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REPORT OF GROUP

ON SEISMOLOGY

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REPORT OF GROUP ON SEISMOLOGY

On the initiative of Dr. B.D. Nag Chaudhuri, a study was undertaken on research work carried out in the field of seismology at various organisations in the country with a view to utilise facilities and personnel available at different places in the best manner. On the basis of information collected from the various organisations a back-ground note (Appendix I) was prepared and discussed at an inter-departmental meeting in the Planning Commission. A copy of the summary record of the meeting is enclosed at Appendix II. It was decided at this meeting that a Group consisting of Dr. A.N. Tandon, as Chairman and Dr. Jai Krishna, Shri V.S. Krishnaswamy, Dr. Hari Narain, Shri T.G. Verghese and Shri H.M. Choudhury as members, should look into the problem in depth and draw up:

(i) long term (say ten years) objectives of research in the field of seismology;

(ii) integrated development programmes showing national net work of observatories required and the role of individual institutions;

(iii) programmes for additional support needed in terms of infrastructure for achieving the research and development needs; and

(iv) schemes for utilisation of data collected and its dissemination to various organisations within and outside the country.

2. In order to facilitate the discussion during the meetings of the Working Group, Dr. A.N. Tandon prepared a working paper (Appendix III), which was discussed at the

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first meeting of the Group on 30th March, 1971. A copy of the summary record of this meeting is given in Appendix IV. The Group held a second meeting on 5th an 6th July, 1971 and considered in detail the items left over in the first meeting and the organisation of seismological research in the country. The summary record of this meeting is given in Appendix V. The gro finalised their work in a third meeting held on 27.11.1 The recommendations made by the Group are outlined in t following pages.

3. The science of seismology which made its beginni with the study of destructive earthquakes, has during t past few decades found applications in many fields dire tly connected with national economy and human welfare. The application of seismic methods for the prospecting o oil reserves has resulted in great economic prosperity to many nations. Even today the seismic method is the best method for the final location of oil fields. A proper interpretation of seismological data also facili- tates the delineation of subterrenean regions of interes in the exploration of other minerals. With growing urbanisation and search for power resources to meet the increasing needs of developing nations, large river valley schemes are being undertaken and new centres of population are coming up in areas prone to hazards due to earthquakes. It has become absolutely essential to know about the possible locations and intensities of

future earthquakes in areas where development is taking place or is likely to take place in future. A correct assessment of the proneness to destructive earthquakes of different geographical regions leads to substantial savings in the design of structures and ensures their long-term stability against dynamic forces originating from the interior of the earth. Seismological studies help to identify the process and time scale of accumulation of the forces which lead to earthquakes, and thereby to attain a modicum of reliability in predicting them early enough to minimise loss of life and property. Seismic methods have during the last two decades been applied to detection of underground nuclear explosions and vast sums have been spent by the world community of nations to perfect the methods of detection. The science of Seismology provides the only direct tool for the study of the interior of the earth. During the last decade as a result of national and international efforts, specially during the International Geophysical year and the Upper Mantle Project, significant progress has taken place in our understanding of the phenomenon of earthquakes. The concept of sea floor spreading and movement of plates (which has directly emerged from seismological studies) is likely to throw light on many important geological and tectonic problems such as mountain buildings and continental drift. The realisation of these broad objectives requires a balanced development in the

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following areas of seismology :

(i) Fundamental Seismology is concerned with evolving a plausible mathematical model of the earth so as to be consistent with all the instrumental observations, seismic, magnetic, heatflow, gravity etc. and interpreting quantitatively the nature and cause of earthquakes and the structure of the interior of the earth. Development of suitable instruments, adaptation of modern techniques of data processing and analysis, introduction of latest mathematical methods, are the essential elements of this branch of seismology.

(ii) Applied seismology seeks to exploit seismic techniques for the location and exploitation of underground mineral resources. It seeks to evolve inter relationship between the seismic behaviour of a region and its mineral content by integrating seismological inferences with other geophysical data. As a significant fall out, this field provides the means of identifying under ground nuclear explosions down to reasonably low limits on a global basis, with a level of confidence which improves steadily with refinements in seismic techniques. The relevance of this capability to world disarmament is obvious.

(iii) Earthquake prediction Seismology attempts to understand, on a global basis, the physical causes which render certain regions susceptible to disastrous earthquakes and to evolve methods for predicting and

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possibly preventing them. The current ideas about plate tectonics and continental drift require considerably more precise seismic data over large periods of time, for confirmation and possible refinement.

4. The Working Group on Seismology considered all the above aspects while formulating their recommendations. The recommendations represent the minimum effort which must be made in order that seismological work may have a direct impact on the economy of many national development schemes and contribute substantially to international efforts in the field of seismology. The recommendations of the group relate to the following items:

(1) Long term (ten year) objectives of research in the field of seismology.

(2) National network of seismological observatories required to be established in the country.

(3) Operation and maintenance of different types of seismological observatories and strong motion instrument, installations.

(4) Data collection, preservation of records and dissemination. Establishment of a Data Centre.

(5) Consultancy services to Government Departments and public.

(6) Establishment of a Central Institute of Seismology

(7) Research problems and the role of different institutions.

(8) Financial implications.

Long term objectives of development in the field of seismology:

5. Long term (next decade) strategy in seismology should be :

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i) to develop and distribute our seismological instrument potential to provide a homogenous seismograph net work adequate to cover the country not only for monitoring earthquake activity down to a reasonably low magnitude say 3.5 on the Richter scale, but also to cover the entire frequency range of earthquake waves, the integrated study of which alone would lead to a proper understanding of the physical processes before, during and after major earthquakes.

ii) to build up a central repository for the entire spectrum of seismological data from this net work as well as from all available world stations, with adequate facilities for the most effective dissemination of this vast data potential to the various research centres in the country and abroad.

iii) to adopt the most advanced technology for instrumentation, data acquisition, processing and analysis and guarantee a reliable set-up for collecting the most reliable and well-calibrated data.

iv) to evolve and equip a Central agency which will be responsible for seismological services of national importance viz. determination and publication of authentic source parameters of Indian Earthquakes in the quickest possible time,

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delineation and updating of seismic zones with the most comprehensive instrumental data and field investigations, preparation of Seismicity maps, as well as the operation, maintenance and improvement of the national network of seismological stations.

(v) to accelerate and consolidate the urgent task of investigating systematically the crust and upper mantle below our subcontinent and thus speed up our earth resources mobilisation programmes and derive data pertinent to the location of deep seated geological faults.

(vi) to build up a sound mathematical and technologically oriented research base for Seismological studies within the country through introducing adequate changes in the teaching set-up vis-a-vis seismology and promoting a vigorous and fruitful scientific dialogue between the universities and national centres of seismological research.

National net work of observatories required to be established.

6. The density and configuration of a suitable net work of seismological stations should be governed by two basic considerations namely (i) the need to obtain high quality data of both local seismic and teleseismic events and (ii) to provide a clear insight of regional seismicity of the site of the various river valley projects already

contemplated or likely to be undertaken in the future. In the absence of adequate seismological data, an over-cautious approach is adopted for designing river valley projects since under assessment exposes the projects to dangers of future earthquakes. With the overassessment of the seismic danger, the cost of the project increases. It is observed that the river valley project authorities set up their own seismological observatories usually after the project under issue has been approved. The data acquired from such observatories is not of much use since by that time a decision about the seismic factor would have already been taken. Collection of seismic data should be started at least five years prior to the design stage of the project. The existing net work of seismological observatories in the country is not adequate for this purpose. A considerable number of our river valley projects are likely to be taken up in the Himalayan belt and other areas which are seismically active. It is essential that we should take up a programme of setting up a suitable net work of observatories in these areas. On the basis of the relevant geological and tectonic data available, a note along with a map showing the tentative locations of seismological observatories to be established during the period 1971-1986 has been prepared and is enclosed in Appendix VI. The following recommendations are made :-

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(i) The objective of a 103 station national net work should be achieved during the period 1971 to 1986. At present there are only 23 stations in existence and therefore an additional 80 stations will be required to be added during this period. The priorities are laid down in Annexure III of Appendix VI. Among these about 6 to 8 observatories may be instrumented as teleseismic stations for serving national and international needs. In addition a suitable number of mobile stations may be required for studying after-shocks and micro regionalisation studies.

(ii) There are at present only 19 seismological stations connected with the investigations of river valley projects. Considering the river valley projects already approved or likely to be implemented during the period 1971-86, a net work of 92 stations would be necessary. This implies an addition of 73 more stations to the existing stations associated with river valley projects. Priorities for this expansion are laid down in Annexure IV of Appendix VI.

(iii) The number of strong motion instruments, i.e. accelerographs and structural response recorders is very inadequate considering the size of the country and the number of large earthquakes taking place. At present there are less than ten accelerographs installed along the whole of the Himalayan Seismic belt and also in the Koyna region. Only 56 Structural response recorder installations exist in India which are also very inadequate for providing data for

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design of structures in the respective regions. The Working Group felt that at least 100 strong motion accelerographs and at least 500 structural response recorders need be installed to provide adequate coverage in the regions liable to shaking by strong earthquakes. The tentative location of the accelerographs and the structural response recorders are listed in Appendix VII. In those locations where seismological observatories are also proposed, these installations may be made in the seismological observatory itself or a separate housing may be constructed for the purpose.

7. Operation and maintenance of seismological observatories:

Since generally seismological observatories are located at out of the way places, the different project authorities and institutes find it difficult to run them with one or two persons. Special staff recruited for the purpose has no further chance of promotion in the set up and are reluctant to stick to these isolated places. It was felt that a central institute with unified policy and with expertise and facilities available at one place for development and repair of instruments and with a large group of staff can look after the operation of all observatories in the country more effectively. Therefore, it would be better if the observatories run by the projects or the Central Water and Power Research Station, Poona, RRL Jorhat and by other organisations could be operated by a central institute.

(i) The strong motion observatories (general) and strong motion observatories attached to projects should be maintained by the School of Research & Training in Earthquake Engineering (SRTEE), Roorkee for the present as the instruments for such observations are still being developed by them. Work on the study of crustal deformation in connection with earthquake prediction programmes has already been started at SRTEE. It is recommended that the school should be encouraged further to undertake such studies in different tectonic units and given additional support if necessary.

(ii) The observatories operated by BARC for specified purpose and by NGRI whose main function is to study the behaviour of the solid earth from various aspects should continue to be run by BARC and NGRI themselves.

8. Data collection, preservation of records and dissemination (Data Centre): The facilities available at present for data collection and dissemination are not adequate. The existing facilities are, therefore, required to be strengthened so that there is quick dissemination of the instrumental data and past records are preserved properly. For this purpose microfilming facility would be essential. In this connection a note is enclosed as Annexure II to Appendix V, showing the type of equipment required for the data centre of the Central Institute which should collect, scrutinise, disseminate and preserve

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data of all the observatories in the country. The Data Centre should build up a library of seismological records including those from selected observatories in other countries.

(i) The strong motion data collected by the central institute should be passed on to the SRTEE, Roorkee who should scrutinise, disseminate and preserve the data. They should also publish the data in the form of a bulletin and circulate it to interested parties.

(ii) For collecting field data, the Geological Survey of India had been sending field parties to study the damage to structures and other phenomenon caused by earthquakes after the occurrence of every important event. During the last few years the Central Water and Power Research Station, Poona and the SRTEE, Roorkee have also associated themselves in the field studies of earthquakes with special emphasis on the engineering aspects. Since field data is very useful, GSI should continue to look after this activity and after every important event they should form composite team including officers from the central institute, SRTEE, Roorkee, CWPRS, Poona and other interested parties for the purpose of collecting field data. It would be better if one version of the report of the composite team under GSI is available in place of different conflicting versions prepared separately by different organisations.

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9. Establishment of an Institute for Seismological Research:

The Committee on Organisation of Scientific Research (COSR) considered the status of seismological work in India. The COSR while making recommendations in regard to research work done in IMD recommended that the Seismological Division working as a part of IMD should be separated and constituted as an autonomous institution. The Government of India accepted the recommendations and the Ministry of Civil Aviation and Tourism was taking steps to give effect to it. Recently, however, the Ministry deferred the decision on the plea that only 20% of the work of the Division of Seismology was research oriented. The group considered the following three alternatives :-

(i) as recommended by (COSR), The Seismology Division of IMD should be completely separated and function as an autonomous institute, or

(ii) (a) with DGO as the head, there should be a wing for operation and maintenance of seismological laboratories and (b) a research wing as an autonomous institution.

(iii) research wing instead of working as an autonomous unit should function as a Research Division under IMD with more flexible rules to permit recruitment of personnel directly at any level.

The Group felt that there would not be much advantage of linking the central institute with IMD, the main interest of which is in the field of meteorology. On the other hand, as suggested by COSR, by completely separating the Seismology Division of IMD and constituting

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it as an autonomous central institute for undertaking research work on seismology and maintenance and operation of national net work of observatories, it would be possible to develop facilities in this important area. To begin with the proposed Institute of Seismology should have at least three main Divisions, one division dealing with the establishment and maintenance of seismological observatories and the collection and dissemination of the data to research workers, the other two divisions dealing with the two main branches of research namely basic and applied. The present seismological organisation under the IMD with suitable additions of staff will constitute the nucleus of the new Institute. Each division should be headed by a scientist of the rank of Assistant Director of a National Research Laboratory. The nucleus of the research divisions should be formed as early as possible and they should be allowed to grow gradually as recommended by COSR. More divisions could be added to the Institute if justified at a later date. A schematic ... plan of the Institute as it should emerge after nearly a decade is enclosed in Appendix VIII.

10. Role of various organisation/Universities: In this connection, a brief note is enclosed as Annexure III to Appendix V. It was felt that universities should be encouraged to undertake both fundamental and applied seismological research work and they should draw upon expertise available at various organisations for

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formulating proper (R&D) programme in this field. As far as basic research is concerned which is mainly person oriented there should not be any fear about duplication of work. As a matter of fact, it would be desirable that more than one person or institute should work on a problem and tackle the same by adopting different approaches. However, even for basic research it would be advisable that a few institutes should build the expertise in a systematic manner. For applied research, requiring costly equipment, it would be essential that the efforts should be coordinated. With the considerations in view, a list giving the various problems required to be tackled and the institute which should be largely responsible for undertaking it is given below:-

Problems to be tackled in future	Institute largely responsible
A. Seismicity	
(i) Improvement in the accuracy of determining epicentral parameters, specially magnitudes of small tremors and depths of shallow earthquakes.	the proposed Central Institute.
(ii) Development of suitable techniques to determine magnitudes more accurately.	
(iii) Development of techniques to determine focal depths of shallow earthquakes.	
(iv) Preparation of maps of epicentres of earthquakes of magnitude 3 and above for the various areas of the country.	
(v) Preparation of maps delineating seismically active faults.	GSI
(vi) Correlation of seismic events with local geology.	Central Institute & GSI.

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Problems to be tackled in future	Institute largely responsible
(vii) Construction of seismic probability maps for different regions of the country.	Central Institute.
(viii) Construction of recurrence curves of earthquakes for small areas based on actual observations of micro earthquakes	
(ix) Studies of patterns of foreshocks and after shocks for important earthquakes and correlation with local geological structures	Any organisation who has expertise and interest in the problem.
B. Causes of Earthquakes:	
(i) Determining of fault plane solutions of past earthquakes by using techniques based on Initial P Wave motions, S waves, and Surface waves.	Central Institute.
(ii) Studies of radiation pattern used on actual seismological data and comparison with theoretical models.	Any organisation interested in the problem.
(iii) Intensive studies relating to movement of rock masses at various depths, collaboration in the International Geodynamics Project.	
(iv) Study of the deformation of the Earth's crust before, during and after seismic events with the help of tiltmeters, extensometers etc.	SRTEE, Institute.
(v) Precise levelling and triangulation to be carried out through out the country specially in areas with large seismicity	Geodetic Branch of Survey of India.
(vi) Geodemeter surveys to be carried out along active faults particularly in areas where large projects exist or are contemplated with a view to study the creep movements along the faults and their correlation with future seismic activity	

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Problems to be tackled in future	Institute largely responsible
C. Microseisms -	
(i) Study of seismic noise by sensitive seismographs with a view to correlate the pattern of noise with the foundation.	largely to BARC and the Central Institute
(ii) Special Study of microseisms in the period range (2-10) seconds caused by sea waves, with a view to investigate their nature, origin and propagation.	
(iii) Investigations of the methods by which storm type microseisms can be used to track storms methods using array techniques as well as matched three component seismographs should be attempted.	
(iv) Empirical techniques to determine the location and intensity of storms should be pursued.	
D. Model Seismology and Laboratory techniques -	
(i) Measurement of velocities of seismic waves in various types of rock specimens under conditions of high temperature and pressure.	GSI & NGRI.
(ii) Study of seismic wave propagation through two and three dimensional models.	
E. Engineering Seismology	
(i) Improvement in the net work of accelerograph stations specially in the Himalayan Seismic belt	SRTEE
(ii) Installation of large number of structural response recorders in the different seismic regions.	SRTEE
(iii) Design and construction of cheap types of accelerograph.	SRTEE
(iv) Study of soil behaviour during earthquakes.	SRTEE
(v) Vibration studies of different types of structures (Tall buildings, water towns, power houses).	SRTEE & CWPRS.
(vi) Behaviour of different types of structures during earthquakes.	-do-
(vii) Design of cheap seismic structures	SRTEE.
(viii) Model studies of special structures like dams, bridges on shaking tables.	SRTEE & CWPRS.
(ix) Site evaluation of dam sites through Blast tests.	-do-

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Problems to be tackled in future	Institute largely responsible
F. Wave Velocities, Travel time and ~~cultural~~ Crustal structure -	
(i) Improvement in observed travel time tables for different types of seismic waves.	Institute and NGRI.
(ii) Construction of T.T. Curves for seismic waves for different tectonic blocks.	
(iii) Studies of the earth's crust and mantle in different regions using data of body waves from near earthquakes.	Institute, NGRI & BARC.
(iv) Deep Seismic Soundings to determine the thickness and properties of crustal layers.	NGRI &* GSI.

* In this connection recommendations of the Panel for earth sciences and oceanography of Indian National Science Academy on the role of NGRI and other organisation are reproduced below:-

"The Committee decided that the project "Deep Seismic Sounding Technique" as approved by the Joint Committee for Indo-Soviet Collaboration be transferred from the India Meteorological Department to the NGRI, Hyderabad, The Committee made the following further observations -

i) NGRI will be main agency who will be responsible for the implementation of the project.

ii) Cooperation from the following organisations may be taken, wherever possible so as to get maximum output -

(1) India Meteorological Department
(2) Oil & Natural Gas Commission
(3) Geological Survey of India
(4) Atomic Energy Commission.
(5) Survey of India
(6) Universities.

The Committee noted that it was very important that we must think in terms of continuing the work on this project even after the present Indo-Soviet collaboration programme comes to an end, and accordingly the implementation agency (NGRI) and all other participating agencies must take action so as to develop permanent units in their respective organisation with Indian know-how and also to fabricate such machinery that may be required for the implementation of the research project locally.

Problems to be tackled in future	Institute largely responsible
(v) Study of the dispersions curve of surface waves for fundamental and higher modes for different tectonic blocks of the country. Both phase and group velocities of surface wave should be determined with the ultimate aim of constructing phase and group velocity maps.	Any organisation interested in the problem.

G. Seismological Instruments

Development of the following type of instruments -

(i) High Magnification electromagnetic seismographs to restrict imports of this item.	Central Institute.
(ii) Seismographs using electronic amplifiers and visible recording.	
(iii) Portable seismographs for study of aftershocks and microtremors.	
(iv) Long Period Vertical and Horizontal type e.m. seismographs.	
(v) Borehole seismographs.	NGRI
(vi) Seismographs for installation at sea bottom	NGRI
Recorders of the following type -	Central Institute.
Photographic recorders using paper or film	
Visible type with recording on paper	
Tape recorders	BARC.
Recorders capable of recording for long period without personal attention	
V.H.F. tele recording devices.	
(vii) Strain seismographs	Central Institute SRTEE
(viii) Development of the following accessories -	
Electronic clocks for time marking, amplifiers, for running Synchronous motors of recorders, Sensitive type moving Coil Short type and Long period galvanometers.	Central Institute.

Problems to be tackled in future	Institute largely responsible
(ix) Digital Seismograph	BARC
(x) Analog to Digital converters	
(xi) Response spectrum analyser	To be purchased from outside.
(xii) Cheap type of Accelerograph with built in displacement meters.	SRTEE.
(xiii) Tiltmeters of water tube type and horizontal pendulum type	
(xiv) Instruments for Engineering and Seismological studies.	

11. Financial Implications of the proposed development programme during next 10 to 15 years.

	Rs. lakhs
Non-recurring (building & equipment)	
(i) Central Institute of Seismology	40
(ii) 80 additional seismological observatories proposed to be set up in about 10 to 11 year period.	80
	120
(iii) 73 additional observatories envisaged to be constructed with river valley projects.	73
(iv) Installation cost of (a) 100 strong motion Accelerographs	20
(v) 500 Structural response records	15
Total Non-recurring:	228

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Recurring

The recurring costs will go on increasing as the number of observatories rises and the staff strength of Seismological Institute increases. However, a rough estimate of the recurring expenditure on completion of the recommendations is given below:-

	Rs. lakhs
Recurring Expenditure	
(i) Maintenance of the Central Institute of Seismology	20
(ii) Maintenance of national net work of observatories (80 additional and 23 existing)	20
(iii) Maintenance of observatories attached with River Valley Projects 73 additional and 19 existing.	18
(iv) Maintenance of 100 accelerographs and 500 structural response recorders.	1
Total: Total recurring expenditure per year.	59

12. The establishment of the Institute and the observatories will provide employment to nearly 600 scientists of various grades in addition to an equal number of clerical and Class IV staff.

Appendix--

PLANNING COMMISSION
(Scientific Research Section)
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Please refer to the Planning Commission circular of even number dated the 26th October, 1970 regarding the meeting to be held on Thursday the 12th November, 1970 at 12.00 hrs. in Room No.131, Yojana Bhavan, New Delhi.

In this connection, a background note giving resume of research work done in the field of seismology at different institutes/departments is sent herewith.

G. Ranganathan

(V. Ranganathan)
Chief (Science)

Dr. B.D. Nag Chaudhuri, Chairman, Committee on Science & Technology.

Department of Atomic Energy

(i) Dr. R. Ramanna, Head, Physics Group, Bhabha Atomic Research Centre, C/o. Atomic Energy Deptt., South Block, New Delhi.

(ii) Shri T.C. Verghese, Bhabha Atomic Research Centre, C/o. Atomic Energy Department, South Block, New Delhi.

Council of Scientific and Industrial Research

(i) Dr. M.S. Iyengar, Director, Regional Research Laboratory, Jorhat-6.

(ii) Dr. Hari Narain, Director, National Geophysical Research Institute, Hyderabad.

(iii) Dr. Jai Krishna, Director, School for Research and Training in Earthquake Engineering, University of Roorkee, Roorkee.

Central Water and Power Research Station, Poona.

Dr. C.V. Gole, Director, Central Water and Power Research Station, Poona-24.

Meteorological Department

1. Dr. P. Koteswaram, Director-General, Meteorological Department (Ministry of Tourism and Civil Aviation), Lodi Road, New Delhi.

2. Shri H.M. Chaudhury, Director, Seismology, Directorate of Seismology, Meteorological Department, (Ministry of Tourism and Civil Aviation), Lodi Road, New Delhi.

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Geological Survey of India

Dr. M.S. Balasundaram, Director-General, Geological Survey of India, 27, Jawaharlal Nehru Road, Calcutta-13.

Prime Ministers' Secretariat

Shri Ashok Parthasarathy, Special Assistant on Science and Technology.

Planning Commission Circular No.10/4/70-RSR dated

Copy for information to:-

(i) P.S. to Member (P), Planning Commission.
(ii) Dr. Atma Ram, Director-General, CSIR, Rafi Marg, New Delhi.
(iii) Dr. V.A. Sarabhai, Secretary, Department of Atomic Energy, South Block, New Delhi.
(iv) Shri T.N. Lakshminarayan, Joint Secretary, Deptt. of Mines and Metals, Sastry Bhavan, New Delhi.
(v) Shri N. Khosla, Joint Secretary, Ministry of Tourism and Civil Aviation, Sardar Patel Bhavan, Parliament Street, New Delhi-1.
(vi) Shri K.G.V. Iyer, Joint Secretary, Ministry of Irrigation and Power, Shram Shakti Bhavan, Rafi Marg, New Delhi.

V. Ranganathan

(V. Ranganathan)
Chief (Science)

PLANNING COMMISSION
(Scientific Research Section)
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Background note giving resume of research work done in the field of Seismology at different institutes/departments in the country.

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Research work in the field of seismology is carried out by the following major organisations/departments of the Government:

1. India Meteorological Department
2. Geological Survey of India
3. Central Water and Power Research Station
4. Department of Atomic Energy
5. The Council of Scientific and Industrial Research:
   (a) Regional Research Laboratory, Jorhat
   (b) National Geophysical Research Institute, Hyderabad.
   (c) School of Research and Training in Earthquake Engineering, Roorkee.

A brief note on the work done by each of the above institution is indicated below.

(1) India Meteorological Department (IMD)

The IMD has been recognised as the official agency in the country for the collection of scientific instrumental data on earthquakes and for seismological research and development. For this purpose, IMD maintains 18 permanent seismological laboratories and 4 mobile units. The Department also runs 7 seismological observatories for meso-scale seismological studies of the region containing the Beas-Dam and the Beas Sutlej link Project.

Facilities available

Four of the laboratories viz. at Delhi, Shillong, Poona and Kodaikanal are equipped with highly sophisticated instruments, supplied by US coast and Geodetic Survey under a scheme of worldwid

network of standardised seismograph stations. Data from these stations are useful for the study of crustal structure and also for the detection of nuclear explosion apart from the general study of earthquakes. The Department maintains two good workshops at New Delhi and Poona where facilities for development of instruments are available. The instruments which are designed and developed are then manufactured in this workshop. The manufacturing capacity is not enough to meet the requirements of other organisations. The following instruments have been developed:-

(i) A simplified model of wood-Anderson seismometer

(ii) Horizontal and vertical component E-M seismometer

(iii) Pen-recording visible recorders

(iv) Photographic recording unit.

(v) Time-making pendulum clock.

(vi) Transistorised crystal clock and power amplifiers

(vii) Transistorised alarm warning system for routine seismic observation.

At present the following posts in officers cadre take up research work:

(i) Director - 1

(ii) Class I (Senior) - 1

(iii) Class I (Junior) - 3
or
(iv) Class II (Gazetted) - 3

(2) Geological Survey of India (GSI)

GSI is primarily concerned with geo-tectonic evaluation of the earthquakes which have taken place in India and adjoining countries, based on the geological, geophysical and tectonic information collected by it. GSI has contributed much in the preparation of the seismic zoning map of India. Uptil now micro-seismic studies on fault plane or active seismic areas have been

carried out by GSI either by themselves or in collaboration with other organisations.

Facilities available

At present unit at GSI consists of a small cell of few geologists and geophysists who have been trained in geoseismological work through the programmes of studies undertaken by the Survey. The total number of personnel consisting of 5 geophysicists and 10 geologists could be deployed only part time for geo-seismological work. The equipment available with GSI which may be utilised for geoseismological studies include the core drills (2000 m. capacity), geophysical survey equipment, and photogeological equipment.

(3) Central Water and Power Research Station (CWPRS), Poona.

The CWPRS pursues research (basic and applied) in 'seismology' and 'vibration engineering' as applied to river valley projects and other engineering structures like bridges foundations of machines, installations etc.

Facilities available

The main equipment comprises of (i) various types of seismographs such as Wood-Anderson and electromagnetic seismograph with accurate time making and recording devices, three-component sprengnether seismographs etc. (ii) vibrographs, transducers, vibration and strain measuring equipments with automatic recording devices, hydrophones, water pressure pick-ups etc. (iii) vibration analysers, frequency spectrometers etc. (iv) dynamic material testing equipments such as ultrasonic material testers specially suitable for in situ tests on dams and other structures, (v) recording oscilloscopes and various types of recorders; and (vii) vibrators (large and small) vibration tables and other

allied equipments.

The research staff in position as on 1.3.1970 consists of the following:-

Chief Research Officer	1
Research Officer	3
Assistant Research Officer	2
Research Assistant	4
Observers	5
Computer	1

(4) Department of Atomic Energy

The Bhabha Atomic Research Centre (BARC), initiated a programme of seismological research in 1965.

The Gauribidanur array was installed with the assistance of U.K.A.E.A. in December, 1965. In its original form it comprised of 10 short period vertical seismometers, each with a natural period of one cycle per second and damping coefficient of .6 (critical) installed at intervals of 2.5 km, to form an 'L' pattern. Each arm of the array thus consisted of 5 equally spaced seismometers. The arms are oriented along 212 degrees and 302 degrees east of north. The centre of the array is located in Bomashettihalli village six miles west of Gauribidanur town. The seismic signals are amplified and transmitted to the central recording laboratory over telephone cables using carrier modulation. At the recording lab, signals are processed suitably for recording on multichannel magnetic tapes along with precise time signals formatted suitably to identify the absolute time after every minute mark. The system incorporates suitable visual monitoring facilities to ensure continuous operation and to indicate the arrival times of seismic events. By the beginning of 1968 the

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array was extended to have 5 additional seismometers along each arm. The station has since been augmented by the addition of a three component long period seismograph system installed in an underground valut recording its output (amplified electronically) on magnetic tape systems along with the time marks and monitoring their signals continuously on visual recorders.

It has contributed to evaluating differences in the characteristics of seismic signals set up by underground explosions and crustal focus earthquakes from those geographical regions to which the array is most receptive.

The Division is at present collaborating with Kolar Gold mine undertaking to install suitable magnetic tape recording instruments inside their mine shafts with the object of locating the source of rock bursts and developing methods for possible means of correlating such events with the strain history of the medium.

Facilities

To reduce the bulk of data collected at Gauribidanur and to deduce the parameters of seismic events such as location, source characteristics etc. digital computation is extremely convenient. Equipment and hardware needed for converting the continuous data from Gauribidanur to a magnetic tape format suitable for the CDC-3600 computer at Bombay were, therefore, built up. This system for off-line transcription consists of -

i) A play back unit compatible with Gauribidanur tape units along with suitable band pass filters.

ii) Multichannel visual monitoring recorder.

iii) Multiplexing system for 16 channels.

iv) A digitising unit capable of 5000 conversions/ sec. with an accuracy of 12 binary bits.

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v) A digital stepping recorder capable of producing computer compatible records on IBM 7 track, half inch, wide magnetic tape.

vi) Associated hookup electronics for interfacing this recorder to the ADC.

The multiplexer-ADC system and the associated hookup units were designed and fabricated completely in the section. Using this system library tapes in computer compatible form are regularly being made to preserve the relevant seismic signals of underground explosions and some earthquakes for further study.

Based on the experience in the off-line processing of Gauribidanur data the requirements of an on-line computer suitable for obtaining the basic parameters of seismic sources of interest to the teleseismic monitoring of underground explosions have been formulated. At present the following staff are deployed in seismology.

i)	Seismological research and analysis	4 officers 3 Assistants.
ii)	Design and development of new instrumentation and maintenance of computer-based digital processing system.	2 Officers 2 Assistants.
iii)	Technical Maintenance of seismic array and long period data acquisition system.	2 officers

(5) Council of Scientific and Industrial Research (CSIR).

Regional Research Laboratory, Jorhat (RRL): A nucleus group in the field of seismology was formed in 1961 to execute the programme approved by the Special Expert and Planning Committee for the laboratory in 1960. This programme jointly drawn by RRL, Jorhat, the Indian Meteorological Department and the School of Research and Training in Earthquake Engineering, Roorkee, provided for the establishment of 12 stations in the regions to collect vital earthquake data on the basis of which further advance in the field of R & D work will be made.

These were in addition to those contemplated by IMD.

The laboratory also maintains a structural response recorder station within its campus on behalf of the School of Research and Training in Earthquake Engineering, Roorkee The Seismology section of BARC has established a microbarograph station with the cooperation of the seismology group of the laboratory.

Facilities available:- The following equipment and facilities are available.

(i) Three component Benioff short period seismograph complete with recorders and accessories.

(ii) Single component sprengnether seismograph complete with recorders and accessories.

(iii) Two component Wood Anderson seismograph complete with recorders and accessories.

(iv) Complete time making outfit for the seismographs.

(v) Photographic and other processing equipments, facilities, for reducing and blowing up of records.

(vi) Blast and vibration recorders, complete with all accessories and suited for recording in the field.

(vii) Work-shop facilities for fabrication, repairs etc. of existing equipments and making new units for experimental purposes.

(viii) Facilities for repairs/fabrication of delicate electrical or electronic components and gadgets.

(ix) Field study of earthquakes effected areas in the region-service of geologists, geophysicists and photographs for such studies.

(x) Service of seismologists both for analysing instrumental records as well as proper evaluation of field data.

(xi) Staff to impart training and supervise the work as envisaged in the programmes of the laboratory.

Staff:-

Scientist C - 1
Scientist B - 3
Service of the supporting staff.

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Besides, the staff working in electronic (instrumentation) and civil engineering (including soil mechanics) group are also, at times, associated with the work.

The service units of the laboratory - workshop and maintenance renders general help to the group.

(ii) National Geophysical Research Institute (NGRI), Hyderabad.

Seismological studies are carried out at NGRI since 1964. A modern seismological laboratory has been established providing much needed seismic data for the Deccan shield. The investigations undertaken include systematic studies of the recent significant earthquake sequences of the Koyna and the Godavari regions, surface wave dispersion studies, determination of P and S wave travel curves for the Indian sub-continent and the study of the upper mantle structure from shallow and deep earthquakes, analysis of body wave amplitudes and magnitude relations for shallow and deep earthquakes (formulation of new fundamental correlation between high magnitude global seismicity and steel lateral elastic wave velocity gradients), studies on the deformation of seismic pulses by layers of non-uniform velocity distribution and the phenomenon of mode equivalence. The seismological observatory is equipped with three component short period Benioff and long period Press Ewing seismometers. The time keeping is done by frequency regulated crystal chronometers. Computations are carried at the RRL where there is a IBM-1620 computer. The instrumentation decision at NGRI also caters to the needs of the seismological observatory. The Division consists of 2 scientists 'C', 4 SSA's, 1 JSA, 2 JRF's and 3 JLA's.

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(iii) School of Research and Training in Earthquake Engineering:

The University of Roorkee set up a School for Research and Training in Earthquake Engineering in 1960 with the financial assistance of CSIR to study the R & D needs of the country with respect to earthquake resistant design of engineering undertakings such as river valley projects, major industries, bridges etc. At the time of setting up, the School was the third of its kind in the world the other two being in U.S.A. and Japan. The School has organised itself into four basic divisions viz.

(a) Engineering Seismology and seismo-tectonics

(b) Field observations instrumentation and model techniques.

(c) Structural dynamics and vibration mechanics.

(d) Soil dynamics and foundation design.

The work carried out so far consists of development of instruments for vibration measurements and recording strong earthquake shocks; analytical and statistical studies of the seismicity of some parts of the country, study of the behaviour of some of the engineering structures such as brick houses, multistoreyed buildings, water towers, arch dams etc. and behaviour of soil under dynamic loads, foundation subjected to vibratory forces, liquefaction of soil and its consequences on dams and other structures etc.

Facilities available

Various types of equipment that have been designed, developed and fabricated at the School are as follows:-

(a) Laboratory equipment for testing models under vibratory forces viz. (i) Accelerometers, (ii) velocity pickups, (iii) Displacement pickup, (iv) pressure transducers, (v) vibration

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tables of several sizes and types for subjecting models or materials to a given horizontal or vertical vibratory motion.

(b) Strong earthquake motion recording instruments viz: (i) Accelerographs (ii) Recorders of earthquake response of idealised engineering structures.

(c) Establishment of stations for observations of forces excited during strong earthquakes.

(d) Apparatus for dynamic testing of soil viz. (i) Dynamic direct shear appratus, (ii) Dynamic triaxial apparatus, (iii) Tilting table, etc.

(e) Oscillator for imparting steady state vibrations.

(f) Ground deformation meter viz. (i) water-tube tiltmeters, (ii) silica tube extensometers.

The staff consists of a 4 professors, including the Director, two readers and 8 lecturers.

Recommendations of COSR in respect of work on Seismology

The Committee on Organisation of Scientific Research (COSR) of which Dr. S. Bhagavantham is the Chairman, considered the status of seismological work in India. The COSR while making recommendations in regard to the India Meteorological Department (IMD) has recommended that the Seismological Division working as a part of IMD should be separated from the IMD and constituted as an autonomous institution. The Committee felt that such a recommendation would help all seismological work in India being brought under one agency and would get the necessary encouragement and coordination. The Government of India have accepted this recommendation and the Ministry of Civil Aviation and Tourism is taking steps to give effect to it. IMD have stated that action has been initiated for converting the Seismological Division of IMD into an autonomous

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institute of Seismology and a draft memorandum of Association and a draft set of rules and regulations have been drawn up and that the proposed institute may be set up before the end of this year. Recently, however, the Ministry of Civil Aviation has deferred the decision on the plea that only 20% of the work of the Division of Seismology was research oriented. The matter has been referred to Chairman, CoSR and his decision is awaited.

The erstwhile Member (Science), Dr. B.D. Nag Chaudhuri was interested to know whether the data collected by different organisations are utilised properly or the same data is collected by several organisations involving wastage of time and labour and also whether the facilities available in different institutions in terms of manpower and instruments are utilised for the benefit of each other.

Continuation of research work in seismology under CSIR

The executive council of RRL, Jorhat at its meeting held on 16th October, 1967 recommended that priority may be given for construction of a seismograph building at an estimated cost of Rs.1.50 lakhs during 1968-69. While conveying the approval of the Vice-President CSIR, to the proceedings of the above meeting the following observations were made:-

"Since the India Meteorological Department has a central Seismological Observatory at Shillong, it is not considered necessary to duplicate the work at the RRL, Jorhat. The recommendations of the Executive Council for a Seismograph building at an estimated cost of Rs.1.50 lakhs has, not, therefore, been agreed to".

This matter was again placed before the Executive Council at its meeting held on 29.6.1968 by the laboratory for further consideration. While conveying the approval of the Vice-President, CSIR to the proceedings of the meeting of the Executive Council

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on 29.6.1968, the following observations were made:-

"The outcome of the discussions to be held between DG, CSIR and IMD authorities may kindly be awaited for undertaking construction of the seismograph building".

Persuant to the discussions at the meeting of the Executive Council held on 29.6.1968, a meeting of a Committee consisting of DG, CSIR, Dr. A.N. Tandon, the then Director (Seismology), IMD, Dr. Jaikrishna, Dr. Hari Narain, Dr. M.S. Iyengar and Secretary, CSIR was convened by DG,CSIR on 9th May, 1969 to discuss the question of continuance of research work on seismology and Earthquake Engineering at the CSIR laboratories. The views expressed by the members in the discussion were that the work on seismology was very important and required to be taken up intensively and for this purpose, a number of seismic stations in the various parts of the country with facilities for data collection and analysis and processing of data should be available. Isolated work taken up in a particular station or laboratory would not lead to any good purpose. The IMD has at present a few seismic stations and but comprehensive work cannot be undertaken by IMD for want of funds. If funds were made available to IMD, they could no doubt take up the work. It was stated by Dr. Tandon that there was a proposal for setting up an autonomous institute of Seismology. If that came up, it can have under it seismic stations at various places with necessary equipment and staff and the work could be coordinated.

The proposal of RRL, Jorhat was considered by the Board and the Governing Body of CSIR at their meetings held on 23rd and 24th July, 1970. The Technical Committee at its meeting on 22nd July, 1970 made the following recommendation:-

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"The Committee is given to understand that the Planning Commission will be soon calling a meeting of all parties who are concerned in seismic work in India. The Committee recommends that in the deliberations of that meeting, whatever work is reassigned to the Jorhat Laboratory may be put to DG,CSIR and that steps be taken to implement it".

The recommendations of the Board made at its meeting held on 23rd July, 1970 is given below:-

"The President desired that the recommendations of the Planning Commission regarding coordination of work on seismology should be available soon. Subject to the above observation, the Board accepted recommendation of its committee".

In this meeting convened by the Planning Commission, it is proposed to discuss:-

(i) collection of seismic data and its dissemination - the role of different organisations.

(ii) utilisation of existing facilities at different institutions.

(iii) Appropriate allocation of research work on seismology at the CSIR laboratories and other institutions vis-a-vis the autonomous institute of seismology proposed to be set up and coordination of research activities between these institutes.

(iv) The need for drawing up a integrated long-term programme in the field of seismology involving all organisations and responsibility to be assigned to each.

Appendix II

PLANNING COMMISSION
(Scientific Research Section)

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Summary Record of the meeting held in Yojana Bhavan on 12.11.70 to review the research work done in the field of Seismology at various institutions/Departments is enclosed herewith.

V. Ranganathan
(V. Ranganathan)
Chief (Science)

(i) Dr. B.D. Nag Chaudhuri, Chairman, Committee on Science & Technology and Scientific Adviser to the Minister of Defence, South Block, New Delhi-11.
(ii) Dr. A.N. Tandon, Dy. Director General of Observatories (Retired), B.7/50, Safdarjung Development Scheme, New Delhi -16.

Department of Atomic Energy

(i) Dr. K. Ramanna, Head, Physics Group, Bhabha Atomic Research Centre, C/o. Atomic Energy Deptt., South Block, New Delhi.

(ii) Shri T.G. Verghese, Bhabha Atomic Research Centre, C/o. Atomic Energy Department, South Block, New Delhi.

Council of Scientific and Industrial Research

(i) Dr. M.S. Iyengar, Director, Regional Research Laboratory, Jorhat-6.
(ii) Shri T.K. Dutta, Regional Research Laboratory, Jorhat-6.
(iii) Dr. Hari Narain, Director, National Geophysical Research Institute, Hyderabad.
(iv) Shri K.L. Kaila, National Geophysical Research Institute, Hyderabad.
(v) Shri M.K. Gupta, National Geophysical Research Institute. Hyderabad.
(vi) Dr. Jai Krishna, Director, School for Research and Training in Earthquake Engineering, University of Roorkee, Roorkee.
(vii) Dr. I.C. Chopra, Asstt. Director General, CSIR, Rafi Marg, New Delhi.

Central Water and Power Research Station, Poona.

(i) Dr. C.V. Gole, Director, Central Water and Power Research Station, Poona-24.
(ii) Dr. S.K. Guha, Central Water and Power Research Station, Poona -24.

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Meteorological Department

(i) Dr. P.Koteswaram, Director-General, Meteorological Department (Ministry of Tourism and Civil Aviation), Lodi Road, New Delhi.

(ii) Shri H.L. Chaudhury, Director, Seismology, Directorate of Seismology, Meteorological Department, (Ministry of Tourism and Civil Aviation), Lodi Road, New Delhi.

Geological Survey of India

(i) Dr. M.S. Balasundaram, Director-General, Geological Survey of India, 27, Jawaharlal Nehru Road, Calcutta-13.
(ii) Shri V.S. Krishna Swamy, Geological Survey of India, 27, Jawaharlal Nehru Road, Calcutta-13.

Prime Minister's Secretariat

Shri Ashok Parthasarathy, Special Assistant on Science and Technology.

Planning Commission Circular No.10/4/70-RSR dated 15..12.70.

Copy for information to:-

(i) P.S. to Member (P), Planning Commission.
(ii) Dr. Atma Ram, Director-General, CSIR, Rafi Marg, New Delhi.
(iii) Dr. V.A. Sarabhai, Secretary, Department of Atomic Energy, South Block, New Delhi.
(iv) Shri T.N. Lakshminarayan, Joint Secretary, Deptt. of Mines and Metals, Sastry Bhavan, New Delhi.
(v) Shri N. Khosla, Joint Secretary, Ministry of Tourism and Civil Aviation, Sardar Patel Bhavan, Parliament Street, New Delhi-1.
(vi) Shri K.G.V. Iyer, Joint Secretary, Ministry of Irrigation and Power, Shram Shakti Bhavan, Rafi Marg, New Delhi.

V. Ranganathan

(V. Ranganathan)
Chief (Science)

PLANNING COMMISSION
(S.R. Section)

....

Summary Record of the meeting held on 12.11.70 in Yojana Bhavan, to review the research work done in the field of Seismology at various institutions/Deptts.

Present

Planning Commission

Shri Pitambar Pant, Member (I)

Dr. V. Ranganathan, Chief (Science)

Committee on Science and Technology (CoST)

Dr. B.D. Nag Chaudhuri, Chairman

Prime Minister's Secretariat

Shri A. Parthasarathy, Special Assistant for Science & Technology

Council of Scientific and Industrial Research

Dr. M.S. Iyengar, RRL, Jorhat

Shri T.K. Dutta, RRL, Jorhat

Shri K.L. Kaila, NGRI, Hyderabad

Shri H.K. Gupta, NGRI, Hyderabad

Dr. I.C. Chopra, CSIR Headquarters

Department of Atomic Energy

Shri T.G. Varghese, BARC

India Meteorological Deptt.

Dr. P. Koteswaram

Dr. A.N. Tandon

Shri H.M. Chaudhury

Geological Survey of India

Dr. M.S. Bala Sundaram

Shri V.S. Krishnaswamy

Central Water and Power Research Station

Dr. C.V. Gole

Dr. S.K. Guha

School for Research and Training in Earthquake Engineering

Dr. Jai Krishna.

Initiating the discussion, Shri Pitambar Pant, said that there is a need to survey various organisations engaged in similar type of scientific research work with a view to utilise facilities and personnel available at different places in the best possible manner. On the initiative of the erstwhile member in charge of Scientific Research in the Planning Commission, Dr. B.D. Nag Chaudhuri, information in respect of the work being carried out in the field of seismology at various organisations was collected and circulated as a background note for the meeting. Though considerable information, knowledge and skill were being built up at the various institutes there has been a feeling in the Planning Commission that data collected by the different organisations were not utilised properly. Also, the facilities available, like expensive equipments, in different institutions could be utilised better for the benefit of each other. This is due to lack of proper coordination between various organisations working in the same field. This meeting had been convened to review the progress of work and pool the ideas and experience together for defining longterm and short term objectives and to ensure continuous coordination. In this way one should be able to distinguish the individual role of various laboratories and institutions in the entire range of work. He requested Dr. Nag Chaudhuri to initiate the discussion.

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Dr. Nag Chaudhuri said that in the field of seismology a lot of data had been collected but the question arose as to how to use them in the best possible manner. A plan for a long-term data collection and direction for R & D effort was required to make the best use of facilities and data available at different places. On a priority basis it was necessary to cover large areas which are earthquake prone and map them. He invited suggestions as to how data could be collected and easily transmitted to various centres of research and maintained at one centre from where these could be easily accessible to others.

Dr. Koteswaram stated that the India Meteorological Department (IMD) has been recognised as the official agency in the country for the collection of scientific instrumental data on earthquakes and for seismological research and development. For this purpose the Department maintained 18 permanent seismological laboratories and 4 mobile units. Recently the Committee on Organisation of Scientific Research (COSR), while making recommendations in regard to the IMD, had recommended that the seismological Division working as a part of IMD should be separated and constituted as an autonomous institution. The Committee felt that such a recommendation would help all seismological work in India being brought under one agency and would get the necessary encouragement and coordination. While the recommendation was being examined, the IMD found that only 20% of the work of the Division of Seismology was research oriented

and therefore it would be difficult to separate the whole of it as a research unit. IMD felt that maintenance of net work of stations and collection of data could be looked after by the Department and separate institute may be set up for research purpose only.

Dr. Koteswaram stated that the Department maintains two good workshops at New Delhi and Poona. They have also developed know-how for instruments for which the country no longer depends on imports. The IMD is also in a position to manufacture most of the instruments required by the seismological laboratories. Hence he felt that it would be advisable that IMD continues to maintain the existing laboratories and collect instrumental data. He said that the IMD is already doing good work in the dissemination of data. The data published in IMD is available to other organisations also and if necessary, this activity could be further strengthened. Other organisations can furnish copies of their record and data in the form of microfilms to the IMD who can then function as a data bank.

Dr. Koteswaram said that in his opinion there is not so much of clash or overlap of work because each organisation has got, to some extent, distinct type of work. The principal objective of the seismic studies of the Central Water and Power Research Station is in the field of 'seismology' and 'vibration engineering' as applied to river valley projects and other engineering structures like bridges, foundations

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for machines, installations etc. while the RRL, Jorhat studies regional earthquakes of high seismicity in the north-east region. The role of IMD is also different as stated earlier. These institutions could continue to work in their respective fields.

Shri Kaila stated that as far as collection and publication of seismological data is concerned, the IMD is doing a fine job and they could continue to publish their data. There are organisations like NGRI and others who are maintaining observatories for specific purposes and are conducting research. They also publish their data. Sometimes, the data published are not enough for certain types of research and if some research worker wants to see the original recording then they experience some difficulties. Hence he desired that these difficulties should be eliminated. He felt that if the main purpose of creating a seismological research institute was to maintain these observatories, then their purpose would be lost. Also research cannot be centralised at one place. The standard of research would improve if the universities and national institutes cooperate and coordinate their work.

Dr. Tandon stated that the IMD has been publishing the data for quite a long time. But it would be humanly impossible to publish the whole data which may not be required by everyone. He pointed out that the problem of standard data collection and dissemination was discussed

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by/UNESCO Consultative Committee of which he was a member. It came to the conclusion that the present system was not adequate.

Shri Varghese stated that he was of the view that the present state of affairs is not at all conducive to the type of work that is required to be done, viz, to make information available in a precise and quantitative manner. It is not possible to do more sophisticated type of research work with the present equipment and staff. He felt that the present instrumentation is not sufficient to cover the entire spectrum of earthquakes which have a periodicity from one hour up to a hundredth of a minute. It is important that more detailed information is supplied to the users who need it. He pointed out that firstly the objectives of research and development work in the field should be clear before one decides about the type of data to be collected, the number of seismic stations etc. Shri Varghese said that in addition to collecting data the research part should be given due importance.

Dr. Iyengar stated that as early as 1961, RRL, Jorhat took up the programme of work in seismology on the recommendation of an expert Committee which included Dr. Tandon. This Committee had suggested the establishment of 12 seismic stations in the north-eastern regions to collect vital earthquake data based on which further advance in the field of research and development would be made.

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He also agreed with Dr. Koteswaram that there was no duplication. Each organisation was working with some specific end in view. What was required was the need for some sort of coordination between the different organisations. The data could be collected in some standard form by the various institutes in addition to the IMD who may publish the data to the extent required.

The question to be considered was whether the work of seismology should be continued at the RRL, Jorhat. If the IMD wants to do the work he would be happy. The executive Council of RRL, Jorhat had approved and subsequently reiterated the need for continuation of studies in the laboratory. He also felt that there was no duplication involved and the programmes were taken up only in consultation with IMD.

Dr. Balasundaram stated that the existing stations are not sufficient and many more stations are required to be set up in the country. But merely setting up stations here and there will not solve the problem. They will have to be looked in a coordinated manner considering the needs of different organisations and not merely their existence under different agencies. Of course, data should be collected in some standard form and disseminated so that these could be used for research purposes at different centres in the country. Regarding preparation of seismological maps he felt that work could be taken up at different centres of research but it is essential that the official version should be only one.

Shri Parthasarathy stated that firstly it was essential to know what the scientific targets and programmes for the next ten years or so were before discussing how best to plan to achieve these targets.

Member (P) agreed with this proposition and said that it was also necessary to be clear about the scale in which a particular activity needed to be carried out and a particular laboratory was the right one for taking it up. For example, the role of regional observatories should be considered in relation to the work done by centralised agencies like IMD, GSI, etc.

Dr. Nag Chaudhuri stated that the data could be collected by different organisations provided IMD is satisfied that it is collected in a standard manner and that all data are made available to them as and when required.

After some discussions it was decided that a group consisting of Dr. A.N. Tandon as Chairman and Dr. Jai Krishna, Shri V.S. Krishnaswamy, Dr. Hari Narain, Shri T.G. Varghese, Shri H.M. Chaudhury as members may be constituted with the following terms of reference to go into the problem in depth.

(i) Long-term (say ten years) objectives of research in the field of seismology;

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(ii) Integrated development programmes, national net work of observatories required, and the role of individual institutions;

(iii) Additional support needed in terms of infrastructure, instruments for achieving the research and development needs;

(iv) Utilisation of data collected and its dissemination to various organisations within and outside the country.

(Action: Dr. A.N. Tandon)

Member (P) desired that the report should be available within two months and the next meeting would be convened after circulating the report.

APPENDIX-III

WORKING PAPER CIRCULATED BY DR. A.N. TANDON FOR CONSIDERATION AT A MEETING OF THE WORKING GROUP TO BE HELD ON 30TH MARCH, 1971 TO REVIEW THE PROGRESS OF RESEARCH IN SEISMOLOGY.

INTRODUCTION

The chain of the great Himalayan mountains extending from the vale of Kashmir in the West to the hills of Assam in the East, have been experiencing earthquakes from times immemorial. Even during the last 100 years this region has been subjected to more than 40 major earthquakes responsible for destruction of human life and property. Mention may be made of the great Assam earthquakes of 1897, the Kangra earthquake of 1905, the Bihar earthquake of 1934 and the Dhubri earthquake of 1930. A very large number of earthquakes of lesser intensity have also taken place in areas slightly to the south of this main belt. Some of these have also been responsible for causing damage to property and loss of life. In addition to this major seismic belt the areas in and around the Rann of Kutch have also experienced earthquakes of destructive magnitudes in the past. The occurrence of the Koyna earthquake in December 1967 has showed that even the margins of the Deccan Shield hitherto regarded as a stable zone are also seismogenic.

No scientific study of Indian earthquakes seems to have been undertaken during the ancient times. Earthquakes were usually believed to occur as an expression of the wrath of God. Whatever accounts are available appear to be incomplete and highly exaggerated. The scientific study of earthquakes in India was first taken up by Dr. T. Oldham, the

first Director of the Geological Survey of India, towards the later part of the 19th century. He was the first in India to have ccmpiled a catalogue of Indian earthquakes from the earliest times to the end of A.D. 1869. Oldham also wrote a very graphic account of the great Cachar earthquake of 1869. His work was continued by his son R.D. Oldham who wrote a memoir on the great Assam earthquake of 1897 which is still regarded as a pioneering contribution in seismology. It is in this memoir that Oldham for the first time gave a physical interpretation of the P and S phases on seismograms and thus laid the foundations of modern seismology. The tradition established by the Oldhams in the Geological Survey of India has been kept up by the officers of the Geological Survey and a systematic field investigation of all the important Indian earthquakes has been carried on since that time.

In the early days, earthquake parameters i.e. Epicentre, Origin time, depth of focus etc. used to be determined only by field study. The introduction of seismological instruments or seismographs to measure the earth vibrations caused by earthquakes, towards the end of the 19th century brought about a revolution in the determination of earthquake parameters. In India, seismological instruments or seismographs of the Mine type were introduced after the occurrence of the disastrous Assam earthquake of 1897, as a result of the recommendations of the seismological committee of the British Association for the advancement of Science. The Government of India agreed to the suggestion of the Committee and established seismological observatories at Alipore (Calcutta) in 1898 at Colaba (Bombay),

and Madras during the year 1898-99. The seismograph at Madras however, was transferred to the Kodaikanal Observatory after a year. In the year 1905 a great earthquake took place at Kangra. The intensity of the earthquake was so large that sensitive instruments of the Milne-type operating at Calcutta, Bombay and Kodaikanal could not record the full ground movements due to the earthquake. This necessitated the installation of less sensitive seismographs and consequently instruments of the Omori type were installed at Simla, Dehra Dun and later at Bombay and Calcutta. During the year 1918-19 the Milne type seismographs at Colaba after two decades of operation were replaced by two horizontal pendulum seismographs. The first Milne-shaw seismograph was installed at Colaba in February 192[illegible] Subsequently the instruments of the Milne type at Calcutta and Kodaikanal were also replaced by Milne-shaw instruments. In 1929, the seismological observatory at Simla was shifted to Agra where the Milne-Shaw seismographs were also installed.

After the occurrence of the Bihar earthquake of 1934 and the Quata earthquake of 1935, the Government of India appointed a committee consisting of H.J. Couchman, Surveyor General of India, A.M. Hiron, Director, Geological Survey of Ind and C.W.B. Normand, Director General of Observatories, to formulate proposals for a proper seismological organisation in India. The committee in their report recognised that the existing organisation was inadequate and emphasised the necessi of a systematic study of the science of seismology. The committee specifically recommended the formation of a

seismological branch under the technical supervision of a committee consisting of the D.G.O., the Director, Geological Survey of India and the Surveyor General. Their recommendations also included (1) the installation of Vertical Component seismographs at some of the existing observatories (2) installation of strong motion seismographs at Calcutta, Dehra Dun and Agra (3) improvement of the equipment at some of the observatories by installation of more sensitive Milne-shaw instruments and (4) opening of new observatories at Shillong, Patna, Allahabad and Waltair. The Committee also recommended that because of the high seismological activity in Assam the seismological organisation should have its headquarters in Shillong. Although the above recommendations were accepted by the Government of India, improvements in the seismological organisation could not be affected due to financial stringancies until towards the end of 1939, when the Government of India decided to make a start by creating a post of Special Officer for seismological research. Before the appointment of this officer, seismological work used to be undertaken by Meteorologists in addition to their own work. The duties of the special officer consisted of the following:- 1) maintenance of liaison with the Geological Survey of India 2) maintenance of the seismological observatories operating in the country, (3) preparation of reports of earthquakes, and microseisms for daily weather report (4) Collection and scrutiny of data from seismological observatories and its publication in a Seismological Bulletin, (5) a critical study

of previous records of earthquakes in India and the neighbouring countries with a view to determine the positions and depths of earthquakes, the accelerations and energies involved and the nature of crustal faults, if any, with which they were associated (6) study of the properties of crustal layers over India and neighbouring countries and (7) development of simple instrumental methods for the intensive study of the nature of the earth movements in the close neighbourhood of earthquakes (8) study of earth movements in the close neighbourhood of earthquake epicentres, with a view to their application in seismic methods used for geophysical prospecting.

The Government of India in 1946 appointed a Planning Committee for geophysics with a view to clarify ideas regarding the development of geophysical work in India in the post-war period. The terms of reference of this committee were to consider and report on the question of organising and developing in India institutions dealing with the study of geophysics. The committee after a series of meetings submitted its report which was published in 1948. Their recommendations stressed that the seismological organisation recommended by the seismological committee of 1936 should be implemented as early as possible with minor alterations. They laid down the main objectives of the seismological organisation as given below -

(a) Purchase or better construction of and installation of instruments to measure the accelerations, periods and amplitude of ground movement in earthquake zones with a view to provide data for designing earthquake resistant buildings and structure

(b) Organisation of seismograph observatories to determine the distribution and frequency of earthquake shocks in the earthquake zones including the study of minor shocks which precede and follow major earthquakes (c) determination of the depths of earthquakes and velocities of travel earthquakes waves at different depths in different regions (d) study of microseisms associated with disturbed weather in Indian seas. A special attention should be paid to the study of earth movements at the site of big dams. The recommendations of this committee were included by the India Meteorological Department in their post-war development plans and a separate seismological section was constituted in the Meteorological Department in 1948. The seismological organisation has undergone considerable expansion as a result of the three five year plans.

As recommended by the Seismological Committee of 1936, the Headquarters of the seismological organisation was shifted to Shillong in 1952 from its temporary location at Poona. After a few years of working it was realised that the Headquarters of the Organisation could not function effectively from Shillong due to its poor communications with the rest of the country, and the necessity of constant liaison between the Seismologist and the user engineers. The Headquarters of the Seismologist who was in charge of the seismological organisation was shifted to Delhi in 1958. A separate Directorate of Seismology under the Director General of Observatories was created in 1961.

PRESENT STATE OF SEISMOLOGICAL WORK IN INDIA

Seismological work can broadly be divided into the following categories.

1. Field study of earthquakes
2. Operation and maintenance of seismological observatories.
3. Collection of seismological data and its distribution.
4. Engineering seismology.
5. Consultancy service in seismology.
6. Research in pure and applied seismology.

1) Field study of earthquakes:

The use of seismographs to study the phenomenon of earthquakes became popular only towards the end of the 19th century. Prior to this the observations of the effects caused by destructive earthquakes used to be studied in the field, after the occurrence of the earthquake. It has already been stated earlier that the Geological Survey of India had been carrying on systematically field studies on earthquakes since the time of Dr. T. Oldham. They have been sending field parties to study the damage to structures and other phenomenon caused by earthquakes after the occurrence of every important event. A large number of memoirs on individual earthquakes have been published by the officers of the Survey. These include details of the damage to engineering structures and other effects caused by the earthquake. Invariably the reports include isoseismal maps for individual earthquakes, and the possible causes of the earthquake. Field observations of earthquakes are also collected by the India Meteorological Department from voluntary observers.

In some important cases special questionnaire forms are issued to public and the information thus collected is used in drawing isoseismal maps. Copies of all the voluntary observers reports are passed on by the India Meteorological Department to the Geological Survey of India.

During the last few years the Central Water and Power Research Station at Poona and the Earthquake Engineering Research School of Roorkee have also associated themselves in the field studies of earth-quakes with special emphasis on the engineering aspects.

(2) Operation and Maintenance of Seismological Observatories:

The maintenance of seismological observatories in India has been mainly the responsibility of the India Meteorological Department for nearly 78 years. As stated earlier, the Department operated seismological observatories at Bombay, Calcutta Delhi and Kodaikanal prior to independence. The Nizamia Observatory at Hyderabad also maintained a seismograph static As a result of the recommendations of the Planning Committee for geophysics in 1948 and the development plans of the Meteorological Department during the Three Five Year Plans, the number of seismological observatories in the country has increased considerably. The present organisation consis of 18 permanent stations, four mobile observatories and seve observatories operating in the Beas and Sutlej catchment areas for special studies. One of these is located at Kara near Ko[illegible] and the other at Kantharia near Broach. A compl list of the equipment installed at each of them is given In Appendix 1. The observatories at Delhi, Poona, Kodaikanal

and Shillong are equipped with the standard seismographs supplied by the United States Coast and Geodetic Survey. These four observatories constitute part of the world wide network of 120 seismological stations established by the United States Coast and Geodetic Survey during the last 10 years. Each Observatory is equipped with three standard short period Benioff type electromagnetic seismographs having magnification of the order of 100 thousand or more and three long period seismographs specially suitable for the studies of long period surface waves. Each station is controlled by an electronic clock which is compared several times a day by Radio time signals, which are automatically impinged on the seismograms. The time accuracy of these stations is fraction of a second.

In addition to the National network of observatories operated by the India Meteorological Department, the Central Water and Power Research Institute, Poona maintains a network of six sensitive stations in and around the Koyna dam, for special studies of the earth tremors taking place in the region. The Observatories are located at Koyna, Satara, Govalkot, Pophali, Mahabaleshwar and Alore. A few strong motion accelerographs are also in operation in and around the Koyna Dam for engineering studies.

In U.P., the Ramaganga and Yamuna projects have opened up seismological observatories atKalagarh, Narendernagar, Rudraprayag, and Tehri with a view to study the seismicity of the catchment areas of Ramganga and Yamuna rivers. The Meteorological Department has rendered all the technical

advice to the project authorities for the establishment of these observatories. At present they are operated by the staff provided by the project authorities but they are experiencing difficulties in their routine operation and a proposal is under consideration to transfer the maintenance of these observatories to the India Meteorological Department, in the same manner in which the department is maintaining the network of seismological observatories in the Beas and Sutlej project areas.

The National Geophysical Research Institute at Hyderabad established a seismological observatory within their campus in December 1967. The Observatory is equipped with three components of sensitive Benioff electromagnetic seismographs and three components of long period seismographs for the study of surface waves. Time marks on seismographs are made by means of an electronic clock as at standardised stations of the United States Coast and Geodetic Survey.

In the year 1965 the Bhabha Atomic Research Centre, Bombay established a seismological Array Station at Gauribidanur about 50 miles to the north of Bangalore. This station is of special significance as it is able to detect many more events than recorded by conventional type stations due to its high sensitivity and low background noise. The station at Guaribidanur also operates long period seismographs.

3. Collection and Distribution of seismological data:-

The seismological data of the network of observatories operated by the India Meteorological Department is collected by the seismological organisation at its headquarters in New Delhi. The data is scrutinised and published in the form of a bulletin issued every month. Monthly seismological bulletins were introduced in the year 1946 and the last number which has been distributed to various recipients relates to the month of March 1968. The data for the period 1938-1945 is available in the form of quarterly bulletins. The seismological data for the period 1892-1937 is available in the Indian Weather Review, a publication of the Meteorological Department. At present there are 130 recipients of the seismological bulletin in India and abroad. The bulletin is normally supplied free of cost to any party who is interested in seismological investigations. Under special circumstances, copies of seismological records of earthquakes are supplied by the department to research workers on request. The department exchanges

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the data collected by it with the other seismological organisations in the world. In addition to the monthly seismological bulletins, weekly data sheets of important stations like Delhi, Shillong, Poona, Kodaikanal are sent regularly to the United States Coast and Geodetic Survey, Washington, International seismological Centre, Edinburgh and BCIS, Strasbourg.

The National Geophysical Institute, Hyderabad published the data of the observatory at Hyderabad in their quarterly bulletin, which is distributed to interested parties. The data of the Gauribidanur station is sent periodically by the Bhabha Atomic Research Centre to the India Meteorological Department but this data is not included in the seismological bulletin issued by the Meteorological Department. The data of special observatories maintained by the Meteorological Department such as the seven observatories operated for the Beas and Sutlej link project and the four mobiles observatories operating around Delhi is not included in their monthly seismological bulletin. Data of the observatories in the Koyna area operated by the Central Water & Power Research Institute, Poona, is not published as a routine and is available only with that organisation.

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4. Engineering Seismology -

In the past the study of earthquakes was mainly of academic interest. The occurrence of destructive earthquakes can neither be prevented nor forecasted. During the last ten years, technologically advanced nations of the world like USA, Japan and USSR have undertaken research schemes to develop suitable methods of predicting the time, place and intensity of earthquakes. It will however take a long time before earthquake prediction can be taken on an operational basis. Considering the havoc to life and property done by destructive earthquakes, it has become necessary that future constructions should be so designed that the hazards due to earthquakes are minimised if not altogether eliminated. A new science called Earthquake Engineering has developed in recent years in which the reaction of earthquake forces to various types of structures is studied. In order to design an engineering structure it is essential that the data on the probability of occurrance of earthquakes of various intensities in the region should be known. This requires an intensive study of not only the past earthquakes which have occurred in the region but also a detailed study of the tectonics of the region. The reaction of earthquake forces of various types on engineering structure should also be known. To study problems in engineering seismology, a school of research and training in earthquake engineering was established in Roorkee University in UP in 1960. This institution is one of the three institutions of its type in the whole world. Besides training engineers in the design of earthquake resistant structures, the school has been carrying on fundamental and applied

research on all problems connected with earthquake engineering. The School imparts training in Earthquake Engineering to post graduate students leading to the degree of Master of Engineering. Research work in all aspects of Earthquake Engineering is carried out and students prepared for the degree of Doctor of Philosophy. The school also imparts short-term specialist course in earthquake resistant design of structures, and soil dynamics for the benefit of practising engineers and teachers.

Engineering seismological studies are also undertaken at the Central Water and Power Research Station in Poona in a limited way. Their problems are usually confined to the engineering projects undertaken by the Central Water and Power Commission. The research station has on several occasions sent field parties to project sites for the studying of the foundations.

5. Consultancy Service in Seismology -

Government departments and private industrial undertakings require seismological data before starting their projects. The proneness of the site to earthquake hazard must be known before, in order that suitable designs for structures could be prepared. This becomes specially important if the proposed undertaking is to be located in an area where earthquakes had occurred in the past. In order to answer the queries of the project authorities a variety of geological and seismological data is necessary.

For a long time queries regarding the assessment of the seismic hazard are being dealt with mainly by the India Meteorological Department and the Geological Survey of India. In the case of more important projects, generally both the departments

had been consulted. The Meteorological Department has been replying to many such enquiries per year. Recently the Ministry of Irrigation and Power has appointed a special committee to advise on the seismic factor to be undertaken in the design of projects under their direction. The School of Research and Training in Earthquake Engineering of the University of Roorkee has also rendered advice to some parties in the past. They also carry on model experiments on request in case of important projects to render advice, regarding the seismic factor.

For the assessment of seismic factor to be considered in the design of ordinary engineering structures like residential buildings, Indian Standard Institution published a Code for Earthquake resistant design of structure (IST 1893-66) in 1966. This publication includes a map of seismic zoning dividing the country into zones liable to different degrees of shaking/some earthquakes. The Code also contains a table of seismic factors to be taken into account in some important places in the country. As a result of the Koyna Earthquake of 1967 and the report of the expert committee on Koyna Earthquake, the zoning map included in this Code has been revised by the Committee of the ISI dealing with the subject. It is expected that the revised code will be published soon. This code is a priced publication and is being used by engineers throughout the country.

6. Research in Seismology -

During the last two decades interest in seismological research has increased considerably. This is shown by the fact that while

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in the pre-independance days there were only a few institutions, like the India Meteorological Department and the Geological Survey of India which took interest in seismological research, there are at present nearly 16 institutions interested in research work in seismology. These are (1) the Seismological Division of the India Meteorological Department (2) Geological Survey of India, Calcutta (3) National Geological Research Institute, Hyderabad (4) School of Research and Training in Earthquake Engineering, University of Roorkee (5) Centre of Advanced Studies in Applied Mathematics, University of Calcutta (6) Seismological Division of the Bhaba Atomic Research Centre, Bombay (7) Directorate of Scientific Research, Naval Headquarters, New Delhi (8) Central Water and Power Research Station, Poona (9) Regional Research Laboratory, Jorhat, Assam (10) Indian School of Mines, Dhanbad (11) Department of Mathematics, Kurukshetra University (12) Department of Geophysics, Banaras Hindu University (13) Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur (14) Department of Geology, Punjab University, Chandigarh (15) Department of Geology, Osmania University, Hyderabad (16) Department of Geophysics, Andhra University.

In general, the universities and other academic institutions usually undertake research problems of a fundamental nature and of theoretical interest, the Government departments and laboratories under the CSIR are interested mainly in applied seismological research. A brief summary of the research work done by the various departments is given in the following pages.

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Seismicity -

Seismicity means proneness of a place to earthquake hazards. Such studies are of great economic significance specially for developing countries where development plans include projects to be constructed in seismically active regions. Any over assessment of the seismic danger increases the cost of the projects while under assessment exposes them to the dangers of future earthquakes. Various approaches are being attempted by which the seismic status of any place or region could be studied. All of them, however, require a variety of geological and seismological data such as the following -

1. Detailed information on past earthquakes, including isoseismal maps of important events.
2. Catalogue of earthquakes giving details of epicentre, origin time, depths of focus and magnitude.
3. Tectonic maps delineating the various fault systems along which earthquakes had occurred as well as those which are currently active.
4. History of formation of geological structures in regions of earthquake activity.
5. Detailed knowledge of the geological foundations on which the structures are to be built.

For a very long time the officers of the Geological Survey of India have been carrying on field studies of all important earthquakes in India and publishing their results in the memoirs and records of the Survey. The seismological Division of the India Meteorological Department has been determining the epicentres and

other parameters of Indian earthquakes with the help of the instrumental data obtained by the Indian and foreign observatories. Result of special studies of important earthquakes have been published in the various publications of the IMD.

During the last five years, three important earthquakes took place, namely (1) The Koyna Earthquake of December 11, 1967 (2) The Bhadrachalam Earthquake of April, 1969 and (3) The Broach Earthquake of March 1970. In each case the officers of the GSI and IMD have carried special investigations. Besides these departments, the NGRI, the Earthquakes Engineering Research School, Roorkee and the CWPRS also carried special investigations of these earthquakes.

Based on the instrumental data on earthquake parameters collected by the IMD, the isoseismal of various earthquakes drawn by GSI, the Tectonic Map of India compiled by GSI and other geological considerations, the Indian Standards Institution published a code for earthquake resistant design of structures (ISI 1893-1966) in 1966 which also included a map of seismic zoning dividing the country into zones liable to different degrees of shaking during earthquakes. As a result of the Koyna earthquake of 1967 and the findings of the expert committee on the Koyna earthquake, this map has now been revised by the Committee of ISI. It is expected that the revised code will be published soon.

It has been found that for any seismic region the number of earthquakes of different magnitudes in a given time interval do not take place at random but follow the law

$$\text{Log } N = a + bM$$

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Where N is the number of earthquakes of Magnitude M, and a & b are constants. Some seismologists feel that this law could be made use of in seismicity studies for determining the recurrence of earthquakes of different magnitudes in a given region. Several institutions in the country namely (1) the India Meteorological Department (2) Banaras Hindu University (3) Central Water and Power Research Station, Poona and (4) National Geophysics Research Institute have made attempts to utilise the above law for regional seismicity studies. Mention may be made of the papers published by Tandon and Chatterjee (1968) for the Himalayan region and areas around Delhi and Sonepat. Chauhan determined the value of the constant a and b for the Himalayan region and concluded that $\frac{B}{A}$ represents the seismicity of an area rather than A or B. Many authors, however, believe that the constant B is a regional characteristic and A is a measure of seismicity.

Regional Seismicity

The seismic zoning map published by ISI divides the country into five zones liable to maximum seismic intensity ranging from MM V to IX and above. In each zone, however, the degree of damage to structures during an earthquake will depend upon a number of factors such as the foundation, the proximity to active faults etc. necessitating the construction of large scale zoning maps for smaller regions. Such studies require detailed geological mapping of faults and zones of weakness and the determination of earthquake parameters of even smaller earthquakes. A close network of seismological observatories is also required for such meso-scale studies. Unfortunately the network of seismological observatories

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in the country as a whole is not adequate enough for the purpose. The Beas and Sutlej Catchment area, the Koyna region, and the areas around Delhi and Sonepat have, however, the minimum network for carrying on micro regionalization studies.

Research in Engineering Seismology

It has already been stated earlier that a School of Research and Training in Earthquake Engineering has been functioning in Roorkee in UP since 1960. Ever since its inception the school has been carrying on fundamental and applied research on all problems connected with earthquake engineering. The main achievement of the school during the last ten years have been the following -

a) Extensive studies of earthquake resistant small housing which has found application in defence projects, industrial establishments etc.

b) Design and construction of structural response recorders and establishment of 53 stations;

c) Design and construction of strong motion accelerographs.

d) Construction of various types of shaking tables for model studies.

e) Development of Tiltmeters and Extensometers.

f) Investigation of foundations specially of liquifaction of soils during earthquakes.

g) Rendering advice in the design of structures under various projects.

During the last ten years the school has published over 125 papers.

Their main investigations carried out by CW & PRS , Poona during last few years have been related to the earth tremors taking place around the Koyna Dam. For this purpose they have been maintaining a close network of 6 sensitive seismological stations in the area. Sets of strong motion accelerographs have also been installed inside and outside the Koyna Dam. The fore shock of September 13, 1966 the main shock of December 11, 1967 and a large number of strong aftershocks were recorded by these instruments. The accelerograms of the December shock are unique records, and will be of great use to designing engineers throughout the world. All the accelerograms obtained at Koyna and their analysis has been published by the CWPRS, Poona.

Wave Velocities, Travel Times

Accurate knowledge of the velocities of seismic waves in different types of rock strata is a fundamental requirement without which earthquake parameters cannot be determined accurately. Since the waves to large distances do not travel along straight lines, it is necessary to have a knowledge of the Travel Times of various waves for different distances. A number of Travel Time Tables are available for use, the most widely used being those of Jeffreys & Bullen (1940). These tables, however, give an average for the whole world and do not give accurate results when applied to regional investigations. It becomes necessary to construct regional travel time table based on data obtained within the region. The best method to construct these is by conducting Deep seismic soundings. During the Fourth Five Year Plan, it is

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proposed to undertake deep seismic sounding along a few sections in the Deccan in collaboration with the geophysicists of USSR. In the absence of result from Deep Seismic Soundings the data on near earthquakes can be utilised for the construction of regional travel time curves, which can be improved further as more and more data becomes available.

Scientists of the India Meteorological Department, the NGRI, Hyderabad and BARC, Bombay have made attempts to find out the velocities of seismic waves in the different crustal layers. Their results are summarised in the following table.

Region	Gangetic Valley		Northeast India		Indian Region		Deccan Shield			Himalayan foot-hills		Near Gauribidanur Array		
	Vp	Vs	Vp	Vs	Vp	Vs	Vp	Vs	T	Vp	T	Vp	Vs	T
1. Sedimentary	-	-	-	-	-	-	-	-	-	2.7	6	-	-	-
2. Granitic	5.96	3.29	5.58	3.43	-	-	5.67	-	22.5	6.2	8	5.67	3.46	15.8
3. Basaltic	6.91	3.71	6.55	3.85	-	-	6.44	-	13.5	6.9	14	6.51	3.96	13.9
4. Base of Moho	7.80	4.38	7.91	4.46	8.0	4.54	8.25	4.75	-	8.2		7.98	4.61	
5. Author	Roy (1939)		Tandon (1954)		Nag (1967)		Tandon & Chaudhury (1968)			Kaila, Reddy & Narain (1968)		Arora (1969)		

N.B: Vp; P wave velocity (km/sec), Vs: S wave velocity (km/sec), T: Thickness (km).

The Crust and Upper Mantle

Seismological studies are of very great importance in the study of the Earth's Crust and Upper Mantle. Use is made of both body waves (P & S phases) and the Surface waves (Rayleigh and Love types) for these investigations. Since the determination of epicentral parameters introduces some amount of error, the best results for crustal structure are obtained by using artificial explosions. In India, development of explosion seismology has almost been insignificant. The Geological Survey of India, and the Oil and Natural Gas Commission have carried field work in a few areas but the charges used by them have been small and their results have therefore given information only about the top most layers.

After the Koyna earthquake of 1967, the GSI carried a seismic survey of the areas around Koyna. The results indicated that the trap rock velocity varies from 4.7 to 5 kms/sec. The travel time curves indicated a high velocity discontinuity underlying the trap rock below the ground surface at a depth of 200 metres at Pophali, 500 metres near Karad and 670 metres at Rampur. It could not be said with certainty that the above depths represented the base of the traps.

In another seismic investigation in the Trap rock areas of Maharashtra, Mysore and Andhra Pradesh, to find out the thickness of the Basaltic Lavas and crustal depths, the following results were obtained

Trap Rock velocity - 4.8 - 5.2 kms/sec.

P Wave velocity below discontinuity 5-7 - 6.5

These velocities were found to be of the same order as in

the Cambay area by Rao.

During February and March 1965 the Indian Naval Physical Laboratory, in collaboration with German Scientists participating in the Indian Ocean Expedition Programme, carried on refraction experiments to study the structure of the crust in the Ocean bottom near Lacadive Islands, the gulf of Cambay, and the Rann of Kutch. For the gulf of Cambay area their results indicated that volcanic ash and pumice existed at a depth of 3000 m from the sea level. Eruptive basalt underlying the upper Deccan Trap appears to have been uplifted at a distance of 80 kms from the coast. The thickness of the pleistocine sediment over the continental shelf is nearly 2500 m and it gradually decreases over the continental slope. The depth of the Mohorovice discontinuity under the continental slopes appears to be of the order of 13 kms.

In the gulf of Kutch, the results indicated the depth of the upper Deccan traps over the continental shelf, between 1 and 1.3 kms. They are not observed over the continental slope. The thickness of the miocene sandstones and Pleistocene sediments overlying the upper Deccan traps is about 600 m and 300 m respectively. The thickness of the same layers over the continental slopes is 2800 m and 2000 m respectively. Other crustal layers observed in this area are the lower Deccan traps and the eruptive basalts. These have been found at depths of 3 and 5 kms respectively from sea level.

Use of Body waves

Using the data obtained from stations within $\Delta = 10^{\circ}$ of the aftershocks of the great Assam earthquake of 1950,

the author (1954) found the average structure of NE India as follows -

Thickness of the granitic layer	=	24.8 kms
-do- Basaltic layer	=	21.5 kms
Depth of Moho below surface	=	46.3 kms

Chakravarty and Ghosh of the Banaras Hindu University in 1960 also investigated the data of near earthquakes recorded by the Indian Seismological Stations for a number of years and concluded that the average depth of Moho under the Himalayas is 38 kms.

Recently Tandon in collaboration with H.M.Chaudhury of IMD analysed the data of near stations of the Koyna earthquake of December 11, 1967 and obtained the thickness of the Granitic and Basaltic layers to be 22.5 kms and 185 kms respectively.

Kaila of the National Geophysical Research Institute, Hyderabad made a statistical analysis of shallow earthquake data and the velocities in sedimentary layers obtained by ONGC and obtained the following result for the thickness of layers in the foot hills of the Himalayas:

Sedimentary	6.3 kms
Granatic	7.5 $\pm$ 4.6
Basaltic	14.3 $\pm$ 8.4
Depth of Moho	28.1 $\pm$ 8.4

S.K. Arora (1969) of BARC Bombay used local earthquake data obtained from the Gauribidanur Array Station and investigated the structure of the earth's crust near the Array. He found the thickness of the granitic layer as 15.8 kms and the depth to Moho as 34.7 kms.

Body wave data for the investigation for the earth's upper mantle utilises the variation of P & S velocities

with depth. For this purpose the travel time curves have to be drawn accurately and the curves then interpreted on the basis of assumed structures. The data usually shows a larger scatter of points within certain distance ranges pointing to the existence of cusps. An interpretation of these cusps and curvatures leads to a better understanding of the velocity - depth relationship.

S.K.Dube of the India Meteorological Department, using the method of Dowling and Nuttle (1964) has analysed the Travel Times of P & S waves, and computed the Upper Mantle Structure over the Indian sub continent. He observed an increase in the velocity of P wave from below the Moho to the top of the Low velocity channel whichis clearly indicated. The top of the channel occurs at a depth of 140 kms and the thickness is about 50 kms. The velocity rises steeply below the low velocity layer

Another method due to Gutenberg uses the P & S wave data of Deep Earthquakes for determining the velocity depth relations. The method consists in observing Travel Times of deep shocks at small epicentral distances. The travel ctime curve has a point of inflexion at which the apparent velocity V observed at the surface will be minimum. This velocity is linked to the true velocity Vr by the following relation

$$Vr = V\left(1 - \frac{h}{r}\right)$$

Using this method, the author found that in the Hindukush region, a low velocity layer exists at a depth of 160 kms so far as S waves are concerned. No clear cut minima is obtained for P waves in which the velocity appears to

remain constant from the Moho down to a depth of 140 kms and then increases rapidly.

Use of Surface Waves

Records of Surface Waves (both Rayleigh & Love types) obtained by Long Period Seismographs show dispersion that is variation of velocity with the period of the waves. This effect is due to greater penetration of the Longer period waves. The longer period waves therefore travel faster and appear earlier in seismograms. Dispersion studies of these waves provide a very important method for investigating the elastic properties of the wave guide. Experimentally obtained dispersion curves are compared with theoretical dispersion curves based on assumed earth models to give the elastic parameters of the layers and the structure of the wave guide.

During the past two decades a very large amount of work has been done on this subject throughout the world. Seismologists of the India Meteorological Department and the National Geophysical Research Institute, Hyderabad have been engaged in this type of work for a number of years. In the majority of cases the work has been confined to Wave periods upto 70 seconds limiting the studies to the investigation of the crust only. Waves having periods larger than 70 sec. penetrate the earth's upper Mantle and are called Mantle Rayleigh or Love Waves. Tandon in collaboration with H.M. Chaudhury made a detailed study of long period records of the Alaska Earthquake of 1964 at Delhi in which the vibrations continued for over 48 hours and periods as high as 10 minutes were crecorded. Some of these waves made more than 20 rounds of the earth. The mantle Rayleigh waves have a group velocity minimum of 3.6 kms sec. at a period of 240 sec. The dispersion curves fitted with the theoretical curves assuming the

existence of a low velocity layer in the upper Mantle, and thus lent suppor to the Gutenberg Model.

A number of authors in IMD and NGRI have applied surface wave dispersion data to study the crust along various sections of the country. Tandon and H.M. Chaudhury (1964) analysed the records of long period seismograms o Delhi and Shillong pertaining to a shock in the Atlantic Ocean whose epicentre lay on the great circle path through these stations. The results indicated are average crustal thickness of 40-45 kms between Delhi and Shillong.

Chaudhury studied in detail the records of the Delhi observatory of a number of earthquakes occurring near the Manipur-Burma border. Dispersio curves of Rayleigh, M-2, Love and higher model Love waves were drawn for group as well as phase velocities and obtained the following results for th Indo-gangetic place.

	Sediments	Granitic	
	3.98	6.15	6.58
	2.30	3.55	3.88
	2.340	2.817	2.922
H	3	17	20

Long period Press-Ewing seismographs were installed at Bhakra, Dehra Dun and Delhi to determine the phase velocities of Rayleigh waves ove the Punjab region. The results obtained from an analysis of two years records gave a crustal thickness of 40 kms over the Punjab plains.

Gupta and Hari Narain of NGRI Hyderabad have studied the dispersion of surface waves along paths across the Himalayas and Tibetan Plateau. They obtained an average crustal thickness of 85-70 kms under the Himalayas. H.K.Gupta has also studied the surface wave velocities between period range 20-40 seconds, and used crossing path techniques of Santo to divide the

Asian continent in regions of same Rayleigh or Love wave group velocity dispersion characteristics.

Theoretical Seismology

In addition to the India Meteorological Department and the National Geophysical Research Institute Hyderabad, work on theoretical problems in seismology is carried on at a number of other institutions in the country, the more important being (i) The department of Mathematics, University of Kurukshetra (ii) the Centre of Advanced Study, University of Calcutta and (iii) The Banaras Hindu University.

In the Meteorological Department S.N.Bhattacharya and S.N.Chatterjee have been working on the propagation of Love and Rayleigh waves in a vertically inhomogeneous media. Bhattacharya gave a systematic method to obtain the inhomogeneity for which the SH wave equation or Love wave equation can be solved in terms of transcendental functions. He also took up the case of Love wave dispersion in a laterally inhomogeneous layer lying over a homogeneous half space. Chatterjee obtained the frequency equation for Love waves in a medium consisting of two finite layers over an infinite half space, the inhomogeneous layer being sandwitched between homogeneous layer and a homogeneous half space. In another paper Chatterjee has derived the frequency equation for Rayleigh waves in a heterogeneous layer lying over a homogeneous half space.

At the University of Kurukshetra theoretical work is conducted under the leadership of Prof. S.D. Chopra. The main problem undertaken by his group concern the propagation of elastic waves in layered media, In inhomogeneous media and in anistropic media. A number of papers have also been published on Finite Source problems and the application of statistical methods to Seismology.

A group of theoretical workers at the NGRI Hyderabad has been investigating problems connected with the propagation of Love Waves under conditions of anistropy and inhomogeneity represented by

i) Power Law Distribution

ii) Exponential variations

iii) Hyperbolic variations of rigidities, velocity and density.

Studies have also been made of the deformation of pulse shapes by media or by moderate or rapid velocity variations.

At the centre of Advanced Study in Applied Mathematics of the University of Calcutta studies have been made on Source Mechanisms of Earthquakes. Theoretical expressions for surface displacement associated with point source as well as with some sources of finite dimensions in finite half space, have been obtained. The results could be used in the investigations of earthquake mechanism at the Hypocentre by comparing the theoretical results with the traces recorded in seismograms. Dr. I.N.Gupta of the Panjab University, Chandigarh has made theoretical studies on body wave radiation patterns from different sources by the use of reciprocity theorem. He has also published papers on standing waves in a layered half space.

The theoretical investigations carried on at the BHU concerned the dispersion characteristics and radiation of patterns of surface waves and the deformation of pulse shapes in different types of anistropic, homogeneous or inhomogeneous layered media. Analysis of the possible curves, related to the production of anisotropic elastic conditions in the upper mantle region due to non uniform stress field.

Model Seismology

Investigations of seismological problems in the laboratory by using two or three dimensional models are being carried on in the laboratories of the Geological Survey of India Calcutta and the Indian School of Mines Dhanba

Dr. D.K. Chaudhury at Dhanbad made an experimental determination of body wave velocities along an internal layer of a two dimensional model. The model consisted of a single low velocity layer (plexi glass) glued between large sheet of higher velocity medium parelytes. The results indicated that the observed phase velocity is a function of layer thickness and wave length. A velocity minimum is observed when the wavelength is twice the layer thickness and a velocity maximum when the wave length is three times the layer thickness.

Studies are also being made on a two dimensional model of the wave amplitudes from a directed source. In this model the radiation pattern due to a directed source, (as happens in national earthquakes) could be studied.

A pulsed ultrasonic equipment for model seismology studies was designed and constructed in the Geophysical Lab. of the Geological Survey of India in 1964. The equipment has been used to carry out the following type of investigations. 1) Measurement of compressional (P) wave velocities in specimen of rock formations, are bodies, and water saturated porons rocks. For the various types of Deccan traps the velocity was found to vary from 5.5 to 6.5 kms. sec.

2) Measurement of the elastic modulii of different rock types.

3) Absorption of compressional waves in different types of rock samples. The absorption coefficient showed a definite trend to increase with decrease in wave velocity.

4) Study of head waves in a large number of two dimensional horizontal and inclined layer models.

5) Model studies of Diffraction pattern of converted waves formed by rock of block of different dimensions in a tank.

Microseisms

The background noise in seismograms due to various natural and

man made causes is known as "microseisms". The period of microseisms ranges from fraction of a second to nearly 30 seconds or more. Microseisms of the period range 2-10 seconds have a special significance as their origin has been traced to weather disturbances in the sea. Dr. S.K.Banerjee a former Director General of India Meteorological Department had shown as early as 1930 that the monsoon winds and cyclonic storms over the Indian areas generated microseisms which were recorded by Milneshaw type seismographs of the observatories at Bombay, Calcutta and Agra. He also developed a theory for the origin of the microseisms on the assumption that the pressure due to the height of the sea waves was communicated to the sea bottom due to the slight compressibility of water. Since Dr. Banerjee's time the scientists of IMD have been continuing their researches on this phenomenon and a number of papers have been published on the subject.

The author observed that microseism generated by cyclonic storms of sufficient intensity in the Bay of Bengal and also in the Arabian Sea were recorded at all inland stations of India if the storm centre was within 200 m depth contour. It has been observed that the amplitude of microseism was maximum at the time when the storm was crossing the coast. The mean amplitude and period for different months at Madras recorded by Sprengnether Microseismograph during 1955 to 1959 was studied by Anjaneyulu. The amplitude is maximum in July and minimum in February; a second maximum occurs in November. Saha noticed that microseisms consisted of 70% Rayleigh waves and 30% Love waves. Nag used the amplitude method of Jensen to find the direction of the source of microseisms. Krishan and Sankaran of the Seismology group of BARC Bombay studied the seismic noise dusing the aArray data of Gauribidanur. They also observed that oceanic disturbances associated with cyclonic activity from the Bay of Bengal results in enhancement of microseisms energy in the spectral band 3.5 to 4.5 seconds. In two cases when cyclonic disturbances existed in Bay of

Bengal they found the direction of approach of microseisms calculated from the data obtained by the Array agreed with the actual bearing of the cyclonic disturbances.

Instruments

For the last two decades the India Meteorological Department has been designing and constructing seismological equipment for installation at observatories operated by them. The following types have been constructed and brought into use.

1. Wood Anderson seismographs.
2. Short Period Vertical and Horizontal Electromagnetic Seismographs.
3. Sprengnether type EM seismographs of period in the range of 7 seconds.
4. Photographic Recorders.
5. Electronic amplifiers for use with seismographs.
6. Visible pen writing recorders.
7. Time marking clocks of pendulum type.
8. Other accessories required at seismological observatories.

During the last few years an electronic time marking device has also been successfully developed.

The Earthquake Engineering School of the University of Roorkee has successfully developed and constructed the following type of instruments.

1. Strong Motion accelerograph.
2. Structural Response recorders.
3. Roorkee Seismoscope.
4. Water tube tiltmeter.

While working at Cal Tech USA in 1948 Dr. S.K.Chakravarti, had given the theory of Benioff type Electromagnetic Seismographs. After return to India he continued his work on the theory of Electromagnetic seismographs and methods of calibration, and has since published a number of papers in collaboration with his colleagues at the Centre of Advanced Study in Applied Mathematics, University of Calcutta. In one of the papers, a set of standard curves have been constructed from which the magnification curves for any continuation of free

periods of seismometer and galvanometer and various values of damping could b drawn.

In the IMD response characteristics of electromagnetic seismographs ha been studied by Chaudhury. The use of the T-type attenuator in seismograph c cuits and the limits of the attenuating factor have been discussed by him in of the papers. In another paper he has discussed the conditions under which magnification of the system can be changed without disturbing the response ch racteristics. It was observed that this was possible only when the seismome and the galvanometer had the same period and the damping of the two are suitably altered.

Seismological Organisations in some developed countries -

In order to compare the existing seismological set up in the country with those of some developed countries, a brief outline of the organisations USA, USSR and Japan is given below.

USA - Seismological work in the UnitedStates of America is carried on both by Govt. Departments and private institutions. Govt. departments principally con cerned are - Advanced Research Project Agency, Air Force Cambridge Research L boratories, Atomic Energy Commission, Bureau of Mines, Bureau of Reclamation, Bureau of Standards,National Aeronautics and Space Administration,National Science Foundation, Office of Naval Research, U.S.Coast and Geodetic Survey, U.S.Geological Survey, U.S.Navy Electronics, Laboratory & the U.S.Navy Oceano graphic Office. While some of these departments such as the U.S.Coast and Ge detic Survey, the U.S.Geological Survey are directly involved in seismological work, the others like NASA support seismological research through grants to other agencies and Universities. During the last ten years, seismological re search output in USA increased tremendously as a result of the grants made by NASA under Project Vela uniform to various govt, and private agencies. The pr grammes under the project were concerned mainly with basic research in those branches of seismology which were related to the detection and identification of earthquakes and underground nuclear explosions.

The principal govt. organisation which is responsible for maintaining essential seismological network is the United States Coast and Geodetic Survey, under the Department of Commerce. The Survey has a seismological division which maintains the national network as well as the world wide network of 120 standard seismological stations established in different parts of the world. The division also operates a seismological field survey office at San Fransisco, California responsible for strong motion studies of earthquakes and for maintaining a close net-work of Accelerograph stations on the west coast, Alaska and South America. During the last few years an autonomous seismological research institute has been created under the survey with the main objective of carrying research work. The USGGS maintains a highly sophisticated world data centre at Ashville in North Carolina. Records obtained at all the world wide network stations are microfilmed at this Centre and preserved for use of seismologists throughout the world. Copies of records of any station for any event can be procured from the Centre at a nominal cost. The seismological division of the USGGS collects through Cable seismological data of daily events from all parts of the world, determines epicentral parameters with computers and mails the results every day to all interested parties.

Besides the USGGS a number of other organisations maintain seismological stations within or outside the

United States. The principle ones are (i) The Jesuit seismological organisation with headquarters at St. Louis (ii) The Seismological Laboratory of the California Institute of Technology, Pasadena (iii) The University of Berkeley, California, (iv) The Lamont Geological Laboratory of the University of New York. The Caltech and University of California Barkely, maintains close network in southern and northern California and neighbourhood for detailed seismological studies of the region and research.

Research work in seismology is largely carried on as in other disciplines by Universities and other non governmental institutions. In most cases the projects undertaken by them are supported through contracts by government Agencies. The following are some of the important institutions in USA which have become famous for their seismological research.

1. The Seismological Laboratory of the California Institut of Technology.
2. The University of California, Barkely.
3. The Lamont Geological Laboratory Palisades, New York.
4. The Geophysics Department of the University of St. Loui St. Louis.
5. Messachusetts Institute of Technology.

USSR - Seismological service in USSR falls under the Institute of the Physics of the Earth, Moscow belonging to the Academy of Sciences of the USSR. In addition

to many other departments the Institute has the following divisions concerning seismology.

1. Seismological Department
2. Department of Seismological service.
3. Physics of Earthquakes department
4. Department of Computors and earthquake investigations
5. Department of seismograph construction
6. Department of Engineering Seismology
7. Department of Geo Dynamics
8. Department of Deep Seismic

Each of these departments functions under a Director. The Institute maintains about 50 first class seismic observatories situated in different parts of USSR and organises every years several special field seismic expeditions. One of them, called complex seismological expedition works permanently in Soviet Central Asia. This project has more than 15 seismological field observatories. The chief aim is to undertake detailed seismic zoning of the region particularly of places where large hydro projects are to be constructed. The network is adequate to detect every earthquake of magnitude 4 or above in any part of USSR with an accuracy of 10 to 25 kms. In areas of dense network of stations such as central Asia the accuracy can be $\pm$ 2 - 3 kms.

In addition to the Institute of the Physics of the earth in Moscow, there are local seismological Institutes with their own seismic observatories almost in all seismi-

cally active areas such as Ukraine, Georgia, Armenia, Azerbaijan, Turkmenia, Tadzik, Uzbeck, and Kazakhstan.

The Geological Institutes in Irkutsk (Siberia) Kamchatka, and Sakhalin have large, almost independent seismological departments with their own seismic observatories.

In Moscow there is council on seismology which belongs to the presidium of the Academy of Sciences of the USSR. This council coordinates all seismological investigations in the country.

A large number of publications exist in which papers relating to seismology are published. One such journal belongs to the Academy of Sciences. Books on seismicity of different areas are issued every year.

Japan - Seismological work in Japan is carried on both by governmental departments and universities. The Japan Meteorological Agency is a government organisation, responsible for maintaining a network of seismological stations in the country. At present there are 108 seismological observatories for earthquake observations and seismological research, 67 of these are reporting stations for the Tsunami warning system. The J.M.A. is responsible for determination of epicentres, dissemination of the information to public, preparation of the national seismological bulletin and its distribution, observation and warning service regarding Tsunamia.

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At the occurrence of an earthquake the J.M.A. determines the hypocentre and the magnitude in a very short time using electronic computers. The analysis is based on the incoming reports from the 67 affiliated stations. The information is immediately announced and Tsunami Warnings issued if one is apprehended. In addition to the routine seismological service the JMA is actively engaged in research. There is a separate section for research work. The problems largely handed by them relate to (i) focal mechanism of earthquakes (ii) fore shock and aftershock sequences of earthquakes (iii) Spectrum analysis and seismicity studies. The Institute also conducts field investigations for detailed study of micro earthquakes with the help of very high magnification seismographs. The results of their researches are published in the Geophysical Magazines, papers in Meteorology and Geophysics, Zisin (the Journal of the Seismological Society of Japan) and in many other foreign journals.

Amonst the other Institutions which undertake research work the Earthquake Research Institute of the University of Tokyo is the most important. A brief account of the activity of this institution is given below -

Earthquake Research Institute -

This Institute was established in 1925 in response to the need for fundamental research in Seismology stimulated by the great Kanto Earthquake of 1923. Though it started with a small nucleus at Tokyo, a number of branch stations

have been opened gradually in later years and the fields of study have also enlarged, with the result that the institute stands unique today and its work has made a telling impression on the subject.

The activities of the institute as at present are indicated below -

1. Theoretical seismology - studies on the causes and mechanism of earthquakes - studies of surface waves and allied problems.
2. Statistical study of earthquakes - periodically and stochastic nature of earthquake occurence - frequencies of earthquakes of different magnitudes and intensities - magnitude of an earthquake an accompanying damage - measures of earthquake danger and expectancy of maximum intensity.
3. Seismological Observations - Routine observations of earthquakes - Seven Channel triggered magnetic tape recorder - temporary observation of aftershocks (Mobile observatories) - Observations of local seismic activities - ice tremors generated in the floating lake ice.
4. Microseisms - routine observation of microseisms and study of their period and energy spectra - tripartite observation of microseisms and their direction of propagation - relation of microseismic activity and cyclonic storms and fronts.
5. Explosion seismology - investigation of the crustal structure in Japan.

6. Studies of the earth's crust and its deformation - morphological and geological studies of earthquake phenomena - continuous measurement of the deformation of the earth - static and dynamic characteristics of earthquake faults - geodetic measurement of present tectonics.

7. Volcanology - Geological and patrological studies of volcanoes - Geochemical studies of volcanoes - Volcano physics - relation of number of volcanic tremors with eruption - georagnetic studies of volcanoes.

8. Geothermy and geomagnetism - Geothermal studies - Anomaly of geomagnetic variations in Japan - Electrical state of the earth's interior - Theories of the earth's magnetic field and its secular variation.

9. Gravity - Gravity survey over whole of Japan - Relation of gravity anomalies with crustal structure.

10. Oceanography - Waves and wave recorders - Tsunamis, their origin - Theories concerning tsunamis - Model studies.

11. Engineering seismology - Earthquake Engineering and engineering seismology - Strong motion accelerographs - Enhancement of earthquake intensity by subsoil conditions. Earthquake motion in the depth of the ground - Micro-tremors and classification of the subsoil - Earthquake forces to be expected in the aseismic design of structures - Vibration characteristics of actual buildings - Automatic correlator - Response computer.

Staff.

The staff of the institute consists of besides a large number of assistants, research assistants, about a dozen professors and about as many assistant professors The head of the institute is the Director who is generall elected from among the professors.

Building.

The Institute has a separate and selfcontained buildin of its own in the campus of the Tokyo University. It has several observation rooms, laboratories, a library a workshop and an office.

Seismological stations.

The Institute has a well-equipped seismological observatory in the main building itself. It gets data from the JMA and other seismological observatories of th world. Besides these, the institute is operating for it pure research needs 16 other observatories of various types. The observatory at Mt. Tsukuba is the most important with its sensitive instruments. Some of the observatories are of a special nature, such as that of Assam which is particularly meant for volcanological studies of volcano Assama. New instruments designed an constructed in the institute are also operated in these observatories.

Publications -

The Institute compiles the data from its own obser- vatories and publishes them in a Bulletin. The results

of research work are discussed regularly in weekly meetings and later published in the Bulletin of the Earthquake Research Institute - one of the most important scientific journals of the world in the field of seismology.

Other Research Organisations in Japan -

Besides the JMA and the Earthquake Research Institute, described above, there are a few other institutions where research in seismology is also being pursued actively. The disaster Prevention Research Institute of Kyoto University was established in 1951 to carry out scientific research concerning prevention of disasters caused under heavy pressure of natural forces. Since then the research on crustal deformation connected with the prediction of earthquakes has been one of the important research subjects on which emphasis is laid in this Institute. Among the staff of this Institute, there are 3 Professors and 6 Assistant Professors.

Research in seismology is also being done in the departments of geophysics at the Tokyo, Kyoto, Nagoya, Tohoku and Hokkaido Universities. Among these the Tohoku University has been independent building for earthquake observations.

Educational activities in the field of seismology -

The importance of seismology and the interest in the subject is further revealed in the educational activities in this regard. The five big Universities of Tokyo, Kyoto, Tohoku, Nagoya and Hokkaido have a total

of 8 Chairs, 8 Professors and 9 Assistant Professors. They have on their rolls more than 100 students at the undergraduate level and more than 60 postgraduates studying seismology.

Problems requiring attention -

In the preceeding sections, a review has been made of the seismological work carried on at the various govt. departments and other institutions. Inspite of the progress made in seismological research during the last two decades, it is apparent that the work has lagged behind both as regards quantity and quality. This deficiency has largely been due to the lack of precise data and inadequacy of the number of qualified personnel engaged in seismological work*. Answers to many seismological querries had to be based on inexact and scanty data. Even the Seismic Zoning map prepared by ISI on the basis of all available data by a committee of experts, had to undergo two revisions in a short span of six years, due mainly to non-availability of the proper type of seismological and geological data required for such work. Research in other fields of seismology has also suffered for the same reason. It is, therefore, necessary, to mention first

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* Even at present the total number of Gazetted Officers responsible for carrying on the routine as well as research work in the India Meteorological Department is only 8.

the nature of the problems which will have to be attended to during the next 10 years in order to improve effectively the quality of research and its output. These are briefly outlined in the following paragraphs under different subject heads. The subject of seismicity is of particular interest as it has an economic significance in the execution of plan projects. Most of the projected multipurpose river valley schemes will be located in areas susceptible to earthquakes of various degrees. Correct assessment of the seismic factors to be undertaken in their design will be most essential. Any overassessment of this factor, which normally happens in the absence of adequate data, will unnecessarily increase the cost. The collection of seismological data will have to be done well in advance of the execution of the project. This is the practice followed in all the technologically advanced countries. In India the collection of scientific data for project sites is usually undertaken after the approval of the project. In the case of major projects it will be necessary to operate close network of seismological stations in the project areas at least 5 to 10 years in advance. The stations may have to continue even after the execution of the project to watch the effects caused by creation of large artificial lakes or to locate new sources of seismic disturbances within the area. The collection of proper type of observational data is most essential for undertaking fundamental work in seismology.

No work could proceed unless the epicentral parameters are known precisely. For some types of work the accuracy is obtained by sensitive teleseismic stations for earthquakes of magnitude 4 abd above. On the other hand, for getting any meaningful correlations with geological features, the accuracy of focal determination has to be within ± 2 to 3 kms. This cannot be achieved by teleseismic stations and hence the necessity of having local networks of stations in areas of special significance.

Seismicity -

1. Improvement in the accuracy of determining epicentral parameters, specially magnitudes of small tremors and depths of shallow earthquakes.
2. Development of suitable techniques to determine magnitudes more accurately.
3. Development of techniques to determine focal depths of shallow earthquakes.
4. Preparation of maps of epicentres of earthquakes of magnitude 3 and above for the various areas of the country.
5. Preparation of maps delineating seismically active faults.
6. Correlation of seismic events with local geology.
7. Construction of seismic probability maps for different regions of the country.
8. Construction of recurrence curves of earthquakes for small areas based on actual observations of mid earthquakes.

9. Studies of patterns of foreshocks and aftershocks for important earthquakes and correlation with local geological structures.
10. Establishment of seismological station network near all sites of important projects well before the construction stage.

Causes of earthquakes -

1. Determination of fault plane solutions of past earthquakes by using techniques based on initial P wave motions, S waves, and Surface waves.
2. Studies of radiation pattern based on actual seismological data and comparison with theoretical models.
3. Intensive studies relating to movement of rock masses at various depths, collaboration in the International Geodynamics Project.
4. Study of the deformation of the Earths Crust before during and after seismic events with the help of tiltmeters, extensometers etc.
5. Precise levelling and triangulation to be carried out throughout the country specially in areas with large seismicity.
6. Geodimeter surveys to be carried along active faults particularly in areas where large projects exist or are contemplated with a view to study the creep movements along the faults and their correlation with future seismic activity.

Microseisms -

1. Study of seismic noise by sensitive seismographs with a view to correlate the pattern of noise with the foundation.
2. Special study of microseisms in the period range (2-10) seconds caused by sea waves, with a view to investigate their nature, origin and propagation.
3. Investigations of the methods by which storm type microseisms can be used to track storms, Methods using array techniques as well as matched three component seismographs should be attempted.
4. Empirical techniques to determine the location and intensity of storms should be persued.

Model Seismology and Laboratory techniques-

1. Measurement of velocities of seismic waves in various types of rock specimens under conditions of high temperature and pressure.
2. Study of seismic wave propagation through two and three dimensional models.

Engineering Seismology -

1. Improvement in the network of accelerograph stations specially in the Himalayan seismic belt.
2. Installation of large number of structural response recorders in the different seismic regions.
3. Design and construction of cheaf type of accelerograph.
4. Study of Soil behaviour during earthquakes.

5. Vibration studies of different types of structures (Tall buildings, water towns, power houses).
6. Behaviour of different types of structures during earthquakes.
7. Design of cheap seismic structures.
8. Model studies of special structures like dams, bridges on shaking tables.

Wave Velocities, Travel times and Crustal Structure -

1. Improvement in observed travel time tables for different types of seismic waves.
2. Construction of T.T. curves for seismic waves for different tectonic blocks.
3. Studies of the earth's crust in different regions using data of body waves from near earthquakes.
4. Deep Seismic Soundings to determine the thickness and properties of crustal layers.
5. Study of the dispersions curves of surface waves for fundamental and higher modes for different tectonic blocks of the country. Both phase and group velocities of surface waves should be determined with the ultimate aim of constructing phase and group velocity maps.

Seismological Instruments -

Development of the following type of instruments -

1. High Magnification electromagnetic seismographs to restrict imports of this item.
2. Seismographs using electronic amplifiers and visible recording.

3. Portable seismographs for study of aftershocks and microtremors.
4. Long Period Vertical and Horizontal type e.m. seismographs.
5. Borehole seismographs.
6. Seismographs for installation at sea bottom.
7. Recorders of the following type -
   a) Photographic recorders using paper of film.
   b) Visible type with recording on paper.
   c) Tape recorders.
   d) Recorders capable of recording for long periods without personel attention.
   e) V.H.F. tele recording devices.
8. Strain seismographs -

   Development of the following accessories -
   a) Electronic clocks for time marking.
   b) Amplifiers for running Synchronous motors of recorders.
   c) Sensitive type moving Coil Short type and Long Period galvanometers.
9. Digital Seismograph.
10. Analog to Digital converters.
11. Response Spectrum Analyser.
12. Cheap type of Accelerograph with built in displacement meters.
13. Tiltmeters of Water tube type and horizontal Pendulum type.
14. Instruments for Engineering seismological studies.

Appendix - A

List of Seismograph stations with their Instruments and constants as on 1.1. 1971.

Station and abbreviation	Lat. (°N.)	Long. (°E)	Height a.s.l. (metres)	Lithographic foundation	Instruments	Components	Period To	Period Tg	Vmax	Damping constant h1	Damping constant h2	Paper speed (mm/min).
1	2		3	4	5	6	7		8	9		10
Bhakra (BHK)	31 25	76 25	410		Electro-magnetic (Hagiwara)	Z	1	1	5600	1	1	20) Film
						N	1	1	5500	1	1	20) Film
						E	1	1	5600	1	1	20) Film
					Wood Anderson AR-240		0.8		1000	0.8		60
					Strong motion recorder	Z,N,E	0.06		7.6 cm/G	0.7		1200
Bokaro (BOK)	23 47	83 53	298	Rock	Press Ewing	Z	15	98)	about		1	30
						N	15	96)	1500		1	30
						E	15	93)			1	30
					Sprengnether	E	7.2	7.2	5000		1	30
					Wood-Anderson	N	0.8		800	0.8	-	30
						E	0.8		920	0.8	-	30
Bombay (BOM)	18 54	72 49	6	Deccan trap	Milne Shaw	N,E	12		250	0.7		8
					Sprengnether	E	7.2	7.2	5000		1	30
					Benioff	Z	1.0	0.2				60
							1.0	87.0				
Calcutta (CAL)	22 32	88 20	6.4	Alluvium	Milne Shaw	N	12		250	0.7		8
					Sprengnether	E	6.5	6.5	1000		1	30
					Omori-Ewing	E	19	30				25.4
						N	15	32				25.4

1	2	3	4	5	6		7	8		9	10
Chatra (CHA)	26 50	87.10	161	Sandstone	Benioff	Z	0.6	0.45		1	60
				Wood Anderson	N,E	0.8		1000	0.8		30
				Milne Shaw	N,E	12		250	0.7		16
				Wenner Accelerograph.	Z,N,E	0.1		50	0.6		600
Delhi (NDI)	28 41	77 13	207	Massive Quartzite	Sprengnether	E	7.6	7.6	5000	1	30
				Wood Anderson	N,E	0.8		1000	1		30
				Milne Shaw	N	12		250	0.7		8
				Electromagnetic	Z	1.6	0.5	50K	1		60
				Benioff (SP)	Z,N,E	1.0	0.75	50K for To = 1 sec.		1	60
				Sprengnether (LP)	Z,N,E	15	100	1500 for Te =15 sec.		1	15
Dehra Dun (DDI)	30 19	78 03	682	Gravel	Wilson Lamison	Z	1.3	1.5	1	1	60
				Wood Anderson	N,E	0.8		1000	0.8		30
				Milne Shaw	N	12		250	0.7		8
Goa (GOA)	15 29	73 49	58	Laterite	Sprengnether	Z	1.1	1.1		1	30
						E	7.3	7.3	5000	1	30
Howrah (HOW)	22 42	88 55	4	Alluvium	Benioff (SP)	Z,N,E	1.0	0.75	1500		
						Z	15.0	100.00	750		
						N	15.0	100.00	375		
						E	15.0	100.00	375		
					Benioff	N,E	1.0	15.0	3000		
NGRI (HYB)	17 25	78 33	510	Granite	Benioff	Z,N,E	1.0	0.75	100K at 1 sec.	17	1
						Z,N,E	15.0	100	1500 at 15 sec. critical.		

1	2		3	4	5	6	7		8		9	10
Kodaikanal	10 14	77 28	2343	Rock	Benioff (SP)	Z,N,E	1.0	0.75	50K at 1 sec.	0.67	1.0	60
					Sprengnether (LP)	Z,N,E	15	100	1300 at 15 sec.	1		15
Karad					Milneshaw	E	12		250	1	1	8
					Electromagnetic	Z	1.6	0.54	30K	1	1	60
					Wood Anderson	N,E	0.8	-	1000	1	-	30
Madras MDR)	13 00	80 11	15	-	Sprengnether	E	7.5	7.5	5000	1		30
						Z	1.53	1.56	-	1		60
Poona (POO)	18 32	75 51	560	Deccan trap	Benioff (SP)	Z,N,E	1.0	0.75	50 at 1 sec.	1		60
					Sprengnether (LP)	Z,N,E	15	100	1500	1		15
Port Blair	11 40	92 43	78.7		Milne Shaw	E	12	-	250	0.7		8
					Wood Anderson	N	2.0		870	1		30
						E	0.8		800	1		30
SEHORE (SEH)	23 10	77 05			Benioff	Z	1.0	1.6		1		30
					Wood Anderson	E	0.8		960	1		30
					Electro-magnetic	Z	1.65	1.67	5000	-		30
Shillong (SHL)	23 34	91 53	1500	Quartzite	Benioff (SP)	Z,N,E	1	0.75	200K at	1		60
				Sandstone	Press Ewing (LP)	Z,N,E	15	100	3000(1 sec.	1		15
				(Shillong	Sprengnether	E	7.4	7.4	3000	2.25	1	30
				Quartzite)	Milne Shaw	N	12	-	250	20	1	8
					Wood Anderson	N	0.8	-	840	1		30
						E	0.8	-	1030	1		30
					Wenner Accelerograph	Z,N,E	0.1		Nearly 50	0.6		600

1	2	3	4	5	6	7	8	9	10
Tocklai (TOG)	26 45	94 46	Alluvium	Wood Anderson	E	0.8	900	1	60
Trivandrum (TRV)	8 29	76 57	Decomposed latrite	Sprengnether	E	7.1 7.1	2500	1	30
Visakhapatnam (VIS)	17 43	83 18 31	Khondelite rock bed	Sprengnether	E	7.6 7.6	3000	1	30
				Wood Anderson	N,E	0.8	1000	1	30
				Electromagnetic (SP)	Z	1.65 1.65	6000	1 1	60
				Milne Shaw	N	.12 -	250	0.7	16
Varanasi	25 18	83 01		Wood Anderson	N	0.8	1000	0.8	60
				Electromagnetic	E	1.62 1.62	3400	1 1	30
					Z	1.6 1.6	4500	1 1	30
						1.5 90	800	1 1	60

Appendix - II

Summary record of the Meeting of the Group on Seismology held on 30th March, 1971 at the India Meteorological Department, New Delhi.

Present

Dr. A.N. Tandon	Dy. Director General of Observatories (Retired).
Dr. Jai Krishna	Director, School for Research and Training in Earthquake Engineering, University of Roorkee, Roorkee.
Shri V.S. Krishnaswamy	Director E.G., Geological Survey of India, Southern Region, "Manoranjan", 5-5-449, Mukkarram Jah Road, Hyderabad-I.
Shri T.G. Verghese	Bhabha Atomic Research Centre, C/o. Atomic Energy Department, New Delhi.
Shri H.N. Chaudhury	Director, Seismology, India Meteorological Department, New Delhi
Shri Hiralal	Senior Research Officer, (Scientific Research Section), Planning Commission, New Delhi.

Dr. A.N. Tandon welcomed the members. Initiating the discussion he stated that the terms of reference of the group were to draw up:-

(i) long term (say ten years) objectives of research in the field of seismology

(ii) integrated development programmes showing national net work of observatories required and the role of individual institutions;

(iii) programmes for additional support needed in terms of infrastructure for achieving the research and development needs; and

(iv) schemes for utilisation of data collected and its dissemination to various organisations within and outside the country.

With the above objectives, a working paper (~~copy enclosed as annexure-I~~) was prepared and circulated. The type of work done by various institutes in the field had been summarised in the paper and problems required to be tackled in

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future had been listed. The list was however not exhaustive. He requested the members to point out further problems so that the same could be discussed and included in the report of the group. To facilitate the discussions he circulated a list of agenda items (copy enclosed as annexure-I). These were taken up for consideration.

1. Operation and Maintenance of seismological observatories and work relating to standardisation, inspection, supplies and personnel:

2. Dr. Tandon stated that the maintenance of seismological observatories in India has been mainly the responsibility of the India Meteorological Department (IMD), who is operating 18 permanent stations, seven observatories in Beas and Sutlej catchment areas for special studies and four mobile observatories. The list of the observatories together with details of equipment is given at Appendix (F) of the working paper. Shri Verghese pointed out that some equipment of high sensitivity type was being wasted at Howrah. He further stated that since the mobile observatories are required generally to be rushed to the place where an event has occured, to study the after shocks, it is essential that equipment installed at the mobile observatories should be suitable for the study of high frequency seismic waves. Shri Chaudhury stated that the equipment installed in the mobile observatory is at par with that of other permanent observatories in the country and is of the type which is usually installed in the mobile observatories abroad. From the point of view of determining epicentre the equipment is satisfactory. As far as frequency and magnification are concerned the approach adopted is to select the best out of the equipments available in the country.

3. Shri Krishnaswamy mentioned that most of the observatories connected with special river valley projects were generally established after long delay by the project authorities. For example, in the case of Bhakra, the observatory could be established after a good deal of persuation for about a decade. In U.P. the Ramganga and Yamuna project authorities opened, after great hesitation, seismological observatories at Kalagarh with the technical advice of the Meteorological Department. After getting over the hurdles of opening the observatories the project authorities face various difficulties in operating the observatories in proper manner. Generally, such observatories are located at out of the way places and the project authorities find it difficult to run them with one or two persons. Special staff recruited for the purpose have no further chances of promotion in the set up and are reluctant to stick to these isolated places. It was felt that a single organisation with unified policy and with expertise and facilities available at one place for development and repair of instruments and with a large group of staff can look after the operation of observatories more effectively. Large group of people can be suitably trained and there are greater openings for promotion for them and in turn people can be transferred from popular to unpopular stations. It would be better if the observatories run by the projects or the Central Water & Power Research Station, Poona and by other organisations could be operated by a single agency. The question was considered whether the strong motion observatories (general) and strong motion observatories attached to projects should be maintained by the School of Research & Training in Earthquake

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Engineering (SRTEE), Roorkee as it has developed the instruments and has the expertise in this special field. Shri Verghese expressed that in view of advantages expressed above of a single agency operating and maintaining observatories, the strong motion observatories should also be maintained by the same agency. The SRTEE, being a small group geared largely to developmental and research work would experience difficulties in maintaining instruments and personnel at places spread over throughout the country. The data collected by the Central Data Centre could be made available to the SRTEE.

4. Dr. Tandon stated that in order to carry out river valley development projects involving huge investment, data in respect of seismicity of the site is required by the project authorities. Since generally full data is not available due to absence of network of seismological observatories, scientific assessment of the proneness of the site to earthquake hazard is not possible. Generally an over-cautious approach is adopted, as under assessment exposes the projects to dangers of future earthquakes. With the overassessment of the seismic danger, the cost of the project increases. Seismological Observatories if any, are usually set up after the project under issue has been approved. The data acquired from such observatories is not of much use since by that time decision about the seismic factor has already been taken. Seismic data is required to be collected over a long period (at least for a minimum period of 5 years) before the project is envisaged. The existing network of seismological observatories in the country is not adequate for the purpose. A considerable number of our river valley projects are likely to come up in the Himalayan belt and other

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areas which are seismically active. It is essential that we should take up a programme of setting up a dense network of observatories in these areas. All such observatories should be maintained and operated by a single agency. Their number and location should be determined in a scientific manner.

5. Shri Verghese stated that along with setting up various permanent observatories in the seismic zones for collecting instrumental data over long duration, we should keep in view the possibilities of collecting data for a shorter duration, say for about one year, with high sensitivity instruments for extrapolating the probable frequency and intensity of future earthquakes. Shri Krishnaswamy stated that in his opinion this short term approach would be risky. Methods used for extrapolating short term seismic data to long periods is still in the research stage and can not be adopted for actual engineering projects. He said that, on the basis of the data available in respect of geological thrusts and other parameters in northwest region he has plotted on the map the sites for future net work of seismological observatories. He showed the map to the members. It was observed that the sites of observatories plotted in this manner cover the areas in which either river valley projects were existing or are likely to come up in future. Shri Chaudhury circulated to the members a list of the observatories along the Himalayan belt (copy enclosed as annexure- II) and a map showing the sites of the observatories. It was decided that Shri Krishnaswamy should prepare similar maps for the other seismic zones, on which the observatories required in future should be shown. On a query raised by Shri Verghese, Shri Chaudhury stated that the cost of setting up one

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main station with three subsidiary stations would be about Rs.1.00 lakh non-recurring and Rs.0.20 lakhs recurring per year per observatory. It was pointed out that the total expenditure of operating a net work of observatories in the Beas project area over a period of 5 years was about Rs.11 lakhs as against a total expenditure of Rs.350 crores on the project.

6. It was decided that a single agency should operate and maintain the existing and future network of seismological observatories of the following types:

(i) teleseismic stations serving national and international needs;

(ii) regional observatories serving national needs;

(iii) observatories at present connected with special projects and run by the Central Water and Power Research Station, Poona and other River Valley Project authorities;

(iv) mobile observatories for mesoseismic work and after shocks studies;

(v) strong motion observatories (general); and

(vi) strong motion observatories attached to projects.

One observatory is being operated at RRL (Jorhat) on a regional basis. In view of the need of a closer national net work of observatories in the country (proposed now) and the suitability of operating the same by a central agency, the observatory run by the RRL (Jorhat) should also be transferred in due course to the central agency. The observatories operated by BARC for specified scientific purpose and by NGRI whose main function is to study the behaviour of solid earth from various aspects should continue to be run by BARC and NGRI themselves.

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II. Data collection, scrutiny, preservation of records and dissemination (Data Centre)

7. Shri Chaudhury stated that the seismological data of the observatories operated by IMD is collected by the Seismological Section at the headquarters in New Delhi. The data is scrutinised and published in the form of a monthly bulletin. There was, however, always a backlog due to insufficient facilities available. With best effort at one time the latest data published was one year old. But the backlog has again increased. The aim should be to reduce it to six months period.

8. Dr. Tandon expressed that the data collection and dissemination was the weakest link and this function was not being fulfiled properly. The data had not been preserved in a satisfactory manner. Facilities would have to be set up so that there was quick dissemination of the instrumental data collected and past records were preserved in appropriate manner. For this purpose microfilming facility would be essential. At the suggestion of Shri Verghese that facilities available at INSDOC, Delhi could probably be utilised, Shri Chaudhury stated that they had tried in the past to utilise the facilities available at the INSDOC for this purpose but the INSDOC have at present no facilities for microfilming of large sized seismograms. The amount of work involved was so heavy that a separate facility would be necessary for this purpose.

9. It was decided that the data of teleseismic, regional, project and mobile observatories and microseismic data should be collected, scrutinised, disseminated and preserved by the same agency who is responsible for maintenance and operation

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of the national net work of observatories. Shri Chaudhury was requested to prepare a note on this spelling out the amount of work involved and facilities and equipment required for this purpose, keeping in view the future developments in this field. It was decided that the strong motion data collected by the central agency should be passed on to the SRTEE, Roorkee who should scrutinise, disseminate and preserve the data. They should also publish the data in the form of a bulletin and circulate it to interested parties.

10. Dr. Tandon pointed out that for collecting field data, the Geological Survey of India had been sending field parties to study the damage to structures and other phenomenon caused by earthquakes after the occurence of every important event. A large number of memoirs on individual earthquakes have been published by the officers of the Survey. Invariably the report includes isoseismal maps for individual earthquakes and the possible causes of the earthquakes. During the last few years the Central Water and Power Research Station, Poona and the SRTEE, Roorkee have also associated themselves in the field studies of earthquakes with special emphasis on the engineering aspects. It was decided that since field data is very useful, GSI should continue to look after this activity and after every important event they should form composite team including officers from IMD, SRTEE, Roorkee, CWPRS, Poona and other interested parties, for the purpose of collecting field data. It would be better if one version of the report of the composite team under GSI is available in place of different conflicting versions prepared separately by different organisations.

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11. Dr. Tandon stated that after the occurence of an important earthquake at a place, where seismological instruments are not installed, reports of voluntary observers are very useful. For this purpose there is an old form which is required to be revised. The IMD used to collect report from the voluntary observers in this form. Since only a few people cooperate voluntarily to fill the form and send the report, sometimes the Department depends merely on Newspaper reports which are not at all sufficient. The system of voluntary observer reports should be improved and made more effective. It was decided that a panel consisting of Dr. Jai Krishna and representatives from the ISI should go into the matter and also revise the proforma for the purpose.

III. Data Processing

12. Shri Chaudhury stated that each of the IMD Stations is staffed with two persons. They tabulate the data and report Indian events after every week and international events after every month. For major events the data is reported by the stations by telegrams on the day of occurence. It is processed the same day and circulated by the Headquarters of the Department to concerned organisations. Shri Verghese stated that he had not seen such data card for preliminary determination of epicentres of important events. In his opinion such preliminary data should be enough for immediate research purposes and it would be useful if the preliminary data cards were circulated widely to all concerned. The IMD should set up a computer facility of suitable type and work out programme for progressive quick processing of instrumental data and determination of epicentres with the help of computer. In this connection BARC

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could help since they had built expertise and were already putting up at Gauribidanur a computer facility indigenously built by ECIL.

13. It was decided that instrumental data collected by the National net work of observatories should be processed by the single agency and for this purpose computer facility of suitable type would be essential. Strong motion data could be processed by the SRTEE, Roorkee. About major events the preliminary data collected and processed should be made available on the same day to concerned organisation in the country. Shri Chaudhury should indicate the facilities required for this purpose also.

IV. Development of Instruments

14. Shri Chaudhury stated that IMD has been designing and constructing seismological equipment for installation at observatories operated by them. The types that have been constructed and brought into use are (i) Wood Anderson Seismographs, (ii) short-period verticle and horizontal electromagnetic seismographs, (iii) Sprengnether type EM seismographs of period in the range of 7 seconds (iv) photographs recorders (v) Electronic amplifiers for use with seismographs, (vi) visible pen writing recorders (vii) time marking clocks of pendulum type (viii) other accessories required at seismological observatories. The Department has, by and large, developed the type of equipment required by seismological observatories and can meet its requirement and supply to others. There is no need now to import such type of equipment. During the last few years an electronic time marking device has also been successfully developed. Dr. Verghese suggested that in the

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field of instruments, development work was being done in other public and private organisations. Facilities and expertise available in other organisations should be kept in view while undertaking work on development of instruments required for seismological observatories. For instance, if we could spell out exact specifications and requirements for instruments such as (i) galvanometer and (ii) tape recorders, it would be possible for industry to produce and meet the requirement. Crystal clock and electronic accessories as part of seismograph had been developed by the ECIL. BARC has expertise for wireless telemetry and they can also look after the development of laser beam technology. NGRI has also done work on the development of geophysical instruments. He said that standardisation of equipment and timing code would help expeditious development in this field.

15. Dr. Jaikrishna stated that SRTEE, Roorkee had developed and constructed instruments such as (i) strong motion accelerographs (ii) structural response recorders (iii) seismoscope and (iv) water tube tiltmeter and would take up work on the development of strain meter. The School has a small section for research and development of such instruments.

16. It was decided that the IMD should develop seismological instruments keeping in view the work being done at NGRI, BARC and School of Earthquake Research and Engineering who should continue development work in their fields. The facilities available at other private and public organisations should be utilised fully to avoid duplication of work and waste of effort.

V. Consultancy Service:

17. Dr. Tandon stated that enquiries are received from public and private organisations by IMD, SRTEE, Roorkee and GSI regarding seismic factors to be taken into account in the design of engineering structures to be constructed in seismically active areas. The Central Water and Power Commission has set up a Committee to advise on the seismic factor to be undertaken in the design of projects under their direction. So far as enquiries from the public are concerned, there is an I.S.I. code which is quite satisfactory for ordinary structures. There are many other types of enquiries too. It was necessary, therefore, to develop an adequate consultancy service. Dr. Jaikrishna stated that there was no harm in supplying the data available with the departments but we should be very cautious to advise in this matter. In view of the absence of geological and seismological data and detailed experimentation for dynamic analysis an adequate consultancy service could not be built immediately.

18. It was decided that the Departments and organisations could continue to deal with enquiries, received regarding suitability of building designs for seismic hazards by furnishing data available and referring to the I.S.I. code. In the case of important structures, the need of further dynamic studies should invariably be pointed out.

VI. Research

19. Dr. Tandon stated that there are about sixteen institutions and universities in the country undertaking seismological research work of a fundamental and applied nature. The role of each type of institute is required to be specified.

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Shri Verghese stated that in U.S.A. a bulk of the fundamental as well as applied research work in this field is being done by the universities. In our country also universities should be encouraged to undertake both fundamental and applied seismological research work and they should, draw upon expertise available at IMD and other institutes for working out proper (R&D) programme. Shri Verghese was requested to prepare a note on the role of universities in seismological research.

20. In the field of engineering seismology it was pointed out that both CWPRS, Poona and SRTEE, Roorkee are doing research work connected with vibration and deformation studies of different types of structures such as tall buildings, dams, roads, tunnels and power houses. Since two places are not too many for research work in this important field both the organisations should continue research work and strengthen their facilities for this purpose.

21. Shri Krishnaswamy stated that the geological survey undertook work relating to (i) structural and tectonic maps of areas lying in active seismic zones in the country (ii) identification of each active fault zone, (iii) detailed geological appraisal of each major earthquake (iv) long term observations of micro-seismic movements in selected active fault zones, and (v) studies on palaeo magnetism in the Indian region.

22. It was decided that BARC and NGRI should continue research work in their specific fields but it should be ensured that the data collected and processed by the central agency should be made available to these organisations for research purposes. Organisations already involved in seismological research should send comments on the role of various organisations in seismological research so that in the next meeting

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the matter could be further discussed.

VII. Establishment of Institute for Seismological Research

23. Dr. Tandon stated that the Committee on Organisation of Scientific Research (COSR) considered the status of seismological work in India. The COSR while making recommendations in regard to IMD recommended that the seismological division working as a part of IMD should be separated from the IMD and constituted as an autonomous institution. The Government of India accepted the recommendations and Ministry of Civil Aviation and Tourism was taking steps to give effect to it. Recently, however, the Ministry deferred the decision on the plea that only 20% of the work of the Division of Seismology was research oriented. He stated that the group could consider following three alternatives

(i) as recommended by (COSR), the Seismology Division of IMD should be completely separated and it should function as an autonomous institute, or

(ii) with DGO as the head, there should be two wings -
(a) Wing for operation and maintenance of seismological laboratories should be under IMD and
(b) research wing should be an autonomous unit, or

(iii) research wing instead of working as an autonomous unit should function as a Research Division under IMD with more flexible rules to recruit personnel directly at any level.

24. It was decided that since the matter required to be gone into depth it should be taken up in the next meeting for consideration and members should send their views in advance so that the same could be circulated before the meeting.

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25. It was tentatively decided to hold the next meeting for two days in the second week of May, 1971 at Delhi.

26. The decisions arrived at the meeting are summarised below.

I. Operation and Maintenance of Seismological Observatories and work relating to standardisation, inspection, supplies and personnel.

(i) A single Agency should operate and maintain the existing and future net work of seismological observatories of the type namely (a) teleseismic stations serving national and international needs, (b) regional observatories serving national needs (c) observatories at present connected with special projects and run by Central Water and Power Research Station, Poona and other river valley project authorities, (d) mobile observatories for mesoseismic work and after shocks studies (e) strong motion observatories (general) and (f) strong motion observatories attached to projects. The observatories run by the RRL (Jorhat) should also be transferred to the single agency. The observatories run by BARC for specified scientific purpose and by NGRI whose main function is to study the behaviour of solid earth from various aspects should continue to be run by BARC and NGRI themselves.

(ii) Shri Krishnaswamy was requested to plot the net work of seismological observatory required in seismic zones in the country.

II. Data collection, scrutiny, preservation of records and dissemination (Data Centre)

(iii) The data of teleseismic, regional, project and mobile observatories and microseismic data should be collected, scrutinised, disseminated and preserved by the single agency who is responsible for maintenance and operation of the national

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net work of observatories. Shri Chaudhury was requested to prepare a note on this, spelling out the amount of work involved and facilities and equipment required for this purpose, keeping in view the future developments in this field.

(iv) The strong motion data collected by the central agency should be passed on to the SRTEE, Roorkee who should scrutinise, disseminate and preserve the data. They should also publish the data in the form of a bulletin and circulate to interested parties.

(v) Since field data is very useful, GSI should continue to look after this activity and after every important event they should form composite team including officers from IMD, SRTEE, Roorkee, CWPRS, Poona and other interested, for the purpose of collecting the data. It would be better if one version of the report of composite team under GSI was available in place of different conflicting versions prepared separately by different organisations.

(vi) A Panel consisting of Dr. Jaikrishna and representatives from the ISI should look into the problem of collecting reports of voluntary observer and also revise the proforma for the purpose.

III. Data processing

(vii) Instrumental data collected by the National net work of observatories should be processed by the central agency and for this purpose computer facility of suitable type should be made available. Strong motion data could be processed by the SRTEE, Roorkee. About major events, the preliminary data collected and processed should be made available on the same day to concerned organisation in the country. Shri Chaudhury would indicate the facilities required for this purpose also.

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IV. Development of Instruments

(viii) The IMD should continue to develop seismological instruments keeping in view the work being done at NGRI, BARC and SRTEE, Roorkee who should continue development work in their specific fields. The facilities available at other private and public organisations should be utilised fully to avoid duplication of work.

V. Consultancy service

(ix) The Department and organisations should continue to deal with enquiries received regarding suitability of building design for seismic hazards by furnishing data available and referring to I.S.I. code. However, in important cases in view of inadequacy of the data available, need of further dynamic studies could be pointed out.

VI. Research

(x) Shri Verghese was requested to prepare a note on the role of universities in seismological research.

(xi) Since two places are not too many for research work in the important field of engineering seismology, both the organisations namely CWPRS, Poona and SRTEE, Roorkee should continue research work and strengthen their facilities for this purpose.

(xii) The geological surveys should continue to undertake work relating to (a) structural and tectonic maps of areas lying in active seismic zones in the country (b) identification of each active fault zone (c) detailed geological appraisal of each major earthquake (d) long term observation of micro-seismic movements in selected active fault zones, and (e) studie on palaeo magnetism in the Indian region.

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(xiii) BARC and NGRI should continue research work in their specific fields and it should be ensured that data collected and processed by the single agency should be made available to these organisations for research purposes.

(xiv) Members of the group should send comments in respect of specific role of various organisations in seismological research so that in the next meeting the matter could be further discussed.

VII. Establishment of Institute for Seismological Research

(xv) It was decided that since the matter required to be gone into depth it should be taken up in the next meeting, for consideration and members should send their views in advance so that the same could be circulated before the meeting.

(xvi) Next meeting of the group should be held for two days in the second week of May, 1971 at Delhi.

Annexure - (I)

Agenda for the meeting of the Group on Seismology

nal

ation, Maintenance of Seismological Observatories, ndardisation, Inspection, supplies and personnel.

a) Teleseismic stations serving national and international needs.

b) Regional observatories serving only national needs.

c) observatories at present connected with special projects.

d) observatories established for specified scientific purpose.

e) Mobile observatories for meso-seismic work and after-shock studies.

f) Strong motion observatories (General)

g) Strong motion observatories attached to projects.

2. Data Collection, Scrutiny, preservation of records and dissemination (Data Centre)

a) Data of Teleseismic and regional observatory.

b) Data of project observatories.

c) Data of Mobile observatories.

d) Microseismic data.

e) Strong Motion data.

f) Field data.

3. Data processing

a) Routine determination of Epicentral parameters (Epicentre, depth of focus, magnitude) and its quick dissemination to interested parties).

b) Processing of strong motion records and publication.

4. Development of Instruments

a) Seismographs and other accessories used in seismological observatories.

b) Development of Strong motion instruments.

c) Development of special instruments for studying the deformation of the earth's crust.

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5. Consultancy Service to Government Departments & Public

6. Research

a) Role of Universities, Governments organisations like GSI, IMD, NGRI, CWPRS, RRL (Jorhat) & BARC.

b) Establishment of Institute for Seismological Research

c) Participation in International projects like the Geodynamics Project of ICSU.

Annexure-II

LIST OF OBSERVATORIES ALONG THE HIMALAYAN BELT

India Meteorological Department

	(°)	(')	(°)	(')
1. Srinagar	34	05	74	45
2. Bhakra	31	25	76	25
3. Dehra Dun	30	19	78	02
4. Bhaisalotan	27	25	83	55
5. Chatra	26	50	87	10
6. Tura	25	30	90	10
7. Shillong	25	34	91	53
8. Lakhpani (Dibrugarh)	27	30	95	00
9. Imphal	24	45	93	35
Beas Project Scheme				
1. Pong Dam	31	55	75	55
2. Mukerian	31	57	75	37
3. Jawalamukhi	31	52	76	20
4. Nurpur	32	18	75	52
5. Dalhousie	32	18	75	52
6. Sundernagar	31	30	76	50
7. Ghaggar	30	47.5	76	55
8. Simla	31	05	77	10
9. Kulu	31	55	77	05
10. Dharamsala	32	10	76	15
Pancheswar & Sarda Project				
1. Lohaghat	29	20	80	05
2. Ranikhet	29	35	79	25
3. Tejam	29	55	80	05
Ramaganga Project				
1. Kalagarh	29	15	79	45

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	(o)	(')	(o)	(')
Giri Project				
1. Giri (Nahan)	30	30	77	30
Salal Project				
1. Jammu	32	40	74	50
2. Ramban	33	10	75	10
3. Dhiangarh	33	45	75	10
4. Riasi	33	00	74	45
5. Udhampur	32	55	75	05
6. Bhadrawah	33	00	75	50
7. Kishtwar	33	15	75	45
8. Sawalkot	33	10	75	00
9. Anantnag (East)	33	40	75	05
Ganga & Yamuna Valley Project				
1. Narendra Nagar	30	05	78	15
2. Rudra Prayag	30	15	78	55
3. Tehri	30	20	78	25
4. Joshimatt	30	30	79	30
5. Maneri	30	45	78	35
6. Tuini	30	55	77	50
7. Gupta-Kashi	30	30	79	05
8. Harsil	31	00	78	40
9. Barkot	30	15	78	10
10. Kishau	30	45	77	40
11. Kalawar	30	30	77	55
Thien Dam Project				
1. Thien	32	45	75	50
Dihang and Subansari Project				
(6 or 7 Stations).				

APPENDIX V

Summary record of the meeting of Group on Seismology held on 5th and 6th July 1971 in Yojana Bhavan, New Delhi.

PRESENT

Dr. A.N. Tandon	Dy. Director General of Observatories (Retired).
Shri H.M. Chaudhury	Director, Seismology, India Meteorological Department, New Delhi.
Dr. K.L. Kaila	National Geophysical Research Institute, Hyderabad.
Dr. Jai Krishna	Director, School for Research and Training in Earthquake Engineering, University of Roorkee, Roorkee.
Shri V.S. Krishnaswamy	Director, E.G., Geological Survey of India, Southern Region, Hyderabad.
Dr. Hari Narain	Director, National Geophysical Research Institute, Hyderabad.
Dr. N.V.V. Parthasarathy	Principal Scientific Officer, Cabinet Secretariat, New Delhi.
Shri T.G. Verghese	Bhabha Atomic Research Centre, Bombay.
Shri Hiralal	Senior Research Officer, Planning Commission.

Dr. A.N. Tandon welcomed members to the second meeting of the Group. Before starting discussions on the agenda items, a list of which was circulated at the meeting and is enclosed as Annexure-I, he invited comments of the members on the minutes of the first meeting of the Group. In the absence of any comments the minutes were considered as approved.

2. Consideration of map of net work of seismological observatories required to be established in the country: Initiating the discussion Dr. A.N. Tandon stated that prior

to starting construction of river valley projects involving expenditure of huge funds in different areas, the order of seismicity of the area is required to be assessed. The present seismological observatories net work in the country is not adequate. Therefore, a scientific assessment of the proneness of the site to earthquake hazard is not possible. For this purpose a denser net work of observatories is required to be established, and instrumental data are required to be collected for a minimum period of five years. In view of this, Shri Krishnaswamy was requested to prepare a map indicating the sites of the proposed observatories after taking into account the needs of the existing and proposed river valley projects. Dr. Tandon also pointed out that map now prepared by Shri Krishnaswamy could be considered along with another map, a copy shown to members, prepared and presented by Shri P.C. Hazra at a Symposium on "Koyna Earthquake" organised by the G.S.I. about two years ago. Shri Krishnaswamy was requested to present the map prepared by him.

3. Shri Krishnaswamy presented the maps prepared by him showing net work of seismological observatories required to be established in different regions taking into account the general tectonic features. He assured that the tectonic maps now available include more information than what was available at the time Shri Hazra prepared the map in which the coverage of the Himalayan region is rather inadequate. For example,

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out of 80 stations shown in Shri Hazra's map only 20 are in the Himalayan region. There are only 8 stations shown in the states of Himachal, Jammu & Kashmir and Punjab. Some more stations have, therefore, been suggested in the map prepared by him. It has not been possible to show the sites of the river valley projects which have been constructed/under construction or planned to be constructed along with the locations of the proposed observatories as complete information in respect of the coordinates of the project sites could not be obtained.

4. Dr. Hari Narain pointed out that it would be useful to indicate separately the type and priority of stations shown in different regions.

5. Shri Krishnaswamy stated that the total number of seismological observatories required for an adequate coverage in different regions of the country would be about 350. Out of these, about 100 stations are meant for the seismic studies of regional tectonic units, that is in areas of known active faults. Since ultimately the whole country would be developed it would be essential to study the order of seismicity and fault features of all the different areas in the country and hence another 100 stations would be required for special study of fault features in different regions. In addition to these, it is estimated that about 100 stations would be required by various river valley projects for detailed seismic studies of their project area. The remaining 50 stations have been included for academic studies on a long term basis.

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6. Dr. Kaila pointed out that the rationale and aim of such a large number of stations should be clearly specified. Along with the proposal of setting up permanent seismological stations, it should also be considered whether the objectives could also be achieved by establishing temporary stations to study micro-earthquakes.

7. Dr. Jai Krishna stated that for the assessment of the order of seismicity of various areas, the roles of permanent stations and short-term studies are complementary. The objectives of the present study is to work out a desirable national net work of permanent stations in the country. In a particular region the net work would depend upon the limit of magnitude of the earthquake to be covered, on the basis of which the distance between various stations in the region as well as the type of instruments to be installed could be decided.

8. On a query raised by a member Shri Choudhury stated that the non-recurring expenditure on building and equipment for one station would be about Rs.1 lakhs. The stations could be equipped with instruments developed indigenously. About four to five persons (including Class IV staff) would be required to maintain and operate a station.

9. After discussion it was decided that since it may not be possible to establish at this stage a net work of 350 stations, a minimum essential net work of 100 priority stations in different regions should be worked out. Shri Krishnaswamy was requested to complete the map along with a note describing the criteria and rationale for the various types of stations shown in different regions.

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10. Observatories for river valley projects: Dr. Tandon stated that Shri S. Balasubramaniam, Director, Dams, Central Water and Power Commission CWPC was invited to attend this meeting so that he could put forth the view point of the CW & PC. He,however, could not attend the meeting. Shri Choudhury, who had earlier held discussion with Shri Balasubramaniam, was requested to elaborate the views expressed by Shri Balasubramaniam.

11. Shri Chaudhury stated that Shri Balasubramaniam had written a letter in connection with seismological observatories to be set up for establishment of Idikki project. In this connection, the Central Water and Power Research Station (CW&PRS) Poona has already started one observatory. The Canadian consultant of the project wanted more detailed study of the area. For this purpose, the CW&PRS, Poona had given a scheme costing about Rs.8 lakhs for setting up net work of five stations. At that stage the Idikki project authorities suggested to take up the matter with the IMD for opening the observatories for the project. In this connection the views of IMD are guided by the controlling Ministry who think that such a type of work, which is not included in the general plan of work of IMD and is required by a project should not be financed by the IMD. The IMD could, however, render all possible technical and scientific assistance to the project authorities. After a good deal of discussion the general consensus was that in such cases the observatories could be set up by the project authorities in the beginning an operated for a few years and later on handed over to the

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Central Institute who could continue their operation if necessary. It was pointed out that at present, funds for setting up of observatories from the project allocations become available only after the approval of the river valley project. The very purpose of the establishment of such observatories is defeated as the data is essentially required for the design of the project and has to be collected a few years before the decision is taken to start work on the project. It was suggested that the Ministry concerned should set apart a development fund for setting up observatories a few years before the project is approved. Later on the cost of the observatories could be recovered, if necessary, from the project funds.

12. Data Collection, scrutiny and dissemination:

Dr. Tandon stated that at present adequate facilities are not available for the preservation and dissemination of instrumental data. At the first meeting of the Group it was pointed out that there is a need to set up a Data Centre which should be the repository of all such data collected in the country. A research worker from any institute in the country should be able to come to the data centre, and consult the records. The data should be disseminated periodically to all concerned in a systematic manner. For this purpose Shri Chaudhury was requested to work out details of facilities required. Dr. Hari Narain suggested that the Data Centre should be built like a library where information of the important world stations could also be available. In this connection Shri Chaudhury circulated a note, a copy of which is enclosed as Annexure II.

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The Data Centre could consist of two divisions, viz. one division for collecting, preserving, and supplying seismological records to interested parties and the second division, for collection, preservation and dissemination of raw data and for processing and issuing collective seismological bulletins. He stated that the broad framework of the Data Centre shown in the note relates to national net work of observatories. Facilities would be required on a much larger scale if the data are required to be collected from the world stations. It was observed that collection of data from about 120 world stations would involve expenditure over lakhs of rupees in foreign exchange. Therefore, data could be collected from about 20 or 30 selected world stations. Dr. Jai Krishna suggested that the data centre should also be equipped with a digitizer. After some discussion the plan of data centre as prepared by Shri Chaudhury was accepted.

13. Consideration of the points raised by Dr. Jai Krishna regarding strong motion data: Dr. Jai Krishna stated that in the last meeting it was accepted in principle that maintenance of strong motion station (general) and strong motion observatories attached to the projects should be done by a Central Institute. Since the instruments installed at these centres are in a development stage and SRTEE is changing components and re-designing the instruments it would not be appropriate at this stage to transfer the technical control of these instruments to the Central Institute. After discussion, it was decided that the Roorkee School should continue to look after these instruments till their design is finalised.

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14. Seismological Research - role of universities: Dr. Tandon stated that so far only the service side of seismological work has been discussed. Now it could be considered how best research activity in the country could be carried out and what should be the role of the universities and Government organisations namely G.S.I., I.M.D., C.W.& P.C. and national laboratories. He stated that at present not much research work is being done in universities who have practically no facilities for specialisation in seismology. A few problems are taken up sporadically, depending on the students available. The facilities in the universities are required to be strengthened so that systematic research could be taken up and expertise could be built in special fields. In this connection Shri Verghese circulated a note, a copy of which is enclosed as Annexure-III. He stated that on the basis of this note recommendation could be made on the role of universities. Dr. Jai Krishna stated that research work in the universities is not related to the practical side of seismology and its application to the construction of earthquake resistant structures. It would be essential to set up advance centres of research in a few selected universities where practical as well as theoretical problems could be studied. Dr. Hari Narain stated that he had discussion with U.G.C. regarding raising of standard of work in Geophysics and Seismology in a few universities. For this purpose it was suggested that NGRI and other institutes should take up a collaborative work in the universities. The manner in which the collaborative work could be funded was still to be decided. He stressed on the need of giving support to a

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few selected universities for setting up suitable facilities for research work in this field.

15. Seismological Research - Role of other organisations: The general consensus was that in respect of basic research which depends largely on the training and aptitude of individual workers there should not be much fear about duplication of work. It is rather desirable that more than one person or institute should work on basic problems and tackle the same by adopting different approaches. It was considered very desirable that even for basic research a few institutes should build up expertise in a systematic manner and encourage research work on topics entrusted to them. For research on problems of a practical nature and having economic significance it would be most desirable that responsibility for execution of such work should be entrusted to specific institutions. In view of this the various problems required to be tackled and the institute which should be largely responsible for undertaking the work were listed as below:-

Problems required to be tackled	Institute largely responsible
A. Seismicity	
(i) Improvement in the accuracy of determining epicentral parameters, specially magnitudes of small tremors and depths of shallow earthquakes.	Central Institute.
(ii) Development of suitable techniques to determine magnitudes more accurately	
(iii) Development of techniques to determine focal depths of shallow earthquakes.	
(iv) Preparation of maps of epicentres of earthquakes of magnitude 3 and above for the various areas of the country.	

	Problems required to be tackled.	Institute largely responsible
(v)	Preparation of maps delineating seismically active faults.	G.S.I.
(vi)	Correlation of seismic events with local geology	Central Institute
(vii)	Construction of seismic probability maps for different regions of the country.	
(viii)	Construction of recurrence curves of earthquakes for small areas based on actual observations of earthquakes	
(ix)	Studies of patterns of foreshocks and aftershocks for important earthquakes and correlation with local geological structures.	Any organisation who has expertise and interested in the problems.

B. Causes of earthquakes

(i)	Determination of fault plane solutions of past earthquakes by using techniques based on initial P wave motions, S waves, and surface waves.	Central Institute.
(ii)	Studies of radiation pattern based on actual seismological data and comparison with theoretical models.	Any organisation interested in the problem.
(iii)	Intensive studies relating to movement of rock masses at various depths, collaboration in the International Geodynamics Project.	
(iv)	Study of the deformation of the Earths Crust before during and after seismic events with the help of tiltmeters, extensometers etc.	Central Institute and BRTEM.
(v)	Precise levelling and triangulation to be carried out throughout the country specially in areas with large seismicity.	Survey of India.
(vi)	Geodimeter surveys to be carried along active faults particularly in areas where large projects exist or are contemplated with a view to study the creep movements along the faults and their correlation with future seismic activity.	

C. Microseisms -

(i)	Study of seismic noise by sensitive seismographs with a view to correlate the pattern of noise with the foundation.	BARC and the Central Institute.
(ii)	Special study of microseisms in the period range (2-10) seconds caused by sea waves, with a view to investigate their nature, origin and propagation.	
(iii)	Investigations of the methods by which storm type microseisms can be used to track storms, methods using array techniques as well as matched three component seismographs should be attempted.	
(iv)	Empirical techniques to determine the location and intensity of storms should be persued.	

Problems required to be tackled	Institute largely responsible
D. Model Seismology and Laboratory techniques -	
i) Measurement of velocities of seismic waves in various types of rock specimens under conditions of high temperature and pressure.	GSI and NGRI.
ii) Study of seismic wave propagation through two and three dimensional models.	GSI and NGRI.
E. Engineering Seismology	
(i) Improvement in the network of accelerograph stations specially in the Himalayan seismic belt.	SRTEE
(ii) Installation of large number of structural response recorders in the different seismic regions	SRTEE
iii) Design and construction of cheap types of accelerograph.	SRTEE
(iv) Study of Soil behaviour during earthquakes	SRTEE
(v) Vibration studies of different types of structures (Tall buildings, water towers, power houses)	SRTEE & CWPRS
(vi) Behaviour of different types of structures during earthquakes.	SRTEE & CWPRS.
(vii) Design of cheap seismic structures	SRTEE
(viii) Model studies of special structures like dams, bridges on shaking tables.	SRTEE & CWPRS.
(ix) Site evaluation of dam sites through blast tests	CWPRS
F. Wave Velocities Travel times and Crustal structure -	
(i) Improvement in observed travel time tables for different types of seismic waves.	Central Institute and NGRI.
(ii) Construction of T.T. Curves for seismic waves for different tectonic blocks.	Central Institute and NGRI.
(iii) Studies of the earth's crust and mantle in different regions using data of body waves from near earthquakes.	Central Institute, NGRI & BARC.
(iv) Deep Seismic Soundings to determine the thickness and properties of crustal layers.	NGRI & GSI.
(v) Study of the dispersions curves of surface waves for fundamental and higher modes for different tectonic blocks of the country. Both phase and group velocities of surface wave should be determined with the ultimate aim of constructing phase and group velocity maps.	Any organisation interested in the problem
G. Seismological Instruments -	
Development of the following type of instruments -	
(i) High Magnification electromagnetic seismographs to restrict imports of this item.	Central Institute.

	Problems required to be tackled	Institute largely responsible.
(ii)	Seismographs using electronic amplifiers and visible recording.	Central Institute.
(iii)	Portable seismographs for study of aftershocks and microtremors.	
(iv)	Long Period Vertical and Horizontal type e.m. seismographs.	
(v)	Borehole seismographs	NGRI
(vi)	Seismographs for installation at sea bottom	NGRI
	Recorders of the following type -	
	Photographic recorders using paper or film	Central Institute.
	Visible type with recording on paper	
	Tape recorders	BARC.
	Recorders capable of recording for long periods without personal attention.	
	V.H.F. tele recording devices.	
(vii)	Strain seismographs	Central Institute and SRTEE.
(viii)	Development of the following accessories -	
	Electronic clocks for time marking	Central Institute.
	Amplifiers for running synchronous motors of recorders.	
	Sensitive type moving Coil short type and Long period galvanometers.	
(ix)	Digital Seismographs	BARC
(x)	Analog to Digital converters.	
(xi)	Response spectrum analyser	could be purchased from outside.
(xii)	Cheap type of Accelerograph with built in displacement meters.	SRTEE.
(xiii)	Tiltmeters of water tube type and horizontal Pendulum type.	
(xiv)	Instruments for Engineering Seismological studies	

16. Establishment of Central Institute of Seismology:

Dr. A.N. Tandon stated that in the first meeting of the Group various alternatives were considered regarding suitable set up for a separate Institute of Seismology. Consensus was that it would be useful if seismology division of IMD is separated and set up as an autonomous organisation. Since COSR had already considered this question and made recommendations,

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Dr. N.V.V. Parthasarathy was requested to give the latest position in respect of report of COSR.

17. Dr. Parthasarathy stated that an autonomous set up for seismological division of the IMD was recommended by COSR with a view to provide an academic atmosphere for carrying on research without being loaded with day to day non-research work. The IMD has not implemented the recommendation on the plea that 80% of the work of their Seismology Division is maintenance and operation of net work of observatories and rest 20% is research oriented. Prof. Bhagawantam and other members of the COSR have not agreed to this plea and they have again reiterated their suggestion for separating the seismology division and giving it an autonomous status.

18. After discussion it was observed that in the past adequate net work of seismological observatories could not be established under the IMD since their main interest is in field of meteorology which has no connection with seismology. Routine work of the IMD will not be affected if the seismological work is taken out of the hands of the IMD, on the other hand, there are certain advantages, if seismological work is separated from IMD. In the field of seismology the collection of data and research work form an integrated part. Therefore it would be extremely useful if the same organisation looked after both the functions. An autonomous Institute of Seismology could take up the responsibility of (i) the establishment and operation of an adequate net work of observatories in a planned manner (ii) collection and dissemination of data and (iii) undertaking research work and development of instruments

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required in the field. For this purpose, the Institute can be staffed and equipped in an appropriate manner.

19. Dr. Tandon stated that a few years back he prepared a basic plan of a Central Institute of Seismology showing its functions and structure in a broad manner. He showed a copy of the draft to members. It was decided that on the basis of this basic plan, Dr. Tandon may suggest suitable structure and function of the autonomous Institute of Seismology in the draft report of the group.

20. It was decided that the next meeting of the Group may be held in September 1971 at Hyderabad to consider the draft report of the group.

ANNEXURE I

Agenda Items for Seismology W.G. Meeting
on 5-6 July 1971.

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1. Operation & Maintenance of Seismological Observatories etc.

   1) Consideration of the network map prepared by Shri V.S. Krishnaswamy.

   2) Observations in River Valley Projects (Shri Balasubramaniam's point).

2. Data Collection, Scrutiny etc.

   3) Consideration of the note on framework of the Data Centre prepared by Shri Chaudhury.

   4) Consideration of the points raised by Dr. Jai Krishna regarding the Strong motion data.

3. Research

   5) Consideration of the note prepared by Shri Verghese on the role of Universities in seismological research.

   6) Establishment of Institute of Seismology.

   7) Participation in International Projects like the Geodynamics Project of ICSU.

   8) Any other points.

ANNEXURE - II

SEISMOLOGICAL DATA & ANALYSIS CENTRE

The India Meteorological Department is running a total of 29 seismological observatories. Out of these 19 are permanent ones and now form the National network. Six belong to the Beas Scheme and four are mobile observatories. The charts from all these observatories are collected and preserved at the HQ office in Delhi. The data are also received here, every month in processed station bulletins and are then combined into one seismological bulletin after determination of the epicentral parameters of the various events. The bulletins are got printed and distributed to interested parties in and outside the country. Requests for data and copies of records pertaining to particular events are also attended to by the HQ unit.

The volume of data handled at present is not small. Every day about 90 charts are added to the collection and the seismological bulletin from data of the network of observatories above runs to about 50 pages. With the existing manpower and facilities, there is some delay in the issue of the bulletins. Request for supply of copies of records can not often be promptly complied with due to difficulty in getting photographic paper and to want of suitable photocopying machines.

In addition to the above, there are at present quite a number of seismological observatories known to be functioning under other organisations. The Central Water and Power Research Station at Poona is running a net work of observatories around the Koyna Dam and the Koyna Project area, in Ukai and in Idikki. The Govt. of Uttar Pradesh have three observatories in position and a fourth is expected to go into commission soon. The Kolar Gold Mining Authority is known to be operating a seismological observatory. Besides these, special research organisations like NGRI, BARC, Calcutta University etc. are also running a few observatories.

It is clear from the above that even at the present level of activity, if all the available records and data are collected at one centre they will double the volume from those which the IMD is handling at present. With the projected future developments in seismological studies, the number of seismic observation posts is likely to reach one hundred and the number of charts per day reach a modest two hundred. The present type of handling of the data and the records will therefore be inadequate to meet the demands. A data centre with improved facilities both in equipment and methods and in manpower has to be a must in the plans for the development of seismology in the country during the next decade. A rough framework of a data centre to meet the requirements is given below -

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Data & Analysis Centre - Functions -

The centre should be responsible for collecting the data and the records from all the seismological observatories in the country. It should also be the single organisation which should take up supply of these to interested parties - both raw data and compiled bulletins. Accordingly the centre could have two broad sub-divisions. One to deal with records, their copying, preservation and supply, the second with collection, preservation, dissemination of raw-data and for processing the data and issuing bulletins.

Staffing -

It is proposed that each of the divisions be headed by an officer (SSO II). The records division may have three cells, for receipt, scrutiny and storage, for supply and for photocopying. The cell dealing with supply of records will have liaison with the photocopying cell as and when necessary. The division may have a total staff as indicated in the chart.

Special equipment, specially for the photocopying cell will have to be provided to enable the proper preservation of records as well as their supply. Tentatively the following equipments are considered necessary. Further additions could be made in due course.

1. Microfiling Machine (Recordak MRD-2)

2. Prostar Processor

3. Contact Printer (ITEK 303 & 303 DL)

4. Printer (Recordak 1824)

5. Reader (MPE-1)

Other small accessories -

The second division will have, for the present, two cells. One will take care of the proper receipt of data from individual stations, their preliminary scrutiny and record and supply. The second will be responsible for preparing the monthly bulletins. The method of work for the bulletin may be the present one in the initial stages. Machine methods of data processing will have to be introduced soon to cope up with the increased volume of dak expected. An electronic digital computer will have to be procured in due course and the staff of the second cell should gradually switch on the computer processing methods. With the introduction of the computer an additional cell under a SSO II may be added with some suitable staff. The scheme of the centre and the staffing pattern is shown in the chart.

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The total manpowerof the Data Centre is given below -

SSO I	-	1
SSO II	-	3
SSA	-	13
JSA	-	16
Technicians	-	3
Typists	-	2
Lab. Attds.	-	6
Daftries	-	5
Peon	-	4

DATA CENTRE

SSO
Typists 2
One Peon

Records (SSO II)

Collection scrutiny and supply of records

torage	Supply
SSA - 1	SSA-1
JSA - 2	JSA-2
Daftry-2	Daftry-1
	Peon -1

Preservation microfiling copying

SSA - 2
Tech-3
LA - 3

DATA (SSO II)

Bulletin

SSA - 4
JSA - 6
LA - 2

Programme (SSO II)

SSA 2

JSA 2 (data cards)

SSA - 1 Electronics
LA - 1

Collection, Scrutiny supply of observation

Record & Scrutiny

SSA -1
JSA - 2
Daftary- 1
Peon - 1

Supply

SSA - 1
JSA - 2
Daftary- 1
Peon - 1

ANNEXURE - III

ROLE OF UNIVERSITIES IN SEISMOLOGICAL RESEARCH

Universities can provide considerable impetus to Seismological Research in the country by

(a) Offering for graduates in Physics and Mathematics an integrated course in experimental and theoretical seismology at the post graduate level in Geophysics. It should include adequate field work arranged in co-operation with appropriate agencies viz. GSI, ONGC, agency in charge of Deep Seismic Sounding Schemes. The course should be so arranged as to bring out the inter relationship among the various branches of Geophysics, viz. geology, seismology, geomagnetism, geothermy, geoelectricity, isostasy, geochemistry and highlight their economic significance. The syllabus should aim at providing adequate competence in the various aspects of mathematics, mathematical physics and computer programming, which is an essential prerequisite for undertaking independent research in modern seismology. Emphasis should be on providing independent capability for formulating real earth problems in rigorous mathematical frame work and solving them.

b) By maintaining constant interaction with governmental centres engaged in seismic data acquisition and dissemination. This would help in identifying areas of competence in special fields and thereby exploiting them through suitable financial arrangements and exchange of ideas.

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c) By becoming increasingly aware of the scope and potential of seismological research and its practical importance. It would be very useful to keep close track of the various developments in the country with regard to seismic data acquisition, computer facilities, as well as the basic objectives of national research by encouraging specialists from government research centres to give courses and lectures on subjects of current interest.

d) By developing a realistic appreciation of the limitation of data resources and reduction facilities within the country so as to be able to choose research projects which are viable and likely to yield definite results within reasonable periods of time.

e) By promoting constant interaction among researchers in various universities and public undertakings possibly through suitable forums such as refresher courses and summer schools.

f) By associating teachers during the vacation season with the research centres in seismology, and the main observatory centres.

g) By introducing research fellowships with financial support from national centres of seismological research in order to accept research assignments on contract basis.

Considerable progress in University participation in Seismological research, especially on real earth problems, could ensue from the establishment of a national depository

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of all available global seismic records in microfilm form. To ensure maximum effectiveness, this centre should be centrally-situated, geographically with reference to all the major universities and properly staffed and equipped.

APPENDIX VI

A NOTE ON THE CRITERIA ADOPTED FOR THE PLANNING OF A NATIONAL SEISMOLOGICAL NETWORK FOR INDIA

By

V.S. Krishnaswamy
Director
Engineering Geology Division
Geological Survey of India
(November, 1971)

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I. INTRODUCTION

At the dawn of Independence, there were only about six seismological stations in the country. In 1971, the national seismological network built up by the India Meteorological Department during the course of two decades and a half, had 19 stations. Besides the above, 4 stations were run by Organisations other than the India Meteorological Department, as follows:- One at Hyderabad run by the N.G.R.I.; one at Gouribidanur run by the B.A.R.C.; one at Howrah run by the Bengal Engineering College and one at Tocklai in Assam run in co-operation with the I.M.D. In 1971, the I.M.D. had also proposed, for execution in the next few years, 11 more stations, thus making a total of 34 stations in the existing and planned network, of which the four stations at Delhi, Shillong, Kodaikanal and Poona also formed part of the International Teleseismic Network.

2. In addition to the existing national network of 23 stations and the proposed addition of 11 stations in 1971, certain River Valley Projects had helped to create short-distance local networks for evaluating the problems of seismicity of particular areas involved in the development of these Projects. In 1971,

(Contd. 2/-)

the River Valley Project network consisted of 19 stations, of which 11 in the Northern Region were established with the help of the India Meteorological Department, while 8 in the Central and Southern Regions were set-up with the help of the C.W. & P.R.S., Poona. The list of stations in the National Network and the River Valley Project Network is given in Annexure I and II.

3. When the Committee of the Planning Commission was entrusted with the study of the long-term objectives of the research and development in the field of seismology in November, 1970 it was felt that the existing national network was quite inadequate for reaching these objectives, considering the size of the country; the status of seismic activity, which is fairly high in certain zones; and the distribution of seismological stations with reference to the different tectonic units and principal faults. Therefore, the geological member of the Committee prepared in March, '71, a sample network for the Northern Region, taking into account the tectonics of the area. The Committee then decided that a similar network should be prepared for the other Regions as well. This was presented in the second meeting of the committee held in July, 1971 and was finalised along with the seismological member of the Committee, Shri H.M. Chowdhury.

II. CRITERIA ADOPTED

4. The first criterion adopted in laying out a minimum national network was to ensure that there was an adequate coverage of the different tectonic units I to V and the roughly corresponding seismic zones of India V to I with decreasing seismic

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magnitude and frequency as listed below:-

Unit I Seismic Zones IV & V	Orogenic Unit with Himalayan-Naga-Lushai folding and faulting of the Tertiary and Quaternary periods. The Shillong massif, which has been greatly affected by the Himalayan orogeny is also included under this Unit.
Unit II Seismic Zones III & IV	Himalayan foredeep and marginal depression, covering parts of the Indo-Gangetic Basin and parts of Gujarat, Kutch and Maharashtra.
Unit III Seismic Zone III	Peninsular Shield with special seismogenic zones involved in Tertiary/Quaternary movements (E.g. West Coast Zone; Narmada Rift Zone; Tapti Rift Zone and their extensions).
Unit IV Seismic Zones III & II	Peninsular shield with Mesozoic faults (E.g. Gondwana rifts) and platform cover of Mesozoic-Cainozic formations.
Unit V Seismic Zone I	Generally aseismogenic parts of Peninsular shield with ancient faults and localised centres of past earthquake activity.

5. The existing national network of 19 plus 4 seismological stations, operated by the India Meteorological Department, and other Organisations (omitting the River Valley Project network as well as the 11 stations proposed by the I.M.D. in 1971, can be distributed as follows amongst the 5 tectonic units and the corresponding seismic zones as mentioned above:-

(1) Himalayan Orogenic Unit (Zones V & IV):

Bhakra, Chatra, Dehra Dun, Delhi, Bhainsalotan, Shillong, Agartala, Imphal, Dibrugarh, Srinagar, Tura and Tocklai
(Total: 12 : Existing 6)

(2) Foredeep and Marginal Depression Unit (Zones IV & III):
Broach, Port Blair, Bhuj (Total: 3 : Existing: 2)

(3) Shield Unit with Tertiary/Quaternary Seismogenic Zones (Zone III):
Bombay, Goa, Calcutta, Howrah, Bokaro, Karad, Poona, Trivandrum, Mangalore, Minicoy (Total: 10 : Existing: 8)

(4) Shield unit with Mesozoic fault zones and younger platform cover (Zone II):
Varanasi, Bhopal (Sehore), Madras, Visakhapatnam
(Total: 4 : Existing: 4)

(Contd...4)

(5) Shield Unit with ancient fault zones (Zone I):

Kodaikanal, Ajmer, Bilaspur, Hyderabad, Gouribidanur (Bangalore).

(Total: 5 : Existing : 3)

(Note: In the above list, the existing stations have been underlined)

6. It will be seen from the above distribution of the existing and planned seismological stations by the India Meteorological Department and other Organisations, that the tectonic Units I and II, which largely encompass the high seismic zones V and IV, and which account for nearly 90% of the earthquakes occuring in India, have an inadequate coverage of only 8 stations out of 23 existing stations. According to the first criterion adopted, therefore, more stations were distributed in these two tectonic units, so as to gain a fuller picture of the status of seismicity of these tectonic units. Thus, in the proposed network shown on the plate, the stations covering these two units have been increased to nearly 40.

7. The occurrence of the Koyna earthquake of 1967, which lay in tectonic unit III as listed above, has emphasised the need for adding more stations in this unit, so as to gain a better knowledge of the activity of the faults and shear zones which are known to exist within this unit, but whose status of seismic activity was either not known or not fully definable with the available network. This lacuna in the existing/planned network has been proposed to be remedied by providing 35 stations in the tectonic Unit III as against the 8 stations as existing now.

8. Even in the last two tectonic units IV and V, earthquakes of fairly high magnitude (6 to 6.5) had occurred at large

intervals of time as, for example, the Bellary and the Coimbatore earthquakes, which took place in the later part of the 19th Century and the early part of the 20th Century. No knowledge exists on the cause of these earthquakes. Also, Prof. I.B. Gubin's recent evaluation of the seismicity of Peninsular India (vide Publication by C.W. & P.C., 1970) has led him to the postulation of specific zones of Tertiary/ Quaternary activity in the southern part of the Peninsular triangle. It was, therefore, felt advisable to add more stations to the available network in these two units, so as to obtain quantitative evidence on the postulations made by Prof. Gubin, mostly on grounds of geomorphology and stray seismological occurrences although the published Tectonic Maps of the country do not portray all the faults postulated by him. Therefore, for the tectonic Unit IV, it is proposed to provide 14 stations as against 4 existing now.

9. In the last tectonic Unit V, which is of the lowest seismic status as interpreted so far in seismo-tectonic studies, 13 stations have been provided as against 4 as existing now.

10. The second criterion followed by the Committee was to provide a national network of stations roughly 80 kms (or 50 miles) apart. Although this was a desirable objective, on practical considerations, this objective had to be abandoned, because, with the total coverage of the Indian Union of 3.268 million sq. kms. and that of Sikkim and Bhutan accounting for another 0.47 million sq. kms., the total number of stations required on the above basis was worked out to be nearly 500 stations. Hence, after apportioning additional stations to

(Contd....6/-)

each tectonic unit, for satisfying the future requirements for regional studies, the network was reviewed with a view to satisfy the need of local studies of all the known major faults, as well as to furnish much of the required data for the studies of the River Valley Projects, and special research problems; this network showed the requirement to be 350 stations. Of these, about 100 stations were required for regional studies of the different tectonic units; 100 stations for the special studies of major fault features in the different tectonic units; 100 stations for the studies required in connection with the planning and design of various River Valley Projects, the balance of 50 stations being reserved for academic studies on a long-term basis. The above network of 350 stations was intended to cover a period of 25-30 years of seismological research and development in the country.

11. After the discussions on this network, held during the second meeting of the Committee in July, 1971, it was decided that it may not be practical to plan for a 25-30 year programme, involving 350 stations, so as to be able to satisfy all the future requirements on different aspects of seismology and seismo-tectonics. Hence, a minimum national network of about 103 stations (including the existing stations) was accepted as being absolutely necessary for execution in the next 10-15 years, so as to permit the regional studies of the various tectonic units as well as limited appraisals of the major faults and areas of past earthquake activity. In addition a suitable number of mobile station may be required for studying after shocks and micro regionalisation studies.

(Contd....7/-)

12. Such a network of 103 stations, covering adequate all the five tectonic units listed above, the principle faults as portrayed in the latest Tectonic Map of India of 1970 and the different seismic zones as put forward by the I.S.I. Committee, has been furnished in the accompanying plate. The national or regional network of 103 stations, which includes the roughly 23 stations as existing now, has been proposed for full development in the course of the next 10 to 15 years 1971-1986. In Annexure-I, the names of all the proposed and existing stations, abbreviated where necessary have been listed along with their geotectonic setting. In Annexure-III, the suggested priority for development of these stations has been indicated, the 1st priority of 40 additional stations covering the period 1971-'80 and the remaining 40 stations being taken up during the period 1981-'86. It will be seen that the 103-station regional network, spreading over the total area of Indian Union-Sikkim and Bhutan (3.738 million sq. kms.) roughly covers individually an area of some 37,000 sq. kms. and thus gives an average network distance between stations of about 195 kms (or little over 120 miles) although the minimum and maximum distance . separating the stations is lesser or greater than this average figure.

13. It must be stressed that some of the locations proposed, particularly in the coastal areas, are tentative. Thus, the actual site reconnaissance, bearing in mind the need for getting good seismological records as well as the availability of site amenities for a modern observatory, may favour the choice of sites farther away from the coast than what has

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provisionally been indicated. All these factors of local geological setting and requirements for effectively and speedily operating the seismological stations will have to be considered when the reconnaissance of the various sites is taken up before the final selection.

III. RIVER VALLEY PROJECT NETWORK

14. Due to the scale of the attached map (1:6,000,000) it has not been possible to plot all the existing local River Valley Project network for the Beas, Ramganga, Ganga-Bhagirathi and Yamuna Projects in the Northern Region and for the Koyna Project in the Central Region, which are being operated by the Indian Meteorological Department and the Central Water and Power Research Station, Poona. It has also not been possible to spell out the likely requirements of all the River Valley Projects in the course of the next 15 years, in the absence of location coordinates of the Project sites, except in the case of the Northern Region Projects, where these locations have already been arrived at by mutual consultations between the Project authorities, the Geological Survey of India and the India Meteorological Department and, in the case of the Central Region Projects, where the local network for the Koyna Project has been designed by the Central Water & Power Research Station, Poona, in consultations with the Project authorities.

15. The likely River Valley Project network for the future has been given in the Annexure II to this note, wherein an overall provision has been made for the number of stations likely to be required for the various River Valley Projects,

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the absence of specific data on their actual locations. It is felt that in addition to the 80 new stations in the National network as proposed now, the local network for River Valley Projects should be separately considered and the spacing of these stations should take into account the location and distribution of the important fault features in the vicinity of the Project area and the locations of the medium and minor earthquakes that had taken place in the Project area in the recent years.

16. The financing of the River Valley Project network was also discussed during the second meeting of the Committee held, in July, 1971 and the consensus of opinion was that the required network of observatories for each Project could be financed by the Project authorities in the beginning and operated by them for a few years with the help of the proposed Seismological Institute while, later on, these could be handed over to the Central Institute of Seismology, which would continue their operation, if found necessary for purposes of seismological research or other special studies.

17. It was also felt that the Irrigation, Power Ministry should set apart a portion of the funds allocated to the different Projects for setting up the required Seismological Observatories, as a part of the programme of investigations and surveys, a few years before the Project is approved, as, otherwise after the sanction of the Project, the very purpose of the establishment of the observatories would be lost, chiefly because the data required for the design of the Project do not become available in time.

(Contd...10/-)

18. The proposed network of the river valley Project consists of some 92 stations, as per Annexure II. Of the 19 existing stations, 11 stations are already at the Northern Region Himalayan Project-sites; 7 stations at the Koyna Project and one station at the Idikki Project. It will be seen that for a large number of the remaining major River Valley Projects in the country there is no adequate local network. The proposed additional number of some 73 stations is expected to largely meet the special requirement of all the River Valley Projects that could be envisaged in the next 10 to 15 years of developmental activity in the country.

IV. COST OF IMPLEMENTATION OF THE NATIONAL & RIVER VALLEY PROJECT SEISMOLOGICAL NETWORKS:

19. As the data available from the 103-station National Network (with 80 additional stations and 23 existing stations) could also be utilised for the broad planning of the River Valley Projects in terms of seismicity of the particular tectonic unit in question, the cost involved in establishing the 100 observatories in terms of the total cost of the Projects is worth examination. A preliminary examination of this question by the Committee has indicated that this would form a very small proportion of the total cost of the Projects that are likely to come up in the next decade of development activity in the country.

20. In this connection, the geological member of the Committee made a perusal of the two brochures on the Perspective Plan for the Development of Irrigation and Power Projects in the decade 1971-1981 put out by the Central, Water & Power

(Contd....11/-)

Commission in May, 1971, and these have supplied useful data. The cited brochures on the decade of development 1971-1981, indicate an investment of some 3,000 crores in order to create an additional potential of 20 million acres and an additional power generating capacity of 29 million Kws, which, even at a minimum cost of 1000 rupees per Kw of installed capacity, would cost about 2,900 acres. Thus, a total investment of nearly 5,900 crores is envisaged on Irrigation and Power Projects planned for the decade 1971-1981.

21. The experience gained so far in the construction and maintenance of seismological stations in the country has indicated that each station will require a capital expenditure of one lakh (non-recurring) and 0.20 lakhs recurring expenditure per observatory per year. Thus, for creating a national network of 103 stations over the next 15 years, the total capital expenditure would be about one crore and the recurring expenditure on all the stations would be of the order of 20 lakhs every year, and for the next 15 years or so, this would aggregate to 3 crores. Even if we include the cost of the

92 additional stations proposed for the River Valley Project network, the total cost is not likely to exceed 9 crores. This amount is only 0.10 -0.20 per cent of the total expenditure of some 6000 crores proposed to be spent on the Irrigation Power Projects in the next decade.

22. If only a total of 100 stations, combining 80 stations of the National network as well as 20 stations of the River Valley Project network is considered as being feasible of

(Contd.....12/-)

implementation during the next 10 years, the cost involved will be 0.05 to 0.10 per cent of the total cost of all the Projects. Since 1 to 2% of the total cost of River Valley Projects is the generally accepted norm for expenditure on all investigations and surveys for planning and design, an investment of 0.05 to 0.10 per cent on seismological studies would seem to be well justified, taking into account to economies possible in the design of the River Valley Projects with the data available from the seismological network and the assurance with which a safe design in terms of seismicity can be worked out. The data obtained from the proposed net-work will also lead to a rational approach to a satisfactory and safe design of the River Valley Projects, instead of a largely empirical approach as obtaining now, which is based largely upon the judgment of individuals, which can either be over-conservative or over-optimistic, depending upon the available data and the extent of judgment exercised in a seismic design.

V. RECOMMENDATIONS

23. The objectives of a 103 station national net-work should be achieved during the period 1971 to 1986. At present there are only 23 stations in existence and therefore an additional 80 stations will be required to be added during this period. The priorities are laid down in Annexure III of Appendix VI. Among these about 6 to 8 observatories may be instrumented as teleseismic stations for serving national and international needs. In addition a suitable number of mobile stations may be required for studying after-shocks and micro-regionalisation studies.

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24. There are at present only 19 seismological stations connected with investigations of river valley projects. Considering the river valley projects already approved or likely to be implemented during the period 1971-86, a net work of 92 stations would be necessary. This implies an addition of 73 more stations to the existing stations associated with river valley projects. Priorities for this expansion are laid down in Annexure IV of Appendix VI.

ANNEXURE-1

I. REGIONAL SEISMOLOGICAL NETWORK

List of existing and planned stations and stations proposed by the Committee of the Planning Commission:

A. NORTHERN REGION

(J & K, Punjab, H.P., Haryana & Delhi)

Name of Station	Geotectonic setting	Abbreviation on Map
A.1. Existing:		
1) Bhakra	Himalaya	BHK
2) Dehra Dun	Himalaya	DDN
@ 3) Delhi	Peninsula	DLH
4) Allahabad (Varanasi)	Peninsula	ALH
A.2. Planned:		
1) Srinagar	Himalaya	SRG
A.3. Proposed by the Committee:		
1) Leh	Himalaya	LEH
2) Kargil	Himalaya	KRG
3) Lahaul	Himalaya	LHL
4) Rampur	Himalaya	RMP
5) Pithoragarh	Himalaya	PTH
6) Badrinath	Himalaya	BDR
7) Pilibhit	Himalaya	PLB
8) Bahraiah (Nampara)	Himalaya	BHR
9) Amritsar	Peninsula	AMS
10) Etah	Peninsula	ETH
11) Jhansi	Peninsula	JHS
12) Lucknow	Peninsula	LCK

Total for Northern Region: 17

Existing: 4; Planned: 1; Proposed: 12;
Out of total 17 stations, Himalayan: 11 & Peninsular: 6 stations.

B. EASTERN REGION

(Bihar, Bengal, Assam, NEFA, Nagaland, Manipur, Tripura, Andaman-Nicobar Islands & Orissa).

B.1. Existing:		
1) Calcutta	Peninsula	CAL
2) Bokaro	Peninsula	BKR
3) Chatra	Himalaya	CHT
@ 4) Shillong	Himalaya	SHL

(Contd....2/-)

5) Port Blair (A & N Islands)	Himalaya	PBL.
6) Howrah+	Peninsula	HWH
7) Tocklai+	Himalaya	TCK

B.2. Planned:

1. Lekhpani (Dibrugarh)	Himalaya	DBH
2. Imphal	Himalaya	IMP.
3. Agartala	Himalaya	AGT
4. Tura	Himalaya	TRA
5. Bhainsa Lotan	Himalaya	BHL

B.3. Proposed by Committee:

1. Patna	Peninsula	PTN
2. Daltongang	Peninsula	DLT
3. Purnea	Peninsula	PHN
4. Alipur Duar	Himalaya	ALD
5. Dumka	Peninsula	DMK
6. Balurghat	Peninsula	BLR
7. Darjeeling	Himalaya	DLG
8. Gauhati	Himalaya	GHT
9. Jorhat	Himalaya	JHT
10. Silchar	Himalaya	SLC
11. Walang	Himalaya	WLG
12. Zero	Himalaya	ZRO
13. Tuensang	Himalaya	TSG
14. Khela	Himalaya	KHL
15. Aijal	Himalaya	AJL
16. Newgang	Himalaya	NNG
17. Thimpur	Himalaya	TPU
18. Kohima	Himalaya	KMA
19. Bondila	Himalaya	BMD
20. Rourkela	Peninsula	RKL
21. Bhubaneshwar	Peninsula	BNS
22. Midnapore	Peninsula	MDP
23. Raygada	Peninsula	RYG
24. Kondul (A.&N. Islands)	Himalaya	KNDL

Total for Eastern Region: 36
Existing:7; Planned:5; Proposed:24.
Out of total 36 stations Himalayan stations: 23;
Peninsular stations: 13.

C. SOUTHERN REGION

C.1. Existing

1. Visakhapatnam	Peninsula	VSK
* 2. Hyderabad	Peninsula	HBD
3. Madras	Peninsula	MAS
@4. Kodaikanal	Peninsula	KDK
5. Trivandrum	Peninsula	TKM
*6. Gauribidanur (Bangalore)	Peninsula	GBD
7. Panjim (Goa)	Peninsula	PNM

(Contd.....3/-)

C.2. Planned

1) Mangalore	Peninsula	MGL
2) Miniccy (L & M Islands)	Peninsula	MNC

C.3. Proposed by Committee.

1) Malkangiri	Peninsula	MLG
2) Guntur	Peninsula	GNT
3) Nellore	Peninsula	NLN
4) Vellore	Peninsula	VLE
5) Mayavaram	Peninsula	MYR
6) Rajapalayam	Peninsula	RJP
7) Karaikudi	Peninsula	KRK
8) Salem	Peninsula	SLM
9) Coimbatore	Peninsula	CMB
10) Ernakulam	Peninsula	ERN
11) Calicut	Peninsula	CLT
12) Hubli	Peninsula	HBL
13) Gulbarga	Peninsula	GLB
14) Bellary	Peninsula	BLY
15) Amindivi (L&M Islands)	Peninsula	AMN

*Note: The existing stations at Hyderabad & Gauribidanur are operated by the N.G.R.I. and B.A.R.C.

Total for Southern Region: 24: Existing: 7, Planned:2, Proposed: 15, all peninsular stations.

D. CENTRAL REGION
(Maharashtra & Madhya Pradesh)

D.1 Existing

1) Bhopal (Sehore)	Peninsula	BPL
2) Bombay	Peninsula	BMY
@ 3) Poona	Peninsula	PNA
4) Karad	Peninsula	KRD

D.2.Planned:

1) Bhilaspur	Peninsula	BLS

D.3. Proposed

1) Jabalpur	Peninsula	JBL
2) Sironcha	Peninsula	SRC
3) Nagpur	Peninsula	NGP
4) Akola	Peninsula	AKL
5) Betul	Peninsula	BTL
6) Sanawad	Peninsula	SNW
7) Jalgaon	Peninsula	JLG

@ Existing teleseismic stations serving national and international needs.

(Contd....4/-)

8) Kolhapur	Peninsula	KLP
9) Ratnagiri	Peninsula	RTN
10) Nasik	Peninsula	NSK

Total for Central Region: 15:
Existing: 4: Planned: 1; Proposed: 10.

E. WESTERN REGION (Rajasthan & Gujarat)

E.1. Existing

1) Broach	Peninsula	BRC

E.2. Planned

1) Ajmer	Peninsula	AJM
2) Bhuj	Peninsula	BHJ

E.3. Proposed

1) Udaipur	Peninsula	UPR
2) Jaisalmer	Peninsula	JSM
3) Kota	Peninsula	KTA
4) Ahmedabad	Peninsula	AMBD
5) Varawal	Peninsula	VVL
6) Rajkot	Peninsula	RKT
7) Rajpipla	Peninsula	RJP

Total for Western Region:10 Existing: 1,
Planned: 2; Proposed: 7.

Abstract of existing, planned and proposed seismological stations of the Regional Network:

Region	No. of Stations			
	Existing.	Planned	Proposed.	Total. Each Region.
A. Northern	4	1	12	17
B. Eastern	7	5	24	36
C. Southern	7	2	15	24
D. Central	4	1	10	15
E. Western	1	2	7	10
Total for all Regions:	23	11	68	102

ANNEXURE II

RIVER VALLEY PROJECT NETWORK

List of existing planned stations and station proposed by the Committee of the Planning Commission

A. NORTHERN REGION

A.1. Chenab Valley Hydel Projects, J & K State.
A.2. Proposed Stations.

1) Anantnag (East) 2) Bhadarwah; 3) Dhiangarh;
4) Jammu; 5) Kishtwar; 6) Ramban;
7) Riasi; 8) Sawalkot 9) Udhampur.

A.2. Ravi Valley Hydel Projects, P. & H.P.
A.2.2. Proposed stations

1) Thein

A.3. Beas Valley Project: Unit I & II: H.P.
A.3.1. Existing stations.

1) Dalhousie 2) Ghaggar; 3) Jwalamukhi 4) Mukerian;
5) Nurpur; 6) Pong; 7) Sundernagar.

A.3.2. Proposed stations

1) Dharmasala; 2) Kulu 3) Simla.

A.4. Ramganga Project:
A.4.1. Existing stations:

1) Kalagarh.

A.5. Sarda Valley Projects
A.5.2. Proposed stations

1) Lohaghat; 2) Ranikhet; 3) Tenjam.

A.6. Giri Hydel Project
A.6.2. Proposed stations.

1) Nahan.

A.7. Ganga-Bhagirathi Valley Hydel Projects.
A.7.1. Existing stations.
1) Narendranagar; 2) Rudraprayag; 3) Tehri.

A.7.2. Proposed Stations
1) Barkot; 2) Gupta-Kasni; 3) Harsil; 4) Joshimath.

A.8. Yamuna Valley Hydel Projects.
A.8.1. Proposed stations.
1) Kalawar; 2) Kishau; 3) Maneri; 4) Tuini.

(Contd.....2/-)

Total for Northern Regior River Valley Projects:

Existing: 11; Proposed: 25; Total: 36.

B. EASTERN REGION

B.1. Upper Brahmaputra, Dibing & Subasiri Projects.
B.1.2. Proposed Stations

Six Stations proposed; locations to be defined.

B.2. W. Bengal Projects:

Three stations proposed; locations to be defined.

B.3. Balimela & Machkund Projects: Orissa:

Three stations proposed; locations to be defined.

Total for Eastern Region River Valley Projects:

Existing: Nil; Proposed: 12.

C. SOUTHERN REGION

C.1. Godavari Valley Hydel Projects, A.P.

Three stations proposed at i) Bhadrachalam; 2) Singareni and 3) Venkatapur, in order to define the status of activity of the Godavari Valley fault which caused the Bhadrachalam Earthquake of 1970.

C.2. Nagarjunasagar - Srisailam Hydel Projects, A.P.

Three stations proposed: 1 & 2) Srisailam & Nagarjunasagar Dam sites; 3) at Kurnool.

C.3. Nilgiri Hydel Projects, Tamil Nadu.

Three stations proposed: locations to be defined.

C.4. Periyar Valley Hydel Projects:

Six Stations proposed by G.S.I. for Idamalayar Project and for evaluating seismicity of Western Ghat Projects.

C.5. Idikki Hydel Projects:

Existing: Idikki Dam site.
Proposed: Five stations proposed by C.W.P.R.S.; locations to be defined.

C.6. Kalinadi Hydel Projects:

Three stations proposed by Geological Survey of India.

Total for Southern Region River Valley Projects:
Existing: 1; Proposed: 24; Total: 25.

(Contd.....3/-)

D. CENTRAL REGION

D.1. Koyna Hydel Project.

D.1.1. Existing stations: 1) Koyna Dam; 2) Pophali; 3) Alore; 4) Covalkot; 5) Satara; 6) Mahabaleshwar; 7) Khadakwasla, (All manned by C.W.P.R.S., Poona)

D.2. Narmada Valley Projects:

Three stations proposed: locations to be defined.

D.3. Tapi Valley Projects:

Three stations proposed; location to be defined.

Total for Central Region River Valley Projects:

Existing: 7, Proposed: 6; Total: 13.

E. WESTERN REGION

E.1. Mahi Hydel Project, Rajasthan.

Three stations proposed; locations to be defined.

E.2. Kadana and other projects in Gujarat:

Three stations proposed; locations to be defined.

Total for Western Region River Valley Projects:

Existing: nil; Proposed: 6; Total: 6

Abstract of Planned and Proposed stations
for
River Valley Projects.

Region	Existing stations.	Proposed stations.	Total for Region.
A. Northern	11	25	36
B. Eastern	0	12	12
C. Southern	1	24	25
D. Central	7	6	13
E. Western	0	6	6
Total for all regions:	19	73	92

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ANNEXURE III

Distribution of National Seismological Network in terms of seismic zones and suggested priority for installation

Note:- Existing stations have been underlined

Seismic Zones & Total No. of stations	List of first priority stations 1971-80 and abbreviations	List of second priority stations: 1981-86; and abbreviations.
IV & V	1) Srinagar ... SRG	1) Kargil..... KRG
TOTAL: 40	2) Leh ... LEH	2) Lahaul .... LHL
Existing:7	3) Amritsar ... AMS	3) Rampur .... RMP
To be added:33	4) Bhakra ... BHK	4) Purnea ... PNR
	5) Delhi ... DLH	5) Balurghat.. BLR
	6) Dehra Dun.. DDN	6) Thimpu .... TPU
	7) Badrinath ... BDR	7) Zero .... ZRO
	8) Pithargarh ... PTH	8) Khela ... KHL
	9) Pilibhit ... PBT	9) Tuensang ... TSG
	10) Bahraich .... BHR	10) Alipur Duar.. ALD
	11) Bainsalotan .. BHL	11) Gauhati .... GHT
	12) Patna ... PTN	12) Kohima .... KMA
	13) Chatra ... CHT	13) Silchar .... SLC
	14) Bomdila ... BMD	14) Aijal .... AJL
	15) Walang ... WNG	15) Kondul .... KNDL
	16) Dibrugarh ... DBA (Lehpari)	Total : 15
	17) Tocklai ... TCK	Existing : Nil
	18) Jorhat ... JHT	Additional } 15
	19) Darjeeling ... DLG	IInd Phase: }
	20) Tura ... TRA	
	21) Shillong ... SLG	
	22) Imphal .... IMP	
	23) Agartala .... AGT	
	24) Bhuj .... BHJ	
	25) Port Blair ... PBL	
	Total : 25	
	Existing : 7	
	Additional } : 18	
	Ist Phase }	

Zone III

Total: 36	1) Lucknow .. LCK	1) Etah .... ETH
Existing: 9	2) Dumka .. DMK	2) Midnapore .. MDP
To be added: 27	3) Calcutta .. CAL	3) Betul .. BTL
	4) Howrah .. HWH	4) Jalgaon .. JLG
	5) Bokaro .. BKR	5) Nasik .. NSK
	6) Bhubaneshwar.. BNS	6) Rajpipla .. RJP
	7) Jubbulpore .. JBL	7) Rajkot .. RKT
	8) Sonawad .. SNW	8) Kolhapur .. KLP
	9) Akola .. AKL	9) Calicut .. CLT
	10) Broach .. BRC	10) Ernakulam .. ERN

(Contd.... 2/-)

Seismic Zones & Total No. of stations.	List of first priority stations 1971-80; and abbreviations.	List of second priority stations: 1981-86; and abbreviations
	11)Ahmedabad .. AMBD	11) Sironcha --SRC
	12)Jaisalmer .. JSM	12) Amin Divi..AMN
	13)Veraval .. VVL	
	14)Bombay .. BMY	Total: 12
	15)Poona .. PNA	Existing: Nil
	16)Panjim .. PNM (Goa)	Additional IInd Phase: 12
	17) Karad .. KRD	
	18)Ratnagiri.. RNG	
	19)Mangalore .. MGL	
	20)Coimbatore.. CMB	
	21)Trivandrum.. TVM	
	22) Guntur .. GNT	
	23) Sironcha .. SRC	
	24) Minicoy .. MNC	
	Total: 24	
	Existing : 9	
	Additional Ist Phase 15	
Zone II	1)Allahabad ... AIN (Varanasi)	1)Daltonganj...DLT
Total : 14	2) Bhopal ... BPL (Sehore)	2)Nellore ...NLN
Existing : 4	3)Udaipur ... UPR	3)Vellore ...VLE
To be added: 10	4)Nagpur ... NGP	4)Mayavaram ...MYR
	5)Madras ... MAS	5)Karaikudi ...KDI
	6) Salem ... SLM	6)Karaikal ...KRK
	7)Vishakapatnam..VSK	7)Rajapalayam...RJP
	Total: 7	Total: 7
	Existing: 4	Existing: Nil
	Additional Ist Phase 3	Additional IInd Phase 7
Zone I	1)Hyderabad ... HBD	1) Bellary ... BLY
	2)Gauribidanur..GHD (Bangalore)	2) Gulbarga ...GLB
Total: 13	3)Hubli ...HBL	3) Raygada ...RYG
Existing: 3	4)Kodaikanal ...KDK	4)Malkangiri...MLG
To be added: 10	5)Rourkela ... RKL	5)Jhansi ...JHS
	6)Bilaspur ... BLS	6)Kota ...KTA
	7)Ajmer ... AJM	
	Total: 7	Total : 6
	Existing: 3	Existing : Nil
	Additional Ist Phase 4	Additional IInd Phase

(Contd....3/-)

ABSTRACT OF THE PHASED PROGRAMME OF INSTALLATION OF NATIONAL SEISMOLOGICAL NETWORK

Seismic Zones.	Ist Phase 1971-1980		IInd Phase 1981-86	For each Zone		
	Existing	To be added	To be added	Existing.	To be added (both phases)	Total
V & IV	7	18	15	7	33	40
III	9	15	12	9	27	36
II	4	3	7	4	10	14
I	3	4	6	3	10	13
Total for all Zones:	23	40	40	23	80	103

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ANNEXURE IV

PROVISIONAL PRIORITY FOR INSTALLATION OF RIVER VALLEY PROJECT NETWORK

River Valley/ Project.	Existing	Proposed under priority I (1971-1980)	Proposed under Priority II (1981-1986).
NORTHERN REGION			
Chenab J & K.	Nil	1) Kishtwar 2) Sawalkot 3) Dhaingarh	1) Anantnag (East) 2) Jammu 3) Riasi 4) Bhadarwah 5) Ramban 6) Udhampur
Ravi, Punjab.	NIL	4) Thein	NIL
Beas	1) Dalhousie 2) Ghaggar 3) Jwalamukhi 4) Mukerian 5) Nurpur 6) Pong 7) Sundernagar.	5) Dharamsala 6) Kulu 7) Simla	NIL
Ramganga	8) Kalagarh	NIL	NIL
Sarda	NIL	8) Lohaghat	7) Ranikhet 8) Tejam
Giri	NIL	9) Nahan	NIL
Ganga-Bhagirathi.	9) Narendranagar 10) Rudraprayag 11) Tehri.	10) Harsel	9) Barket 10) Gupta-kashi 11) Joshimath.
Yamuna	Nil	11) Kalawar 12) Kishau 13) Maneri.	12) Tuini
EASTERN REGION Brahmaputra & tributaries.	NIL	14 to 16 Three stations.	13 to 15 Three stations.
West Bengal	NIL	NIL	16 to 18 Three station
Balimela & Machkund.	NIL	17) Balimela dam site.	19 to 20 Two stations.
SOUTHERN REGION Godavari.	NIL	18) Bhadrachalam 19) Venkatapur.	21) Singareni.
Nagarjunasagar-Srisailam.	NIL	20) Srisailam 21) Nagarjunasagar.	22) Kurnool.

(Contd....2/-)

River Valley/Project	Existing	Proposed under Priority I (1971-1980)	Proposed under Priority II (1981-1986)
Nilgiris	NIL	NIL	23 to 25 Three stations.
Periyar	NIL	22 to 24 Three stations.	26 to 28) Three stations.
Idikki	12) Dam-site	25 to 29 Five stations	Nil
Kalinadhi	NIL	30 to 31 Two stations.	29) One station
CENTRAL REGION			
Koyna	13) Dam site 14) Pophali 15) Alore 16) Govalkot 17) Satara 18) Mahabaleshwar 19) Khadakvasla.	NIL	NIL
Narmada	NIL	32) One station	30 to 31 Two stations.
Tapi	NIL	33) One station	32 to 33 Two stations
WESTERN REGION			
Mahi	NIL	NIL	34 to 36 Three station
Kadana & others	NIL	NIL	37 to 40 Four stations.
Total:	19	33	40

APPENDIX VII

STRONG MOTION INSTRUMENT INSTALLATION NET WORK

The teleseismic instruments that shall be installed in the proposed stations in the National Seismological net work would be too sensitive to give the basic earthquake data for engineering requirements. The number of strong motion instruments i.e. accelerographs and structural response recorders is very inadequate considering the size of the country and the number of large earthquakes taking place. At present there are only 7 accelerograph installations along the whole of the Himalayan Seismic belt and only one in Koyna region. Only 56 structural response recorder installations exist in India which also are very inadequate for providing data for design of structures in the respective regions. It is, therefore, recommended that one hundred Strong Motion Accelerographs and 500 Multiple structural Response Recorders need be installed to constitute National Strong Motion Installation network. It would be worth while to mention here that these instruments are now available indigenously (being developed at School of Research and Training in Earthquake Engineering University of Roorkee, Roorkee). The proposed locations listed separately for each seismic zone for accelero-graph installations are given in Table and also marked on the Map enclosed. Some of these proposed locations may have to be changed due to some other considerations to nearby locations later when the net work is being established. More instrument have been proposed to be installed in the regions falling under zone V and IV as more data is likely to come

(Contd...2/-)

from these regions. The Multiple Structural response Recorders need be installed around each of the accelerograph installation as per following distribution:-

Accelerograph installation in Seismic Zone	Proposed number of Multiple SRR around each accelerograph.	Total Number of Multiple SRR installations.
V	Eight	264
IV	Six	180
III	Two	40
II	-	16
	Grand Total:	500

LIST OF PROPOSED STATIONS FOR ACCELEROGRAPH INSTALLATIONS

STATIONS FALLING UNDER SEISMIC ZONE - V	STATIONS FALLING UNDER SEISMIC ZONE - IV	STATIONS FALLING UNDER SEISMIC ZONE - III	STATIONS FALLING UNDER SEISMIC ZONE-II	STATIONS FALLING UNDER SEISMIC ZONE-I
1. Gulmarg	34. Kargil	64. Bhatinda	84. Ganganagar	95. Kota
2. Srinagar	35. Sonamarg	65. Hissar	85. Jaipur	96. Jhansi
3. Kangra	36. Pahalgam	66. Bikaner	86. Gwalior	97. Aurangabad.
4. Rampur	37. Anantnag	67. Jaisalmer	87. Udaipur	98. Hyderabad.
5. Chamoli	38. Leh	68. Mathura	88. Bhopal	
6. Lakhpat	39. Keylong	69. Shahjahanpur.		
7. Sitamarhi	40. Amritsar	70. Lucknow	89. Allahabad	99. Bilaspur
8. Bhuj	41. Pithoragarh	71. Rajkot	90. Ambikapur	100. Rourkela
9. Darbhanga	42. Dehradun	72. Ahmedabad	91. Nagpur	
10. Chatra	43. Ambala	73. Varanasi	92. Kodaikanal	
11. Goalpara	44. Nainital	74. Jabalpur	93. Madras	
12. Tura	45. Moradabad	75. Broach	94. Vishakhapatnam.	
13. Cherapunji	46. Meerut	76. Bombay		
14. Shillong	47. Delhi	77. Panaji		
15. Gauhati	48. Rohtak	78. Calicut		
16. Nowgong	49. Lakhimpur Kheri	79. Trivandrum		
17. Tezpur	50. Bahraich	80. Bellary		
18. Bomdila	51. Gonda	81. Bhubaneswar		
19. Zero	52. Dwarka	82. Bokaro		
20. NorthLakhimpur.	53. Jamnagar	83. Calcutta.		
21. Jorhat	54. Gorakhpur			
22. Lumding	55. Ratnagiri			
23. Silchar	56. Patna			
24. Agartala	57. Motihari			
25. Aijal	58. Monghyr			
26. Imphal	59. Purnea			
27. Kohima	60. Darjeeling			
28. Tuensang	61. Gantok			
29. Khela	62. Thimpu			
30. Dibrugarh	63. Alipur Duar.			
31. Digboi				
32. Teju				
33. Port Blair.				

APPENDIX VIII

INDIAN INSTITUTE OF SEISMOLOGY - FUNCTIONAL CHART

Director - Head of the Institute

Administrative Unit (Administrative Officer of the grade of an Under Secretary.

1. General Administration.
2. Budget & Planning
3. Establishment work.
4. Works & Housing.
5. Cash & Accounts.
6. Deputation.

Consultancy Service Unit (SSO-I)

1. Consultancy service to Govt. Deptt. & public.
2. Consultancy service to River Valley Project.
3. Technical Reports.
4. Technical Enquiries.
5. Annual Reports.

Basic Research Unit (Asstt. Director)

1. Studies of the interior of Earth including crust & Mantle in different
2. Mechanism of Earthquakes.
3. Forecasting of earthquakes.
4. Studies of seismic surface waves.
5. Propagation of seismic waves & preparation of regional travel times.
6. Theoretical seismology.

Applied Seismology (Assistant Director & Instrumentation Unit)

1. Seismicity
2. Mesoscale seismology
3. Explosion seismology
4. Model seismology
5. Microseism.
6. Strong Motion work.
7. Workshop -
8. Development, manufacture and repair of instruments.

Services Unit (Assistant Director)

Observatories Section

1. Maintenance & Inspection.
2. Opening of new observatories.
3. Technical Control.
4. Epicentre determination & press reports.
5. Training.

Data Centre

1. Collection & preservation.
2. Scrutiny of departmental data.
3. Preparation, printing & distribution of seismological bulletins.

Organisation Section

1. International collaboration.
2. Coordination with national & Scientific technical organisation.
3. Ceremonies & function.

Procurement & Supply

1. Maintenance of store.
2. Indent & procurement
3. Supply
4. Loan of instruments.

INDIAN INSTITUTE OF SEISMOLOGY - STAFF A REQUIREMENTS

Units	Director	Asstt. Director.	SSO I	SSO II	SSA	Foreman.	JSA	Mech. Asstt.	UDC	Steno.	Tech-Dini-Mancian.	Mech. gr. I	Mech. LDC	gr. II	Lab. Attdt	Peon	Mazdoor	Chowkidar.	Other Class IV
1. Head of Instt. & His personal	1									1						1			
2. Basic Research Unit		1	4	8	8				1	1			2		3	8			
3. Applied Seismology & Instrumentation Unit.		1	6	25	28	1		2	1	1		1	10	1	10	8	8	8	
4. Service Unit		1								1						1			
i) Observatories Section.			1	3	5		5						2		3	4	1		
ii) Data Centre			1	3	13		16		1		3	3		2		4	4	2	
iii) Organisation Section.			1	1	1		2		1					1		1	2	2	
iv) Procurement & Supply			1	2	2		4		1					1		1	2	2	
5. Observatories																			
i) x 103 regular					20		184								103			103	
ii) 92-River Valley projects.							184								92			92	
6. Consultancy Service Unit.			1	1	2		2							1		1	1		
7. Administrative Unit			1	2	2		4		8	1				4		2	3	4	Mali 2
																			Sweeper 2
																			Farash 3
TOTAL:	1	3	16	45	81	1	401		13	5	3	4	10	14	10	218	34	15	199 7