JOURNAL

OF

NEPAL GEOLOGICAL SOCIETY

ABSTRACTS

**Fifth Asian Regional Conference
on Engineering Geology for Major Infrastructure Development
and Natural Hazards Mitigation
28–30 September 2005
Kathmandu, Nepal**

Fifth Asian Regional Conference on

Engineering Geology for Major Infrastructure Development and Natural Hazards Mitigation

28–30 September 2005

Organised by

Nepal Geological Society

Organising Committee

Convener: **Dr R. P. Bashyal**

Co-Convener: **Dr M. R. Dhital**   *Co-Convener:* **Mr R. K. Aryal**

Members

Dr R. M. Tuladhar
President, NGS, Nepal
Dr V Dangol
Vice-President, NGS, Nepal
Mr L. N. Rimal,
General Secretary, NGS, Nepal
Mr J. R. Ghimire,
Treasurer, NGS, Nepal
Mrs R. Shrestha,
Deputy General Secretary, NGS, Nepal
Dr N. Rengers
President, IAEG, The Netherlands
Dr M. Deveughèle
Secretary General, IAEG, France
Dr P. Potherat
Treasurer, IAEG, France
Dr H. Ohshima
IAEG Vice-president for Asia, Japan
Dr D. N. Petley
Durham University, United Kingdom
Professor F. M. Guadagno
University of Sannio, Italy
Professor O. Hungr
University of British Columbia, Canada
Mr V. K. Singh
AIT, Thailand
Professor Dr B. N. Upreti
Ex-President, NGS, Nepal
Mr K. P. Kaphle
Ex-President, NGS, Nepal
Mr A. M. Dixit
Ex-President, NGS, Nepal
Mr A. N. Bhandary
Ex-President, NGS, Nepal
Mr P. S. Tater
Ex-President, NGS, Nepal
Mr B. R. Aryal, *Deputy Director General*
Dr T. Sharma, *Managing Director, NESS*
Dr S. Shah, *Managing Director*
Mr B. M. Jnawali, *Chief PEPP*
Mr G. S. Pokharel
Mr B. D. Kharel
Mr J. N. Shrestha

Dr D. R. Kansakar
Mr Shyam Bahadur K.C.
Dr T. N. Bhattarai
Mr S. P. Pradhan
Dr I. R. Humagain
Mr R. Khanal
Ms S. Shrestha

Advisory Committee

Director General, *DMG*
Director General, *DoI*
Director General, *DWIDP*
Director General, *DoR*
Director General, *DoLIDAR*
Managing Director, *NEA*
Director General, *ICIMOD*
Mr M. R. Pandey, *Hon. Member, NGS*
Mr J. M. Tater, *Ex-President, NGS*
Mr G. S. Thapa, *Ex-President, NGS*
Mr N. D. Maskey, *Ex-President, NGS*
Mr N. B. Kayastha, *Ex-President, NGS*
Mr V. S. Chettri, *Ex-President, NGS*
Professor Dr M. P. Sharma
Tribhuvan University
Dr P. C. Adhikary
Head, CDG, *Tribhuvan University*
Professor Dr J. R. Pokharel
President, Nepal Engineers' Association
Mr L. R. Bhattarai
Chairman,Nepal Engineering College
Mr D. B. Thapa, *Ex-DC, NEA*
Mr P. R. Joshi, *Ex-DDG, DMG*
Mr M. B. Thapa, *UNDP*

Congress Secretariat

Mr G. B. Shrestha,
MREU, TU, Nepal
Mr R. K. Dahal,
DG, TC, TU, Nepal
Mr P. Dhakal,
DMG, Nepal
Mr M. S. Dhar,
PC, TU, Nepal

Acknowledgements

Contents

Engineering Geology

i

Hydrogeology

Natural Hazards and Environmental Geology

iv

Engineering Geology

Effect of confining pressure on the strength of granular materials: a DEM based simulation

Md. Abdul Alim[1], Md. Wasiul Bari[1], Kiichi Suzuki[2], and Kazuyoshi Iwashita[2]
[1]Department of Civil Engineering,
Rajshahi University of Engineering and Technology, Bangladesh
[2]Department of Civil and Environmental Engineering,
Saitama University, Japan

Numerical simulation was carried out to study the effect of confining pressure on the stress-strain-dilatancy response of granular materials using Discrete Element Method (DEM). Three samples were generated at random arrays of circular discs in square loading frame using a computer code. The assembly was first isotropically consolidated and then strain controlled biaxial compression tests were carried out to investigate the effect of confining pressure on the mechanical behaviour of granular materials. The stress-strain and volumetric curves qualitatively show a good agreement with the actual behaviour of granular materials like sands. The failure stress increases with the increase of confining pressures, while the dilatancy is reduced with the increase of confining pressure. The maximum dilatancy index occurs at the peak stress level.

Analysis of elastic behaviour of granite using homogenisation theory

Y. Baek[1], O. I. Kweon[1], *Y. S. Seo[2], K. S. Kim[2], and G. W. Kim[3]
[1]Dept. of Geo-tech. Eng., Korea Inst. of Construction Tech., Goyang, 411-712, Korea
[2]Dept. of Earth & Environmental Sciences, Chungbuk Nat'l Univ., Cheongju, 361-763, Korea
[3]Dept. of Geology, Kyungpook Nat'l Univ., Daegu, 702-701, Korea
*(*Email: ysseo@cbu.ac.kr)*

Granite is composed of several rock-forming minerals and discrete features such as grain boundaries, microcracks, and microcavities. Their evolution and interaction considerably affect the macroscopic mechanical response of granite. Thus, it is a complex composite with numerous microstructures.

The information on the mechanical behaviour of granite at a shallow depth of the crust is important for various national concerns, such as radioactive waste isolation and earthquake hazard reduction.

At first, the study was carried out by photographic analysis of the randomly-distributed discrete elements in granite. The modal analysis of granite was also conducted simultaneously with the above photographic analysis. The result shows that quartz and feldspar including mica occupy 99.4% of the Inada fine-grained granite.

Based on the results of the previous analysis, an elastic homogenisation theory was applied to analyse the macro-level stress distribution in the Inada granite, which is a composite material of rock-forming minerals with micro-discontinuities.

For proper sampling of rock and preparation of specimens, a representative elementary volume (REV) should be determined in rock mechanical test and numerical analysis. We determined REV of the Inada granite using stereoscopic microscope and homogenisation numerical analysis.

Parametric study on the internal friction angle and dilation angle of intact rock and discontinuities from the cavern of Siah Bisheh power station

Nadia Shafiezadeh[1] and Mehdi Bagheri[2]
Lar Consulting Engineers, Tehran, Iran
[2]Iran Water and Power Development Company,
Siahbishe Pump Storage Project, Iran

The values of internal friction angle and dilation angle of rock mass control the visco-elastic displacements in the perimeter of underground structures. Since the rock mass is either intact or with discontinuities, the present parametric study was conducted to determine the effect of dilation angle of intact rock as well as internal friction angle and dilation angle of discontinuities within the range of visco-elastic displacements with the help of statistical Yates method. The cavern of Siah Bisheh power station was selected for this purpose. This elasto-visco-plastic analysis was done using finite element software FESTO3. Visco-elastic displacements were obtained by changing the dilation angle of intact rock and discontinuities, and the internal friction angle of discontinuities. With the increase in the dilation angle, the displacement in the X-direction is decreased and increased in the Z-direction. In the Yates method, the direct effect and interaction of the concerned parameters on displacements and sensitivity of effects are considered. By this way, one can decide whether the concerned parameter has a direct effect on the result. On the basis of the results, an optimum value can be chosen for the studied parameters. It was found that a variation in the dilation angle of intact rock and internal friction angle of discontinuities induced a similar variation in the values of displacements, but the sensitivity of these variations was not high. Therefore, the visco-plastic displacements are not significantly affected by these parameters. However, a change in the dilation angle of discontinuities caused a considerable variation in the visco-plastic displacements. The variation in visco-plastic displacement around the cavern is discussed to determine the optimum value of the dilation angle of discontinuities.

A comparison between different methods of rock mass strength investigation

*Mehdi Bagheri and Abdol Hadi. Ghazvinian**
Faculty of Engineering, Tarbiat Modares University, Tehran, Iran
*(*Email: Mehdi_baghery_ir@yahoo.com)*

Rock mass strength is one of the most critical parameters used to design underground structures. Concerning the complexity of rock mass, evaluation of its strength is very difficult. Some researchers such as Ramamurthy, Sitharam, and Barton have tried to evaluate rock mass strength. Rock mass strength is obtainable by using Joint Factor or rock mass classifications. In this paper, the discussion will be continued on the applicability of equations proposed by Sitharam, Ramamurthy, Barton, Hoek and Brown, and Kalamars to evaluate rock mass strength. The results show that Barton equation is overestimating in comparison with others, where as the Hoek and Brown equation is underestimating the strength value. The Ramamurthy and Kalamars equations are estimating almost the same strength for the rock masses. Finally, using the Ramamurthy or Kalamars equations is suggested to evaluate the rock mass strength.

Effect of reversed loading on shear behaviour of reinforced concrete beam

Md. Wasiul Bari, Md. Abdul Alim, M. M. Younis Ali, and Md. Robiul Awall
Department of Civil Engineering,
Rajshahi University of Engineering & Technology, Bangladesh

During an earthquake, waves transfer energy in any direction. Hence reversed loading is appropriate to assimilate this condition. Therefore the shear behaviour of reinforced concrete (RC) short beam under reversed loading is necessary to investigate. RC deep beam is the main structure usually found in transfer girders used in multistoreyed buildings to provide column offsets, in foundation walls, and shear walls. In contrast to an ordinary beam, the depth of beam is comparable to its span length. RC short beam with shear span to effective depth ratio of 1.5 was selected in this study. To investigate the shear mechanism in concrete alone, RC short beams without web reinforcement were studied.

The experimental frameworks were divided into two series according to the percentage of main reinforcement: 1.15 or 1.805%. Four RC beams without web reinforcement were tested in this investigation. All beams were doubly reinforced with equal tension and compression steel in each case. The variables were the reinforcement ratio, 1.15 or 1.805% and loading pattern (monotonic or reversed loading). The test beams were simply supported and were subjected to mid-span one-point load.

The test programme was divided into monotonic and reversed loading. For reversed loadings, the test beams were manually turned upside-down. The tests revealed that the experimental setup was important to control the precision, especially the position of mid-span load.

Reversed loading gave the yield load identical to the monotonic loading, but with significantly lower ultimate deflection. In this study, displacement ductility was also investigated. Displacement ductility is defined as the ratio of deflection at ultimate load to the deflection at first yield of the tension steel. The experimental results showed that higher reinforcement ratios produce higher loss of displacement ductility under reversed loading.

Aseismic suspension structure with elastic tie-rods

Federico Bartolozzi
Via dei Carracci, 4, 21100 Varese, Italy
(Email: ciuciuzza@iol.it)

The proposed aseismic suspension structure has the following characteristics:

- absence of direct contact of the structure with the soil (i.e., suspension structure);
- transfer of the load to the soil by means of elastic steel tie-rods.

The inertial force in a structure due to an earthquake undulatory shock is directly proportional to its displacement variation and inversely proportional to the tie-rod length. The displacement variation of the structure is never equal to zero if the soil displacement and the structure displacement are in phase; and vice versa. It is equal to zero only when the in-phase opposition with reference to the design seismic frequency is equal to $\varphi_p = 1.41\varphi_{o,n}$, where $\varphi_{o,n}$ is the horizontal natural frequency of structure. The design seismic frequency is selected only on the basis of statistical data concerning the design area. In order to safeguard the structure against the resonance danger, which occurs when the seismic frequency equalises the natural frequency of structure, it is necessary to determine an interval of undulatory and sub-undulatory seismic frequencies, where the frequencies – including the resonance – are not compatible with the safety of the structure. Therefore, with respect to this emergency interval, it is essential that suitable devices (i.e., horizontal dampers and vertical frequency converters) spontaneously start in order to decrease the horizontal and vertical displacements of the structure to values not greater than prearranged admissible displacements of design. These admissible horizontal and vertical displacements of the structure are designed with respect to the prearranged maximum horizontal and vertical displacements of the soil. It is to be pointed out that a numerical analysis reveals that the inertial force in the suspension structure with tie-rods is about 4% of the corresponding inertial force in the same structure without tie-rods. This considerable decrease of earthquake energy in the structure gives to the proposed system a remarkable economical competitiveness with respect to other existing aseismic systems.

Status of soil erosion in the Siwaliks with reference to the Khajuri watershed, Udaypur, east Nepal

***Tara Prasad Bhattarai, Vishnu Dangol[1], and Sohan Ghimire**[2]
[1]Department of Geology ,Tri-Chandra Campus, Kathmandu, Nepal
[2]Department of Irrigation, Lalitpur, Nepal
(*Email: tbhattarai@hotmail.com)

Soil erosion and related phenomena prevail in the Khajuri watershed. The study area lies to the south of the Central Churia Thrust and to the north of the Himalayan Frontal Thrust. A strong to extreme rate of erosion in the Siwaliks was observed during the 3 years of field study (Bhattarai 2005). The paper concentrates on the quantitative data collected during the period from selected stream banks, gullies, and erosion plots. These data were analysed and correlated with the local geology. The erosion pin method of sampling (Moyerson and Tervuren 1980) and monitoring of stream and gully width as well as the expansion of gully head were applied during the study. This study shows that about 7 mm depth of soil is removed annually from the entire watershed, which signifies the burning issue of erosion in the Nepal Himalaya (Galay 1987).

REFERENCES

Bhattarai, T. P. , 2005, Soil erosion in Khajuri catchment and geology of the adjacent area, Udaypur, eastern Nepal, unpublished, M. Sc. Thesis, submitted to the Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal (Unpublished).

Galay V., 1987, Erosion and Sedimentation in Nepal Himalaya. CIDA, ICIMOD, IDRC for water and Energy Commission Sec. HMG Nepal, Kathmandu.

Moeyerson J. and Tervuren, 1990, Soil loss by rainwash: a case study from Rwanda. Z. Geomorph. N. F. 34 – 4 , pp. 385– 408. Stuttgart, Berlin.

Roadside slope instabilities and their mitigation practice in Nepal

Ranjan Kumar Dahal
Department of Geology, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal
(Email: ranjan@ranjan.net.np)

Roads of Nepal regularly suffer from various mass movements controlled by geological, geomorphological, and climatic factors. In this study, an attempt has been made to present some of the landslides developed within the last five years on the roadside slopes of major highways (viz. the Siddhartha Highway, Arniko Highway, Prithvi Highway, Banepa–Sindhuli Highway) and a number of district and rural roads of Nepal. The roads are evaluated in terms of their instability problems and mitigation practices. Field studies revealed that there is a lack of sound investigation and design procedure. As a result, the structures constructed on slopes to mitigate the instabilities are not functioning properly. Some of the structures have already failed and others are partly damaged. The problems are seen both on soil slopes and rock slopes. The Kattike Mool Landslide located at Km 2 + 400 of the Siddhartha Highway (Pokhara–Syangja section) is one of such problems. The mitigation measures undertaken to stabilise the slope were quite inadequate. Improper roadside drain management, construction of retaining walls on poor foundation, and inappropriate bioengineering practices have aggravated the situation. Likewise, no discontinuity analysis is carried out even on highly hazardous rockslides and rock falls that have already killed many passengers. Field observations showed that there is no mechanism of routine evaluation of slopes, and consequently, the roadside slopes are severely affected by the monsoon rain.

Road construction challenges in Nepal Himalaya: case studies of high-intensity rainfall

Megh Raj Dhital
Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal
(Email: mrdhital@wlink.com.np)

The Himalayan environment is harsh and fragile, and road construction on these mountain slopes is a formidable task. Any kind of unsound engineering decision may lead to a disaster. Wherever the road passes through dip slopes, plane rockslides and debris slides may develop, whereas on counter dip slopes, rock falls, debris falls, and debris flows may prevail. As there are very thick (more than 10 m) colluvial zones, talus deposits, and residual soils, the rainwater easily infiltrates into and percolates through them. It results in the development of a high porewater pressure, which triggers many slides and flows on the natural as well as cut slopes. On the other hand, owing the presence of at least three joint sets, many plane and wedge failures as well as topping failures are generated. The lithological contacts between resistant and weak rocks as well as faults (with crush zones) are other favoured areas of mass movement. Most of these types of mass movement are frequently triggered by a high-intensity rainfall and they may be quite difficult to control.

The 30 June 1987 rain in central Nepal severely damaged the Arniko Highway and the Lamosanghu–Jiri Road at Charnawati. Large landslides are encountered near Dolalghat, Balephi, Kothe, north of Barabise and Chaku, and near Kodari.

The high intensity rain of 19–20 July 1993 in south-central Nepal caused a great disaster. It destroyed 3 bridges on the Prithvi Highway and also devastated the Tribhuvan Highway by sweeping away several bridges and triggering many landslides. Large landslides developed in the vicinity of Tistung, Daman, and Mahabir.

Owing to a heavy rainfall of 30–31 July 2003, a number of landslips and debris flows occurred on the Mugling–Narayanghat Road. The road was partially blocked for two years.

The incessant rain of 5–13 July 2004 activated numerous landslips, erosive gullies, and debris flows in the watershed of the Dudh Koshi River in east Nepal. As a result, the Hilepani–Jayaramghat–Diktel Environment-Friendly Road was devastated. Apart from the rainfall, geological, geomorphic, land use, and road construction practices were the other important factors leading to the disaster. Most of the damage was concentrated on concave slopes, whereas the ridges and convex slopes were relatively safe. Severe damage was seen in almost every gully crossing. The entire alignment was devoid of any breast or retaining walls protecting the high, steep, and bare soil cut slopes, and it resulted in extensive cut slope failures. Similarly, the side drains and cross drains were almost nonexistent. There were very few gully protection structures (i.e., check dams), but like the retaining walls constructed below the road, the check dams also suffered from poor construction quality, poor foundation, and inadequate keying practices. Some of the most awkward structures were the loops founded on unstable slopes with high (up to 15 m) and robust gabion walls at the bends, and deep box cuts above them. In these circumstances, the concentrated runoff and subsequent debris flow from the box cut devastated the entire hairpin bend.

Role of bedrock incision, tectonic uplift, and erosion in controlling orographic precipitation and consequent effects on landsliding and disastrous construction of large dams in Himalaya: case studies from India

Chandra S. Dubey, Manoj Chaudhry, and B. K. Sharma
Department of Geology, University of Delhi,
Delhi-110007, India

The lesser Himalayan sequence in western and eastern Himalaya consisting mainly of active or reactivated MCT II (Munsiari Thrust) shows a lateral variation of exhumation and uplift from west to east. In western Himalaya, out of sequence thrusting (OST) and relatively high exhumation rates (45 mm/yr) and consequent uplift give rise to high erosion rates in this part as well as in the Nepal and Sikkim Himalaya. Both OST and bedrock river incision due to increased precipitation and consequent river discharge accentuate erosion rates.

Such areas depict high precipitation as well. It is important to understand whether such heavy precipitation in these areas is due to the reaction of the emerging southwest monsoon in relation to active mountain belts, i.e. the mountain belts of high slopes and active tectonics shaping the mountains to interact with SW monsoons and culminating into the local high orographic precipitation areas.

Lithology, slope angle, and active thrusts and faults control most of the landslides occurring in the Lesser Himalayan region, and heavy precipitation triggers catastrophic landslides in this part of the Himalaya in some heavily populated places. Such landslide-prone hilly terrains are also affected by the construction of infrastructures such as large dams. Tehri, Uttarkashi, Nathpa Jhakri in Uttaranchal and Himachal as well as Tista, Rongli, and Rangpo in the Sikkim Himalaya are some important sites where large dams are being constructed. Most of these dam sites are on nick points where V-shaped valleys, large slopes, and a sudden fall in gradient is useful for the location of dam sites. Such nick points are also the locations of active thrusts and faults with high bedrock incision, tectonic uplift, and consequent high erosion rates.

We present some case studies on construction of such large dams and their vulnerability to active faults and thrusts based on the role of river incision, exhumation and uplift, erosion, orographic precipitation, and consequent landsliding, seismic b-values, and seismic design parameters in the western and eastern Himalaya with a special reference to the Sikkim Himalaya.

An account of Quaternary deposits of Hetauda area, central Nepal, and their engineering significance

A. K. Duvadi, A. Koirala, L. N. Rimal, D. Nepali, B. Piya, and S. P. Manandhar
Department of Mines and Geology, Kathmandu, Nepal
(Email: dmgrss@info.com.np)

Hetauda is a fast-growing city. It is a dun valley in the Siwaliks of central Nepal and consists of thick young sediments. Construction of residential buildings on the soft and fragile ground, disposing of municipal wastes into the riverbeds, haphazard mining of the construction material from the riverbeds and unplanned urbanisation are some of the acute problems of the Hetauda Municipality. Hetauda though an unplanned town, is not yet too late to start proper planning.

An engineering and environmental geological investigation was carried out to prepare an engineering and environmental geological map of the Hetauda Municipality and its surroundings. The sediments of the study area belong to the fluvio-lacustrine deposits and were differentiated into ten different units based on their geological setting and engineering geological characteristics. The engineering and environmental geological map shows important features such as the

distribution of bedrock and quaternary deposits, erosion- and landslide-prone areas, springs, tectonically weak zones, zones susceptible to subsidence, and gravel extraction areas.

Some of the important findings of the study are the following.

– The central core area of the Hetauda Municipality is located on an old fan deposited by the Rapti River flowing from north to south.

– In the past, lacustrine environment was developed in various tributaries of the Rapti River including the Karra Khola.

– The Hetauda Municipality does not have a sanitary landfill site yet and is urgently in need of one.

– The lacustrine deposit named as the Chihandanda Formation is hazardous from construction point of view owing to its susceptibility to subsidence and consolidation, whereas it could be suitable for developing a sanitary landfill site.

– The highest terrace deposit named as the Padampokhari Formation is suitable for construction of buildings and infrastructures as well as the red soil developed on its top is usable as one of the components in cement production.

Investigation of liquefaction potential of footing foundations with improved soil

Mahmood Ghazavi, Amir Soltani, and Hamzeh Ahmadi
Faculty of Civil Engineering, Khaje Nasir University of Technology
19967-15433, Tehran, Iran

Studies on soil liquefaction have been conducted by many researchers. It has been detected that the liquefaction strength and its related behaviour are influenced by many factors, such as confining stress, soil density, grain size, and fines content. A severe damage of infrastructures constructed on these soils is commonly observed when an earthquake occurs. Some structures like usual buildings with footing foundation are constructed on these soils, and most of them are quite vulnerable to earthquakes.

Soil improvement is one of the useful methods of earthquake risk reduction for structures with footing foundation. In this method, the soil under the footing is replaced by a non-liquefiable one. This paper describes various aspects of soil improvement including its depth and width using a finite element method, constant earthquake response spectrum, and dynamic analysis. Firstly, we study the influence of some parameters of soil such as density, modulus of elasticity, Poisson's ratio on liquefaction zone, and Ru ratio, then we investigate the width of footing foundation and the depth and width of improved soil and their influence on the Ru ratio, liquefaction zone, and settlement of footing foundation. The value of a constant load, footing width, and depth of improved soil significantly influence the Ru ratio and affect soil liquefaction. There is a minimum value of the Ru ratio in this method. By comparing the parameters before and after the proposed soil improvement, it is possible to come up with an optimum design of footing foundation on a liquifiable soil.

Some geo-engineering problems of buildings of the Greater Dhaka City, Bangladesh

A. T. M. Shakhawat Hossain
*Engineering Geology Section, Dept. of Geological Sciences,
Jahangirnagar University, Savar, Dhaka–1342, Bangladesh
(Email: shakhawathos2004@yahoo.com)*

Rapid urbanisation in the greater Dhaka city has led to an increased interest in the geo-engineering problems of buildings. The Dhaka soils are reddish to yellowish brown mottled clays. These reddish brown deposits contain ferruginous cements, concretions, and nodules. These soils are characterised as an intermediate- to high-plasticity inorganic clay (CI to CH).

This study has evaluated the causes of structural damage in some residential and official buildings of the greater Dhaka city. Attempts have been made to identify some of the problematic engineering structures. Three dimensional (3D) ground deformations and ground responses are carefully evaluated and the results are compared with the soil mineralogy. It was observed that there was a significant difference in soil properties both in lateral and vertical directions. It was also observed that in the 3D measurements, all samples showed a significant amount of deformation for 5 to 6 days. The rates and magnitude of deformation for different samples at different areas were different. For the first few days, the deformation rate was maximum, after that it reduced. It was observed from the deformation characteristics that most of the buildings of the investigated area were founded on soils of low to medium expansiveness, and crack development in engineering structures might be due to the upheaval of foundations. Efflorescence and surface deterioration were also observed in many buildings of Gazipur, Joydevpur, and the Savar area of Dhaka.

Tectonic setting of the Nepal Himalaya and potential for hydrocarbon exploration

Bharat Mani Jnawali
*Department of Mines and Geology,
Kathmandu, Nepal
(Email: pepp@wlink.com.np)*

Nepal lies at the collision zone between the Indian subcontinent and the Tibetan plateau of the Eurasian continent. It is made up of enormous tectonic stacking of sedimentary and metamorphic rocks with granite intrusions that resulted from the dramatic collision and underplating of the Indian Craton with the Lhasa block of Tibet. The four major tectonic zones separated from each other by fault contacts from north to south are the Trans Himalaya, Higher Himalaya, Lesser Himalaya, and Siwaliks. On the northern margin of the Indian subcontinent, foreland sedimentary basins began to develop just after the terminal collision between the northward-drifting Indian Plate and relatively passive Eurasian Plate in the Late Eocene. The southern part of Nepal, known as the Terai and Siwalik foothills, lies in the northern margin of the Ganga Basin and Purnea Basin, which extend from India. Such basins with a thick accumulation of sediments are considered as the potential areas for petroleum exploration.

Seismic refraction, gravity, and magnetic data combined with surface mapping and basin analysis have established the subsurface framework of southern Nepal. The geological settings potential for hydrocarbon prospects recognised in Nepal include structural traps related to normal faulting involving pre-Siwalik formations and thrusting involving the Siwaliks; structural traps associated with frontal blind thrusts, anticlines, and thrust faults; basement-controlled structures and stratigraphic pinchouts. Subsurface structural models of the western Terai has been constructed based on seismic and geological data and kinematic evolution analysis.

Oil and gas seeps have been observed in the Dailekh area emanating through deep faults. Geochemical analysis of these seep samples indicate that these oil and gas have geologic al origin from mature source rocks. Various outcrop samples from different parts of the country have been found rich in organic carbon. The s ource rock maturity basin modelling constructed for various sections indicates that the level of thermal maturity is within the oil and gas generating window. The Potwar Basin to the west in Pakistan and the Assam Basin to the east in India having exactly similar geological settings to that of Nepal are producing oil and gas since a long time. In the Indo-Gangetic plain across the border with India, many deep wells have recorded the presence of gas and hydrocarbon. The evaluation of available data acquired so far indicate that there is a fairly good possibility of discovering petroleum resources in Nepal.

Dimension stones and aggregates in Dandeldhura district, Far Western Nepal

Ganesh Raj Joshi
Department of Environmental Science, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal
(Email: ganeshr_joshi@hotmail.com)

The study area lies between latitudes 29°37'20"N and 29°12'30"N, and longitudes 80°34'15"E and 80°38'30"E. It consists of the Lesser Himalayan low-grade metamorphic rocks of the Budar Metasedimentary Complex and the medium-grade Dandeldhura Crystalline Complex (Gansser 1964; Hagen 1969; Fuchs 1977). The South Dandeldhura Thrust (SDT) is the tectonic boundary between these two units. The low-grade Budar Metasedimentary Complex consists of two formations: the Budar Quartzite and the Rupaskarna Phyllite. The Dandeldhura Crystalline Complex consists of three formations: the Gaira Schist, the Saukharka Granite-Gneiss, and the Pokhara Phyllite.

The Budar Quartzite consists predominantly of milky white quartzite with minor greenish grey phyllite. The Rupaskarna Phyllite is composed mainly of grey to greenish grey phyllite with some quartzite, amphibolite, and mylonitic augen gneiss. The Gaira Schist made up of biotite-garnet-feldspar schist with minor carbonaceous slate alternating with quartzite. Many pegmatite veins and augen gneiss bands are also common within the formation. Besides the peripheral part of the Saukhark Granite-Gneiss, which is essentially composed of augen gneisses, the core zone shows different mineralogical variations. A few bands of garnetiferous schist are common in the Saukharka Granite-Gneiss. Pokhara Phyllite essentially consists of lead- grey to black carbonaceous phyllite with light grey phyllite and minor quartzite bands.

The area shows good potential for various kinds of metallic and non-metallic mineral resources (Joshi 1978; Kaphle 1981). A few sites along the Dhangadhi–Dadeldhura road section show the potential reserves of building and construction materials.

REFERENCES

Fuchs, G., 1977, The Geology of Karnali and Dolpa Regions, western Nepal. Jahrbuch Geol. Bundesansalt, v. 120, pp. 165–217.

Gansser, A., 1964, *Geology of the Himalayas*. London, Interscience Publisher, John Wiley and Sons, 289 p.

Hagen, T., 1969, Report on Geological Survey of Nepal. Vol.1, Preliminary reconnaissance. Zurich, Denkshrifen der Schweizerischen Naturforschenden Gesellschaft, Memories de la societe Helvetique des sciences naturelles, v. 86, 185 p.

Joshi, P. R., 1978, Report on Geological and Geochemical Investigation on Mineral Resources of a part of Dandeldhura Granitc Massif., Dandeldhura district, Mahakali zone. DMG, Kathmandu, Nepal, 10 p. (Unpublished).

Kaphle, K. P., 1981, Geological and Geochemical Exploration of Copper Tungsten Prospect at Bamangaon and Adjacent Area, Dadeldhura District, Far Western Nepal. *In*: Proceeding of Symposium on Tungsten Geology, ESCAP/RMRDC and Ministry of Geology, P. R. China, pp. 123–126.

Engineering geology of Waterside Green, Sydney, Australia

∗Indra Jworchan, Tony O'Brien, Emged Rizkalla, and Paul Gorman
Geotechnique Pty. Ltd.,
Lemko Place, Penrith, Sydney, Australia
(∗Email: indra.jworchan@geotech.com.au)

Development of low-lying land affected by high groundwater table and the presence of saline and sodic soils and local swampy areas, remains a challenge for Local Government, Developers, and Statutory Regulators. The proposed residential and commercial subdivision, in Penrith, Sydney, Australia, is located in such a site. The proposed subdivision comprises a commercial area consisting of two to four-storey buildings and office blocks (16 ha), a residential area for 700 future dwellings, internal roads (40 ha), five lakes and several laterals (17 ha). The development control plan for the site states that the drainage and stormwater management system within and across the site should be improved from existing conditions and that future dwellings and other structures should be constructed on ground higher than the 1 m in 100 year flood level, without the necessity to import filling material. Therefore, the subdivision master plan proposes excavation of a series of lakes and laterals to improve drainage, implementation of a stormwater management system, and use of materials gained from excavations to raise site levels above the 1 m in 100 year flood level. Site works for the subdivision are estimated to involve movement of approximately 570,000 m^3 of site material, and possible import of approximately 75,000 m^3 of clay for lining the sides and bases of lakes and laterals.

This paper presents the results of engineering geological and geotechnical investigations for the proposed subdivision. The study was carried out to determine the nature of subsurface profiles across the site, groundwater conditions, characteristics of soils and suitability of soils for reuse as topsoil, engineered fill, and impermeable clay liner for lakes and laterals. This paper also provides recommendations on appropriate construction methods in areas with saline soils.

The subsurface profile at the site comprises alluvial deposits underlain by residual soil, which in turn is underlain by bedrock, such as shale, and sandstone. In the eastern portion of the site, the alluvial deposit comprises a sequence of clay, sand and gravel (clayey profile), and in the western portion, the alluvial deposit comprises a sequence of sand and gravel without clay (sandy profile). The alluvium in the eastern portion of the site is saline, but the alluvium in the western portion of the site is generally non-saline. All saline soils are sodic and most non-saline ones are non-sodic. Depths to groundwater levels within the clayey profile range from 3.6 m to 5.9 m. In the sandy profile, depths to groundwater level range from 3.0 m to 4.7 m.

The study revealed (1) relatively saline and dispersive soils cover about 35% of the total site, mainly in the eastern portion. (2) Topsoil can be used as part of engineering fill after completion of special treatment. (3) Sandy and clayey alluvial soils are suitable for use as engineering fill, (4) Depths to groundwater levels vary considerably from place to place, however, groundwater levels at each monitored location did not vary significantly with time. (5) Clayey soils encountered within the site are not suitable for use as clay liner for the proposed lakes and laterals even after special treatment, and importation of suitable clay will be required. (6) Earth works for the proposed development should be carried out in accordance with an appropriate soil management plan to deal with saline, sodic, dispersive, and aggressive soils. (7) Appropriate construction methods and materials suitable for moderately aggressive sites should be used.

Application of subsurface geophysical imaging for earthquake hazard mapping: a case study from Dhaka Metropolis, Bangladesh

Aftab Alam Khan
Department of Geology, University of Dhaka,
Dhaka–1000, Bangladesh
(Email: aftab@univdhaka.edu)

Geophysical investigations were conducted in the Dhaka Metropolis area for subsurface imaging pertaining to electrical tomography, seismic velocity, and dominant frequency. Electrical tomography is useful in identifying shallow faults, buried channels, filled zones, and lithology with saturation status. The seismic velocity status of shallow subsurface up to engineering bed rock depth helped to identify the spatial zones characterised by high particle

velocity and attenuation. Dominant frequency determinations indicated the most likely resonant wavelength that would cause possible building collapse.

An integrated approach was adopted to understand the interactions between the geological conditions affecting the Dhaka Metropolis area in the light of earthquake hazard vulnerability, and to apply this understanding for useful predictions and probabilistic hazard assessment. Earthquake risk assessment and hazard zoning pertaining to dominant frequency character, maximum possible magnitude of fault reactivations, and other geological site characterisation are possible in an area where the real-time seismological data acquisition is lacking. Evidence of pre-historic fault ruptures and the present-day seismicity trend have also been correlated for assessing earthquake risk and hazard zoning.

Application of GPR in building foundation evaluation

Murari Khatiwada
Central Department of Geology,
Tribhuvan University, Kathmandu, Nepal
(Email: Murex_7@yahoo.com)

Among the applications of the nondestructive geophysical tests, ground penetrating radar (GPR) is one of the simple, efficient, reliable, and portable methods for the investigation of shallow subsurface. This method is entirely based on the propagation of the electromagnetic (EM) waves through the subsurface materials and their response to the electromagnetic waves. GPR signals are governed by the Maxwell's equations. At high frequencies, in poorly conducting media, the conduction term in the electromagnetic equation is negligible compared to the displacement term. GPR uses the EM waves with short pulses and high frequencies ranging from 10 MHz to 1200 MHz.

GPR can be used for post construction evaluation and monitoring of engineering structures. Ideal electrical properties of concrete, rebar, and other common construction materials make exploratory studies using GPR extremely efficacious. Easy data collection procedures and on-site visual analysis on the portable computer devices have made this method popular worldwide, and is preferred especially in the field of engineering and environmental applications. Post construction evaluation studies in the foundation of the building complexes involve the identification, qualification,

and quantification of reflected GPR signals. These GPR signals include, but may not be limited to, reflection strength, signal polarity, two-way travel time, signal attenuation, and hyperbolic reflection, which is necessary for subsurface feature identification and delineation.

GPR presents a viable option for the post-construction evaluation and monitoring of buildings and other engineering structures by estimating deterioration, and identification of position and displacement of the rebar at the basement. It has a high accuracy and less variability than traditional visual estimation and other geophysical methods including the costly destructive methods. This nondestructive technique provides valuable information of building foundation, enabling efficient spending and decision-making regarding the nature and types of problems that might occur after the construction of multi-storeyed buildings and other engineering structures. This method is also very useful in identifying and locating the deformation of rebar, spacing of ebar, depth and thickness of concrete slabs and beams, depth and width of foundation, voids in the filling materials and cracks in the basement of many engineering structures.

A borehole electrical conductivity experiment for determining hydraulic conductivity

Yeonghwa Kim
Department of Geophysics, Kangwon National University, South Korea

An electrical conductivity experiment was carried out for determining hydraulic conductivity in boreholes. The experiment was based on the monitoring of conductivity change within boreholes with given salinity contrasts between a borehole and formation fluids (Tsang and Hale 1989; Kim and Lim 2001). Fluid conductivity was obtained by the reciprocal relationship with resistivity. The study was made first by a simplified physical model hole study, and

then by in-situ borehole tests. The physical model hole study was made in order to find out the controlling factors in electrical conductivity variation created by salinity changes as well as to derive a model equation for determining hydraulic constants from the relationship between conductivity change and flow rate. The apparatus consisted of a model hole and a measuring system for the electrical conductivity of borehole fluid. The model hole was composed of a transparent plastic tube with a diameter of 75 mm and devices for controlling the amount of incoming and outgoing fluids.

Different kinds of automatic systems were set up for fluid resistivity measurement in the physical model hole and in-situ borehole experiments, although both systems consisted of a digital multimeter, a terminal block, and Labview software provided by National Instruments Co. The main difference was in their electrode configuration: the 4-electrode method was applied for the physical model experiment using two outermost electrodes as the current electrodes and two inner ones (spaced at 5 cm interval) as the potential electrodes; and the 2- electrode method was selected for in-situ borehole measurements, where the two adjacent electrodes (among 64 channels spaced at 50 cm interval) were the current and potential electrodes simultaneously.

In the model hole measurement, distilled water was used as the formation fluid and various concentrations of NaCl (from 0.01% to 0.1%) solution represented the hole fluid. In the borehole, 0.05% and 0.07% NaCl solutions were used for the hole fluid while the formation fluid whose conductivity was about 80 μS/cm flowed into the borehole. The following results were obtained from the model study: 1) the amplitude of conductivity decrease shows a proportional relationship with salinity; 2) a rapid upward movement of incoming fluid caused by smaller NaCl concentration of formation fluid could be compensated effectively by controlling the temperature difference between the hole and formation fluids; 3) a significant proportional relationship was shown between gradients of conductivity decrease and flow rates, and the corresponding model equation was the same as it was assumed to be a simple replacement of ionic fluid by non-ionic fluid.

In the borehole measurement, an attempt was made to confirm the efficiency of the model equation derived from the model hole study. Salinity contrast was chosen high as far as the incoming fluid does not create rapid upward movement according to the temperature control of borehole fluid. The in-situ borehole measurement showed a fairly good correlation between the permeability values obtained from the electric conductivity measurement and straddle injection packer test. The results also indicated a need of further study of the measuring system as well as method for replacement of borehole fluid without disturbing the formation fluid.

REFERENCES

Kim, Y. and Lim, H., 2001, A physical model hole experiment for determining hydraulic constants in borehole using an electrical conductivity log technique. 2001 Annual Conference of the International Association of Mathematical Geology, Cancun, Mexico, A1–11.

Tsang, C. F. and Hale, F., 1989, A direct integral method for the analysis of borehole fluid conductivity logs to determine fracture inflow parameters, Nagra-Doe Cooperative Project Report, Earth Science Division, Lawrence Berkeley Laboratory, 21 p.

Development and operation of cut slope management system and real time monitoring system to reduce damages

Hobon Koo, Jong Hyun Lee, and Jung Yub Lee
Geotechnical Engineering Research Department,
Korea Institute of Construction Technology, Korea
(Email: hbkoo@kict.re.kr; jhrhee@kict.re.kr; yeupi@kict.re.kr)

The Republic of Korea needed to expand its national road network in order to reconstruct and develop the national economy in 1960s and 70s, during which a number of cut slopes were created due to the topographical conditions that more than 70% of territory is covered by mountainous districts. In 1960s, when the industrialisation started, there were concerns about the quick access, and roads were constructed hastily with a poor technology, and the stability of cut slopes did not get due attention. The risky cut slopes of that period are still found at a number of places, and they fail every year. In the past, the hazardous cut slopes were rehabilitated only after their failure through post-management measures. Recently the government changed the direction and is working for the prevention of any potential collapses in order to protect people's lives and property. As part of it, the Korea Institute of Construction Technology (KICT) and the government (Ministry of Construction and Transportation) have developed and operated a Cut Slope Management System (CSMS) project in order to maintain the stability of cut slopes nationwide since 1998.

The cut slopes scattered nationwide are investigated through the CSMS project, and they are ranked into 5 risk grades based on their repair priority. With these data, further

analysis is carried out to come up with appropriate slope stability measures. For this purpose, a database was created in a geographic information system (GIS). The GIS enables to study and analyse each site and determine its risk grade together with the required road rehabilitation design.

Recently, a real time monitoring system (RTMS) is being implemented in addition to the existing civil engineering and GIS database for the purpose of monitoring the risky cut slopes from office or mobile communication. Furthermore, an early warning system is also installed to prevent any road accident. As part of reviewing the applicability and effectiveness of this early warning system, rockfall hazard lights were installed around several cut slopes in 2004.

The above systems show the results of combining the traditional civil engineering and rapidly developing information technology (IT). It is also expected from such studies that we can have more improved systems if civil engineering and construction is advantageously combined with IT, by which the current road system can be stably operated by significantly reducing any damages owing to cut slope failures.

3D wedge analyses carried out during DPR-stage investigations of Pung-Dehar Silt-Flushing Tunnel project, district Mandi, H. P.

Sanjiv Kumar
Geological Survey of India, Engineering Geology Division,
Barmana, H. P., India
(Email: kumarsanjiv2003@yahoo.co.in)

This paper discusses results of 3D wedge analyses carried out during the DPR-stage geological investigations for the Pung-Dehar Silt-Flushing Tunnel project, which envisages the construction of a 3.8 m wide (diameter) and about 13.5 km long tunnel (one aqueduct to cross the Alsed Khud) with the intake near the balancing reservoir of the BSL project at Sundernagar. The silt will be flushed into the river Sutlej downstream of the BSL switchyard near Kangu. Tunnelling will be carried out in the sandstone and claystone or siltstone sequence of the Dakshai Formation and dolomite belonging to the Shali Formation in more than 90% of the reach.

The wedge analysis was done on the basis of jont data recorded during the geological mapping and exploratory drifts logging. It was based on the following assumptions:

- The joints are continuous and the kinematically most suitable combination for wedge formation occurs at one place during the excavation;

- The cohesion along joint planes is nil and the angle of internal friction is taken as 30°;

- The failure of rock mass occurs due to the structural discontinuities;

- Steep capacity of bolts is 25 tonnes and the anchor capacity is 10 tonnes; and

- Shear strength of shotcrete is 200 tonnes/sq m.

Relationship between fracture pattern, bedding, and **b**- axis of Mish Anticline

Asghar Laderian
Engineering Department, Arak University, Iran
(Email: asg_laderian@yahoo.com)

Joints developed during folding are widespread in the Mish Anticline. They vary in orientation, timing, and type, and also are controlled by the thickness of the formation. The joints control the reservoir properties of limestone constituting the oil belt southwest of Iran. A detailed joint analysis was carried out for the Mish Anticline which is in the north of the Gachsaran city and has an outcrop area of 625 km^2 in the Zagros fold belt. A number of outcrops were selected and the analysis was carried out to find out the relationship between the fracture pattern, bedding, and β–axis of the anticline at different locations.

Geotechnical investigation of Chameliya Hydroelectric project

A. S. Mahara[1] **and R. B. Sah**[2]
[1]*Middle Marsyangdi Hydro-Electric Project,*
Site Office, Lamjung, Nepal
[2]*Central Department of Geology, Tribhuvan University,*
Kirtipur, Kathmandu, Nepal

The proposed Chameliya Hydroelectric project (30 MW) located in the Darchula District of the Mahakali Zone in Far Western Nepal, lies geologically in the Inner Lesser Himalayan Autochthonous Zone of Darchula Carbonate Group. A geotechnical study was carried out at the design level of the project. The dam is proposed in purple siliceous dolomite; underground desanding basin is in mottled dolomite; 4 km long power tunnel is in dolomite, slate, sandstone, and purple shale with conglomerate and diamictite beds; and powerhouse is on alluvial deposits. The subsurface geological information was obtained from 4 km long seismic refraction survey and 400 m core drilling in 12 holes. Apart from the Bhelgad section and powerhouse area, all other proposed civil structure locations are considered sound from geotechnical point of view. The Bhelgad section and powerhouse area show deep (about 40 m) overburden. A fault passes close to the powerhouse. A seismic coefficient of 0.15 g is proposed for the project design.

Monitoring of tailings dam at Kiruna, northern Sweden, using self-potential method

*****Ganesh Mainali**[1]**, Sten-Åke Elming**[1]**, and Hans Thunehed**[2]
[1]*Division of Ore Geology & Applied Geophysics,*
Luleå University of technology SE-971 87, Luleå, Sweden
[2]*Geo Vista AB PO Box: 276, SE-97108 Luleå, Sweden*
(*Email: Ganesh.Mainali@ltu.se)

The stability of large dams can threaten the safety of people and industrial property as well as cause substantial environmental effects. Internal erosion caused by seeping water constitutes a significant threat to the stability of dam embankments. Self-potential (SP) method has the possibility to detect and locate seepage zones at an early stage of their development.

SP measurements were carried out for identifying anomalous seepage zones and monitoring tailings dam at Kiruna in northern Sweden. The tailings dam consists of a central core of compacted till surrounded by sandy filters and supporting rock fill. The surface of the dam is covered by coarse materials. The entire dam was mapped by SP measurements during 2002. The general pattern of positive SP values at the downstream slope has been revealed, which is in agreement with the expected result of streaming potentials developed over the dam core. Four smaller areas with some SP anomalies were selected for detailed SP measurements. The measurements were performed during summer 2002 and the results confirmed the anomalies. The dam was raised during 2003 and new SP measurements were repeated thereafter during the autumns of 2003 and 2004 at the same areas. The results from 2003 measurements deviate from 2002 measurements; with in general, more negative potentials along the downstream slope. It is likely that a redistribution of soil moisture was still taking place when the 2003 measurements were taken, and it is also possible that the pressure distribution in the dam core has not reached equilibrium. The acquired potentials are therefore probably not reflecting the seepage pattern within the dam. The potential distribution obtained from 2004 measurements is compatible with the results obtained before the raising of the dam. No major anomalies that can be related to anomalous seepage can be expected. The large positive anomaly refers to potentials caused by metallic observation pipes.

Four lines of fixed electrodes were installed across the dam, each consisting of one current electrode and four potential electrodes. SP measurements during 2003 and 2004 were also carried out with those fixed electrodes at roughly monthly intervals for one full year, except winter seasons when ground around the electrodes was frozen. SP variations with fixed electrodes agreed with pool level data indicating that streaming potentials are the cause of the SP variations.

Geological and geotechnical investigations of Tapovan–Vishnugad Hydropower Project, Chamoli District, Uttaranchal, India

*Ajay K. Naithani[1], K. S. Krishna Murthy[2], and Aditiya K. Bhatt[1]

[1]*Department of Geology, H.N.B. Garhwal University, Srinagar (Garhwal), India*
[2]*GSI, 928, 22nd Main Road, IV'T' Block, Jayanagar, Bangalore, India*
(*Email: ajay_naithani@hotmail.com)

Tapovan–Vishnugad Hydroelectric Project is a run-of-the-river scheme across the river Dhauliganga in the Alaknanda valley in the district Chamoli of the Uttaranchal Himalaya. The project envisages utilising a 518 m drop available in the river Dhauliganga. The installed capacity of the project is 520 MW (4 x 130 MW) with a designed discharge of 90 cumecs. In the project area, the exposed rocks of the Central Himalayan Crystallines are composed mainly of medium- to high-grade metamorphics. Towards the south, the Crystallines are thrusted over the Lesser Himalayan rocks of the Garhwal Group along the Main Central Thrust. The proposed barrage site across the river Dhauliganga is located near Tapovan. Augen gneiss is exposed at the barrage site at the river level on the right bank. On the left bank, the area is occupied by highly jointed and sheared metabasics with bands of gneiss and schist. The sedimentation tank is proposed to be located on the left bank of the river before the impounded water is led into the headrace tunnel. The layout of this tank indicates that it is aligned along an old course of the river Dhauliganga made up of alluvial and colluvial deposits. The tank exit is also occupied by alluvial material whereas the slopes on the left bank are occupied by highly jointed metabasics with gneiss and schist bands, and extensive excavation will be required to reach a sound foundation. The proposed headrace tunnel alignment passes through a rough and rugged terrain, on the left bank of the rivers Dhauliganga and Alaknanda. The tunnel will encounter the Tapovan Formation consisting of augen gneisses, fine-grained quartz-mica gneisses, quartzites, and micaschists; and the Joshimath Formation of coarse-grained garnet-biotite-kyanite gneisses with schist bands. The alignment of pressure shaft falls along the ridgeline of the Shelong village, occupied by fine-grained quartz-mica gneisses (banded gneisses) at the higher level, and schists and quartzites at the lower level. The pressure shaft has to be located in fine-grained quartz-mica gneisses, micaschists, and quartzites. In the underground powerhouse area, the rocks will be micaschists, quartzites, fine-grained quartz-mica gneisses, and augen gneisses belonging to the Tapovan–Helong Formations of the Central Crystallines. The tailrace tunnel area at the surface is occupied by the quartzite forming the Animath ridge, and micaschist on its southern slope and on either bank of the Animath Nala. Further downstream, the Alaknanda river terraces are noted.

In this paper an attempt has been made to classify the area geotechnically on the basis of observations made in the exploratory drift as well as the information obtained from drill holes and surface mapping. The geological and geotechnical methods employed at the investigation stage include rock mass classification using Q and RMR system. Rock mass classifications are important indirect requirements for applying numerical procedures in designing underground structures in rock. On the basis of above study, recommendations are also made for the proper and safe constructions in the project site.

Shotcrete mix design in Middle Marsyangdi Hydroelectric project, Nepal

Kaustubh Mani Nepal
Middle Marsyangdi Hydroelectric Project, Lamjung, Nepal

This study deals with various designs of shotcrete mixes for the support of slope and underground structures in the Middle Marsyangdi Hydroelectric project. In this project, three different types of shotcrete mix are designed. The strengths of all mixes designed initially were more than required. About 50% (in average) of 28 day strength was achieved in one day. The mixing ratios were 1:2.03:1.57 for dry, 1:2:1.69 for wet, and 1:1.74: 1.24 for fibre shotcrete. The water:cement ratio varied between 0.33 and 0.48, the amount of cement was 420–475 kg, and the admixture used was in the range of 1.5–2 % by the weight of cement. Some per cent of fly ash was used in the shotcrete mixes for better workability. But, in the project, shotcrete mixes were without silica fume. The one-day average compressive strength of dry shotcrete was 20 MPa, that of wet shotcrete was 16 MPa, and that of fibre shotcrete was 13.7, whereas 28 day strengths were 45, 33, and 35.3 MPa, respectively. The cement used for designing the shotcrete mixes was of Type V (low alkali). Based on this study, recommendations were made for the mix design of different types of shotcrete mixes for further construction works.

Geological aspect of bridge construction in hills of Nepal

Badan Lal Nyachhyon, Tara N. Bhattarai, and Nar G. Rai
MULTI Disciplinary Consultants (P) Ltd.,
Kathmandu, Nepal

The bridges in the Terai and hills frequently cross faults, and are also subject to major geological phenomena, such as debris accumulation at the bridge site, landslide movement, bank undercutting, and soil erosion.

The wash out of Malekhu Bridge (two times in 5 years), abutment rehabilitation at Galchhi, Trishuli, for raising the bridge height, river diversion to a new tributary abandoning the existing bridge at Chisang-Letang, are a few examples of bridge damages that may be caused by geological and meteorological activities at the bridge site and in the upstream areas. These cases invite for serious thinking in identification of appropriate locations as well as their monitoring.

The geological aspect of bridge construction in Nepal is one of the weakest parts and normally not adequately dealt with. The paper examines the geological conditions that affect the bridge design and construction in hills based on the preliminary study of 26 bridges by the Department of Roads and JICA.

Reinforced earth mat foundation over fibre-reinforced sand columns inside soft clay

Emad Adbelmoniem Mohammed Osman
Civil Engineering Department, Faculty of Engineering,
University of Minia, Egypt
(Email: e_osman@hotmail.com)

In this paper an attempt has been made to highlight a new geotechnical geocomposite system. It presents the results of a preliminary laboratory investigation of soft clay strengthened by reinforcement. The system consists of fibre-reinforced sand (mixed with randomly oriented fibres and compacted in layers) between two geotextile sheets over fibre-reinforced sand columns inside the soft clay. The new geotechnical composites are similar to the structural composites in dissimilar materials (as in sandwich panels), and are used together to improve the performance of a constructed system. The lateral restraint of the system dose not depend only on the surrounding soft clay but also on the randomly fibre-reinforced sand columns. The laboratory model test comprised circular footing on sand layers followed by the new composite system underlain by soft clay in a testing tank, a static loading system, and measurement devices. The load settlement behaviour of footing and the bearing capacity characteristics were obtained and interpreted with respect to various parameters, such as dimensions of the new composite system, pressure ratio, settlement, and bearing capacity characteristics. The results have indicated that the settlement decreases by using the new system. The new composite system shows some promise to solve the problem of large settlement of footings over problematic soils such as soft clay.

Geochemical analysis and reserve estimation of the Sindali limestone deposit, Sukaura, Udaypur, east Nepal

P. R. Pandey
Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal

The Sindali limestone deposit within the Lesser Himalayan zone lies in eastern Nepal and is part of the Bhainsedobhan Marble that overlies the garnetiferous schist of the Raduwa Formation and underlies the schist of the Kalitar Formation. The grade of limestone is highly affected by the intercalation of dolomite layers. The landslides found in the area threaten the infrastructures in the quarry site and the habitat.

The chemical analysis of limestone was carried out in the Udaypur Cement Factory, by the titrational method, and also the minerals present in it were studied using the X-ray diffractometer. A variation diagram was prepared to understand the chemical grade of limestone.

The chemical analysis shows that the Sindali Limestone contains 49.20% of CaO and 2.65% of MgO by weight. The variation diagram shows that at the bottom part (up to 55 m) and at levels between 130 m and 220 m, the quality of limestone is comparably better than at levels 75 m, 100 m, and in the upper part (250 m thick sequence). The X-ray diffractogram shows the presence of calcite, dolomite, and muscovite in the limestone samples. Similarly, the modal composition also shows a higher calcite content (about 90%), indicating that the limestone is of good quality. The total probable reserve of the cement-grade limestone calculated by the cross-sectional method is about 85.12 million tonnes.

Geology and design of desanding basin backslope in weak rock: a case study from Kali Gandaki "A" Hydroelectric project, Nepal

Dibya Raj Pant
Nepal Electricity Authority, Kathmandu, Nepal
(Email: dibyapant@yahoo.com)

Excavation and completion of the desanding basin of the Kali Gandaki "A" Hydroelectric project experienced problems during its construction stage due to the need to cut and stabilise a 125 m high cut slope in weak rock to accommodate a surface desanding basin. The presence of weak and sheared carbonaceous phyllite at the upper part of the slope, unfavourable sheared geological contact between overlying carbonaceous phyllite and underlying fractured dolomite, and presence of less quantity of dolomite than expected at the toe of the desander

back slope caused partial failure of the cut slope during construction, and forced to redesign the back slope.

The redesign was finalised by additional geotechnical exploration, review of updated geotechnical data, installation and monitoring of geotechnical instruments, and slope stability analyses. A final solution to the problem was found with a gentler slope. Post construction monitoring indicates a satisfactory behaviour of the cut slope at present.

The need of tunnelling and the challenges we face in Nepal

K. K. Panthi
Department of Geology and Mineral Resources Engineering,
Norwegian University of Science and Technology (NTNU),
Alfred Getz vei 2, N-7491 Trondheim, Norway.
(Email: krishna.panthi@geo.ntnu.no)

Tunnels and underground caverns are needed to harness the huge hydropower resource of Nepal. However, due to active tectonic regime, the rock masses in Nepal are fragile and somewhat different in their engineering behaviour. This

change in the mechanical behaviour is mainly caused by a high degree of folding, faulting, shearing, fracturing, and deep weathering. As a result, many stability problems associated with this complex geological set up have to be faced during

tunnelling. This is the major challenge that has to be overcome for making the tunnel option cost effective, feasible, and safe.

The main aim of this paper is to highlight the areas of difficulties in tunnelling and discuss the major geological challenges that were faced during tunnelling in Nepal in four recent hydropower projects. In addition to this, the paper also deals with the selection criteria of various tunnels and underground caverns in fragile Himalayan conditions.

Electrical methods for the study of dam leakage: example from Jhimruk Hydropower project

Surendra Raj Pant
Central Department of Geology,
Tribhuvan University, Kathmandu, Nepal
(Email: spant@wlink.com.np)

Conventional electrical resistivity (ER) and electromagnetic (EM) methods are frequently used for dam site investigation. ER and EM methods are capable to detect water tables, moisture variation in the porous material, different material types, and bedrock depth. These methods are categorised as artificial source methods. New developments in these methods have greatly enhanced their capacity in subsurface exploration. The new methods such as electrical resistivity tomography (ERT) have been widely used for the evaluation of embankments, earth dams, concrete dams, and natural dams. ERT has a high accuracy and resolution, and can map any minor changes in the subsurface. These methods are used for the monitoring and evaluation of dams.

Self-potential (SP) methods are also widely used for the localisation of the leakage zone in water reservoirs. SP method is based on the measurement of the electrical fields developed due to the movement of water in porous and permeable media. The intensity of SP anomaly depends on many different factors.

Electrical methods such as ERT and SP were used for detecting the damaged part of the HDPE liner towards the upstream from the dam. The leakage of water or electrical current could take place through the damaged part of the HDPE liner. The damaged part of the HDPE liner was indicated by a low electrical resistivity, whereas the leakage areas were indicated by a high value of negative potentials from the background. The results of the investigation indicated that not every damaged part of the HDPE liner is leaking. Some of the damaged part of the HDPE liner could be sealed by clay. There were five negative SP anomalies. Four of these were located in the HDPE liner area and one was probably related to the leakage through the damaged part of the concrete liner. These zones were named as Leakage Zone I through Leakage Zone V. Leakage Zone I is related to the concrete liner area. If there is no damage in the concrete liner, which allows the percolation of the reservoir water, then this anomaly is most likely related to the concentrated flow below the concrete liner. However, there is no sufficient data coverage to exactly locate the Leakage Zone I. Leakage Zones II, III, and IV are in the area of the HDPE liner, and Leakage Zone V is related to the covered left-end bypass. The nature of the anomaly in zones II, III, IV and V suggest that the leakage is occurring at different depth levels. Narrow anomalies are related to a shallow depth and wider anomalies are related to a greater depth. The wider anomalies are attributable most likely to the area below the dam foot. The narrow anomalies are close to the dam crest and are created either by the leakage through the joints of the HDPE liner or the joints of the dam. Moderately high potentials are observed between Leakage Zones I and II, and Leakage Zones IV and IV, and these were found to be related to the outflow of water through the damaged part of the HDPE liner. Very high positive potentials were also observed in the lower stilling basin, which is related to the intense seepage. This is contributed by infiltrating water near the dam crest and groundwater in the upstream. Field repair crew has excavated the suspected area of damage of the HDPE liner as given by ERT. Larger zones suspected by ERT were found to be related with the damage and smaller zones were found to be intact. The smaller zones are most likely to be related with the degradation of the dam materials.

This study showed that electrical methods are very useful for identifying the leakage discharge zones in reservoirs. Any damage in the liner that was laid for the purpose of obstructing infiltration can be detected. The study was also able to show the channelling and intensity of seepages that usually occur at the base of the dam and in the downstream part of the dam.

Estimation of soil loss in southwest Kathmandu due to July 2002 rainfall

*Pradeep Paudyal and Megh Raj Dhital

*Central Department of Geology,
Tribhuvan University, Kathmandu, Nepal
(*Email: ppaudyal@gmail.com)*

A large number of landslides and debris flows occurred due to a high-intensity rainfall of July 2002 in the southwestern hilly region of Kathmandu, Nepal. Besides these mass movements, surface erosion also took place in this area causing a considerable soil loss. Landslides and debris flows were concentrated mainly in poorly managed dry cultivated lands and bush lands. Gully formation and channel erosion were observed in the upper steep terrain, while the gentle lower regions were characterised by sheet and rill erosions.

In order to calculate the soil loss due to surface erosion, the study area was classified into four land use classes: well developed forest, well managed rice terraces, well managed maize terraces, and poorly managed sloping terraces.

The average surface erosion rate in this area was about 950 tons/ km^2/ year. More than 29,375 tons of soil was washed out due to the high-intensity rainfall of July 2002 by means of mass movements and surface erosion.

New insights into the processes of rock slope failure

D. N. Petley, N. J. Rosser, M. Lim, S. A. Dunning, and R. J. Allison
*International Landslide Centre, Department of Geography,
University of Durham, DH1 3LE, United Kingdom*

In recent years there have been considerable advances in the techniques available for the assessment of rock slope stability. These improvements include better techniques for characterising rock masses; new approaches to the deterministic and probabilistic analysis of stability; and improved 2-D and 3-D simulation of the development and progression of slope failures. However, a major challenge remains the analysis of the temporal dimension of failure –i.e. when the failure will occur and, in some cases at least, how fast the movements will be once large-scale strain develops. Most existing techniques provide little insight into this part of rock slope stability. In this presentation, results are presented from ongoing work examining the development of failure both in the laboratory and in the field. A number of active rock slopes have been monitored on a monthly basis for over two years using high resolution photogrammetry and laser scanning technologies. This has allowed the

detection of a statistically large number (>100,000) of individual detachments, ranging in volume from a few cubic centimetres to over a thousand cubic metres. This has allowed analysis of the temporal and spatial patterns of rockfall activity, including determination of the role of discontinuities, lithologies, and environmental forcing in the triggering of rockfall events. This has been backed up in the laboratory with experimental work examining the processes occurring within geological materials during the evolution of brittle fracture, this paper demonstrates that existing reductionist models of the development and timing of failure in rock cliffs may oversimplify the actual processes occurring, but that detailed analyses can allow better forecasts of likely future behaviour. Thus, the work highlights potential developments that will in the short to medium term lead to considerable improvements in our abilities to characterise unstable rock slopes.

A comparison of bearing capacity of impact- and vibratory-driven piles in stiff clay

*F. Rocher-Lacoste[1], L. Gianeselli[1], and M. Bourdouxhe[2]
[1]Laboratoire Central des Ponts et Chaussées (LCPC),
58, boulevard Lefebvre
75732 Paris cedex 15, Paris, France
[2]Profilarbed S. A., Arcelor Group, Luxembourg
Research -Product Piling
66, rue de Luxembourg
L-4009 Esch-sur-Alzette, Luxembourg
(*Email: frederic.rocher.lacoste@lcpc.fr)

This paper presents the results of an extensive field test carried out in the framework of the "French National Research project on vibratory driving" and a Profilarbed research programme (Fig. 1), to investigate the behaviour and performance of eight impact- and vibratory-driven piles. The test site is located in the airfield of Merville, North France. The subsoil consists of dense Flanders clay (Fig. 2). Various piles were driven using an ICE 815 vibratory driver and an IHC S70 impact hammer to the same depth. All these piles were instrumented with accelerometers and strain gauges positioned at the top and at the toe. Penetration rate, uplift load applied by the crane, vibrations transmitted to the ground, operating pressure and oil flow at the vibratory power-pack, and energy per blow for the hammer were continuously recorded. The paper presents the main results obtained on double sheet piles (AU16 type) driven to 7 m depth, on a small wall of two sheet piles (AU20 type) driven to 8 m depth, on HP steel bearing piles driven to 10.2 m, and steel open-ended tubes, 508 mm in diameter, which were installed to 9.4 m depth. After a rest delay of 6 to 8 weeks, the piles were statically loaded to failure (Fig. 3). The piles were instrumented using LCPC removable extensometers, which make it possible to measure the mobilisation of shaft friction (Fig. 4) and toe resistance (Fig. 5). The measured bearing
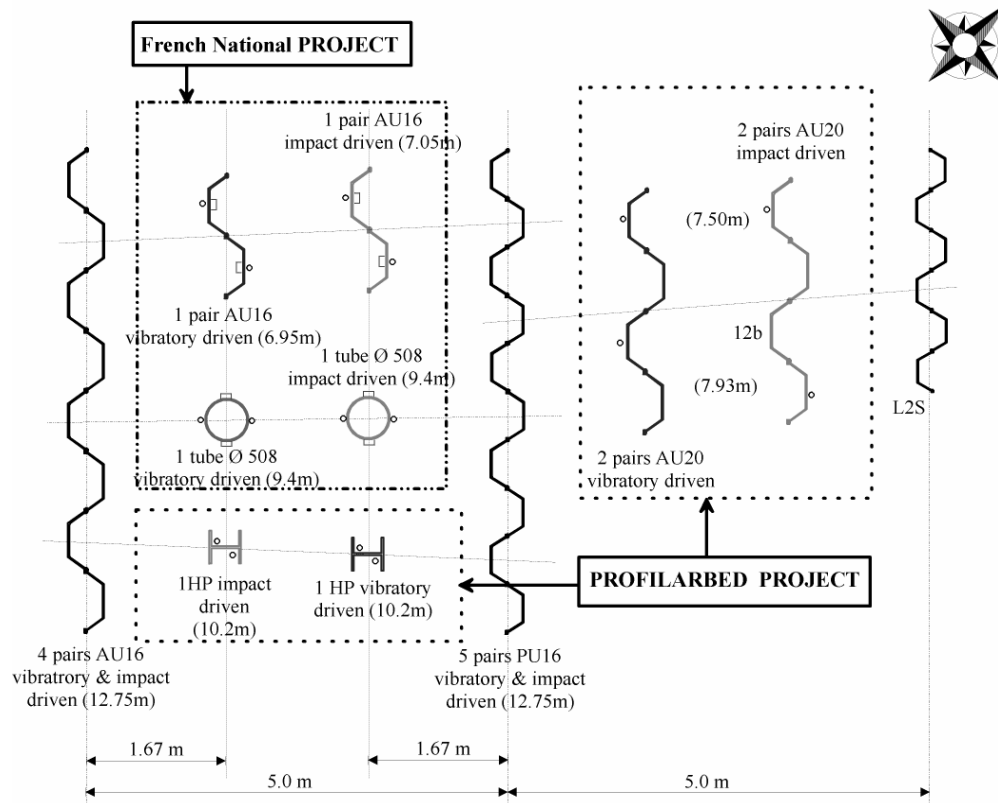
Fig. 1: General layout of the site
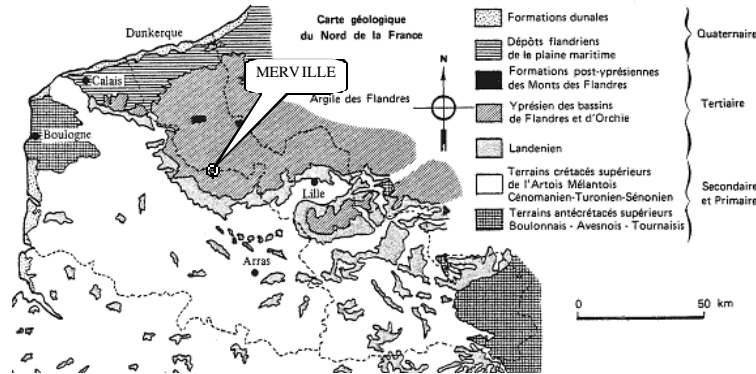
Fig. 2: Outcrops of Flanders clay (North France)

Fig. 3: Reaction beam and loading device
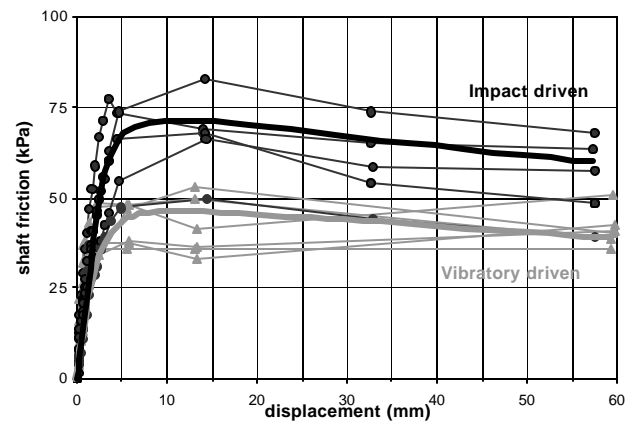
Fig. 4: Mobilisation of shaft resistance along the steel open-ended tube, Ø 508 mm

capacity was significantly lower for the vibratory-driven piles (around 35 %), which confirms the results obtained by the LCPC in other sites (Bustamante and Doix 1991; Borel et al. 2002).

REFERENCES

Borel, S., Bustamante, M., and Gianeselli, L., 2002, Two comparative field studies of the bearing capacity of vibratory and impact driven sheet piles. *Vibratory Pile driving and deep soil compaction. Proc. intern. symp., Louvain-la-neuve, 9–10 September 2002.* Rotterdam: Balkema.

Bustamante, M. and Doix, B., 1991, A new model of LCP removable extensometer. *Proceedings of 4th International Conference on Piling and Deep Foundation. Stresa. 7–12 April 1991.* Rotterdam: Balkema.
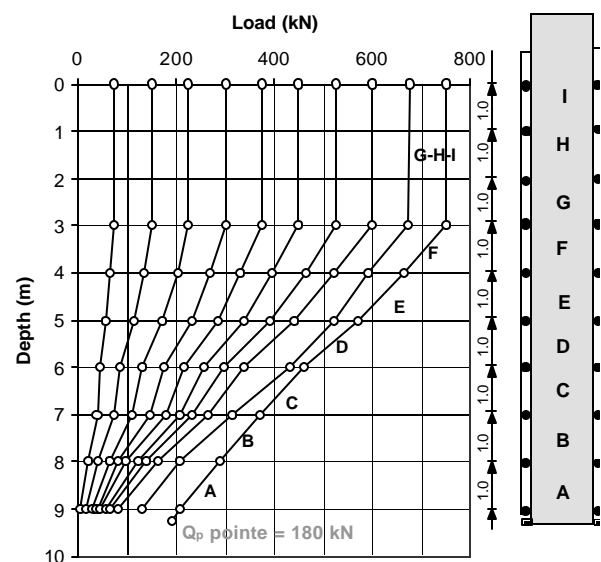
Fig. 5: Load distribution versus depth for the vibratory-riven steel open-ended tube, Ø 508 mm

Local infrastructure provision and development control system in Malaysia

*Dani Salleh[1] and Ho Chin Siong[2]
[1]Faculty of Public Management and Law,
Universiti Utara Malaysia, Sintok, Kedah, Malaysia
[2]Faculty of Built Environment, Universiti Teknologi, Malaysia
(*Email: dani@uum.edu.my)

The rapid urbanisation process has created pressure for additional requirement of infrastructures and support services. Therefore, sufficient and efficient infrastructure facilities are very important for the local development. Significantly, due to the rising cost of infrastructure there is a shift from the publicly built infrastructures to privately constructed ones. The main reason was the scarcity of resources of local authorities to finance the infrastructure construction, and hence the private sector was involved in the infrastructure development.

Infrastructure provision policies and proposals as outlined in development plans are generally very broad in nature. They provide with a basis for relevant agencies to prepare their infrastructure development programmes, and particularly for private developers to comply with the requirements outlined by the local authorities.

In Malaysia, most of the infrastructure facilities such as road maintenance, sewerage treatment plants, drainage system maintenance, upgrading of traffic system, maintenance of street lighting system, maintenance of traffic light system, and maintenance of sewerage pipeline system were traditionally undertaken by the local authorities. It created a financial burden to the local authorities concerned. In order to reduce such a burden, an alternative means to secure the infrastructure was required. Under the present practice of planning system, the local authorities should be proactive in identifying ways to accommodate with the incremental developments within these areas. As provided under Town and Country Planning Control Act 1976 (Act 172): Part IV, the local authorities regulate the planning process. It enables them to impose requirements to private developers for financial contribution, adequate public amenities, and appropriate infrastructure facilities.

Besides discussions on the methodological framework of local infrastructure provision, this paper also attempts to answer the following questions.

i. How local authorities secure their infrastructure?

ii. How infrastructure provision and development control (planning gain) is practiced?

iii. What are the problems faced by private developers in obtaining planning approval related to infrastructure provision?

A study of critical stress level causing rock failure in tunnels

**Gyanendra Lal Shrestha and Einar Broch
Department of Geology and Mineral Resources Engineering,
Norwegian University of Science and Technology, Trondheim 7491, Norway
(*Email: gyanendra.shrestha@geo.ntnu.no)*

One of the factors that may cause stability problems in a tunnel is the stress level acting around the underground opening. It is evident that a tunnel fails when the stress exceeds the strength of rock mass around the opening. If the stress level does not exceed the rock mass strength, but is sufficient to cause creep, it may lead to rock failure after some time. If the creep remains below the critical stress level, it does not lead to rock failure. Thus, in a tunnel stability assessment, the determination of critical stress level is important.

In this paper, results and analysis of laboratory tests carried out on rock samples from the Melamchi tunnel project in Nepal are presented. In order to determine the critical stress level, creep tests were carried out on the gneissic rock cores from the project site located in the Himalayan region. The time-dependent deformation curves were used to estimate the steady-state deformation rate for the given constant stress level.

The resulted creep test curves were fitted with Burger's model and the rheological parameters were calibrated as suggested by previous researchers. Tunnel deformations were calculated for various time periods at a given stress level. On the basis of the creep test results at various uniaxial stress levels at constant temperature, an equation is given for the relation between the strain rate and stress level.

Drillability and physico-mechanical properties of rock

Vasudev Singh[1] and T. N. Singh[2]
*[1]The University of Oklahoma, Sarkeys Energy Center, Suite R 108, 100 East Boyd Street
Norman, Oklahoma 73019-1014, USA
[2]Department of Earth Sciences, Indian Institute of Technology,
Mumbai 400076, India*

To explore and exploit the natural resources like oil, gas, economic minerals, and water, drilling is still considered to be the reliable and economical method. When a drill bit penetrates the rock mass by percussion, rotation, or sometimes a combination of both, the drilling process generates stress and thrust on the rock mass as well as on the drill bit. The strength and hardness of the rock govern the life of the drill bit and its runnage. The physico-mechanical properties of rock have great influence on drillability. It is observed that higher the strength of rock, shorter the drill bit life. An attempt was made to establish a relationship among various physico-mechanical properties (i.e., uniaxial compression strength, tensile strength, shear strength, Schmidt hardness, and abrasivity) with the drillability of different rock types. The specific energy of each rock type was calculated using micro-bit drilling. The rocks from different lithological successions were collected. The rock specimens were prepared according to the norms of International Society of Rock Mechanics (ISRM).

It was found that the drillability is inversely proportional to the strength of the rock. A good correlation was established between the drillability and specific energy, hardness, and abrasivity. Based on the analysis, some empirical relations are proposed. This study will help the exploration and exploitation engineers to understand the relationship between the energy consumption and drillability to optimise the drill bit performance. It is also useful to select a rock-friendly drill bit for better utilisation and energy conservation.

Problem of shear zones and faults in construction of infrastructures in the Nepal Himalaya

S. C. Sunuwar
Butwal Power Company Limited, Lalitpur, Nepal
(Email: subas.sunuwar@bpc.com.np)

Generally ductile and brittle shear zones or faults are identified in the Nepal Himalaya according to the physical condition in which deformation occurred. Among them, brittle shear zone or fault is geotechnically problematic during construction of infrastructures. The brittle shear zone and fault are characterised by sheared, crushed, and folded loose rocks containing strong, lenticular to rectangular, randomly orientated rock fragments or blocks supported by soft and weak matrix (Fig. 1). Most serious geological problems in development of infrastructures are generated by shear zones and faults. The problems related to shear zones and faults are due to their heterogeneity in internal structure, contrasting properties of weak matrix and strong rock fragments, and the presence of groundwater. In engineering practices, only the strength of weaker matrix is generally considered for design purposes, which can be very conservative and costly. Thus, the study of shear zones and faults in the Himalaya is quite promising. There are a large number of hydropower projects requiring tunnelling, dam foundation works, mountain road construction projects, and other infrastructure development activities, which are implemented rapidly and bound to frequently encounter such problematic rocks.

The construction of infrastructures through such problematic shear zones and faults is risky and may cause the loss of life as well as generate many serious problems such as slope instability, structure failure, overbreak, and rock squeezing. The paper describes some of the examples from the Kerabari and Dolalghat landslides in road sections and overbreak and rock squeezing problems in the tunnels of Khimti, Chilime, and Modi Hydropower projects.
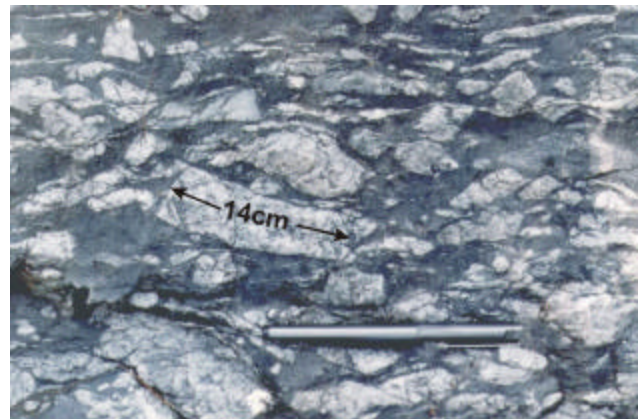
Fig. 1: Brittle shear or fault zone containing rectangular and lenticular blocks (about 40%) in weak matrix (about 60%)

Rock support design practice in hydropower projects of Nepal: case studies

S. C. Sunuwar
Butwal Power Company Limited, Lalitpur, Nepal
(Email: subas.sunuwar@bpc.com.np)

The principal objective of rock support is to assist the rock mass to support itself; one common example is where the rock support system (rock bolts and shotcrete) actually become integrated with the rock mass. Rock support strengthens the rock mass surrounding an excavation by creating a reinforced zone (Fig. 1) within the rock mass, which maintains the integrity of the excavated surface, possesses sufficient flexibility to allow for the redistribution of stresses round the excavation and has enough stiffness to minimise the dilation (opening) of discontinuities. Rock mass classification systems are commonly used as the basis for tunnel support design worldwide. The Q and RMR rock mass

classification systems (with some modifications) have been extensively applied in rock support design in most of the hydropower projects of Nepal. Generic design guidelines based on rock mass classification systems cannot provide suitable rock support for every site. Therefore, some modifications, based on the local rock mass conditions and geological hazards, are necessary to suit the site-specific conditions.

There are relatively few tunnels excavated in the tectonically active Nepal Himalaya. Large-diameter tunnels in Nepal are commonly lined with concrete, whereas more recent small-diameter tunnels are either shotcrete lined or left unsupported. "Leaky" lining has been used in most of the projects to avoid the heavy reinforcement that would be needed to withstand the sometimes very high external water pressures. Some examples of rock support in hydropower projects of Nepal are presented in this paper.
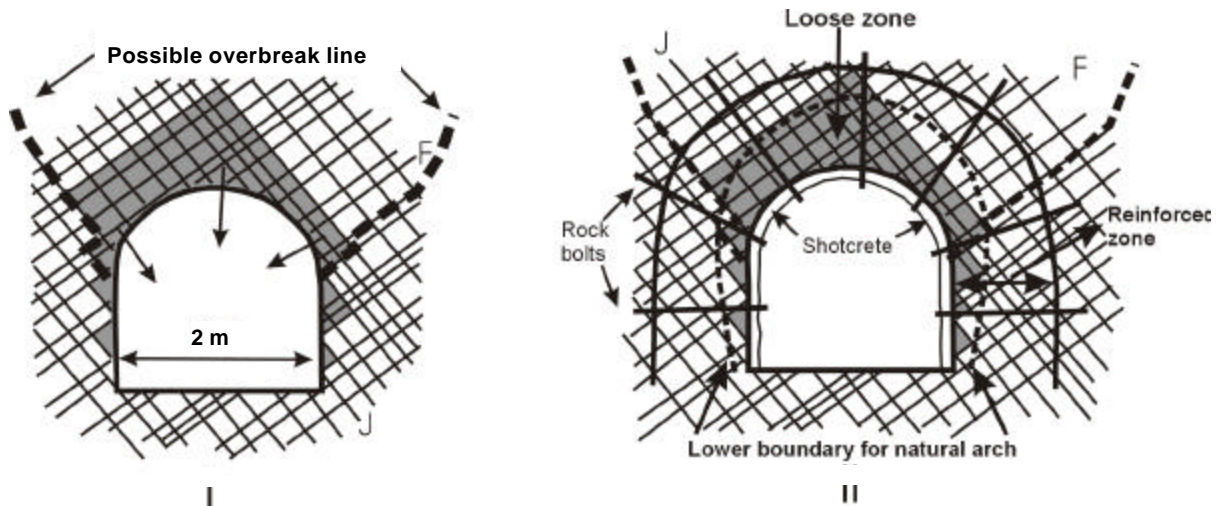
Fig. 1: A hypothetical case of rock support: I. Possible failure path after excavation due to changing of stress field around opening and II. Rock supports (rock bolts and shotcrete) helping rock mass to support itself by creating a reinforced zone

Comparison of engineering properties of fluvial and lacustrine sediments of fallow lands around Bagmati River in Kathmandu valley

*Pramod Kumar Thakur and Suman Panthee
Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal
*(*Email: pramodgeo@hotmail.com)*

The Bagmati River is flowing through the centre of the Kathmandu valley. There are extensive fallow lands available, which can be developed for a number of purposes, such as creation of a green belt, development of entertainment spots, and establishment of seasonal commercial centres. Generally, the fallow lands are the floodplain deposits formed on the lacustrine sediments. The engineering properties of sediments depend on their composition, texture, origin, and state of maturity. The engineering properties of fluvial sediments of the Bagmati River vary from Sundarijal to Hasdol. Similarly, the sedimentary cycles of lacustrine and fluvio-lacustrine deposits of Kathmandu also vary from Sundarijal to Hasdol. Keeping in view the increasing urbanisation rate and related encroachment of the fallow

lands around the Bagmati River, these variations may be vital in assessing the safety and stability of constructed engineering structures. For this purpose, fluvial hazard mapping is also equally important.

This paper deals mainly with the comparison of engineering properties of sediments according to their origin for the development and management of the fallow lands.

Hydrogeology

Role of rainfall factor in groundwater management: a case study in Ujjain region, Madhya Pradesh, India

Vikas Barbele and Pramendra Dev
School of Studies in Geology,
Vikram University, Ujjain, MP 456010, India

Rainfall is a critical and most important meteorological factor, which plays a vital role as a hydrometeorological parameter in augmentation of groundwater reservoir. The implication of rainfall phenomena has been visualised in Ujjain region located in Madhya Pradesh of India.

The rainfall data in respect of Ujjain region for a period of 30 years (1975 to 2004) have been analysed by employing both arithmetic and statistical methods. The arithmetic computation of 30 years' rainfall data revealed the annual mean of 923.98 mm. The plots of rainfall data indicate that during 1976, 1977, 1980, 1984, 1986, 1988, 1990, 1993 to 1999, and 2003, there was more rainfall amount than the computed mean indicating the prevalence of favourable periods for groundwater recharge. The trends of departure and cumulative departure from the annual mean rainfall were examined to delineate the rainfall contribution to the groundwater system.

The rainfall data were analysed for central tendencies such as mean, mode, median, standard deviation, coefficient of dispersion, coefficient of variation, and coefficient of skewness (Table 1).

The implications of statistical parameter of rainfall are discussed. The computed value of statistical parameters indicate a negative trend of the rainfall. The expected future rainfall trend for the period of 2005 to 2010 has been predicted on the basis of time series analysis of the rainfall data under examination (Table 2).

Table 1: Computation of statistical parameters and expected future rainfall trend in Ujjain region, Madhya Pradesh, India

Parameter	Value
Mean	923.98 mm
Median	927.27 mm
Mode	907.69 mm
Standard deviation	253.59
Coefficient of variation	27.44
Coefficient of dispersion	0.27
Skewness	0.064

Table 2: Expected rainfall trend for the period of 2005 to 2010 in Ujjain region, Madhya Pradesh, India

Year	Trend value, mm
2005	919.8
2006	919.6
2007	919.4
2008	919.2
2009	919.0
2010	918.8

Application of morphometric analysis in groundwater targeting: a case study of Khan River basin, Madhya Pradesh, India

Rakesh K. Dubey and Pramendra Dev
School of Studies in Geology,
Vikram University, Ujjain – 456010, M. P., India

The morphometric analysis of Khan River basin from the Malwa region of Madhya Pradesh, India, was carried out by conventional techniques. The parameters pertaining to area as well as linear and relief aspects of the river drainage basin have been computed with the aid of the Survey of India topographic maps 46N/14, 46N/13, and 46M/16 on a scale of 1:50,000. Based on determined values of morphometric parameters and their inter-relationships, suitable areas for groundwater exploration were delineated.

The Khan River basin extending over 761 km^2 is limited to latitude 22°35' to 23°8'55" N and longitude 75°45' to 75°57'30" E, and constitutes part of the Malwa region in Madhya Pradesh. The Khan River originates from Nimboli

Table 1: Morphometric parameters of the Khan River basin

SN	Parameter (notation)	Khan River Basin					
		Sub-basin 'A'	Sub-basin 'B'	Sub-basin 'C'	Sub-basin 'D'	Sub-basin 'E'	Sub-basin 'F'
01	Bifurcation Ratio (Rb)	3.35	4.28	4.71	3.91	3.29	3.44
		3.40	3.60	4.67	3.29	5.25	4.50
		5.00	2.50	6.00	7.00	4.00	-
	Average	-	2.00	1.00	1.00	-	-
		3.91	3.095	4.095	3.80	4.18	3.97
02	Drainage Density (Dd)	1.711	1.519	1.359	1.123	0.594	1.167
03	Length of Overland flow (Lo)	0.292	0.329	0.368	0.445	0.842	0.428
04	Stream Frequency (Fu)	1.649	1.397	1.177	0.856	0.487	0.801
05	Form Factor (Rf)	0.258	0.399	0.250	0.235	0.285	0.296
06	Circulatory Ratio (Rc)	0.470	0.677	0.382	0.287	0.580	0.592
07	Elongation Ratio (Re)	0.573	0.712	0.564	0.547	0.602	0.614
08	Lemniscate Ratio (R_L)	0.967	0.627	1.00	1.062	0.877	0.845
09	Constant of Channel Maintenance km^2/km	0.584	0.658	0.736	0.890	1.684	0.857
10	Basin Relief (H)	224	211	96	130	130	59
11	Relief Ratio (Rh)	16.35	15.51	4.016	5.28	4.971	2.548
12	Ruggedness Number (Rn)	383.264	320.50	130.46	145.99	77.22	69.03

Tank ($22^o37'N – 75^o54'E$), near the Indore city and traversing a course of approximately 73 km from the south to north, finally merges with the River Kshipra at a place known as Triveni, in the vicinity of the Ujjain town. It was a perennial river in the past, and now it is a seasonal river.

Most of the area in the Khan River basin is occupied by different basaltic lava flows covered by black soil, which is their alteration and supergene-weathering product. Based on the colour, grain size, hardness, texture and composition, six different lava flows have been recognised. The soils reveal a variation in colour at several places.

The morphometric analysis involves the determination of various variables and parameters pertaining to number, length, and order of streams as well as basin perimeter and basin area. The parameters pertaining to area as well as linear and relief aspects of the Khan River basin have been computed to characterise its drainage pattern (Table 1).

The geomorphic significance of computed morphometric parameters of the Khan River basin is discussed. The bifurcation ratio indicates a flat topography and soil-filled terrain. The higher drainage density values indicate a high proportion of stream network with greater runoff and lesser infiltration of water. The average stream frequency is 1.061, which points out to a lack of variation in surface relief forming a flat river basin. The parameters of basin shape point out that it is more-or-less elongated. The relief ratio varies from 2.54 to 16.35 and its higher values indicate that Sub-basin 'A' is characterised by a high relief with a high intensity of erosion processes.

Spatial distribution patterns of metals in the sediments of artificial reservoirs in South Sardinia, Italy

S. Fadda[1], M. Fiori[1], C. Matzuzzi[1], S. M Grillo[2], and S. Pretti[2]
[1]*Istituto di Geologia Ambientale e Geoingegneria del CNR, Cagliari, Italy*
[2]*Dipartimento di Geoingegneria e Tecnologie Ambientali, University of Cagliari, Italy*

Most of Southern Sardinia is supplied by the Flumendosa–Campidano hydraulic system that includes many interconnected artificial lakes of different sizes. Lake Flumendosa collects water from an extensive drainage area, and from two minor lakes. Lake Mulargia stores excess water, conveyed through a tunnel, from Lake Flumendosa: in addition small basins downstream ensure the water resources to the distribution network that is mainly located in the Campidano plain. For about 30 years, this system is being used as the main water supply for all kinds of

consumption, civil, agricultural and industrial uses, to the most densely populated zone of Sardinia, an Italian island at the centre of the western Mediterranean.

The lake levels are strongly influenced by the climate characterised by two short rainy periods and a long dry season, during which lake levels drop and extensive bottom areas gradually emerge all along the lake borders and sediments undergo alternate phases of dryness and exposure. With the rains, the lakes slowly fill up again attaining the maximum possible level and remain full for a short time span. The drainage basins of these reservoirs mostly include ore-rich terrains hosting mixed-sulphide mineralisations. Several of these bodies have been explored and some of them have been mined, so that trenches, galleries, and exploitations gave origin to numerous dumps that along with unexplored mineralised outcrops, supply heavy metals to the aquatic environment of these reservoirs either as a direct action of mining or owing to acidification of the rains by oxidation of pyrite. As a result of complex physical, chemical, and biological processes a major fraction of these metals is found associated with the bottom sediments. Although the period of most intense acid generation has passed, the transport of contaminants through underlying aquifers will continue. The study of reservoir sediments revealed the influence of dispersed and concentrated sources, which were apparently derived from the main feeders. The contaminants were derived from the constituents of primary rock-forming minerals, the mineral formed during weathering, the minerals typical of mineralisations, the ions adsorbed onto colloidal particles and clays, and those combined with organic matter. For each element, distribution maps were drawn by means of computer-assisted cartography in order to visualise the inlets of the contaminants as well as dispersion and accumulation effects. The location of main anomalous areas well fits with the known geological characteristics of the terrains constituting the investigated area as well as the human activity. A rather high metal content in the lake sediments is a matter of concern for drinking water supply. A significant post-depositional leaching of metals from the sediments into the overlaying waters is most likely when, immediately after emersion, the infiltrating water through the sediments oxidises sulphide to sulphate, and an acidic (pH<7) environment is established causing metals to be mobilised; however a sudden increase of pH is able to re-precipitate metals in less soluble forms giving rise to an important downward flux from the overlying acidified water to some subsurface sedimentary sink located below the sediment-water interface where metals would be effectively retained by the sediments. At present the metal-rich sediments of the lakes appear sufficiently stable, as metal concentrations in the water reaching the treatment plants are normally below the permissible limits for domestic use. Apart from the obvious dilution effect, the cyclic mobilisation-re-precipitation processes suggested by the present study are certainly effective in keeping the soluble metal contents sufficiently low in the waters of these lakes.

Protecting groundwater from leachate contamination: Design of landfill liner system at Sa Kaeo landfill, Thailand

Deb P. Jaisi[1], Ulrich Glawe [1], and Suman Panthee[2]
[1]Geotechnical and Geoenvironmental Engineering,
Asian Institute of Technology, PO Box 4 Klong Luang,
Pathumthani 12120, Thailand
[2]Central Department of Geology, Tribhuvan University, Kathmandu, Nepal
*(*Email: jaisidp@muohio.edu)*

This research focuses on the design aspect of primary and secondary drainage layers to effectively isolate landfill leachate at the Sa Kaeo landfill, Thailand. The apparent permeability of granite gravels and flow rate per unit width of geocomposite was measured in permeameter cell and transmissivity device designed and locally constructed conforming to ASTM D 2434-68 and ASTM D 4716-00, respectively. Compression and creep of geonets were measured in site-specific overburden stress. The leachate production was calculated based on the 30-year rainfall cycle, maximum moisture-holding capacity, and other related engineering properties of industrial waste that are designed to house in the hazardous unit of the Sa Kaeo landfill. The effect of daily cover to the landfill was also accounted.

Although, the analysis was performed for 2, 10, and 100 years of landfill life, this research was focused basically on the worst scenario in the phase of active waste placement, when the height of waste pile was at or below the ground level and artificial dewatering was not effective during flooding. This extreme condition was important to uncover the possibilities that heavy and toxic metals in leachate flow out of engineered structure and contaminate pristine groundwater.

The result showed that, under the designed load of 200 kPa and thickness of primary drainage layer of 30 cm, the long-term in-soil hydraulic conductivity (k_{LTIS}) of the coarse gravels resulted in a safety factor of 35.6 for primary drainage layer

with a slope of 0.02. The long-term in-soil hydraulic transmissivity ($\boldsymbol{q}_{LTIS}$) of the best geocomposite (among three geonets, and six configurations of each) resulted in safety factors of 26, 3.1, and 1.2 in secondary drainage layer for 2, 10, and 100 years of landfill life, respectively at a leachate production rate of 10% of maximum rainfall. It suggested that, under current design, the leachate overflow would not occur even in the worst-case scenario. However, this research does not take into account the time-dependant chemical and physical degradation and clogging of drainage materials specific to this site, which depend upon the composition of the future leachate.

The results showed that a higher degree of isolation of landfill leachate, and therefore its effective interception and removal, can be attained by using a properly designed double liner system.

Groundwater quality evaluation for irrigation in Mandsaur region, Madhya Pradesh, India

Vinita Kulshreshtha[1] and Pramendra Dev[2]
[1]Department of Geology, P.G. Government College, Mandsaur – 458001, India
[2]School of Studies in Geology, Vikram University, Ujjain – 456010, India

The groundwater is a dynamic, replenishable, and vital earth resource. It acts as an elixir of life and contains some dissolved minerals or salts derived from the rock during weathering and erosion. Sedimentary rocks as compared to igneous rocks contribute a substantial amount of dissolved salt in groundwater. The groundwater may be contaminated by heavy metals and toxic organic substances. Hence, monitoring of groundwater quality is essential for irrigation to achieve the target of optimum growth of agriculture. The present study deals with the evaluation of groundwater quality for irrigation purposes in the vicinity of the Mandsaur township located in the Malwa region of Madhya Pradesh, constituting part of the Deccan Volcanic Province, India. The area is presently facing with a severe problem of drought.

The chemical analysis of 22 groundwater samples collected from representative open dug wells from the Mandsaur area was carried out both in the field and laboratory. Their colour, odour, taste, pH, total hardness and electrical conductivity; ionic concentrations and various parameters for quality estimation (per cent sodium, Kelley's ratio (Kr), sodium absorption ratio (SAR), residual sodium carbonate (RSC) and magnesium-hazards) were determined.

The calculated values of per cent sodium, Kelley's ratio, SAR, RSC, and magnesium-hazards indicated that, except for a few places, the groundwater in general is suitable for irrigation.

The SAR and electrical conductivity values of the groundwater samples plotted on the U.S. Salinity diagram indicate that 8 samples fall in C_2S_1 type (medium salinity and low sodium hazards), and 14 samples belong to C_3S_1 type (high salinity and low sodium hazards). In general, the groundwater is suitable for irrigation.

Willcox diagram has also been frequently used to study the suitability of water quality for irrigation. The values of electrical conductivity and sodium percentage determined in respect of groundwater samples of Mandsaur area were plotted on Willcox diagram. The plot indicated that 4 samples belong to excellent to good categories; whereas 18 samples fall in well to permissible categories of quality suitability. Based on this classification, the groundwater of Mandsaur area in general is suitable for irrigation purposes.

Vadose zone hydrology and its effect on landslide initiation

Scott E. Munachen and Paul A. Hayes
Geohazard Research Centre, 38 Lincoln Way, Harlington,
Dunstable, Bedfordshire, U. K.
(Email: scottmunachen@bezemer.demon.co.uk)

High infiltration capacities associated with the residual soil mantle of steep, humid hillslopes, and the presence of less permeable bedrock at depth create conditions that favour the mobilisation of shallow landslides. Typically, rainwater and snowmelt permeate the subsoil under gravity and capillary forces to an underlying low conductivity layer. The permeability contrast leads to the development of a perched water table, and downslope saturated flow ensues. In regions where shallow subsurface storm flow is the dominant means by which water reaches the channel, all incident precipitation must pass through a largely unsaturated soil profile before contributing to runoff. Hence, unsaturated zone processes may directly control the timing and magnitude of positive pore pressure development and slope instability.

This paper presents the results of a series of field experiments designed to investigate the mechanisms by which rainfall signals propagate through an unsaturated soil profile. The behaviour of a small unchannelled headwater basin, driven to quasi-steady state by sprinkler-irrigation, was monitored by an instrumentation system comprising a network of tensiometers, piezometers, time domain reflectometry probes, discharge meters, and rain gauges. The analysis of hydrological response reveals that unsaturated zone dynamics plays a primary role in dictating the spatio-temporal evolution of pore pressures and discharge from the hillslope. During initial infiltration, some of the deeper tensiometers responded before the arrival of the advancing wetting front. With continued irrigation, most

tensiometers registered near-zero matric suctions before the majority of piezometers responded fully, and a stable groundwater flow field occurred only after a steady state developed in the vadose zone. Interestingly, the data also indicate that the response time of the tensiometers was faster than a simple plug flow approximation. This time lag in the development of the pressure head field in unsaturated slopes is shown to be critical to understanding the mechanisms controlling their stability.

The porewater retention characteristics yielded near-zero pressure heads throughout the soil profile for slight but persistent rain. With the onset of steady discharge, the unsaturated zone, saturated zone, and groundwater flux became delicately linked, such that a rapid increase in rainfall intensity led to a saturated zone response and peak discharge which occurred much faster than could have happened through advection alone. The precipitation spike produced a transient pressure wave that travelled relatively rapidly through the unsaturated zone, inducing a large change in hydraulic conductivity and the rapid effusion of stored porewater. Hence, minor rainstorms which fall on nearly-saturated hillslopes can produce small variations in pressure head that are accompanied by correspondingly large changes in water content, giving rise to the transmission of pressure waves in response to increased rainfall intensity and a relatively rapid response in the vadose zone. Such a coupled dynamic process is believed to be the underlying mechanism that enables short bursts of rainfall to induce slope instability.

Coupling of coastal belt and sea by groundwater-borne nutrient transport: greening of near shore waters of Arabian Sea

*Joseph Sebastian Paimpillil[1], K. K. Balachandran[2], and T. Joseph[2]
[1]*Centre for Earth Resources and Environment Management,*
K. K. Road, Near Parkland Apts, Cochin 17, India
[2]*National Institute of Oceanography, Regional Centre, Cochin 14, India*
(*Email: psjoseph@eth.net)

In water budget and mass flux estimations for coastal margins, submarine groundwater discharge is often overlooked because it represents a non-point source. The groundwater influences ocean chemistry by discharging nutrients. The investigations in coastal waters had sufficient hints of groundwater seepage to the Arabian Sea through a

narrow strip of submerged porous lime shell beds running almost parallel to the coast. These beds supply considerable quantities of primary nutrients to the coastal waters and precondition them for rich primary production. The active faults in the regions of submerged porous lime shell beds are probably coupling the adjacent watershed and the sea.

The poor sanitary facilities in the coastal belt are the main suppliers of nutrients to the groundwater. The differences in land-use mosaic among sub-watersheds resulted in differences in the rate of nutrient loading to the groundwater and hence to receiving coastal waters. The long-term trend of chlorophyll showed a "greening" of the near-shore waters with 3 times greater chlorophyll-a (14 mg/m^3) than the peak reported values. A band of N/P >15 funnelling out from coastal region provided an indication of 'external source' of nitrogenous compounds into the coastal waters. This groundwater fluxes depend on factors such as: climatic (monsoon) variability, which controls the fresh water discharge into backwaters providing the necessary force to overcome the frictional resistance of the porous lime shell deposits, anthropogenic factors (land use mosaic, socio-economic, and sanitary conditions), and tidal factor that controls the hydraulic difference between seawater and brackish water. A significant quantity of groundwater flow occurs during the monsoon months when water level in the backwater is high and the sea level remains at its annual low.

The possibility of heavy rains and flash floods is high with climate change, and such conditions can occur during other seasons and also at similar oceanic locations. The human population along the coastal belt with more than 70 % of households without proper sanitation facilities has contributed in concomitant increases by widespread use of septic tanks and nutrient inputs to coastal waters, particularly from regions occupying limestone beds. The groundwater quality of the region had shown up to 12 ìM nitrate in sediment extract, 8 ìM ammonia in water, 14 ìM urea in water, 15 ìM urea in sediment extract. The nutrient levels in coastal waters also had seasonal variations with the maximum values in post monsoon months with the minimum levels in monsoon months. So far, the coastal nutrient enrichments, primary productivity boosting, and a slow change in biodiversity were identified only at a few coastal pockets along the west coast of India. The details of the exchange of coastal water and groundwater across the sediment-water interface deserve more attention.

Groundwater contamination and possible solutions: a case study of Gokarna landfill site

Suman Panthee
Central Department of Geology,
Tribhuvan University, Kathmandu, Nepal

Waste management has become a major urban problem in Nepal. Landfill site development and management in Nepal is at its initial stage. The Gokarna landfill site lies in the north of the Kathmandu valley. Though it was the first solid waste disposal site in Nepal developed under the technical supervision, several parameters and precautions were not considered. The landfill site was abandoned after eighteen years of its operation. Presently, the leachates from the landfill site are contaminating the groundwater, a major source of drinking water in the Kathmandu valley. They are also polluting the surface water and soil of the area.

The Gokarna area comprises alternating beds of sand, silt, and clay, whose hydraulic conductivity varies from 1.26 x 10^{-3} to 35 m/day. Consequently, the area affected by hazardous pollutants is increasing, especially in the west–southwest direction, which is the flow direction of groundwater. Similarly, the extent of polluted soil is also increasing, but with a very slow rate.

The geological setting of the soft sediments of Gokarna is comparable with the Terai area of Nepal where several major cities are located. Therefore, the findings of this study may also help to develop and manage the landfill sites in the Terai.

Modelling the regional peak flows of Sefid-Rood Dam drainage sub-basins using Artificial Neural Network

Ali Rezaei
Natural Resources and Agriculture Research Centre of Zanjan,
PO Box: 45195-1474, Iran

The model discussed in this paper was created based on Artificial Neural Network (ANN) and calibrated in the Sefid-Rood basin (excluding the Khazar zone). This research was done by selecting peak flows of hydrographs originated by rainfall. These hydrographs were gathered from 12 sub-basins with their concentration time equal to or less than 24 hours. From these selected sub-basins 661 hydrographs were prepared for modelling. The input variables of model were

area of sub-basin; main channel length; main channel slope (10–85%); similar daily flood rainfall depth; similar antecedent (five days before) rainfall depth; area occupied by geological formations and rock units at three hydrological groups of I, II, and III; and base flow. The output of model was only the peak flow. Feed Forward Artificial Neural Network does the function approximation of inputs to output. The created model passed the 3 procedures of training (learning), testing, and validation. The performance of model based on mean square error between observed and estimated peak flow during validation was 0.34, whereas R^2 and F of the model were 0.85 and 32.67 respectively.

Evaluation of groundwater quality at Hangarakatta village, Udupi district, Karnataka State, India

*K. Narayana Shenoy[1] and K. N. Lokesh[2]
[1]Civil Engineering Department, Manipal Institute of Technology,
Manipal- 576 104, India
[2]NITK, Surthkal, India
(*Email: kn.shenoy@mit.manipal.edu)

The village Hangarakatta is situated 20 km north of the Udupi Town of the coastal Karnataka state, India. The people of the village complained that the water drawn from their wells was of inferior quality, having peculiar taste, and staining their clothes and vessels. A study on the quality of groundwater from 18 wells in the area was conducted during the post-monsoon period of 2002. Analysis of various chemical constituents present in the groundwater such as pH, turbidity, total dissolved solids, total hardness, chlorides, electrical conductivity, ammoniacal nitrogen, iron and dissolved oxygen, revealed that all parameters were within the stipulated limits of IS: 10500-1983, apart from the iron concentration.

As per IS: 10500-1983, the concentration of iron present in water, for the purpose of drinking, should not exceed 0.3 mg/l. The samples taken from the village however, contained an excessive iron concentration, well above the permissible limit. Analysis of the iron content was conducted for a period of 3 months in order to establish a trend in the variation of iron concentration with time, and to determine the highest concentration during the study period.

A system has been designed, with priority being given to removal of iron, to purify the water drawn from the wells. The system consists of three units, namely an aerator, a sand filter and an activated carbon unit, each with varying degrees of iron removal capacity, as well as purification of water in general. The system is extremely effective, removing all iron for concentration less than 0.3 mg/l and restricts the concentration of iron within the permissible limits for the worst case (12 mg/l). As the system is required in rural area, inexpensive and locally available materials have been incorporated in its design. The overall cost of the filter is also low.

Groundwater quality assessment for drinking and irrigation applications: a case study in Ratlam industrial area, Madhya Pradesh, India

B. K. Singh[1] and Pramendra Dev[2]
[1]Department of Civil Engineering,
Ujjain Engineering College, Ujjain- 456010, India
[2]School of Studies in Geology,
Vikram University, Ujjain – 456010, India

The groundwater in the Ratlam industrial area located in the Malwa region of Madhya Pradesh, India, is polluted due to industrial effluents causing the deterioration of groundwater quality for drinking as well as irrigation applications. The results of an assessment of the chemical quality of groundwater of the Ratlam area are discussed herein.

The area of present investigation extends between 23°05' to 23°15' N latitude and 75°00' to 75°10' E longitude (Survey of India topographic map 46 M/3). Ratlam is a well known industrial complex having a fairly good development of industries such as drugs, dyes, alcohol, textiles, foundries, and agrobased products.

The physical parameter determinations included colour, odour, taste, pH, and electrical conductivity. The groundwater is reddish-brown in colour mostly along the stream course. The colour is mainly due to organic compounds discharged through the various textile industries. The pH of groundwater ranges from 7.7 to 8.3 indicating its alkaline nature. The electrical conductance values reveal a range from 1,500 to 6,300 micro mhos/cm.

The ionic concentrations of groundwater samples namely calcium, magnesium, potassium, sodium chloride, carbonate, and bicarbonate were determined. The significance of these concentrations is discussed in the paper. The various chemical parameters such as per cent sodium, Kelley's ratio, sodium adsorption ratio, residual sodium carbonate, and Mg hazards were determined for the assessment of chemical quality.

The groundwater quality assessment for drinking purpose was made on the basis of plotting the ionic concentration values in epm on the trilinear Piper's diagram. The plotting of the data revealed that a majority of water samples belong to Ca^{++}, Mg^{++}, Cl^- type facies. The water is of moderate quality and can be used for drinking purpose after colour removal.

The groundwater quality for irrigation use was delineated with the help of Wilcox and U. S. Salinity diagrams. The determined values of electrical conductivity and per cent sodium in respect of groundwater samples were plotted on the Wilcox diagram. The plotting of the data revealed that only one sample falls in the good to permissible category whereas two samples represent the permissible to doubtful category, four samples belong to the doubtful to unsuitable category and three samples represent the unsuitable category. In general, the groundwater is not favourable for irrigation purpose.

The plots of sodium adsorption ratio and electrical conductivity on the U.S. Salinity diagram revealed sodium and salinity hazards. The computed SAR and EC values of groundwater samples indicated that a maximum number of samples fall in C_4S_2 (very high salinity and medium sodium hazard) type, three samples belong to C_3S_2 (high salinity and medium sodium hazard) type and only one sample falls in C_3S_1 (high salinity and low sodium hazard) type. In general, the groundwater in the Ratlam area is moderately suitable for irrigation purpose.

Status of coal mine water pollution in Basundhara Block, IB Valley Coals, Mahanadi Coalfield Limited, Orissa

K. N. Singh and R. K. Singh
School of Studies in Geology,
Vikram University, Ujjain – 456010 (MP), India

Water pollution in coalmines has become one of the serious concerns of everyone with the growing demand of energy. The quest for more coal exploitation has increased, and coal mining and mine water pollution have become vital issues of today. The mine water pollution and its different parameters need general discussion. The Basundhara block of lB Valley (Orissa) is an opencast mine under its developing stage. This paper looks into the state of the coalmine and its impact on water quality and the environment.

Serious health problems arise due to the use of untreated mining water. To control such problems, the installation of accumulator or absorbent plants are discussed in this paper.

Artificial recharge structure: a tool in groundwater management in basaltic terrain of Sonkatch area, Deccan Trap Province, Madhya Pradesh, India

Nandita Singh and Pramendra Dev
School of Studies on Geology,
Vikram University, Ujjain, M. P. 456010, India

Artificial recharge is a process by which water can be infiltrated into or added to an aquifer. It is in common usage throughout the globe as a basic component of management planning of a groundwater reservoir. The role of construction of artificial recharge structures as augmentation strategy of groundwater resource management in the basaltic terrain of the Sonkatch area forming part of the Deccan Trap Volcanic Province, located in Madhya Pradesh, India is discussed in the paper.

A concise account of the concept, objectives, and methods of artificial recharge are included. The term artificial recharge has been defined as the process by which infiltration of surface water into groundwater system is increased by altering natural conditions of replenishment. The prime objectives of artificial recharge of groundwater include (1) to control rapidly depleting trend of groundwater levels, (2) to conserve water for future applications, (3) to control main subsidence by increasing hydrostatic pressure conditions in artesian aquifers, (4) for the purpose of filtration of water, (5) to check saltwater encroachment, and (6) to prevent aquifer from pollution. The most widely used artificial recharge techniques include: spreading methods, pit methods, induced recharge, and well methods. The selection of a particular method mainly depends upon the nature of topography as well as geological and soil conditions of the geographic area.

The identification of an area is the first step for selection of artificial recharge site. The basic requirements for artificial recharge of groundwater include planning of artificial recharge scheme, monitoring, and auditing. The choice of construction of artificial recharge structures is based upon the factors such as the objectives of project which involve policy issue and hydrological characterisation including the estimation of groundwater reserve, storage of drainage water for irrigation and fresh water in saline aquifer, and identification of groundwater protection zones.

In Indian subcontinent, the Sonkatch area located in the Malwa region of Madhya Pradesh, is currently a drought-prone region, which is facing water crisis and requires the management and planning for augmentation of the groundwater resource with a view to provide remedial solution for safe and sustainable water supply.

Based on geological, geomorphological, geochemical, hydrometeorological, and remote sensing data analysis of the Sonkatch area, the construction of artificial recharge structures such as percolation tank or pond, *nala* bund, stop dam, pit and trenches, subsurface dyke, and injection well, is favoured. In addition to the implementation of the plan for the construction of artificial recharge structures, it is also suggested to launch a scheme for rainwater harvesting by giving a priority to the optimum development of afforestation in the Sonkatch region.

Evolution of geomorphic surfaces in northern Ganga plains and their groundwater prospects: a remote sensing and field-based study

*Aniruddha Uniyal[1], C. Prasad[2], and K. V. Ravindran[3]
[1]Remote Sensing Applications Centre, Sector "G", Jankipuram, Lucknow, India
[2]489, Uphar, Udhyan Ist Colony, Jail Road, Lucknow, India
[3]VMC House, Karamel, PO Annur, Distt. Kannur, Kerala, India
(*Email: aniruddhauniyal@yahoo.com)

Investigations were carried out along the Ganga River and its tributaries viz. Solani, Malin etc. in the area around Haridwar, Roorkee, and Bijnor. Various geomorphic units were delineated using satellite remote sensing data (LANDSAT MSS, IRS 1A LISS I, and IRS 1C LISS III images) aided by field investigations. The major geomorphic surfaces

identified include Active Floodplain (T_0), abandoned Older Floodplain (T_1), the Upland Terrace Surface (T_2) and Piedmont fan surfaces viz. PF_2 (older), and PF_1 (younger). All these surfaces display distinct characters and are separated by significant breaks in slope.

Field observations show that while T_0 and T_1 surfaces are composed predominantly of silty and clayey materials, the Piedmont fan surfaces are made up of gravels and sands, gravelly in the lower part and sandy in the upper part.

The detailed analysis of geomorphic data indicates that all these surfaces were evolved by the deposition of sediments derived from the rising Himalayan ranges during the Late Pleistocene and Holocene. T_2 exposed in the southern part of the study area is the oldest depositional surface. Earlier workers have used the term megafan surface to it and were of the view that this surface was laid down during the Sangamonian interglacial phase. Present investigations have revealed that T_2 is in fact the reworked megafan surface and presently retained as older alluvial plain. All other depositional surfaces viz. younger alluvial plain T_1 along with T_0 and also the Piedmont fan surfaces are superimposed on T_2. During the retreat of glaciers in the Middle Wisconsin phase, the Ganga carved its valleys through these megafans and laid down its floodplain deposits (T_1). During the same phase, PF_2 surface was being evolved in the areas away from the floodplains of Ganga and its tributaries. However, the younger piedmont fans of PF_1 surface were deposited in the post-glaciation phase after Late Wisconsin. The T_0 Surface constitutes the present-day floodplain of the Ganga and its tributaries, formed as the rivers abandoned their older courses as a result of the deposition of younger piedmont fans. The deposition of alluvial and colluvial material is still going on adjacent to Siwalik range in this area, as a result of which the rivers are displaying minor shifts in their courses.

Presently the T_0 surface and proximal part of the alluvial fans of PF_1 Surface are witnessing active deposition while all other geomorphic surfaces viz. T_2, T_1, PF_2 and distal part (lower portion) of PF1 are no more under active deposition from Ganga River. However, deposition from sheet-wash is pronounced locally on some of these surfaces. The earlier workers have suggested that the T_2 Surface was abandoned by Early Wisconsin followed by the abandonment of T_1 Surface in Late Wisconsin. The present study shows that the older Floodplain Surface (T_1) is witnessing deposition by yazoo streams developed on this surface and also from the gullies developed along the edges of T_2 and PF_2 surfaces at their junction with the T_1 surface. Upland terrace Surface and Older Piedmont Fan Surface are at higher elevation as compared to the T_1 Surface. The deposition on Older Piedmont Fan Surface (PF_2) is attributed to the sheet erosion on Younger Piedmont Fan Surface (PF_1) and subsequent accumulation on the PF_2 Surface. The Upper 6-10 km wider stretch of Younger Piedmont Fan Surface (PF_1) is witnessing fan building activity in the form of debris flows along the piedmont streams and small gullies. This fan surface juxtaposes the Siwalik range and small colluvial deposits are noticed at this edge of Siwalik.

The study indicates that the processes of deposition are active only in the Active Floodplain (T_0) and upper part of the Younger Piedmont Fan Surface (PF_1), while all other surfaces, viz. PF_2, T_1, and T_2 are not witnessing active deposition at present. Yet, the aggradational processes have not ceased altogether on these geomorphic surfaces but have only subdued in intensity as compared to that in the Holocene.

Geomorphic surfaces PF_2, lower part of PF_1 and T_1 and T_0 have very good to excellent groundwater prospects. As the piedmont fan surfaces PF_2 and lower part of PF_1 constitute the zone of discharge whereas the groundwater prospects of T_1 and T_0 surfaces are attributed to the continuous recharging by the Ganga and yazoo streams. However, T_2 also has good to very good groundwater prospects, particularly in its parts where the relics of an ancient drainage system exist.

Natural Hazards and Environmental Geology

Bank instability and erosion problems of Bishnumati River, Kathmandu, Nepal

*Basanta Raj Adhikari and Naresh Kazi Tamrakar

Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal
*(*Email: limestone20@hotmail.com)*

The Bishnumati River is one of the major tributaries of the Bagmati River in the Kathmandu basin. It is about 18.4 km long sixth order perennial stream with a low gradient. Soil erosion, bank instability, and environmental degradation are the major problems of the Bishnumati River. They are responsible for the loss of sediments, modification of river morphology, loss of vegetative buffer zone, and deterioration of stream habitat. Bank erosion hazard in the Bishnumati River was assessed at ten different reaches from the head to the mouth of the main stream using the parameters such as bank height ratio (BHR), ratio of riparian vegetation rooting depth to bank height, rooting density percentage, bank slope, and bank surface protection. Vertical and lateral stability of the river was assessed at four reference segments, namely at Bishnumatigaun, Okhaltar, Mahadevtar, and Tamsipakha, respectively from upstream to downstream (Fig. 1). In these areas, entrenchment ratio (ER), BHR, meandering width ratio (MWR), bank erosion hazard index (BEHI), and width to depth ratio (W/D ratio) were calculated.
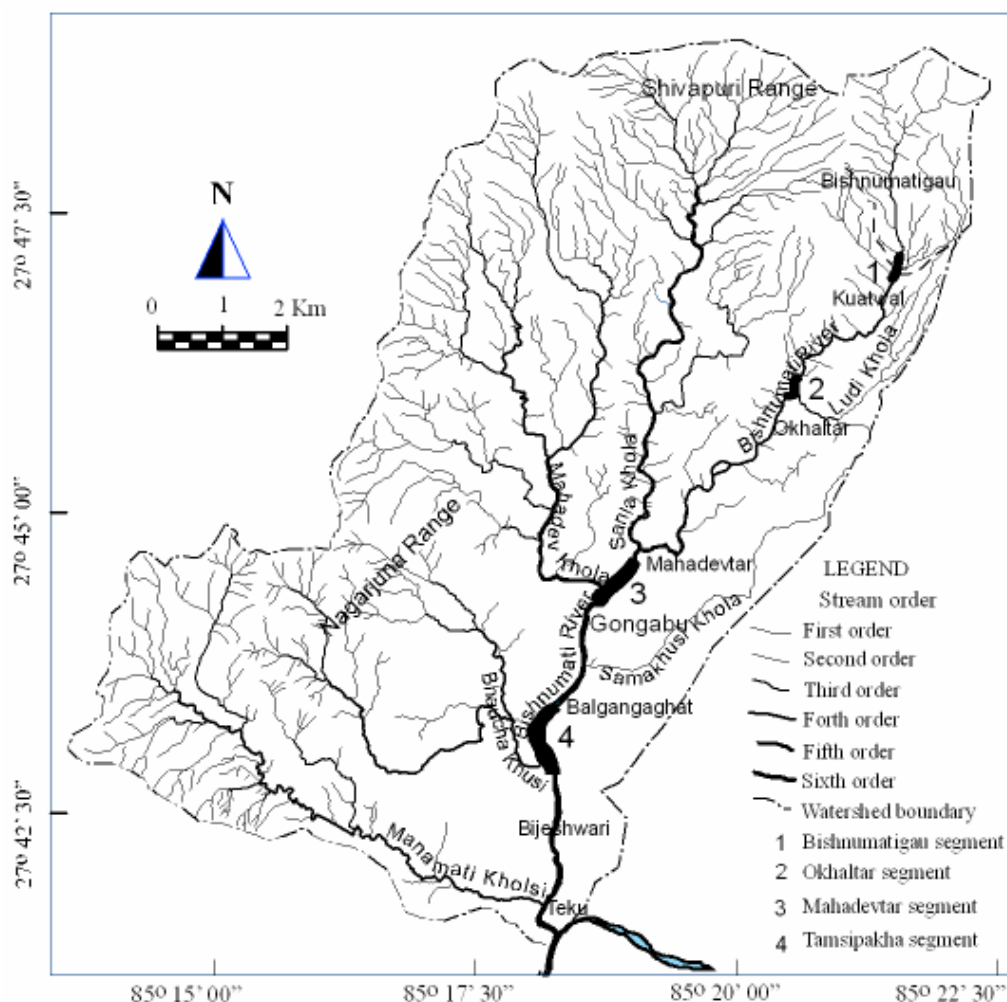
Fig. 1: The Bishnumati watershed showing reference segments for vertical and lateral stabilities of the river

The riverbanks in the Bishnumatigaun segment exhibit a low BEHI, and therefore have low potential of stream bank erosion probably due to the presence of mega gravel banks. BEHI increases up to the confluence of the Bishnumati River with the Ludi Khola, and it gradually diminishes towards Balgangaghat. Further downstream, BEHI increases indicating a high hazard to bank erosion in the segment between Bijeswori and Teku. BHR of all four segments exceeds 1.5, and therefore they are vertically unstable. ER is less than 1.4 in three segments (i.e., except Okhaltar). Tamsipakha and Okhaltar segments have a high risk of lateral shifting, as they possess high values of BEHI, MWR, and W/D ratio.

The main causes of river instability are excavation of river sediments, encroachment of river banks, clearing of riparian vegetation, channelisation and damming, and land use changes. Measures such as restrictions to sediment excavation, re-establishment of riparian vegetation zones along the river, and stabilisation of banks using local resources should be implemented immediately to improve the conditions of channels and banks of the Bishnumati River.

A study on socio-economic effects of landslides in Iran

Reza Bagherian and Massoud Goodarzi
Soil conservation and watershed management research institute (SCWMRI),
PO Box 13445-1136, Tehran, Iran
(Email: bagherian@scwmri.ac.ir; goodarzi@scwmri.ac.ir)

Landslides are among serious problems occurring in the mountainous regions of Iran. Landslide fatalities and damages are not systematically recorded in Iran, therefore estimating the relevant economic losses is difficult. In this paper, the extent and major factors influencing the distribution of landslides in Iran are studied with focus on economic impacts. The study indicated that landslides occur along the major tectonic zones and in regions with heavy precipitation. Many landslides, although always related to the periods of continued rainfall or other natural phenomena, are reactivated and triggered by human activities. Road construction and deforestation are the main human activities that cause such failures. The greatest social and economic impact of landslides is on the human life and farmlands. Landslides usually cause road obstruction and destroy bridges. In some areas, villages have been abandoned due to slope stability problems. Economic and environmental impacts also arise when landslides contribute to reservoir sediments.

Landslides are increasing throughout the world, in spite of improvements in their recognition, prediction, mitigation measure, and warning systems. This trend is expected to continue in the 21st century, due to the following reasons:

1. Increased urbanisation and development in landslide-prone areas,

2. Continued deforestation in landslide-prone areas,

3. Increased regional precipitation due to changing climate patterns.

Landslides cause human and animal loss, adversely affect the residential and industrial development, as well as destroy agricultural and forestlands, lifelines, bridges, and negatively affect the water quality in rivers and streams.

Landslide mapping in Sagarmatha National Park using remote sensing and geographic information system

Sagar Ratna Bajracharya
International Centre for Integrated Mountain Development (ICIMOD),
Lalitpur, Nepal
(Email: sagbajracharya@icimod.org.np)

Sagarmatha National Park (SNP) is located between latitude 27° 40' N and 28° 07'N, and longitude 86° 30' E and 87° 0' E to the northeast of Kathmandu, in the Khumbu region of Nepal. It lies in the higher Himalayan rock and Tethys sediments. Because of a large number of landslides and their relative inaccessibility in mountainous terrain, satellite images and aerial photos were used to map them. The high-resolution 4 m (MSS) and 1 m (Pan) IKONOS imagery of 2001 November and the aerial photos of 1992 were used. The IKONOS high resolution multispectral data were used to prepare a colour composite and false colour composite image to locate shallow landslides and vegetation cover that was crosschecked with 1992 aerial photos.

The most straightforward approach to landslide hazard zonation is the preparation of landslide inventory and landslide distribution maps, based on satellite image, aerial photos, and database of historical occurrences of landslides in an area. The final product gives the spatial distribution of mass movements represented as polygons with attribute data.

In SNP, rockfall is found in many places because of the high relief and very steep slope. Rockfall is predominant in the higher region in the permafrost area due to the freezing and thawing of snow and also it is predominant on northeast-facing slopes. The area is very fragile due to highly fractured and jointed nature of rocks in the area of faults and folds running parallel to the valley. Rockfall covered 27.53 % of the total landslide area. The largest rockfall occupies 897331.45 m^2 and the smallest one covers 513.18 m^2.

Slides make up 72.46% of the total landslide area. The largest slide covers an area of 962863.27 m^2 and the smallest one occupies 396.72 m^2, which includes 1.24% of the total area. Though, many historical debris flows were reported from SNP, at present there is no visible evidence of them.

In SNP, gully erosion is predominant in the higher region due to the high velocity of runoff and glacier erosion. Gullies cover 0.983% of the total area. The largest gully occupies an area of 585130.06 m^2 and the smallest one covers 3589.14 m^2.

Characteristics of decomposed waste in landfill

Md. Niamul Bari, Md. Wasiul Bari, Md. Robiul Awall, and M. M. Younis Ali
Deptartment of Civil Engineering,
Rajshahi University of Engineering & Technology,
Rajshahi-6204, Bangladesh

A laboratory investigation was carried out to determine the characteristics of decomposed waste from the municipal solid waste dumping site of Rajshahi City Corporation. Samples were collected from various depths by driving a PVC pipe at different locations of the dumping site. The laboratory analysis of collected samples revealed that the concentrations of most of the constituents are higher in all depths compared to the Bangladesh Environmental Quality Standard. The concentration of heavy metals like lead and cadmium up to a depth of 1.5 m goes beyond the toxic limit. The concentrations of all constituents show a decreasing trend at the deeper levels of fill. The constituents at greater depths percolated through the unlined bottom of this crude dumping site. The decomposed waste at the dumping site as well as other similar places are polluting the groundwater and surface water.

Impact of mass movements on stability of suspended bridges along Kaligandaki River, west Nepal

*Tara Nidhi Bhattarai[1], Masaru Yoshida[1,2], Bishal Nath Upreti[1], Santa Man Rai[1], Prakash Das Ulak[1],
Ananta Prasad Gajurel[1], Subodh Dhakal[1], and Ranjan Kumar Dahal[1]*
*[1]Department of Geology, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal
[2] Gondwana Institute for Geology and Environment, Hashimoto, Japan
(*Email: tnbhattarai@wlink.com.np)*

The Beni–Jomsom–Kagbeni trail along the Kaligandaki River in west Nepal is one of the most familiar trekking routes in the Himalaya. It crosses many suspended bridges over the Kaligandaki River and its major tributaries. The main objectives of this investigation were to evaluate the engineering geological conditions of some suspended bridge sites and to study the ground response to the load of the bridge. For this purpose, the regional geological framework was examined, a longitudinal section of the Kaligandaki River (from Kagbeni to Beni) was prepared, and detailed engineering geological studies of some important bridge sites were carried out.

The sub-vertical cut slope at the right abutment of the suspended bridge over the Kaligandaki River at Kagbeni has triggered a landslide, which has threatened the stability of the bridge itself. The right abutment of the suspended bridge over the Lete Khola was constructed on an old landslide (Fig. 1). There are many tension cracks around the crown of the slide and the Lete Khola is undercutting its toe. Consequently, the bridge abutment is at the verge of failure. Similarly, the road widening works have left a steep cut slope at the left abutment of the Beg Khola suspended bridge. Since one of the prominent joint sets is daylighted, there is a possibility of triggerring a rockslide, which may damage the bridge.

This study revealed that the Kaligandaki River valley is susceptible to different types of mass movements, which

have severely affected the stability of some of the suspended bridges. Hence, a detailed engineering geological study is required for the construction of suspended bridges at stable locations.
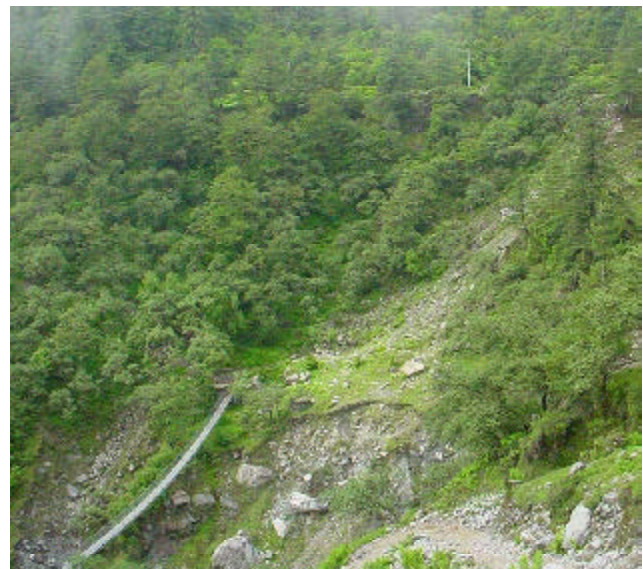
Fig. 1: Right abutment of the Lete Khola suspended bridge is on an old landslide. Notice the reactivation of the landslide due to toe cutting near the abutment.

Use of spatial data of infrastructures for assessing urban vulnerability to multiple hazards

Veronica F. Botero
*International Institute for Geoinformation Science and Earth Observation (ITC),
The Netherlands
(Email: botero@itc.nl)*

In the last two decades, geohazards and weather-related hazards, have claimed the lives of more than 700,000 persons around the world (OFDA/CRED 2004) and have produced an estimated damage of 740 billion US dollars.

A considerable number of risk management initiatives, also called disaster reduction initiatives, have been made in the past years. Results however, show that the impact of hazards on urban areas, especially in developing countries, has not been reduced.

Specifically, urban vulnerability to natural hazards has been inadequately estimated for years. Most models do not consider the complex interaction between human behaviour and the hazard itself. Although the methods address different aspects, none of them analyse all the variables (physical, social, economic, cultural, institutional, and political) in an integrated manner, within a Spatial Data Infrastructure (SDI).

Accurate and reliable information is the primary input for GIS-based vulnerability assessments. Therefore, standardisation of all issues related to the accuracy, reliability, political neutrality, collection processes, analysis, storage, maintenance, and dissemination of data should be taken into account. Thus, an SDI especially designed to deal with the factors relative to vulnerability can be a turning point in risk management initiatives.

This research focuses on the variables and factors defining vulnerability. This information may be used by local authorities in multiple administrative tasks. For the latter, two municipalities in developing countries were selected as case studies (i.e., Lalitpur in Nepal and Medellín in Colombia). These two cases exhibit diverse conditions in terms of information systems and data management.

A turning point in vulnerability assessment is the understanding of how municipal offices, external agencies at the national level (e.g. Land Survey Department), NGOs, and INGOs collect, manage, and share the data pertaining to vulnerability. In the following figure (Fig.1), a conceptual model of the research is presented.
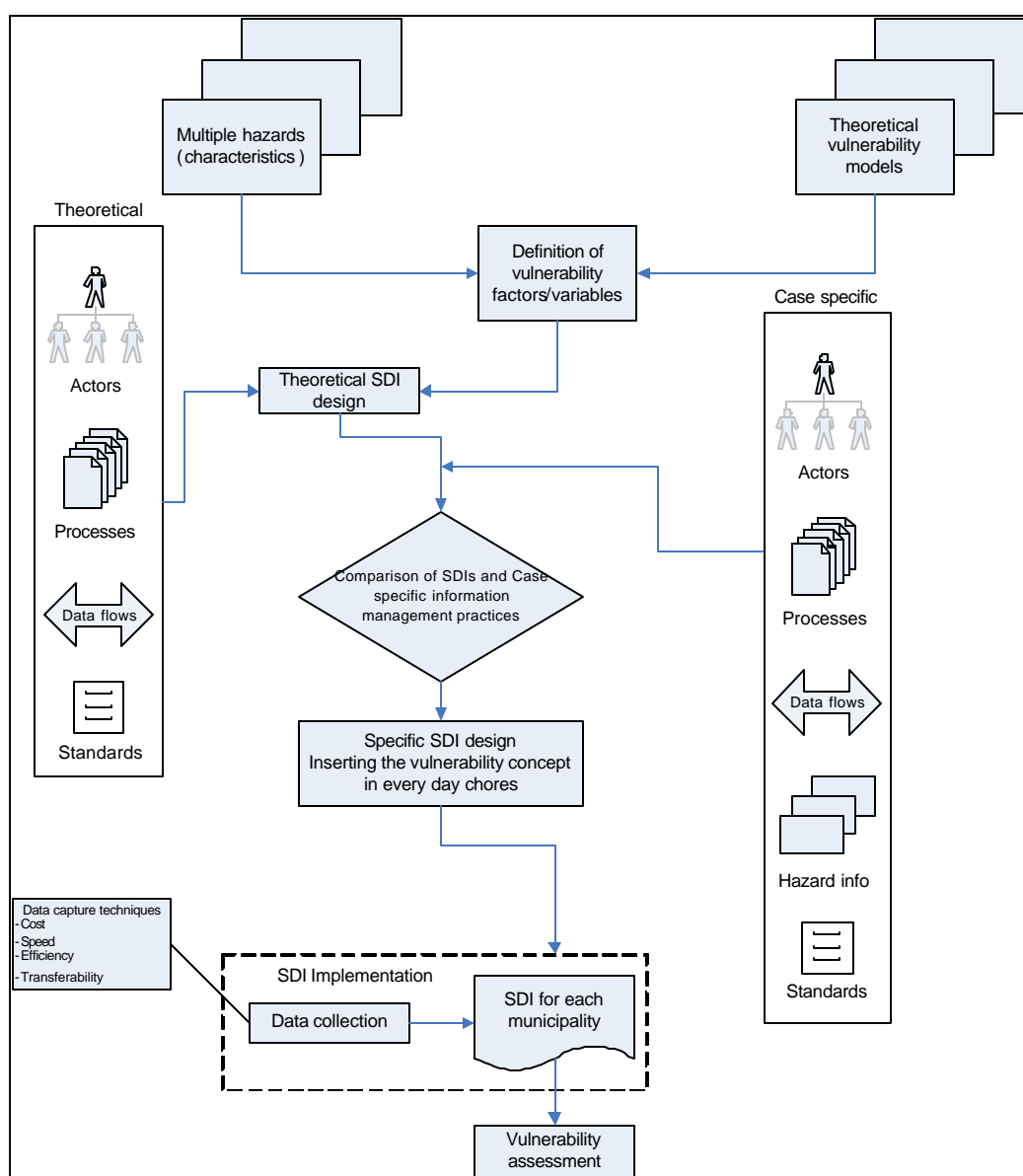
Fig. 1: Conceptual research model

Research activities of National Seismological Centre, Kathmandu

*G. R. Chitrakar, Guillaume Yclon, U. Gautam, P. L. Shrestha, D. R. Tiwari, and B. Koirala

National Seismological Centre, Department of Mines and Geology,
Kathmandu, Nepal
(*Email: nscdmg@mos.com.np)

Many devastating earthquakes have occurred in Nepal and some historical earthquakes date back to the 13th century. The occurrence of earthquakes in Nepal is due to the underthrusting of Indian plate below southern Tibet with an average convergence rate of 2.0 cm per year. Nepal covers 850 km stretch (i.e., about one third) of the Himalayan arc and has experienced four great earthquakes, namely the Assam earthquake (1897), Kangra earthquake (1905), Nepal–Bihar earthquake (1934), and Assam earthquake (1950). The Department of Mines and Geology (DMG), His Majesty's Government of Nepal in technical Collaboration with Laboratoire de Géophysique Appliqué (LGA), France, has been monitoring the earthquakes since 1978 with a single vertical component. By 1998, the seismic stations were increased and upgraded to 21 with two independent recording centres, one in at the National Seismological Centre (NSC), Kathmandu, and the other in Birendranagar, Surkhet.

The NSC has carried out several research activities in collaboration with DASE (Département d'Analyse et de Surveillance de l'Environnement) and other institutions that helped to develop seismotectonic model based on geophysical, geological, and geodetic data, which show stress and strain accumulation in a mid-crustal ramp during the interseismic period. The Nepal Himalaya shows high seismicity based on historical data, data obtained from the bulletin of the International Seismological Centre (ISC), and

data from the operation of NSC. Microseismic activities are more intense in Central and Far Western regions of Nepal.

The Seismic activities in Nepal are characterised by a narrow zone of intense micro seismicity, which follows the topographic front of Higher Himalaya, and most of the events are found between the Main Central Thrust and Main Boundary Thrust (in plan view) within a depth of 10 to 30 km, although there are also some deeper events.

Monitoring of earthquakes both in time and space may provide valuable information to study seismic hazard and recurrence pattern of earthquakes. More than 70,000 earthquakes have been localised and processed by the NSC during the period 1994 and August 2005 including local and teleseismic events with waveform data. Projects like "Himalayan Nepal–Tibet Seismic Broadband Experiment (HIMNT)", "Himalayan Tibet Continent Lithosphere During Mountain Building", and "Combined Geodetic and Seismological Observation in Nepal Himalaya" will greatly help to understand the nature of different tectonic boundaries as well as surface deformation. Our seismic data are used by the ISC, U. K., for their global localisation. Seismic data are also used for the design of earthquake-resistant constructions, such as hydropower stations, dams, reservoirs, and other major structures.

The environmental impact of the underground in Bucharest city

Viorica Ciugudean Toma and Ion Stefanescu
S. C. Metroul S. A. Geotechnical and Hydrogeological Department,
Bucharest, Romania

The impact of underground subway (metro) construction works on the environment appears to be quite significant. Metro construction works affect the subsoil, groundwater, atmosphere, and most importantly – the inhabitants who use it in their everyday life.

The underground excavation is carried out using precincts with diaphragm walls and hydrological shields in complex geotechnical conditions. The negative environmental impact of metro works in Bucharest are as follows:

– ground subsidence around rectangular or circular tunnels;

– inundation related to the rise in water level (i.e., when the underground structures obstruct the subsurface flow, the buildings in the vicinity are submerged);

– chemical deterioration of the soil;

– vibration and noise (from the rails); and

– hazardous emissions and smog.

The metro designers should take into consideration these factors in order to minimise the negative impact of metro construction works on the environment.

Engineering geological study of a slope instability at Chalnakhel, Kathmandu

Prakash Dhakal[1] and Prakash Chandra Adhikary[2]
[1]Department of Mines and Geology, Kathmandu, Nepal
[2]Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal

The landslide of Chalnakhel is located about 11.5 km southwest of Kathmandu on the Kathmandu–Pharping Road (27°38'7.5" to 27°39'22.5" N latitude and 85°16'15" to 85°17'11.25" E longitude). It has damaged the road and three houses. The Bagmati River and Bosan Khola are the main rivers draining the area. The Chalnakhel landslide is facing northeast, covers an area of 0.07 km^2, and is developed in residual and colluvial deposits underlain by low-grade metamorphic (calcareous) rocks. Its investigation and monitoring began in 1990.

Geotechnical and geophysical investigations were carried out at the Chalnakhel landslide to reveal its sediment types, their index properties, and groundwater conditions. The Chalnakhel landslide is a rotational soil slide, which shows perceptible movements occasionally in the monsoon season shortly after the intense rainfall. The slide was divided into two zones, and three profiles were taken for the calculation of its factor of safety: profiles E1–E2 and P1–P2 lie in Zone A and profile A1–A2 falls in Zone B. The safety factor calculations for the existing unsaturated conditions indicated that profile E1–E2 was unstable, and profiles P1–P2 and A1–A2 were almost in equilibrium, whereas all the profiles were unstable for fully saturated conditions.

Study of Bhadaure Landslide in Pawati VDC, Dolkha district, central Nepal

*****Sunil Kumar Dwivedi[1] and Shreekamal Dwivedi[2]**
[1]Department of Geology, Tri-Chandra Campus, Kathmandu, Nepal
[2]Department of Water-Induced Disaster Prevention, Lalitpur, Nepal
*(*Email: sunil_dwdd@hotmail.com)*

The Bhadaure landslide is located on the right bank of the Tamakoshi River in the Pawati VDC of the Dolkha district in central Nepal. This rotational slide has been a threat to the local people and it has caused severe damage to the houses and cultivated land. Geological, stratigraphic, and geomorphological observations were made for the stability assessment of the slide. The area falls in the Lesser Himalayan belt of central Nepal. In the area, the Quaternary topsoil overlying the augen gneiss permits a large amount of precipitation to infiltrate. The infiltrated water makes a perched water table owing to the presence of clay and clayey silt beds in the alluvial terrace of the Tamakoshi River. A detailed study of causes and mechanism of failure was carried out in the field. The field assessment and safety factor analysis revealed that the landslide is quite unstable in the monsoon period. Hence, some cost-effective mitigation measures such as gulley protection and bio-engineering works are urgently needed.

Understanding traditional wisdom of earthquake-resistant construction in the Himalayas

*Amod Mani Dixit, Jitendra K. Bothara, Surya Narayan Shrestha, and Bijay K. Upadhyay

National Society for Earthquake Technology (NSET) – Nepal,
PO Box: 13775, Kathmandu, Nepal
(*Email: adixit@nset.org.np)

The traditional knowledge on earthquakes and earthquake-resistant methods of construction in the cultures along the Himalayan range is known for quite some time. A few scientists have tried to explore the aspects of such constructions. However, no inventory of historical buildings or monuments exists, let alone a systematic study of the earthquake-resistant features of this time-tested construction of monuments that have survived one or more episodes of large to very large earthquake shaking during the past centuries. These buildings are like open laboratories in which signatures of indigenous wisdom in earthquake-resistant construction, technologies that have protected these structures against vagaries of nature including earthquakes, and the socio-cultural factors that have been at play for their preservation could be observed and studied. Such knowledge is considered useful also for the implementation of earthquake risk reduction initiatives. It is becoming increasingly evident that the success of the programme for improving seismic performance of construction depends much on the level of acceptance of the proposed technologies by the communities. The target monuments of the proposed study are the true examples of the building culture that not only was acceptable in the concerned community, but was well integrated into the respective social and cultural lives. Hence, knowledge of prevalent indigenous technologies and their seismic behaviour, and the history of application and conservation, could be very helpful in identifying proper improvements in construction practices using traditional construction materials, and for sustainable earthquake protection and conservation.

These issues are expected to be addressed by the pan-Himalayan study of historical buildings, conceptualised by the National Society for Earthquake Technology-Nepal (NSET), and proposed to be implemented jointly by NSET and other research institutions of the Himalayan region. The goal of the multi-year project would be to understand the nature of the employed construction materials and technologies, the construction processes and the wisdom behind it, the designs adopted, and then a proposal to develop a database with a focus on the understanding of the seismic behaviour of these buildings. The study will also help to understand how biodiversity shaped the building typologies in the region and the changes in the employed structural systems over the time in any locality.

Use of Global Positioning System (GPS) in post-mining landscape reconstruction and visual impact assessment: a case study

S. Fadda, M. Fiori, and C. Matzuzzi
Istituto di Geologia Ambientale e Geoingegneria del CNR,
Cagliari, Italy

Global Positioning System (GPS) is a satellite-based tool, which can determine on its own the position that it occupies without any relation to the topography or otherwise. The user GPS receiver (Master) tracks the satellites and decodes the signals computing the position through post-processing transformation software. The purpose of such geodetic measurements is to make highly accurate topographical maps thus forming the backbone of a project. The aim of this work is to combine conventional and satellite measurements with advanced visualisation techniques comprising Virtual 3D landscape environments, programs, and Geographical Information Systems (GIS) in a possible recovery project of the abandoned excavations in the talc-chlorite-feldspar mining district of Orani, central Sardinia (Italy) where several mining sites have long been exploited.

Most of these operations are open-pit excavations, which have not been recovered as yet. The possible recovery of one of them is related to local morphology and to the presence of abundant water from aquifers drained through faults crossed by mining operations in the open pit of Bonucoro. On the basis of the naturalistic and geographical contexts of the mining area and its surroundings, a few proposals concerning the re-utilisation of these excavations through stabilisation and remediation interventions, are presented. New technologies such as GPS, CAD, and GIS, to create three-dimensional perspective views and computer-aided image analysis in addition to conventional air photo interpretation techniques were utilised. The primary objectives include: smoothing and re-modelling of local morphology, restoration of the removed soil covers, and rehabilitation of the newly formed surfaces. The preparatory work consisted of a topographic survey integrated with photogrammetric and geomorphological surveys. A hand-held Topcon Gps-Rtk (RealTime) was utilised throughout the work for collecting field data in "World Geodetic System 1984 (WGS84)" coordinate system. In order to describe the morphological features of the landscape, elevations of single points were recorded. Traverse points were set up for densification of the network as needed including hard break-lines to avoid smooth interpolation across these lines. GPS survey data were then exported for the subsequent three-dimensional analysis and geoprocessing by commercial GIS/CAD software. A complete DTM in TIN format of the site and its environs was produced in the computer-aided design using AutoCAD 5.0, which was integrated in GIS applications. The generated application is capable of handling topographic data as DEM in raster GRID format for surface reconstruction and textural information. The final step is represented by the use of E-On software's VUE (software scenery generator) that is capable to integrate graphical data with geological and morphological attributes, to perform queries and spatial analysis, and finally to produce thematic maps. Virtual 3D landscape environments were finally generated by the use of Autodesk 3D Max Release 6.0, which supports a wide range of image-rendering enhancements to give an imagination of a present, past, or future landscape. The remodelling and restoration or improvement scheme for the Bonucoro site was designed taking into account the strongly changed local topography and seeking to enhance the ecological value of the area. The computer-based model of restoration described here is a formidable aid to illustrate the proposed changes and the merging of the final restored landform into the existing, adjacent landscape. 3D data modelling when combined with GIS can be a powerful means to describe a landscape and to monitor and manage its conservation and development.

Study on palaeoseismology in the Kathmandu basin sediments, Nepal, from soft sediment deformation and liquefaction structures

*A. P. Gajurel[1,2], **P. Huyghe**[2], **B. S. Sukhija**[3], **J. L. Mugnier**[2], **D. V. Reddy**[3], **and B. N. Upreti**[1]

[1]*Dept. of Geology, Tribhuvan University, Tri-Chandra Campus, Kathmandu, Nepal*
[2]*Université Joseph Fourier et CNRS, Grenoble, France*
[3]*National Geophysical Research Institute, Hyderabad -500007, India*
(*Email: apgajurel@yahoo.com)

The Kathmandu valley is a large intermontane basin transported by the main Himalayan Thrust. The basin is filled up with fluvio-lacustrine sediments consisting of a thin alternation of weakly consolidated and cohesionless silty and sandy layers having a rather good sorting. The Himalayan thrust system gets shortened by about 20 mm/year and accumulates a large amount of strain. Great Himalayan earthquakes have affected the Kathmandu valley during the historical time, but have only partially released the total accumulated strain. It is important to make a realistic seismic hazard assessment in the Himalayan region by reconstructing its seismic history and evaluating the recurrence period of the great Himalayan earthquakes.

The sediments of the Kathmandu basin reveal hydroplastic deformation, liquefaction and fluidisation as well as soft-sediment deformation structures in several places. Field investigation since 1997 has resulted in the discovery of 13 sites of palaeoseismic structures, which are related to a large number of seismic events. These features are observed in the oldest Lukundol Formation to youngest river deposits. Altogether 30 dykes and synsedimentary soft-deformation structures (ball-and-pillow structures) from 15 stratigaphic levels (typically in Thimi, Koteswor and Sunakothi) were discovered. A marker layer in the basal zone of ball-and-pillow structures attests to the simultaneity of compression and extension deformation structures, a combination of structures that excludes slope failure origin for the soft-sediment deformation. The aim of this work is to establish palaeoseismic records.

At Gothatar, along the Bagmati River section a recent historical earthquake (before the settlement of Jorpati) is evidenced by dyke and soft-deformation structures (Fig. 1).

These sand dykes are intruded into the overlying 1 m thick silty clay layer and are oriented N140º to N150º. The vertical extension of dykes is less than 40 cm and the thickness of highly disturbed sand and silt layer is 42 cm. From a comparison of thickness of Quito area seismite (Hibsch et al. 1997), these features could be related to an intensity of shaking greater than IX.

Other prominent liquefaction features are observed in two cliffs of the Gokarna Formation at Duwakot, where sand dykes appear at two levels separated by a 3–4 m thick undisturbed sand bed. However, both the dykes are trending approximately NW–SE. At Baniyatar, in the Gokarna Formation, the dykes are associated with normal faults and are orientated N75º to N105º. Another set of prominent sand dykes is also found in the older Lukundol Formation close to the basin boundary. These sand dykes intrude into the overlying black sandy clay layer and originate from its thick sand bed. They display an E–W trending direction. At Thimi, the dykes are oriented approximately in north–south direction (N10º to N50º).

The dykes are found in a various geological formations and their orientations are quite different. Therefore, it is inferred that they are related to different palaeoseismic events and could be due to different seismic sources.

REFERENCE

Hibsch, C., Alvarado, A., Yepes, H., Perez, U., and Sébrier, M., 1997, Holocene tectonics and liquefaction/ soft sediment deformation in Ecuador: a paleoseismic history record in lacustrine sediments. Jour. Geodynamics, v. 24, pp. 259–280.

Fig. 1: Soft-sediment deformation structures and dykes observed in the Bagmati River terrace at Gothatar

Reconnaissance geophysical methods in investigation of Galdian landslide, northern Iran

J. Ghayoumian, S. R. Emam jomeh, and E. Gohari
*Soil Conservation and Watershed Management Institute,
PO Box: 13445-1136, Tehran, Iran*

Landslides site investigation may be very expensive since they may be extremely large, structurally complex, and topographically severe. Engineering geological investigation of landslides can aid to reduce subsurface investigation and save time and resources.

The Roudbar–Manjil earthquake of 20 June 1990 produced the largest area of landslide destruction in Iran's history. About 120 large and small landslides were triggered by the main shock and aftershock, and more than 200 people were killed as a result of slides. A huge landslide of about 32 million m³ occurred east of the city of Roudbar during the 1990 earthquake.

In this research, engineering geological investigation of the Galdian landslide is presented. The work includes aerial photo interpretation, field investigation, and geophysical measurements.

Aspects such as shape with a particular reference to shear surface, hydrogeological regime, and the detection of movement within the slip mass as well as its characteristics were considered in a geotechnical appraisal.

With an approximate understanding of the overall topographic extent of the slide, a detailed field investigation was conducted to delineate the aerial extent and general direction of movement of the landslide zone, assess the geology and geological structure, estimate the causes of sliding, and predict future movements. On the other hand, all surface deformations were recorded to define the boundaries of the landslide size, direction of the movements, and optimal locations for geophysical works.

A combination of electrical sounding and seismic refraction measurements were conducted with the principal aim of providing additional information about the geological framework and mechanism of the active slide.

A seismic refraction survey was carried out to determine the thickness of the unconsolidated materials. Seismic data interpretation was based on the standard method for a multi-layer geological structure. The boundaries of different materials were obtained by geoelectrical and seismic methods.

The results indicate that the Galdian landslide is composed mostly of the eroded sediments of the Shemshak Formation and Quaternary sediments. The active block is a rotational slide. The results of field investigation and geophysical sounding are presented in an engineering geological map and several cross-sections, which clarify the geometry and subsurface characteristics of the slide.

Glacial study in Madi watershed with special reference to GLOF of 2003

Manoj Kr. Ghimire [1], Shreekamal Dwivedi[2], and Subhrant K. C.[1]
[1]Kathmandu University, Dhulikhel, Nepal
[2]Department of Water-Induced Disaster Prevention, Lalitpur, Nepal

On 15 August 2003, the Madi River suddenly experienced an unprecedented flash flood, which destroyed the recently-built rural road and triggered various mass movements. In the absence of other causes of flood, like intense precipitation, it was concluded that a glacier lake outburst flood (GLOF) had occurred. However, field verification was not done regarding the nature of glaciated region and the mechanism of flood.

In the present work, an attempt has been made to study the general characteristics of the glaciated region with reference to the cause and nature of the GLOF of 15 August 2003, and a subsequent flood that occurred nearly a year later on 8 August 2004. These floods, which occurred without any significant input of precipitation, have caused severe damage downstream resulting in an immense change in the landscape. The GLOF was not related to the opening of the dam of Kabache Lake, but originated from the Sonbu glaciated region. In addition, the GLOF seems to be related with a dynamic Type C glacier, which shows an extreme seasonal variation rather than being related to a relatively static Type D valley glacier of the Kabache region. Nevertheless, the retreating characteristics of Kabache need some attention as well. Further detailed investigation is required to understand the mechanism of annual release of water from the Sonbu glacier.

Analysis of terrain, river morphology dynamics, and hazard assessment of Ratu Khola Basin, Nepal using GIS and remote sensing

Motilal Ghimire [1], K. B. Thapa[2], and Mandira Shrestha[3]
[1]Central Department of Geography, Tribhuvan University, Nepal
[2]Central Department of the Hydrology and Meteorology, Tribhuvan University, Nepal
[3]International Centre for Integrated Mountain Development (ICIMOD), Nepal

This paper investigates the flood hazard (Fig. 1) and risk in the Ratu Khola basin using remote sensing and GIS. The recent topographic map (1:25,000); and the aerial photographs of 1953–54, 1978–79, and 1992 (1:50,000) were used for the study. In addition, Landsat Imageries of 1975, 1991, 1998, and 2001 were also incorporated in the study. Geomorphic approach of hazard mapping has been adapted in the study using the parameters (interpreted from aerial photographs or imageries) such as flood-affected areas, floodplains, and areas of sheet flooding, bank cutting, channel shift, and debris flow together with old channels and moist areas.

The upper reach of the basin is comprised of the Siwalik rocks (Lower, Middle, and Upper Siwaliks). The lower reach is represented by the landform made of Quaternary deposits. Hillslopes; inner river valleys; inactive, active, and peripheral fans; and upper (Middle Terai) and lower (Lower Terai) reach alluvial plains are the major geomorphic landforms. Hillslopes are highly dissected and subdued. Relatively wide valleys and larger colluvial and alluvial fans are developed. This type of geomorphic setting is attributed to the highly fragile and erodible Siwalik rocks, mostly of the upper Siwaliks affected by the monsoon climate.
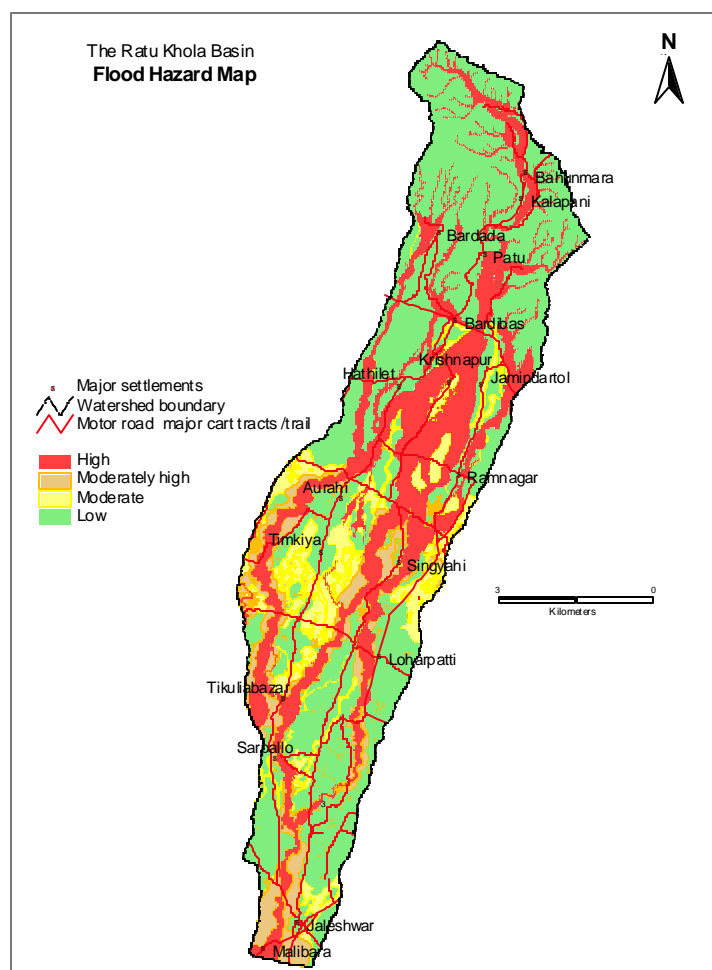
Fig. 1: Flood hazard map of the Ratu Khola basin

A study of aerial photos and imageries showed that the river morphology is frequently changing and the change is most pronounced in the fan. In the inner river valleys and active fans, a rain shower of few hours is enough to yield a huge sediment load with a high proportion of bed materials leading to debris torrents and flash flood accompanied by sedimentation, bank erosion, incision, and river course shifting.

Owing to a very low gradient and poor drainage, inundation and sheet flow is a typical flood hazard in the floodplains of the middle and lower Terai. The inter-basin flow of water due to a lack of defined basin drainage and induced by the infrastructures is common in the lower Terai. Local residents reported that the intensity of river activity has increased over the last 40 years, ever since the hill

migrants have settled and encroached upon the hazardous areas of inner valleys and fans, and have disturbed the fragile and forest-fire prone slopes. There has been a gradual extension of coarser material towards the south (lower Terai) as well as increase in the channel width:depth ratio and decrease in flow capacity depth causing frequent sheet floods and incidences of channel shift.

The hazard assessment reveals that about 26% of the watershed area is under high hazard, where 14% of the houses and 18% of the built up areas lie. Likewise, 25% of the agricultural land is under the high hazard. Similarly, 16 and 15% of the surveyed infrastructures fall in respective high and moderately high hazard zones. Considering the risk (a product of hazard and vulnerability), about 11% of the watershed area falls in a high risk zone.

Role of three-thorned acacia (*Gleditshia caspica*) in controlling landslides on forest slopes

*Ghasem Habibi Bibalani[1], Baris Majnonian[2], Ebrahim Adeli[3], and Homauon Sanii[4]

[1]*Azad University of Shabastar, Iran,*
[2]*Faculty of Nat. Res., University of Tehran, Iran*
[3]*Nat. Res. of Azad University of Tehran, Science & Research University*
[4]*Tarbiat Modares University of Tehran, Iran*
(*Email: ghhabibi@iaushab.ac.ir)

In recent years, forest trees are considered vital in controlling landslides. There are many landslides on forest slopes of Iran owing to the incorrect use of vegetation and clear-cutting of forest in the past. For this reason, the study of mechanical effects and bioengineering potential of three-thorned acacia (*Gleditshia caspica*) is very important. The factors such as depth, density and angle of internal friction

of soils, and the tension resistance of three-thorned acacia roots were studied . On the basis of this studies, the safety factor of the forest soil slopes was determined. The study showed that the safety factor of forest slopes planted with the three-thorned acacia increased by 0.6 in comparison with their earlier value.

Stabilisation of trail bridges in the landslide area

Narayan Gurung
Kadoorie Agricultural Aid Association, British Gurkhas Nepal
British Gurkhas Pokhara, Nepal
(*Email: kaaajbg@fewanet.com.np*)

A number of trail bridges are built on landslide-prone slopes of Nepal. There might be various reasons for constructing bridge in such geologically poor sites, such as potential interest, a lack of knowledge, and a strategic position. Some of such sites are in the Myagdi and Taplejung districts. In these places, the ground continues to move even after the

bridge construction. To stabilize these bridges, a wheel anchorage system was developed. This system has made the bridge moveable with respect to the ground movement at the abutment. The landslide control works also involve other civil and bio-engineering systems to stabilize the entire slope. The wheel anchorage system is functioning well for last three years.

The post-glacial Kalopani landslide dam in Kali Gandaki Valley: an analogue to the Usoi landslide dam in Tajikistan

Joerg Hanisch
JorgeConsult, Rahlfskamp 9, 30659 Hannover, Germany
(Email: jorgeconsult@gmx.de)

Lake Sarez in the Murgab valley in the Pamir Mountains of Tajikistan was formed by a natural dam of a huge landslide which occurred in 1911, triggered by a heavy earthquake. The dam is about 2 km^3 in volume and up to 750 m high, and it is the highest dam on earth. The lake is up to 500 m deep, 60 km long, and comprises a volume of about 17 km^3.

A similar dam was found to have blocked the Kali Gandaki Valley in West Nepal in post-glacial times. This is reflected by the presence of huge piles of lacustrine sediments along the flanks of the Kali Gandaki Valley upstream of Kalopani up to the southern parts of Upper Mustang area. These deposits lie unconformably upon the moraines of the last glaciation and the top of the sequence is found to be at a continuous level of about 3050 m above sea level. As remnants of the landslide dam have been identified at the same level near Kalopani there is little doubt that this post-glacial "Lake Mustang" was filled totally by sediments (which include deltaic and debris flow deposits) before erosion started to wash them away together with the dam. The study of the Kalopani dam and its lake provides a unique opportunity for a long-term prognosis of the stability and development of Usoi dam and Lake Sarez in Tajikistan.

Extreme high-mountain risks in Asia: possibilities and limits of their mitigation

Joerg Hanisch
JorgeConsult, Rahlfskamp 9, 30659 Hannover, Germany
(Email: jorgeconsult@gmx.de)

High-mountain hazards have become an increasingly threatening risk for the population living in and near the mountains because of three major reasons: (i) global warming has been rising the permafrost boundary exposing the frozen ground until now stable to processes of erosion, landsliding, and liquefaction, (ii) the dramatically fast retreat of glaciers has been leading to the fast formation of moraine-dammed lakes prone to burst and form devastating floods or debris flows, and (iii) population growth has been leading to settlements in vulnerable territories.

The ablation and retreat of glaciers can also cause huge rockslides (from the missing ice support in the typically U-shaped valleys) able to cover and destroy whole villages and to dam the river valley. In many cases, the failure of such natural dams has caused devastating floods and debris flows in the downstream areas. The debris flows, in general, are among the most threatening hazards in high mountain regions (especially those generated by glacier lake outbursts). They are able to run quite far even into rather flat areas and to reach extreme velocities with enormous destructive forces.

The paper presents extreme examples from Nepal, Tajikistan, and the Caucasus. It also demonstrates ways of disaster management and gives examples of successful remedial works.

An evaluation method for roadside rock slope stability: a study from Sri Lanka

***U. de S. Jayawardena**[1] **and K. P. Jayawardena**[2]
[1]*Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka,*
[2]*Road Development Authority, Kandy, Sri Lanka*
(*Email: udsj@pdn.ac.lk)

In Sri Lanka, so far geological features have not been considered for the construction of highways. That is the main reason for the occurrence of landslides along the newly constructed roads and uneven settlements of road bases. Hence a study was carried out to evaluate the geological conditions along a newly constructed highway in the hilly region of Sri Lanka. The objective of this study was to develop a simple evaluation method to recognise the situation of slopes in an area prior to the construction of new roads.

Stable and unstable locations along the existing road alignment were identified based on the analysis of slope height and angle, rainfall intensity, occurrence of springs, overburden thickness, land use, watershed area, weathering condition, orientation of bedding and joints, presence of crush zones, and rock type. A numerical value was given for each parameter.

According to the rating systems, the slope was divided into three stability zones: least affected, highly affected, and very highly affected. Accordingly, the designers can use their highway engineering knowledge to construct a new road and prevent the future damages to the road after its construction. Further, they can calculate the total construction cost including the slope stability measures.

How major landslides along Narayangarh–Mugling Road can be stabilised in a sustainable manner?

Surendra Prasad Joshi
Mugling–Narayangarh Water-Induced Disaster Prevention Project,
DWIDP, Lalitpur, Nepal

There are 15 major landslides along the Narayangarh–Mugling Road. The Department of Road is trying to maintain the Road corridor by cleaning the accumulated debris on the road, constructing check dams and retaining walls near the corridor to retain the debris coming from gullies. However, the debris flows are continuing and disturbing the traffic movement each year owing to a lack of necessary structural and non structural measures to stabilise the landslides and gully erosion in the watershed.

Therefore, the Government of Nepal has established the Mugling–Narayangarh Water-Induced Disaster Project under the financial support of the Japanese Government to stabilise the road sector in a sustainable way. The project has started the study of major gullies and streams. There are several small and big landslides on the banks of each gully, which need special treatment. The streams like the Khahare Khola with a large catchment area and huge debris mass need a series of long check dams, while gullies like the one at Km 30+890 with small catchment area need only small check dams, retaining walls, and catch drains to control the debris flow. Therefore, it is very important to study the catchment area of each gully and stream to maintain the smooth traffic flow on this strategic road in a sustainable manner.

Nonessential trace elements in cropped soils of Kathmandu valley

Krishna B. Karki
Soil Science Division, NARC, Khumaltar, Lalitpur, Nepal

Five different land uses, namely paddy cultivation with drainage water irrigation (Bungmati), upland maize cultivation (Chunnikhel), vegetable cultivation with sewerage water irrigation (Shankhamul), vegetable cultivation with river water irrigation (Thimi), and rice cultivation with river water irrigation (Khumaltar) were selected for the study of nonessential trace elements in the soil. The soil profiles in each land use were opened, and samples from each horizon were collected and processed systematically. DTPA and HNO_3 extracting solutions were used to extract the trace elements from the soils and detected by ICP. General soil fertility of these land uses showed that the Shankhamul and Khumaltar soils were most fertile with higher CEC (34 me/100g) values.

However, the top fertile soil of Khumaltar is excavated for brick making. Among the nonessential trace elements, although a higher amount of phosphate fertiliser is applied to all the land uses, the amount of Cd is low (0.21 mg/kg) in all the soils. Cr also shows a similar trend (0.34 mg/kg), which goes higher when the soil depth is increased. A comparatively higher amount of Ni (6.71 mg/kg) was observed in the Sankhamul soil, and the concentration decreased with the depth. A high amount of Pb (7.02 mg/kg) was observed in the surface horizon of all the soils except at Khumaltar, where a higher amount (10.27 mg/kg) was found. All these elements so far accumulated in the soil through different sources show that they are below the toxic level.

A study on environmental geomorphic status of Lut Desert in the eastern part of Iran

Kaveh Khaksar and Massoud Goodarzi
*Soil conservation and watershed management research institute
(SCWMRI), PO Box: 13445-1136, Tehran, Iran
(Email: kavehkhaksar@gmail.com; goodarzi@scwmri.ac.ir)*

Over two thirds of Iran receives less than 300 mm of annual precipitation. The Lut Desert lies in the ultra arid parts of Iran. It is one of the driest regions in the world. In some parts, there falls only 20 mm of precipitation per year. Still, there are some positive aspects in this area. Special species of flora and fauna make it interesting. Besides, there are mines of different minerals. The Lut Desert is rich in halite, sylvite, celestine, sulphur, and many others.

This paper describes the environmental status of this area with the emphasis on environmental geology and geomorphology. It consists of an introduction to the desert, a brief study on existing ecological systems of the ultra arid deserts, existing flora of Lut, mineral mines and resources of the study area, its present status, and planning for the future.

Sensitivity of bedrock to weathering: a case study of Maharlu basin, Zagros range

Kaveh Khaksar and Mohammad Reza Gharibreza
Soil conservation and watershed management research institute
(SCWMRI), PO Box: 13445-1136, Tehran, Iran
(Email: kavehkhaksar@gmail.com; goodarzi@scwmri.ac.ir)

The Maharlu watershed lies in the south of Iran and covers an area of approximately 4200 km^2. Mainly calcareous rocks crop out in this area.

Three physical and mechanical analyses were carried out for the sensitivity evaluation of rock units to weathering. They were: rock resistance estimation with a geological hammer (ISRM method), evaluation of mechanical properties and grade of weathering using a Schmidt Hammer (Brand method), and measurement of fissure and joints (Bienawski technique). The acquired data together with the various rock types constituting the basin were analysed, and their sensitivity to weathering was determined. Finally, a map of weathering sensitivity was prepared for different geological formations.

The results indicate that the Asmari-Jahrum Formation is the least sensitive to weathering and most resistant rock succession and belongs to the slightly weathered category, whereas the Bakhtyari Formation, Bangestan Formation, Tarbur Formation, and Sachoun Formation are moderately sensitive to weathering. The Hormos Series, Pabdeh-Gurpi Formation, Razak Formation, and Aghajari Formation are highly sensitive to weathering.

Seismic microzonation of Kathmandu valley using GIS and SHAKE 2000

*R. P. Khanal[1], C. J. van Westen[2], and Ir. S. Slob[2]
[1]Department of Mines and Geology (DMG), Kathmandu, Nepal
[2]International Institute for Geo-information Science and Earth-Observation (ITC),
Enschede, the Netherlands
(*Email: rpkhanal03@hotmail.com)*

Since the Kathmandu valley is situated in a seismically highly active zone, there is an urgent need for a seismic micro hazard zonation. The main cities of the valley (i.e., Kathmandu, Lalitpur, and Bhaktapur) are underlain by thick Quaternary lacustrine deposits, which can be highly susceptible to ground motion. Modelling of ground response is one of the important aspects of seismic microzonation. This, however, greatly depends on the availability of detailed subsurface geological and geotechnical information as well as strong motion records. There are only limited borehole data up to the bedrock level, a few geophysical surveys, and also very limited information on geotechnical properties of rocks and soils. Therefore, the one-dimensional seismic response-modelling software (Shake 2000) was used for making a number of assumptions concerning the geotechnical parameters and soil depth. To model the seismic responses, the strong motion data of the 1999 Chamoli earthquake in the nearby Indian state of Uttaranchal were used. The computed ground motion is described in terms of peak ground acceleration, spectral acceleration, Modified Mercali Intensities, response spectra, and amplification ratios.

Historical records and recent experiences indicate that ground motion from nearby and larger, more distant earthquakes was felt widely in the valley. Earthquake Intensities up to X (10) have been reported in the past with the higher intensities concentrated in the southern part of the valley. This study attempts to produce input for a preliminary seismic micro hazard zonation map of the valley. Altogether 134 soil profiles from various sites of the valley were used for the seismic response analysis. Five spectral acceleration maps were prepared for different frequencies related to the most common building heights in the valley. The spatial distribution of the spectral acceleration map at 10 Hz and 5 Hz frequencies showed the lowest acceleration values in the range of 0.06–0.28 g. Most of the highly populated core areas of the valley have spectral acceleration values less than 0.15 g.

Prediction of waste dump stability of a surface coal mine: a neural network approach

Manoj Khandelwal and T. N. Singh
Department of Earth Sciences,
Indian Institute of Technology Bombay,
Powai, Mumbai – 400 076 India

Coal is still a prime source of energy in India. To fulfil the growing demand of energy in domestic as well as industrial sector, the production of coal is being increased every year. Due to the increasing demand of coal, large and big surface mines are being planned and designed to ensure maximum resource recovery and to enhance the safety. They require the removal of huge quantities of overburden to reach the coal seams. The waste is kept in such a manner that it acquires minimum land, but on the other hand the stripper dump slopes are more prone to failure due to a high slope angle. Their height varies from a few metres to a few hundred metres. Unscientific and haphazard disposal of dump often causes failures and invites danger to the life. A number of such failures have been reported all over the world.

There are a number of factors that control the stability of dump. They include geo-mechanical, geotechnical, and bio-engineering characteristics of the dump as well as surrounding environment, like the presence of water bodies, fauna, flora, stripping of dumping ground, method of dumping, angle of dump slope, and height of dump. It is difficult to unearth a particular parameter, which is more influencing over the others. It is also not possible to incorporate all the influencing factors in a numerical computational program or in empirical formulas. Owing to the development of fast-computing techniques, it is now possible to incorporate the maximum-influencing parameters and one of the techniques is the artificial neural network (ANN).

The ANN is an information-processing system simulating the structure and functions of the human brain. It attempts to imitate the way in which a human brain works in processes such as studying, memorising, reasoning, and inducing with a complex network, which is performed by extensively connecting various processing units. It is a highly interconnected structure that consists of many simple processing elements (called neurons) capable of performing massively parallel computation for data processing and knowledge representation. The paradigms in this field are based on direct modelling of the human neuronal system. A neural network can be considered as an intellectual hub that is able to predict an output pattern when it is acquainted with a given input pattern. The neural network is first trained by processing a large number of input patterns and showing what output resulted from each input pattern. The neural network is able to identify the relationship when presented with a new input pattern, after a proper training, and then it predicts the output pattern.

Neural networks are able to perceive similarities in inputs, even though a particular input may have never been seen previously. This outstanding interpolation capabilities make it useful especially when the input data are noisy (not exact). When the data are analysed using a neural network, it is possible to detect imperative predictive patterns that were not previously perceptible to a non-expert. Thus, the neural network can act like an expert. A particular network can be defined using three elementary components: transfer function, network architecture, and learning law. One has to characterise these components, depending upon the problem to be unravelled.

Here, an attempt has been made to predict the stability of waste dump of a large surface coal mine using ANN by incorporating all the possible influential parameters. The validation of ANN results was made by comparing them with the statistical analysis results.

Soil contamination by sulphuric acid

*R. N. Khare [1], Abhay Kumar Jain[2], and R. G. Gupta[3]
[1]Department of Civil Engineering, BIT, Durg (Chhattisgarh)-91001, India
[2]Department of Civil Engineering, Govt. Engineering College, Rewa (M.P.), India
[3]Department of Civil Engineering, Govt. Engineering College, Jabalpur(M.P.), India
(*Email: rn_khare@rediffmail.com)*

The wastes both in the form of solid and liquid have increased especially in the Bhilai township (Bhilai Steel Plant), state Chhattisgarh, along with the industrial growth of this newly formed state. The application of sulphuric acid may result in charring of the soil, and reduction in pH of soil and water. The effect on soil pH is not that large; it leads to a reduction of about 0.2. The compound is not persistent, and the dissipation and buffering capacity of soil and water are likely to return the pH to acceptable levels within a relatively short period. Sulphuric acid is fast-acting and is quickly neutralised in the environment by reacting with the vegetation canopy (which intercepts much of the chemical), soil, and water in the soil. This means that the hazards associated with this chemical rapidly decrease from the time of application.

Sulphuric acid is known to break down relatively quickly, reducing the possibility of problems with long-term effects on the environment. In order to gain approval for use as a chemical commodity, it is also required to confirm that such use does not pose a risk to wildlife. In Bhilai, the risks to birds, mammals, various invertebrates, and aquatic life was evaluated and necessary restrictions were imposed. The strength of soil is reducing due to the contamination by H_2SO_4.

Influence of fly ash sand on engineering characteristics of arsenic-bearing soil

*R. N. Khare [1], Abhay Kumar Jain[2], and R. G. Gupta[3]
[1]Department of Civil Engineering, BIT, Durg (Chhattisgarh)-91001, India
[2]Department of Civil Engineering, Govt. Engineering College, Rewa (M.P.), India
[3]Department of Civil Engineering, Govt. Engineering College, Jabalpur(M.P.), India
(*Email: rn_khare@rediffmail.com)*

The problems posed by arsenic-bearing gravel have been recorded in the Chhattisgarh state, India. Moreover, a huge amount of fly ash generated at Bhilai steel plant stations and other industrial plants posing a great environmental problem has led to a worldwide search for effective utilisation and disposal of this waste material. Present experiment was carreid out to study the influence of fly ash sand on engineering characteristics of arsenic-bearing non-cohesive soil. An attempt was made to reduce the swelling and plasticity index of gravel caused by arsenic contamination and increase its shrinkage limit, maximum dry density, and permeability with the use of fly ash. Study was carried out by grading and mixing the arsenic-bearing gravel and fly ash sand in specified percentage by weight. The results are quite encouraging.

Provisions of micro-reinforced vegetation against erosion on slopes

R. N. Khare [1], Abhay Kumar Jain[2], and R. G. Gupta[3]
[1]Department of Civil Engineering, BIT, Durg (Chhattisgarh) – 91001, India
[2]Department of Civil Engineering, Govt. Engineering College, Rewa (M.P.), India
[3]Department of Civil Engineering, Govt. Engineering College, Jabalpur(M.P.), India
*(*Email: rn_khare@rediffmail.com)*

Natural and cut slopes are susceptible to erosion due to water and wind. The problem of erosion could be acute in the case of loose, cohesionless soils, steep slopes, and high intensities of rainfall. Erosion is the process by which individual soil particles are dislodged from the soil mass and carried away by a transporting medium. Water is the principal agency causing erosion. Soil particles on the surface are dislodged by the impact of raindrops and are carried away by the surface runoff. The development of small rivulets and gullies further accelerates the process. Springs and seeps emerging on the slopes also could lead to erosion.

The effectiveness of vegetation in controlling erosion is well known. However, in many situations requiring superior performance, natural turfing alone may not be adequate. In such cases, the use of a geomat enhances the effectiveness of vegetation by increasing the root density from the normal value of 1800 kg/ha to about 4800 kg/ha, and by reinforcing the root system. The resulting micro-reinforced vegetation offers a cost-effective solution for difficult erosion control problems on natural and cut slopes.

Landslide hazard mapping in the Tinpiple–Banchare Danda area, central Nepal

Matrika Prasad Koirala and Prakash Chandra Adhikary
Central Department of Geology, Tribhuvan University, Katmandu, Nepal
*(*Email: matrikakoirala@hotmail.com)*

The Tinpiple–Banchare Danda area is located northwest of the Kathmandu valley. In this area, the construction of buildings, roads, irrigation canals, and landfill site are in progress. Since the area is a mountainous terrain consisting of varieties of slopes, the construction activities may be threatened by landslide-related phenomena. It is therefore desirable to have a landslide hazard map of the area to plan the activities properly. This paper describes the methodology used in preparing the landslide hazard map of the Tinpiple-Banchare Danda area.

The landslide hazard is defined as the probability of occurrence of mass movement in certain area with specified period of time (Varnes 1984). Landslide hazard mapping is based on the assumption that landslides occur as a result of similar geological, geomorphological, and hydrological conditions that lead to past and present landslides. As a first step of landslide hazard mapping, basic maps that include slope map, soil depth map, soil type map, geological map, drainage map, landslide inventory map, and land use map of the area are prepared (Deoja et al. 1991). Then, for each spatial area some rating is assigned to each attributes associated with rock and soil slopes. Based on the total value of rating assigned for each component, the area is classified into high, medium, and low hazard zones. The rating values used in this study were based on the work of Thapa and Dhital (2000).

The geological investigation reveals that the study area lies in the Lesser Himalayan zone. Rocks exposed in the area belong to the Phulchauki Group of the Kathmandu Complex (Stöcklin and Bhattarai 1977). The rock types include metasandstone, limestone, and gneisses. The area also contains alluvial, colluvial, and residual soils. In general, the thickness of these soils varies between 1 to 3 m. The natural hill slope angle, in general, is more than 35 degrees in rock slopes, whereas in the case of soil slopes it does not exceed 30 degrees. Although many stream and rivers dissect the
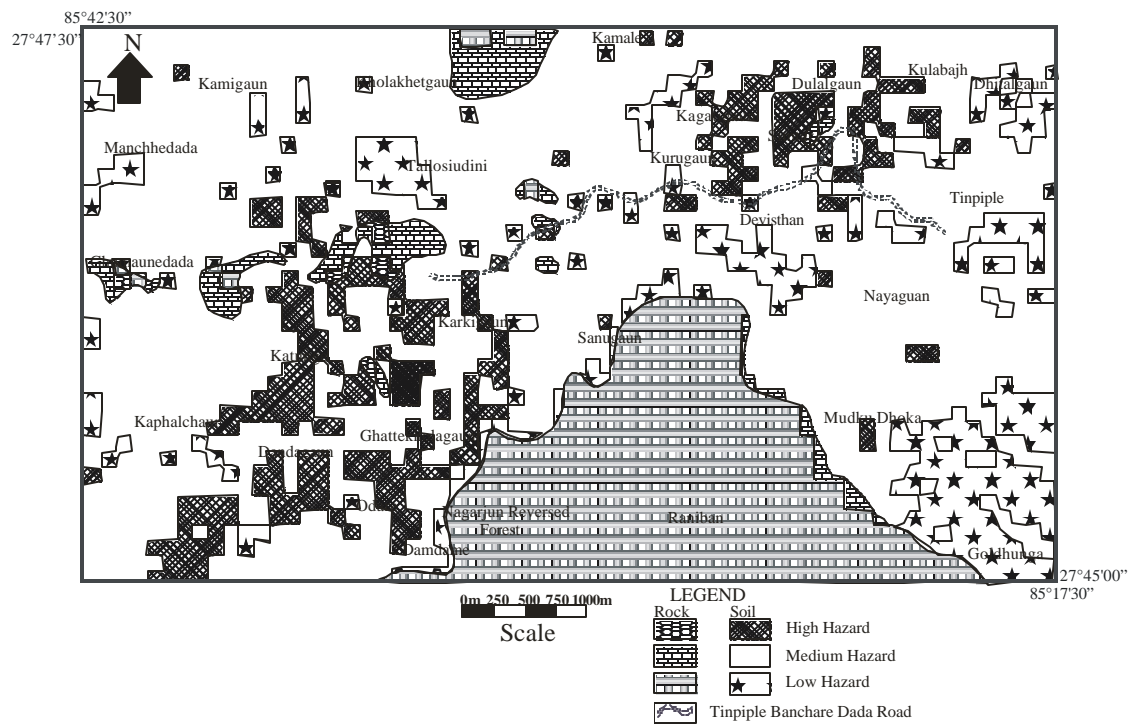
Fig. 1: Landslide hazard map of Tinpiple–Banchare Danda area

area, the groundwater table is deep. In terms of land use, the area consists mainly of dry cultivated land followed by wet cultivated land. Both, dormant and active landslides exist in the area. Active landslides occupy about 0.56 km^2, which is 1.5% of the total area of investigation. It was found that 90% of the total landslides observed in the area are confined within the soil slopes whose inclination varies from 15 to 35 degrees. A majority of landslides are on residual soil. About 47% of the area is dry cultivated land, in which the occurrence of landslide is maximum (38%).

For the purpose of landslide hazard assessment, the area was divided into rock slopes and soil slopes. The attributes associated with each slope unit were then analysed separately. The results revealed that about 60 % of the area belongs to a medium hazard level whereas about 10 % of the area is under a high hazard level (Fig. 1).

REFERENCES

Deoja, B., Dhital, M., Thapa, B., and Wagner, A., 1991, *Mountain Risk Engineering (MRE) Handbook Part I and II*. ICIMOD, Kathmandu, 875 p.

Stöcklin, J. and Bhattarai K. D., 1977, Geology of Kathmandu Area and Central Mahabharat Range, Nepal Himalayas. Technical Report. HMG/UNDP Mineral exploration project, Kathmandu 86 p. (Unpublished).

Thapa P.B. and Dhital, M. R., 2000, Landslide and debris flow of 19–21 July 1993 in Agra Khola watershed of Central Nepal. Jour. Nepal Geol. Soc., 21

Varnes, D. J., 1984, Landslide hazard zonation: A review of principle and practice. UNESCO press, Paris, pp. 63. In: Soeters, R. and western, C. J., 1996, Landslide investigation and mitigation, special reports 147. Transportation Reaserch board, National research Council, USA, 673 p.

Geo-environmental modelling for local-level economic benefits

Arjun Kumar Limbu
Central Department of Environmental Science,
Tribhuvan University, Kathmandu, Nepal
(Email: arjunlimbu@hotmail.com)

This paper gives an overview of geo-environmental modelling of locally-available unused resources for their economic benefits at grassroots. It also intends to assist in identifying and sharing the ideas that could be applied at low-cost investments to overcome not only the poverty, but also the psychological growth of a person. This spatial modelling targets both national and international tourism and strives for the sustainable development.

Practical methods for simulating volume and rheology changes in rapid landslides

Scott McDougall and Oldrich Hungr
Department of Earth and Ocean Sciences, University of British Columbia,
6339 Stores Road, Vancouver, Canada

Landslide mobility is related to the volume and character of the source material, but often more importantly to the extent, depth and character of the surficial material encountered along the path. Volume changes due to entrainment of path material are a dominant characteristic of debris avalanches and debris flows, and can significantly increase their peak discharge and the size of their impact area. At the other end of the magnitude spectrum, the mobility of large rock avalanches can be controlled by a relatively small volume of path material that may only be present near their margins or base.

The important influence of path material on landslide dynamics has been recognised for a long time (e.g. Buss and Heim 1881), but it is commonly neglected in dynamic modelling of landslide motion. The models of Sassa (1988) and Hungr (1995) are notable exceptions. Sassa (1988) used a spatially-variable frictional rheology and proposed that the frictional parameters could be measured using high-speed ring shear tests on samples taken from the path. Hungr (1995) used a spatially-variable open rheological kernel and proposed that the rheology type and its parameters could be calibrated by the systematic back-analysis of case histories. A volume change algorithm was also included. This efficient and flexible method allows the simulation of a variety of landslide types, including those involving significant entrainment.

An extension of Hungr's (1995) model has recently been developed for the analysis of landslide motion across 3-D terrain. With necessary modifications for multi-dimensional analysis, the new model retains the important volume and rheology change features of the original. The user controls the following inputs: 1) the extent and depth of erodible path material, 2) the volume change rate, which governs mass and momentum transfer between the landslide and the erodible bed, 3) the rheology type and its parameters before entrainment, and 4) the rheology type and its parameters during and after entrainment.

These inputs are not arbitrarily adjusted during calibration. The distribution of path material can be estimated using surficial geological maps, aerial photographs, pre- and post-event DEMs and, whenever possible, field data. This information can be used to construct a volume balance curve (volume passing each point along the path versus distance from the source), which can then be used to back-calculate the volume change rate. The initial rheology and its parameters can be estimated based on a stability analysis of the source, taking into account the mode of failure and the character of the source material. Finally, the post-entrainment rheology can be constrained by trial-and-error simulation of the event. Again, the character of the path material is an important factor in the selection of an appropriate rheology.

A back-analysis of a real landslide is used to demonstrate this simple methodology, which can be easily implemented in other dynamic models. Comparison analyses using traditional constant volume and rheology assumptions are also presented. The results suggest that volume and rheology change capabilities are essential for the successful simulation of landslides that override and entrain path material.

REFERENCES

Buss, E. and Heim, A., 1881, Der Bergsturz von Elm. Worster, Zurich.

Hungr, O., 1995, A model for the runout analysis of rapid flow slides, debris flows, and avalanches. Canadian Geotechnical Journal, v. 32, pp. 610–623.

Sassa, K., 1988, Geotechnical model for the motion of landslides. Proceedings of the 5th International Symposium on Landslides, Lausanne, v. 1, pp. 37–56.

Collisional granular flow and its implications for microstructural theories of avalanche motion

Scott E. Munachen
Geohazard Research Centre, 38 Lincoln Way, Harlington,
Dunstable, Bedfordshire, U. K.
(Email: scottmunachen@bezemer.demon.co.uk)

Particulate flow behaviour is governed by interactions occurring at the microstructural, or particle level. For dry granular avalanches in which the interstitial fluid effects and cohesion are negligible, the mechanical behaviour is determined entirely by the forces exerted at interparticle contacts and mean stresses may be generated by a number of different mechanisms. In general, the instantaneous motions of particular grains, their translational velocities and spins, are different from the mean motion of the bulk. Individual particles may interact with one another in various ways; in rigid clusters of particles which generate a network of contact forces through sustained rolling or sliding contacts, or by nearly instantaneous collisions during which linear and angular momentum are exchanged and energy dissipated because of inelasticity and friction.

The modification of kinetic theories for dense gases to describe collision-dominated flows represents a paradigm shift that has greatly advanced understanding of rapid granular avalanches. Direct particle-scale observations from physical experiments have played little role in the formation of these theories, however, largely because of the difficulties in observing particle motions within flux interiors. Thus, despite the micromechanical complexion of their conceptual frameworks, development has been driven primarily by bulk flow observations, physical experiments yielding such macroscopic quantities as the stresses exerted on the boundaries of viscometric devices, and computer simulations. In this paper attention will be focused on understanding the interactions that take place between particles at the microstructural level as a means to establish the constitutive relationships that determine the overall macroscopic bulk flow fields.

Velocities and rotations of individual particles in quasi two-dimensional flows were measured in a novel centrifugal flume using high-speed photogrammetry, permitting detailed observation of the gravity-dependent kinematics of the flows whilst preserving the essential physics of the collisional process. The experiments, which were carefully designed to minimise extraneous forces arising from air drag, sidewall friction and electrostatic effects, provide a well-defined set of observations for refining and validating predictive models, and point out some important limitations of kinetic theory. Characteristic profiles of solid fraction, mean velocity, and granular temperature were systematically measured and compared with the predictions of kinetic theory for both collisional and dilute kinetic regimes.

The results demonstrate the importance of taking both frictional and collisional stress generation mechanisms into account when dealing with shallow geophysical flows. For example, it was not uncommon for collisional and translational contributions to be the principal mechanism near a free surface, while frictional effects became predominant at quite modest depths. In disperse flows the kinetic contribution to the stress tensor was much greater than the collisional contribution over nearly the entire flow depth, while in dense flows the collisional contribution dominates in that part of the flow extending from the bed up to about 10 particle diameters. The layered flux morphology produces a directional anisotropy in the vectors connecting the centres of the colliding particles, so that a large number of collision vectors are either parallel or perpendicular to the bed and a bimodal mix of glancing and head-on collisions occur. Profiles of translational and rotational granular temperature reveal slip at the basal interface of between 15% and 25% of the mean flow velocity, whilst mean rotation rates in the bed-normal and bed-parallel directions are less than 10% of the cross-slope component.

Avalanche defence structures: a study of shock wave formation and granular vacua

Scott E. Munachen and David C. Poole
Geohazard Research Centre, 38 Lincoln Way, Harlington,
Dunstable, Bedfordshire, U. K.
(Email: scottmunachen@bezemer.demon.co.uk)

Debris flows and avalanches are the most pervasive and destructive geologic hazard in many mountainous regions, posing particularly severe threats in tectonically active areas with an abundance of unlithified sediment and weak rock. Their frequency and amplitude continue to rise worldwide as urbanisation encroaches onto mountainous terrain under the pressures of increasing populations, deforestation and changing climate patterns. Despite recent advances in our capabilities to mitigate and respond to these hazards, losses continue to result in human suffering, billions of dollars in property and infrastructure maintenance, and environmental degradation. Indeed, their socio-economic impact has become so significant that the United Nations declared 1990-2000 the International Decade for Natural Disaster Reduction.

Understanding and modelling these flows is of considerable practical interest for the design of defences to protect structures and lifelines. Whilst field investigations are critical for documenting the areal extent of antecedent deposits, quantitative models are necessary for making objective, reproducible hazard forecasts. Torrent training structures that serve to dissipate the kinetic energy of the incoming flow are typically designed to withstand dynamic thrusts and point impact forces imparted by avalanche surge fronts. Contemporary standards, however, are based on rudimentary centre-of-mass considerations, and provide no explicit means of linking avalanche flux state to three-dimensional interaction dynamics in order to predict how diverted flow depth and direction emerge from collisions. Through the use of centrifuge modelling, this paper develops a computational framework to quantify how local topography and obstacles modify the avalanche path and run-out zone, with the objective of providing an accurate and reliable method of delineating the limits of avalanche inundation.

The spatio-temporal evolution of avalanche depth and velocity during impact is studied via a series of centrifuge tests that accurately reproduced the self-weight stresses and gravity dependent kinematics of prototypical flows in the laboratory. The effects of model deflection berms and check dams on dense, gravity-driven, granular flows down an inclined plane are investigated from initiation to run-out, with particular emphasis on the dynamics of shock wave formation. The experiments employ a novel method of laser cartography to map the three-dimensional morphology of rapidly moving avalanches, providing high-resolution data for comparison with model output. A non-invasive instrumentation system facilitates the real-time measurements of basal-normal and shear stresses, bulk density, and the impact and drag forces acting on the obstacles. Surficial velocity fields are visualised using a combination of close-range photogrammetry and particle image velocimetry to track the motion of individual grains, permitting the mechanistic distinction of the dominant modes of energy dissipation and momentum transport. A shock-capturing continuum theory for rapid granular flows is developed to describe the interaction of avalanches with defence structures on non-accelerative slopes. It consists of depth-integrated balance laws of mass and momentum of an incompressible, cohesionless, particulate obeying a Mohr-Coulomb type yield criterion both in the interior and at the bed. The emerging field equations for the distribution of the avalanche thickness and depth-averaged velocity are a set of nonlinear hyperbolic partial differential equations. To resolve the steep height and velocity gradients observed in the experiments the model equations are solved for different topographic configurations by implementing a high-resolution Non-Oscillatory Central differencing scheme with Total Variation Diminishing limiter. For the avalanche free boundary problems it must be combined with a front-tracking method, developed here to properly describe flux margin evolution.

A study of the landslides associated with human impact in the forest environment of Kerala

K. Shadananan Nair

Cochin University of Science & Technology, Vallayil House, North Gate
Vaikom - 686 141, Kottayam Dt., Kerala, India
(Email: nair59@yahoo.com)

Human impact on the environment results in hazards such as landslides and floods in many parts of the world. These hazards bring about casualties, and a tremendous loss of agricultural land and property. The issue becomes serious in regions such as the State of Kerala in India with dense and fast-growing population, and a weak economy. The eastern side of the narrow coastal state is bordered by the Western Ghats Mountains, the orography of which provides heavy and intense rainfall in Kerala. Because of the steep slopes, the water flows fast to join the Arabian Sea. Deforestation and introduction of plantation crops replacing the natural vegetation have affected the topography and water-holding capacity of soil. Together with this, the construction of a number of dams and the development of large-scale sand and rock quarries in the hills have resulted in landslides and flash floods in almost every rainy season. Landslide-induced debris flows have considerably reduced the river runoff and converted some of the perennial rivers into seasonal ones. Consequently, the state, receiving rainfall three times more than the global average, experiences seasonal water scarcity. The rules and regulations to protect the environment are not properly implemented because of social and political reasons as well as widespread corruption.

Adsorption of nitrate as a groundwater pollutant by the soil particles

Chieko Nakayama[1] and Yoshinori Tanaka[2]
[1]*Civil Engineering, Graduate School of Engineering, Toyo University,*
2100 Kujirai, Kawagoe-city, Saitama 350-8585, Japan
[2]*Civil and Environmental Engineering, Toyo University, Japan*

Nitrogen-based fertilisers used in agriculture are the main contributors of nitrate to groundwater and the soil in many areas of the world. The possibility of drinking water contamination has resulted in an increased awareness among the public. The World Health Organisation (WHO) recommends a standard for nitrate concentration of less than 50 mg/l (nitrogen-nitrate of less than 10 mg/l) in drinking water. Drinking water contaminated by nitrate is suspected of being associated with methemoglobinemia (blue baby syndrome) when the contaminated water is used to prepare infant feed, and chronic nitrate exposure in drinking water is suspected of being responsible for stomach cancer. In European countries, the high nitrogen content in drinking water has become a serious problem.

A groundwater quality survey conducted in Japan revealed several areas with nitrogen-nitrate concentrations exceeding 10 mg/l. The Japanese Ministry of the Environment investigated the groundwater quality over the country in 2004. The survey showed that out of 5129 wells, 421 (6.5%) exceeded nitrogen-nitrate environmental quality standards. High nitrogen-nitrate concentrations were obtained in the area occupied by diluvial terraces of the Kanto plain. The top layer of the terrace contains a volcanic ash soil of Kanto loam with allophane-rich clay. Generally, these soil types have a high cation exchange capacity. The negative charge of soil particles promotes leaching of nitrate through the soil profile. However, the positive charge of the allophane mineral in clay under conditions of low pH means that the sorption of anions is a characteristic feature of allophane-rich volcanic ash soils.

This study discusses nitrogen adsorption in several soil samples of Kanto loam from two locations from the Kanto plain. Chemical properties were assessed in each soil sample and pure allophane clay by instrumental analysis using batch and soil column tests.

Nitrogen-nitrate adsorption by sample soils was determined by the 10-hour batch test using a nitric acid solution

of 0.14 mmol. The saturation column test was conducted to obtain a breakthrough curve and to calculate the coefficients of dispersion and retardation. The extent of nitrate adsorption in soil samples was confirmed by percolation with 0.14 mmol nitric acid through columns packed with 25 g of the soil sample, and silicate sand.

In the batch test, it was found that the amount of nitrate adsorption was greater in allophane-rich volcanic ash soils with the amount of nitrate adsorption increasing under conditions of low pH. The breakthrough curve determined by the column test showed that the coefficient of retardation increased in both allophane-rich soils and in amorphous inorganic matter. The retardation factor in the column packed with silicate sand was markedly higher than in the other soils analysed.

Adsorption of nitrates by Kanto loam soils was thus found to be dependent upon the content of allophane and amorphous inorganic matter. Given that the positive charge of allophane has the potential to reduce the nitrate content in groundwater, it could therefore be effectively applied to alleviate nitrate contamination in groundwater.

Seismic features of the lithosphere of southwest High Asia

Sagynbek G. Orunbaev and Vladimir D. Suvorov
Institute of Geophysics SB RAS, Novosibirsk, Russia
(Email: suvorov@uiggm.nsc.ru; sagynbek@uiggm.nsc.ru)

Interests in the deep lithospheric structures of High Asia have not declined for many decades. Recently, a number of models of its deep structure were based on seismic tomography. However, this method is very sensitive to starting model and it does not allow for finding out seismic boundaries. Therefore, it is apparently necessary to construct a seismic lithosphere model, parameters of which may be confidently taken from the seismological data. This type of model could be useful to find the basic kinematics characteristics of recorded waves and to study their nature. Thus, the greatest attention should be given to the study of lithosphere stratification, first of all to the Moho boundary and other probable seismic boundaries in the upper mantle.

This report incorporates preliminary results of the kinematic analysis of the first arrivals along the Hindu Kush–Himalaya geotraverse, located in the areas with the densest arrangement of seismological stations. In the vicinity of this area, 48 earthquakes were chosen from the International Seismological Centre (ISC) catalogue with magnitude more than 5, registered on 30 stations. The total number of records was about 1300.

We have found quite significant changes in apparent velocity and travel time of waves, despite the possible mistakes in locating the centres of earthquakes and their origin times. Therefore, the apparent velocity on a short-range part of travel time curves (up to epicentre distances of 1000–1500 km) varies from 8 to 8.6 km/s. These values may differ in direct and reverse directions, testifying to a significant relief of the Moho. For epicentre distances of 1500–2500 km, the apparent velocity changes from 8.6 up to 9 km/s, and it is caused, most likely, by the velocity anomalies or by the slope of seismic boundaries in the mantle. For the distances of 2200–6000 km on direct and reverse directions, unusually a high apparent velocity of 9–10 km/s (?) is observed.

Most of the considerable changes in travel time are determined by the hypocentre depth and thickness of lithosphere. The variation in travel time reaches 8 s over these factors, and it is much more than what are caused by horizontal velocity heterogeneities in the mantle. The apparent velocity at minimum epicentre distances may be used to estimate the travel times at zero distances (i.e, above hypocentre). The greatest part of such data depicts a clear trend of the hypocentre depth by which the crust can be divided into the upper and lower velocity stages. The remaining data considerably deviate from such a trend, and the deviation may be due to the errors in hypocentre locations or the variation in the Moho depth in the epicentre vicinity.

The detected variations of apparent velocity and travel time of the first arrivals testify the vertical stratification of lithosphere with complicated lateral variations of the Moho depth and velocity in the mantle.

Seismotectonics of Nepal Himalaya: review of recent results

M. R. Pandey
Gyaneshwor, Kathmandu, Nepal
(Email: shailaj@mail.com.np)

The results obtained by DASE, France, Colorado University, USA, Oregon University / Illinois University, USA, working under different collaboration projects with the HMG, MOIC, Department of Mines and Geology, Nepal, and other institutions in the first five years of this century have advanced our understanding of kinematics and seismotectonics of the Nepal Himalaya considerably.

Interpretation of metamorphic thermometry, thermochronology, and structural geology data suggests that the Lesser Himalaya has been accreted to the Himalayan range mainly by underplating of the upper part of the Indian plate at mid crustal depth. Indian basement underthrusts below the lesser Himalaya with 15 mm/yr velocity. The Lesser Himalaya is exhumed jointly with the overlying nappes as a result of overthrusting by about 5 mm/year

Receiver function, calculated from broad-band IRIS–PASCAL seismic data installed in central and eastern Nepal, exhibits clear seismic images of the Himalayan decollment at the base of the Himalaya, and also the base of the crust. The Moho appears to be smoothly dipping below the Himalaya over a distance of 120 km. South of the Higher Himalaya, the Himalayan wedge is well determined by a strong seismic anisotropic layer. Anisotropy develops above the decollment in response to shear process that is taken up as slip in great Himalayan earthquakes. Lateral variation of the structure is not significant within central and eastern Nepal.

Shear strain accumulated in the decollment is ultimately released as sudden slip seismic events in a seismic cycle.

However, the loading and unloading of stress may not be uniform with zones of stress concentration in asperity. The heterogeneous distribution of microseismicity in the lateral direction may be related to the development of asperities. On the contrary the geodetic data reveal a rather uniform pattern of interseismic straining oriented with long-term geodetic deformation. The geodetic data and seismicity distribution are reconciled from a model in which microseismicity is interpreted as driven by stress buildup increase in the interseismic period. The uneven seismicity pattern is shown to reflect the impact of the topography on the stress field, indicating low deviatoric stress (<35 MPa) and a low friction (<0.3) on the Main Himalayan Thrust or decollement. Strain must be rather uniform during a significant fraction of the interseismic period, and can be explained by a fully locked seismogenic zone, which extends from the Main Frontal Thrust at the surface to beneath the front of the high range, over an average width of about 100 km along the 1000 km long arc segment of the Nepal Himalaya. This means that the Himalayan megathrust mainly slips during transient events. Although recurring large earthquakes analogous to the 1934 Bihar–Nepal event are probably dominant, transient aseismic events similar to those recently observed at places on the subduction zones might also contribute to this stress transfer. This suggests that a major earthquake along the seismic gap extending from the Kathmandu area to Dehra Dun is highly plausible, but also suggests continuing efforts in seismic and geodetic monitoring.

Earthquakes: astrostatistical context

Ramesh Pandya[1] and H. N. Dutta[2]

[1] *Department of Statistics, Government Arts and Science College, Ratlam, M. P. India*
(Email: rameshpandya 1955@yahoo.com)
[2] *National Physical Laboratory, New Delhi – 110 012, India*
(Email: hndutta@nplindia.ernet.in)

Ancient Indian society was very well known for its scientific advancements in the field of yog or yoga – the complete body cure by the body itself, meditation-mental cure, the best dead body cremation system, invented zero knowledge of astrology – a science beyond astronomy, Indian earthquake insigma devised by our ancestors (King Cobra holding earth, University of Nalanda and others). But like many other lost branches of science and knowledge civilisation, the knowledge of astrology was also lost, perhaps due to major earthquakes in India.

The advent of computers have developed interest to study the vital movement of celestial bodies, which may effect an individual or collective density of the society or simply jolt a part of our living planet earth. In the past, the Indian astrologers translated the movement of the celestial bodies (Precisely measured) to predict extraterrestrial phenomena like, eclipses of Sun, Moon, Rahu, and Ketu. The high-and-low tides of ocean, found to be associated with the relative movement of the moon and the Sun, led to a forceful pull or push on the water bodies. Perhaps, air and the solid earth, the water bodies are the easiest to be seen but they have caused an impact on other objects situated on the earth too. At the same time, the power of a planet is basically based on its size, gravity, magnetic field, and colour (wave length of optical light/energy).

In the context of earthquakes, it is mentioned in our astrological books – Vedas and Puranas that Lord Brahma made earth as "Achla" means immovable, but it moved due to the movement of big mountains. This means, we knew that different parts of the earth also moved, leading to the formation of the earthquakes. Lord Brahma said "I can't stop the movement of these big mountains (plates), but they will be active only under certain special situations". This means that only under special circumstances, the earth may shake to produce the earthquakes. It is also written that during the 24 hour period, "Vayu, Agni, Indra , and Varun" will cause shaking in the first, second, third, and fourth parts of the day and night, respectively. Alsothe science of earthquakes is related to mortality at the society level, which means, we have to predict the death – its time and cause on a mass scale.

All the horoscopes related to earthquakes occurred in India and Japan, and associated planetary positions have been tabulated. The possible link between the earthquake and combination of planets establishes a basis for prediction of a future earthquake.

Analysis and verification of landslide hazard using GIS and infinite slope model

Hyuck Jin Park[1], Woon Sang Yoon[2], Seong Wook Park[2], Byeong Hyun Han[3],
Byung Don Ro[3], Kang Ho Shin[3], and Jae Kwon Kim[3]
[1]*Dept. of Geoinformation Engineering, Sejong University, Seoul, Korea*
[2]*Nexgeo Inc., Korea*
[3]*Samsung Engineering and Construction, Kyonggi-do, Korea*

Landslides are one of the repeatedly occurring geological disasters in a rainy season resulting in about 23 human losses in Korea every year. The landslides mainly depend on the spatial and climatic properties, such as geology, geomorphology, and heavy rainfall, and hence, their prediction or hazard assessment is a difficult task. Therefore, geographic information system (GIS) and various statistical methods are implemented for landslide analysis. In particular, GIS techniques are widely used for the analysis because they effectively handle a large amount of spatial data. GIS techniques can be divided into two categories: quantitative and deterministic. The quantitative techniques range from stability ranking based on criteria such as slope, parent material, and geometry, to more sophisticated techniques

Fig. 1: Infinite slope model

such as statistical models, which link environmental attributes based on spatial correlation. In contrast, the deterministic techniques analyse the mechanical conditions of slope and evaluate its stability. That is, physical properties of slope are used in a mathematical model to evaluate the landslide hazard. Most GIS techniques used in many previous studies, however, only consider the statistics between landslide occurrence and related factors (such as soil depth, soil strength, slope angle, and vegetation), not the failure mechanism. That is, they consider only the statistical relationship between landslide occurrence and the affecting factors without any mechanical analysis. Therefore, in order to overcome the limitations of the quantitative techniques, a deterministic technique is utilised in this study. Accordingly, an infinite slope model that considers the balance of forces applied to the slope is considered here for the GIS based landslide analysis. The proposed model is advantageous over other approaches, as it considers the failure conditions and calculates a quantitative value of the factor of safety. The spatial parameters used to evaluate the factor of safety in this study are slope angle, slope direction, soil texture, topography, soil effective thickness, and rock types. In addition, the actual landslide sites were used to verify and compare the predicted landslides. Rainfall is another important factor of landslide occurrence. Therefore, the ratio


Fig. 2: Factor of safety distribution in study area when *m* =1

of groundwater distance to the soil depth, *m*, is used in the infinite slope model (Fig. 1).

The infinite slope analysis correctly predicted 87.5% of the existing landslides, hence the factor of safety distribution map (Fig. 2) can be utilised for landslide prediction and hazard assessment.

Application of remote sensing and GIS in landslide hazard zonation and delineating debris flow susceptible zones in Garhwal Himalaya, India

*Dinesh Pathak [1], P. K. Champati ray [2], Ramesh Chandra Lakhera [2], and Vivek Kumar Singh [2]

[1]Department of Geology, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal
[2]Geosciences Division, Indian Institute of Remote Sensing,
4 Kalidas Road, Dehradun, India
(*Email: dineshpathak@wlink.com.np)

Landslides and debris flows are important geomorphic events in many parts of the world. Basically, debris flows are initiated in steep valleys of a dissected terrain. A significant percentage of debris derived from landslides or weathered mantle remains as a thin colluvial cover, which acts as a debris flow source area.

The active tectonics in the Himalaya is responsible for the generation of faults, crush zones, and several sets of joints that make the rocks weak, resulting in steep hill slopes susceptible for sliding. In order to understand the landslide and debris flow phenomena in the Himalaya, the present study was carried out around the Chamoli–Joshimath area, lying in the northernmost belt of the Garhwal Himalaya, India. In the study area, most of the landslides occur along the road section, river section, and thrust or fault zones. The area is comprised of low- to high-grade metamorphic rocks as well as carbonate rocks like limestone and dolomite. Aerial photographs and satellite images were used to identify lineaments, faults, landslides, and debris flows, which were verified during the field survey. The landslide zones are strongly controlled by the Main Central Thrust and other faults. Most of the unstable slopes are prone to plane and wedge failures. The debris generated by past landslides as well as fluvio-glacial materials accumulated on slopes are the potential sites of debris flow. Most of the active landslides resulted from the reactivation of pre-existing ones. Many landslides are dormant and covered by vegetation.

The information gathered from reports, maps, aerial photographs, satellite images, and field investigation was integrated to prepare various thematic layers (such as geomorphology, lithology, lineaments, and slope) using GIS. Different weights and ranks were assigned to each theme and its classes. Thereafter, index overlaying of each thematic layers was carried out to generate the landslide hazard zonation map of the study area. The predicted landslide hazard zones are in good agreement with the historical landslide locations. Similarly, the debris deposit sites fall in medium to high hazard zones, suggesting the possibility of debris flow in the future.

A new model for the analysis of slope movements

*D. N. Petley[1], T. Higuchi[1], K.-Y. Ng[1], S. A. Dunning[1], N. J. Rosser[1],
D. J. Petley[2], and M. H. K. Bulmer[3]*
*[1]International Landslide Centre, Department of Geography,
University of Durham, Durham DH1 3LE, United Kingdom*
[2]School of Engineering, University of Warwick, United Kingdom
[3]JCET, University of Maryland, USA
(*Email: d.n.petley@durham.ac.uk)

Traditionally, analyses of the susceptibility of a slope to the effects of landslides have tended to treat the system as an essentially static entity. Three main approaches are commonly adopted in this framework: 1. To consider the forces acting on the slope and the forces resisting movement in order to determine the factor of safety; 2. To use an existing distribution of landslides to determine the key factors influencing slope stability, and then to use the combination of these factors to predict where future failures might occur; and 3. To treat the slope as a hydrogeological system, and to calculate where areas of high excess pore pressure might be generated. Whilst all have advantages, in general these approaches have proven to be disappointing in terms of determining susceptibility to future triggering events. Ongoing research at the International Landslide Centre uses a rather different approach. Here, analyses of movement records of a large number of landslides have been used to examine the patterns of acceleration associated with slope failures in both weathered and unweathered materials. It has been demonstrated that each deformation mechanism in the basal regime of the landslide can be characterised by a specific movement pattern within the landslide mass. This has been backed up by laboratory experiments, including the application of a novel back-pressured direct shear machine that allows infinitely variable control of normal stress, shear stress, and sample pore pressure. This has permitted the construction of a new framework within which the behaviour of landslides can be characterised from a dynamic perspective. A series of simple direct shear experiments under genuinely representative stress conditions allows the dynamic behaviour of the system to be determined, including the conditions required for the triggering of failure and the likely mode of movement before and after the failure event occurs. This understanding of landslide systems provides a new framework within which landslide susceptibility can be assessed, and can result in much better analyses. Based upon this, we present a new framework for the understanding and analysis of slope failures.

The analysis of global landslide risk through the creation of a database of worldwide landslide fatalities

*D. N. Petley and K. Oven
International Landslide Centre, Department of Geography, University of Durham,
Science Laboratories, South Road, Durham. DH1 3LE, U. K.
(*E-Mail: d.n.petley@durham.ac.uk)*

There is little doubt that most global datasets on fatalities caused by landslides greatly underestimate the impact of landslides. The reasons for this are varied, and include a tendency to classify disasters by trigger rather than mechanism (so a landslide triggered by a seismic event will be recorded as an earthquake disaster); the occurrence of landslides in remote locations in less economically developed countries; and the frequency of large numbers of relatively small landslides involving less than ten fatalities, which do not get reported widely. In consequence, investment into the prevention of landslide disasters, especially in mountainous, less developed countries has lagged behind that of other, actually less significant hazards such as volcanic eruptions. To counter this, the International Landslide Centre has embarked upon the generation of a worldwide landslide database, initially concentrating on events that cause fatalities.

The analysis of the initial landslide database has generated some surprising results. It is clear that in terms of fatalities landslide disasters are focussed upon less economically developed countries, especially in mountainous regions that are subject to precipitation extremes such as tropical cyclones or the monsoon. Excluding

rare, very large events, in most years the majority of rainfall-induced landslide fatalities of occur in China and South Asia during the northern hemisphere summer. A second peak occurs in the annual cycle during the December and January, as heavy rains along the Indonesian archipelago induce extensive landsliding. Interestingly, the data suggests that the number of fatalities each year caused by rainfall induced landslides is closely correlated with the global temperature anomaly, which may account for a clear increase in landslide occurrence worldwide over the past twenty years. Finally, it is interesting to note that there is a strong correspondence between the locations of rainfall-induced failures and high global seismic hazard. The implications of these data, and the trends of increasing landslide occurrence, are analysed in terms of landslide hazard and risk assessment, and suggestions are made for future research directions in the context of the distribution of landslide fatalities.

Remote sensing and GIS for flood forecasting and warning service in Bangladesh

Md. Mizanur Rahman[1] **and Sharmistha Saha**[2]

[1]*Flood Forecasting and Warning Centre, Bangladesh Water Development Board*
Wapda Building 9th Floor, Motijheel C/A, Dhaka-1000, Bangladesh
[2]*Survey of Bangladesh, Tejgaon, Dhaka 1208, Bangladesh*

In Bangladesh, flood brings sufferings to the human and deteriorates country's economy. The extreme flood inundating about half of the country's landmass causes huge damages of agriculture and infrastructures. Hydrological characteristics of Bangladesh are very complex in nature. Flood control and protection in Bangladesh is difficult, since it requires the integration of regional hydrological and geographical aspects. Therefore, a flood forecasting and warning service is emphasised as a non-structural measure for flood loss mitigation or minimisation. Since its inception, the Flood Forecasting and Warning Service of Bangladesh used to forecast flood by coaxial correlation, analysing gauge to gauge relation, and using Muskingum-Cunge Routing Models. A flood forecasting and warning system based on an advanced hydro informatics comprised with MIKE-11 (Rainfall-Runoff and hydrodynamic) model has been applied in Bangladesh from the early 1990s. But the system is limited to the forecasting of rainfall in the upper riparian country, and the dissemination system was insufficient to easily understand the forecasts by the rural population. The NOAA satellite data are being utilised from 1998 for the estimation of rainfall in the upper riparian country. A new flood-forecasting system has been integrated in a GIS environment and provides a very powerful tool for real-time flood forecasting and warning through a user-friendly interface for dissemination of flood warning to affected people as well as to organisations concerned with flood disaster management. Under this GIS environment, the flood inundation area can be visualised on a flood extent map. But, owing to the constraints of the latest geo-information, the prepared flood extent maps are not matching with the real world, which may mislead the end user.

Plaeoseismological study in Nepal Himalayas along the Main Frontal Thrust

**S. N. Sapkota[1], B. Kafle[1], G. R. Chitrakar[1],
J. Lave[2], D. Yule[3], M. Atal[2], and C. Madden[3]**

[1]*National Seismological Centre, Department of Mines and Geology, Lainchour, Kathmandu, Nepal*
[2]*Laboratoire de Géodynamique des Chaînes Alpines (UMR 5025) , Grenoble, France*
[3]*Department of Geological Sciences, University of California Northridge, USA*

Locating an earthquake rupture and reconstructing its history are critical in assessing the seismic hazard in the Himalayan region. Two very large historic earthquakes occurred in eastern Nepal in 1255 (M>8?) and 1934 (M8.4). However, no surface rupture was reported for either earthquake. How complete is the historical record for M>8 earthquakes in the region? What structures generate these very large earthquakes and do they rupture to the surface? To address these questions we have begun a geomorphological and palaeoseismological study of the Main Frontal Thrust (MFT) in Nepal. The MFT was chosen because deformed river terraces show that the late Pleistocene and Holocene deformation across the Nepal Himalaya is expressed in the frontal fold above the MFT. The surface trace of the MFT therefore provides an opportunity to document the large earthquake ruptures, and determine their size and recurrence.

About 15 potential sites were identified for further field investigation using available aerial photograph and satellite imagery along the trace of the MFT in Nepal. Field checks of these sites revealed clear evidence of the late Holocene surface rupture on the MFT. One natural exposure of the fault, on the left bank of the Rajpur Khola near Butwal, shows about 8 m vertical offset of fluvial gravel, confirming that the earthquake ruptures the MFT surface, presumably during large earthquakes. However, the Butwal exposure is a poor site for palaeoseismic study due to the very coarse nature of pre-faulting strata, and the apparent lack of post-event sedimentation in the footwall.

Another more promising palaeoseismic site was identified in the Mahra Khola in the Mohattari district of central Nepal, where a natural exposure shows clear evidence of surface rupture cutting finer-grained fluvial gravel. Here, small gullies drain the hanging wall and deposit small alluvial fans on the footwall. These post-event depositst can help to distinguish the earthquakes. In the first step of our trenching work, we successfully opened two trenches across this site in December 2001. Here, we present evidence from a series of 3 palaeoseismic trenches from the Marha Khola region, where a very large earthquake broke the MFT at the surface in 1100 ± 50 AD. The displacement during this event was about 17 m (+5/-3 m), its lateral extension could be larger than 300 km and its moment magnitude could have reached Mw=9. Such very large earthquakes would transfer 50 to 75% of the shortening across the Himalayas. In contrast, the rupture associated with the 1934 Bihar–Nepal Mw=8.4 earthquake was not observed in the trenches and it confirms the previous reports stating the absence of surface ruptures. Warping of Holocene terraces 30 km away of the trench site, but on the same monoclinic structure, indicates that most of the 20 mm/yr of shortening across the Himalayas is expressed in the frontal fold and that this folding has to result from strain transfer probably by both large and very large earthquakes. We thus propose that the 2 km most superficial segment of the MFT in the unconsolidated conglomeratic part of the Gangetic molasse deposits represents a zone of velocity strengthening for the rupture that only very large earthquakes can break through. In this upper fault zone, the rupture associated with large Mw<8.5 events would decelerate before reaching the surface, and would not be able to create surface ruptures. However, co-seismic and post-seismic deformation would substantially contribute to the folding of the most frontal Himalayan structures. If such a scenario, established from a single site, could be confirmed in the future, it would have major implication on the seismic hazard, seismic rupture modelling, and on the strategy for trenching and conducting palaeoseismological studies for large thrust systems.

Landslides and debris flows: a case study of Uttarkashi

Raju Sarkar
G.. B. Pant Polytechnic, New Delhi, India
(Email: sarkar_raju@yahoo.com)

Natural disasters strike countries, both developed and developing, causing enormous destruction, creating human sufferings, and producing negative impacts on national economies. One of such disasters is landslide. As long as landslides occur in remote, unpopulated regions, they are treated as just another denudation process sculpting the landscape, but when they occur in populated regions, they become subjects of serious study. Globally, landslides cause damage worth billions of dollars, and deaths and injuries of thousands of people each year. Every landslide, or slope movement, is unique, and is best judged on a case-by-case basis. The specific behaviour of individual landslides is most often unpredictable, even when studied in detail. Similar to other part of India, Uttaranchal is also suffering from environmental hazards and the landslide is one example of such phenomenon that affects the household, road, and buildings. Though the landslides occur periodically in different parts of the Uttarkashi district, Uttaranchal, India, they are severe particularly during the last few years inflicting threat to life and damaging property. The present study on landslide was carried out to find its possible causes, effects, and remedial measures in the study area of Uttarkashi.

Assessment of remote geohazards in western Pamir, central Asia

Jean F. Schneider
Institute of Applied Geology,
University of Soil Sciences, Vienna, Austria

In 2002 and 2003, two field missions were carried out in GBAO,Tajikistan, to assess the remote geohazards, such as glacier lake outburst floods (GLOFs), mass movements, and earthquakes, focusing on the Vanch valley as well as the Gunt, Shahdara and Pjanch valleys in the Western Pamir mountains.

The utilised methods of hazard assessment were:

– Regional interpretation of satellite imageries (Corona 1968, Landsat ETM+ 2000/01, Terra Aster 2002/03), as well as available aerial photographs;

– Airborne survey with a helicopter in the areas with high potential hazards;

– Terrestrial investigation of selected sites to confirm the detected hazards;

– Meteorological and hydrological data interpretation of records from the last decades;

– Flood and debris flow calculation as well as estimation of impact size and areas; and

– Interpretation of regional seismic data concerning triggering of mass movements and GLOFs.

Besides potential landslide dams, 355 lakes were classified and ranked according to their proximity to infrastructures, size, and outbreak potential. The study identified the following::

– 133 lakes with ice dams;

– 45 lakes with moraine dams;

– 12 lakes dammed by mass movements (rockslides or landslides);

– 16 lakes dammed by composite materials (moraines covered by rock debris); and

– 149 lakes on bedrock or with stable hydraulic barriers, which cause no threats.

The inventory of glaciar lakes and areas prone to mass movements is based on multi-temporal satellite image and aerial photo interpretation as well as field investigations. The main task of the study was to create a hazard map for assessing the possible impact on the population and infrastructure below. After screening, the following areas with the highest hazard potential were identified and specific risk-prone sites determined:

– Sites with high potential for GLOFs, ranked according to lake type, size, maximum discharge, and possible impact on the downstream area;

– Sites with potential landslides or active sagging (deep-seated gravitational creep); and

– Sites with active faults or potential massive rock falls.

Several sites suffer a combination of these phenomena with a resulting higher risk.

The Bear glacier and the RGO glacier in the upper Vanch valley are prone to surge (downstream movement of about 300 m each in 2.5 years). On the latter, a debris flow with a volume of up to 8 million m^3, originating in a side valley (Glacier 96) was triggered with high certitude by an earthquake of early March 2002 of magnitude 6–8. The resulting mudflow stopped on the wide glacier surface, similar to the ones observed on the Sherman glacier in Alaska in 1964. In the Gunt valley as well as in the Shahdara valley, there are several hazardous locations with a high impact potential, but with a low recurrence rate. In the upper Pjanch valley (Wakham Corridor), several catastrophic debris flows occurred in historical times from the southern tributaries and flanks. A major former event that dammed the main river was located upstream from Dasht-Suleyman. The breaking of the resulting dam must have created a large flood wave. These cross-border (Tajikistan-Afghanistan) events have not yet been studied in detail.

High flows turning into catastrophic floods in Kathmandu valley

Binod Shakya[1] and Ramita Ranjit[2]
[1]*Central Department of Hydrology and Meteorology,*
Tribhuvan University, Kathmandu, Nepal
(Email:anja@wlink.com.np)
[2]*Central Department of Environmental Science, Tribhuvan University,*
Kathmandu, Nepal
(Email: tucdhm@enet .com.np)

Flood is a natural disaster, which is most difficult to predict. In Nepal, devastating floods result from intense rain, and they may affect from a few km^2 to hundreds of km^2 of land depending on the intensity and coverage of weather system. In addition, human activities make the flood more intense and destructive. An example of it is the flooding in the Kathmandu city in 2002 with a large death toll. In the Kathmandu valley, high flows are turning into catastrophic floods due to constrictions in the river channel by infrastructures as well as owing to the development of settlements near the floodplains of the Bagmati, Bishnumati, and Balkhu rivers.

'Seismic Vulnerability Tour': an innovative method for enhancing community participation in urban earthquake vulnerability reduction

*Binod Shrestha, Amod Mani Dixit, Jitendra K. Bothara, and Mahesh Nakarmi
National Society for Earthquake Technology (NSET) – Nepal,
PO Box: 13775, Kathmandu, Nepal
(*Email: bshrestha@nset.org.np)

'Seismic Vulnerability Tour' is a method used by the National Society for Earthquake Technology-Nepal (NSET) for convincing representatives of the donor agencies and community representatives on urgency of urban earthquake vulnerability reduction initiatives. This is one of the several efforts towards enhancing the level of awareness and also for educating people on the need of investing in earthquake vulnerability reduction initiatives in Nepal. The "Tour" consists of a guided walk along a predetermined route in the core area of Kathmandu. The participants are encouraged to take part in the discussion on existing vulnerabilities along the route and their potential remedies. A range of hazards, primary as well as secondary, are considered and discussed for the locality. Likewise, all the phases of disaster, from the onset of the event through the problems of rescue and response, rehabilitation and reconstruction, and the necessity of introducing mitigation in the reconstruction, are talked about during the tour at appropriate moments. The discussion is mostly informal.

The tour allows and encourages the participants to identify the vulnerabilities in a neighbourhood, to assess the extent of the problem, and to explore possible measures that needs to be promoted and implemented. The entire exercise appears to make very profound impact on the participants, and hence considered as one the most effective methods of risk communication.

NSET is expanding the concept of vulnerability tour to organise separate tours for policy- or decision-makers, elected representatives, municipal authorities, community people, professionals, community pressure groups, and donor agencies. A handbook 'Seeing is Believing' has been prepared as a guidebook for young volunteers who wish to organise such tours in their own neighbourhoods. The guidebook encourages potential tour operators to use the empirical methods of visual assessment of seismic vulnerabilities of buildings and infrastructures along a street before the tour, guides them in preparing necessary handout materials and maps for distribution to the participants, and advises on do's and don'ts for the conduct of the tour.

A "Total Slope Analysis" methodology applied to an unstable rock slope in Washington, USA

*A. Strouth, E. Eberhardt, and O. Hungr
Geological Engineering/EOS, University of British Columbia,
Vancouver, Canada
(*Email: astrouth@eos.ubc.ca)

A "Total Slope Analysis" methodology, that combines several numerical techniques (e.g. Stead and Coggan 2005), is used to investigate an unstable rock slope in the Washington State, USA. For this specific study, the distinct element numerical code UDEC is used to assess the stability and potential failure volume of the rockslide. Once the potential rockslide volume has been estimated and failure mechanism assessed, the runout path, distance and velocity are assessed using the numerical dynamic, rheological flow model DAN3D. The results of the Total Slope Analysis can be directly applied to mitigation and prediction of the landslide hazard, and provide key components of qualitative and quantitative risk analysis.

The methodology is developed and calibrated by means of an earlier rockslide at the site (approximately 1 million m^3 in size) that collapsed in November 2003. The rock avalanche debris travelled more than 600 m in elevation down a steep slope onto Washington State Route 20 (SR20), an important route through the North Cascade Mountains. Portions of the roadway and guardrail were destroyed and boulders up to 3 m in diameter were deposited on the road. The slope continues to threaten SR20 due to potentially unstable material at the top ridge formed by the earlier slide event.

Phase one of the Total Slope Analysis involves the back-analysis of the most recent rockslide. Analysis begins with

basic observation of the slope, field data collection, and construction of a simple numerical model. The data required for the simplified distinct-element model includes the topographic profile of the slope, key discontinuity orientation(s), material properties for all rock mass types, and discontinuity strength properties. Practical limitations, both in terms of economics and rock face accessibility, often exist for most natural rock slopes; therefore many of the input parameters must be estimated. The Geological Strength Index (Marinos and Hoek 2000) is used to get these initial estimates. Key parameters are then systematically varied in the model until the reaction of the modelled slope accurately reproduces the shape and location of the failure surface in the actual slope. In addition to providing an estimate of rock mass properties, the iterative nature of back analysis also helps to provide further understanding of the failure mechanism, slope geometry (including location and orientation of weak zones, identification of controlling discontinuity sets, etc.), and material behaviour during runout.

The inputs required for the dynamic runout analysis include the material properties along the runout path, the material properties of the runout material (dependent on the chosen rheology), and the volume of the initial sliding mass. A range of material properties is determined through back-analysis of the most recent rockslide. Hungr (1995) notes that such back-calculated properties can be applied to the forward prediction of future events with reasonable confidence; this leaves the initial volume of the potential rockslide as the most important (i.e., least constrained) parameter for the runout analysis.

The second phase of the Total Slope Analysis begins by determining the potential rockslide volume. The current slope configuration is modelled in UDEC, incorporating the topography of the slope, material properties, orientation of discontinuities, and locations of weak zones that are constrained by the results of back analysis. These parameters are systematically varied (within the reasonable range of values) and the failure volume and location of failure is noted. This range of failure volumes is then combined with information regarding the potential source zone and runout path, and a subsequent runout analysis is performed. Thus by integrating elements of field observation, stress-strain discontinuum modelling, and dynamic runout analysis, a Total Slope Analysis of the Washington, USA rock slope is achieved providing valuable information for assessing different hazard mitigation options.

REFERENCES

Hungr, O., 1995, A model for the runout analysis of rapid flow slides, debris flows, and avalanches. Canadian Geotechnical Journal, v. 32, pp. 610–623.

Marinos, P. and Hoek, E., 2000, GSI: A Geologically Friendly Tool for Rock Mass Strength Estimation. *In* GeoEng 2000. Melbourne, Vol. CD-ROM.

Stead, D. and Coggan, J. S., 2005, Numerical modelling of rock slopes using a total slope failure approach. In Evans *et al.* (Eds.), *Massive Rock Slope Failure: New Models for Hazard Assessment, Proc., NATO Advanced Research Workshop, Celano, Italy*. In Press, 10 p.

Land use pattern and geo-environment of Balkhu Khola watershed, Kathmandu valley, Nepal

Pramod Kumar Thakur and Suman Panthee
Central Department of Geology, Tribhuvan University,
Kathmandu, Nepal
*(*Email: pramodgeo@hotmail.com)*

The Balkhu Khola originates from the northwest flank of the Kathmandu valley and confluences with the Bagmati River near Balkhu in the central part. It is feasible to classify the Balku Khola watershed into three separate zones on the basis of major composition of the terrain (Tables 1 and 2). During the last five years, there has been significant

encroachments on the forest and agricultural land of the watershed due to rapid urbanisation.

This paper deals mainly with the changing trend of the land use pattern in the watershed and its impact on the geo-environment. Some practical measures to combat the negative impact are also discussed.

Table 1: Characteristics of the Balkhu watershed

Zone	Major composition	Area, km^2	Major land use
Upper	Colluvial deposits	12.91	Forest
Middle	Alluvial deposits	9.46	Agriculture, settlement
Lower	Lacustrine deposits	20.41	Settlement, agriculture

Table 2: Land use types of the Balkhu watershed

Major land use	Area, km^2
Forest	3.09
Agriculture	16.05
Settlement	23.64

GIS-based landslide and debris flow hazard modelling of Agra Khola watershed, central Nepal

P. B. Thapa[1,2], T. Esaki[1], Y. Mitani[1], B. N. Upreti[2], and T. N. Bhattarai[2]
[1]Institute of Environmental Systems, Faculty of Engineering,
Kyushu University, Japan
[2]Department of Geology, Tri-Chandra Campus,
Tribhuvan University, Kathmandu, Nepal

A comprehensive method of Geographic Information System (GIS) was applied to assess the physical characteristics of landslides and debris flows in the Agra Khola watershed of central Nepal. The geomorphological and geological variables were quantified for the characteristics derivation. The GIS analysis revealed that slope angle and rock structure are the most influential variables controlling slope failures. Most of the failures are confined to a slope angle of 27° (within the slope range of 25°–35°), and they are structurally oriented either along the soil-rock contacts or bedding planes of rock parallel to or gentler than the natural slope.

For the hazard assessment, a statistical relation between the potential for landsliding (dependent variable) and causative factors (independent variables) was developed using the GIS. The model is based on an innovative approach, which integrates the spatial data with the set of data linked to the actual behaviour of slope movements. The results were validated by comparing the hazard map with the landslide distribution map.

This study indicates that very high hazard zones are confined mainly to the upper and middle reaches of the study area. Also, a few spatially localised very high hazard zones are found to be surrounded by medium to high hazard zones.

Geology of slopes in the Crocker Range mountain, Sabah, Malaysia

*F. Tongkul, H. Benedict, and F. K. Chang
School of Science and Technology,
Universiti Malaysia Sabah,
Locked Bag No. 2073, 88999 Kota Kinabalu, Sabah, Malaysia
*(*Email: ftongkul@ums.edu.my)*

Slope failures are frequent on the roads of Malaysia. Not until recently, geological inputs were rarely sought when designing and constructing roads in mountainous areas. This paper highlights the result of a geological study on selected slopes along a major road across Sabah's mountain range, the Crocker Range. It is comprised mostly of folded Eocene sedimentary rocks. A total of 48 potentially unstable slopes were studied, and the following four main potential sources of failure were recognised:

1. Intensely sheared mudstones within a localised fault zone;

2. Highly jointed sandstone beds with its planes parallel or sub-parallel to the slope face;

3. Intensely fractured and sheared sandstone and mudstone beds within a regional fault or fold zone; and

4. Old landslide deposits.

The main recommendations made to stabilise the problematic slopes include covering the unstable slope face with concrete and cutting back the slopes to stable angles.

'Earthquake clinics' for achieving earthquake resistance in new non-engineered constructions

***Bijay Upadhyay[1], Binod Shrestha[1], Amod Mani Dixit[1], Surya Narayan Shrestha[1], Jitendra K. Bothara[1], Varun Shrestha[1], Mahesh Nakarmi[1], Ramesh Guragain[1], and Bishnu Hari Pandey[2]**

[1]National Society for Earthquake Technology (NSET) – Nepal,
PO Box: 13775, Kathmandu, Nepal
[2]UNCERD, Japan
(*Email: bupadhyay@nset.org.np)

Despite the general availability of adequate scientific and engineering knowledge on earthquake-resistant construction in academic institutions for more than a decade, and the demonstrated feasibility of improving earthquake resistance even of construction using traditional materials such as brick masonry and adobe, earthquakes have been taking huge tolls of lives and properties in developing countries largely because of poor construction practices. In Nepal and other countries, poor construction of buildings is identified as the main source of earthquake risk. Obviously, the knowledge on earthquake-resistant construction has not reached to the main players of building construction process. It is a pathetic situation that under different pretext, teachings of national building codes are not practiced even in the national engineering institutions of so many developing countries. Hence, 'trickling down' of the knowledge along the classical academic path will be very slow, and hence there should be some methods for accelerating this process of using available knowledge for reducing earthquake vulnerability of new constructions in developing countries where a vast majority of residential buildings are so-called non-engineered construction.

The concept of 'earthquake clinics' was developed by the National Society for Earthquake Technology-Nepal (NSET) with the aim to accelerate the process of knowledge transmission for improved seismic safety in the Kathmandu valley, Nepal. Earthquake 'clinics' are organised in a variety of ways – regular 'clinics' are held at a fixed venue at a fixed time ('fixed clinics') or the 'clinics' are mobile and the team of earthquake-resistant technologists moves around in a vehicle and provides the knowledge at construction sites. While fixed 'clinics' are in schools, municipal offices or in other public places, the 'mobile clinics' are held at the site of building construction.

In the 'clinics', earthquake engineers read the building design, assess the construction method in terms of quality of materials and process, discuss pertinent issues with the house-owner, and provide prescription for improving earthquake performance of the new construction considering all constraints. The concept of 'incremental safety' is adopted. The 'mobile clinic' offers better possibility of intervention into the process of construction. Convincing the house owner and making him/her internalise the problem is much better achieved by the 'mobile clinic'.

The approach has helped professionals of NSET to better understand the dynamism of knowledge transfer at household levels and to refine advocacy approaches for implementing earthquake risk management initiatives in Nepal. It also helps to understand the details of the prevalent construction practices and employed technologies, the shortcomings and the priority areas of intervention.

Conventional and modern measures to protect riverbanks from erosion: a case study of the river Kamla Balan

Anand Verdhan and Shantjee Kumar
ICT Pvt. Ltd., and SSWSEM,
New Delhi, India

Erosion of riverbanks and riverbeds is the major geo-engineering problem for the safety and life of the hydraulic structures constructed to contain, pass, or regulate the flood or supercritical flow. This problem exists in all types of geological, geographical, or geomorphological base of river system. The solution is technical, but a site-specific action is more effective than a general one. Bank erosion of rivers, e.g. the Ganga, Kosi, Bagmati, and Kamla Balan all originating in the Himalayan hills of Nepal flowing through the alluvial plains of North Bihar is a chronic and common phenomenon. River courses fluctuate laterally to the left or right due to cutting or erosion, and subsequently deposition or siltation results in shifting or meandering of the river endangering the embankment, rail, roads, bridges, barrage, and countryside valuable land.

The river Kamla Balan carries a heavy silt load and it has a dominant nature of aggradation and degradation. It faces the problem of bank erosion throughout its length, but the section or stretches at Km 37 and Km 62 are highly unstable, critical, and vulnerable. This paper deals with the problem in detail. It also demonstrates the effectiveness and efficiency of geo-textile with an economical rip-rap layer to protect the base and foundation material.

The geo-textile based approach was tested through a model study and was found suitable under various conditions. The geo-textile of woven type (with sufficient pores to dissipate pore pressure) effectively restores the foundation soil. The soil is represented by silt with d_{50} of 0.02 mm, which may get eroded and transported at a flow velocity of above 0.15 m/sec. The study shows the effectiveness of geo-textile reinforced revetment to cope with the alarming situation of cutting and erosion by the river Kamla Balan.

Mitigation measures for the land subsidence: example from the Pokhara basin

M. Yoshida[1,2], S. R. Pant[3], P. C. Adhikary[3], V. Dangol[1], and S. Shrestha[3]
[1]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*Gondwana Institute for Geology and Environment, Hashimoto, Japan*
[3]*Central Department of Geology, Tribhuvan University, Kathmandu, Nepal*

The Pokhara valley is well known for the danger of land subsidence due to the recent debris flow deposits that form the basement of the Pokhara city and wide areas surrounding it. Therefore, all constructions of the Pokhara city are situated on these deposits. Due to the calcareous matrix of the debris flow deposits, they are more-or-less well cemented, even though their age ranges just from 12,000 to 700 years. There are numerous caves and caverns in these deposits. To mitigate the danger of subsidence, ground penetrating radar and the electrical resistivity tomography were employed to detect and map the caves and caverns. The results are quite encouraging and the above methods are found to be quite effective in formulating the control measures to the land subsidence hazard.

Estimation of mudflow activity under the changing climate

Roza Yafyazova
Republican state-owned enterprise "Kazhydromet"
32, Abay Ave., 050022 Almat, Republic of Kazakhstan
(Email: stepanov@kniimosk.almaty.kz)

The major mudflow characteristics, such as the area of mudflow distribution, duration of mudflow discharge, its volume, and genesis depend largely on climate. The regional climate change (predicted by global warming) can lead to sharp changes in mudflow activity in the territories with extreme altitude and relief.

If the summer air temperature increases even by 2–3 °C, a sharp change in the mudflow activity may take place in the mountainous and sub-mountainous zones of the Northern Tien Shan, where the altitude is close to 5000 m, and there are glaciers and huge masses of till accumulated as moraines at an altitude of 2500–3500 m.

In the middle of 19th century, after the end of the Little Ice Age in the Tien Shan region, degradation was accompanied by the formation and development of lakes. These lakes matured by the middle of the 20th century. The outburst of these glacier lakes resulted in the formation of large mudflows. During the deglaciation of the mountains, it is possible to expect insignificant activation of glaciar-related mudflows, and then, as glaciers disappear, the attenuation of mudflow activity takes place.

In the near future, the rain-induced mudflows originating in the high mountainous zone will pose the greatest threat to the sustainable development of extensive regions in Central Asia. The mudflow activity was relatively low in the Holocen as the precipitation was mainly in the solid phase at the upper reach of mudflow zone. Only once in 50–100 years, the precipitation occurred there in the form of rain, and it led to large mudflows.

Global warming can intensify rain-induced mudflows in the Northern Tien Shan. The duration of mudflow and the probability of rainfall occurrence in the upper reaches will increase. It will lead to the annual mudflow disasters in place of the earlier ones occurring once or twice a century.

The reality of such a scenario is proved by a study of mudflow activity in the Northern Tien Shan, where they have occurred for last 150 thousand years. It is established that mudflows practically do not occur in the region during the Ice Ages. It is evidenced by a thick layer of loess accumulated on the debris cones of the mountain rivers flowing from the northern slope of the Zailiysky Alatau Mountain Range in the Northern Tien Shan.

Mudflows become more active when the air temperature in Antarctica (the Vostok station) exceeds its present mean value by 2–3 °C. Hence, during the Riss-Wurm interglacial period, about 1 billion m^3 of mud was deposited within several decades on the Malay Almatinka River debris cone (for all the Holocene, the volume of sedimentation does not exceed 3 million m^3). The activation of mudflows can lead to the destruction of settlements as well as to the desertification of vast territories and the loss of biodiversity in mountains and sub-mountains.

The current defense strategy of detaining mudflows by means of dams will not protect the population and infrastructures from the catastrophes caused by global warming. The building of mudflow check-dams is inexpedient economically, besides it is hazardous as the filled mud-storage reservoirs turn into the potential mudflow origination sites. To prevent the disastrous activation of the rain-induced mudflows, it is necessary to change the existing defense strategy against mudflows: to develop methods of preventing mudflows or modify their flow characteristics.

Ice-rock avalanche of 2002 in the Genaldon river valley, North Caucasus, Russia: consequences and problems

E. V. Zaporozhchenko
Inst. "Sevkavgiprovodhoz", Pyatigorsk, Russia
(Email: skgvh@skgvh.ru)

September 2002 saw the biggest glacial disaster in the Russian history. A huge ice-rock-water flow went down the Genaldon river valley with a speed of 320 km/h from the Kola glacier. Having covered a distance of 18.5 km, it was stopped by the narrows of the Rocky Mountain Range and filled the Karmadon hollow with 120 million m^3 of deposits. The ice-rock-water mass was pressed through the narrows (about 2 km) forming a debris flow, which went down the valley (10 km) devastating all the constructions in the riverbed. A total of 125 people were reported dead. The glacier disaster of 2002 was unexpected, though such events had already taken place in 1834 and 1902. Slow sliding up to a distance of 4.5 km was noticed in 1960–1970 without any disastrous consequences. In 2002, two months before the disaster, a series of collapses from the Djimarai-Hoh slopes (more than 4000 m) on the backside of the glacier triggered the avalanche. The last ice-mass collapse had a volume of 10 million m^3. As a result, the glacier hollow formed. The material from the glacier hollow was knocked out and went down the valley with the superficial moraine. The 100–150 m high water-ice-rock mass (with air also) was moving down the 400–500 m wide valley. The area covered from the collapse zone to the narrows was 12.7 km^2. The area of the ice-rock mass stopped by the "Karmadon Gates" was 2.1 km^2, 3.6 km long, and 135–140 m wide with an average height of 60 m. The debris flow, which went down the narrows of the Rocky Mountain Range, covered an area of 2.5 km^2, and its total volume was about 9 million m^3 with a thickness of 1 to 15 m. The flow on its way down the valley was also fed by the slope deposits and, to a greater extent, by the frontal masses of three huge ancient landslides on the left bank with a total volume of about 40 million m^3. The high-energy flow undercut the toes of these landslides and displaced their material to a distance of 10–20 m. However, there was no riverbed blockage during the disaster, neither after it (up to 2005). In half a year, the movement stopped. The hazards of September 2002 were due to the increase in the slope gradient of runout path in the trough-shaped valley; filling up of the hollow by the ice-rock avalanche and formation of a lake; and deposition of sediments on the riverbed downstream from the narrows by debris- and mudflows.

At present, the area seems to be rather stable. Only an earthquake of magnitude 8 on the MSK scale and fully saturated (5 to 6 times more than actual) landslide debris can lead to a similar disaster. Such a scenario does not exist, and the landslides of 2003 and 2004 have not moved, either. By 2005, the volume of ice in the dam and lake has reduced by 50% and the maximum discharge of meltwater in summer has not exceeded 5 m^3/sec. Actually, the blockage does not influence the flood. The dammed lake, which had an initial capacity (October 2002) of 4.9 million m^3, is discharging naturally, and the remaining water in the lake by January 2005 had a volume of 0.5 million m^3. However, the behaviour of dam during gradual melting of its ice core and piping leading to infrequent minor floods (about 1% of peak discharge) is not clearly understood.

One of the possible causes of disaster could be the lake outburst. For example, the increased discharge (up to 1.5 m of drawdown per hour) in June 2003 created a water-rock freshet (with a discharge up to 25 m^3/sec) flowing down the narrows. The Genaldon River could not accommodate it, as its riverbed was already overloaded by the earlier deposits. The debris flow overtopped the riverbanks and had severe erosive consequences (e.g., abutments of two bridges were destroyed).

On the other hand, the second half of 20th century saw floods with a very high discharge rates of up to 90 m^3/sec. About 20,000 m^3 of landslide debris was accumulated on the left bank of the Kauridon River (above the dam) due to the erosion of soil slopes. The floods also destroyed some structures. But, with a decrease in the lake water level, the landslide activity ceased. In 2002–2004, the debris flow deposit was not stabilised yet and was being eroded from time to time. A surge wave with a discharge of 20–30 m^3/sec and (or) a storm flood of similar scale can entrain the debris and adversely affect the densely populated foothill areas (with hydrotechnical facilities, canals, water and gas pipelines, roads, and settlements) situated some km downstream.

Natural hazard and exogenous geological processes in Caucasus

Nikolay Ivanovich Zelensky
Kuban State University, Department of Geology,
Stavropolskaya 149,
Krasnodar, Russia

The rapid development of resorts and recreational centres on the Black Sea coast of Russia has resulted in severe environmental degradation. Buildings and other structures are constructed on steep slopes and valleys, which are characterised by high landslip, collapse, and mudflow hazards. A majority of these processes are complex and practically unpredictable.

Considering the last decade, the chronology of natural disasters in the Caucasus began in 1995, when a landslip occurred in Pshad and destroyed 20 apartments buildings at the Gelendgik resort of Russia. In August 2002, a powerful tornado hit the Black Sea coast of Russia in the vicinity of port Novorossiysk, the funnel of which reached 200 m in diameter and 3000 m in height. More than 100 persons were killed and 7000 houses were flooded. Near Novorossiysk, a railway tunnel collapsed and 5 passenger trains were trapped in. The reason of tornado was a rise in air temperature. As a result of the storm, a huge volume of water descended to the river valleys and triggered numerous earth flows, which destroyed motorways, houses, and communication structures. In September 2002, the snow-rock avalanche from the glacier Kolka in Northern Ossetia caused huge ice-water flows in the river Genaldon in almost 15 km of its stretch. Hundreds of people were killed and the settlement of Nizhniy Karmadon was destroyed.

The activation of landslip processes is connected with not only natural but also anthropogenic factors. The shelf and coastal zones are the area of interaction between the sea and the land, and are characterised by the increased dynamism of natural processes together with the sensitive anthropogenic influences pertaining to the active economic development. The beach serves as an impediment to the coast and its destruction due to the construction material extraction inevitably accelerates abrasion – the sea washes away beaches, destroys engineering constructions on coastal slopes, triggers collapses and landslips. Consequently, the valuable resort territories are lost. Severe problems are observed on the Black Sea coast between the cities of Tuapse and Sochi and also on the high coast of Tamansk peninsula. In the settlement area of Lazarevskoe, the coast has receded by 23 m in 5 years. It was the direct consequence of quarrying the channel alluvium. Right after the beginning of seaport construction in Tuapse, the coast began to degrade. The zone of washout has extended for 12 km at an incision speed of 4 m /year. The landward incision due to failures and washouts has reached 20 m in places. The natural equilibrium of coastal slopes seems to be lost and ancient landslips have reactivated.

The major task for the researchers of the world community is the creation of a unified international monitoring system (consisting of regional divisions) of exogenous geological processes. Its main tasks should be the following:

- the creation of risk maps of various divisions, such as mountain areas, sea coasts, and fold belts;

- the creation of prevention and early warning systems targeted to the local population; and

- the development and enforcement of engineering geological norms for design and construction of various structures in view of possible hazards due to various exogenous processes.

Author Index

Instructions to Contributors

Manuscript

Send a disk file (preferably in MS Word) and three paper copies of the manuscript, printed on one side of the paper, all copy (including references, figure captions, and tables) double-spaced and in 12-point type with a minimum 2.5 cm margin on all four sides (for reviewer and editor marking and comment). Include three neat, legible copies of all figures. Single-spaced manuscripts or those with inadequate margins or unreadable text, illustrations, or tables will be returned to the author unreviewed.

The acceptance or rejection of a manuscript is based on appraisal of the paper by two or more reviewers designated by the Editorial Board. Critical review determines the suitability of the paper, originality, and the adequacy and conciseness of the presentation. The manuscripts are returned to the author with suggestions for revision, condensation, or final polish.

After the manuscript has been accepted, the editors will ask the author to submit it in an electronic format for final processing. Manuscripts are copy edited. Final changes must be made at this time, because no galley proofs are sent to authors.

Illustrations

Identify each figure (line drawing or computer graphic) or plate (photograph) with the author's name, and number consecutively, at the bottom, outside the image area. Never use paper clips or tape on illustrations and do not write with pen on the back of figure originals or glossy prints. Where necessary, mark "top". Keep the illustrations separate from the text, and include a double-spaced list of captions. Do not put captions on the figures themselves.

Prepare clean, clear, reproducible illustrations that are drafted at a size not more than twice the publication size. All lettering on illustrations must be drafted or laser printed, not typed or handwritten. Put type, labels, or scales directly on a photograph rather than on a separate overlay. Use graphic scales on illustrations; verbal scales (e.g., "x200") can be made meaningless by reduction of an illustration for printing. Calibrate graphic scales in metric units. Indicate latitude and longitude on maps. Plan all type sizes large enough so that the smallest letters will be at least 1.5 mm tall after reduction to publication size. For review purposes, copies of illustrations must be legible and relatively easy to handle, and any photographs must be direct prints. Do not send original illustrations until asked to do so. Keep at least one copy of all illustrations, as the NGS cannot be responsible for material lost in the mail.

For colour figures, authors must bear all costs, and about $50 per colour figure/plate will be charged.

Style

Authors are responsible for providing manuscripts in which approved geological and other scientific terminology is used correctly and which have no grammar or spelling errors. Authors must check their manuscripts for accuracy and consistency in use of capitalisation, spelling, abbreviations, and dates.

Abstract

The abstract should present information and results in capsule form and should be brief and objective, containing within a 250-word maximum the content and conclusions of the paper. The topic sentence should give the overall scope and should be followed by emphasis on new information. Omit references, criticisms, drawings, and diagrams.

Captions

Make captions precise and explain all symbols and abbreviations used. Type captions in consecutive order, double-spaced. Do not put captions and figures on the same page.

References

All references mentioned in the text, figures, captions, and tables must be listed in the References section. Only references cited in the paper are to be listed. For example:

Auden, J. B., 1934, Traverses in the Himalaya. Rec. Geol. Surv. India, v. 69(2), pp. 133–167.

Todd, D. K., 1980, *Groundwater Hydrology*. John Wiley & Sons, Singapore, 535 p.

Tokuoka, T. and Yoshida, M., 1984, Some characteristics of Siwalik (Churia) Group in Chitwan Dun, Central Nepal. Jour. Nepal Geol. Soc., v. 4, (Sp. Issue), pp. 26–55.

Reprints

Authors will receive twenty-five copies of reprints free of cost. Additional copies may be ordered for purchase when proofs are returned to the editor.

Submission of Manuscripts

The manuscripts and all the correspondences regarding the Journal of Nepal Geological Society should be addressed to the Chief Editor, Nepal Geological Society, PO Box 231, Kathmandu, Nepal (e-mail address: info@ngs.org.np).