THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM–SCIENTIFIC STATUS. By Thomas C. Hanks, U.S. Geological Survey Bulletin 1959, 40 pp. 1985. Available for U.S. $ 1.75 from Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402, U.S.A.

Developments in 1975, i.e. the successful scientific prediction of the Heicheng earthquake in China following reports of promising developments in earthquake prediction-related research in USSR, and the occurrence of an earthquake sequence adjacent to the Oroville Dam in California reminding again that people can condition the occurrence of earthquakes by manipulation of water supplies; together with attendant public and political concern culminated in the Earthquake Hazards Reduction Act of 1977. This Act directed the President of U.S.A. to establish a National Earthquake Hazard Reduction Programme (NEHRP) with the following objectives:

(1) The development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant, giving priority to the development of such methods and procedures for nuclear power generating plants, dams, hospitals, schools, public utilities, public safety structures, high-occupancy buildings, and other structures that are especially needed in time of disaster;

(2) The implementation, in all areas of high or moderate seismic risk, of a system (including personnel, technology, and procedures) for predicting damaging earthquakes and for identifying, evaluating, and accurately characterizing seismic hazards;

(3) The development, publication, and promotion, in conjunction with State and local officials and professional organizations, of model codes and other means to coordinate information about seismic risk with landuse policy decisions and building activity;

(4) The development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including methods of controlling the risks from earthquakes, planning to prevent such risks, disseminating warnings of earthquakes, organizing emergency services, and planning for reconstruction and redevelopment after an earthquake;

(5) The education of the public, including State and local officials, as to earthquake phenomena, the identification of locations and structures which are especially susceptible to earthquake damage, ways to reduce the adverse consequences of an earthquake, and related matters;

(6) The development of research on–
   (a) ways to increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards;
   (b) the social, economic, legal, and political consequences of earthquake prediction; and
   (c) ways to assure the availability of earthquake insurance or some functional substitute; and

(7) The development of basic and applied research leading to a better understanding of the control or alteration of seismic phenomena.

The purpose of the document being reviewed, is to examine the scientific status of NEHRP, i.e., to describe and assess the present body of scientific understanding and data bases pertinent to objectives of NEHRP.

Under *Introduction* Thomas Hanks focusses attention on the growing awareness that potentially damaging and destructive earthquakes are a nation-wide problem. A figure depicting locations of earthquakes of modified Mercalli intensity V or greater in USA from colonial times supports this contention. During the 1971 San Fernando earthquake of magnitude 6.6, modern constructions following earthquake resistant design criterion did well. Most of the 58 people killed were due to collapse of two structures built in 1925. However, Hanks observes that (page 1) :

> 'Only luck and a low water level, however, prevented the inundation of 80,000 people living in the flood plain beneath the lower Van Norman Reservoir; the dam itself failed, in any mechanical sense of the word'

and

> 'The San Fernando earthquake itself was a major impetus, focussing attention again on earthquake hazards and the point that luck alone is no sure protection against them'.

Although earthquakes have effected works and psyche of man from time immemorial, it is only in recent years that nationally integrated and meaningful earthquake hazards reduction programmes are undertaken.

The next heading, *Trends of the Science,* emphasises the importance of preparing accurate and complete earthquake catalogues; use of seismic moment and seismic moment tensor in estimating the size of earthquakes; earthquake cycles and application of paleoseismicity in estimating average fault slip rates and recurrence intervals between major earthquakes; understanding of the structural and tectonic control in causing earthquakes; and the part played by inhomogeneities in the earths crust with respect to earthquake faulting process.

Under *Specific Accomplishments,* Thomas Hanks has highlighted certain salient features of recent work. Detailed *crustal deformation* studies, particularly in California, have been undertaken involving establishment of gravity stations, levelling baselines and trilateration networks. The measurements are repeated during the past 5 to 10 years. These measurements have revealed very interesting results. For example, for San Andreas fault, it is found that strain accumulation now occurs along the two locked segments, those which broke in the great earthquakes of 1857 and 1906. It has also been figured out that strain accumulation can be accompanied by remarkable episodicity in deformation rate. *Paleoseismicity* studies have extended the short instrumental/historical record of earthquakes backward in time by several thousands of years. Evidences have been collected for occurrence of 12 earthquakes, comparable in size to the 1857 earthquake, during the past 1700 years at Pallet Creek, California with a recurrence interval of about 150 years. Detailed *seismicity studies* have enabled establishing close association between seismicity and active crustal fault zones. The section of the San Andreas fault that broke in 1857 and 1906 great earthquakes, is conspicuously aseismic. Same is the case with the east front section of Sierra Nevada that broke during the great 1872 earthquake. Under *magmatic seismicity* the dramatic association between seismic activity, crustal deformation and emplacement of partially molten rocks into the earth's crust are investigated. Monitoring of micro seismicity in the vicinity of calderas is useful in monitoring magma movements and forewarning volcanic eruptions. Observation of continuous earthquake swarm activity since 1978 and 40 cm of uplift across Long Valley caldera since 1979 led USGS to issue Volcanic Hazard Notice for the area in May 1982. However, volcanic eruption has not occurred so far. It could occur next week – or may not occur for the next 100 years. While the impending hazard is real, its timing is very uncertain. Following occurrence of induced earthquakes of $M \gtrsim 5\frac{1}{2}$ in the vicinity of the reservoirs at Koyna, India; Kariba, Zambia Zimbabwe; Kremasta, Greece; Oroville, California; Hsingfengkiang, China; and Aswan, Egypt, and at Klerksdorp Mining District, South Africa, has further focussed attention on the phenomenon of *induced seismicity*. In recent years several measurements and experiments have been conducted at Monticello Reservoir in South Carolina to investigate the earthquakes which occurred after the impoundment of the reservoir. It is found that the seismicity at the Monticello reservoir was, indeed, driven by the perturbing action of the reservoir itself. Much new work on *stress measurements* have been reported and a map showing the orientation of the maximum principal horizontal stress for the North American plate has been compiled. Under the topic *earthquakes in the 'eastern' United States*, results of recent work are reported. On the close-in seismologic recording, the eastern earthquakes are indistinguishable from Californian earthquakes on the basis of stress drop. *Strong ground motion* estimations play an extremely important role in earthquake hazard reduction efforts and are an essential ingredient of the earthquake resistant design of important structures. Strong motion seismology began more than 50 years ago. It continues to be plagued by the uncertainties as to how strong the ground motion can really be. Close-in records from recent earthquakes have been important milestones. However, they have also set an extremely difficult task as peak accelerations recorded during the 1979 Imperial Valley earthquake of 1979 were 1.75 g. Even at present time, there are very few records at close distances for major earthquakes ($M \gtrsim 7$). Recent work shows that the root mean square ground acceleration can be associated with dynamic stress drop which is remarkably constant, at least for Californian earthquakes. This provides a firm theoretical basis for calculating peak amplitudes, velocities and accelerations for at least $M \gtrsim 6\frac{1}{2}$. For larger M, some uncertainties yet remain because of observational constraints and the nature of large to great earthquakes for which the fault length becomes progressively greater than fault width. Other related topics covered are *calculation of risk* and *seismic zonation*.

Under the last heading, *Scientific Progress and Program Perspectives*, Thomas Hanks observes that 'there can be little doubt that the most certain protection against the dangers of earthquakes is an informed citizenry well prepared for them'. That the USA is progressing steadily towards the objectives of NEHRP is evidenced by increase in popular interest of citizens in earthquake related matters. In major projects such as the Southern California Earthquake Preparedness Project, and the Bay Area Earthquake Studies, the project staff works with representatives of cities, counties, business, schools, and various volunteer groups to stimulate and review earthquake preparedness procedures. In the recent past an impressive string of $M \gtrsim 6$ earthquakes has occurred in California (Coyote Lake 1979, Imperial Valley 1979, Livermore 1980, Mammoth Lakes 1983, Coalings 1983, and Morgan Hill 1984). None of these have been associated with definite short term precursors. Hanks observes (page 39):

> ‘From this, we might conclude that short-term earthquake prediction is now and forever beyond our reach. More rationally, we may conclude that we have simply performed the wrong experiments in the wrong places and at the wrong times. And, to be critical about matters, we might say that we have hardly conducted any experiments at all, to the extent we have allowed the occurrence of the earthquake itself to drive subsequent analysis on observations more often than not recorded from afar’.

and

> ‘That is to say, the earthquakes we would most like to predict – and are most likely to predict – have not yet occurred, but we now know where to look, perhaps the single most significant accomplishment of NEHRP. In fact, an $M \geq 6$ earthquake has already been predicted to occur near Parkfield within the next 5 years, and it is appropriate to execute experiments here with a very sharp focus. Also as a result of the scientific accomplishments of NEHRP, we now have a far better idea of what experiments to perform and how to perform them at a high degree of resolution’.

The scientific essence of NEHRP is the accurate and complete evaluation of potential earthquake hazards and the mechanisms by which they become real. It is widely agreed that the scientific and the engineering advances achieved under NEHRP are leading to meaningful reduction of earthquke hazard.

A ‘three page’ review of a ‘40 page’ report may appear out of place. However, the amount of information packed in the valuable document calls for it. This candid review, against a backdrop where tall claims on earthquake prediction are made by individuals and organizations, often scientifically unsubstantiated, comes as a breeze of fresh air. As far as seismology, earthquake hazard assessment and mitigation in India are concerned, there are several lessons to be learnt and much work is to be done. Non-occurrence of a major or great earthquake in India since 1950 has developed a false sense of security.

Everyone, who has anything to do with earthquakes, would benefit from this excellent inexpensive document.

Centre for Earth Science Studies
Trivandrum - 695 010, India

HARSH K. GUPTA