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GOVERNMENT OF INDIA
MINISTRY OF MINES

BASE DOCUMENT

ON

"GEOSCIENCE FOR SUSTAINABLE DEVELOPMENT"

COMMITTEE - XII

CENTRAL GEOLOGICAL PROGRAMMING BOARD

GEOLOGICAL SURVEY OF INDIA

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BASE DOCUMENT ON

GEOSCIENCE FOR SUSTAINABLE DEVELOPMENT

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GEOSCIENCE FOR SUSTAINABLE DEVELOPMENT

1. INTRODUCTION

1.1 The Geological Survey of India (GSI), a premier scientific organization in the country is relentlessly pursuing its objectives to fulfill the society's requirement of minerals and raw materials for industrial growth. The objectives of GSI since inception has been to understand basic geologic framework of the sub-continent through sustained research work; to evaluate and assess economic mineral resources; to develop the Nation's Earth Science Database by taking up systematic geological, geochemical and geophysical mapping, exploration and refining it, at progressively larger scale, as per the demand of the time and application of evolving technology and knowledge base. GSI's activities extend to off-shore area and also within icy continent of Antarctica for geo-scientific studies and inventory of resources. Basic data generated and synthesized by GSI has positive impact and contributes significantly in almost all spheres of national endeavors-industrial and infrastructural development, irrigation and water resources management, mitigation of natural and public health hazards, planning communication network, environmental assessment etc. The developmental activities in the mineral and mineral – based industries, energy and water resource sectors in the country are spin-off of the geo-scientific database of GSI in these areas.

1.2 Today's society recognizes that it requires not only resources from its surroundings – its environment – for development, but also rendering this development environment friendly in order to avoid loss of natural capital and degradation of environment. Furthermore, there is recognition of temporal relationship with natural resource identified through the concept of sustainable development wherein the ethical considerations suggest that man should utilize resource to meet not only today's need, but also the need of future generation. This requires solving issues involving need and ability, ethics and practicality in the ultimate protection and preservation of environment and growth. Consequently today's society looks at the geo-science not only for providing its mineral requirement but also generating data to resolve issues of impact of developmental projects on environment, prevalence of natural hazards and health hazards. The implication is simple, that the geoscientists: geologists, geochemists, geophysicists, geomorphologists, geo-engineers, have to get together in such integrated projects of investigations. Furthermore the geo-scientists need to reorient themselves for collaborating with other branches of earth science such as biology, zoology, ecology, planning etc., to cater to societal needs. In fact, since the beginning of the seventies the Survey has been utilizing its long experience of geo-scientific database generation for providing input for geo-scientific appraisal of Regions, States, Districts, individual sites, for water resource development, urban development, mining, natural and public health hazards all over the country. This, the GSI believes holds the key for alleviating poverty by providing the basis of properly utilizing natural resources. It is imperative that such integrated approach requires cooperation at all relevant levels with networking to both collect and disseminate its database.

1.3 The Geological Survey of India (GSI) an attached office of the Ministry of Mines, which has been tasked with:-

- Preparing national geological, geophysical and geochemical maps.
- Assessing mineral and energy resources of the country.

- Creating and maintaining earth science databases and acting as a national repository of earth science data generated by various organizations and disseminating these in the public domain for development, educational and societal needs, etc.

1.4 GSI also coordinates the work of the geoscientific sector through the mechanism of the Central Geological Programming Board and its various Committees. Recently a new Committee on **'Geoscience for Sustainable Development'** has been constituted, whose terms of reference are given below:-

(i) To facilitate integration of geosciences into policy making for environmental issues and to transmit the concepts to potential interest groups including policy makers, non-governmental environmental agencies and general public.

(ii) Helping develop a framework and methodology for promoting sustainable development strategies (including optimum land use) through best use of geoscientific data gathered in the course of survey and exploration by GSI and other geoscientific organizations in the country.

(iii) Assisting nodal agencies concerned by developing new areas for geoscientific data collection, particularly spatial data such as geomorphology to help them analyse ecosystem functions and make informed planning decisions.

1.5 List of members and special and permanent invites including the NGOs of all-India stature is annexed **(Annexure-1).**

2. THRUST AREAS OF ACTIVITY BY GSI

2.1 The thrust areas of GSI's activities have evolved with the changing national priorities and are presently oriented in the light of the objectives and goals set up in the XI plan. The major thrust areas identified for of GSI are:

- Creation and updating of National geo-scientific database through specialized thematic studies, geochemical and geophysical mapping.
- Concept oriented search for concealed mineral deposits with stress on deficient and high-tech minerals.
- Seismic micro-zonation of urban clusters, active fault mapping and observational seismology for delineation of potential risk zones for geo-hazard management.
- Compilation and digitization of maps for archival and dissemination purposes.
- Modernization programmes of GSI.

2.2 Specialized thematic studies, multi-elemental geochemical mapping of the country with ultra-low detection level analytical facilities, low-altitude aero-geophysical multi-sensor surveys and ground geophysical mapping of prioritized areas have been stressed to locate so far undiscovered and/ or deep-seated/ concealed prospects/ deposits based on new concepts of ore genesis. Seabed survey will continue in Territorial Waters and parametric survey in EEZ along with preliminary assessment of mineral wealth and economic materials in seabed.

2.3 The principal thrust of GSI in the mineral exploration would remain on noble metals, precious stones, base metal, coal and lignite.

Appraisal will continue for ferrous and non-ferrous (bauxite), fertilizer, strategic, refractory and high-tech minerals. In addition, to the mineral prognostication, the organization would continue with systematic updating of the data base in the mineral resource sector to provide reliable and relevant information on mineral and other natural resources to the public and private sector entrepreneurs to sustain investment in mineral sector.

2.4 The country being endowed with about 7,500 km of coastal tract, GSI pursues its policy of carrying out studies of coastal processes, landform and geo-techniques to provide data for ameliorating coastal erosion and problems of saline water incursion in the sub-surface domain of the tract.

2.5 As a part of hazard mitigation studies, increased emphasis on environmental geology programmes, seismotectonic and earthquake process, landslide zonation studies and floods for societal needs will continue with modernization as well as upgradation of laboratories at National, Regional and Operational level facilities to provide high quality laboratory support.

2.6 Intensification of programme on digital archive and creation of database, with networking of GSI office and setting up of GSI's Portal is being pursued in right earnest and the achievement till date is very significant.

2.7 GSI's expertise in the field of engineering geology has been utilized in all major programmes of water resource development, communication and other miscellaneous projects. Thus, GSI's advises to handle geological surprises for selection of dam site, tunnels and canals alignments remain the basis of clearance for all concerned projects at feasibility, pre-construction, construction and maintenance stages. While investigations will continue to meet these demands, additionally GSI's views will increasingly be sought to provide solutions to geo-environmental problems related to these developments.

2.8 GSI takes into cognition the fact that reorientation of its jobs will definitely necessitate gearing and reorganizing its human resources to meet these needs and thus plan for appropriate training facilities and placement. The various fields of activities have been well defined in the HPC report and the following areas emerge as the priority domains of work in future for GSI:

(i) **Baseline Geoscience Data Generation:** This comprises mainly systematic geological mapping, geophysical mapping including gravity, electrical resistivity, magnetic, electromagentic, radiometric surveys through ground, airborne and marine surveys, geochemical mapping and geomorphological mapping. Hyperspectral mapping is the new field of activity under this domain. With sustainable development concept well placed, GSI may need to develop additional geoscientific baselines in future.

(ii) **Mineral Resource Surveys (Non-fuel and Non-coal):** Baseline geosciences data generation has delineated an area of around 5.7 lakhs sq. km area as potential area for future mineral search. GSI has to survey and explore minerals which have poor resource-cum-reserve base in the country. The reserve estimation by GSI has to be done on UNFC system in various phases of investigation.

(iii) **Regional exploration (Energy Resource – Non-oil, Non-atomic)**: The thrust on regional exploration for coal will be mainly focused to locate shallow level resource with quarriable potentiality, power grade coal at shallow depth, additional resource of semi-coking coal and identifying resource of coal at intermediate and deeper level. For lignite, area of exploration is envisaged to be enlarged in Rajasthan and Gujarat as well as exploration work has to be undertaken in Kerala. The future regional exploration programme will be based on the database generated on Coal Geology of the country and will have a component on regional exploration of potential areas containing deeper level resources (>900 m). High resolution seismic survey is envisaged for this purpose. Deep drilling along with multi-parametric logging will give the vital input. Coal Bed Methane (CBM), Underground Coal Gasification (UCG) and Coal to Oil (liquefaction) are the other fields of operation in the non-oil, non-atomic energy resource domain. GSI has already drawn comprehensive programme for generation of baseline data on CBM in the coal basins of thick low rank coal and in lignite fields.

(iv) **Geothermal Energy:** Geothermal energy sources will be further explored by GSI through deep drilling in collaboration with other national organization and with the help of other major geothermal energy producer countries (New Zealand, Iceland, China, and Australia). The areas of operation will be in Himachal Pradesh, Chhattisgarh, Madhya Pradesh and Maharashtra.

(v) **Research & Development:** Multidisciplinary studies including geological (petrological, structural geology, etc.), geochemical and geophysical and isotopic studies are envisaged to be undertaken. The research activities will be focused on priority mineral sector aimed at developing concept oriented exploration and ore deposit modeling, characterization of all important geotectonic / orogenic and metallogenic belts of the country to understand its crustal evolution, experimental petrology, planetary science, tracing evolution of the life forms and palaeo-environment and preparation of standard reference samples (SRS) to be used in NGCM, petrological research etc. It is emphasized that the research findings thus made, should be reported and published expeditiously.

(vi) **Engineering Geology:** This will include geotechnical investigations for sponsored multi-purpose (hydel, nuclear, etc.) and communications projects (railways, road, and tunnel), river linking projects and mine subsidence, etc. Foreign collaboration is also envisaged project based training and advanced technical know-how particularly in rock mechanics.

(vii) **Landslide Hazard Studies:** This will continue to one of the major areas of operation by GSI including zonation of the land slide prone areas according to the degree of susceptibility to landslides. This activity will be integrated with the Disaster Management Group of National Disaster Management Authority (NDMA) and will have linkages with State DMAs. Foreign collaboration with organizations like GSC, NR Can in real time monitoring of the landslides is also envisaged.

(viii) **Earthquake and Related Studies:** Mapping of Active faults including seismo-tectonic assessment of some intraplate and interplate faults, macro-sesimic surveys, seismic hazard microzonation, micro-seismic surveys and GPS monitoring for crustal movement studies will be remain the main focus of work under this. The seismic observatories will be of importance for these studies.

(ix) **Climate Change and Related Studies**: GSI will continue to undertake coastal studies, glaciological studies, desert geology (including salinity change studies), palaeo-climatic studies and initiate carbon sequestration studies along with generation of geospatial data for climate change studies. The palaeo-climatic studies will have an integrated approach with studies in Quaternary Geology, palaeontology, speleology, glaciology, ice core studies, etc.

(x) **Environmental Geology**: GSI with its repository of knowledge base of geological processes and thematic maps has been contributing in environmental studies including preparation of Environment Impact Assessment (EIA) of urban and industrial growth centers. Studies were also undertaken in mangrove areas, coastal lowlands, for assessment and remedial measures on elemental contaminations and toxicity in ground water etc. The environmental geological studies encompasses public health hazard studies (including arsenic and fluoride toxicity etc.), industrial waste disposal, and trace element hazard from fly ash in coal based thermal power plants etc. These studies by GSI for evolving site specific details for geo-environmental appraisals will involve getting into strategic partnership with other reputed organisations/ laboratories e.g. National Environmental Engineering Institute (NEERI), The Energy and Resources Institute (TERI), etc. Foreign collaboration will continue to be in vogue for researches in some of the critical areas including public health hazard studies such as Arsenic toxicity in groundwater occurrences in Indo-Gangetic plains, etc. The strategies and milestones set up for each of the above study domains are being infused in the modernization plan of GSI.

(xi) **Medical geology:** Contamination of water by geogenic and anthropogenic processes is now a major area of concern in many countries. In India also cases of arsenic and fluoride in groundwater have been observed. This has definitely led to a situation where impediment to utilization of the vital resource of water has been experienced. Studies carried out by GSI has opened a new vista for researches in these issues and further studies will definitely be the key to future unraveling of many new facets in nature and consequent identification of relevant remedial measures to meet societal needs.

3. GEOSCIENCE AND SUSTAINABLE DEVELOPMENT

3.1 Study of environment involves understanding of two major set of conditions:

(i) physical conditions and

(ii) social and cultural conditions.

3.2 **Physical conditions constitute mostly the abiotic attributes** of the environment such as the earth material, minerals, soils, water, landforms, air that together affect growth and development of man.

3.3 The social and cultural conditions include environmental parameters such as the ethics, economics, aesthetics, etc. which affect the behaviour of individuals or a community.

3.4 Environmental geological appraisals of a terrain recognize the potential hazards and resource utilization pattern. These investigations are either site specific or problem specific respectively. Environmental geoscientific studies by GSI involve preparation of various thematic and derivative maps, syntheses of collateral and primary data and finally integrated comprehensive and synoptic output is generated in the form of geoenvironmental maps showing environmental hazards and the potential resource utilization pattern. Based on the land-capability assessment, a suggested landuse map is prepared for overall regional development and optimum resource utilization for sustainable development in the area.

3.5 Further specific details on the various geofactor considerations and analyses of their environmental impacts are provided and discussed in the following sections.

4. APPLIED ASPECTS OF GEOMORPHOLOGICAL MAPPING

4.1 Geomorphological maps contain information concerning the (i) *morphology* (appearance of landform), (ii) g*enesis* - effects of passive (in terms of lithology) and active (in terms of tectonic) structures, (iii) the *dynamic relief forming processes* (endogenic and exogenic) by various agents viz. fluvial, glacial, structural, volcanic, aeolian, marine, denudational etc.), (iv) *age/relative age* of the relief (morphochronological view point) and (v*) spatial arrangement of various relief elements* and their interrelationships(morpho association/ morphofacies or morphoregions) for facilitating geomorphological regionalization. Besides, the geomorphological maps must consider the practical significance of the relief to man.

4.2 Geomorphological Survey and Mapping may be directed to different aims. Thus there can be following types of geomorphological surveys and maps:-

(a) General Geomorphological Survey and Mapping concerned with the sculptures, genesis, dynamics and age of the relief forms and conditions of modeling.

(b) Special Geomorphological Map concerned only with particular aspect of information about relief forms i.e. morphology, genesis, relief forming processes, age and value added information.

(c) Applied Geomorphological Survey and Mapping provide basic information about the relief (information mostly detailed in General Geomorphological Maps) plus value-added information to achieve different goals.

(d) Regional Geological Survey and Mapping concerned with regional differentiation of relief (with respect to lithology, structure, forms and age) for both General and Applied Geomorphological Mapping.

4.3 The scale of mapping is very important for both General Geomorphological Mapping and Applied Geomorphological Mapping. In larger or medium scale geomorphological mapping, relief forms (morphostructures) must be connected with the tectono-lithologic conditions; while in case of smaller scale geomorphological mapping it is not connected.

4.4 Landscape modifications have been going on owing to the geomorphic processes operating over the earth materials. However, their magnitude and frequency are subject to change due to natural and man-induced changes which have been very rapid in recent times. Hazardous earth processes must be recognized and avoided where possible so as to minimize threat to human life and property. Since most natural systems are self-regulating, priority-wise response to environmental hazards should be: avoidance, stabilization (e.g. engineering measures to train a flood-prone segment of a river or arrest mobility of active dunes by suitable plantations, etc.) and provision for safety in civil structures, e.g., incorporation of recommended a-seismic designing, etc.

4.5 Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. The scope of geomorphology has further expanded with the landform maps finding increasingly wider applications in various fields of resource surveys, environmental analysis, hydrological studies, Civil engineering applications and geo-tectonic studies, urban planning etc. Thus it is desirable to map the entire country on 1:50,000 scale due to demands from various user communities mentioned above. Geomorphology and landscape mapping also forms an important input for National Geochemical Mapping Programme of GSI.

4.6 Similarly, the significance of lineaments, which 'reveal the hidden architecture of rock basement' has been recognized only recently with the advancement in geologic remote sensing data imaging. Lineament studies have found applications in various fields of earth science such as global tectonic studies, delineation of litho-contacts and tectonic units, analysis of deformation pattern, ground water and oil exploration, geo-technical and geo-engineering applications and seismo-tectonic studies. Also, with the advancement in digital image processing techniques, the satellite data in conjunction with Digital Elevation Model (DEM) have great potential in lineament detection and mapping. Therefore, there is a need for detailed lineament maps of the entire country, which along with landform maps could form the basis for applications in various fields of earth science.

4.7 With this background, the need for taking up a nationwide project of **Geomorphological and Lineament mapping** under the **NNRMS Standing Committee on Geology and Mineral Resources** (NNRMS SC-G) was discussed in detail. Based on the recommendation of SC-G, GSI and Indian Space Research Organization (ISRO) jointly carried out the pilot project in different geomorphic provinces. The results of the pilot study were presented recently in NNRMS SC-G meetings. The Chairman, NNRMS SC-G & Secretary, Ministry of Mines, Government of India, while appreciating the requirements for taking up such an important national mission, desired a joint project proposal by GSI and ISRO under the purview of NNRMS SC-G. The project proposal was prepared by a Committee constituting the members from both ISRO and GSI. The Project has been under implementation since February 2010 with rigorous quality checks on output maps in place.

(a) Objectives

The proposed project envisages the following two objectives:

- To map landforms for the entire country on 1:50,000 scale, (and on digital version)
- To map lineaments of tectonic and structural significance and classify them for the entire country on 1:50,000 scale.

(b) Pilot Projects

Initially five pilot projects were taken up as representative of various geomorphic provinces.

S.No.	Area	Geomorphic Province	Lead Responsibility
1.	Mahanadi Delta, Orissa	Coastal landforms	GSI
2.	Kulu, Himachal Pradesh	Structural landforms	GSI
3.	Jalore, Rajasthan	Arid landforms	ISRO
4.	Tiruchirapalli, Tamil Nadu	Denudational landforms	ISRO
5.	Hoshangabad, Madhya Pradesh	Denudational and Structural landforms	ISRO

(c) Recommendation of the task team after completion of Pilot Projects

1. The historical (legacy) database could be consulted during mapping process.

2. Fresh mapping needs to be carried out under National Natural Resources - Repository (NNR-R) since aggregations, reclassification and updating would be time consuming using the historical database.
3. Some of the older maps prepared in the Quaternary cover requires updation using latest satellite data because of dynamic nature.
4. The satellite data base created for three season NNR-R landuse (Rabi data acquired) can be used as an input for NNR-R Geomorphology.
5. On screen interpretation could be faster on this data rather than boundary adjustments

(d) **Software customization and classification scheme:** Genetic based National Legend Scheme has been formulated by the team consisting GSI and NRSC/ISRO members which is incorporated in the customized software *NRCGeom*, based on ArcGIS platform for carrying out onscreen interpretation.

(e) **Quality check: Stage-1 (Internal Quality checking)**: Internal Quality checking by the work centres with identified focal point as certifying authority. This checking should be carried out at two stages – pre field and post field. This should include quality checking of thematic boundaries, verifying with the legacy database, confirmation to the geo-database standards as per the manual.

Stage-2 (External Quality Checking): After the internal quality checking, the external quality checking will be carried out after post field interpretation. The external quality checking of the map will be carried out teams from GSI and ISRO.

i. If necessary, field checks may be done along with the workers.
ii. SOP for quality has been prepared with detailed guidelines.

5. GEOENVIRONMENTAL AND RELATED STUDIES

5.1 The major physiographic regions of India comprise deserts, semi-arid areas, vast fertile alluvial plains, densely forested regions, coastal tracts, mountainous areas etc. The scientific management of environment in these different physiographic domains is likely to provide a possible key to the solution of India's basic problems of poverty and unemployment. Programmes of scientific management of environment will no doubt have to be drawn up specifically in relation to the different situation.

5.2 Geoenvironmental studies focus on the future trying to predict geosystem response to various types of active interactions. It is an in-depth treatment of the relations between man and his geologic, geomorphic, physical and cultural environments. Environmental geology is essentially the geology of interactions amongst various geofactors. Environmental geological appraisals of a terrain lead to recognition of potential hazards and natural resources potential and deals in either the site or commodity specific as well as the problem specific aspects of environmental impacts. Investigations on geologic environments include: river basins or hydrological systems, contamination of groundwater regime, dryland environments such as the deserts and aspects of desertification; coastal environments processes of erosion and deposition; cold environments and glaciers, naturally hazardous earthquakes, active faults, volcanic eruptions, mud flows, landslides and mass-wasting events, etc., and above all the bio-geochemical cycles and human health. Anthropogenic activities and changing land use practices have accelerated the pace environmental degradation in rural and urban areas. Mining and processing of minerals and rocks have posed another set of geoenvironmental problems that required their impact assessment and suitable remediation.

5.3 Several geoenvironmental investigations which are essentially multidisciplinary and adopt a comprehensive and integrated approach have been carried out in different terrain conditions in India. These include flood hazards, landslides, earthquake related natural hazards, water-logging and salinity/ alkalinity aspects, urban and rural development, environmental degradation due to resource exploitation, mining areas and soil erosion and watershed management, environmental impacts of surface water reservoirs, dams and barrages, coastal dynamics and shore-line changes, medical geological and geotourism studies, etc.

5.4 Regional geoenvironmental appraisals are carried out on 1:250, 000 scales and the site or problem specific Environmental Impact Assessment (EIA) and Environmental Management Plans (EMP) are generated on 1:50,000 or larger scales of mapping. Geoenvironmental hazards are categorized into natural and/ or man-induced or anthropogenic. Integration of total geoenvironmental data results in evolving a suggested landuse map depicting remedial measures where required. There are two types of resources: 1) those that must be extracted and processed/ utilized elsewhere, 2) those that are utilized in place, e.g., valley floors, coastal environments, beaches, mountains, deserts which may be naturally attractive for recreational use and eco-tourism. Other resources used in place, but partly extractive include: watersheds, groundwater aquifers and soils from which water and crops nutrients are extracted by fauna and flora.

5.5 Consequent to India's whole hearted support to the formal declaration of United Nations Conference on Human Environment at

Stockholm on 5th June 1972, geoenvironmental investigations in GSI were given due importance in formulation of its annual programmes of investigations. Urban geological and related geoenvironmental investigations were initiated in 1974 for the Delhi Metropolitan Area – the national capital city and the twin cities of Hyderabad–Secunderabad in Andhra Pradesh (GSI, 1978).

5.6 Systematic geological studies in Geological Survey of India were initiated in 1968 for specific environmental problems or phenomena with Quaternary geological and geomorphological investigations on the Bramputra river regime for aiding flood control planning. Further diversification took place in 1970-71 with initiation of studies on urban geology and regional development and district level multi-disciplinary studies on 1:250,000 scale, beginning with drought prone and backward rural areas of Anantpur district in Andhra Pradesh and Puruliya district in West Bengal (GSI, 1979 and 1980).

5.7 Geoenvironmental studies in GSI involve preparation of different thematic maps and delineation of hazards vulnerability, both due to natural as well as anthropogenic causes. Accordingly maps are generated on geology, lithology and mineral/rock resources, geomorphology and landscape evaluation including drainage pattern and slopes; soils types and distribution, geotechnical attributes and neotectonic features, geohydrology: groundwater distribution depth to water status and quality and surface water resources; landuse - landcover aspects. Several **derivative and synoptic maps** are prepared based on these basic data sets and thematic maps that help in improved understanding of the natural geofactors leading to preparation of desired and suitable or suggested landuse maps.

5.8 As the different maps so prepared are to be utilized by the district planners and public at large, environmental geological maps are prepared in user friendly manner. Applications of such thematic maps in planning of developmental programmes for the district were proved fruitful when targeted drilling was carried out over the suggested and delineated zones of colluvium / alluvium traversed by interpreted lineaments in drought prone district of Anantpur in Andhra Pradesh. Further based on various thematic maps prepared for the area, sites were suggested that would be suitable for urban waste disposal, wild life sanctuaries, development of fisheries and live-stock rearing, brick manufacturing and lime kilns, water supply for urban areas and potential areas for groundwater development and delineated different landscape units and land capability classes for different and sustainable utilization of available resources.

6. GEOCHEMICAL CHARACTERIZATION OF LANDSCAPE

6.1 Geochemical characterization of landscape, soils and water is also attempted systematically for environmental interpretations besides mineral targeting and remedial measures. **National geochemical mapping** (**NGCM**) programme of GSI has added several new elements in the database generation. This now includes fluoride analyses for stream sediments and soils besides already available inventory of major oxides and trace elements. Fluoride provides important environmental information from human health point of view. Soils/sediments put to agricultural use with more than 200 ppm F values are unsafe and induce toxicity in the cultivated produce.

6.2 On the basis of the NGCM surveys done GSI till date a few anomalous zones viz. Base Metals in Western Region, Gold in Eastern Region and REE in Southern Region have been identified by GSI. Based on such elemental dispersion anomalies, new FSP items were formulated involving detailed sampling and mapping of the areas and these are in progress in these Regions. A few examples of ongoing investigations consequent to the NGCM analyses and appraisal are given in the following sections.

1. Agri-Geochemical Interpretation and Environmental Application: Study based on NGCM Programme in Rajasthan - Case Study from GSI WR uploaded in GSI Portal

- The study area falls in parts of toposheet numbers 45K/3, 4, 7 & 8 covering parts of Bhilwara, Chittaurgarh and Rajsamand districts. The cultivated areas have been sorted from the field observation data and superimposed on the distribution maps of Chromium, Zinc and Phosphorous, which are of primary importance to plants and agricultural practices. The micronutrients are important components of soil and plant enzyme systems, which catalyze and regulate all biological functions when ingested by mammalian life forms. Potential hazards associated with trace element pertain to their accumulation in soils, which may either lead to toxicity condition or result in increased uptake of metals into the food chain.

- Most of the areas under cultivation show Cr values exceeding 65 ppm with certain areas having values between 160 to 190 ppm contributing toxicity to the soil. This may be due to the presence of mafic intrusive bodies. However, the UK standard reveals the areas falling in the range of above 130 ppm are not occupied by agricultural /cultivated field.

- From the agricultural point of view the entire area appears to be free from any Zn toxicity or deficiency.

- The study area shows a relative enrichment of phosphorus in the sectors with agricultural land use. The reason may be due to excessive use of phosphoric fertilizers in the agricultural fields. The higher concentration of phosphorous, which is above the normal range, is observed in the northwestern part of the study area, which in turn is not occupied by any cultivation / agricultural activity.

2. Re-evaluation of the stratigraphy, structure, metamorphism of Karoi- Rashmi area of Pur -Banera belt, Rajasthan for

Metallogenic prognostication - Case Study from GSI WR uploaded in GSI Portal

As a spin off of NGCM programme, an approved item on investigation for Basemetals in Karoi-Rajpura Area, Pur-Banerabelt, Bhilwara District, Rajasthan was taken up for evaluation. Surface indication of basemetal mineralisation in the area is expressed by magnetite rich rocks, profuse malachite staining and disseminations of pyrite, chalcopyrite, bornite and galena. Cu, Pb and Zn values of up to 0.73%, 0.75% and 0.73% has been recorded in bedrock samples collected from different litho-units. On the basis of these evidences, potentially mineralised areas are identified in the vicinity of Karoi, Bassi to Karjiakhera, and Sopura. The item is being continued for further evaluation.

3. Based on Au values, in T.S. 45K/1,2,3,5 and 6, Preliminary investigation for gold in parts of Ajmer and Bhilwar districts, Rajasthan, was taken up by project : Gold in 2005-07. However, the results were not encouraging

NORTHERN REGION

State Unit: J&K

4. The NGCM sampling from Hanle area of Indus Ophiolite belt, which runs parallel and to the south of Shyok Tectonic Belt has shown encouraging results for Cr, Ni, Co and Cu elements. The scanning of the Shyok Tectonic Belt for these elements during the course of investigation is also proposed.

The Siwalik Groups of rocks and the sediments derived from them have indicated 0.1 to 0.14 ppm Au in Mawa Brahamana area 43 L/9, Jammu district. The NGCM sampling of the 43P/3 was taken up in the Jammu Province for the field season 2009-10. NGCM of only one sheet (52L/13) was done during field seasons 2002-03 to 2004-05 that lies in Indus Ophiolite belt and results of Cr, Ni, Co & Cu are encouraging. As a spin off, further geochemical mapping in the nearby 52L/14 & 52K/1 sheets is proposed to fix up the regional geochemical anomaly of the area during field seasons 2010-11 & 2012-13.

SOUTHERN REGION

State Unit: Andhra Pradesh

5. NGCM study has indicated some anomalous values of gold in 57E/12, radioactive nature of granites in 57E/3 and anomalous zones of REE in parts of 57M/11.

6. Local inhabitants of the area falling under T.S.: 57M/10&11 are found to be severely suffering from various health problems which appears to have been resulted due to the consumption of polluted water from various sources, which are contaminated with REE and toxic elements.

7. NGCM spin off programme of preliminary search of Molybdenum and REE in Kanigiri area, Prakasam district has led to the delineation of a 40 to 70 Cm wide mineralized zone of app. 100 m strike length besides, some anomalous concentration of Mo, Pb and Zr in adjoining areas.

State Unit: Karnataka &Goa,

8. Analytical data from toposheets 56D/8,11,12,15 & 16 indicate anomalous zones of REE, U, Th, Nb,Zr and Hf over granitoids on the eastern and northern side of the Hatti-Maski Schist Belt. A 25 m long Cu enriched zone beyond the occurrences of Tinthini Cu prospect has been identified besides, some higher values of Fe Ti, V and Sc.

State Unit: Tamil Nadu and Puducherry

9. During the F.S.2001-02 to F.S.2009-10, higher incidences (compared with crustal abudance) of gold, REE, U, Th, Zr and Hf have been recorded in few composite stream sediment samples collected in toposheet 58J/5,58I/4, 7&8. Consistent lean values of gold (5 to 73 ppb) are recorded over a stretch of 7 km, along the south flood plain of Cauvery River inT.S.58J/5. However, no well defined probable economic zone is identifiable.

State Unit: Kerala

10. Till F.S.2009-10, under National Geochemical Mapping programme, interpretation of the analytical data of the first phase of NGCM carried out during F.S. 2003-04 and 2004-05 in T.S. 58A/4 and 58B/1 lying southwest of the Nilambur Gold Belt of Malappuram district indicate significant geochemical anomalies for Au, Th and REE. Two distinct gold anomalous zones (zone-I & zone-II) have been brought out by the NGCM studies in Toposheets 58A/4 and 58B/1. As these zones are inferred to continue in adjacent Toposheets (49M/16 and N/13) geochemical mapping was extended into these sheets during F.S.2009-10 for the delineation of the westward extension of the anomaly zones. Geochemical mapping is being continued in the area in the F.S.2010-12 besides, a new item of GCM in T.S. 49M/15 has been taken up in F.S.2010-12.

11. Gold Anomaly in the Precambrian Rocks in and around Viyyur area, Thrissur District, Kerala – A NGCM finding already uploaded in the GSI Portal as case study.

Geochemical mapping brought out incidence of gold mineralization in and around Thrissur covering Toposheet 58B/2 bound by north latitude 10°30’ and 10°45’ and east longitudes 76°00’ and 76°15’. Occurrence of gold was hitherto unknown from this area. The area of study forms part of the Southern Granulite Terrane and falls south of Palghat-Cauvery Shear Zone.

EASTERN REGION

12. Based on Au values(3 ppb to 95 ppb) in Rudra area in T.S. 73J/09, Bankura dist,WB, a two year MIP item has been taken up for gold prospecting.

13. Processing of NGCM data for Gold in T.S. 73J/16 has yielded two zones with anomalous Au content of 145 ppb and 120 ppb at Tilkanali and Kelepathar area, Bankura dist, WB. A two year MIP item has been taken up for gold prospecting.

14. Based on Niobium anomaly in T.S. 73I/08 apatite investigation was taken up around Madnitner and Beldih, Purulia dist, WB. The apatite deposit is associated with carbonatite complex enriched in REE and Nb.

NORTH EASTERN REGION

15. Geochemical mapping in Bomdila-Dirang-Mathow area, West Kameng district, Arunachal Pradesh - A Case Study (Uploaded in the GSI Portal).

Field observations made during GCM mapping also has resulted in identifying the following significant features related to geology and mineralization of the area:

- A widespread zone, about 500 m along the road, of intermittent sulphide mineralization is identified within NW-SE trending and moderately dipping towards west, greenish laminated cherty quartzite interbanded with biotite schist, partly ferruginised/ gossanised, of Dirang Formation along Mandela-Nagagji road at 5 km from Mandela road-crossing.
- Presence of black, possibly graphite bearing horizons are identified at several places within schists and quartzites of Dirang Formation e.g. at (i) about 5 km on road from Mandela road-crossing (close to sulphide zone), (ii) about 3 km from Mandela road crossing along Mandela-Phudung road, (iii) south of Pangma on Thembang road, (iv) 3 km from Jeri on Selari road section, (v) as small boulders near Khenda Ro and NE of Rahung near GCM site 056. Analytical results of geochemical samples are awaited.

- An incidence of kyanite showing upto 10 cm long blades is seen associated with vein quartz within garnetiferous biotite schist in a boulder paved in foot track at about 500 m before Bishun on Phudung-Bishun track.
- Pebbles of fuchsite quartzite are seen at GCM site 066 southwest of Cherong; and also near GCM site 051 west of Munna camp.

16. Preliminary exploration of base metals in the area between south of Nongpoh and north of Umran (P-1), Ri-Bhoi district, Meghalaya was taken up based on Cu Pb Zn etc. anomalous values in 78O/13 toposheet.

7. HEALTH AND MEDICAL GEOLOGY

7.1 Medical Geology is the science dealing with the relationship between natural geological factors and health in humans and animals and with understanding the influence of ordinary environmental factors on the geographical distribution of such health problem. It is a broad and complicated subject that requires interdisciplinary contribution from various scientific fields if its problems are to be understood, mitigated, or resolved. Medical geology, which focuses on the impacts of geologic materials and processes (i.e. the natural environment) on animal and human health, can be considered as complementary to environmental medicine. The field of medical geology brings together geoscientists and medical and public health researchers to address health problems caused or exacerbated by geologic materials such as rocks, minerals, and water and geologic processes such as volcanic eruptions, earthquakes, and dust.

7.2 Any increase in the amount or concentration of elements in human body causes increasing negative biological effects, which may lead to inhibition of biological functions and, eventually, to death. However, despite the harmful effects of some elements, others are essential for life. Therefore, deleterious biological effects can result from either increasing or decreasing concentrations of various trace elements. Thus, as with many aspects of life, either too much or too little can be equally harmful. All of the elements that affect health are found in nature and form the basis for our existence as living creatures. The periodic table of elements, as an indicator of the roles played by the elements in the biosphere, is the basis for our understanding.

7.3 Geology may appear far removed from human health. However, rocks and minerals comprise the fundamental building blocks of the planet and contain the majority of naturally occurring chemical elements. Many elements are essential to plant, animals, and human health in small doses. Most of these elements are taken into the human body via food, water, and air. Weathering processes break down rocks to form the soils on which crops and animals are raised. Drinking water travels through rocks and soils as part of the hydrological cycle and much of dust and some of the gases contained in the atmosphere are of geological origin. Hence, through the food chain and through the inhalation of atmospheric dusts and gases, human health is directly linked to geology.

7.4 The volcanic eruption of Mount Pinatubo is a splendid example of the dramatic effects of geology. Volcanism and related activities are the principal processes that bring elements to the surface from deep within the Earth. During just two days in June, 1991, Pinatubo ejected 10 billion metric tones of magma and 20 million tonnes of SO2; the resulting aerosols influenced global climate for three years. This single event introduced an estimated 800,000 tonnes of zinc, 600,000 tonnes of copper, 550,000 tonnes of chromium, 100,000 tonnes of lead, 1000 tonnes of cadmium, 10,000 tonnes of arsenic, 800 tonnes of mercury, and 30,000 tonnes of nickel to the surface environment (Gerrert, R.G. 2000) Volcanic eruptions redistribute many harmful elements such as arsenic, beryllium, cadmium, mercury, lead, radon, and uranium. Many other redistributed elements have indeterminate biological effects. At any given time, on average, 60 volcanoes are erupting on the land surface of the Earth, releasing metals into the environments. Sub-marine volcanism is even more significant than that at continental margins, and it has been conservatively estimate that at least 3000 vent fields are currently active along the mid-ocean ridges.

8. URBAN GEOLOGICAL STUDIES CARRIED OUT BY GSI

8.1 Urban geological studies provide vital integrated earth-science information to decision makers on natural potentials and limitations of subsoil, geotechnical prosperities of the foundation media and groundwater conditions in terms of quality and potential and recharge characteristics, areas vulnerable to hazardous geological and natural geomorphic processes: intense gully erosion, slope instability, areas prone to flooding and land subsidence, coastal erosion/ aggradations and coastland management for sustainable development. Considering the fact that as per United Nations, about 50% of the global population will be dwelling in urban centers by 2050. Therefore, urban geological studies must form a very important area of geoscientific investigation.

8.2 GSI has carried out urban geological studies since its first venture into the area at the Twin Cities of Hyderabad-Secunderabad. Since then GSI had carried out detailed investigation for Delhi, Itanagar, Kohima, Vishakapatnam, Chennai, Mysore, Bangalore, Patna, Ranchi, Kolkata, Asansol Urban Area, Durgapur, Mumbai, Ahmedabad, Jaipur, etc.

8.3 The geo-engineering studies for a Rapid Transit System by GSI in Delhi ultimately emerged as a Geotechnical Project in the 1970's and 80's and helped in generation of data on geology, landforms, geotechnical properties of soil, surface water, groundwater, georesource and geohazards. Subsequent studies have also helped in identification of area suitable for urban waste disposal. The interaction with Delhi Development Authority in the early days ultimately led the Dept. of Science and Technology to request GSI to provide the database for further planning and also to carry out seismic micro-zonation for the capital city.

8.4 Similarly, the Calcutta Metropolitan Development Authorities, on the basis of a MoU, had requested GSI to generate data on micro-relief, slope and drainage, geotechnical foundation properties of the sediments, groundwater and landcover in nine selected sectors of CMDA. The GSI findings have not only been highly appreciated by CMDA and internationally as the programme was taken up at the instance of Forum for Urban Geology Asia-Pacific after both CMDA and FUGAP had appreciated an earlier comprehensive study of CMDA carried out by GSI.

8.5 Brief descriptions of some representative on various Urban Geological studies carried out by GSI during the recent years are given below:-

1. Geo-environmental appraisal studies have been carried out in **Asansol-Durgapur** area primarily to delineate future settlements in the areas. Major landcover, landuse classes have been identified and natural/anthropogenic geo-hazards recorded in the maps. Seasonal flooding in the low-lying areas is also a common hazard and has been delineated on maps.

2. Study of urban agglomeration of **Mysore City** and its environs reveal that the environmental hazards are due to natural as well as anthropogenic factors. The fresh water lakes and the streams traversing the area are highly polluted due to heavy silting, weed growth, dumping of garbage and municipal sewage. The major lineaments associated with thick weathered zones in migmatite-gneissic terrain facilitate rapid migration of pollutants and pathogens both in horizontal and vertical directions resulting in wider ramification of contamination. The groundwater quality is generally poor due to high contents of salt nitrate, chlorides and hardness and bacteriological contaminations.

3. Geo-environmental studies around **Rajahmundry and Kovvuru**, East and West Godavari districts of Andhra Pradesh revealed that in spite of the discharge of untreated urban sewerage into Godavari River, water quality at intake point of municipal drinking water supply to Rajahmundry town is within safe limits. The area falls under arable land with red sandy soils over the Traps, Tertiary sandstone, and deltaic alluvial deposits. The area in and around Kovvuru is prone to flooding.

4. Geo-environmental assessment in **Hazaribagh** and adjoining areas of Jharkhand showed that the area comprises plateaus, residual hills and intermountain valleys. Geological, geomorphological, drainage and landcover maps have been prepared and study of soil profiles in various sections i.e., measurement and logging of borrow pits have been carried out to prepare geotechnical profiles for foundation grades.

5. Geo-environmental appraisal of **Durgapur-Panagarh urban agglomerate** in West Bengal have recorded four geomorphic units namely lateritic uplands, older alluvial surface, younger alluvial surface and present day surface. Developments of badland topography with extensive gully erosion and unpaired terraces have been observed. Pre and post monsoon measurements of DTW in dug wells have recorded fluctuations of 0.74-13.90 m and 0.90 – 12.50 m. respectively. Land cover units identified by PGRS studies are urban settlement, rural settlement, water body, agricultural land, fallow land, forest land and airstrip. Though field geologists identified certain signatures of neo-tectonic movement in field, the geophysical MEQ data have shown very low seismic activity.

6. The geoenvironmental, geohydrological and geotechnical appraisal of the urban agglomeration of **Agartala Town, Tripura,** was taken-up. The Agartala town forms a part of the Haora river basin. Five types of soil have been observed in the area under study. These are clayey loam soil, loamy sand soil, loam soil, sandy loam soil and lateritic soil. The water quality is potable except for the presence of excessive iron. The major part of the area under study is occupied by loosely compacted, light brown to deep brown sandy and silty clay with occasional sub-rounded to sub-angular quartz pebbles and fragments of fossil wood belonging to the Tipam Group. Occasionally, thin layers of weathered ferruginous sandstone and ferruginous concretions are found. Isolated patches of the Dupi Tila

Group of rocks, consisting of ferruginous concretions and fossil wood fragments are found overlying the Tipam Group of rocks in the southern part of the area. The recent deposits include (i) the point bar deposit of coarse medium sands consisting of mica-flakes and opaque iron minerals, with fine clay interlayer and (ii) flood plain materials of silty clay and fine sand and their admixture form the major portion of Haora river basin.

7. Geo-environmental appraisal studies of **Leh Township, Ladakh district**, Jammu & Kashmir, revealed that the area under study is occupied by the Ladakh Granitoid Complex, the Indus Group of rocks and Quaternary sediments. The geo-hazards identified are low TDS and low specific conductivity of surface and groundwater, land erosion accelerated by high wind velocity, incidence of silicosis reported from the local people of Chushot area, flooding of low lying areas, kakar land formation, scarcity of drinking water accentuated by high influx of tourists, poor sewerage system and absence of urban solid waste disposal site in addition to the deterioration of surface water quality and ambient air quality.

8. Geo-environmental appraisal and microzonation of **Pakyong and Soreng area of Sikkim**, have recorded incidences of landslides, rock falls, sinking spots, gully erosions etc. near the contact of the Gorubathan Formation and the Darjeeling Gneiss. The area is composed mainly of high grade Darjeeling Gneiss and phyllite-quartzite sequences of the Gorubathan Formation. Soil erosion is more pronounced on the slopes of hills comprised dominantly the Gorubathan Formation. East of Soreng major part of the area is moderately undulating and comes under cultivation mostly along gentle and stabilised slopes with isolated houses.

9. Geo-environmental appraisal of **Barddhaman Urban agglomeration** and its environs, W. Bengal, for sustainable developmental activities

was carried out over a part of Ajay-Damodar Rivers interfluves occupied by older and younger alluvium. The major geo-environmental hazards include seasonal water logging, occasional flooding and sand deposition in agricultural land during high flood, lowering of ground water level during summer, land scarification due to brick kilns and bank erosion at delineated locales.

10. Geo-environmental appraisal of **Shantiniketan urban agglomeration**, an area under Shantiniketan - Sriniketan development authority has recorded Older and younger alluvium surfaces in the study area. The surface areas, at places, are covered with lateritic hard crust and covered by residual sandy soil. At places extensive soil erosion in the form of head ward and gully erosion is observed. Standard Penetration Tests upto 10m bgl conducted at 10 different sites reveal N-value 7 to 24 in clayey silt/ silty clay where as in sandy silt, sand and concretion rich layers the N value is 18 to 54. Ground water occurs under shallow unconfined condition (5-12m bgl) and is tapped through dug wells. Post-monsoon DTW ranges from 0.45m to 10.57m bgl. Deeper confined aquifers occur at the depth range of 30-350m bgl. And post-monsoon piezometric surface ranges from 1.5 to 10.25m bgl. Land cover includes built up land (both urban and rural), agricultural land, forest land, plantation, brick kilns, ponds/lakes and rivers. Hazards identified in the area include gully erosion in laterite upland, removal of top soil in brick kiln areas, river bank erosion, seasonal water logging /flooding in low lying areas and scarcity of ground water in laterite upland area.

11. Geo-environmental studies and impact of rapid urbanization of **Bangalore area** was carried out in 310 sq. km. in and around Bangalore urban agglomeration. The area comprised a matured undulated pediplain between 700m to 900m above msl. Migmatite and gneiss are dominant rock types in the area along with linear outcrops of amphibolite and talc-tremolite schist trending N-S in the

central part. Thick lateritisation is recorded in north-eastern and eastern part of the area. Many artificial lakes located on shear zones serve as potential areas for groundwater recharge. Urban and industrial wastes are polluting both the surface and groundwater bodies.

12. Urban geological studies carried out in about 90 sq.km area around the **Aizwal town of Mizoram** on 1:25,000 scale and 7 sq.km. on 1:5,000 scale in Aizwal town has recorded geological, geomorphological, structural, geohydrological attributes of the area vis-à-vis the slope stability – an important parameter in planning developmental activity. The alternating sequence of bands of sandstones, shale and siltstone folded into a series of anticlines and synclines and traversed by faults of limited extent comprise the geology of the area. Surficial cover ranges upto 7m. 5 sets of joints traverse the rocks, of which bedding joint is significantly developed. Alluvial deposits are seen in the lower levels along the nala.

13. Geoenvironmental appraisal study of **Medinipur-Kharagpur Urban Area** and its environs forming a part of the Kansai Basin reveals that the area is covered by laterite and latosol (Lalgarh surface/Formation) in the upland area with gully erosion at places and alluvium (Sijua surface/formation and Panskura surface/Formation) in the low lying areas of the Kansai basin. In general, laterite profile is represented by hard crust and/or ferruginous concretion (*morrum*) with a thin veneer of latosol cover (0.3-0.6m thick) overlying matrix supported gravel/pebble horizon admixed with sand and silt, locally displaying bedding and cross bedding. This gravel/ pebble horizon is underlain by mottled (greyish white with brownish patches) clay/sandy clay with sharp and undulatory contact. Shallow boring down to 10m b.g.l. reveals that the mottled clay is underlain by sand horizon at a depth around 8m bgl. Groundwater occurs under both unconfined and confined

conditions. Depth range of shallow and deeper confined aquifers range from 8-15m b.g.l. and 30-90m b.g.l. respectively. The latter usually occurs in the area covered by younger sediments of Kansai River. Depth to water level ranges from 1.14m bgl to 7.16m bgl. in post monsoon and from 1.58m bgl to 14.78m bgl. in pre monsoon with seasonal fluctuation ranging from 0.15 to 11.95m bgl. Piezometric surface in tube wells ranges from 1.6m bgl to 17.63m bgl. in post monsoon and from 3.62m bgl to 20.88m bgl in pre monsoon period with seasonal fluctuation ranging from 0.3 to 14.7m. Major land cover/land use classes include built up land (both urban and rural), agricultural land (both single and double/triple crop), forest land (mainly Sal and Eucalyptus), water bodies (river, ponds/tanks, reservoir, canal, etc) and brick kilns. Hazards include gully erosion in laterite upland, bank erosion, seasonal water logging, removal of fertile top soil for brick kilns, scarcity of ground water particularly in laterite upland and high iron content in groundwater.

14. For Geo-environmental impact on rapid urbanization of **Berhampore - Murshidabad** townships and their environs in West Bengal, field investigations were carried out to evaluate environmental hazards, like flood, water logging, soil erosion, river bank erosion and geochemical hazards. Near surface lithology up to 3 m b.g.l. was studied by auguring. Depth to water table of selected tube wells was measured. Soil samples were collected for geochemical studies. SPT were conducted at 10 boreholes, up to 10m b.g.l., for N-value determination and 30 nos of undisturbed samples were collected for studying geotechnical parameters of soils. The area is mainly comprised of Quaternary sediments of Holocene age, deposited by the Ganga-Bhagirathi- Bhairab river system. Two distributaries of the River Ganga, the Bhagirathi and Bhairab, flowing north-south, demarcate the western and eastern boundaries of the study area. In

the study area, two geomorphic surfaces are identified, i.e., the Recent day deposits and Older Flood Plain Deposits of Holocene age. To the western part of the study area, there lies Late Pleistocene to Early Holocene Older Deltaic Plain. It shows undulatory topography and occupies higher elevation levels well above the level of surrounding flood plain and meander belt. The present study area lies on the eastern bank of Bhagirathi River and exposes mainly sediments of Older Flood Plain Deposit of the Bhagirathi-Bhairab river system. A number of palaeochannels and abandoned channels are seen all over the area, which indicates that Bhagirathi River has oscillated in the area several times in the recent past. In the study area, pre- and post-monsoon depth to water varies from 3.2m to 8.56m b.g.l. and 1.8m to 5.6m b.g.l. respectively. Seasonal fluctuations are recorded maximum in the northwestern and southern part of the area and vary from 0.64m to 4.19m. Most of the study area is almost flat with a very gentle southward slope. Presence of two river channels on either side prevents the area from being water logged during rainy season. Bank erosion on Bhagirathi River is seen near Ghospara, Nasipur, Khusbagh and Lalkuthi. Study of near surface lithology reveals a fining upward fluviatile sequence of sand, silt and clay. N-values vary between 1 and 38. Low N-values are recorded in silty or clayey layers whereas sand layers giver high N-values. Average co-efficient of permeability of soil varies between 3.06148E-07 cm/sec and 9.7578E-07 cm/sec. Total Hardness of groundwater varies from 145 to 360 ppm as $CaCO_3$ and SAR value ranges between 0.184 & 0.949. Chemical analyses of groundwater samples indicate presence of arsenic above permissible limit of 0.05 ppm. Concentrations of **Fe** and Mn in some of the water samples exceed their respective recommended limits of 0.3 ppm and 0.05ppm. In Berhampore and Murshidabad-Jiaganj blocks, assessment of ground water resource indicates net annual groundwater availability of 11594 ha m. and 11306 ha m. respectively. However as per CGWB considering the stage of groundwater development, which is at present 114.63% and 109.96% respectively, these two blocks have been classified as semi- critical.

9. WATER MANAGEMENT AND SUSTAINABLE DEVELOPEMNT

9.1 Although water is a renewable resources, its reserve in nature is limited and therefore, we have to plan for its sustainable development and efficient management so that the growing demands of a rising population, expanding industries and rapid urbanization are adequately met. Development of water resources in the country has revolved largely around creation of irrigation potential, providing safe drinking water to people, meeting industrial water demands, and addressing environmental issues.

9.2 It is reported that the access to safe drinking water sources in urban areas of India was about 90% in the year 1990 and 93% in the year 2000 and this has improved to about 96% by the year 2008. In rural India, access to safe drinking water sources has increased from about 58% in 1990 to about73% in the year 2008. Similarly, as per the reports of the Joint Monitoring Programme of World Health Organization and UNICEF, the use of improved sanitation coverage in rural areas of India was 7% in the year 1990 and this increased to about 21% in 2008. The urban sanitation coverage was 49% in 1990 and increased to about 54% by the year 2008. Analyzing the flood management, the total flood prone area in the country has been estimated to be about 46 million hectares. However, the area provided with reasonable degree of protection through structural measures is about 19 million hectares. Along with structural measures, efforts have also been made to adopt non-structural measures.

9.3 The water sector in the country is faced with challenges like reducing per capita availability of water due to increasing population, deterioration in quality, over-exploitation of ground water resources leading to decline in the ground water table in many areas, sub-optimal utilization of the created facilities and relatively lower efficiency of the facilities for water utilization. The per capita availability of water in 1951 was assessed to be 5177 cubic meter. Due to increase in population, urbanization and industrialization this has come down to about 1650 cubic meter. Unplanned development and lack of proper lows to govern extraction of ground water has led to its over-exploitation and a resultant decline in ground water table in many areas. About 15% of the Blocks/ Talukas / Mandals in the country are presently in the category of over-exploited. Another challenge relates to over-use of surface water which has resulted in irrigation drainage problems causing water logging in some areas. Pollution of rivers and deterioration in the quality of ground water are well known. A large share of pollution is caused by untreated sewage from the urban area and effluent from the industry. Excessive use of chemicals, fertilizers and pesticides is also a major cause of pollution.

9.4 Further, water is also central to another major challenge of our times, namely climate change. Although precise quantitative assessment of the impact of climate change on water resources is yet to be made, various reports indicate that there could be further intensification of the temporal and spatial variation in the availability of water and particularly the extreme events of flood and drought. Therefore, there is an urgent need for taking up research for assessment of the impact of climate change in quantitative terms and plan adaptation measures. In order to overcome temporal variations in water availability, we have to resort to various means of conservation of water resources through storages in reservoirs, ground water aquifers and traditional water bodies. The high spatial variation can be addressed through various measures for diverting water from surplus basins to deficient basins or regions.

9.5 GSI has recently signed an MoU with CGWB, Minister of Water Resources on Geoscientific data sharing and Cooperation in the field of ground water, sub-surface geology and hydrology. Major objectives are:

- To cooperate and facilitate sharing of geo-scientific data available with both the organisations for sustainable development of ground water resources.
- Planning a common programme for GSI and CGWB by using the resources available with both the organizations for achieving and pooling in common objectives.
- To integrate and synthesise the scientific database available with both the organizations.
- Knowledge sharing, Training and capacity building of personnel of both organisations through training programmes
- Pilot project to be taken up initially for joint studies.

9.6 GSI & CGWB have specialized scientific manpower and various kind of equipments and technological infrastructures including drilling rigs. The facilities with both the organizations are not common but may be mutually useful to support the special studies. The identified areas of co-operation for joint studies are as follows:-

- Application of deep geophysical resistivity surveys for prospecting of deeper Ground Water aquifers in alluvium upto 1000 m. The studies may be initiated in the Ganga alluvium in part of Uttar Pradesh as a pilot project. The Resistivity data will be validated through test drilling to be done by CGWB. The areas for joint studies and surveys may be for mutually agreed locations.

- Support of geochemical/mineral /Trace element/ Temperature variation analysis by using the available facilities of GSI labs. and hydro-chemical /Trace element/ Temperature variation analysis by using available facilities of CGWB labs. for the study of geogenic contamination due to presence of excessive Arsenic, Fluorides, Iron & Nitrate in ground water in mutually agreed priority areas. This will ensue to understand the genesis of the contamination and for evolving the long-term remedial measures and other alternatives. A joint study on Nitrate contamination in ground water in parts of Punjab shall be taken up on priority.

10. CLIMATE CHANGE AND SUSTAINABILITY

10.1 Climate refers to the average, or typical, weather conditions (mainly temperature and precipitation) observed over a long period of time (usually over 30 years) for a given place or region. Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period. Presently the climate change and its impacts on socio-economic and ecological system have become formidable challenges for the entire world. It is debated the world over how impacts of climate change would be more severe for developing and poor countries. Therefore, it is important to understand the linkages between climate change and the spatio-temporal changes in socio-economic and environmental well-being of humans for designing appropriate mitigation and adaptation strategies.

10.2 Climate around earth has changed many times in the geological past, especially during the last two million years of Quaternary geological period. However, it is a significant global environmental challenge ever since the humans have exerted influence through industrial revolution involving fuel combustion, agricultural systems, changing landuse patterns, etc. Such anthropogenic activities have increased contributions of various green house gases and impact on the earth's radiation budget.

10.3 The Intergovernmental Panel on Climate Change in its 4^{th} Assessment Report published in 2007 has predicted that global average surface warming by end of 21^{st} Century relative to 1998-99 would be higher by 1.8 to 4.0°C and sea level would rise by 0.18 – 0.59 m with frequent heat waves and heavy precipitation events. Adverse impacts of climate change may include threats to agriculture and food security, biodiversity, water stress, sea level rise, human health, etc. The panel also predicted an increase in rainfall over the sub-continent by 6–8 per cent and that sea level would rise up to 88 centimeters by 2100.

10.4 India is characterized by diverse geographical regions and many agro-climatic zones, supporting a rich biodiversity. It generally enjoys a tropical monsoonal climate with some parts having semi-arid and humid conditions prevailing in the south-central and central, northwestern and northern regions respectively. While the major rivers in the Deccan originate as springs and are monsoon controlled, the extra- peninsular rivers are fed by the glaciers in the Himalayas. Erratic behavior and delay in onset of monsoon and its sluggish northward movement have jeopardized the usual agrarian practices, affecting hydro power generation and also put pressure on large reservoirs, which supply drinking water to the urban centers. Variability of monsoon rains and seasonal cloudbursts have often led to unpredictable flash floods resulting in landslides and loss of human lives and property and increased soil erosion. Climate change would have direct impact on the behaviour of southwest monsoon wind system resulting in frequent and unexpected flooding in river basins and drought in other parts of the country and influenced the intensity of impact on surface and ground water availability and its quality.

10.5 Main causes of climate change are grouped into two: natural, and anthropogenic. The natural causes of climate forcing include changes in the Earth's orbital parameters (related to the Sun-Earth geometry), variations in the Sun's output and volcanic eruptions. Volcanic eruptions inject dusty material into the atmosphere that decreases the net solar radiation reaching the Earth's surface. These in turn cause changes in the energy balance and hence alter the atmospheric circulation patterns. Periodic variations in the amount of energy emitted by the Sun, as indicated by sunspots, have been linked to climatic changes on the Earth. It has been known for a long time that the number of sunspots varies on timescales of 11 years, 80 years and longer. The Little Ice Age during the 17^{th} and 18^{th} century and the warming of the 20th century has been attributed to changes in the solar output.

10.6 The long-term episodic occurrences of colder periods (Ice Ages or glacial periods) and warmer periods (interglacial periods) during the last couple of million years have been associated with changes in the Earth's orbital parameters. A Serbian mathematician Milutin Milankovitch first identified the cyclic changes in the Earth's orbital parameters, eccentricity, axial tilt and precession. These three cycles are collectively known as the Milankovitch Cycles. Eccentricity refers to the shape of the Earth's orbital path around the Sun. The shape changes between, more and less, elliptical and circular at an interval of approximately 100,000 years. The axial tilt refers to the inclination of the Earth's axis in relation to its plane of orbit around the Sun. Changes in the degree of Earth's axial tilt (between 21.5° and 24.5°) occurs on a periodicity of 41,000 years. Precession is the

Earth's slow wobble as it spins on its axis. This wobbling has a periodicity of 23,000 years and these changes cause changes in the Earth climate with similar periodicity.

10.7 Climate is a vibrant phenomenon and undergoes continuous changes over centuries. Mitigation and adaptation strategies to manage causes and impacts of climate change though falling within the purview of this book are not given adequate treatment. Mitigation involves actions that reduce the likelihood of the event or process, e.g., problems arising out of pollution caused to air, water and soils and related impacts on climate change. Important factors responsible for climate change casually contributed by human civilization and industrialization on earth include: Green House Gases (GHG), deforestation, landuse change, energy usage, generation of solid waste, etc. Mitigation measures include: GHG emission reduction, switching from fossil fuel based power generation to alternative renewable forms of energies (e.g. wind, solar, bio-fuel and nuclear energies). Adaptation in climate change scenario is adjustment in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. It involves actions that reduce the impact of the event or process without changing the likelihood that it will occur. The process may include relocating the communities living close to the sea level or switching to crops than can withstand higher temperature, promotion of energy efficiency in all sectors, adopting the concept green buildings, and promoting use of energy efficient equipments/ gadgets in the household, emphasize on rapid mass transport and effective traffic management, emphasize on renewable including bio-fuels plantations, accelerated development of nuclear and hydropower for clean energy, focused R&D on several clean energy related technologies, etc.

10.8 Considering global concerns, United Nations Framework Convention on Climate Change (UNFCC) was created as a multi-lateral Framework for integrated efforts to tackle problems of climate change. This Convention entered into force on 21st March 1994. 192 countries ratified the Convention. Article 3.1 states that Parties should protect the climate system for the benefit of present and future generation of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country's parties should take lead in combating climate change and adverse effect thereof. UN conference on climate change held recently at Bangkok has made it clear that market-oriented arrangements such as the Clean Development Mechanism (CDM) and emission trading ushered in Kyoto Protocol will continue beyond 2012.

Key vulnerabilities to Climate Change in the Indian context:

10.9 Climate change refers to a statically significant variation in either the mean state of the climate or in its variability, persisting for an extended period. Climate around earth has changed many times in the geological past, especially during the last two million years of Quaternary geological period. However, it is a significant global environmental challenge ever since the humans have exerted influence through industrial revolution involving fuel combustion, agricultural systems, changing landuse patterns, etc. Such anthropogenic activities have increased contributions of various green house gases and impact on the earth's radiation budget.

10.10 The Intergovernmental Panel on Climate Change in its 4th Assessment Report published in 2007 has predicted that global average surface warming by end of 21st Century relative to 1998-99 would be higher by 1.8 to 4.0°C and sea level would rise by 0.18 – 0.59 m with frequent heat waves and heavy precipitation events.

Adverse impacts of climate change may include threats to agriculture and food security, biodiversity, water stress, sea level rise, human health, etc. The panel also predicted an increase in rainfall over the sub-continent by 6–8 per cent and that sea level would rise up to 88 centimeters by 2100.

10.11 India is characterized by diverse geographical regions and many agro climatic zones, supporting a rich biodiversity. It generally enjoys a tropical monsoonal climate with some parts having semi-arid and humid conditions prevailing in the south-central and central, northwestern and northern regions respectively. While the major rivers in the Deccan originate as springs and are monsoon controlled, the extra- peninsular rivers are fed by the glaciers in the Himalayas. Erratic behavior and delay in onset of monsoon and its sluggish northward movement have jeopardized the usual agrarian practices, affecting hydro power generation and also putting pressure on large reservoirs, which supply drinking water to the urban centers.

10.12 Erratic monsoon rains and seasonal cloudbursts have often led to unpredictable flash floods resulting in landslides and loss of human lives and property and increased soil erosion. Climate change would have direct impact on the behaviour of southwest monsoon wind system resulting in frequent and unexpected flooding in river basins and drought in other parts of the country and influenced the intensity of impact on surface and ground water availability and its quality.

10.13 Considering essence of Indian traditions of conservation and sustainability of its biodiversity, GSI has been making persistent efforts in addressing earth science related problems having a bearing on climate change and essentially in conformity with the main principal of the National Environment Policy (2006). It emphasizes that the human beings are the centre of concerns of sustainable development and that they are entitled to a healthy and productive life in harmony with nature. The following geoscientific domains have been covered by GSI:-

1. Glaciological studies in the Himalayas,
2. Studies on changes in Polar Ice cover in Antarctic and Arctic regions,
3. Desert Geology and Desertification in dryland environment,
4. Sea-level changes and Coastal Zone management.

11. GLACIOLOGICAL STUDIES IN THE HIMALAYAS

11.1 The glaciers are considered as proxy records for the climate change, the monitoring of glaciers has been assigned a priority status. GSI has monitored more than 40 glaciers during the last hundred years or so. During the last ten years alone, GSI has monitored twenty-five glaciers (details are appended in the Table 1). The majority of Himalayan glaciers are passing through a phase of recession. The likely impacts include changes in the river hydrology, increased debris production and siltation of the rivers in downstream regions.

11.2 Melting of the Himalayan glaciers under the climate change scenario as predicted by IPCC (2007) may affect the water availability in the major rivers, existence of wetlands and the deltas, affecting millions of population and the rich bio-diversity. Besides, recession of glaciers may also lead to formation of glacial lakes, enhanced mass wasting and debris production which along with other weather elements like extreme weather events, higher rainfall, etc., may lead to increase in the frequency of floods and water logging of low lying areas.

11.3 Monitoring of glaciers in Himalayan region has remained one of the important thrust areas of GSI. During the last ten years GSI has monitored twenty five glaciers, viz. Hamtach, Jobri, Beas Kund, Gl. No.30, Sara Umga, Mantalai (Gl.No.115), Tal, Manimahesh, Roche Lungpam Mulkila, Panchi nala-1, Panchi nala-II (near Patsio), Gangstang and Tingal Goh in Himachal Pradesh and Bandarpunch, Jaundar Bamak, Jhajju Bamak, Tilku, Meola, Jhulang, Chipa, Pindari, Bhagirathi Kharak, Adikailash and Nikarchu in Urrarakhand., It is proposed to continue studies on Hamtah glaciers and glaciers of Baspa valley and the glaciers of Sikkim Himalaya.

11.4 With a view to assess the potential hazards associated glacial lakes including Glacial Lake Outburst Flood (GLOF), inventory of glacial lakes of Chandra-Bhaga basin was prepared and one large pro-glacial lake – Gepang Gath glacier was monitored during 2008. Similar studies can be undertaken in other glaciated regions of Himalaya in a phased manner.

11.5 The studies carried out by GSI have revealed that the majority of glaciers of Himalayan region are passing through a phase of recession as has been the case with the glaciers located in other parts of the world. The observed rate of recession of Himalayan glaciers is not alarming. The rate of recession in different climatic zones of Himalaya is found to be variable in different years. This variable rate of recession can be attributed to the several factors like micro as well as macroclimate, orography, size of the glacier, nature of nourishment, etc.

11.6 In addition to the above, mass balance studies have been undertaken on several glaciers, viz. Rulung, Neh Nar, Gara, Gor

Garang, Shaune Garang, Dunagiri, Tipra Bank, Hamtah, etc. These glaciers for majority of the years have shown negative mass balance that corroborates their recessional trend.

11.7 The recession of glaciers may result due to subnormal snowfall, higher temperature during summer, less severe winter or a combination of all of them. Even the reduction in the snowfall in the catchment may lead to recession of the glaciers without any appreciable change in the melting regime. The following Himalayan glaciers have been studied for the first time to generate baseline data (**Table –I**).

Table – I: Retreat of some of the Himalayan Glaciers monitored by GSI

Name of glacier	**Period**	**Average retreat (m/year)**
(1)	**(2)**	**(3)**
Bandarpunch	1960-1999	25.5
Jaundar Bamak	1960-1999	37.3
Jhajju Bamak	1960-1999	27.6
Tilku	1960-1999	21.9
Gangotri	1935-	18.8

	1996	
Bhrigupanth	1962-1995	16.7
Dunagiri	1992-1997	3.0
Gl.no.3 (Arwa)	1932-1956	8.3
Bhagirathi Kharak	1962-2001	16.7
Chaurabari	1992-1997	11.0
Pindari	1958-2001	9.41
Chipa	1961-2000	26.9
Meola	1961-2000	34.6
Jhulang	1962-2000	10.5
Nikarchu	1962-2002	9.2
Adikailash	1962-2002	12.8
Poting	1906-1957	5.1

Shankalpa	1881-1957	6.8
Milam	1848-1997	16.7
Burphu	1966-1997	4.8
Chhota Shigri	1962-1995	6.8
Bara Shigri	1906-1995	29.8
Sonapani	1906-1957	17.6
Hamtah	1961-2005	14.4
Miyar	1961-1996	16.4
Triloknath	1968-1996	17.86
Yoche Lungpa	1963-2006	19.53
Panchinala - I	1963-2007	10.57
Panchinala - II	1963-2007	11.93
Gnagstang	1963-	29.67

	2008	
Tingal Goh	1963-2008	16.00
Mulkila	1963-2006	14.77
Nagpo Tokpo	1962-1998	6.40
Man Talai (Gl. No. 115)	1989-2004	23.30
Sara Umga	1989-2004	43.30
Beas Kund	1963-2003	18.80
Gl. No. 30	1963-2003	13.80
Jobri	1963-2003	2.50
Tal	1963-2005	39.88*
Manimahesh	1968-2005	29.05

(*Due to bedrock configuration)

11.8 The recession of glacier is a natural cyclic process. Presently, we are in an interglacial phase during which the recession of the glaciers is a natural phenomenon. Throughout the history of the earth there have been number of glacial and inter-glacial periods. The last period of glaciation ceased at about 10,000 years B.P. Since then, a period of deglaciation has set in with little fluctuations in between. During the interglacial phase (Holocene period), pulses of minor glacial advancements commonly referred as 'Little Ice Age' (LIA) have been reported by various workers in different parts of the World including Indian Himalaya. During the last 1000 years, a little ice age appeared between 1450 and 1850 AD, when mountain glacier all over the world had advanced.

12. POLAR ICE COVER IN THE ANTARCTIC AND ARCTIC REGIONS

12.1 Antarctic, the icy continent, holds about 30 million tons of ice. Antarctic Ice sheet is a repository of global climate change. It is vulnerable to rapid changes in the earth atmosphere and land – ocean interactions. Systematic studies by Geological Survey of India on glaciers and ice cores drilled in the icy continent of Antarctic have provided valuable information on palaeoclimatic perturbations experienced and recorded during the Quaternary period. GSI has established major research stations and base camps to pursue continuing multidisciplinary geoscientific studies including those of the glaciers and the lake bottom sediments in the Antarctic region to understand the impacts of climate change.

12.2 Recently Geological Survey of India has joined the worlds leading countries and mounted collaborative efforts on similar investigations in the Polar ice covered Arctic region. GSI has started studies on inter-annual and annual parameterization of glaciers in Northern Hemisphere to variations of climate. Various aspects of glacier morphometry and its dynamics, peri-glacial geomorphic processes, aerosols/ particulate matter and chemical characterization of snow and ice, etc., are being investigated on expedition basis by GSI in the selected parts of Vestre Broggerbreen glacier since 2008.

13. DESERT GEOLOGY AND DESERTIFICATION

13.1 Desertification is the continuous degradation of land due to natural and anthropogenic causes in various agro-climatic domains such as the dry-subhumid, semi-arid or arid. Thar Desert in Rajasthan, which receives about 250mm rainfall at the core and 500mm rainfall at the fringes, will have adverse impact of climate change. Unusual excess in rainfall in the desert core areas may result in water logging and flooding due to absence of organized drainage network. On the other hand, prolonged periods of scanty rainfall and resultant droughts would cause extensive and intensive dust storms and trigger down-wind marching of desert or the desertification of the margins.

13.2 Geoscientific investigations have been carried out to characterize and map different components of the Thar Desert in India. Several palaeoclimatic indicators have been identified and studied to infer various operative processes and geological evolution of the Thar Desert. Geological features and sedimentological records and geomorphic evidences are studies and some of these are dated to infer different absolute ages of different episodes of desertisation and dune formation in the Thar Desert. Impacts of desertification particularly along the sensitive and ecologically fragile desert margin are studied in some selected segments of the Thar Desert.

13.3 The investigations carried out so far in The Desert on geoenvironmental appraisal studies, indicate localized reactivated spread of sand and remobilization of sandy silt due to intensive agricultural and other developmental activities. Two years ago, excessive heavy rainfalls in Barmer and Jaisalmer districts in Thar Desert in Rajasthan caused flash-flooding, water-logging and inundation of villages. Preliminary geoscientific investigation revealed that the absence of integrated drainage network needed for natural draining of surface water, hazardous locations of the inundated villages within the low-lying tracks or depressions, dry channel courses and presence of sub-surface duricrusts preventing recharge or infiltration into ground water saturation zone were the major causes of water logging for a prolonged time period.

13.4 For tackling the problems arising from climate changes such as excessive rainfall or prolonged drought periods in Thar Desert research projects are to be formulated to make contingent plans. Satellite data based change detection studies aided by satellite imageries followed by mapping of affected areas will help in planning for remediation and sustainable development. Terrain mapping in the vulnerable areas, devoid of surface drainage networks will be taken-up to solve water logging problem. Similarly, studies related to desertification, dust storms and soil erosion are to be taken up. Geomorphic processes related to dust storm and desertification gets intensified in prolonged dry spells. Detailed study of impact will be helpful in preparing mitigation measures such as watershed management, rain water harvesting, for soil and water conservation, stabilization of mobile sandy dunes, etc.

14. SEA-LEVEL RISE AND VULNERABILITY OF COASTAL AREAS

14.1 Another alarming feature of the climatic change due to green house effect is the possible sea level rise. Sea level has always been fluctuating throughout geologic time relative to the land surface. During the late Pleistocene, the most recent Ice Age, sea level was approximately 100 to 120 meters lower than at present which started rising with the onset of Holocene. The reasons for sea level rise have been attributed to thermal expansion of sea water and melting of land-based ice due to warming up of the environment by greenhouse effect.

14.2 In the Indian context, which has varied climate zones and morphologically distinct regions like glacier capped mountains, desert, alluvial plains to long coastal zones, the key vulnerable area to be affected include:

i) Vulnerability of shoreline and coastal hazards through erosion, salt water intrusion, etc;

ii) Vulnerability of Indian agriculture to climate change due to variation in monsoon pattern leading to floods and droughts, cyclones, etc;

iii) Vulnerability of biodiversity of marine and wildlife flora and fauna and impact on ecosystem mangroves, corals, etc.

14.3 Rising sea levels could threaten coastal mangrove and wetland systems, and increase the flood risk faced by the quarter of India's population that lives on the coast. Change in the rainfall pattern is a serious threat to agriculture, which in turn, affects country economy and food security. It is very important to study the past monsoonal variability to understand and predict likely variations in future rainfall pattern.

14.4 The direct impact of sea level rise is drowning of the coastal fringes/ delta margins with attendant loss of the productive arable lands. New areas will thus be subjected to active erosion or sedimentation at different places. It also leads to submergence or water logging of all low-lying coastal margins including geomorphic landforms namely, tidal flats, mangrove swamps, tidal creeks, etc. There will be landward shift of inter-tidal marshy lands and mangrove ecosystem affecting the associated coastal biodiversity. It leads to increased salinity of coastal alluvium landward shift of salt water-fresh water interface, thereby causing salt water intrusion along coastal areas, besides increased sedimentation/sand casting along the coastline. It leads to changes in geomorphic landforms by destroying or modifying the existing ones white creating new landforms at other places.

14.5 On the river regime, the important changes contemplated include rise of base level of erosion leading to slower river discharges resulting ill increased rate of sedimentation with attendant rise of river bed as well as in the downstream reaches, choking 'the river mouths causing floods and water logging near the confluence. On the socioeconomic front too it impacts inhabitants by way of loss of fertile lands, destruction of salt pans, burial of industrial economic mineral sands drowning of aquaculture/prawn ponds, increased salinity in soil resulting in loss or reduced production especially impacting the fishery sector and fisherman community. Perched ground water aquifers having potable water along the sandy coasts will be destroyed and scarcity water will become acute. The wetlands and wet land biodiversity no doubt will be severely impacted. The sea ports and harbours and strategic naval and other commercial industrial establishments and inland water transport system as well as tourist and recreation centers/ religious/archaeological sites will be will also be affected due to water logging/ drainage congestion, salinity problems, etc.

14.6 The change in monsoonal climate is well preserved in the marine records of Bay of Bengal and Arabian Sea. Marine Wing, GSI has taken projects to decipher late Quaternary climate changes with the help of study of microfossils to understand the sea surface temperature (SST) variation and its relation with monsoonal precipitation pattern and has identified the time line of these changes on millennium to century scale from Last Glacial Maximum to Middle Holocene. Studies suggest a strong correlation of increased SST with intensification of Monsoon over Bay of Bengal. Study also suggests that future rise in global temperature would lead to abrupt change in rainfall pattern as it has happened in the past during transition from last glacial to interglacial at around 11,000 to 10,000 yrs. BP.

14.7 The rise in sea level is going to affect the coastal regions by submergence and coastal erosion. To understand the effects of global climate changes and consequent sea level rise, it is necessary to prepare maps showing areas likely to be submerged when sea level rises, by 50 cm / 1 m / 1.5 m etc and the measures to be taken to mitigate it. Incursion of saline waters into the surface and ground water table is another area that has to be looked into. Vulnerability maps have to be prepared considering these consequences. These investigations can be carried out by the Geodetic & Research Branch of Survey of India who are working on this field of recording and maintaining tidal gauge network since 1877 and also by the Central Ground Water Board. At present, Marine Wing, GSI has no scope to work on this aspect since Marine Wing does not have any infrastructure with respect to measuring and monitoring any tidal data. However, Marine Wing carries out survey on the coastal domain to look for the changes in the coastlines vis-a -vis zones of erosion and accretion which might be one of the effects of sea level fluctuation.

14.8 To study and understand monsoonal pattern in Indian context, it is proposed to take up the following projects in near future:

1. Century scale climate change records from the shelf sediments of Bay of Bengal and Arabian Sea to study monsoonal variation pattern during late Holocene.
2. Holocene monsoonal evolution records from northern Indian Ocean with the help of planktonic foraminifera.

14.9 Studies carried out in the coastal areas of Gujarat were aimed at establishing the spatial distribution of coastal geomorphic units and also working out Quaternary stratigraphic framework. Palaeontological studies relate to foraminifera, ostracods were able to establish faunal assemblage vis-a-vis changing sea level. Studies related to trends in strand line changes during the Quaternary period were also carried out.

14.10 Future work on the coastline of Gujarat should be on the impact study of sea level rise related to climate change. Detailed coastal terrain evaluation and impact study on habitation, industrial and recreation sites, ports are to be carried out.

15. GEOTHERMAL AND RENEWABLE ENERGY RESOURCES

15.1 The energy scenario in India is fast changing with the emphasis given in the XI Five Year Plan on non-conventional and renewable sources of energy. Though the dominance of fossil fuels viz. coal and oil will continue in the energy sector, the concern for reducing the green house gas emission warrants increasing use of green energy/non-conventional energy sources as a substitute to oil and coal. Solar energy and wind energy are major contributors of the renewable energy as these resources are widely distributed all over India and are available round the year. Geothermal energy is also an additional source of renewable energy with site specific availability with consistent supply in all the seasons / throughout the year.

15.2 Geothermal is a source of energy which requires special mention. Geothermal energy is renewable if proper techniques are used for exploration and utilization of this energy. Geothermal energy is liquid energy which can be recycled with proper technology. Government of India has formulated a National Mineral Policy for exploration and mining of mineral resources. Similarly a policy of exploration and exploitation of oil and gas as well as atomic minerals and thermal power generation is released by the Government of India. As the mandate for exploration of geothermal energy resources on a national scale was primarily bestowed on Geological Survey of India (GSI), most exploration and drilling activities were carried out by them, with complementary efforts from the National Geophysical Research Institute (NGRI) and a few other organizations. Also, the utilization of geothermal energy was pending due to non-availability of both robust estimates of potential for different geothermal fields as well as appropriate machinery and equipment for drilling and exploitation. For these reasons, a formal policy on Exploration and Development of Geothermal Energy Resources has not been conceptualized so far. With the advent of the worldwide progress in geothermal energy utilization, private entrepreneurs have started taking initiative in geothermal energy exploration. The increase in demand for power in rural sector has necessitated the exploitation of site specific energy sources as a substitute to fossil fuel energy. Hence, it has become imperative to formulate guidelines and policy for exploration of the geothermal energy resources and their further utilization for power production and direct heat utilization.

15.3 Realistic estimates of geothermal energy potential in India are not available. While a few locations suggest some geothermal energy potential based on shallow drilling done by the GSI two to three decades ago, this is not considered adequate and relevant basis to conclude on the potential. India's geologic setting is also not favourable for the occurrence of very large geothermal energy potential of the kind found in the active volcanic regions such as Phillipines, United States of America, New Zealand, Indonesia, or countries such as Iceland that are located over mid-oceanic ridge where magmatic source of heat is abundant. There may be opportunities for larger capacity once EGS technology is commercially proven and is brought to India. Nevertheless, it is thought that a sizeable geothermal potential exists in the hot spring zones of India. However, in the absence of sufficient and relevant preliminary data regarding the potential of the resources coupled with the lack of policy support, this sector has failed to pick up any momentum so far.

15.4 Geothermal energy is a source of natural resource stored in the interior of the earth which requires transportation to surface for utilization. Thus, the source requires exploration activity, mining activity and production for fruitful utilization of the energy.

15.5 The following work components need to be considered for exploration and utilization of the geothermal energy.

1. Prospecting and mining lease
2. Exploration for geothermal resource

3. Systematic geochemical studies and geophysical surveys
4. Reservoir extent and parameters
5. Environmental and pollutant studies
6. Drilling data with sub-surface temperature profile and production parameters
7. Reservoir characteristics and resource assessment
8. Production potential, suitable technology and thermodynamic input parameters
9. Economics of the project
10. Societal issues

15.6 The overall development of the geothermal resource may be classified under the following three categories:

1. Prospecting and exploration
2. Resource assessment and production technology
3. Economics and environmental aspects

15.7 The recent developments in the energy sector have given impetus to the development of non-conventional energy sources. The need to control green house gases emission and global warming has created an urgency to explore the new avenues for energy sources. India is presently banking on solar and wind energy as a main substitute to fossil fuels, while other sources of energy are upcoming with contribution at local level. Geothermal energy is a site specific renewable source of energy specifically suitable for catering to the energy needs of remote/interior localities. Considering the possible utility of geothermal energy as a substitute of heat as well as energy source, the Geological Survey of India needs to play a proactive role jointly with the Ministry of New & Renewable Energy for the exploration and development of geothermal resources in India.

15.8 Geothermal resource neither falls under solid mineral resource category nor shallow ground water resource category. Geothermal fluids constitute a liquid resource situated in the deep underground. Prospecting for mineral resources is controlled by state governments while the ground water development and utilization is controlled by ground water exploitation guidelines set out by the central and state governments. Considering these aspects, though the land owner has a right to exploit shallow ground water, he will not have any right to exploit any geothermal resource located beneath his land. Geothermal resources / prospects will be the sole property of the Government of India, as is the case with hydrocarbons. State guidelines may however be followed for providing relevant approvals / licenses for exploration and mining.

15.9 **Geothermal Springs vis-à-vis Religious Places**

(i) In India, places of worship have developed in the vicinity of most hot springs. Concrete enclosures ("*kunds*") have been built covering the area of the hot spring discharges, which are traditionally used for religious bathing and sometimes as hot water baths in cold areas and for balneological purposes. A number of people earn their livelihood from such activities. Before development of such areas for utilization of geothermal energy can be contemplated, awareness campaigns need to be launched by local government to make the local people aware of the benefits of such utilization and possible sharing of the resources.

(ii) As far as possible the surface manifestations may be preserved and their public utilities continued with the condition that such activities will not adversely affect the quality of water as well as the existence of the surface thermal manifestations. The local authorities may be involved in implementing these measures. The exploitation of the resource can be undertaken simultaneously in these areas without affecting the thermal manifestations.

15.10 **Direct uses of geothermal heat energy**

(i) Direct uses of geothermal energy are one of the important aspects wherein a large amount of fossil fuel energy can be substituted. Direct uses can be made available at the sites where the transportation and transmission of electricity and water may be difficult due to remoteness of the area. The direct heat utilization of geothermal water can be also planned for the water effluent from geothermal power plant having suitable heat content. Direct uses are also useful in partial saving of the energy required in industrial uses like vegetable drying, concrete block curing etc. Besides this, direct heat uses have a major societal impact in the form of bathing centres, skin cure centres, geothermal and botanical parks for entertainment purpose, spas used for tourist attraction, green housing and cold storage for utility of local population and farming industry.

(ii) In India, direct heat utilization has only been carried out on a demonstration basis at Puga, Chhumathang, Manikaran and Parbati valley. It is therefore proposed that the MNRE should encourage suitable direct heat utilization at different geothermal areas. MNRE shall formulate site specific direct heat utilization schemes which shall be implemented through local agencies like spa centres through Tourist Development Corporation, green housing and cold storage, etc. through Marketing Federations and suitable local bodies. The direct heat utilization by MNRE will have social benefit as well as impact on the development of low temperature geothermal resources. This effort will also make the public in general and the industry in particular aware about the role geothermal energy can play in development of interior areas and for societal benefits.

(iii) The producer shall be encouraged to utilize the water effluent from power plant for direct uses, like house heating, aquaculture, green housing, canning, bottling, pulp making, fish drying, drying of wool and fibres, milk pasteurization, brewing of low percentage alcoholic beverages, and a host of other uses. MNRE shall provide technology for direct uses of effluent water as well as heat/electricity substitution.

16. FUTURE PROSPECTS AND STRATEGIES

16.1 THE PERSPECTIVE AND THE WAY FORWARD

(a) Geoscience today constitutes a huge and fast expanding domain. As has been elaborated in HPC Report 2009, advancements in science and technologies are constantly providing new and previously undreamt of opportunities to explore the near-infinite variety which comprises the earth and its systems: the lithosphere, biosphere, hydrosphere and atmosphere. Besides, globalization in all its socio-economic dimensions is posing new and increasingly complex challenges to science in general and geoscience in particular.

(b) It is important to note that we are using more and more natural resources and the way we are utilizing our resources has started to affect our ecosystem more perceptibly and more irreversibly than ever before. All this has the potential to impact our ability to sustain the economy, protect national security and preserve the natural environment.

(c) The science strategy to meet the challenge of finding the resources to meet increasing demands and to predict and, if possible, mitigate the adverse impacts that we are having on our planet has to be broad and multidisciplinary. The three dimensions which have to be part of any geoscience strategy include: 1) the need for an 'ecosystem-based' response. 2) the fact that understanding the issues and finding responses involves a very high degree of geospatial information and 3) the fact that some of the cumulative impact of the changes are now becoming significant enough to be able to be compared with similar events in the geological past. This implies a temporal dimension spanning geological periods, and study of the geological past will give indications of the trends for the future, and may help shape responses and mitigate effects in diverse areas.

(d) New scientific approaches, new interdisciplinary linkages, new demands arising out of socio-economic development and of course, new ecosystem situations all will have major impact on the work of a national geoscientific organization.

(e) Traditionally, GSI's core competence has been geospatial data collection and geological mapping. As this activity will continue to be the *raison-d'être* of GSI and the basis for the role envisaged in the **Vision** for GSI that can perhaps be stated as the ***aspiration***:

- ***To develop into a world class institution for fundamental as well as applied geoscience, always keeping up with the latest technologies and methodologies.***
- ***To create a close-knit national geoscientific community through leadership and collaborative partnerships; and***
- ***To acquire and provide expertise and widely disseminate geoscientific information to facilitate informed decision-making by policy makers and public and enable use of geoscientific information for sustainable socio-economic development.***

(f) Considering this background and the new roles that GSI is called upon to embark upon, the following principles emerge as has also been enumerated in the HPC Report that should facilitate GSI in further determining its role as the future evolves:-

- As a facilitator, GSI need not always and in every area be the activity centre. It could be an 'incubator' as it has been in the past, developing new areas of expertise that may lead to the formation of new specialized organizations. As a facilitator it could have a passive role, and sometimes be a 'repository' of scientific knowledge, of data, of multidisciplinary expertise. As a facilitator, it could be a catalytic 'clearing house' a one-stop reference centre for geoscientific data, no matter where the activity centre may be.
- As a provider of expertise and disseminator of information to policy makers, commercial users and society, GSI performs a public service. All non-commercial data other than that restricted on considerations of national security must not only be in the public domain, but GSI must constantly ensure that the data is as complete and accurate as technology permits, and is easily accessible to society in a form that would be generally required for socio-economic purposes. To achieve this would require development of sophisticated geospatial and multidisciplinary applications on a continuing basis.
- Geoscientific information could be of many kinds. Any new and emerging area of geoscientific activity not within the domain of an existing organization and coming within the purview of GSI's Vision *must* be taken up by GSI as a facilitator to the extent warranted by the requirement of society to ascertain the nature of the geoscience and its implications for understanding its effect on the sustainable management of the ecosystem.
- As an enabler, GSI could be the integrator of scientific data of various scientific disciplines in order to evolve responses to ecosystem events based on geoscientific considerations.

(g) With a fairly clear perception of GSI's role in terms of its Vision and its core competence, it is now possible to enumerate the major challenges and opportunities in the geoscientific sector and how GSI fits into the scheme of things. Therefore, besides the Systematic Geospatial Survey and Mapping; Natural Resources Assessment and inventorisation; Geoinformatics; the **Multidisciplinary Geosciences** assume significant position in GSI's future activities that impinge directly on the society and its impacts on operative geomorphological processes on earth. Thus it is imperative to consider the following in greater details.

(h) Understanding ecosystems and ecosystem changes in the geoscientific context involves on the one hand study of interaction of ecosystem components in the past, discernable through palaeo-geoscientific and palaeo-environmental studies; on the other hand it involves geoscientific baseline determination, data collection particularly in relation to glaciers, sea coasts and fragile ecosystems. In Canada, United States of America, United Kingdom and many other countries, the National Geological Surveys are tasked with such issues because of the essential linkage of geosciences to the study of ecosystem change including climate change (now often called global change since climate change brings in its wake a host of other changes). GSI will clearly be an important though not pre-eminent player in this domain. However because there are fundamental geospatial underpinnings in this area, GSI can potentially increase its role very considerably.

17. GEOTECHNICAL RESEARCH AND STUDIES

(a) Complex geomorphic, geologic and meteoric conditions give rise to potentially catastrophic situations which includes seismic activity, landslides, avalanches, volcanoes, floods/drought, water logging, erosion, mass wasting, cyclone, tsunami etc., and this requires adequate preparedness for hazard mitigation. Location – specific inputs from geosciences are vital for management and mitigation initiatives. GSI may not be the pre-eminent player in every case; however over time it will develop certain inherent strengths in specific areas and this process needs to be carefully nurtured.

(b) It is pertinent to record that GSI carries out geoscientific investigations to deal with many societal issues amenable to solution using geoscientific or geotechnical tools. In the new paradigm of ecosystem based geoscience, the basic strength of GSI as a generator of geospatial data and as an agency with an all-India presence needs to be fully leveraged in the larger public interest in order that GSI systematically monitor and collect data (where possible on a spatial basis) on a large number of parameters relating not only to landslides and earthquakes, but also other public-health and public good issues having a geospatial dimension. In this context, it may be pointed out that in the National Action Plan on Climate Change (NAPCC), there are 8 Missions, which include a Water Mission, a Green India Mission, a sustainable Agriculture Mission and a Strategic knowledge for Climate Change Mission. Geoscientific dimensions of these Missions include:-

- Soil mapping
- Carbon storage (Carbon sequestration)
- Potential for deep ground water storage systems
- Glacial data (Cryospheric studies)
- Sea surface temperature and salinity
- Sea-level change and coastal erosion studies
- Water quality (presence and spatial distribution of heavy metals, radicals etc.)
- Palaeo-climate studies and modeling etc.

(c) GSI will need to further develop its expertise in these areas and ensure that its survey and mapping activities are adequately coordinated with the requirements for baseline and site specific data in respect of these areas.

(d) An understanding of the earth and its geological history is the key to an ecologically sustainable development of the planet's resources. To have an understanding of the earth and its system, fundamental research in the fields of petrology, geochronology and isotope geology, neotectonics and seismotectonics, palaeontology, stratigraphy, and remote sensing is essential and integrating inputs derived from these fundamental geoscience disciplines is necessary to develop a better assessment of the various processes shaping and affecting the earth.

(e) The need for GSI to carry on with fundamental, applied and multidisciplinary research cannot be overemphasized. On the one hand, the vast amounts of data generated and accessible to GSI make its very well placed to do so. On the other hand, the fast pace of geoscientific activity makes it necessary for GSI to develop and sharpen its research capabilities in order to retain its relevance in the geoscientific community. This is one area where the GSI – academia linkage should be fostered, scientific excellence recognized and rewarded and opportunities provided to allow easy access to international scientific fora for keeping abreast with the latest developments in the science.

(f) The task of creating a close-knit geoscientific Community has many implications. In the context of the aspiration to develop into World class institution, there is a clear underlying thought that GSI needs to ensure that the human resources under its control need to be the best, and that they need to be continuously be exposed through training and interaction to the latest technologies and practices. But GSI, in its leadership and partnering role has also to be able to help in the same way other stakeholders of the sector, including Central Institutions, State Governments and the Private Sector.

18. GEOSCIENCE PARTNERSHIPS

(a) In the context of CGPB Committee XII on “Geosciences for sustainable development”, the concept of partnership has now to pervade all of GSI’s Missions in tune with the Vision. Partnerships in geoscientific areas is not only desirable for its own sake, in the Indian context, given the federal structure, it is necessary for GSI to partner with State level geoscientific organizations, particularly to enable the best use of natural resource assessments, ensure that multidisciplinary applied geoscience and special studies address local needs effectively, and geoscientific information is available for a variety of developmental purposes. Such partnerships would prima-facie seem to be highly favourable to State level institutions, since it will include capacity building, knowledge transfer, sharing of GSI's resources etc. However, in the long run it will improve GSI's ability to focus on new and emerging areas by transferring many responsibilities to State levels, as was done in the case of USGS. It will also increase GSI's outreach through project-specific partnerships.

(b) Partnerships with Central institutions engaged in geosciences will also create synergy, and by avoiding wasteful effort, help GSI grow in the directions it really needs to grow. At a broad level, the basic partnership would be for information sharing and data pooling. However, it would be advisable if GSI could identify agency-specific projects for such partnerships leveraging its own strengths, particularly in geospatial information management and field presence.

(c) Partnership with international institutions would be useful to GSI firstly in areas like climate change or plate tectonics where issues of a truly global nature need to be addressed. In such cases GSI needs to be in the forefront, leveraging its position within the country and profiting from the sharing of knowledge and the developing of its expertise at the international level.

19. DATA SHARING AND ACCESSIBILITY

19.1 Being a National Mapping and Survey organization, GSI deals with vast volume of geospatial data. Data is being generated through execution of field season projects over the years. This work gets done throughout the country in distributed centers in various domains. Since manual management of this huge volume of multi-thematic spatial data has become increasingly difficult without the imposition of organizational standards and proper infrastructure – GSI has already built an Intranet Enterprise GIS system, which is being used to collate and consolidate the baseline geological data mapped at scale 1:50,000. GSI, under the Online Core Business Integrated System (OCBIS) project, intends to extend the scope of this Enterprise GIS to collate the complete spectrum of published (Maps, Reports and Publications) and unpublished data, build a centralized repository capable of housing multi-domain data and serve these data to stakeholders, especially the private sector through user-interactive services for different types of geo-information. These services will be available based on authorization and authentication.

19.2 On sharing and dissemination of geoscientific data in public domain and for sustainable development it is pertinent for GSI to consider the following points:-

- Use and enable the integration of data from a wide array emerging technologies encompassing gravity, magnetic, electrical, electromagnetic, gamma ray, magnetotelluric sensing including tomography, resistivity profiling and ground penetrating radar etc.
- Develop as part of the NNRMS/NSDI process, capability of managing geospatial data, to produce state of-the-art outputs of earth images and subsurface images including 3-D visualization and modeling capability and develop policies allowing users easy access.
- Effective sharing of data between agencies will require addressing differences in organizational data policies and heterogeneities in data formats, models, and semantics. Experiments conducted under NRDMS/ NSDI activities have demonstrated the usefulness of data/ process standard specifications from Open Geo-spatial Consortium (OGC) / International Standardisation Organisation (ISO). OGC/ ISO standards based software products have been used in the development of NSDI's India Geo Portal **(www.nsdiindia.gov.in)** and

Government of Karnataka's State Geo Portal (www.karnatakageoportal.in) to ensure interoperability.

- DST is supporting various national and state level agencies for developing interoperable data nodes for automated data sharing. With spatial databases developed on Relational systems, data sets are shareable in the form of web-based services like Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), or the Catalogue Service on Web (CS-W). Related metadata sets are accessible through CS-W to facilitate data discovery. The Union Cabinet has approved in June 2010 a broad framework for drawing up a National Data Sharing & Accessibility Policy (NDSAP) so that each data generating agency could bring out a data sharing policy of its own for making useful data sets inaccessible to user agencies. Appreciating the recently signed MoU between GSI and CGWB and the upcoming MoU between GSI and TERI as important steps forward in automated data sharing, it is suggested that Committee XII may consider adopting the OGC/ ISO standards in making the respective data sets accessible to the end users/ stakeholder agencies for further processing and analysis.

- Mineral prognostication require diverse types of datasets, ranging from basic geological maps to geochemical, geophysical, hyperspectral airborne and multispectral satellite imagery. This proposed system will allow geoscientists engaged in mineral exploration to bring these datasets together and accurately calculate economic potential on a single client.

- OCBIS project for GSI envisages an interactive integrated system with the state-of-art GIS – RDBMS technology at its core. The proposed system will be integrated with all scientific and administrative business processes of GSI, such that any information, spatial or non-spatial generated out of these processes are captured, stored and disseminated to authorized users. The data will be served using OGC compatible Web Services, making it easier for the user to integrate GSI information with own data / data from other sources such Mineral Tenement

Sl. No.	Maptype	Metadata	Image
1	Atlas	3	1
2	Coalfield maps	10	3
3	District Resource maps	351	336
4	Geol. Maps of States & Regions	26	19
5	Geological Quadrangle maps	292	164
6	International maps	7	5
7	Entire India maps	12	8
8	Marine maps	27	24
9	Mineral belt maps	120	114
		848	**674**

Information System of IBM.

- **Finalization of lithological layer of GMS in 1:50K national grid and uploading of the same with attribute data on Geodatabase**

20. COLLABORATION WITH OTHER CENTRAL AND STATE GOVERNMENT DEPARTMENTS

(a) There are also many areas where GSI will benefit by MOUs with geoscientific agencies in other countries, particularly in terms of knowledge. Here too it is essential that GSI takes a proactive role in developing such relationships in order to improve its own capability. Few specific examples include multi-institutional collaboration of GSI with National Remote Sensing Centre, ISRO (Department of Space) on National Geomorphological Lineament Mapping (NGM) and Hyper-spectral Mapping of mineralized belts and 2) Collaboration between GSI and Central Ground Water Board, Ministry of Water Resources, collaborations with a PSU of Tamil Nadu Government (TAMIN),etc.

(b) Finally GSI needs to develop partnerships with geoscientific institutions of nations well endowed with natural resources, in furtherance of the national interest even if such nations do not yet have a vast geoscientific knowledge base and in such cases GSI would have to be able to provide useful services like training and capacity building and even be able to bring to bear its core competence in survey and mapping.

21. AEROMAGNETIC SURVEYS

(a) It has been proposed that **National Aeromagnetic mapping programme** could be one such important initiative for improved geoscientific understanding of buried and deeper levels of earth crust and to augment mineral inventory. Importance of collaboration of various stake holders for such national efforts is stressed and the example of **National Geomorphological and lineament mapping** in multi-institutional collaborative mode with quality checks at different stages of work is cited for similar efforts.

(b) To discuss the present status of the aeromagnetic survey in India and for stimulating collaborative efforts for up scaling the aeromagnetic coverage as a part of National Geophysical Programme. A preliminary Concept Note providing status and Background Information on aeromagnetic survey prepared by MoM-GSI has been prepared and also circulated amongst members and special invitees prior to the 17th Meeting of the Standing Committee on Geology (NNRMS) held under the Chairmanship of Secretary (Mines) on 23rd December 2010. The following points and actions emerged from the discussions -

(1) Based on the review of the present aeromagnetic surveys coverage of the country by different organizations including GSI under different projects since 1967 in the country, it was brought out that the surveys completed so far are of varying details and different altitudes / scales and resolution. It was highlighted that the regional coverage for the county has gaps and this needs to be covered in total. It was also brought to the notice of the committee that the major coverage under National Programme of Aerial Surveys (NPAS) was regional in nature with 4km line spacing and from high altitude varying from 5000' to 9000' and it was not amenable to detailed interpretation as required for mineral prospecting. It is necessary that the line spacing will have to be reduced to 500m or 1km. It was stressed that for obtaining high resolution data it is necessary to maintain the altitude of sensors at much lower level of 300m to 120m above ground level.

(2) It was debated by the participants and that there were two scenarios with line spacing 1km and altitude of 300m and line spacing 500m and altitude of 120 m. With the second option of line spacing 500m and altitude of 120 m. it will also be feasible to take up radiometric surveys along with magnetic surveys. This will form an important

geoscientific data base in GIS environment for integration with geological, geomorphological and geochemical data.

21.1 NATIONAL AEROMAGNETIC MAPPING PROGRAMME

(a) National Aeromagnetic Mapping programme for entire India is under consideration and planning by Ministry of Mines, Government of India, on uniform scale which may be supplemented by other aero geophysical sensors such as Gamma ray spectrometer and gravimeter (selected areas) to obtain and archive a variety of geophysical data for the use of mineral sector, oil sector and also for augmenting ground water resources and other studies.

(b) Aeromagnetic survey is an important stage between the collation of geoscientific data and the resource discovery and has been used as a reconnaissance tool to aid in geological mapping and determination of strategy for finding buried deposits under cover of overlaying soil, weathered and loose rock and water. The surveys are useful for bringing out regional geological setting and deciding the strategies for exploration along the extension of the mineral prospects. The proposal for National Aeromagnetic Mapping programme is prepared for putting forward the plans for taking up airborne magnetic (Total Field), Gamma-ray spectrometric and gravity (over selected areas) surveys on uniform scale on national level covering the different parts in systematic way as a joint endeavor of different Government organizations for producing seamless aero-geophysical maps of India. A concept note on the proposal was submitted to the Ministry of Mines, by Remote Sensing & Aerial Surveys [RSAS] of Geological Survey of India, Bangalore.

(c) The issues related to survey parameter and sensors to be used for airborne survey were discussed in the 17th and 18th NNRMS, SC-G meetings chaired by the Secretary [Mines] at Ministry of mines and attended by representatives of different Government organizations.

The previous efforts to take up aeromagnetic surveys on national scale were reviewed along with information of similar efforts in different countries and the advantages accrued upon by these surveys. The scale of the surveys has been discussed taking into account the different factors such as line spacing, flight altitude above ground level and the resolution of individual bodies as a function of the width of the anomalies produced. The merits of taking up multi sensor geophysical surveys were also considered. It was decided to have airborne Geophysical survey with 500 m line spacing and flight altitude of 120m above ground level (AGL). The magnetic and gamma-ray spectrometry sensors were agreed upon to be used for the survey.

(d) Considering the enormity of the task with area, time and budget it was decided that the surveys may be prioritized over different parts of the country on the basis of two important sectors e.g. mineral and oil sectors. The areas to be covered in phased manner are listed below.

1) Peninsular plateau including coastal plains
2) Northern mountains including Himalayan region
3) Northern Great plains (Indo-gangetic and Brhamaputra plains)
4) Territorial waters
5) Exclusive Economic Zone (EEZ) in offshore

(e) The estimated time for completion and budget requirement are discussed for this project which is expected to span over next three five year plans for the total area of India. The Secretary [Mines] has accepted the proposal to cover entire India including Himalayan Region, offshore Region and EEZ by airborne Geophysical surveys.

(f) The execution of this project will be funded by the Government of India with technical and other cooperation of all stake holders. The project is proposed to be completed within stipulated time of three Five year plans starting with the XII plan w.e.f. 01-04-2012. The execution of airborne survey, processing of acquired aero-geophysical data and preparation of final maps etc will be completed by outsourcing. The data available as and when will be deposited in the geophysical/aeromagnetic data repository of Geological Survey of India for availability of the stake holders. The project of this size may not be possible to complete in desired time frame by any one or all Government organisations together due to shortage of infrastructure e.g. aircrafts, instruments and sensors. All Govt. organisations put together may have 2-3 aircrafts capable of carrying out such surveys, whereas minimum 10 aircrafts is the basic requirement to take up the project. Therefore, outsourcing is the possible solution for execution of this project of national importance.

(g) The Director General, Geological Survey of India has constituted a committee of representatives of different Govt. organisations and outside experts for suggesting further necessary steps for completion of the project. The committee is also entrusted to suggest the final specifications and standards for the aeromagnetic survey and maps to be prepared. The present expert committee comprising representatives from RSAS, GSI, Bangalore, AMD, Hyderabad and Indian Institute of Geomagnetism, Mumbai, met on 22nd June 2011 at Hyderabad and decided to take the opinion of all stake holders including all States and their Directorate of Geology & Mines related to their participation in the project. Some of the stake holders opined to include the gravity along with magnetic and gamma-ray spectrometry for the proposed airborne Geophysical survey in their comments sent to RSAS, GSI. The experts have also advised for further reduction of line spacing over penisular pleatau area to 250m which is prospective of minerals having a smaller footprint. The committee discussed the issue and agreed to include gravity where ever it is possible without changing the survey parameters e.g. Indo-Gangetic and Brahmaputra plains, desert of western India and offshore areas including EEZ.

(h) However, this committee will be expanded to include more stakeholders after receiving the response from all concerned government organizations including that from States. The committee will have to consider different aspects of the project and will discuss the matter in detail and submit its report to the Ministry. The participation of all States in this project of national interest is very essential as far as the mineral, petroleum and water resources are concerned. All stake holders may participate in this project in a possible way by sharing the information related to airborne geophysical surveys carried out by them and the type of data collected. This information will be very usefull to plan the proposed airborne Geophysical survey. The willing stake holders may participate in this project by sharing their resources and man power. Since the project will be beneficial to entire country mainly in minerals, oil and gas sector and deeper level water aquifers, all stake holders including all States have been requested to participate in this project in a big way to explore further reserves of natural resources. The interested stake holders may intimate their willingness to participate actively in this program.

22.0 INDIAN GEOSCIENCES CONGRESS

(i) **T**he geoscientists work in a variety of institution, Central Government, State Government, Private Sector and academia, etc. There is an enormous amount of geoscientific work going on within the country which is of interest to various streams of geoscientists. With a view to orsyter geoscience partenerships and encourage applications of geosciences for sustainable development amongst ptyher objectives, the Ministry of Mines has taken the lead to establish an **Indian Geoscientists Congress** as a registered body of professionals at D.G. Camp Office, New Delhi with the provisions that:-

- The Ministry should provide initial and partial recurring funding
- The Congress should open its membership to professionals, industry associations and mining and geosciences sector related institution including academic institutions.
- The Congress should be a non-profit body devoted to the cause of geosciences and should provide a platform for interchange of geoscientific knowledge outside the Government.
- The Congress should hold annual session, where Technical subjects can be discussed, papers read and workshops and exhibitions held State and Central Government should facilitate the holding of these annual events (which can be over a weekend) by literally allowing desirous geoscientists to attend (subject of course to exigencies of work) and bearing travel and accommodation expenses of Government geoscientists since it helps professional development.

(ii) This proposal is also in line with the recommendation of High Power Committee (HPC) and the proposal for setting up of a Society named "Indian Geosciences Congress" is made.

(iii) The role of geoscientists is critical for the sustainable development of the country's large natural resources. For effective interaction amongst the geoscientist community of the country from Geological Survey of India, State Department of Geology and Mining, Academic institutions, Public Sector Undertakings and Private agencies, It is proposed to set up a registered society **"Indian Geosciences Congress" (IGC)**, under the aegis of the Ministry of Mines to provide a common platform. The main purpose of the Society will be to encourage the study and advancement of fundamental and applied research on various aspects of geoscience and socio-economic activities having geo-scientific underpinnings or amenable to geo-scientific analysis. In this regard, Memorandum of Association and Constitution including by-laws of the proposed Indian Geosciences Congress is prepared submitted for formal approval of the Planning Commission and Department of expenditure in the Ministry of Finance.

(iv) The Society shall:

- Hold periodical meetings, conferences and social gatherings.
- Arrange courses in association with Geological Survey of India Training Institute other Organizations etc, discussions and demonstration on any subject of interest of the Society.
- Actively encourage research, teaching and training programmes at various centres of GSI/IBM and other institutions/departments recognized for the purpose.
- Engage in public education and training with the objective of creating a well-informed citizenry.
- Publish, distribute or otherwise circulate, records, transactions and proceedings of the various meetings and conferences of the Society, Publish and circulate a journal (Indian Geoscience Journal) which shall have a character specially related to the Geosciences and shall be the official organ of the Society.
- Coordinate as necessary and as seen fit with other Societies or Organisations having similar and allied objectives.
- Raise and borrow money and invest any sum belonging to the Society not immediately required, in such a manner as the Society may think fit.
- Maintain, Improve or alter and keep in repairing any building occupied by the Society.

- To encourage geoscience in the country. Life Time Achievement award to outstanding contributor in the field of Geoscience; encourage Geoscientists to carry out fundamental work in the field of Geoscience for which Research Scholarships may be provided,
- To encourage students to take higher studies at post graduate level in the field of Geoscience by providing monthly stipends to the students belonging to SC/ST and other backward classes and studying in the Universities/Institutes located in backward districts of the country.
- Do all such other things as are cognate to the objectives of the Society or are incidental or conducive to the attainment of the above objectives.

(v) The **Indian Geosciences Congress** will provide a common platform to the geoscientist community and related discipline by holding as annual congress to discuss technical subjects and hold exhibitions, encourage interaction, and increase awareness of contemporary research, and futuristic trends in geosciences. It develops coordination between Government, and Non- Governmental and academic institutions working on similar thrust areas by co-ordinating with leading International organizations in the field of geosciences to adopt synergetic strategies and to derive advantage of their expertise in the field.

(vi) The **Indian Geosciences Congress** will organize workshops, seminar and exhibition on various topical issues, particularly to involve academia and the private sector. It helps to propagate new technologies and concepts in geosciences, disseminate web-based information generated through its proceedings, and bring out special theme based publications, maintain updated databases of experts in different disciplines of geosciences. It encourages desirous person and scientists to participate in important geoscientific events by bearing travel and accommodation expenses, for their professional development where necessary.

(vii) The **Indian Geosciences Congress** will help to enlarge the scope for geoscientific intervention for sustainable development in different sphere of society in general and mining sector in particular where application of geosciences is required or possible and function as a non-profit body devoted to the cause of geoscience for interchange of geoscientific knowledge outside the official structures. The Congress will provide a broad based platform and forum for exposing and analyzing critical geoscience issues which are likely to emerge and impact society in near future for deliberations and providing recommendations for their solution.

23. MAPPING OF HUMAN RESOURCES AND SKILLS FOR THE GEOSCIENCE AND MINING SECTORS IN INDIA

23.1 The Mining Industry has contributed approximately 2.5%-3% to the GDP over the last few years and the same is expected to increase to about 5% to the GDP over the next few years. Also, the Mining Industry in India is a largest employer and the sector is poised for rapid expansion, thus, it is essential that the knowledge and skills in the workforce be attuned towards growth opportunities. In this context, the Mining Industry has rightly identified availability of skilled human resources as an enabling factor for the realization of the growth plans, and foresees a widening gap between supply and demand in this regard.

23.2 India produces as many as 86 minerals, which include 4 fuels, 10 metallic, 46 non-metallic, 3 atomic and 23 minor minerals (including building and other materials). The mineral production (excluding petroleum and natural gas) has increased from Rs. 53,713 crore in 2004-05 to Rs. 86,780 crore in 2008-09 at a CAGR of 12.7%. Fuel minerals account for the majority share, however, the share of fuel minerals in the overall production has declined from 61% in 2004-05 to 51% in 2008-09. During the same time period the share of metallic mineral in the overall production has increased from 19% to 34%. Globally, India ranks among the top 5 players in terms of production of several important minerals and India has abundant reserves of several important minerals. Orissa, Chhattisgarh, Andhra Pradesh and Jharkhand together contribute to more than 39% of total mineral production in India.

23.3 The National Mineral Policy, 2008 is focused on encouraging private sector participation in exploration and mining in order to encourage discovery and scientific mining of minerals, including those at deeper levels requiring high technology at prospecting and exploration stage.

23.4 There are several key forces affecting the human resource and skills requirement in the Indian Mining Industry as listed be low:

- Technology upgradation
- Increasing growth of mining output
- Retaining and attracting talent
- Ageing profile of the workforce
- Increase in productivity
- Long gestation period for skill acquisition
- Equity issues relating to relating to local population acquiring necessary skills

23.5 At present around 9 lakh persons (covering direct and outsourced) are employed in the mining & exploration of Coal, Metallic and Non Metallic, Minor & Other minerals. Coal accounts for more than 75% of the total employment as shown below:

Category	Employment (No.)
Exploration and Regulatory	20,565
Fuel Minerals (Coal & Lignite)	767,761
Metallic & Non-Metallic Minerals	116,029
Minor Minerals	87,762
Total	**992,117**

23.6 In terms of distribution of employment across geography, Orissa, Rajasthan, Jharkhand and Karnataka together accounts for around 58% of total Metallic, Non-metallic and Minor minerals employment whereas Jharkhand, West Bengal, Andhra Pradesh and Madhya Pradesh together accounts for more than 73% of total Coal & Lignite employment. Of the total employment, Women constitute only about 7% of total employment in the Mining industry. The low participation of women is primarily because of nature of working environment of mines. However, given the current level of employment there is scope for further increase in women's share of employment. Given the estimated increase in the mining output as well as the expected changes in the productivity levels, the total employment in the mining & exploration of Coal, Metallic and Non Metallic, Minor & Other minerals is estimated to increase to 1.1 million by the year 2017 and 1.2 million by the year 2025. Coal and lignite is expected to continue to be the maximum employment sector till 2025. The human resources requirement in Exploratory and Regulatory is expected to increase in the near future but to remain stable after 2017 .

23.7 **Education related initiatives**

It is proposed to take a set of initiatives to improve the employability of human resources through HRD Ministry interventions –

a) Geosciences – Given the thrust on the exploration activities in the National Mineral Policy, 2008, demand for the geoscientific personnel is expected to rise. Based on our estimated demand and the current supply from various educational institutes, a demand supply gap of about 1,500 and 2,200 is expected during the period

2009-2017 and 2009-2025 respectively. Also courses related to areas such as Geoinformatics, Climate change, Advanced course in Remote sensing are required to cater to the growing need of the industry.

b) Mining Engineering – Mining engineering category is expected to experience a demand supply gap of about 3,000 in the short term (2009-2017) and about 8,500 over the longer term (2009-2025). The course curriculum also needs to be updated with focus on mine safety, environment related and rock mechanics to better address the requirement of the industry .

c) Diploma engineering – There are lack of diploma courses catering to the mining sector. The current course in surveying needs to be updated with focus on imparting computer knowledge for capturing the survey data in digital form and usage of advanced survey machines. Also given the increase in the level of automation in the mining industry there is requirement of diploma in mining machinery course.

d) One of the major areas of concern is the lack of mineral specific professional such as lawyer, financial analyst, economist, etc. To support the growth of the mining sector there is immediate requirement to start courses for mining lawyers, mineral financial analyst/economist. Also new courses such as Diploma in mining machinery, M.Tech in spatial technologies, etc. needs to be introduced.

e) There is a large network of academic institutions providing basic education and training in geosciences, and other mining related courses. These institutions ensure good availability of fresh graduates and post-graduates. However, investment and efforts in keeping the knowledge, expertise and skills of manpower update has been inadequate which has been adversely affecting their capabilities. Thus, there is need to re-engineer the current human resources to enable to meet the requirements of the industry. This calls for corrective action by training of manpower in key areas, institutional strengthening, curriculum development, training of trainers, faculty development,

f) introduction of new & advance courses, networking with national & international agencies thereby promoting collaborative approach, evolving a long time human resource planning for the mining sector, & establishing linkages between academia and industry.

g) There is a need to increase the numbers of seats on the mining engineering and geosciences field. An estimate for the expected demand supply gap is provided in the detailed report. There is a need to align mining related courses in order to make them more relevant to the growing demand of the industry. Curriculum of courses such as Geoinformatics, Climatic change studies, Remote sensing, Mining engineering, Diploma in surveying, etc. needs to be updated to make them relevant to the current trend and demand.

h) To improve the attractiveness of mining programme, we propose setting up of scholarship program on the lines of Canadian Mineral Industry Education Foundation Scholarship and Mendenhall Research Fellowship Program of US Geological Survey. The scholarship can be offered to students attending courses in geology, mining or metallurgy, or any other discipline related to the mining industry in ISM, ITBHU, IIT, etc. The funding for the scholarship could be provided through collaboration among various industry players. On line of ISM, new University may also be set up in PPP mode in collaboration with leading petroleum and mineral sector industries. The Indian School of Mines established in 1926 on the pattern of Royal School of Mines, London which initially catered to mining, mining machinery,m ineral and petroleum industries has since 2006 started offering 14 new courses in related sector industry environmental engineering. It is a university positioned to close skill gap at higher level and to function as an incubator for new institutions on similar line at other potential locations. However, that requires close coordination's between the Ministry of HRD (the administrative ministry) and Ministries of Coal, Mines, Petroleum and Steel. A Study needs to be separately conducted to ensure that ISM is also more responsive to needs of industry, and the exploration sector.

i) Given the change in technology and growing environmental concerns there is a need to skill personnel already employed in the industry in areas such as safety, environment, health and surveying etc., through the short term refresher courses. To synchronize the efforts of the Industry, Government and Educational Institutions, we pro pose setting-up of Industry Skills Centre on the lines of "Mining Industry Skills Centre (MISC), Australia". Industry needs to take a lead in setting up formal structure for industry-institute coordination.

ANNEXURE – I

TERMS OF REFERNCE OF THE COMMITTEE NO. XII "GEOSCIENCE FOR SUSTAINABLE DEVELOPMENT"

1. To facilitate integration of geoscience into policy making for environmental issues and to transmit the concepts to potential interest groups including policy makers, non-governmental environmental agencies and general public.

2. Help develop a framework and methodology for promoting sustainable development strategies [including optimum land use] through best use of geoscientific data gathered in the course of survey and exploration by GSI and other geoscientific organizations in the country.

3. Assist nodal agencies concerned by developing new areas for geoscientific data collection, particularly spatial data such as geomorphology to help them analyse ecosystem functions and make informed planning decisions.

4. The Committee may co-opt other institutions as invitees.

ANNEXURE –II

List of Members of Committee No. XII
Geoscience for Sustainable Development

1. Secretary (Environment),
   Ministry of Environment and Forests,
   Deptt. of Environment,
   CGO complex, Lodhi Road,
   New Delhi

2. Secretary (Forests),
   Ministry of Environment and Forests,
   Deptt. of Environment,
   CGO complex, Lodhi Road,
   New Delhi

3. Secretary, Department of Science and Technology,
   Ministry of Science and Technology,
   Technology Bhawan, New Mehrauli Road,
   New Delhi

4. Secretary,
   Ministry of Health & Family Welfare,
   Nirman Bhawan, New Delhi

5. Secretary,
   Ministry of Agriculture,
   Department of Agriculture and Cooperation,
   Krishi Bhawan,
   New Delhi

6. Secretary,
   Ministry of Rural Development,
   Krishi Bhawan,
   New Delhi

7. Secretary,
   Department of Land Resources,
   Nirman Bhawan,
   New Delhi

8. Secretary,

Ministry of Urban Development,
Nirman Bhawan, New Delhi

9. Secretary,
Ministry of Water Resources,
Shram Shakti Bhawan,
New Delhi

10. Secretary,
Ministry of Earth Sciences,
Mahasagar Bhawan,
Block No. 12, CGO Complex,
New Delhi

11. National Environment Engineering Research Institute,
Nehru Marg, Nagpur
Maharashtra – 440020

12. The Controller General,
Indian Bureau of Mines,
Indira Bhawan, Civil Lines,
Nagpur

13. Central Ground Water Board,
NH-14, Bhujal Bhavan,
Faridabad – 121001

State Agencies dealing with GIS/ Spatial data

14. Karnataka State Remote Sensing Agency Centre (Karnataka),
Department of Information Technology & Biotechnology,
Govt. of Karnartaka, No. 611, 6th floor,
4th Stage, Multi-Storeyed Building,
Dr. B.R.Ambedkar Veedhi, Bangalore –560001

15. Commissionerate of Geology and Mining (Gujarat),
Block No. 1-2, 7th Floor,
Udyog Bhawan, Gandhinagar,
Gujarat

16. Bhaskaracharya Institute of Space Applications and Geo-Informatics (BISAG),
Near CH ‘O’ Circle, Indulal Yagnik Marg,
Gandhinagar – Ahmedabad Highway,
Gandhinagar-382007, Gujarat

17. Director,
Department of Town and Country Planning,
Kattarathi Buildings, Palayam, Thiruvananthpuram -695001

18. Shri Kuldeep Singh, Additional District Magistrate,
Administration of the
Union Territory of Lakshadweep (Collectorate),
Kavaratti

19 . Dr. A.S.Sivakumar, Director,
Dte. of Survey and Land Records,
2nd floor, Revenue Complex, Saram,
Puducherry – 605013

20. Director,
Rajasthan State Mines & Minerals Ltd.,
4-Meera Marg
Udaipur, Rajasthan

21. Ms. Elizabeth Ngully,
Under Secretary to the Govt. of Nagaland,
Government of Nagaland,
Department of Geology and Mining,
Kohima

Permanent Invitees

NGOs of all India Character nominated in consultation with Ministries/Departments

1. Mr. B.K.Kakade,
Vice-President,
BAIF Development & Research Foundation

2. Dr. Manibhai Desai Nagar,
National Highway No. 4,
Warje , Pune 411058

3. Director,
Professional Assistance for Development Action,
Post Box No. 3827,
3 Community Shopping Centre,
Niti Bagh New Delhi – 110049

4. The Energy and Resources Institute,
Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110003

5. Development Alternative Information Network,
Development Alternatives,
111/9-Z, Kishangarh,
Vasant Kunj
New Delhi –110070

6. Dr. V.Selvam,
Director - Coastal Systems Research,
M.S.Swaminathan Research Foundation,
322, II Main Road, Mariappa Nagar North,
Annamalai Nagar Post 608002
Cuddalore District
Tamil Nadu (Ph. No. 04144-238509)

7. Himalayan Environmental Studies &
Conservation Organisation,
Ghisarpadi, P.O. Mehuwalavia, District Dehradun,Uttarakhand

8. Geological Society of India, No. 63,
12th Cross Basappa Layout, Gavipuram,
Bangalore – 560019, Karnataka

9. Dr. Abhilash Malik,
Voluntary Health Association of India,
B-40, Qutab Institutional Area, New Delhi –110016

10. Mr. Areendran Gopala,
Director,
The Indira Gandhi Conservation Monitoring Center
WWF India, 172-B, Lodhi Road,
New Delhi- 110003 Ph. No. 41504791

11. Dr. Ashok Khosla,
Chairman, Development Alternatives
111/9-Z, Kishangarh, Vasant Kunj, New Delhi –110070

12. Shri D.S.Meshram,
President,
Institute of Town Planners India, 4-A, Ring Road, I.P.Estate, New Delhi –110002

13. Centre for Science and Environment,
41, Tughlakabad Institutional Area, Delhi -110062

14. Zoological Survey of India, Prani Vigyan Bhawan, M-Block,
New Alipore- KOLKATA- 700053

15. BSI Management Systems India Pvt. Ltd.
The MIRA Corporate Suites (A-2)
Plot 1 & 2 Ishwar Nagar
Mathura Road
New Delhi –110065

16. Director,
NBSSLUP, Amravati Road,
Shankarnagar PO,
Nagpur-440010

17. National Spatial Data Infrastructure,
East Block No. 7,
Level – 5, R.K.Puram
New Delhi –110066

18. National Resources Data Management System,
Department of Science and Technology,
Ministry of Science and Technology,
Technology Bhawan,
New Mehrauli Road, New Delhi – 110016

19. Professor S. Mukherjee,
Professor and Head (Geology and Remote Sensing),
School of Environmental Sciences, JNU
New Mehrauli Road, New Delhi – 110067
Telefax : 26704312

20. Indian Institute of Remote Sensing,
National Remote Sensing Centre,
Department of Space,
4, Kalidas Road, Dehra Dun –248001

21. Indian National Centre for Ocean Information Services,
“Ocean Valley”,
P.B. No. 21, IDA Jeedimetla P.O.,
Hyderabad – 500055