 MW) | 84.75 |
| 3   | Application for Survey License for Generation (Above 100 MW) | 0     |
| 4   | Survey License for Generation (Below 1 MW)                   | 0     |
| 5   | Survey License for Generation (1 to 25 MW)                   | 4.8   |
| 6   | GoN Reserved Survey License for Generation                   | 48    |
| 7   | Operating Power Plants                                       | 0.895 |

Source: www.nea.org.np

#### v. Health

Here, the statistics of health facilities along the Bheri river corridor which is influenced by the project are tabulated.

Table 8-11 Health statistics in the Bheri River Umbral zone of influence area

| S.N | District | Hospitals | PHCC / HC | HP | SHP | PHC Out reach Clinic | EPI Clinic | FCHV | NGO / INGO & Private Sector |
|-----|----------|-----------|-----------|----|-----|----------------------|------------|------|-----------------------------|
| 1   | Surkhet  | 1         | 4         | 9  | 38  | 173                  | 181        | 920  | 4                           |

| S.N | District | Hospitals | PHCC / HC | HP | SHP | PHC Out reach Clinic | EPI Clinic | FCHV | NGO / INGO & Private Sector |
|-----|----------|-----------|-----------|----|-----|----------------------|------------|------|-----------------------------|
| 2   | Kailali  | 2         | 5         | 7  | 31  | 206                  | 253        | 1086 | 6                           |

Source: District Development Profile of Nepal 2010/11

#### vi. Transport

This project area is lacked from the transportation network compare to other project area. Since, there is low no. of highways aligned in this area. Here we can find Gravel road and few planning feeder roads. The Bheri River doesnot pass through to E/W highway, it has to merge with Karnali River to link with Mahendra Highway. The Ratna Highway connecting Nepalgunj and Surkhet has been aligned along the Bheri River route. Surkhet district has Airport along the Bheri River corridor. Here, the data of Transport facilities along the Bheri River corridor which is influenced by the project.

Table 8-12 Statistics of accessibility in the Bheri River umbral zone of influence area

| District | Types of Road |        |      |        | Road Category |       |     |    |      | Pop. Influence Per Km (Nos) | Road Density (Km / Km <sup>2</sup> ) | Air port |
|----------|---------------|--------|------|--------|---------------|-------|-----|----|------|-----------------------------|--------------------------------------|----------|
|          | BT            | GR     | ER   | Total  | NH            | FRN   | FRO | MH | PR   |                             |                                      |          |
| Surkhet  | 59.49         | 119.35 | 52.3 | 231.14 | 90.14         | 129   | 0   | 12 | 0    | 1248                        | 9                                    | 1        |
| Kailali  | 157           | 63.77  | 48   | 269.6  | 150.78        | 83.12 | 0   | 0  | 35.7 | 2287                        | 8                                    | 2        |

Source: District Development Profile of Nepal 2010/11

Table 8-13 Agricultural Road in Bheri River umbral zone of influence area

| District | Total Km | Completed  |             | Transportation Running Part (KM) |
|----------|----------|------------|-------------|----------------------------------|
|          |          | Dusty Road | Gravel Road |                                  |
| Surkhet  | 374.5    | 202.8      | 19.3        | 0                                |
| Kailali  | 129.5    | 95.5       | 91          | 79                               |

Source: District Development Profile of Nepal 2010/11

### 8.4 Hydrology Study of Proposed Waterway Corridor

#### 8.4.1 Hydrology

Water transport is based on the hydrological characteristics which are mainly precipitation, base flow, high flood level. To determine the waterway design, the detailed hydrological and metrological data from river and DHM has been collected. The collection of the data for Karnali Basin from Bheri River Proposed waterway of 123 km has been carried during the month of December, 2011.

The hydrological study is concerntrated in determining the obstruction for the proposed waterway and location of the terminal station with repect to high flood level. The depth of the river with its critical and narrow section has been surveyed result in plotting of profile of bed level with respect to water surface level. Here, Critical section refers to those sections along the proposed waterway which may affect in the maneuverity of the vessels due to bends, sandbars, boulder deposition, rapids etc.

#### 8.4.2 DHM data for Gandaki Basin Proposed Waterway Analysis

To study the availability of navigational discharge during different seasons in a year it is required to analyze the historical discharge data on the waterway under consideration for development. The discharge data has been collected from Department of Hydrology and Metrology (DHM), Babar Mahal and analyzed to establish low discharge and to study the availability of water for navigation.

In the length of 123 km of proposed waterway in Bheii basin, there are three gauging stations at Samajighat, Jamu and Chisapani. The details of these stations are given in table 6-14,

Table 8-14 Hydrological Station in Bheri Basin Proposed Waterway

| River   | Gauging Site | Station No. | Lat.     | Long.    | Elevation (m) | Area (km <sup>2</sup> ) | Records (From-To) | Remarks |
|---------|--------------|-------------|----------|----------|---------------|-------------------------|-------------------|---------|
| Bheri   | Samajighat   | 269.1       | 28 31 02 | 81 39 25 | 500           | 12200                   | 1992 - 2006       | Good    |
| Bheri   | Jamu         | 270         | 28 45 20 | 81 21 00 | 246           | 12290                   | 1963 - 2006       | Fair    |
| Karnali | Chisapani    | 280         | 28 45 20 | 81 17 30 | 191           | 42890                   | 1962 – 2006       | Good    |

Source: DHM, BabarMahal

### Samajighat

The mean monthly discharge at Samajighat for the years 2001 - 2010 are furnished in table,

Table 8-15 Average Discharge over the year in Bheri River at Samajighat

| Year | Jan  | Feb  | Mar  | Apr  | May  | Jun | Jul | Aug  | Sept | Oct | Nov | Dec |
|------|------|------|------|------|------|-----|-----|------|------|-----|-----|-----|
| 2001 | 96   | 81.6 | 74.2 | 84.4 | 132  | 403 | 941 | 1150 | 605  | 256 | 151 | 114 |
| 2002 | 100  | 98.7 | 99.3 | 126  | 216  | 244 | 543 | 1070 | 658  | 265 | 156 | 114 |
| 2003 | 101  | 102  | 97.9 | 119  | 147  | 266 | 789 | 1190 | 1120 | 341 | 170 | 120 |
| 2004 | 102  | 88.5 | 79.8 | 81.4 | 106  | 138 | 586 | 1060 | 378  | 245 | 144 | 110 |
| 2005 | 97.5 | 93.6 | 93.8 | 101  | 122  | 171 | 713 | 1020 | 558  | 269 | 155 | 115 |
| 2006 | 92.6 | 82.2 | 81.3 | 83.4 | 123  | 184 | 732 | 907  | 543  | 230 | 140 | 111 |
| 2007 | 90.8 | 90.1 | 106  | 120  | 135  | 198 | 738 | 1020 | 673  | 313 | 155 | 114 |
| 2008 | 95.7 | 85.6 | 79.7 | 87.6 | 108  | 438 | 929 | 1350 | 576  | 279 | 145 | 109 |
| 2009 | 89.5 | 80.7 | 72   | 74   | 85.6 | 110 | 425 | 823  | 607  | 424 | 161 | 114 |
| 2010 | 94.6 | 87.3 | 81.9 | 83.8 | 87.9 | 113 | 605 | 1170 | 1070 | 293 | 150 | 107 |

Note: All discharge in Cumecs

Source: DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 72 cumecs in the year 2009 and high flow are noticed during August of about 1350 cumecs in the year 2008.

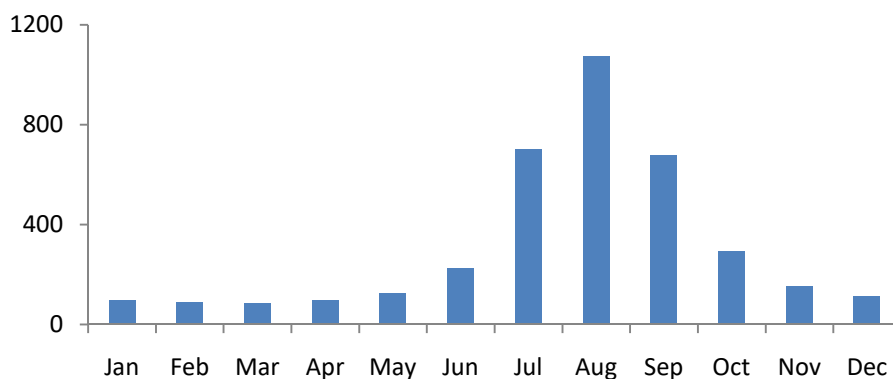


Figure 8-1 Hydrograph of Bheri River at Samajighat

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Bheri at Samajighat. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 1100 cumecs from lean season to flood season, the river rises by about 6.25 m.

### Jamu

The mean monthly discharge at Jamu for the years 1999-2008 are furnished in table,

Table 8-16 Average Discharge over the year on Bheri River at Jamu

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug  | Sept | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|-----|------|------|-----|-----|-----|
| 1999 | 212 | 208 | 200 | 212 | 208 | 405 | 821 | 973  | 679  | 427 | 279 | 245 |
| 2000 | 358 | 358 | 294 | 304 | 308 | 566 | 948 | 1390 | 692  | 353 | 289 | 244 |
| 2001 | 184 | 174 | 168 | 181 | 216 | 420 | 717 | 820  | 426  | 300 | 243 | 198 |
| 2002 | 169 | 177 | 180 | 188 | 194 | 221 | 480 | 839  | 409  | 248 | 215 | 186 |
| 2003 | 230 | 253 | 233 | 245 | 246 | 287 | 798 | 1130 | 879  | 412 | 298 | 263 |
| 2004 | 189 | 187 | 176 | 176 | 182 | 260 | 456 | 735  | 382  | 252 | 209 | 184 |
| 2005 | 175 | 175 | 164 | 163 | 172 | 294 | 634 | 738  | 447  | 284 | 226 | 208 |
| 2006 | 200 | 203 | 203 | 234 | 305 | 330 | 794 | 895  | 632  | 353 | 227 | 222 |
| 2007 | 184 | 197 | 172 | 181 | 176 | 239 | 734 | 727  | 349  | 278 | 225 | 205 |
| 2008 | 213 | 221 | 212 | 220 | 216 | 453 | 765 | 904  | 444  | 272 | 234 | 213 |

Note: All discharge in Cumecs

Source: DHM, BabarMahal

The table indicates that the low discharge are generally observed during April of about 163 cumecs in the year 2005 and high flow are noticed during August of about 1390 cumecs in the year 2000.

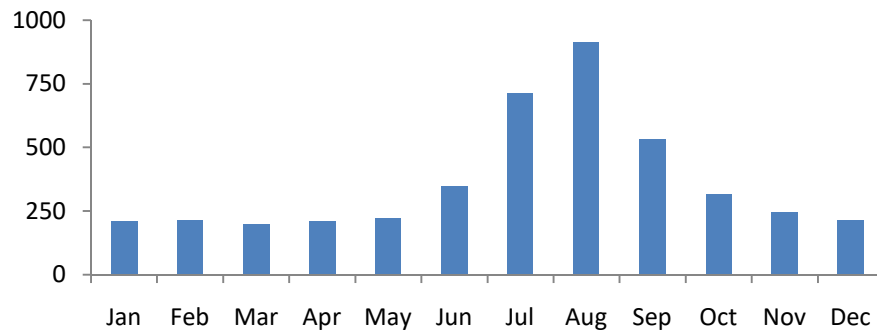


Figure 8-2 Hydrograph of Bheri River at Jamu

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Bheri at Jamu. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 700 cumecs from lean season to flood season, river rises by about 6.8 m.

#### Chisapani

The mean monthly discharge at Chisapani for the years 2001-2010 are furnished in table,

Table 8-17 Average Discharge over the year in Karnali River at Chisapani

| Year | Jan | Feb | Mar | Apr | May  | Jun  | Jul  | Aug  | Sept | Oct  | Nov | Dec |
|------|-----|-----|-----|-----|------|------|------|------|------|------|-----|-----|
| 2001 | 354 | 223 | 193 | 272 | 799  | 1890 | 4110 | 4110 | 2060 | 964  | 544 | 350 |
| 2002 | 282 | 321 | 347 | 582 | 1170 | 1330 | 2360 | 4330 | 3290 | 1120 | 626 | 385 |
| 2003 | 294 | 340 | 320 | 520 | 777  | 1530 | 3400 | 4600 | 4460 | 1580 | 780 | 519 |
| 2004 | 412 | 314 | 249 | 276 | 510  | 778  | 2410 | 4370 | 2240 | 1310 | 665 | 462 |
| 2005 | 386 | 400 | 448 | 519 | 800  | 1250 | 3240 | 4230 | 2720 | 1380 | 701 | 470 |
| 2006 | 331 | 248 | 247 | 294 | 726  | 1030 | 3060 | 3960 | 2430 | 987  | 575 | 401 |
| 2007 | 263 | 282 | 456 | 576 | 777  | 1210 | 3540 | 4630 | 2980 | 1480 | 695 | 456 |
| 2008 | 320 | 247 | 214 | 307 | 568  | 2120 | 3760 | 5560 | 2730 | 1340 | 686 | 442 |
| 2009 | 400 | 347 | 287 | 322 | 489  | 770  | 2040 | 3810 | 2420 | 2390 | 725 | 462 |
| 2010 | 350 | 322 | 296 | 333 | 463  | 603  | 2250 | 4580 | 3890 | 1170 | 587 | 391 |

Note: All discharge in Cumecs

Source: DHM, BabarMahal

The table indicates that the low discharge are generally observed during March of about 193 cumecs in the year 2001 and high flow are noticed during August of about 5560 cumecs in the year 2008.

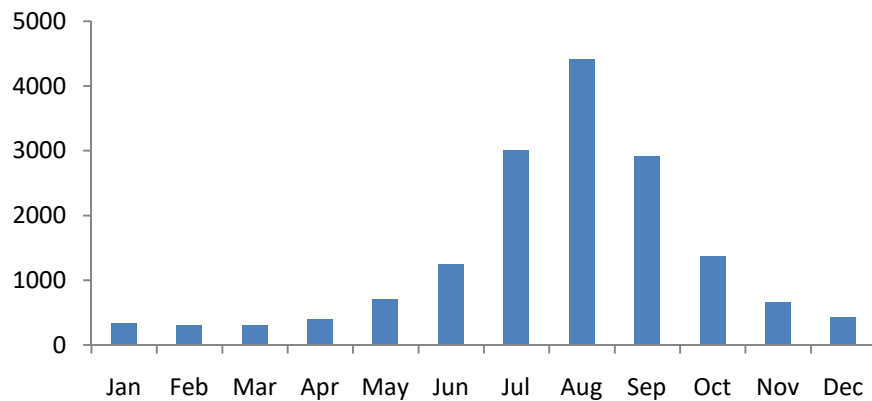


Figure 8-3 Hydrograph of Karnali River at Chisapani

This hydrograph is based on the ten years average data which indicates the general behavior of the flow variation in the river Karnali at Chisapani. The river experiences lowest low water during March and the river start rising from May and reaches peak flood during August. This shows if the discharge of the river is increased by about 4500 cumecs from lean season to flood season, the river rises by about 10.64 m.

#### 8.4.3 Field Investigation for Bheri Basin proposed Waterway

Hydrographic survey was conducted on December for proposed waterway in Bheri Basin. The survey was done using rafting boat from Botechaur to Chisapani in Bheri and Karnali River. The elevation difference of 277 m has been observed in 123 km proposed waterway. The hydrographic survey in these stretches, the position and sounding depth has been recorded by using EchoSounder and GPS. All the conspicuous objects nearby banks were obtained with the help of GPS and noted on the survey book.

##### Profile of River surface and its bed level

The data from the DHM is the secondary data to analyze the water level w.r.t discharge. The primary data collected from hydrographic survey has been used to plot the profile of river surface and its bed level. The gradient in section B-CG of Karnali River seems to be mild and increase in gradient in proceeding section of Bheri River. This can be visualized in the data and drawing of profile of the bed level and water surface level of Proposed waterway which has been attached in Annex.

##### Identification of obstruction in proposed waterway

The proposed waterway in Bheri River has been identified as the class 2-3 where numerous small rapids can be found. Rapids are the high current area formed due to the excessive boulders deposition at its bed level. The converging of tributaries, bends and landslide area are mainly places of rapid formation. If the boulders deposition are excess, then the formation of rapid with shallow depth in downstream and dam phenomenon in upstream creating still section with maximum depth. The velocity of the Bheri River is quite high since, the gradient of river is uniformly descending. The proposed waterway in Karnali River is found to be quite still and the width of entire length is fairly wide.

During field investigation some of the possible obstruction for proposed waterway in Bheri basin has been detected which are Rapids, Bends and Bifurcation. But among these, rapid is the most crucial in our study. The summary of identified rapids has been tabulated below:

Table 8-18 Summary of Rapids

| Section | No. of Rapids |
|---------|---------------|
| B-CG    | 5             |
| B-GT    | 14            |
| B-TK    | 13            |
| B-KB    | 23            |
| Total   | 55            |

The details of the rapids have been attached in the Annex.

#### Identification of Civil Infrastructure in Proposed waterway

The infrastructures which are on operation, obsoleted or under construction have been identified along the proposed waterway in Gandaki basin. The summarized data has been tabulated below:

Table 8-19 Summary of Identified Civil Structure

| Type of Structure               | Numbers |
|---------------------------------|---------|
| Tread Bridge                    | 10      |
| Motor Bridge                    | 2       |
| Under Construction Motor Bridge | 1       |
| Ropeway                         | 6       |
| Transmission Line               | 3       |
| Gauging Station                 | 3       |

The details of the identified civil infrastructures have been attached in the Annex

## 8.5 Geological and Environmental Study of Proposed Waterway Corridor

### 8.5.1 Geological Features in Proposed waterway

Physiographically, the proposed waterway of 123 km passes from centre of Siwalik range and aligned parallel to the MBT.

Siwalik zone also called Churia Hills consists of fluvial sedimentary rocks of Neogene to quaternary age (14 to 1 million years) which elevation ranges from 200 m -700 m above sea level. This zone is bounded to the north by MBT and to south by MFT. Rocks of this zone are divided stratigraphically into 3 parts. The lower Siwalik consists of fine grained mudstone, siltstone and shale. The middle Siwalik is marked by thick multistoried stone beds cycle of finding upward sequences is normally observed. The upper Siwalik is characterized by very coarse grained rocks such as boulder conglomerates.

Geologically, the purposed waterway in Bheri River is found fragile due to the parallelly aligned MBT and lying of waterway in Siwalik range itself is critical. In this region, earthquake frequently hits and one volcanic action has occurred in section B-TK (5+000) at Tal due to this settlement in Tal has to be shifted.

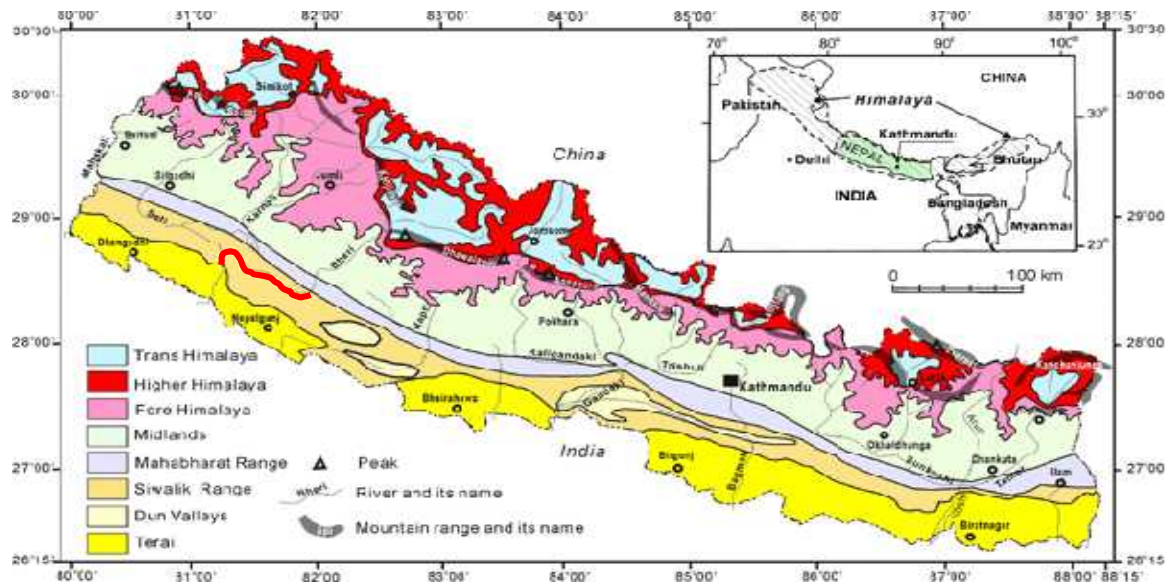


Figure 8-4 Physiographic map of Nepal

### 8.5.2 Environmental Features in Proposed waterway

The baseline information of the existing physical and biological environment of the proposed Bheri waterway project is described as below:

#### i. Physical Environment

##### Climate

Sub-tropical to warm temperate climatic conditions prevails in the Bheri waterway area. Air temperature measured is lowest in winters (January mean temperature of 7.2-12.2 °C) and highest in May and June (Mean temperature 28-31.20C). Mean annual rainfall for Bheri River basins is 1,302 mm.

##### Topography and Land Use

The proposed bheri waterway is located in the Chure region. The elevation of the proposed waterway ranges from 200m to 480m. The major land use types within the Bheri watershed are cultivated land (10.96%), forest (36.09%), bush (7.11%), and grazing land (15.67%). The different land use type of the Bheri watershed is given in the table below and the map is shown in Annex Vol-II.

Table 8-20 Land Use Type of Bheri Watershed

| Landuse Type | Percentage (%) |
|--------------|----------------|
| Built up     | 0.0001         |
| Cliff        | 0.04           |
| Cultivation  | 10.96          |
| Forest       | 36.09          |
| Orchard      | 0.0004         |
| Grass        | 15.67          |
| Bush         | 7.11           |
| Sand         | 1.43           |
| Barren Land  | 27.20          |
| River/Stream | 0.28           |
| Pond/Lake    | 0.08           |

Source: Department of Survey, 1995

## Air, Noise and Water Quality

As there are no any large scale development project and industries in the proposed waterway area, the quality of Air and Water observed good. Only water in the local streams gets polluted with flash flood, which carries sediments with it during rainy season. No any serious causes of noise pollution are observed.

## ii. Biological Environment

A rich bio-diversity is observed in the proposed area consisting of significant composition of flora and fauna.

### Natural Forests and Tree Vegetation

The major tree species in the proposed surrounding waterway area are Sal (*Shorea robusta*), Saj/Asna (*Terminilia alata*), Barro (*Terminilia bellerica*), Harro (*Terminilia chebula*), Karma (*Adina cordifolia*), Banjhi (*Anogeissus latifolia*), Kusum (*Scheichera trijuga*), Amala (*Embilica officinalis*), Botdhyenro (*Lagrostomeia parviflora*), Jamun (*Syzygium cumini*), Khayar (*Acacia catechu*), Sissoo (*Dalbergia sissoo*), Simal (*Bombex Ceiba*), Sandan (*Ouginia oojenensis*), Jhingan (*Eurycia acuminata*), Rajbrikshya (*Cassia fistula*), Bhalayo (*Semecarpus anacardium*), Koiralo (*Bauhinia variegata*), Mauwa (*Engelhardtia spicata*).

Major shrub and herb species found in the study area are *Murraya exotica*, *Indigofera pulchella*, *Nyctanthes arbor-tristis*, *Barleria cristata*, *Cassia tora*, *Cassia odoratissima*, *Careya arborea*, *Justicia adhatoda*, *Clerodendrum infortunatum*, *Colebrookea oppositifolia*, *Holoptelia integrifolia*, *Holmskioldia sanguinea*, *Jasminum pubescens*, *Woodfordia fruticosa*, *Phoenix humilis*, *Kurilo (Asparagus racemosus)*, *Bayar (Zizyphus mauritana)* etc.

Bhorla (*Bauhinia vahlii*), *Spatholobus roxburghii*, *Vitis sp.*, *Smilax macrophylla* are some of the lianas and climber species found in the study area.

### Terrestrial Wildlife

Historically, this area is very much suitable for wildlife and there was a good population of wild animals in these area but are now degraded in most areas except Bardia National Park (BNP), mainly due to land clearing, habitat fragmentation and over hunting.

The main larger terrestrial mammals making substantial use of the riverine zone in BNP include deer (i.e. sambar and barking deer), wild boar, fishing cats, rhinoceros and elephant, tiger, Gangetic dolphin, hispid hare, and four horned antelopes etc. Of the total 53 mammal species found or suspected to be found in BNP, 10 mammals species are protected by National Park and Wildlife Conservation act 1973. These protected species are Hispid Hare, Gangetic dolphin, Stripped Hyena, Leopard, Tiger, Asiatic Elephant, Rhinoceros, Swamp Deer, Black Buck and Four Horned Antelopes.

Major avian species of the area are black stork (*Ciconia nigra*), giant horn bill (*Buceros bicornis*), Indian gibbon (*Gyps indicus*), blue breasted quail (*Coturnix chinensis*), Wood peckers, Kingfishers, Vultures. Other common species include House Sparrow, Mayur, Dove, Common Crow, and Crane etc.

### Fish and Other Aquatic Animals

There is an endangered population of Ganges River Dolphins in the Karnali River between the irrigation barrage in India and Karnali gorge, and their long-term viability is in question. Sometimes these dolphins use the Karnali/Bheri confluence area. A diversion of 40m<sup>3</sup>/s represents less than 3% flow of the Karnali River's mean monthly flow and the river levels in the area are influenced by Karnali River levels. Thus the diversion would probably have limited or negligible effects on the Karnali River's Dolphin populations.

Turtles, crocodiles (*Crocodylus palustris*), frogs (Indian skipping frog, Cricket frog and Indian bull frog) toad (Asian toad and marble toad), lizards (Cashmir rock agama, Asian house gecko, common keeled grass skin),

snakes (Asiatic rock python, Olive keel back water snake, common krait, Cobra, banded krait) are found in the proposed waterway area.

The fisheries resources of the Bheri River systems are extensive and characterized by fish migration for spawning and are subject to over fishing, particularly in the area accessible from main roads. Fish species found in the Bheri River are given in the given table.

Table 8-21 Fish species in Bheri River

| S.N | Local Name    | Scientific name                      |
|-----|---------------|--------------------------------------|
| 1   | Katle         | <i>Neolissocheilus hexagonolepis</i> |
| 2   | Rajbam        | <i>Anguilla Bangalensis</i>          |
| 3   | Thend         | <i>Bagrius bagrius</i>               |
| 4   | Faketa        | <i>Bagrius barna</i>                 |
| 5   | Faketa        | <i>Bagrius bendalensis</i>           |
| 6   | Chiple faketa | <i>Bagrius vagra</i>                 |
| 7   | Baghi         | <i>Botia almorhae</i>                |
| 8   | Jalkapoor     | <i>Clupisonagaura</i>                |
| 9   | Lori          | <i>Garra annadalei</i>               |
| 10  | Buduna        | <i>Garragotyla</i>                   |
| 11  | Kabre         | <i>Glyptosternum blythi</i>          |
| 12  | Kabre         | <i>Glyptosternum telchitta</i>       |
| 13  | Gard          | <i>Labeo angara</i>                  |
| 14  | Gardi         | <i>Labeo dero</i>                    |
| 15  | Chuchee bam   | <i>Mastacembelus armatus</i>         |
| 16  | Gadela        | <i>Neomacheilus rupicola</i>         |
| 17  | Kabre         | <i>Pseudecheneis sulcatus</i>        |
| 18  | Tite          | <i>Psilorhynchus pseudechensis</i>   |
| 19  | Buchheasala   | <i>Schizothorax taylori</i>          |
| 20  | Chuchheasala  | <i>Schizothorax prostratus</i>       |
| 21  | Sahar         | <i>Tor putitora</i>                  |
| 22  | Sahar         | <i>Tor tor</i>                       |

## 8.6 Existing Water Transport Senerio

In Context of Nepal, Water transport is mainly for promotion of tourism industry rather than public transportation. The promotion of the tourism industry in water transport is done by white water rafting. The white water rafting has been started in late 1960's by two French in Sunkoshi. In 1976, the first Commercial River rafting company named Himalaya River Expedition was launched and experienced river guide, Mike Yager of America was brought to manage the company and to train Nepalese guides. From this phase to present, rafting in Nepal has really taken off and Nepal is known as one of the world's premier river running destinations.

In Bheri Basin, under the proposed waterway there is only one type of existing Water Transport i.e. Adventure / Recreational purpose

### 8.6.1 Adventure / Recreational purpose

Bheri River is one of the most scenic rivers in Nepal with golden cliffs, green jungle, crystal clear green water, white beaches, excellent fishing, good bird watching, coupled with sparkling rapids of moderate difficulty which has attracted the expedition in the river. The rafting agency has marked the starting point Devisthal and end point Chisapani which length is about 142 km and they have scheduled the rafting trip for about 5-6 days. According to the rafting agency, the best month for rafting in this river is in February to May and October to November, when the discharge of the river starts to increase and decrease.

## 8.7 Traffic Study of Proposed Waterway Corridor

According above chapter, the Traffic description for particular waterway,

| Section | Type of service           | Vessel Capacity | Frequency/day | no. of passengers/day | No. of Vessel | remarks          |
|---------|---------------------------|-----------------|---------------|-----------------------|---------------|------------------|
| B-CG    | Jet boat for sight seeing |                 |               |                       |               | Existing service |
| B-GT    | Jet boat for sight seeing |                 |               |                       |               | Existing service |
| B-TK    | Jet boat for sight seeing |                 |               |                       |               | Existing service |
| B-KB    | Recreational/Rafting      | Rafting Boat    |               |                       |               | Existing Service |

According above chapter, traffic count for proposed waterway,

| Section | Type of service                               | Vessel Capacity | Frequency/day | no. of passengers/day | No. of Vessel | remarks                  |
|---------|-----------------------------------------------|-----------------|---------------|-----------------------|---------------|--------------------------|
| B-CG    | Jet boat for sightseeing Bardia National Park | 25              | 2             | 50                    |               | Proposed Jetboat service |
| B-GT    | Jet boat                                      | 25              | 4             | 100                   |               | Proposed Jet boat        |
| B-TK    | Jet Boat                                      | 25              | 4             | 100                   |               | Existing service         |
| B-KB    | Recreational/Rafting                          |                 |               |                       |               | Existing Service         |

## 8.8 Engineering Characteristics of the Proposed Waterway Section

### 8.8.1 Section: Chisapani - Ghatgaun (0+000 – 15+590)

The section lies in the Karnali River where deep gorges are formed by the river with mild gradient throughout the length of the section. The both bank have dense forest and Bardiya National park is located in right bank. The left bank have few settlement area linking with E-W highway with the service of earthen road. The major settlements are Chisapani, Pitmari, Kachali, Kuineghat and Ghatgaun. The section has been linked with the E-W Highway at Chisapani. During the hydrographic survey, the deepest area of about 15.6 m has been detected in Chisapani. The average discharge of Karnali River according to Kotagaun gauging station is 1380 cumec (DHM, 2010). The average gradient of the section is about 1 in 708 with average velocity of 1.4 m/s and average depth of 6.6 m.

### 8.8.2 Section: Ghatgaun - Taranga (0+000 – 36+990)

The section seems to be confined by the hills on the either side but in the area where the tributaries have been confluence it has been widen due to the flash floods and formation of sandbars can be observed. The section is mostly governed by the dense forest area and steep hills on the side of the bank. This section exist rapids of class 2-3 where the shallow area are identified as critical. The cultivation land can be identified near the settlement area. The major settlement areas in this section are Ghatgaun, Jamu, Chepan and Taranga. Absence of the road service has forced the local and neighbouring district people to walk along the Bheri River. According to field investigation, many people use this section for route to India via Chisapani. The average discharge of Bheri River according to Jamu gauging station is 391 cumec (DHM, 2008). The average gradient of the section is about 1 in 355 with average velocity of 2.3 m/s and average depth of 3.74 m.

### 8.8.3 Section: Taranga - Kamalpur (0+000 – 19+804)

This section also passes through the narrow gorge with hills on either side confining the river to the width for about 70 m. The braiding of the river can be taken in consideration with few rapids of class 2-3. This section is also mostly governed by the dense forest area and steep hills on the both side of the bank. In the top of the hill at Tal (4+500), the volcanic disaster has occurred in 2007 A.D. due to which the settlement of Tal has to shift nearby

places. The cultivation land can be identified near the settlement area. The major settlement areas in this section are Taranga, Pagma and Kamalpur. The service road is also absent in this section. The average gradient of the section is about 1 in 340 with average velocity of 2.2 m/s and average depth of 4.04 m.

#### 8.8.4 Section: Kamalpur - Botechaur (0+000 – 50+510)

This section also passes through the narrow gorge with hills on either side confining the river to the width for about 65 m till Ramghat (26+000) and above it the plain lands are seen where the settlement is densely populated. The lower reach of the section is mostly governed by the dense forest with few settlement areas whereas upper reach of the section is fully administered by the settlement with cultivation land. The major settlements are Kamalpur, Ramghat, Mehelkuna, Dasarathpur and Botechaur. The Ratna Highway has been linked with proposed waterway at Ramghat. The river seems to be shallow with crystal clear water. The difficulty grade of the section is 2-3. The average gradient of the section is about 1 in 446 with average velocity of 2.1 m/s and average depth of 3 m.

## 9. PROPOSED INTERVENTIONS FOR WATER TRANSPORT

### 9.1 Selection of Vessel

The guiding factor for the water transport for operation on the Koshi, Gandaki and Bheri Basin Rivers are river current, depth and obstructions in the river. Many types of vessels can be selected in different areas of the proposed waterway. The vessel selected should maneuver through out the length of proposed waterway in two ways continuously. Taking consideration of these entire factors, the most feasible boat can be,

#### Power Boats:

Power Boat is a boat which is powered by an engine. Some motorboats are fitted with inboard engines, others have an outboard motor installed on the rear, containing the internal combustion engine, the gearbox and the propeller in one portable unit. An inboard/outboard contains a hybrid of a powerplant and an outboard, where the internal combustion engine is installed inside the boat, and the gearbox and propeller are outside. This type of boat can be feasible in the lower reaches of the proposed waterway, due to the propeller; it cannot maneuver in the rocky areas having shallow areas. In our context, the locally made similar to power boats are operated in the dam area of Kali Gandaki.

| Specification |             |
|---------------|-------------|
| LOA           | 20.95 m     |
| Beam          | 5.20 m      |
| Draft         | 0.8 m       |
| Depth         | 1.5 m       |
| Capacity      | 30-50 seats |
| Speed         | 15-30 kmph  |



Photograph 9-1JL2100, Public Boat, China

#### Jet Boat:

Jet boat is boat without propeller which operates in the principle of Newton's Third law of motion. The water is intake from its suction unit and pressurized jet of the water is flushed out from the nozzle which pushes the boat forward. It has high speed, can maneuver against the river current and have shallow running capabilities. Its body is made from aluminium and chassis is extremely tough which can resist high degree of impact. This type of boat is mostly feasible in the most areas of proposed waterways. This type of boat can be found in operation in Chatara-Simle existing waterway, operated by private service provider. Refer Annex for specification.

| Specification |               |
|---------------|---------------|
| LOA           | 34'           |
| Beam          | 11'           |
| Draft         | 14"           |
| Engine        | 2-340 HP      |
| Capacity      | 20 - 25 seats |
| Speed         | 100-105 kmph  |



Photograph 9-2Jet Boat Twin Diesel, USA

**Hovercraft:**

Hovercraft is fully amphibious machine which can operate over water, land, sand banks, mudflats, ice, rocks and rapids. It is diesel engine which has low operating cost similar to conventional boats. It operates by lifting the vessel with air generated by the turbines. It is easy to operate and takes the same time to learn or operate as driving cars and trucks. The noise traditionally associated with hovercraft has reduced by the use of diesel instead of turbine engines. This type of machine can maneuver in all areas of proposed waterway. **Refer Annex for specification.**

| Specification |               |
|---------------|---------------|
| LOA           | 12.7 m        |
| Beam          | 6.1 m         |
| Draft         | 14"           |
| Engine        | 585 HP        |
| Capacity      | 20 - 25 seats |
| Speed         | 60-65 kmph    |



Photograph 9-3 Hovercraft 2400TD, Britain

## 9.2 Improvement of Waterways

The unsuitable river sections are subjected to the physical improvement of river cross section. The improvement of river cross section is technically difficult and uneconomical. However, improvement of short section may play vital role for the development of water transport. The development of water transport routes along the river in the hilly topographical region is very difficult due to the following reasons.

**Young river geology of area:** the Himalayn geology is characterized by the relatively newly formed rock hills and mountains. The slope stability on the river banks is very critical issue for any the human intervention. The slight change in the natural stability may result in the huge mass flow during rainy season. The appropriate technical technical assessment of river bank slope should be conducted before improvement of river cross section.

**Steep river bed slope:** steep river bed slope formed by the impermeable layer of hard rock formation results the high water velocity in the river. The rapid sections along the proposed water transport routes creat the obstruction to the vessel movement. The river bed slope could be improved by removing boulders or cutting the bed rock. Depending upon the river sections and water level methodology may differ at different sections. Boulder removing methodology is described below.

**Rainfall pattern:** rainfall pattern in the country is very critical to the yearround water transport services. Rainy season with full cross sectional flow is risky for transport. The water transport is not possible from June to August.

### 9.2.1 Boulder removing

Most of the critical river sections are due to the boulder depositions on the river bed. The high current of river water transport the big boulders from steel bed slope to the relatively mild slope. This transportation mechanism of deposition may raise the river bed and create the rapid sections in the river. Winching can be done, since it takes an incredible force of water to move boulders in a river. The work to perform the boulder removal from the rivers with the help of tools is Winching. For moving boulders in shallow and bank areas, it can be done by hand using 5-foot (or longer) steel pry bar.

### Different types of winches:

#### i. Come-Along:

A “come-along” is a portable, hand-operated winching device that can be of considerable help to a small-sized digging program. It can be used to move those boulders that are not huge, but which are too large to be moved by hand.

#### ii. Grip-Puller:

There is a handle that you crank back and forth, similar to a come-along. Each time the handle is cranked in each direction, the device moves an inch or two along the cable.

#### iii. Using truck for winching:

If the vehicle (Bull Dozer) can be driven to a nearby position, the cable can be stretched from the vehicle to the boulder. The proper direction of pull can be rigged up by running the cable through snatch blocks (heavy-duty pulleys) which can be anchored to trees, boulders or whatever is available. Then the pulling-power of the truck will help move the boulders out of the way.

#### iv. Auxillary truck winch:

Auxiliary automotive winches are also able to move small to mid-sized boulders for a dredging operation with excellent results. Some of those little winching units have a wondrous amount of power. A typical 8,000 or 10,000-pound electric winch will move a surprisingly-large boulder. If you are going to be using an electric winch, you may want to consider installing dual batteries in your vehicle. It also helps to keep the engine running while you are winching, so the batteries can quickly regain their charge between pulls.

#### v. Portable Powered Winches:

Gasoline-powered, mechanical and hydraulic winches are available in all sizes. Generally, the larger they are, the more winching-power that they produce. But, the added size and weight also makes them more difficult to pack into some of the less accessible areas. The more pulling-power you have available, the smoother and faster winching will go.

### Process of winching boulders from river:

Since, the winching is one the most labourious and technical work for boulder displacement from river. The steps of the winching boulders from river are:

#### i. Feasibility of moving Boulders

A dredging operation that requires a lot of boulders to be winched is going to move slower than if little or no winching is required. A winching operation almost always requires the involvement of at least one other person, sometimes even two or more. Those “extra hands” will usually expect to get something for their active participation in your dredging project. So you will find that when you need to use a winch, you will be moving slower through the pay-streak, and it will usually cost more to run the operation. Therefore, a pay-streak that has lots of boulders usually needs to pay pretty well to make the additional effort worthwhile.

#### ii. Setting up a hole for winching

Before you start winching boulders, it is a good idea to first make sure that you have located the lower (downstream) end of the pay-streak.

### iii. Building of ramp

It can be really tough to pull a boulder out of a hole without a ramp. Cobbles can be used to make an effective ramp for winching boulders out of a dredge hole.

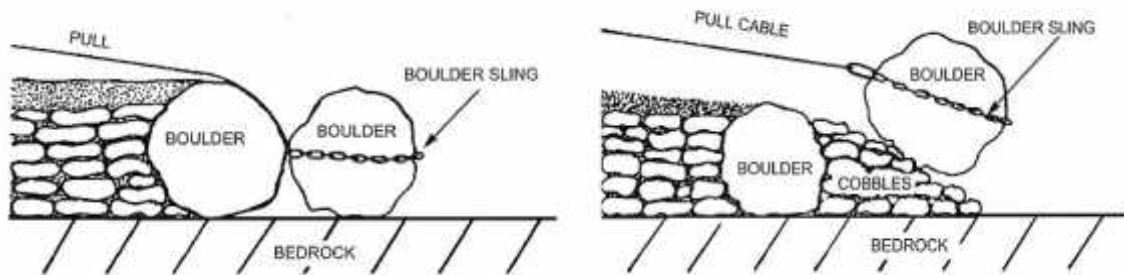


Figure 9-1 Boulder out of hole without and with ramp

### iv. Setting up a winch for operation

When you are using a portable power winch to move boulders in a dredging operation, the winch must be set up on a solid and stable foundation. It takes a tremendous amount of force to move a boulder. Sometimes, the boulder will move quickly. Or, sometimes, the sling will slip off the boulder, causing the cable to suddenly go slack. Maybe the boulder will loosen up and roll the wrong way, causing a sudden, heavy stress on the cable. When these things happen, and they do happen, you do not want your winch bouncing around or sliding off the platform. That could be extremely dangerous! The winch must be stable!

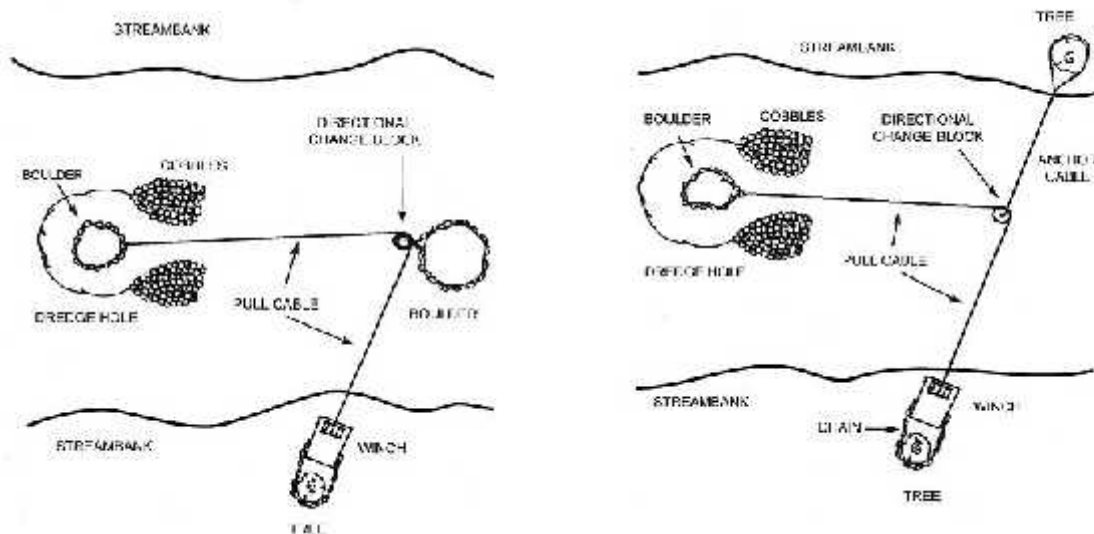


Figure 9-2 Graphical view for various winching operation

### v. Pulling of Boulders

Some boulders come easy and some do not. A lot of the problem is in breaking the boulder's initial suction/compaction in the streambed. If your winch does not have the power to pull a boulder the way you have slung it, sometimes you can break the boulder free by using a rolling hitch. A "rolling hitch" is rigged by slinging the boulder backwards, then running the chain or cable over top of the boulder. This places the winch's pulling-power along the most-leveraged position on the boulder. This will sometimes free a stubborn boulder by rolling it.

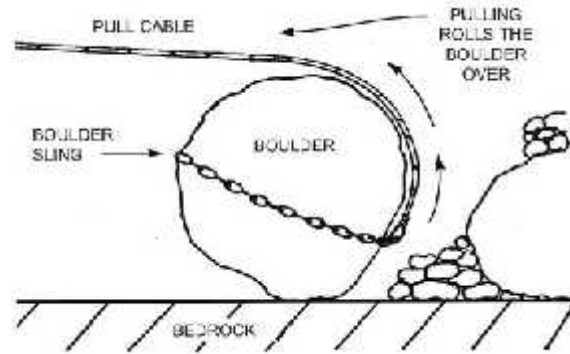


Figure 9-3 Pulling a boulder with the help of Sling

### Diver's Safety

A diver will be safest by staying well away from the area where a boulder is being winched, and the path it will be taking as it is being pulled. The forces involved in winching are more than enough to cause a very serious accident. Since the diver is underwater, the winch operator sometimes cannot see what is happening where the boulder is located.

What can happen down there, though, is when the diver sees the boulder getting hung up on things as it is being pulled along, he wants to move in and help it along with his pry bar. The less power that your winch provides, the more the diver will naturally feel the need to help the boulder along in this way. Never forget that your safety margin is considerably reduced when you get near a boulder while it is being pulled! A safer course of action would be to stop the pulling and reset the harness, or reset the direction of pull, or improve the boulder ramp, or find a stronger winch for the job.

### 9.2.2 Hard rock cutting

The impermeable or hard rock on the river bed sometimes may create the obstruction to the vessel movement. Generally the sharp bends and huge boulder in the river bed formed by the hard rock causes unfavourable flow pattern for the water transport. These sections could be improved by the cutting of hard rock. The blasting of the hard rock might be an appropriate method for the correction of such sections. Any rock or boulder (more than 0.5 cum in volume) which requires use of mechanical plant or blasting for excavation or splitting. The blasting method is only favourable for armed personnels which are authorized by the national security. If blasting is prohibited for any reason and excavation has to be carried out by chiselling, wedging or any other agreed method (Winching).

### 9.3 Legislation and Institutional Policy Framework

Related to the water transport in Nepal, the different act and policy can be incorporate to build the unite policy in the absence of the Act. The project should be executed underlaying the Act and policy of the Nepal Government. The Act that can be incorporate are:

#### i. Water Resources Act, 2049

It has prioritized the water tranport in level 6. The hierachy of the priority for the utilizing the available water resources has been presented below,

1. Drinking Water
2. Irrigation

3. Agricultural Purpose (fish farming)
  4. Hydropower
  5. Cottage or Industrial Use including Mining use
  6. Water Transport
  7. Other use
- ii. Insurance Act, 2049
  - iii. Geneva Convention on the High Seas, 1958
 

High seas means all parts of the sea that are not included in the territorial sea or in the internal waters of a state. It deals with the freedom of navigation, fishing, flyover over high seas for both coastal and non-coastal states.
  - iv. United Nations Convention of the Law of Seas, 1982
 

Ratified by Nepal on 2nd November, 1998 in which the rights for the landlocked states like Nepal for the promotion in the economic sector.

#### 9.3.1 Context of National Transport Policy-2058

MoPPW has 'National Transport Policy-2058' which contains the long term strategy and action plans for the development of overall transport sector. However, its overall review and update has been realized. This policy document mainly highlights the issues related to the infrastructure development strategies and action plans for different modes of transport such as road, air, rail and water transport. National Transport Policy-2058 has pointed out the following strategies related to the water transport:

- For those remote areas where road -transport is difficult internal water transport system shall be developed by identifying the feasible areas integrating nearest road system.
- Necessary legal provisions shall also be made for the development of internal water transport infrastructure.
- Identifying the feasible areas for developing water transport, priority shall be given to develop in coordination with private sector.
- For the development and operation of waterways, His Majesty's Government shall arrange to operate the waterways according to the Act, Rules and Directives by prescribing the measurement taking in view the expansion and security of the same.
- To connect feasible internal water transport infrastructure - with the water transport system of neighboring country shall be developed with necessary coordination.
- Coordination shall be made with the Ministry of Water Resources and the Water and Energy - Commission for study, investigation and data bank about water transport.

The context of above mentioned water transport policies has not been fully adopted till now. However, MoPPW has started to conduct feasibility study some important river basins. Above mentioned issues should be addressed by the formation of separate institutional arrangement, which would be responsible for overall development of the sector.

#### 9.3.2 Water transport Policy issues

The field team held in depth interview with stakeholders of existing water transport services at Chatara (Koshi basin) and at Mirmee (Kali Gandaki basin). The major concerns were found same in both cases. The private

service providers and user group both are conscious for the legal provision of water transport services. Major policy issues related to the water transport were found as below:

- The need for separate entity looking after the matters of water transport under the MoPPW,
- Vessel Import policy related to the taxation and provision of reconditioned vessel for import,
- Registration and insurance policy of vessel,
- Licensing of Vessel operators
- Policy on Government investment for infrastructure development of waterways,
- Policy on Technical assistant programs by the Government such as for vessel repair and maintenance such as conducting training programs for human resource development working on water transport,
- Safety of water transport and passenger insurance policies,
- Water transport fare regulations mechanism
- Entrepreneurship development in water transport as affordable, safe, competitive service to the remote areas where road transport is difficult.

The sustainable water transport development should be guided by the proper policy documents. MoPPW at this stage could take the initiatives for the development of 'Water Transport Policy'. Furthermore, water transport Act and Regulations should also be formulated.

#### 9.4 Environmental Assessment of Project Area

The basins for the waterway is covering more than 50% of the total land of the Nepal. The different races of people, animals, birds and vegetation are habitated stabilizing the current environment. Thus, before the project execution the Initial Environment Examination (IEE) and Environment Impact Assessment (EIA) study should be performed. During construction of the terminal buildings and access road, the extraction of construction materials from the nearby places like forest, river etc. should also be taken in environmental account. During the usage of the explosives for the boulder removal, rock breaker and excavator, the impact in the environment should be take in consideration. The maneuvering of the jet boat will also lead to bank erosion due to the heavy waves formed during operation which should also be accounted in environment effect. The effect in the aquatic habitat should also be taken in consideration.

This study for water transport corridors in Koshi, Gandaki and Bheri River basins is not only limited as the competitive modes for road transport but this study includes the harmonizing the overall transport modes in the region i.e roadways and waterways. Transport network model was developed for each corridor for the sake of analysis of efficient transport in terms of travel time.

The network analysis has been done using the premium solver software. The solver optimizes the given network and gives result of shortest distance and routing information. For optimizing the shortest route, the nodes are selected as origin and destination by -1 and +1 respectively. The routing values are taken as changing variable. The total distance to route is minimized while setting target cell.

Objective Function:  $\text{Min}\{\sum X_{ij} * w_{ij}\}$

The network analysis has been done considering distance and delay factor according to the type of friction mode (gravel, black top and water). The value defined for delay factor in the intermodal network analysis for black top road, Waterway and gravel road are 1, 1.25 and 2 respectively.

The major roadway network in this basin is provided by the Mid-Hill highway and Koshi highway. The road link connecting Ghurmi-Jayaramghat-Diktel- Leguwaghat-Hile-Mulghat-Dharan-Itahari is main road transport corridor for this basin. There are two North-South road links at Lahan and Kanchanpur providing accessibility to the basin in this region.

The length of roadway transport link from Ghurmi to Dharan is about 305 km, whereas the water transport route along the Koshi river is about 138 km. This length difference between Origin and Destinations via water and roadway could be major hint for the development of intermodal transport links in this region. The network analysis of this basin is shown in the separate table in Annex.

the type of friction mode (gravel, black top and water) will follow Dharan, Lahan, Hetuuda and Kathmandu via E-W Highway which covers length of 447 km in time 9.93 hrs.

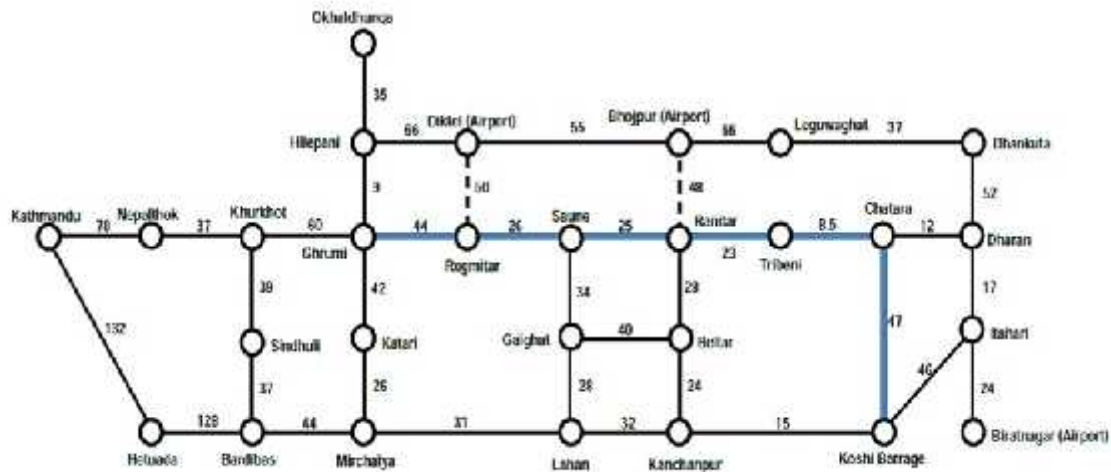


Figure 10-1 Intermodal Network Analysis for Koshi Basin

### 10.3 Gandaki River Basin

This region with relatively high socio-economic indicators has good transport road linkage. Prithivi Highway, Siddhartha Highway and Narayanghat-Muglin Highway are major roadway connections serving this region. Trisuli and Kaligandaki river basins are at the center of this study.

From Galchi to Muglin (about 60 km) of the Prithivi Highway follow the Trisuli river valley. The settlements along this river basin are served by the road transport from very beginning of the transport service in Nepal. The entire route of the Muglin-Narayanghat highway (36 km) follow the Trisuli river basin and it serves the major transport link for the country connecting Mahendra Highway and Prithivi highway. The road transport along the Trisuli River could not be substituted the development of water transport. However, the recreational mode of the water transport such as Rafting has better prospective for the tourism development in this region. Prithivi Highway from Muglin to Pokhara does not follow the specific river basin. However, only very short section of this highway i.e from Muglin to Ambukhairteni follows the Marshyandi River valley.

Kaligandaki River basin from Ramdi to Devghat is the major part for the study. The total length of this corridor is about 130 km which does not have any roadway links across this area. This provides strong basis for the higher priority of the water transport development for this basin. Settlements along this river valley could be significantly benefited by the proposed water transport route. The overall transport network and its analysis is shown in the annex of this report. The transport network diagram is shown in the figure below.

The Headwork site of the Kaligandaki Hydropower project at Mirmee provides the suitable water level for the water transport for this locality. From Mirmee to Setibeni about five km long route has been serving to the area efficiently. This short link is very important supplementary link to the road head at Mirmee.

The results from the analysis under taking distance shows that the route to link Kathmandu and Seti Beni will follow Kathmandu, Fishlin, Muglin, Devghat, Aptar, Ramdi, Galyang, Mirmee and Seti Beni via Prithivi Highway, Muglin-Narayanghat highway, Devghat-Ramdi waterway and Siddhartha highway which covers length of 324 km in time 8.8 hrs. However under taking and delay factor according to the type of friction mode (gravel, black top and water) will follow Kathmandu, Muglin, Pokhara, Galyang, Mirmee and Seti Beni via Prithivi highway and Siddhartha Highway which covers length of 330 km in time 7.97 hrs.

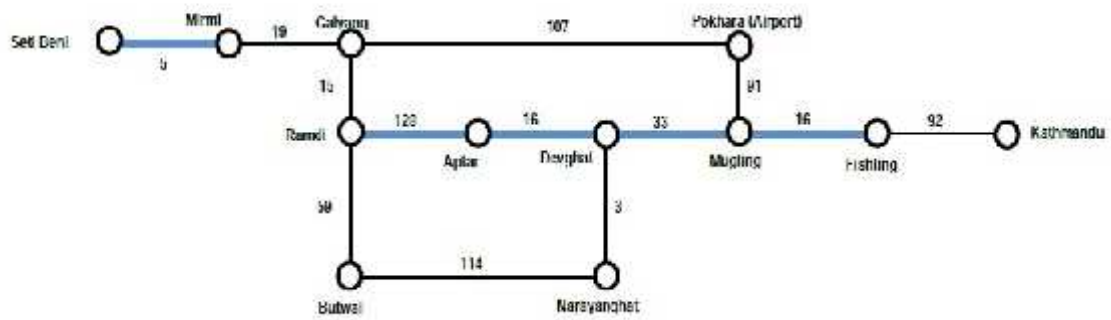


Figure 10-2 Intermodal Network Analysis for Gandaki Basin

#### 10.4 Bheri River Basin

The major roads in this river basin are Ratna Highway, Karnali and Chinchu-Jajarkot Road. Kohalpur is only the exit point from this region to the Mahendra Highway. Bheri River before meeting the Karnali River at Ghatgaun does not possess the favorable conditions for water transport due to the water current and river bed gradient. However, the downstream flow pattern along the river is relatively suitable for different types of water transport. The multimodal network diagram is shown in the figure below. The analysis table is provided in the annex of this report.

The results from the analysis under taking distance and delay factor according to the type of friction mode (gravel, black top and water) shows that the route to link Botechaur and Attariyawill follow Botechaur, Chinchu, Kamalpur, Taranga, Ghatgaun, Chisapani and Attariya via waterway and linking with E-W highway which covers length of 201 km in time 5.15 hrs.

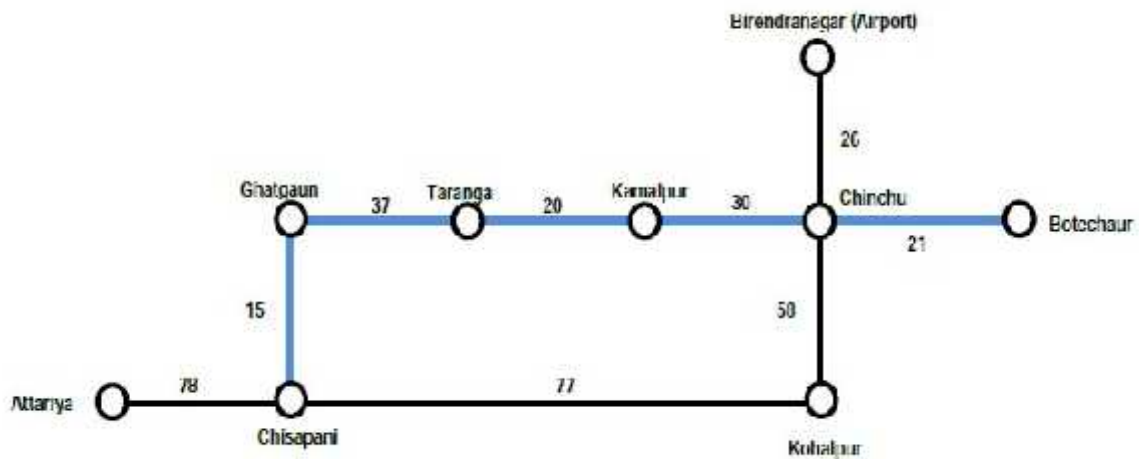


Figure 10-3 Intermodal Network Analysis for Bheri Basin

## 11. COST ESTIMATES

Cost estimates of the infrastructure such as Main terminal stations, intermediate station and access road has to construct for the water transport development project. The numbers of components to be built in the proposed waterway are shown in table below:

Table 11-1 No. of Infrastructure to construct in proposed waterway

| Basin   | Main Terminal Building | Intermediate Terminal Building | Access Road, km |
|---------|------------------------|--------------------------------|-----------------|
| Koshi   | 2                      | 3                              | 3               |
| Gandaki | 2                      | 3                              | 2               |
| Bheri   | 2                      | 2                              | 2               |

The places for the construction of the terminal station has been listed below,

Table 11-2 Purposed Terminal Station in Proposed waterway

| Basin   | Main Terminal Building | Intermediate Terminal Building     |
|---------|------------------------|------------------------------------|
| Koshi   | Chatara and Saune      | Koshi Barrage, Tribeni and Ranitar |
| Gandaki | Devghat and Mirmi      | Aptar, Seti Beni and Mugling       |
| Bheri   | Chisapani and Kamalpur | Ghatgaun and Taranga               |

The boulder identified for the removal can be washed out or deposited according to the precipitation intensity. Thus, the approximate removal of identified boulder for the ease in the maneuvering the jet boat in the proposed waterway are summerized below,

Table 11-3 Summary of the boulder removal for the proposed waterway

| Basin          | Section | River        | Length, km | Quantity, m <sup>3</sup> |
|----------------|---------|--------------|------------|--------------------------|
| Koshi          | K-BC    | Saptakoshi   | 47.05      | 0                        |
|                | K-CT    | Saptakoshi   | 8.72       | 18.5                     |
|                | K-TS    | Sunkoshi     | 48.47      | 173.5                    |
|                | K-SG    | Sunkoshi     | 69.12      | 2443.75                  |
| Gandaki        | G-DR    | Kali Gandaki | 130.425    | 277.69                   |
|                | G-DM    | Trishuli     | 32.638     | 146.75                   |
|                | G-MF    | Trishuli     | 16.6       | 301.75                   |
|                | G-MrS   | Kali Gandaki | 5          | 0                        |
| Bheri          | B-CG    | Karnali      | 15.59      | 11.75                    |
|                | B-GT    | Bheri        | 36.99      | 31.81                    |
|                | B-TK    | Bheri        | 19.804     | 18.94                    |
|                | B-KB    | Bheri        | 50.51      | 60.94                    |
| Total Quantity |         |              |            | 3485.38                  |

The details of the boulder removal has been attached in the annex and the identified boulder for removal is only for the maneuvering of the jet boat in the proposed waterway.

Since, the project is feasibility, the detailed estimates has to be forwarded during the detail engineering study. The estimates of the terminal stations and other miscellaneous works has be done according to the master plan

of terminal station which has been attached in the Vol II of the final report. The lumsum rates of each terminal stations and its miscellaneous works has been tabulated below:

Table 11-4 Cost Estimates for Economic Analysis

| Components                    | Lumsum (Rs.)             |
|-------------------------------|--------------------------|
| Main Terminal Station         | 1.5 Crore per Station    |
| Intermediate Terminal Station | 50 Lakh per Station      |
| Access road                   | 2 lakh per km            |
| Jet Boat                      | Rs. 3 Crore without tax  |
| Boulder Removal               | Rs. 3 thousand per cu. m |

Since, the cost estimate has been required for the economic analysis of the project, from where only the study can decide weather the project is econmically viable or not. In this report, the economic study has been introduced in proceeding chapter as Economic Analysis.

## 12. ECONOMIC ANALYSIS

### 12.1 Approach of the economic analysis

The approach used for the evaluation of the project follows conventional appraisal methodology used for road projects. It compares 'without project situation' the situation, where there is no water transportation with 'with project situation', the situation, where there is inland navigation and pedestrians and goods traffic divert to vessel traffic.

The economic analysis of this project is attempted to do by several methods.

- I. Comparing without project situation and after project scenario.
- II. Computation of B/C ratio, NPV and IRR for the project taking Discount rate of 12%, construction costs for main and intermediate stations and total estimated benefit that are expected to come from passengers
- III. Computation of the optimum amount of fare to obtain 1,50,00,000 as net benefit from Vessel Operation cost calculation.

#### 12.1.1 Analysis Parameters

The project is assumed to be built according to different sections in different basins. Simple construction work of Main terminal and Intermediate terminal buildings are to be built. Implementation of the project is assumed to start in 2012 and completed by the end of 2014. The life of the project is assumed to be 30 years up to 2042. The social discount of 12% is taken which is the economic opportunity cost of capital which is used for the economic evaluation.

Cost and benefits are estimated in economic prices. Economic price reflects the resource cost or value of an item to the country. The economic prices are obtained by excluding every tax, duty or subsidy included in the financial prices.

#### 12.1.2 Economic Indicators

Three indicators of economic viability are: Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit Cost Ratio (BCR) are calculated to test the viability of the project.

#### 12.1.3 Evaluation

Evaluation is done on the basis of calculations done in three ways mentioned above. The first method analyses the tentative economic benefit and cost for the project. This is the scenario analysis of before project and after project. From this we can conclude to be economically viable the after project cost must be cheaper than before project cost of travel. In our calculation of existing Chatara-simle, it is clear that this project in terms of cost is economically not sound because cost of travel in water is quite higher than cost of travel by walking. For this purpose per hour rate of local passenger is assumed to be Rs 15.

The second method gives clear picture of NPV, IRR and BCR for someone to invest in infrastructure and earn from vessel operation in the given section of various basins without excluding vessel operating costs.

The third analysis gives the clear picture of needed fare to obtain the particular profit of Rs 1,50,00,000. This amount is chosen such that it can be used to pay for the vessel lease or purchase. Vessel operating cost for 25 seat capacity Jet boat is calculated and keeping net profit, number of trips, number of passengers constant; the fare rate is calculated using a software solver. Non-linear analysis of this scenario is done.

## 12.2 Maintenance Cost

### 12.2.1 Economic maintenance Cost

Estimation of benefits arising from the implementation of this project requires comparison of “with project” situation with “without project” situation. The later, is therefore, critical in that it determines the level from which incremental benefits from the implementation of the project are derived.

Presently “without project” situation, there is a foot trail and terminal and intermediate buildings are not present. The expenditures on maintenance activities in the trail are negligible and are not considered. The suggested maintenance activities of annual routine maintenance and periodic maintenance are assumed accordingly. The deterioration of the road over time under the traffic loadings and environment is, therefore, not for economic evaluation.

## 12.3 Road User Cost

### 12.3.1 Transport Cost

In “without project” traffic are non-vehicular. Travelers have to walk and freights have to be transported by porters and pack animals. Data are gathered in the project area on freight rates charged for porters and animals. All the freight transported is converted to passenger equivalent for the sake of simplicity of calculation.

In “with project” situation the pedestrians will use boats and displace porters. Hence, Vessel Operating Cost (VOC) of 25 seat jet boat are transport cost in “with Project” situation.

In order to predict VOC, the model requires following three sets of data:

- Unit prices of each VOC component of vessel.
- Characteristics of vessel

Unit prices: In predicting VOC, the model predicts the amount of resources consumed such as fuels, lubricants, crew costs etc. and then multiplies these consumptions by the unit prices of each resource. It is therefore necessary to provide unit prices of VOC components as the basic input data. Based on the observation in the Chatara-Simle near to project area, Jet boat with 25 seats is selected for the analysis.

### 12.3.2 Value of Time

There is evident that the time saved in a journey is often put to some purpose that is generally valued by society. Hence it has economic value and should be included in the economic evaluations. Travel time costs are normally considered in economic evaluations of road projects in Nepal to assess time saving benefits for pedestrians and vehicle passengers resulting from higher speeds on roads. Saving in travel time costs of passengers represent significant proportion of total benefits. Conventionally, a distinction is made between traveling in course of employment and in traveler's own time. Travel time spent in the course of work is expected to affect the productivity of traveling employees. Therefore, the value of work related travel is linked to the value of production foregone. Travel time outside work may have been utilized in other activities, including leisure. Therefore, saving travel time is generally preferred and brings about increased satisfaction or ‘utility’ on the part of traveler. In Nepal where majority of people are engaged in agriculture, work trips include trips made in the course of work as a self-employed person and trips made for purchasing/selling of goods for profit. Commonly used method for valuing work time savings is valuing the average wage of time spent on traveling. ‘The manual on valuation of Rural Travel Time Saving in Least Developed Countries’ published by I.T Transport limited, Ardington, UK for DFID has suggested different methods for valuing work time and non-work time travel. One of the suggested approaches to value work time travel is valuing average wage rate spent in travel adjusted by shadow wage rate (SWR) factor. Similarly, one of the suggested methods for valuing non-work time travel is valuing average wage rate spent in travel adjusted by Standard Conversion Factor(SCF) and multiplied by a factor of 0.55.

The average wage rate in the project district is Rs. 265 per day. 90 percent travels in Nepal are observed to be in non-work time and only 10 percent are in work time. There are no calculated SWR and SCF for Nepal. Hence, the SWR of 0.8 and SCF of 0.9 as suggested by the manual are used for valuing the work and non-work travel time respectively. The weighted average of calculated value of work and non-work travel time is Rs. 10.5 per hour. Rs 15 have been used to estimate travel time values of pedestrians. The average speed of pedestrians in trails is assumed to be 5 km per hour based on actuated speed of 3 km per hour adjusted for shorter trail length. The average speed of buses in the project road is assumed to be 20 km per hour.

## 12.4 Benefit Analysis

### 12.4.1 Road Users' Benefit

Road users' benefits from the implementation of the project will arise from savings in vessel operating costs and travel time of traffic from the implementation of the project. Thus, traffic level of the project road in 'without project' and 'with project' situations are estimated as described below. As mentioned above traffic are non-vehicular in 'without project' situation. Travelers have to work and freights have to be transported by porters or animals.

Movements of people and goods in Nepal are subject to a range of influences, some of which are seasonal. The seasonal influences are usually crop harvestings and rainfall. During the harvesting season, traffic levels are increased due to more movements for labour, transport of crops and increase in other associated activities. Hence, it is observed that traffic levels are usually below the annual average during the period July to November. Between January and June, traffic levels are higher than annual average

It is almost certain that the potential traffic flow is suppressed in the foot trail of Nepal and additional generated traffics result from the construction of an improved mode of transportation, which allows increased speeds and more reliable travel times. Experiences elsewhere in Nepal have suggested that additional freight traffic and passenger traffic can be generated up to 15% and 25% of their normal traffic respectively.

### 12.4.2 Producer's Surplus Benefits

The producers' surplus benefits can occur when the reduction in transport cost associated with construction of a new means of transportation is large enough to induce an increase in output of the area of influence of the road. In the sector of Wide Road Program and PIP study, 2006, the World Bank/DOR a review was made of the attempts of earlier studies to forecast agricultural development benefits and of the empirical evidence of actual responses in the area where road access had been provided. The study found very little evidence that benefits from increased productions (agricultural) were obtained after construction of roads in hill area of Nepal. Due to the lack of additional land that can be brought under cultivation, and apparent reluctance of farmers to change to diversify from traditional subsistence crops there is normally a very small response to the provision of road access. The same things are true for the project area and producers' surplus benefits are not considered for the economic evaluation of the project road alternatives.

## 12.5 Results

In the base line scenario, the proposing waterway to meet the minimum values for NPV (positive),  $IRR > 12\%$  and  $BCR > 1$ , mostly all project is feasible which is shown in summary table below and detail has been shown in Annex. But from the existing service is economically not viable but financially its highly viable. The stakeholders can generate high profit by providing this service due to the high willingness to pay in the existing waterway. If the jet boat having 25 seats has to operate to earn profit of Rs. 1 crore p.a. then the price that has to be Rs.114 for Chatara to Tribeni and Rs. 58 for Mirmi to Setibeni after deducting all the depreciations in the existing waterway and all other rates has also been shown in annex.

Table 12-1 Summary of Economic Analysis for Proposed Waterway

| Section                | Service                                     | NPV     | IRR    | B/C    | Remark                                  |
|------------------------|---------------------------------------------|---------|--------|--------|-----------------------------------------|
| K-BC                   | Proposed Waterway for Recreational          | -11.37  | 2.63%  | 0.44   | Unfeasible                              |
| K-CT –Simle            | Existing Waterway                           | -432.36 | 900%   | -34.98 | Feasible due to high willingness to pay |
| K-TS                   | Proposed Waterway for Public Transportation | 157.4   | 86.38% | 10.69  | Feasible                                |
| K-SG                   | Technically Not Feasible                    |         |        |        |                                         |
| K-Dolalghat to Chatara | Existing Rafting Route                      | 41.06   | 36%    | 3.53   | Feasible for Tourism                    |
| G-DR                   | Existing Rafting Route                      | 15.33   | 19.68% | 1.75   | Feasible for Tourism                    |
| G-Devghat to Aptar     | Proposed Waterway for Public Transportation | 14.82   | 19.7%  | 1.72   | Feasible                                |
| G-DM                   | Proposed Waterway for Recreational          | 38.12   | 24.28% | 2.31   | Feasible                                |
| G-MF                   | Existing Rafting Route                      | -8.75   | 6.39%  | 0.57   | Unfeasible for Jet Boat                 |
| G-MrS                  | Existing Waterway                           | 18.06   | 21.3%  | 1.88   | Feasible                                |
| B-CG                   | Proposed Waterway for Recreational          | 91.27   | 49.56% | 5.44   | Feasible                                |
| B-GT                   | Proposed Waterway for Public Transportation | 4.43    | 14.05% | 1.22   | Feasible                                |
| B-TK                   | Proposed Waterway for Public Transportation | 3.73    | 14.1%  | 1.18   | Feasible                                |
| B-KB                   | Not Feasible due to no willingness to pay   |         |        |        |                                         |

The detail of economic analysis of the proposed waterway is attached in Annex.

## 13. CONCLUSION AND RECOMMENDATION

### 13.1 Conclusions

The main objective of the project assignment was to identification of possible water transport routes along the Koshi, Gandaki and Bheri River Basin. The major criteria for the selection of possible routes were technical characteristics of river sections, and estimated traffic demand for the proposed route. The three types of transport services are proposed for water transport in Nepal: Recreational (Rafting and sightseeing), passenger and goods transport.

The feasibility study concluded the following subject matters:

- The existing water transport services in Nepal have not been widely explored, however, the recreational (i.e. rafting) is very famous for tourist attraction one of the types of sport-adventure. The promotion of this services and its marketing would be very beneficial to the tourism industry in the country.
- The river flow pattern in Nepal is very difficult for motor boats. The water flow speed along the still sections speed may vary 0.5-1.0 m/sec. However, these sections are limited due to the steep river bed gradient and debris obstruction of the river bed. These sections are feasible for only motor boats of propeller type. These types can be manufactured in local workshop by the use of bus/truck engine and wooden body with steel frame structure.
- The higher water speed more than 2.0m/sec are characterized as 'Rapid' sections. The speed of such flow can only be overcome by the Jet boats which are very expensive and are not possible to manufacture in local market. These types of boats should be mainly imported from USA.
- The River depth highly varies with season. It is also very inconvenient for the water transport in rivers. The rainy seasons with high flood level are not favourable for water transport. Generally, the favourable period for water transport is from September to June.
- The any physical infrastructure developed/constructed along the river corridors below the high water level should be avoided due to the flood risk.
- The improvement of river cross section for the use of water transport is not recommended at this level of study. However, it may be decided after the detailed Geological and Hydrological study of particular sections.
- The obstruction of the river like rapids or the removal of huge boulders can bring adverse effect in U/S as well as D/S of the river
- The construction of dam for hydropower or irrigation projects and ponding/ formation of water body upstream could be a very favourable for the water transport. It could be proved at the dam-site of Kaligandaki Hydropower project and Kulekhani Dam Hydropower Project.
- The passenger or goods transport along the river with the goods road transport facility is not recommended for the commercial water transport. However, recreational types of water transport could be very prominent for these sites. Trisuli river corridor is the case of this conclusion.
- The proposed sites for the different types of water transport services are shown in the respective chapters of the study basins.
- The sustainable water transport development should be guided by the formulation appropriate policy documents and implementing institution.
- Intermodal transport sector development could be achieved by the study of other water transport corridors in the country.

### 13.2 Recommendation

Feasibility study of this project could be the important stage of the development of specific water transport sections. The long stretches of considered river basins were divided into sections of possible transport projects. The public investment for the development and promotion of water transport could play vital role for the water transport. The study has recommended the following issues.

- MoPPW should take initiation for the formation of Water Transport Policy for the sustainable development of water transport sector.
- The detail study for the operational level of transport services should be further conducted before investment for the particular project.
- The public private partnership (PPP) approach should be initiated for the promotion of all types of water transport services.

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