# Executive Summary

The Rural Access Project (RAP) in Bhutan commenced at the end of 1999. A World Bank credit to the Department of Roads under the Ministry of Works and Human Settlement (MoWHS) is supported by the SNV Netherlands Development Organisation. The project has focused on Environmentally Friendly Road Construction (EFRC) techniques in order to maximise the environmental sustainability of the project. This EFRC support is coming to end in December 2005. The DoR plans to take up construction of another 65 to 75 km feeder roads under a follow up/next credit of the World Bank.

Slope instabilities and other geo-technical problems, could have substantial effect upon the stability, sustainability and cost not only during the project implementation phase but also during the post construction phase. In 2004, RAP feeder roads suffered significant damage due to heavy monsoon rain. The study conducted by DoR through Scott Wilson, suggested that such failure could be minimised if roads are designed and constructed by understanding the geological/geotechnical conditions of the ground. Therefore, the Department of Roads (DoR), Bhutan entrusted Geo-tech Consultancy Services, Thimphu to undertake the geological and geotechnical study of the following roads including its impact and ways to mitigate such adverse effects :

| Name of Road | Dzongkhag | Length | Length to be Studied |
|---|---|---|---|
| Jangchucholing – Tashidingka Road | Wangdue | 14.30 Km | Entire road |
| Drujeygang - Balung | Dagana | 42.50 Km | First 15 Km. |

Existing reports and various maps were interpreted / reviewed. Geological/geo-technical data such as slope inclination, soil/rock types, surface/ground water conditions, slope instabilities etc. were collected during the field study. Limited tests were carried out for evaluation of material properties. Rock and soil slope stability analyses were carried out at relevant sections to assess the failure scenario of the proposed road corridors. Thematic maps such as slope map, geological map and drainage map have been prepared. Besides these, Engineering Geological and Landslide Susceptibility Map have also been produced. Suitable quarry and spoil disposal sites were identified along the proposed road corridors.

Landslide Susceptibility Maps have been prepared by using guidelines developed by Scott Wilson Kirkpatrick & Co. Ltd. under the Landslide Risk Assessment (LRA) Project in 2003. Two fold susceptibility schemes of LRA Guidelines have been used for this purpose. Combining Landslide Susceptibility Map with Engineering Geological Information, made it possible to evaluate the Hazard/Risk levels and potential geo-technical problems along the road corridor. The proposed road corridors were then reviewed based on hazard/risk ratings and failure assessments results.

**Jangchucholing-Tashidingka Road :**
The total length of this road is 14.30 km and takes off at Jangchucholing which is about 3 km east from Nobding which is a village located on the existing highway. The road from Jangchucholing to Chuba Chu via. Chuguni Pang is being constructed by DoR departmentally. This section of road passes predominantly through the Colluvium deposit and occasionally through the Residual soil. Steep cut slopes on the soil has started to fail at few locations. Frequent failures on the steep cut slopes do seem to be inevitable in coming monsoon if not protected. This problem could be

mitigated by flattening the existing cut slopes (in 1:1 slope) with application of Bio-engineering structures (refer section 5.5) on the bare cut slope surfaces.

A minor bridge having about 25 meters span needs to be provided at Chuba Chu. Similarly, a bridge having about 20 meters span would be required at the tributary of Chuba Chu. The stability condition of the Chuba Chu is critical at the event of natural disasters due to existence of numerous slides at the catchment area of this stream. Abutments protection works and high free board may expect to safeguard the bridge at Chuba Chu during the normal monsoon period.

From Chuba Chu, the alignment almost runs at flat gradient to the terminal point Tashidingka except after crossing Samo Chu where the alignment climbs through 3 zigs. The alignment passes through the gently inclined Colluvium deposit except near the Samo Chu where the slope is relatively steeper. From Chainage 10+765 to 13+250, there exist swampy areas for short stretches particularly around the valley sides of the drainage lines. Cut and fill balance approach with gabion retaining structures up to km. 12+000 would be useful to avoid/limit slope failures during the road construction. Slope drainages (having shallow sub-surface drains) in the herring bone pattern around swampy slope surfaces would be very much useful to minimise the slope failures. The roadside drains at swampy area shall be lined. French drains under the roadside drains at swampy areas would be useful.

The left bank of Samo Chu Bridge may require breast walls to avoid slope failures. The proposed bridge needs to be shifted by about 15 meters down stream from the proposed bridge axis to avoid the left bank abutment damage from the existing active landslide at this bank. Masonry or concrete edge walls at around km 12 stretch need to be provided to minimise the rock mass cutting.

**Drujeygang-Balung Road :**

The approximate length of this road is about 42.50 km and takes off at about 20-30 meters away from the last hair pin bend (Makhuma hair pin bend) of the approach road to Drujeygang. First 15 km length of this road is considered for this study.

The proposed road alignment predominantly passes either through the cultivated terrace or through the border line between barren land and cultivated terraces till km 5+700 except at the valleys of streams and dry rivulets where this alignment passes through the steep slopes covered by dense forest. Seepage from the unlined irrigation channel which runs almost parallel to the proposed road alignment, may cause problem to the road stability. Loose, silty Sand with angular boulders predominates the entire stretch. The talus deposit with big fallen rock blocks (some of the blocks have least dimension >4 meters) in the matrix of loose sandy soil can be seen from Chainage 4+900 to 5+700. The road bench could be lost in stretches if the seepage from the unlined irrigation channel is not controlled. The concept of cut and fill balance with minimum disturbance to the loose slope and lining the irrigation channel are the main aspects that need to be given due consideration during the detailed engineering design.

The proposed alignment from 5+700 to 10+100, passes through fine to coarse grained, thickly bedded, moderately weathered Quartzite rock with intercalation of Schist rock for about 400 m from 5+700 meter and the remaining stretch passes through the Colluvium. No major threat is expected if the concept of cut and fill balance, flatter cut slope angles (1:1) and complementary bio-engineering structures on the cut slope faces are followed.

The alignment passes through loose Residual soil for about 400 m from km 10+100. Box cutting around the saddle point near the Baibithang area has been proposed where some stability problem

may exist if it is cut at the steeper angle otherwise, this segment of road is stable. From 10+500 to terminal point, the alignment passes through the orange plantation area. The slope is comprised of loose colluvial soil which is inclined at around 20-30° in general. Quartzite rock outcrops at Chainage from 13+740 to 13-780. The rock slope is stable. The slope at this short stretch is moderately to highly steep requiring heavy rock mass cutting. Masonry wall with stepped footings or concrete edge walls with dowel bars can be used to limit the excessive rock mass cutting. For remaining Colluvium slope, the concept of cut and fill balance shall be applied. Gabion retaining wall may be required at the valley side at the Colluvium deposits.

This report recommends to :

- accompany an experience Geo-technical Engineer or Engineering Geologist during the detailed engineering design and construction phases,
- accompany a Junior Engineer experienced in Bio-engineering implementation during the construction phase,
- undertake detailed geo-technical investigation at Chuba Chu bridge site of Jangchucholing-Tashidinkha Road, and
- carry out follow up geo-technical study at the critical sites as construction of the road progresses.