FIFTH CONFERENCE

OF

INDIAN INSTITUTE OF GEOMORPHOLOGISTS (IGI)

(REG. NO 655/1988-89)

AND

INTERNATIONAL SEMINAR

ON

ENVIRONMENTAL HAZARDS AND THEIR MITIGATIONS

29–31, January, 1993

SOUVENIR

DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF CALCUTTA
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1992

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Prof. Rathindranarayan Basu,
M.Sc. (Ag.), Ph.D., (I.A.R.I.) D.Sc. (Cal.)
VICE-CHANCELLOR

January 25, 1993

I am happy to note that this year the Department of Geography, Calcutta University is organising this Inter-National Seminar on 'Environmental Hazards and their Mitigation' during January 29-31. I understand that scientists from our country and abroad will take active participation in the academic discussinns on many important issues in respect of environmental hazards which threaten our existence on this dear planet of ours. I also presume that the problems of environment as seen by the geomorphologists will be highlighted during the deliberations and remedial measures will be suggested. I trust that these valuable suggestions will go a long way in the mitigation of hazards and save the mankind at large.

I convey my felicitations to the organisers and wish the function a great success.

R. N. Basu

(R. N. Basu)

PREFACE

Geomorphology, the science of landforms by its very nature has an applied bias like that of geography, as observed by Professor R.L.Singh (1966) and the response by geomorphology to the contempory problems of society has, indeed, been very close throughout its evolution. The very inception of geomorphology as a discipline concerned with explanation, surveying and mapping of areas was motivated by practical needs of mankind. Under the auspicious of the Department of Geography, University of Calcutta, the Fifth Annual Conference of the Indian Institute of Geomorphologists (IGI) is being held in Calcutta during January 29-31, 1993. Along with the Conference we are organising an International Seminar on 'Environmental Hazards and their Mitagation'. We are gratified to have as our collaborators in this academic exercise the following :

1. Center for Study of Man and Environment
2. Institute of Landscape, Ecology and Ekistics
3. National Atlas and Thematic Mapping Organisation, Govt. of India
4. Geological Survey of India, Govt. of India
5. Central Ground Water Board, Govt. of India
6. Indian Institute of Environment, and others.

The present volume contains the souvenir of papers relating to the focal theme and subthemes of the conference. About five papers in the field of geomorphology dealing with pure, applied and environmental aspects will be presented by a number of geomorphologists and allied scientists in the various technical sessions. Contributors in the focal theme of the conference, "Environmental hazards and their mitigation" are associated with several Universities, Institutes, Organisations from different parts of the country and abroad.

The organising committee of the 5th IGI conference and International seminar and the Executive Council of IGI wish to place on record sincere apreciation and gratitude to all who have contributed papers with abstracts, agreed to deliver invited lectures and show a documentary film and those who have helped in processing and publishing this abstract volume in such a short time. The committee members are especialy grateful to the authorities of the University of Calcutta for providing facilities toward the holding of this conference and the seminar, and the well wishers and the collaborators for their coperation.

S.C.Mukhopadhyay
Convener
5th IGI, 1992
Department of Geography
Calcutta University

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CONTENTS

THE UNSTABLE EARTH AND ITS ENVIRONMENTAL CHALLENGES

Professor Kanan Gopal Bagchi
President, Institute of Landscape Ecology and Ekistics

(Key note address for
International Seminar on Environmental Hazards
and their Mitigation : January 1993)

The first component of the Environment according to the Earth Scientists is the terrain on which the human drama is enacted. The earth's crust is the platform, considered as more or less stable on which ekistical activities are performed. The cultural landscape that evolves are based on a number of parameters that vary from region to region depending on the contents of the total ecology. But let us first consider the aspect of stability of the terrain since hazards are essentially associated mostly with it.

Oldham's xraying the earth on the basis of Assam earth-quakes and subsequent studies according to western and eastern seismologists have demolished the concept of a stable earth. The interior, though behaving as a solid to suddenly imposed stress, is after all a super dense liquid. The subcrust is also potentially liquid and assumes plasticity whenever the required temperature is obtained. The crustal fragments, forming the basis of continental blocks and oceanic floors, press heavily on the subsurface materials but with varying intensity. Airy in connection with gravity determination in the Kalyanpur and Kaliana region detected certain anomalies which were interpreted by Pratt as proving that the Himalayas were not in a state of balance. Nor the peninsula or for that matter the oceanic floors on either side.

This imbalance and the attempt at attaining a compensation along with convection currents due to geothermal gradient provide incentive for the fragmented blocks on which the Himalayas, the intervening plains and the Decean shield tend to slide relative to one another resulting in what is known as drifting of the plates. The plates bordering geosynclines confront in opposition leading to the development of folds which are mostly symmetrical in nature. But most often the movement involves the translation of the plates on one side over the other resulting in over thrusts and under thrusts, and the involved geosynclinal materials are thrown into disarray of a complicated nature. Glyptogenesis stamps its marks etching out a beautiful mountain panorama.

Evolved in this manner the Himalayan rocks form a very unstable seismic belt in which a potential threat of instability is always there. The violent earthquakes of 1938 in Quetta in Pakhtunistan (Pakistan) resulted from rock bursts in Western syntaxial bend of the Himalayas. The devastating earth-quakes of Uttarkashi in 1991 may be attributed to the inching of the Decean hinterland acting as a ramp against the Tibetan foreland, the thrust planes providing facilities of easy movement. The entire Himalayan field is under mild tremors every now and then, the violence aggravating occasionally wherever the competence of rock structures is exceeded. This has to be remembered whenever constructions are planned in the Himalayan terrain. But this is observed more in the breach. The last earthquake at Uttar Kashi exceeded 6 on the Richter scale. That at Quetta was even greater and it originated at a shallow depth comparatively speaking. But the powerful Bihar earth-quakes in 1934, 1937 and the earth-quake of Assam coinciding with the inauguration of the Republican day in 1950 manifest several types of earth movements different from those in the Himalayas.

No, it is not the Himalayas or even the vast plains of the Indus cum Ganga cum Brahmaputra girdling the northern edge of the Peninsula alone which pose the epithet of the term unstable. The firmer tract of the basalt capped Dakshinatya is also prone to quakes. The Koyna earthquake which threatened to submerge the Koyna dam periphery is still fresh in public mind. In fact the shield is highly fissured and is the outcome of successive convulsions since and inclusive of the Azoic era. Eroded stumps of fold mountains and plateaus indicate vast formations of sediments in geobasins and their subsequent elevations into mountains, some of which even dwarfed the Himalayas in bulk and elevation represented, say, by the Nilgiris, the Nallamalai hills and the Aravalli mountains of the proterozoic geosynclines still persisting as mountains are the Vindhyas, the Satpuras and the Mahadevas. The orogeny in each geological period was accompanied by vulcanicity. The Panjal volcanics, the Rajmahals and the Sylhet traps constitute grim reminders in addition to innumerable intersedimentary flows in each of geological formation. But most outstanding of all has been the cretoeocene Deccan traps covering the stretch between the Western and Eastern ghats. This vast extent of quiet exothermic flow was spewn out of geographically scattered of conical vents many of which were violent in character. Imagine the catclysmic events accompanying such phenomena. Even the tertiary has not escaped tectonic movements as is evidenced in the river terraces abounding in Deccan rivers which constitute favourite haunts of the Archaeologists, the Historians and of course the Fluvial morphologists. As also the marine transgressional deposits in the coastal regions.

The Tertiary's record per se is, however, the rise of the Himalayan mountains in three phases, the Ecocene, Miocene and the pliocene. The southern hinterland cracked up somewhere along the alignment of the Narbada valley and the northern block surged forward to dip below the advancing Tibetan foreland, crushing the Tethyan geosyncline in the process as mentioned earlier.

The phase of glyptogenesis is not over yet and the tendency to rise still persists. The stupendous gorges in the valleys of the Indus, the Jhelum etc. to as far as the Tista in the east are testimony to this. The upwelling of mud in Chandrakup, the emittance of fire at Jawalamukhi and the hot springs (Tatapani) dotting the Himalayas are the resultants. The paired terraces in most Himalayan streams confirm that the terrain is not firm yet. The Barren Islands in the Bay of Bengal and the atolls in Indian ocean are unmistakable indications of instability of the crust covering Indian peninsula and the oceans around.

The natural hazards do not end at this. Avalanching, rock flows, landslides, bilzzards are frequent phenomena with which the people in the mountain terrain have to contend with. In the valleys lower down in the the great plains of the Indus-Ganga and Brahmaputra, nay also in the southern rivers of Deccan, floods take their toll almost annually. We have attempted to husband some by the multipurpose strategy but this has been partially successful only due to faulty planning and inadequate inputs. These need scrutiny and correction as has been forcefully pleaded by the speaker time and again in the media and professional journals.

This august body of scholars is also aware that cyclones and tornados take their toll in the coastal regions of India and may be designated as a prime killer of humans and cattle and destroyer of crops and settlements. With a chain of radars and the help of landsat imageries it is now possible, although inadequately, to track down the cyclones and forewarn floods. It takes 40 hours for catchment downpour to reach from the upper valley of the Mahanadi to the delta and the duration in case of the Damodar is 18 hours. It is also possible to forecast about floods in Himalayan rivers by snow surveying. We have however to perfect our investigations regarding tracks followed by cyclones in land over the subcontinent. Cyclones pursue tracks which are considered whimsical now, but may have some relationship with upper atmospheric phenomena. In case of Bengal (E and W) they occasionally tie up with the jet streams and force their way far to the north carrying havoc all the way. Thus cyclones from the southern coastal regions progressing longitudinally have traversed through the Tista valley occluding in the mountains. The mystery needs probing.

Ladies and gentleman, I have indicated only some of the hazards that we have to investigate for deliberating on the remedies. The process is already afoot. The Tehri region of the Himalayas and the Garo-Khasi block in the north-east is being studied by the Geologists (Kumaon University and GSI respectively) to identify the intensity of stress in proven belts and forewarn about impending dangers. Moon rocks are under study in one of the Universities of UP (Allahabad if I may guess) to find out the geothermal conditions (pressure, temperature etc.) under which such components were formed particularly the crystal structure and chemical composition. Comparable rocks are also found in India, it is presumed, and the conclusions will prove interesting for the geomorphologists in deciphering the geolithological environment of this subcontinent.

A mention about pollution caused by man in conjunction with nature. Run off in most cases whether flowing down rivers or percolating down to subsurface when contaminated by factory effluents or farm washings pose serious danger to public health. Mismanagement of farms also lead to desertification. Disposal of waste from Atomic plants and metropolitan areas sometimes creates baffling situations. Hotting up of the atmosphere due to various activities ultimately lead to rise of sea level and climatic change. The holes in the ozone layer over the Antarctic and the Deccan plateau (alleged) are matters of serious concern for climatologists and bioscientists. These are challenges that need be attended to demanding viable solutions.

CONTEMPORARY GEOMORPHOLOGY

Professor S.C.Mukhopadhyay, Convener

In the Nineties the geomorphologist has secured a unique status to analyse the unpredicted natural phenomena and specify ways and means towards the mitigation of modern environmental hazards. This establishes the fact that environment and geomorphology are interrelated which is the focal theme of the academic exercise.

Geomorphology represents the particular science that contributes a long term historic perspective to the study of natural systems. Indeed, one can hardly expect to understand or deal with an environment of obscure origin. It may be claimed that it is the only science that integrates an environmental approach to these systems. Further, geomorphology teaches a special awareness of the role of process-agency interaction inclusive of form-process relationship as part of a natural system, where many of the same systems simultaneously comprise habitats for living organisms and man of this planet earth. In an interpretative sense, as suggested by Richards and others (1990). It is not difficult to perceive a recent methodological development in geomorphology. Indeed the pages of Earth Surface Processes and Landforms can be used to illustrate this, in the context of studies of chemical denudation and solute processes. The estimation and mapping of denudation rates (Walling and Webb, 1978) clearly necessitated careful, detailed sampling of the temporal variations of solute concentration with changing river discharge, and the establishment of the solute rating relationships to be combined with the discharge hydrograph. However, that sampling revealed complex hysteretic behaviour and seasonal variation and understanding of these temporal pattern demanded that total solute load be disaggregate into the ionic species behaviour. To understand that behaviour, it becomes necessary to investigate soil mineral stability conditions, water flow pathways through the soil, and the chemistry of the weathering processes responsible for solute uptake. It is perhaps unfortunate that fluvial geomorphology has remained for so long concern with input-output studies based on empirical rating equations. Significant practical issues-such as surface water acidification-demand an understanding of the underlying mechanisms not provided by such empirical studies, which in any event have been used inaccurately and without due consideration for statistical problems. It is, however, the progressive revelation of a phenomenon illustrated by this example which raises questions about the relevance, in contexts other than research programme management, of the model provided by the experimental sciences. The reductionist sequence of analyses outlined above clearly illustrates a shift from extensive to intensive research designs, and is characteristic of the uncovering of 'ontological depth' emphasized by realist philosophers of science and its methods.

In the realist programme, the objective of science is to develop explanations based on the identification of networks of underlying causal mechanisms. A distinction is drawn between (1) 'real', natural generating mechanisms, (2) events, and (3) empirical observations; (1) may not give rise to (2) unless the contingent circumstances are appropriate, and (2) will not always be represented by examples of (3). However, it is the identification of (3) which initiates the search for (1); the empirical regularities observed during experiment are not in themselves indications of the nature of the generating mechanisms. This recalls the common requirement for 'bridge principles' in the critical rationalist method: these are necessary to connect a theory with observations based on measuring devices that only generate information loosely correlated with the phenomenon or mechanism being observed. The turbidity meter, for example, produces data influenced by particle size and water colour to such a degree that their significance in terms of suspended sediment transport needs careful examination (Gippel, 1989). Many geomorphologists will perhaps be unsurprised to discover that their geomorphology is essentially realist. However, the realist position implies a great deal more about scientific method as well as about the objects of scientific enquiry, and in particular rejects the critical rationalist methodology which has been emphasized in writings by geomorphologists. Critical rationalism is, of course, itself based on a distinction between invariant (covering) laws and contingent (initial) conditions. However, the laws are identified by experimental activity which requires that predictions generated by hypotheses are compared with observations. The realist argues that the necessary conjunctions are themselves an artefact of the experimental closure imposed by the scientist on an 'open' system in which, in reality, complex networks of causal mechanisms operate within complex contingencies. The conclusion reached is that to assume scientific enquiry follows a critical rationalist procedure is to accept an absurdity, namely that the laws of experimental science may be caused by the scientific activity that enables them to be identified. Although one can argue that experimentation is necessary to control all but one factor, the realist response would be that this may not reveal anything useful about the relationships between the objects/phenomena in question in a real 'open' system, since interacting mechanisms may result in behaviour (events) quite distinct from that (those) observed in the specific contingent circumstances of the experiment. What this further implies is that the hypothesis-testing which has dominated geomorphological methodology since the 1960s may not assist in the uncovering of real causal mechanisms, in part because the assumption is questionable that falsification is any more likely to be possible in 'open' systems than verification. Instead, therefore, alternative (non-predictive) demarcation criteria are required to justify the adherence to particular theories. These are based on the internal consistency of a theory, and the consistency of its explanations with evidence relating to the same phenomenon at other time and space scales, and to other, related phenomena at comparable scales. The criteria for acceptance of a theory are not based on predictive success, but on explanatory power. This is evidently necessary when geomorphologists, faced with the need to develop numerical simulation models to 'accelerate' landform development, judge the results of those simulations after sensitivity analyses.

Obviously, Beck (1987) has pointed towards the difficulties encountered in predictive hypothesis-testing in the complex open systems described by catchment hydrological modelling. Here, model parameters often require optimization, and when subsequent prediction failure occurs, it is difficult to identify the reasons for this in terms of the parameter set employed. This example also raises a further interesting issue, namely the relative influence on research programmes and methods in geomorphology of 'engineering' and 'science'. It is evident that research agenda are strongly influenced by practical exigencies, and that the methods used to acquire the knowledge needed for rational management of geomorphological systems may be less than scientifically-rigorous because of economic constraint. However, the objectives of geomorphology which have been outlined in other editorials in Earth Surface Processes and Landforms refer to explanation of landforms using process understanding. If there is a means of reconstructing such explanations at appropriate scales, and reversing the reductionist trend bemoaned by Slaymaker (1987) and implied by the outline of solute studies above, it must involve the emergence of new structures and relationships employing the identified mechanisms, and the development of iterative and spatially-distributed, form-process-form feedback models seems most likely to achieve this. A qualitative example of such an approach is provided by Williams's analysis of Chinese karst, in which the landforms at one time influence the pattern of process to determine the evolution into the next time step. Examples also occur, at smaller time and space scales, in fluvial geomorphology and these raise questions about the value of equilibrium concepts, and equilibrium models derived from experimental activity, applied to the explanation of continuously-evolving systems. The role model of the experimental sciences is just one possible model, providing geomorphologists with some ideas on 'how to do geomorphology'. When Churth et al (1985) referred to 'geomorphological sociology', they indirectly identified an alternative model. Much that is written on the realist approach is written by social theorists, scientists norwithstanding the politically-motivated decision to rename their research council in Britain by excluding the word 'science'. Perhaps environmental scientists have as much in common with such scientists as with, say, physicists, given (1) the open nature of the systems forming the objects of their enquiry, (2) the limitations that may be placed on explanations developed after a closure effected for experimentation, and (3) the necissity for explanations to be reconstructed, after a period of reductionist searching for mechanism, at scales appropriate to landforms and the Quaternary relating to the establishment of contemporary geomorphology.

ON THE ENVIRONMENTAL ISSUES RELATED TO GROUND WATER DEVELOPMENT

By

Dr. S.P. Sinha Roy
Director
Central Ground Water Board, Calcutta

Introduction :

Water is a basic need of life and is used in many ways to cater the needs of modern developing society. Rapid population growth, urbanization, increased water use arising from structural changes in agriculture, industry and other economic activities, as well as decreasing flows in the river systems due to upstream withdrawl call for changes in the pattern of water use and water related land use. Water is a commodity which is becoming increasingly scarece and as such, precious.

With the continued thrust for meeting the water requirements in drinking water and irrigation sector not to speak of industrial requirements from ground water to keep pace with the development activities and urbanization there has been considerable stress on ground water resources in the country. Like all development activities, ground water resources development also can create environmental hazards and contribute to the ecological imbalances locally.

Major Issues :

The estimates on replenishable component on the ground water potential of the entire country works out to 45.33 m ha.m/yr., of which 38.34 m ha.m/yr. is available for irrigational use, setting aside 15% of the potential for drinking, industrial and other committed uses. Although average utilisation in the irrigation sector for the whole country is around 40%, in some areas it may be as high as 70-80%. Again, sometimes in certain localities a situation like 'over exploitation' have been manifested due to indiscriminate use of ground water locally. In West Bengal, with the growing tendency to bring more areas under 'Boro' cultivation due to its high return, exploitation of ground water is reaching to a critical stage during summer months because of excessive water requirement of the crop. Ironically, this is the period when the availability of ground water is minimum. Moreover, as the boro paddy is a paying one, the shallow irrigation wells by the individual farmers are increasing in number day by day because of the facilities of having financial assistances from the banks and construction cost being within the relatively easy reach of the farmers. This has put a tremendous pressure on ground water resources available from the shallow aquifers resulting into decline of water table to the tune 5 to 8 metres. Such decline of water table is causing great concern for drinking water supply in rural area as the ordinary pumping system provided with the tubewells are not able to lift water from such deeper levels. In big city like Calcutta, demand of water is increasing beyond proportion due to high population growth and the shortage of municipal water supply based on surface water compelling an excessive ground water draft to cope up with drinking water requirements. This has created almost a permanent decline of piezometric head, 5 to 10 m, in last two decades. Apart from deficiency in last two decades. Apart from deficiency in drinking water supply through conventional pumping devices, it may cause serious consequences like land subsidence as has been evidenced in other parts of the World. It is therefore, needed to have some legal control for regulation of the development of ground water resource in the country on scientific lines. Although it must not appear restrictive, the policy has to aim at the optimality of ground water resource utilisation and its equitable distribution commensurate with the hydrogeological environment and ground water regime conditions. In planning agricultural development, it will be necessary to think of change of cropping pattern so that drinking water supply position can not be further sacrificed to accommodate high water consuming crops during the period when natural water availability condition is minimum. Side by side, it will be prudent to consider augmentation of ground water by artificial methods wherever feasible. Since drinking water supply has been attached rightly the topmost priority, it has to be seen that decline of water table should not create any hazard to drinking water supply. This can be achieved partly by changing suitable pumping device and also by keeping provision of a part of water for drinking purposes from the heavy duty irrigation wrlls wherever possible. In some cases it has been found that heavy duty deep tubewells tap partly shallower aquifer also. As this affects water table of the shallow aquifer also, designing heavy duty tubewells with partial tapping of shallow aquifers is to be discouraged. In otherwards, endeavour should be made to utilise improved technology available in withdrawl, distribution and augmentation of ground water so that environmental hazards due to over-withdrawl can be minimised substantially.

In the coastal areas, extensive surveys and explorations, have revealed the existence of large fresh ground water resources at deeper levels. However, since almost everywhere the fresh water-saline water systems in the sub-surface co-exist in a characteristic hydro-dynamic balance, over-exploitation of ground water may cause ingress of sea water into sweet water aquifers. To meet the ever increasing demands of fresh water in the coastal areas, it will be obligatory to understand the hydrogeologic environment precisely so that a mechanism of controlled ground water withdrawals without upsetting the hydrochemical and hydro-dynamic balance can be developed to protect environemntal degradation arising out of over development of ground water in the region. Modern technology in construction of tubewells in coastal area can be adopted whereby even the chances of vertical percolation of saline water from the upper aquifer can be prevented. Encouragement of cultivation of salt water tolerant crops can also reduce the fresh water requirement in coastal area. Again, available brackish ground water can also be utilised for the development of pisciculture. Mixing of fresh water from deeper aquifers with relatively less brackish water of the suitable upper aquifer, sometimes may yield better results in this regard. The strategy of ground water development in coastal areas should aim at restrained withdrawl within the permissible economic limits.

In the drought prone areas of the country, environmental hazards are generally characterised by lack of rainfall causing reduced pasturage, over grazing, inability of sown crops of mature and above all shortage of domestic and drinking water resulting into displacement of the habitats and migration of people. Development of ground water resources has received considerable attention and focus in recent years in drought mitigation. Ground water has a definite role to play in view of its tremendous potential and significant contributions towards ameliorating drought situation in the country. Shallow aquifers may go dry consequent to failure in rainfall in consecutive years. But deeper aquifers having distant recharge facility in space and time and lying below the zone of annual water-level fluctuations of shallow aquifers can serve as capital reserves of ground water that can be drawn in periods of drought. Proper management in developing this resource would enable people and other liverstock with basic subsistence during drought. However, suitable and cost effective ground water augmentation structures can bring additionality to ground water reservoir during surplus periods of precipiration. 'Micro-watershed development' approach by constructing rain-water harvesting structures, percolation tanks, contour bunding, sub-surface dam together with afforestaion may be very successful in drought amelioration.

The pollution of ground water from surface or near-surface sources, such as waste dumps, sanitary and chemical land fills, septic tank systems, municipal and industrial waste water ponds, pesticides and fertilizers applied during irrigation etc. can pose serious environmental threat. The process of ground water pollution is complicated and quite different from that of surface water while in case of surface water, the pollution process is rapid and is manifested in short time in the form of changes in colour, odour and at times by aquatic dead life. It may take several months and years for the pollutants to reach saturated zone. Ground water once polluted is much more difficult to treat it and in many cases ground water becomes non-usuable forever. Since cleaning up of contaminated ground water is expensive, efforts should be for prevention rather than cleaning the ground water. Some of the more common measures employed for preventing ground water contamination are source control strategies like volume reduction, physical chemical alteration measures, interceptor systems like collector drains, interceptor trenches etc. and in-situ treatment methods including chemical and biological, waste water treatment etc. Considering the serious implications of this problem, it may necessiate integrated approach to undertake ground water pollution monitoring and abatement programmes. Stringent measures for enforcement of tolerance limits prescribed for industrial effluents have to be taken because of extensive ground water pollution from industrial effluents. Similarly in agricultural sector threat of ground water contamination due to application of fertilizer, pesticides etc. have to be controlled to protect the precious ground water resources and safe-guard the health of the people. Recent reports about arsenic contamination in ground water in parts of West Bengal is quite alarming. It has brought immense miseries and health hazards to thousands of people. As a short term measure it is necessary to plug arsenic affected wells and use water from deeper aquifers if found suitable. However, technologies need to be developed for in-situ treatment of water from such tubewells in the long run so that safe, arsenic free water can be made available to the people. Vigorous research in this line is a crying need of the day. Identification of cause for such menace has also to be made more precisely so that alternative measures can also be worked out.

Concluding Remarks :

The pace of growth in the use of ground water is expected to be maintained if not increased by the turn of the century. However, to sustain their continued use will depend, in large measures, by resource endowments, institutions, technological changes and policies. The extent to which an environment conductive to such development exists will largely depend upon the policy makers, executors and beneficiaries for their attitude towards maintaining sustainable environment without hampering developmental efforts.

SUSTAINABLE DEVELOPMENT THROUGH SOIL AND WATER MANAGEMENT ON THE BASIS OF MICROBASINS

S.P. Das Gupta

Center for Study of Man and Environment, Calcutta

It has been aptly said that "we are only 15 centimetres away from our annihilation" (Dhruva Naryana *et al.*, 1990), for it is on the topmost thin layer of productive soil that the survival and prosperity of the human race depend. It is well known that the top soil is now being removed at an alarmingly rapid rate, primarily due to human interference with nature. The Central Soil and Water Conservation Research and Training Institute at Dehra Dun has estimated the soil loss in India at 5,333 million tonnes per annum (Table 1). The rate of soil loss per hectare comes to as high as 1622 tonnes per square kilometre of the land surface or about 16 tonnes per hectare per annum. Some 30 per cent of this amount is totally lost, 20 per cent being washed down to the sea and the remaining 10 per cent being deposited into our water reservoirs every year.

Soil erosion problem

In many parts of the country the soil cover is rather shallow, hardly 20 centimetres deep, such as in the great red soil region of the Peninsular uplands extending over 68,800 square kilometres. These soils are subject to severe sheet erosion. Similarly, the lateritic soils which occur on undulating terrain spread over 61,000 square kilometres are usually subject to heavy rainfall condition and are affected by continued sheet erosion. Again, the black soils, covering over 67,340 square kilometres of our plateau region largely lie without any crop cover during the monsoon period and are thereby liable to be easily washed away. Elsewhere in India, rampant deforestation, extension of arable farming into marginal lands, construction of habitations and road systems and other forms of human interference have resulted in widespread rill erosion and development of gullies and enormous ravines. It is

Table 1 : Soil loss in India

	Land resource region	Area (square kilometres)	Rate of soil loss per annum (tonnes/km²)	Total loss per annum (million tonnes)
1.	North Himalayan Forests	131,700	287	37.798
2.	Punjab-Haryana Plains	101,250	330	33.913
3.	Upper Ganga Plains	200,000	1410–3320	473.000
4.	Lower Ganga Plains	145,500	287–940	89.264
5.	North-Eastern Forests	161,002	2780–4095	553.444
6.	Gujarat Plains	62,750	240–3320	111.659
7.	Red Soil Region	68,800	240–360	20.640
8.	Black Soil Region	67,340	2370–11,250	458.585
9.	Lateritic Soils	61,000	3930	239.730
10.	Other areas	2,288,440	1448	3314.931
	India	3,287,782	1622	5333.000

(after Dhruva Narayana and Ram Babu 1983)

*This paper published in the Annual volume 1991, Center For Study of Man and Environment.

said that some 4 million hectares of valuable alluvial soils on the Yamuna, the Chambal and the Mahi rivers are affected by ravine formation and gully erosion. This alarming situation has been created more due to the misuse of land by human activities rather than by natural historical causes. The soil loss has eventually brought about severe disturbance in the water flow characteristics leading to droughts, floods and depletion of crop yields. Soil conservation measures, therefore, are the most essential elements in raising the land productivity, by way of conserving the water resource potential, in maintaining the ecological balance and in sustaining the economy at a reasonable level.

Soil conservation practices

Several methods of conservation of soil are well known. On agricultural lands, in particular, soil conservation practices include such devices as contour ploughing, bench terracing, graded bunding, ditching, etc. By practising contour ploughing alone the soil flow from agricultural fields can be reduced considerably, say from 30 tonnes to 20 tonnes per hectare per annum. This technique can be used in all types of soil texture with rainfall up to 600 millimetres per annum, and with adequate infiltration rate.

In heavier rainfall zones with more than 600 millimetres of annual rainfall, graded field bunding technique with arrangements for draining off the excess water to farm ponds is particularly useful on lands sloping at an angle of 2 to 4 per cent. Such bunding system has been found to reduce the run off and the peak discharge of water by 62 and 40 per cent respectively in high rainfall areas. The method can also be followed on clay beds (such as in black cotton soil area) having rainfall less than 600 millimetres per annum. In deep black soil zones, ditching is useful with trough like trenches dug along contours at a vertical interval of a metre or so. These trenches can also serve as water harvesting structures for temporary storage of water in the fields. On steeper slopes, however, bench terracing is the only reliable method available for conservation of soil and water.

All these engineering methods of soil conservation can be successfully executed by using various mechanical devices. But proper maintenance of the soil conservation structures requires close surveillance and continuous care or monitoring, and this is possible only if the management is organised on the basis of small drainage basins and if only the local people's participation in managing is ensured in the affairs of soil and water management.

Besides the mechanical measures indicated above, it is also possible to reduce the soil loss by adopting appropriate land use method and land management practices on different types of soils and by planting different appropriate species of protective vegetation, such as vetiveria grass along the edge of cultivated fields and across the land slope. Experiments, recently conducted by the School of Fundamental Research in Purulia district, indicate that the close-knit roots of this species of grass penetrate deep down to more than 3 metres, thus conserving both the soil and the moisture at once.

Various land management practices, such as : mixed cropping, inter-cropping, strip cropping, rotation cropping, mulching, application of organic manures, appropriate residue management, etc., go a long way to reduce soil erosion and to conserve sub-soil moisture more effectively.

In non-agricultural lands, the best way to reduce soil erosion and enhance soil moisture is to plant protective trees providing vegetative cover to the soil. Even the natural grass cover can considerably reduce the soil loss. At Dehra Dun, for instance, under heavy rainfall condition (1250 millimetres from June to September) the loss of soils from lands covered by natural grasses at a slope of 9 per cent comes to only one tonne per hectare, whereas the loss from the ploughed fields and bare lands has been found to be as high as 16 tonnes per hectare (Dhruva Narayana *et al.* 1990). Grasses, whether natural or planted, are highly efficient agents in reducing soil erosion.

Besides protecting the soil by the root system, trees also effectively intercept the falling drops of rain, reducing the velocity and impact of the rain drops to a great extent, saving the top soil from being loosened off its moorings. By merely providing protection to the plant kingdom and thus allowing the natural tree cover to grow, it is possible to conserve soil and water resources of the country. No wonder, therefore, the best way to conserve the soil and water wealth is to grow a green canopy by carrying out afforestation and plantation of trees allover the country.

In certain areas, especially in waste lands, agroforestry has been recommended for conservation of soil and moisture. Besides, agroforestry also help increase the yield of land, andat the same time, it combines the production of field crops, tree crops, forests and animals, either simultaneously or sequentially. All these systems of soil management can succeed if the unit of management is small, like a microbasin and if local people are involved in their planning and management.

Watr conservation

S. torge of rain water in small structures for subsequent use in agricultural fields is an age-old practice in this country. But, unfortunately, most of the old works are now in disuse, es pecially after introduction and development of the large modern irrigation systems in different parts of the country. Experience now shows that at the local level traditional and small scale water harvesting systems are really more effective in irrigating the fields. Water harvesting entails collection of the available excess rain water during the wet season, its stor agnd optimum use through appropriate delivery systems. Usually, in flat areas the tor f water can be effected in dug out tanks (3 to 5 metres deep), while in undulating terra torage can be more effectively done by throwing embankments at appropriate locat on the downslope side so as to hold back the excess rain water for subsequent use. Vario ypes of treatment of the soil or lining the reservoirs with appropriate materials have r been in practice avoidable loss of water through seepage. Since water harvesting is rath expensive, carefully controlled use and recycling of water, preventing all losses, is usua advocated.

People participation

While ap ropriate methods for conservation of soil and moisture are technically well establish applicable for various types of landscape, as indicated in the foregoing discussion, the actual experience during the last four decades of development planning shows that it is difficult to sustain and run the soil and water conservation projects at the field level unless the local populace are fully involved in their planning, creation and operation. That is why, despite large canal irrigation projects and extensive soil conservation structures being built during the past five year plans, soil erosion in the country is mounting and we are running short of water day by day.

It is now being realised that along with the existing large scale engineering projects, for which complex and extensive organisations are needed, it is also essential to have small and medium scale field level programmes for soil and water use and their conservation to make the effort really fruitful. The land resource cannot be protected unless the soil cover is rigorously guarded at local level by the people themselves. It is now, more or less, an accepted fact that a large segment of our rural society will necessarily have to depend more and more upon dry farming practices on rather marginal lands, by raising of livestock on poor grazing lands, and by living off the depleted forest lands and waste lands. It is, therefore, high time now to devise really effective methods of microlevel planning for development of soil and local water resources for sustainable development of the rural economy. Such local level soil and water conservation planning must have to be chalked out and executed at absolutely grass-root level by the local inhabitants themselves without any interference from the outsiders including the authorities who are established in the seats of power.

The next question which comes to mind is that how it would be possible for the common rural folk in India to organise themselves in conserving and managing own soil and water resources. Successful introduction of many a new measure in rural India since Independence has proved that our rural folk has tremendous capacity to accept modern ideas and technologies and organise themselves. For making soil and conservation system work in sustainable manner, the local people in each small water catchment basin would have to come forward to organise themselves and plan out the development of their own basic natural resources like land and water and implement the programme without depending much upon outside help. It is well known that in the pre-plan periods, before Independence, Indian rural society often had a large measure of autonomy in the matter of jointly sharing and using the village wastelands, commons, forests and water sources. That system has to be revived and given a new shape.

In a country like India, having markedly seasonal rainfall, it is a universal truth that water is the single-most crucial input in agricultural and other rural operations. Needless to say that this scarce resource must have to be fully harnessed and preserved for providing water to crops and plants. The source of water is, therefore, a most natural focus for unification of interests of all members within a rural community. There is no reason why it should be difficult to impress upon the rural folk to organise themselves for joint use of the common stock of the available soil and water resource. Hence, the village level microplanning involves planning and management of land and water systems, water harvesting structures, moisture conservation and rational utilisation of water resources for effective biomass generation. The management of the available water resources would have to be so planned out and water use so organised within each catchment area so that all the farmers and villagers are equitably benefited.

Microbasin planning

While the rural planning body, in a microbasin , comprising local villagers, should operate independently of the government to be really an effective tool for ensuring peoples' participation in development, it is obvious that such a micro-planning agency must have to react with the local government bodies and other organisations. The National Wasteland Development Board (1991) has already declared that on the government side, the local district administration would set up an appropriate committee comprising experts and officials to advise and to coordinate the activities of different rural microplanning organisations operating within a district.

Microplanning process

In formulating microlevel plans by the villagers lying within a small and well defined catchment basin, the first step should be identification of the human settlements to be planned for and demarcation of the drainage area delimited by micro-watersheds or waterparting lines within which the plan programmes will operate.

In the next stage, it would be necessary to carry out rapid reconnaissance of the existing resource base within the defined microbasin. The socio-economic problems of the area would then have be identified (cf. Zilla Parishad Medinipur, 1985). In the microbasin planning effort, the very first task has to be directed towards delineating the waterparting line defining a stream basin, on the ground as well as on a map at a suitable scale. If detailed contour maps of the area concerned are available, the task of demarcation would be relatively simple; otherwise, the waterparting line has to be put on a map by carrying out a proper survey with the help of survey instrument. Luckily, for the greater part of the country, maps, satellite imagery and air photographs are already there which can be made use of in demarcating the waterparting line defining microplanning areas.

A case study of microbasin planning for soil and water conservation and for improvement of the rural economy is provided by the classical example of Nalota Nala basin in Dehra Dun conducted by the Central Soil and Water Conservation Research and Training Institute (see Figures 1 and 2). The environmental impact of the current usage of the available resources within a microbasin has to be properly assessed and measures to combat the adverse impacts have to be chalked out for sustainable development of resources. The available soil and water resources have to be carefully estimated and measures to conserve and use these resourc[illegible] ithin the catchment basin should have to be suggested and project details ted c[illegible] for successful implementation of the soil and water management plan for the fit of [illegible] l the villagers. The entire operation of surveying, assessment, project formulation, emen[illegible] of programmes, administration and monitoring of the projects will have to on [illegible] body set up for the purpose by the villagers themselves.

ch [illegible] sin, whether large or small, is separated from the neighbouring basin by dge-lik[illegible] se with the land sloping down towards opposite directions. Such uprises a[illegible] known [illegible] terpartings or watersheds. Unfortunately the term watershed has often be[illegible]n wrong[illegible] sed by many to denote water catchment area instead of the waterparting line.

Conclusion

The deterioration of the fragile environment and degradation of our land and water resources can be effectively checked and the economy boosted up by adopting microbasin development approach for rural areas in India. Obviously, the basic unit of economic development in such an approach is the village or human settlements located in a definite microriver basin which is the only viable hydro-geological unit for management of soil and water resources. Since in such an attempt the village people concerned can be directly involved as participants in plan formulation, execution and monitoring, the system becomes automatically sustainable.

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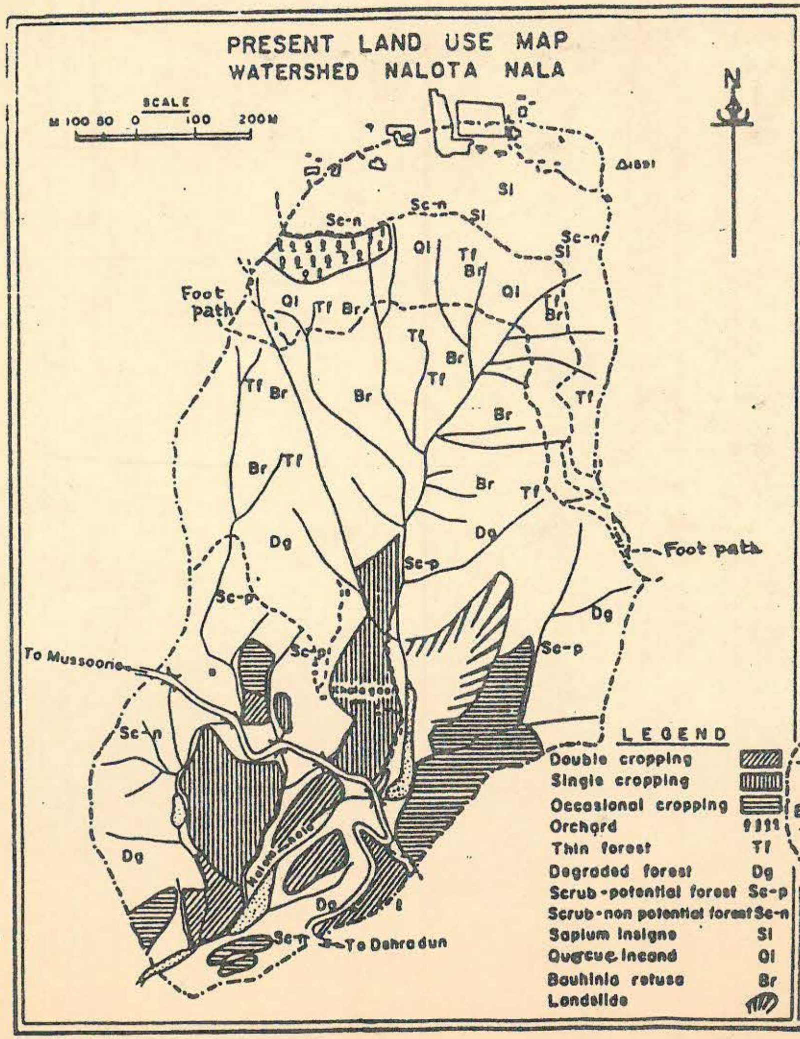
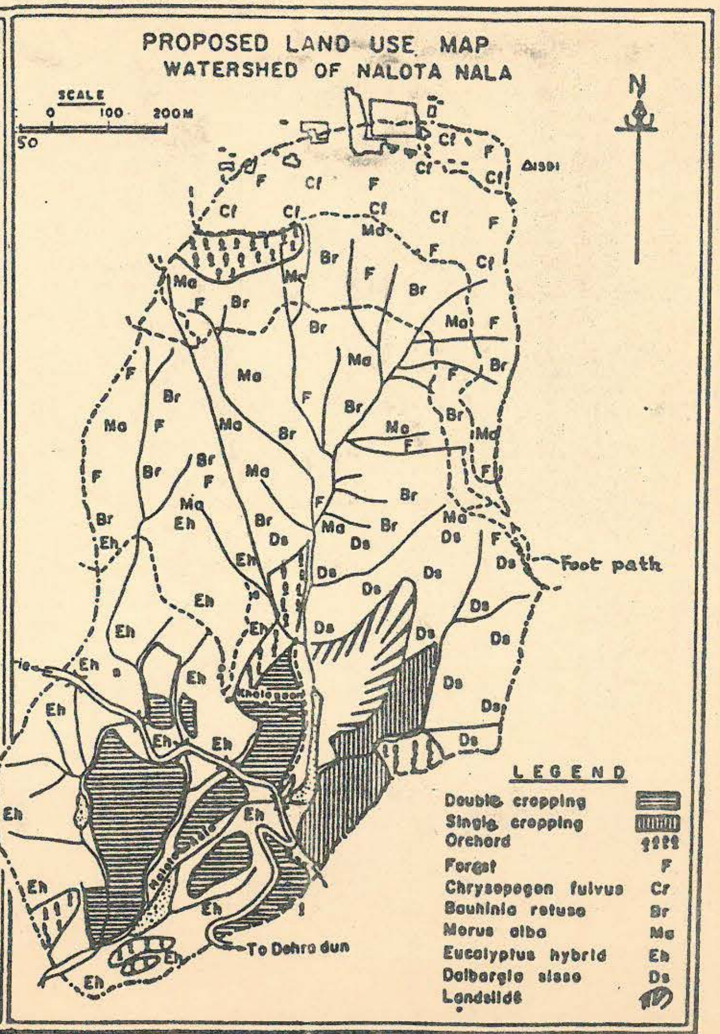


Fig. 1



Source: Dhruva Narayana et al. (1990)

Fig. 2

SEDIMENTATION AND HYDROGEOLOGICAL CHARACTERISTICS OF THE ICHHAMATI-BIDYADHARI INTERFLUVE AREA, WEST BENGAL

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The present paper concern with the study of sedimentation in various stages in the Ichhamati-Bidyadhari Interfluve area, West Bengal and its hydrogeological characteristics. The Ichhamati-Bidyadhari interfluve area is covered by alluvium of quaternary age deposited by the Ganga and its tributaries. The top of the alluvium is clayey in nature and becomes sticky when wet. Fine sand and silty clay cappings also occur in small patches in the alluvium. A succession of Tertiary and Mesozoic formations within the depth range of 350-400 m is established by drilling. The Mesozoic floor, which is encountered at a depth of 3,529 m b.g.l. in the northern part and in the south - western part it is 4,041 m b.g.l. indicating the gradually increasing thickness of the alluvium south east ward towards the sea. The pleistocene floor, which is established at 183-189 m b.g.l. from the Palaeontological evidences at Algaria ($22^{0}45'$ N and $88^{0}30'$ E) and Khamatkulla ($23^{0}03'$ N and $88^{0}46'$ E) is expected to be encountered at greater depths towards south.

In this area the boreholes drilled down to the maximum depth of 446 m b.g.l. for groundwater exploration in the southern part reveal a succession of coarse to fine grained sand, clay and kankar and their various admixtures with localized patches of gravel and cemented sand grains. On the other hand, the sand horizon which appears at the surface of the northern part of this area is overlain southwards by a gradually thickening clay bed. The sub-surface geology in the southern part of the area in found to be consisting of a thick succession of unconsolodated sediments comprising clay, silt of various colours and grades and gravel. The top surface in this tract is marked by a effective clay blanket, whose thickness varies from 15-76 m. Undertaking the clay blanket occurs a huge thickness of sediments composed of fine to coarse sands, fine gravel, silt and clay. The gravel horizon appears to have thickened eastwards. This gravel horizon may be considered as a marker horizon which is underlain by another extensive clay zone at varying depths and beneath this clay zone occurs a second group of aquifers in the depth range of 180-330 m with considerable aerial extent. Hydrogeologically this second group of aquifer is most important as it contains fresh-water of considerable reserves in the area, where surface water as well as ground-water occurring at shallow depths are significantly saline.

From the structural point of view this area forms a part of the Bengal Basin occurs the south western part of the Ganga Delta proper. It is built by a huge thickness of marine deposits of sub-aqueous nature in the estuaries of the Hooghly - Pandua - Meghna. Geophysical surveys carried out by the Geological survey of India indicated a depositional break in the Bengal Basin, where the extent of the Mio-Pliocene unconformity is rather uncertain because of the nonpersistent seismic reflector. The sun-surface is marked by a flexture zone commonly known as the Hinge zone, which is of regional important passes through north-western region. This hinge zone of the area has been defined as the zone of faulting between the stable shelt zone and the geosynclinal trough and played a major role in the tectonic and depositional history of the Bengal Basin. Moreover, the nonpersistent, seismic reflection in the zone of flexure passing through extreme western part suggests the possibility of a change in the lithofacies. The facies change from arenaceous to argillaceous sediments of the deeper basin are found in the younger Tertiary particularly Miocene and Pliocene sections.

Another notable observation is the pronounced changes in the lithofacies in the Tertiary section suggest that the depositional environment of the Bengal Basin changed from stable shelf to deeper basin conditions in the western part.

Practically, the occurrence and movement of groundwater is controlled by the primary porosities of these sediments. As evident in this area groundwater occurs both under water table and confining conditions. Clay beds generally act as confining layers in parts of the area where groundwater occurs under confining conditions. In the extreme southern part of this interfluve area and specially in the active delta of the Ganga, groundwater occurs under confining conditions. A fresh water group of aquifer system occurs here within the depth span of 120-300 m sandwitched between saline aquifers. In this interfluve area the behaviour of groundwater level follows the general trend i.e., it is highest in August and lowest in April corresponding to high and low incidence of rainfall in July-August and January-March months. The similar relation exists between the behaviour of piezometric surface and rainfall distribution pattern. In major parts of the area, seasonal fluctuation of water level is 1-3 m while in isolated pockets in the extreme northern parts of this interfluve area is records greater fluctuation of 3-5 m and it is even less than 1 m in general. Recent groundwater exploration in this deltaic tract by the Central Ground Water Board has established that 30-40 m thick such aquifer tapped by standard designed tube well may yield about 100 m^3/hr. of fresh water. In this area the chloride content of groundwater is within permissible limit. The high concentration of chloride in the groundwater in the upper aquifers is probably due to contamination of groundwater owing to sea water intrusion because of proximity to the sea and tidal influence. By and large the groundwater is characterized by $Ca-Mg-HCO_3$ type in the western part of the Ganga and in the eastern and southern part sodium and chloride ions increases gradually changing its quality to Na-Cl type in lower Gangetic plain of Southern West Bengal. The electrical conductivity ranges between C_1 and C_2 in the Western and C_3 and C_4 towards eatsern and southern parts. In some of the wells of this interfluve area sodium content of groundwater is moderate in the higher side. Excess iron content in groundwater in isolated patches in this area are due to the acidic nature (pH values vary from 6.5 to 7.2) and high TDS content of water. The floride content in this area is slightly more than 1.0 mg/l. Since as per the Indian Council of Medical Research the upper limit of flouride content is 2.0 mg/l, groundwater is quite suitable for drinking purposes even in these area. Anyway, in the event of prevailing hydrochemical and hydrodynomical situation, any large scale groundwater development in this interfluve area need to be planned scientifically so that over exploitation of such aquifers may not cause saline water intrusion into otherwise fresh aquifer system. Because of deltaic environment of deposition of sediments, the aquifer are made of very fine to fine sands which require special attention in designing tube wells in this interfluve area.

Analyses of hydrogeological and chemical data furnish valuable result on the groundwater regime characteristics of the various hydrogeological units identified in West Bengal. From the studies and analyses of these data it has been possible to have an idea about the pattern of groundwater movement and direction of groundwater flow in the entire parts of this interfluve, annual recharge of groundwater and seasonal variation characteristics of water level, behaviour of piezometric surface variation consequent to large scale groundwater development, chemical composition of groundwater in time and space. Here also found to identifying and delineating areas prone for lowering of water table and pressure head where large scale groundwater withdrawal are taking place to cope up with agricultural requirements. Possible groundwater pollution hazards due to excessive agricultural activities and unplanned discharge of industrial effluents in certain areas also observed. However, there exists still considerable gap of information in certain sectors which need special attention in future planning for monitoring of groundwater regime.

In these context to strengthen the better utilization of groundwater in the VII Five Year Plan the recommendations in this area are the coastal areas where upper aquifers are brackish should be monitored as to know whether there is change in quality of water consequent to withdrawal of groundwater from underlying fresh water aquifer system. It will also help in understanding whether there will be decrease in head due to vertical percolation to the underlying aquifer system. The selected Piezometres should be fitted with automatic water level recorders. It is very essential to set up some monitoring stations still now for screening the deeper aquifers and more number of observation wells should be established in this interfluve area.

Acknowledgement :

The author is grateful to Prof. S.C. Mukhopadhyay, Head, Prof. S.R. Basu, Department of Geography, University of Calcutta, Prof. K.N. Mukherjee, Srichaitanya Research Institute, Calcutta, Dr. S.P. Sinha Ray, Director, and Shipra Banerjee, Central Ground Water Board, Calcutta, for their encouragement and suggestion in the preparation of such review paper.

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