Intergovernmental Oceanographic Commission

Workshop Report No. 58

IOC Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation

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A supplement to this Report containing selected papers presented at the Workshop will be published separately, as IOC Workshop Report No. 58 Supplement.

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FOREWORD

During the past sessions of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), great emphasis was placed on the educational program on tsunamis and the training of officials of ICG/ITSU member countries. This need was further emphasized by the United Nations declaration of the next decade as the International Decade of Natural Disaster Reduction (IDNDR).

Tsunami is one of the major disasters that threatens the coastal populations of the world oceans and inland seas. The Tsunami Warning System in the Pacific (TWS), has been a major effort spearheaded by the Intergovernmental Oceanographic Commission (IOC) and its International Co-ordination Group for the Tsunami Warning System in the Pacific, to mitigate the effects of the tsunami disaster. The Tsunami Warning System in the Pacific has been in existence since 1965. However, a great deal of progress has been made in the last few years on instrumentation, communications and computer applications, which have had or could have great impact on the improvement of the Tsunami Warning System. The state of the art is rapidly changing and even experts in the field have to review from time to time progress that is being made in technology to familiarize themselves with new concepts and learn to apply these concepts into operational techniques that can result in better tsunami analysis, prediction and communications. Improvements can be obtained in data collection and rapid processing of data, as well as in prediction of tsunami heights and inundation by applying the new technology and new instrumentation to data gathering, processing and analysis. Therefore, a real need was identified to have workshops and training sessions, even for the experts, during which instruction and information can be given on new technological advancements, information concerning computer circuitry and data transmission techniques, data collection and calibration techniques and communications. Training of officials involved in the Tsunami Warning System is an important part of the overall educational requirements of ITSU member countries because these officials are, in turn, responsible for operational improvements in their own countries and for a program of general public education.

As early as August 1983, the IOC Secretariat called a special meeting in Paris, which included the Chairman of ICG/ITSU and the Director of the International Tsunami Information Center (ITIC), to review the educational needs of ITSU members. Suggestions were made that tsunami workshops should be held under the auspices of the TEMA program and that a plan for a workshop be drafted and that appropriate experts be designated for such training. ITIC was charged with the responsibility of developing a curriculum and locating instructors. It was also suggested that such a workshop could be held consecutively to the ITSU and IUGG sessions so as to maximize participation and minimize cost.

On the basis of these suggestions, ITIC, in close consultation with the IOC Secretariat and the Chairman of ICG/ITSU, developed a curriculum for the training of such officials and for familiarization of participants in the TWS, not only with conceptual improvements that have been made, but with the inner workings of the TWS including computer applications, on-line processing and numerical modelling. Thus, the first IOC sponsored Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications, was held at Sidney, B.C., Canada, on 29 July - 3 August 1985, prior to the ITSU-X Meeting, and prior to the IUGG Conference in nearby Victoria.

Four years have since elapsed, and in this time interval, the technology has greatly changed. This Second Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation was held to bridge the gap of four years of independent developments in the TWS and to bring together tsunami specialists from different countries to improve their knowledge of the tsunami phenomenon and to help find practical solutions to the improvement of TWS for the mitigation of the tsunami hazard. As with the first Workshop, the second Workshop was held right after the IUGG Tsunami Conference, and just prior to the ITSU-XII Session. The Workshop was part of the overall TSUNAMI 89 Conference and was held in the modern and attractive research town of Academgorodok, which is located 20 km south from downtown Novosibirsk, the capital of Siberia, in a pine-tree forest growing along the bank of the Ob river. The USSR Academy of Sciences and the Computing Center of its Siberian Division hosted the TSUNAMI 89 Conference and this Second Workshop.

The present Report contains a summary of the proceedings of this Workshop, as well as Annexes containing the Workshop Programme, the Recommendations and a List of Participants. The full text of papers presented at this Workshop will be published as a Supplement to the present Workshop Report.

1. OPENING OF THE WORKSHOP

The Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation was opened at the Dom Uchenyh Hall at the scientific town of Akademgorodok, Novosibirsk, USSR, on 4 August 1989, at 9:00 am.

Dr. K. Kitazawa, Assistant Secretary of the Intergovernmental Oceanographic Commission (IOC), opened the Workshop, and speaking on behalf of the Secretary IOC, extended to the participants of the Workshop a very warm welcome. He stressed the importance of this second international workshop to the strengthening of the international cooperation needed for the mitigation of the tsunami disaster. Mr. R. Hagemeyer, Chairman of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), speaking on behalf of the Member States of the Group, extended to the participants a very warm welcome and wished all success in achieving the objectives of the Workshop.

Dr. G. Pararas-Carayannis, Director of the International Tsunami Information Center (ITIC), was nominated and subsequently elected as Chairman. Mr. T. Sokolowski (USA) was designated as Rapporteur of the Workshop.

In his opening statement, Dr. Pararas-Carayannis welcomed participants and briefly reviewed the beneficial exchange of views and concepts between participants at the first International Workshop which took place in Sidney, B.C., Canada, on 29-31 July 1985. He expressed hope that this second International Tsunami Workshop would familiarize participants with the progress that had taken place in the last four years and would facilitate the resolution of a number of problems of operational nature for improved Tsunami Warning Services.

The Chairman explained that the main idea of the Workshop is to bring together as many tsunami specialists from different countries as possible, so as to continue this exchange of views, leading to better understanding of the practical needs for the mitigation of the tsunami hazard. He emphasized that this can only be accomplished with improved tsunami warning systems, better understanding of the latest scientific results for tsunami evaluation and prediction, and through a programme of tsunami preparedness and public education. Then, he explained the rationale for the formulation of the Workshop programme and the need for participants to review, not only the tsunami threat in the Pacific Ocean, but in other world oceans and inland seas. Furthermore, he emphasized the need for Workshop participants to review their knowledge and information on existing seismic data processing systems, on data bases, latest developments on instrumentation, and on future projects, which may have practical application for tsunami disaster mitigation. The Chairman stated that tsunami disaster mitigation measures should be implemented, keeping in mind the objectives of the International Decade on Natural Disaster Reduction (IDNDR), a recent United Nations initiative.

In closing, the Chairman reviewed briefly the workshop programme, and emphasized the need for continued interaction following the Workshop. Then, he stressed the importance of documenting the Workshop proceedings into two parts: A summary report containing abstracted presentations, discussions and recommendations, and a second report containing the full text of the presentations. Both reports are to be published by IOC.

Finally, the Chairman thanked the participants and, on their behalf, thanked also the IOC for the sponsorship of the Workshop, other organizations that cosponsored this event, and the USSR Academy of Sciences and its Computing Centers for hosting and coordinating this important training event.

2. INTERNATIONAL COOPERATION IN THE FIELD OF TSUNAMI RESEARCH AND WARNING

2.1 INTERNATIONAL COOPERATION IN THE FIELD OF TSUNAMI RESEARCH AND WARNING, (G. PARARAS-CARAYANNIS)

Only one paper was given under this section. According to this presentation by Dr. G. Pararas-Carayannis, tsunami disasters have posed a major threat to the coastal populations of the Pacific and of island seas and have claimed thousands of lives in the last four decades alone. Mitigation of the effects of the tsunami disaster can only be achieved through international co-operation and by the concerted action of nations. By declaring the 1990's as the International Decade of Natural Disaster Reduction (IDNDR), the United Nations have taken a lead role in the mitigation of disaster effects. The Tsunami Warning System in the Pacific is an example of how the tsunami disaster can be mitigated through international cooperation, proper research and the exchange of knowledge and information. Started over 25 years ago, long before the International Decade was proclaimed, the Tsunami Warning System in the Pacific has dealt effectively on an international scale with this natural disaster. This has been made possible through the leadership of the Intergovernmental Oceanographic Commission (IOC) in forming the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) and the International Tsunami Information Center (ITIC), and by the generosity of the member nations which have joined this system and have contributed their resources. However, the tsunami disaster still poses a major threat to the coastal communities in all the oceans and inland seas, but its effects can be further mitigated through continuous international cooperation in: (i) Scientific and Engineering Research; (ii) Evaluation and Prediction Capability; (iii) Development of the Pacific and Regional Warning Systems; (iv) Development of Operational and Emergency Preparedness; (v) Development of Planning and Zoning Criteria; and (vi) Public Education and Awareness.

After this general overview, Dr. Pararas-Carayannis went into specific descriptions as to how international programmes in these areas can lead to the successful implementation of the principles of IDNDR in reducing the effects of the tsunami disaster in the next decade.

3. SURVEY OF EXISTING TSUNAMI WARNING CENTERS - PRESENT STATUS, RESULTS OF WORK, PLANS FOR FUTURE DEVELOPMENT

Nine papers were given by participants on the existing Tsunami Warning Centers and on their present and future activities.

3.1 PACIFIC TSUNAMI WARNING CENTER (G. BURTON)

Mr. G. Burton (USA), Geophysicist-in-Charge of the Pacific Tsunami Warning Center (PTWC), described the activities of the Center, located in Ewa Beach, Oahu, Hawaii. According to his report, improvements are being made in obtaining a new computer system (MASSCOMP) that will enhance the present operations. It will improve their system in the areas of data acquisition and evaluation and information dissemination. It will also be linked to the National Earthquake Information Center (NEIC) which is located in Colorado, USA, to obtain seismic data from their future network.

He stated that Resolution VIII.3 resulting from the VIII session of the International Co-ordination Group for the Tsunami Warning System in the Pacific (13-17 April 1982, Suva, Fiji) has been implemented to provide immediate watch and warning services in a time step fashion to developing countries. These warnings are based upon historical data which were classified according to their past effects and the magnitude (MS) of the earthquakes. The Pacific Basin was divided into various zones of potential tsunamigenesis based upon earthquake (MS) magnitude.

The PTWC tsunami data acquisition system throughout the Pacific Basin has been extended to 31 tide platform stations which report tide data to the PTWC via the GOES satellite system. In addition to reporting tsunami data, these devices will be able to detect earthquake P Wave times and sent to the PTWC to aid in the accuracy of earthquake locations. A few seconds of wave form data will also be transmitted along with the P arrival times.

3.2 HAWAII REGIONAL TSUNAMI WARNING SYSTEM (G. BURTON)

The Hawaii Regional System consists of seismic and tide stations on several of the Hawaiian islands. The data are transmitted to the PTWC in real-time to rapidly locate and size an earthquake. The PTWC standby duty personnel can respond to an alarm within 2 minutes to process an event. Warnings are issued for local earthquakes that have a magnitude of 6.8 or more.

3.3 ALASKA REGIONAL TSUNAMI WARNING CENTER (T. SOKOLOWSKI)

The Alaska Tsunami Warning Center's (ATWC) activities were presented by Mr. T. Sokolowski, Geophysicist-in-Charge. He gave a brief history of the Center and discussed the present status, accomplishments, and future development plans.

The ATWC's real-time data networks include more than 30 seismic stations throughout Alaska, and through a cooperative agreement, 14 stations from the National Earthquake Information Center's (NEIC) lower 48 states' network. Tide data are available from more than 16 sites distributed along the coastal areas of Alaska, Canada, and the U.S. West Coast.

In automation the ATWC has implemented an advanced microcomputer system that automatically computes earthquake parameters in real-time and within seconds after receiving appropriate data. In addition to the automatic system, the same microcomputer contains interaction software which is linked to the automatic processes for concurrent processing and rapid message dissemination. This automation has resulted in a very effective system with warnings being issued within 8-15 minutes after the earthquake's origin time. Other microcomputer applications will involve distributed systems connected to each other by a local area network to perform backup functions to existing micros, and real-time and near real-time access, retrieval, and analysis of remote tide gauge data. This automation has considerably decreased the response time between the occurrence of an earthquake and the issuance of a warning, increased accuracy and quantity of information, and standardized and simplified procedures.

Community preparedness continues to take place at the ATWC from the far western Aleutians through southern California. This includes visiting outlying communities, weekly tours through the office, and presentations for special events. Other improvements, enhancements, and development projects include: initial modeling efforts of the Yakutat series of earthquake that occurred in 1987-88; historical earthquake and tsunami data bases; satellite communications to rapidly disseminate watches and warnings; immediate transmission of automatic earthquake parameters by the computer to the ATWC personnel; and artificial intelligence studies for determining advanced criteria for initiating warnings and prediction of hazard zones, wave heights, etc.

3.4 JAPAN TSUNAMI WARNING CENTER (N. HAMADA)

Mr. M. Okada of the Japan Meteorological Agency (JMA) gave an introduction of the Japan Tsunami Warning System for Dr. N. Hamada who was unable to attend the Workshop in person, but did appear on a video explaining their activities. On the video tape, Dr. Hamada explained the operations of JMA and showed some interesting effects from the 1983 tsunami which occurred in the Sea of Japan.

At JMA, a modern seismological data acquisition and processing system, called Earthquake Phenomena Observation System (EPOS), has been operational since 1987. EPOS consists of several super minicomputers, telecommunication links, and telemetering facilities which process data from more then 60 seismic stations for automatic determination of a hypocenter location and size. After the earthquake satisfies some criteria, the JMA warning services are conducted by the system, but the final decision to issue warnings are made by the duty officer. The time required for these services from detection to warning dissemination has been shortened to an average of 8 minutes. In other local centers, warning services are produced by a computer based data acquisition and processing systems, which are scheduled to be upgraded to an EPOS system in the future.

In communications, a system called the Emergency Warning System (EWS) automatically activates radios and televisions when information about disasters must be disseminated urgently, and over a wide area, by broadcasting the information. Since implementation in 1985, many main TV and radio stations have joined the EWS for rapid dissemination of tsunami warnings.

3.5 USSR TSUNAMI WARNING CENTER (B. KUZNETSOV)

The activities of the Tsunami Warning System in the USSR were presented by Dr. B. Kuznetsov. The USSR system has been in operation at the Yuzhno-Sakhalinsk, which is the main Center, since inception in 1956. The Tsunami Service consists of two autonomous operational services, which have their Centers at Yuzhno-Sakhalinsk and Petropavlovsk-Kamchatsky. It is the USSR Academy of Sciences seismic stations that initiate the warning for those events that occur in a nearby zone of the USSR coasts. For teleseismic events, warnings are issued by the USSR's Goskomgidromet organization. Local authorities also play a role in the evacuation of coastal populations.

The improvements include the introduction of computer technology along with new seismic and hydrophysical sensors being installed to mitigate the tsunami threat from potentially dangerous zones in Kurile-Kamchatka areas. This new automation will include the receiving, collecting and processing of seismic, as well as hydrophysic information, and preparing and transmitting critical messages to affected areas. At the present time, the dissemination of messages takes about 1 minute compared to previous times of about 15-20 minutes.

3.6 FRENCH POLYNESIA TSUNAMI WARNING CENTER (J. TALANDIER)

The status of the French Polynesia Tsunami Warning Center (CPPT) was presented by Dr. J. Talandier, its Director. The French Polynesia Tsunami Warning Center, which is also a research geophysics laboratory, disseminates the data recorded by the Polynesian Seismic network. This network includes 21 short-period stations divided in telemetered subnetworks, 4 broad-band instruments, three component long-period instruments, and 2 tide gauges Also, it receives, in real-time, data from the Handar GOES platforms of five islands in the South Pacific. The CPPT is equipped with permanent digital recordings of the PCN type and automatic acquisition system on hard disc. It displays, also, graphics recordings. This system covers all spectral frequency between 20Hz to 3,600 sec of period and this different records are made with large dynamic.

To estimate the tsunami risk the CPPT calculates, in real-time, the seismic moment through the Mm magnitude. From the seismic moment, the amplitude of the expected tsunami is deduced after correlation with experimental data that has been theoretically justified.

Mm magnitude is based on the measurement of mantle Rayleigh or Love wave energy and directly related to the log of the seismic moment. The direct relation between seismic moment and amplitude of tsunami is justified by the normal mode tsunami theory and is experimentally verified according to the amplitude of the tsunamis recorded in Papeete harbor since 1958. Papeete harbor minimizes amplification and resonance effects and additional corrections are applied for other receiving sites.

Thus, on the basis of seismic moment, (Mm magnitude), the CPPT defines the tsunami risk levels. As suggested by historic data which is in agreement with Ward's theoretical data, suggests that the potential for destructive tsunamis exists from earthquakes that have seismic moments greater or equal than 5×10^{28} dyn-cm for the Samoa, Tonga region, and for earthquakes with seismic moments equal or greater than 10^{29} dyn-cm for areas distant of French Polynesia.

The tsunami detection device used by the CPPT is entirely automated. A computer detects, locates, and estimates the seismic moment through the Mm magnitude, and, in terms of the moment gives an amplitude window of the expected tsunami. These different operations are executed in real time, in the following sequence:

(i) Two detection devices work simultaneously for short and long-period seismic waves.

(ii) Two locations are also independently executed in short and long-period. The first is based on the P wave arrival times at 12 telemetered stations. The second uses the P waves three-component polarization.

(iii) The Mm magnitude is evaluated with Rayleigh waves, in the frequency domain and in the time domain and in the frequency domain with the Love waves.

(iv) When these estimates of Mm are obtained, the computer prints out automatic estimates of tsunami heights.

Thus few minutes after the arrival of the seismic surface waves the tsunami risk is estimated, long-time before the arrival of a tsunami. Used since 1986 this device has stood the test of time. This method used by CPPT is fully automatic and can be applied at other teleseismic warning centers in the Pacific.

3.7 CHILE TSUNAMI WARNING CENTER (E. LORCA)

Mr. E. Lorca (Chile) briefly presented the history of the Chile Tsunami Warning Center and of the Tsunami Hazard Reduction Utilizing System Technology (THRUST) programme. Chile has participated in the tsunami warning system since July 7, 1958. The instrumentation for the tide stations have been improved with the replacement of the old Ballauf Standard tide gauge by the bubbler type in 15 locations besides the installation of five Handar Data Collection Platforms (DCP) provided by the U.S. National Oceanic and Atmospheric Administration (NOAA).

According to Mr. Lorca, the existing seismic network is still far from having a good coverage of the country; however, four short period seismometers have been recently installed around the Iquique seismic gap, and two THRUST seismic triggers are in operation at Iquique and Valparaiso ports.

Communications with the National Emergency Office has been improved with a HF transmitter which permits linking with all the Regional Emergency Offices along the country. The Standard Operations Plan in case of tsunami has been tested in a tsunami simulation exercise, where some problems have surfaced between different emergency agencies; a revision of the Plan has been adopted.

3.8 TSUNAMI WATCHES AND WARNINGS IN FIJI (G. PRASAD)

Activities related to tsunami watches and warnings in Fiji were presented by Mr. G. Prasad. He reported that tsunami is only one of the several natural disasters affecting Fiji. Cyclones and hurricanes are much more common causing much destruction. Nevertheless, the tsunami of 1953 produced by an earthquake near Suva claimed several lives in Suva and on the island of Kadaru. This makes it necessary for Fiji to prepare for a possible damaging tsunami especially with the encroachment of populations near the coast and just above the high water level. Tsunamis that are produced from distant earthquakes have also been recorded in Fiji, such as those generated by the 1960 Chilean and the 1964 Alaskan earthquakes.

The Emergency Services Committee (EMSEC) is responsible for mitigation of natural disasters in Fiji. A sub-committee of EMSEC is responsible for developing a national strategy on the awareness and preparedness for natural disasters in order to minimize human injury and damage to property. Other organizations included in tsunami warnings in Fiji are:

(i) The Mineral Resource Department's Seismology Section which is responsible for operating a network of seismograph stations for collecting and distributing earthquake data.

(ii) The Marine Department Hydrographic unit which is responsible for tide gauge operations at Suva.

(iii) The Meteorological Services, which is Fiji's link with the PTWC, and operates Communications 24 hours a day.

(iv) The Fiji Police Force which has the responsibility of informing authorities and organizations as quickly as possible.

(v) Radio Fiji which is the communication medium to the public.

The tsunami warning system in Fiji is good and should work well for far field tsunamis, but becomes less effective for locally produced tsunamis. In this case, public education becomes very important and is being actively pursued.

3.9 ASSESSMENT AND MITIGATION OF THE TSUNAMI HAZARD IN THE MEDITERRANEAN AREA (S. TINTI)

Although not in the original Workshop programme, the Chairman asked Professor S. Tinti (Italy) to give a presentation on the "Assessment and Mitigation of the Tsunami Hazard in the Mediterranean Area". Professor Tinti accepted. According to Professor Tinti, the Mediterranean Sea, the Black Sea, as well as the Eastern Atlantic Ocean facing Portugal and Morocco, are all known to have been threatened by very large tsunamis in historical times. These events were originated mainly by earthquakes or by massive earthslides triggered by the shocks, but some of them were also related to the volcanic activity in the Aegean arc and in Southern Italy. Even though historical records show that the tsunami threat cannot be disregarded, practically neither a global nor a regional system exists in the area to prevent or to mitigate the tsunami risk. An international project has been recently financed by the ICSC World Laboratory (Lausanne, Switzerland) with the final goal of reducing the tsunami hazard in the Mediterranean and in the adjacent seas. However, this effort should be regarded as a first step towards the solution of the problem, and should be promotional of other substantial steps that should be taken by international organizations, as well as by the individual nations concerned.

4. SURVEY OF SOME EXISTING SEISMIC DATA PROCESSING SYSTEMS AND FUTURE PROJECTS

Following the presentations on existing tsunami warning centers and the need for new ones, a comprehensive review of existing seismic data processing systems and of future projects was undertaken. Three presentations were made under this section.

4.1 OPERATIVE SEISMIC DATA PROCESSING IN THE NEIC AND PLANS FOR THE NEW US NATIONAL SEISMIC NETWORK (J. DEWEY)

The first presentation was by Dr. J. Dewey of the U.S. Geological Survey who elaborated on the National Earthquake Information Center's (NEIC) processing of the seismic data and on future plans for the new U.S. national seismic network. Presently NEIC locates and sizes major earthquakes usually within an hour following the earthquake. However, a shortening of the time elapsed between the occurrence of our earthquake and issuance of earthquake information as the NEIC will soon upgrade its recording and processing of seismological data. Dr. Dewey outlined in detail the present NEIC capabilities and discussed how the upgraded NEIC networks will improve its capability in improving the estimation of earthquake parameters and making these parameters more rapidly available to users.

Subsequently Professor R. Geller (Japan) of Tokyo University, gave a presentation on the POSEIDON Project, and its application to the better understanding of the nature of the interplate earthquakes.

4.2 POSEIDON PROJECT - ITS APPLICATION TO THE BETTER UNDERSTANDING OF NATURE OF THE INTERPLATE EARTHQUAKES (R. GELLER)

According to Prof. Geller, Japan's proposed Pacific Orient Seismic Digital Observation Network (POSEIDON) will cover the Western Pacific and Far East. When completed in 1997, the network will consist of 14 broadband digital sub-real stations (10 outside Japan and 4 within Japan), and 5 broadband ocean bottom stations to be deployed in the Western Pacific. Funds have been allocated for a "pre-POSEIDON" project, which will include the installation of several stations inside and outside Japan, but final approval has not yet been received for the full-scale POSEIDON project.

The primary purposes of the POSEIDON Network are to study earth structure and the earthquake source process. However, some of the stations will be telemetering data in real time, and these data may be of use in tsunami warning operations. The improvement in the resolution of earth structure that can be expected for POSEIDON was evaluated theoretically.

Although ITSU members are coodinating their efforts with the corresponding national seismological organizations, there is no formal liaison between ITSU and the Federation of Digital Broadband Seismograph Networks (FDSN). It was suggested that a formal liaison between ITSU and FDSN would be of great benefit to the members of both organizations.

5. METHODS FOR FAST EVALUATION OF TSUNAMI POTENTIAL AND PERSPECTIVES OF THEIR IMPLEMENTATION

5.1 A REVIEW OF EARTHQUAKE PREDICTION METHODS (G. PARARAS-CARAYANNIS)

The first presentation in this section of the Workshop programme by Dr. G. Pararas-Carayannis was an overview of Earthquake Prediction methods particularly as they may affect tsunami prediction. In order to reduce the risk of an earthquake and reduce and mitigate its effects, particularly those which may be associated by a generated tsunami, it is necessary to predict where and when future, large tsunamigenic earthquakes may occur. Earthquake prediction at the present time is far from an exact science and forecasts have not been very accurate. Several statistical, geophysical, geological and chemical methods are presently used for earthquake prediction. However, what is presently referred to as "prediction" is not really that. It is simply scientific research on understanding the workings of earthquakes. There is not sufficient historical data on which to base the number of hypotheses that have been proposed for earthquake predictions and, therefore, no way to judge the ultimate success or failure of such predictions.

Dr. G. Pararas-Carayannis discussed the various methods and instrumentation employed by different scientists who attempt to predict earthquakes. These involve statistical probabilities, physical measurements, and geochemical observations. He commented in particular on the social and economic implications of a prediction which in some instances, may be as devastating as the earthquake itself. Tsunami prediction at the present time is based primarily on a statistical determination of the recurrence frequency of major tsunamigenic earthquakes in well defined geographical regions of the Pacific and other areas. It is fairly simple to determine the recurrence frequency of smaller magnitude earthquakes for which there is a wealth of recent historical data. However, it is much more difficult to determine the recurrence frequencies of the larger destructive tsunamigenic earthquakes for which no similarly abundant data exists.

5.2 MM: A VARIABLE-PERIOD MANTLE MAGNITUDE (J.TALANDIER, E. OKAL)

The subsequent presentation was a paper entitled, "Mm: A Variable-Period Mantle Magnitude" by J. Talandier and E. Okal. According to Dr. Talandier (France), who made the presentation, a well known problem of any of the classical magnitude scales measured at a constant period (T) is their saturation when the duration of rupture along the fault becomes comparable to T. Thus, for large earthquakes, and in particular those causing tsunami risk, Ms measured at 20 sec., at fraction MB measured at one second loses significance.

Measured on the flat portion of the source spectrum at a frequency less than the corner frequency, the magnitude Mm avoids this saturation effect. Mm is calculated with the first or multiple passage of mantle Rayleigh waves and is directly linked to the seismic moment. Mm can be determined in the frequency domain as well as in the time domain, so that usual graphic recordings could be used. This is based on the development and measurement of Mm on the theory of excitation modes and surface waves by seismic source, separating the effect of propagation from source excitation and allowing for geometrical spreading and for corrections in the time and frequency domain.

In the same way Mm can be calculated with Love waves following the same principle. Tectonic models and source corrections are then adapted. A study of more than 250 records shows that the standard deviations of the residuals between values of Mm computed and measured are of the order of 0.2 unit of magnitude. These numbers compare very favorably with the scatter in moment values published.

Dr. Talandier summarized his presentation by stating that Mm is a universal magnitude scale perfectly adapted to the measurement of large earthquakes, and useful for tsunami warnings, but it can also be adapted for small earthquakes.In addition, the calculations involved in real time in the computations of Mm are extremely simple.

5.3 ON EARTHQUAKE TSUNAMI GENERATION CRITERIA (A. IVASHCHENKO, A. POPLAVSKY, S. SOLOVIEV)

In the paper by A. Ivashchenko, A. Poplavsky and S. Soloviev (USSR), entitled "On Earthquake Tsunami Generation Criteria" an analysis was presented of the efficiency of various proposed seismic criteria and features of earthquake tsunamigeneity, as well as the efficiency of the Soviet regional tsunami warning system for the last 30 years. The presentation made by Dr. Ivashchenko stated that the Soviet Tsunami Warning System is not highly efficient so that new and more efficient seismic criteria and features in addition to principal Ms-criterion are necessary for practical operation. However, numerous new features proposed by Soviet researchers have not been compared with each other and with Ms-criterion, so their practical capabilities are not yet realized.

The authors proposed a simple unified approach, based on calculating a number of first and second kind errors in the selections available. Some uniform estimates of the efficiency have been obtained for: (i) the Soviet TWS as a whole and (ii) various new proposed seismic criteria and features of earthquake tsunamigeneity.

In conclusion, Dr. Ivashchenko stated that the most effective seismic features are determined by the amplitude levels and durations of various seismic signals, so that combining them with Ms-criterion, one can improve the reliability of seismic forecasting of tsunamis significantly. These features are recommended to be tested in various regional TWS, based upon seismic data.

5.4 THE FEASIBILITY OF MEASURING THE LOW FREQUENCY T PHASE FOR TSUNAMI WARNINGS (S. IWASAKI)

The next paper, entitled "The Feasibility of Measuring the Low Frequency T-Phase for Tsunami Warnings", was presented by Dr. S. Iwasaki (Japan). In his presentation Dr. Iwasaki elaborated that tsunamigenic earthquakes generate also a strong T phase which propagate at the speed of sound waves in the layer of the ocean known as the SOFAR channel. The low frequency T phase in particular carries information from which source characteristics of a tsunami can be determined, thus rendering this information useful for evaluation and the issuance of tsunami warnings. The low frequency T phase is a useful tsunami precursor event which can be easily detected by a hydrophone. Furthermore, by comparing the signatures of the signals recorded by a hydrophone and a seismograph, inferences can be made of the arrival time and wave height of the tsunami, as well as the initial tsunami wave form. The latter can be predicted using the maximum magnitude of the low frequency T phase and the distance from the source region to an observing point. Prediction of maximum tsunami height at the terminal point can be made if amplification factors of tsunami waves have been determined for each source region.

5.5 APPLICATION OF NEW NUMERICAL METHODS FOR NEAR-REAL TIME TSUNAMI HEIGHT PREDICTION (V. GUSIAKOV, AN. MARCHUK, V. TITOV)

A paper, entitled "Application of New Numerical MethPods for Near-Real Time Tsunami Height Prediction", co-authored by V. Gusiakov, An. Marchuk and V. Titov (USSR), was presented by both Drs. Gusiakov and Marchuk. The authors presented their development of new effective numerical algorithms that permit the mathematical modeling of tsunami generation, propagation and run-up which will eventually be incorporated in the mini and micro-computer facilities of the regional tsunami warning centers for operational application and tsunami evaluation.

5.6 THE GOAL AND EFFICIENCY OF THE AUTOMATED TSUNAMI WARNING SYSTEM PROJECT IN THE FAR EAST OF THE USSR (I. KUZMINYKH, M. MALYSHEV, A. METALINKOV)

Another paper, entitled "The Goal and Efficiency of the Automated Tsunami Warning System Project in the Far East of the USSR", co-authored by Drs. I. Kuzminykh, M. Malyshev and A. Metalnikov (USSR), was given by Dr. I. Kuzminykh. In this presentation the Tsunami Warning System in the Far East of the USSR was discussed as well as efforts to improve its reliability through automation of data acquisition, data processing, and through mathematical methods and computer simulations.

5.7 INTEGRATED WARNING SYSTEM FOR TSUNAMI AND STORM SURGES IN CHINA (H. YANG)

The last paper in this section of the programme was given by its author, Dr. Yang Huating (People's Republic of China) and it was entitled "Integrated Warning System for Tsunami and Storm Surges in China". In his presentation, Dr. Yang outlined how the historical data on tsunami and storm surges in China, as well as the present situation of operational oceanographic services in his country, were documented leading to the formulation of governmental policies integrating the responsibility for a warning system for tsunami and storm surges.

6. TSUNAMI DATA BASES

6.1 AN AUTOMATED TSUNAMI CATALOG. (A. BOBKOV, C. GO, N. ZHIGULINA, K. SIMONOV)

The first paper in this session was entitled "An Automated Tsunami Catalog" by A. Bobkov, C. Go, N. Zhigulina, K. Simonov (USSR). The presentation was made by A. Bobkov, who elaborated on the usefulness of developing historical tsunami data catalogue by computer. In particular, he commented on the Soviet efforts to computerize and automate tsunami historical data by integrating existing historical tsunami data compiled in other catalogues in the USSR, Japan, USA and Canada. Following this introduction, Dr. Bobkov then illustrated the type of information included in this automated catalog and the format by which it is arranged, or retrieved, giving specific examples.

6.2 TSUNAMI DATA BASE FOR BRITISH COLUMBIA TSUNAMI WARNINGS. (T. MURTY, W. RAPATZ.)

A second presentation by Dr. T. Murty and Mr. W. Rapatz (Canada) dealt with the Tsunami Data Base for British Columbia Tsunami Warnings. According to Dr. Murty who made the presentation, the data base developed for the British Columbia Tsunami Warning System, uses a set of numerical models. The first model is the deep ocean model (D.O.M) that uses a O.5 degree latitude and longitude as grid. The Boussinesq equations are solved for prescribed ocean bottom motion in a spherical polar coordinate system. The output from D.O.M. is used to run a 5 km grid shelf model which solves the two dimensional shallow water equations. The output from the shelf model is then used as input to some twenty-one dimensional models for the inlet systems. One-dimensional shallow water equations are solved on a 2 km grid for the inlets.

The maximum tsunami amplitudes and maximum currents are listed in tables for some 185 locations on the British Columbia coast and stored on a personal computer along with the travel times. With some modifications, the system can be adapted to other areas on the globe, e.g. Alaska-Aleutians, Chile, Fiji, etc.

6.3 HISTORICAL APPROACH TO THE STUDY OF TSUNAMIS: RECENT U.S. RESULTS. (J. LANDER.)

The third presentation in this section was made by Mr. J. Lander (USA), entitled "Historical Approach to the Study of Tsunamis: Recent U.S. Results". According to this presentation an essential element is developing an appropriate response to a tsunami hazard is detailed data of historical tsunamis, which can be used in warning systems, public education, insurance, emergency planning and modelling and engineering studies which may be combined in tsunami hazard mitigation. Then, Mr. Lander proceeded in giving examples of the diversity of the tsunami hazard for different regions of the United States and the Puerto Rico/Virgin Islands area.

6.4 THE DEVELOPMENT OF NUMERICAL SIMULATION OF TSUNAMI WAVES AT THE COMPUTING CENTER AT KRASNOYARSK (YU. SHOKIN, L. CHUBAROV, V. NOVIKOV, A. SUDAKOV, K. SIMONOV)

Another presentation which was not included in the original Workshop programme entitled, "The Development of Numerical Simulation of Tsunami Waves at the Computing Center at Krasnoyarsk" was by Yu. Shokin, L. Chubarov, V. Novikov, A. Sudakov, and K. Simonov (USSR), and given by Academician Shokin.

The goal of this particular investigation was to create a closed system of numerical models and corresponding software with high efficiency and applicability for such problems as: (i) Providing reliability of long-term and short-term forecast of destructive actions of natural and man-made hazards, including tsunami and storm surges; (ii) Coastal zoning of the risk of marine hazards and the design of new objectives for mitigation; (iii) Improvements in the construction of coastal structures and proper siting for the purpose of reducing potential losses caused by marine hazards; (iv) Obtaining new fundamental results in the field of wave hydrodynamics, including tsunami; and (v) Increasing the efficiency of making decisions on population security and protection of coastal zones with respect to the natural and man-made hazards.

Based on this introductory assessment of potential problems, Dr. Shokin proceeded in explaining the efforts of the Computing Center at Krasnoyarsk to resolve them, particularly the development of computational models and algorithms, often used for the numerical simulation of some real events.

7. TSUNAMI INSTRUMENTATION AND OBSERVATIONS

7.1 A LONG-TERM DEEP OCEAN TSUNAMI MEASUREMENT PROGRAM: STRATEGY AND INSTRUMENTATION (F. GONZALEZ, E. BERNARD, H. MILBURN, D. MATTENS)

The first presentation under this section was entitled "A Long-Term, Deep Ocean Tsunami Measurement Program: Strategy and Instrumentation" by F. Gonzalez, E. Bernard, H. Milburn and D. Mattens (USA). The presentation was made by Dr. F. Gonzalez who spoke of the difficult challenges with the establishment and maintenance of long-term deep ocean monitoring network and the Pacific Marine Environmental Laboratory's (PMEL) successful tsunami measurement program using bottom pressure recorders (BPRs) in the North Pacific. Then, Dr. Gonzalez described the strategy for the selection of sites to place these BPR systems at locations that can result in the collection of a wide variety of other important oceanographic phenomena and at the same time near locations with high probability of occurrence of a large tsunamigenic earthquakes. The present BPR systems are deployed for a period of approximately one year and are designed as research tools rather than real time data collection devices.

7.2 TSUNAMI OBSERVATIONS USING OCEAN BOTTOM PRESSURE GAUGE (M. OKADA, M. KATSUMATA)

A paper entitled "Tsunami Observations Using Ocean Bottom Pressure Gauge", by Drs. M. Okada and M. Katsumata (Japan), was presented by Dr. Okada. He discussed the concern for a large earthquake off Tokai District, south of Honshu and Japan Meteorological Agency's (JMA) efforts in improving its system of data acquisition and processing. One of the major initiatives in recent years to enhance JMA's system has been the development of the Permanent Ocean Bottom Seismograph System (OBS) and its installation off Cape Omaezaki made in 1978 by the Meteorological Research Institute (MRI). Dr. Okada described this system which comprises of four seismographs and one pressure gauge, and designed to detect tsunamis and the crustal movement precursors of large earthquake. Also, he described another OBS system which has been deployed off Boso Peninsula, Kanto District, since 1986. This system comprises of four seismographs and three tsunami gauges. Both OBS systems are currently operational and transmit signals via submarine cable on a continuous basis for the purpose of earthquake prediction and operational tsunami warning.

7.3 OFFSHORE TSUNAMI WARNING STATION - MEGA (G. RYBIN)

The next presentation by Dr. G. Rybin (USSR) was entitled "Offshore Tsunami Warning Station - MEGA". This is an automatic system of tsunami warning developed for the Far East coastal area of USSR. This is primarily a sea level measuring device with sensitivity in the range of $\pm$ 5 cm and a total range up to 20 meters. The station comprises of an offshore and an onshore unit connected by a four component cable which handles the power supply and data telemetry. The submarine sensor is located at a depth of 15 meters. The land based unit houses the power supply and a microcomputer which is programmed to regulate and process the incoming data.

7.4 RE-USE PLAN OF COMMERCIAL SUBMARINE COMMUNICATION CABLE FOR GEOPHYSICAL RESEARCH (J. KASAHARA)

The final paper in this section of the Workshop Programme was by Dr. J. Kasahara, but in his absence it was presented by Professor Tsuji (Japan). The title of the paper was "Re-Use Plan of Commercial Submarine Communication Cable for Geophysical Research". However, the title was modified later by its author and became "TPC-1 Re-use and Global Seismology". According to this presentation many submarine cables that have been used for the last two decades are being replaced by new optical fiber cables which have a tremendous capability to accommodate far more numerous telecommunication channels. Thus, cables such as TPC-1 will be retired soon. However, current studies for seismological data telemetry, as with the POSEIDON project, have found that reuse of the existing TPC-1 as a seismic cable would be the most practical and economical way to realize a global seismic network. Initial plans are to use the Japan-Guam segment of the cable and to attach to it appropriate seismic and hydrophone sensors and connect them to a transmission station, or power feed station and a data center. Finally, according to the author, the installation of the TPC-1 geoscience cable system might greatly contribute not only to global seismology, but also to tsunami and other ocean geoscience measurements.

8. TSUNAMI PREPAREDNESS

8.1 TSUNAMIS OF THE 21ST CENTURY (G. PARARAS-CARAYANNIS)

Only one paper was presented in this session, entitled, "Tsunamis of the 21st Century," by Dr. Pararas-Carayannis who in his capacity as Chairman, used also this opportunity to summarize some of the conclusions of the workshop and to present a broader perspective on what can be expected in the future in terms of tsunami disasters and what can be done to predict them and mitigate their effects. Dr. Pararas-Carayannis classified tsunamis as events which occur in cycles. He characterized each tsunamigenic region of the world as having its own cycle and pattern producing tsunamis ranging from minor to catastrophic. He commented on the validity of statistical methods of earthquake prediction and on the limited accuracy of the seismic gap theory to help in the prediction of future tsunamis, cautioning about major tsunamis in areas other than those designated. He expressed the opinion that the 30 year interval which is the criterion for establishing a seismic gap may be too short of an interval for tsunami predictions, and for certain geographical areas, and proposed a "tsunami gap theory," with gap designations and criteria differing from region to region. According to this proposed theory, the time path of variables of each future tsunami can be established, or at least estimated statistically for each potential tsunamigenic area, and the same historical criteria can be integrated with measured seismic tsunami source parameters and precursor events to form predictive schemes. Dr. Pararas-Carayannis named the centerpiece of this proposed methodology as "historical tsunami determinism", which differs from the usual collection of qualitative historical tsunami data collection and interpretation of cursory seismic data for the real-time warning system, or for prediction of tsunamigenic earthquakes. The methodology he proposed for tsunami prediction and real-time evaluation should include also the accurate quantitative measurement and cataloguing of all the meaningful tsunami source parameters, including seismic and geophysical precursory phenomena, historical data, as well as the techniques for integrating and processing this diverse data into a meaningful scheme of pattern recognition. This methodology of "historical tsunami determinism", as he labeled it, will require the development of an extensive and standardized historical tsunami data base which should include also seismic, geophysical and geological parameters, non-existent in present data bases, as for example, data on focal mechanisms and power spectra of seismic waves of tsunamigenic earthquakes. Finally, in concluding, Dr. Pararas-Carayannis suggested that a wealth of data exists but needs to be properly collected, organized and shared by all those who have interest in tsunami warning systems, and in tsunami disaster mitigation.

9. GENERAL DISCUSSION AND ADOPTION OF RECOMMENDATIONS

Following the conclusion of the presentations, an open forum was called by the Chairman, urging a general exchange of views among lecturers and participants for the purpose of identifying action items and problems which may have been brought into focus during the conduct of the Workshop. Furthermore, the Chairman requested an analytical and constructive discussion of existing problems and the means by which such problems can be overcome. As a result of this exchange of views, a number of operational problems were discussed and resolved, or will be resolved by agreed-upon follow-up action and the recommendations of the Workshop were formulated.

An appraisal was undertaken by the lecturers and participants, expressing their views as to the overall conduct of the Workshop, the comprehensiveness of its programme and its usefulness. It was the consensus of opinion of all the participants that the Workshop was very well conducted, that it was properly balanced in its content and that there is a need to repeat such training at frequent intervals to keep up with new methodology, instrumentation and research progress.

Following the conclusion of the session, the recommendations were read by the Chairman and adopted by the participants (Annex II). **The Workshop gave** editorial license to the Chairman to finalize a Summary Report of the Proceedings. **The Workshop furthermore recommended** that its Report be published by the IOC in its Workshop Series in two parts, as agreed: The Summary Report proper and a Supplement containing the full selected papers presented at the Workshop.

10. CLOSURE OF THE SESSION

The Chairman expressed his satisfaction at the successful outcome of the Workshop. He thanked all the lecturers and participants for their valuable contributions and co-operation and congratulated them for having arrived at such important conclusions and recommendations.

On behalf of the participants, he expressed his special thanks to the Soviet authorities and to the USSR Academy of Sciences for hosting the meeting, to the Director of the Computing Center of the Siberian Division of the USSR Academy of Sciences, Academician A.S. Alekseev, who also served as Chairman of TSUNAMI 89 Organizing Committee, and to the Secretary of the Committee, Dr. V. Gusiakov and the staff of the Computing Centers at Akademgorodok and Krasnoyarsk, for coordinating local arrangements which contributed to the success of the Workshop. A spokesperson for the Group expressed appreciation to all the lecturers for their presentations and thanked the Workshop Chairman, Dr. Pararas-Carayannis, for his outstanding direction of the overall Workshop programme. Furthermore, the Group thanked Mr. R. Hagemeyer, Chairman of ICG/ITSU, and Dr. A. Tolkachev, Senior Assistant Secretary of IOC, and asked him to extend the Group's appreciation to the IOC Secretary, Dr. G. Kullenberg, for the Secretariat's support and for the Commission's sponsorship of the Second IOC Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation.

ANNEX I

PROGRAMME OF THE WORKSHOP

1. OPENING OF THE WORKSHOP

2. INTERNATIONAL COOPERATION IN THE FIELD OF TSUNAMI RESEARCH AND WARNING

   2.1 International Cooperation in the Field of Tsunami Research and Warning, (G. Pararas-Carayannis)

3. SURVEY OF EXISTING TSUNAMI WARNING CENTERS - PRESENT STATUS, RESULTS OF WORK, PLANS FOR FUTURE DEVELOPMENT

   3.1 Pacific Tsunami Warning Center (G. Burton)
   3.2 Hawaii Regional Tsunami Warning System (G. Burton)
   3.3 Alaska Regional Tsunami Warning Center (T. Sokolowski)
   3.4 Japan Tsunami Warning Center (N. Hamada)
   3.5 USSR Tsunami Warning Center (B. Kuznetsov)
   3.6 French Polynesia Tsunami Warning Center (J. Talandier)
   3.7 Chile Tsunami Warning Center (E. Lorca)
   3.8 Tsunami Watches and Warnings in Fiji (G. Prasad)
   3.9 Assessment and Mitigation of the Tsunami Hazard in the Mediterranean Area (S. Tinti)

4. SURVEY OF SOME EXISTING SEISMIC DATA PROCESSING SYSTEMS AND FUTURE PROJECTS

   4.1 Operative Seismic Data Processing in the NEIC and Plans for the New US National Seismic Network (J. Dewey)

   4.2 POSEIDON Project - its Application to the Better Understanding of Nature of the Interplate Earthquakes (R. Geller)

5. METHODS FOR FAST EVALUATION OF TSUNAMI POTENTIAL AND PERSPECTIVES OF THEIR IMPLEMENTATION

   5.1 A Review of Earthquake Prediction Methods (G. Pararas-Carayannis)

   5.2 Mm: A Variable-Period Mantle Magnitude (J.Talandier, E. Okal)

   5.3 On Earthquake Tsunami Generation Criteria (A. Ivashchenko, A. Poplavsky, S. Soloviev)

   5.4 The Feasibility of Measuring the Low Frequency T Phase for Tsunami Warnings (S. Iwasaki)

   5.5 Application of New Numerical Methods for Near-Real Time Tsunami Height Prediction (V. Gusiakov, An. Marchuk, V. Titov)

   5.6 The Goal and Efficiency of the Automated Tsunami Warning System Project in the Far East of the USSR (I. Kuzminykh, M. Malyshev, A. Metalinkov)

5.7 Integrated Warning System for Tsunami and Storm Surges in China (H. Yang)

6. **TSUNAMI DATA BASES**

6.1 An Automated Tsunami Catalog.
(A. Bobkov, C. Go, N. Zhigulina, K. Simonov)

6.2 Tsunami Data Base for British Columbia Tsunami Warnings. (T. Murty, W. Rapatz.)

6.3 Historical Approach to the Study of Tsunamis: Recent U.S. Results. (J. Lander.)

6.4 The Development of Numerical Simulation of Tsunami Waves at the Computing Center at Krasnoyarsk (Yu. Shokin, L. Chubarov, V. Novikov, A. Sudakov, K. Simonov)

7. **TSUNAMI INSTRUMENTATION AND OBSERVATION**

7.1 A Long-term Deep Ocean Tsunami Measurement Program: Strategy and Instrumentation (F. Gonzalez, E. Bernard, H. Milburn, D. Mattens)

7.2 Tsunami Observations Using Ocean Bottom Pressure Gauge (M. Okada, M. Katsumata)

7.3 Offshore Tsunami Warning Station - MEGA
(G. Rybin)

7.4 Re-Use Plan of Commercial Submarine Communication Cable for Geophysical Research (J. Kasahara)

8. **TSUNAMI PREPAREDNESS**

8.1 Tsunamis of the 21st Century (G. Pararas-Carayannis)

9. **GENERAL DISCUSSION AND ADOPTION OF RECOMMENDATIONS**

10. **CLOSURE OF THE SESSION**

ANNEX II

RECOMMENDATIONS

Recommendation 1

CO-OPERATION BETWEEN IUGG/TSUNAMI COMMISSION AND IOC/ITSU

The Workshop,

Recognizing that the majority of tsunami damages to human community occurs within 30 minutes and 400 kms of its source,

Recognizing further that sufficient scientific knowledge and technical expertise is currently available to develop appropriate early tsunami warning systems,

However, **recognizing also** that many difficulties exist both in transferring scientific results to operational procedures and in communicating operational requirements to research communities,

Considering the objectives of the UN International Decade on Natural Disaster Reduction (IDNDR) and the need for international and interdisciplinary co-operation in mitigation of tsunami hazards,

Recommends that an *ad hoc* Joint IUGG/Tsunami Commission - IOC/ITSU Group of Experts be formulated with objectives of:

(i) formulating a project on tsunami disaster mitigation as a contribution to the International Decade on Natural Disaster Reduction;

(ii) providing adequate advice on implementation of the project to both sponsoring organizations;

Recommends also that IUGG and IOC seek possibility to hold a Joint Scientific and Technical Seminar on Mitigation of Tsunami Hazard in 1990/91.

Recommendation 2

THE NEED FOR CO-OPERATION BETWEEN ITSU AND THE FEDERATION OF DIGITAL BROADBAND SEISMOGRAPH NETWORKS (FDSN)

The Workshop,

Understanding that the Tsunami community now recognizes the importance of broadband, wide-dynamic range seismic waveform data for issuing tsunami warnings and that it is therefore moving rapidly to establish real-time seismic networks,

Recognizing that the international earthquake seismology community has established a consensus on the importance of broadband, wide-dynamic range seismic waveform data for studying: (i) the three dimensional distribution of elastic and anelastic properties of the earth's interior; and (ii) the details of the earthquake source process. Through IASPEI, the earthquake seismology community has established the FDSN for the purpose of (1) establishing standards for broadband seismic stations (2) establishing formats and procedures for data exchange; and (3) co-ordinating the plans of various networks to avoid unnecessary duplication of effort,

Furthermore, recognizing that even if limitations on telemetry do not permit the transmission of the full bandwidth, the broadband data should be recorded on tape and sent to the data center rather than being discarded,

Considering that in general the members of ITSU have excellent liaison with earthquake seismologists in their own country. However, on an international level, at present, there is no formal liaison between ITSU and FDSN.

Considering also that a real-time seismic network for tsunami warning also is a real-time network that permits accurate and almost instantaneous determination of the source parameters of all damaging earthquakes, anywhere in the world; a goal of tremendous importance for disaster relief authorities, which can greatly contribute to the goals of IDNDR.

Recommends that formal liaison between ITSU and FDSN should be established for their mutual benefit, and that when seismic stations are being established by ITSU Member States in support of Tsunami Warning Systems, FDSN Members should, whenever possible, be advised of this fact so that they may have the opportunity to investigate the feasibility of upgrading the stations to meet FDSN standards for broadband stations.

Recommendation 3

TSUNAMI WARNING SYSTEMS IN OTHER REGIONS

The Workshop,

Considering (i) that tsunamis have occurred in the past in areas of the globe other than the Pacific also; (ii) that some of these tsunamis were reported to be highly disastrous resulting in great property damage and considerable catastrophic life loss; (iii) that growing world population, increasing urban concentration and larger investment in the infrastructure of societies are taken place nowdays particularly along the coastal regions and are expected to grow in the future; (iv) the important role played by ITSU towards international co-operation in tsunami research and tsunami warning systems; and (v) the important experience and archievement gained by actual ITSU member stastes and the needs to transfer such experience to other countries concerned with tsunami hazards,

Recommends that ITSU strongly urges the IOC to encourage the establishment of organizations similar to ITSU to address the needs of other Tsunami-prone areas and to offer ITSU technical advice to these new organizations to facilitate their establishment and the development of Tsunami Warning Centers within their area of responsibility.

ANNEX III

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ANNEX IV

LIST OF ACRONYMS

ATWC	Alaska Tsunami Warning Center
BPR	Bottom Pressure Recorder
CPPT	French Polynesia Tsunami Warning Center
DCP	Data Collection Platforms
DOM	Deep Ocean Model
EPOS	Earthquake Phenomena Observation System
EMSEC	Emergency Services Committee
EWS	Emergency Warning System
FDSN	Federation of Digital Broadband Seismograph Networks
GOES	Geostationary Orbital Environmental Satellites
IOC	Intergovernmental Oceanographic Commission
ICG/ITSU	International Co-ordination Group for the Tsunami Warning System in the Pacific
IDNDR	International Decade of Natural Disaster Reduction
ITIC	International Tsunami Information Center
IUGG	International Union of Geodesy and Geophysics
JMA	Japan Meteorological Agency
NEIC	National Earthquake Information Center
NOAA	National Oceanic and Atmospheric Administration
OBS	Ocean Bottom Seismograph
PMEL	Pacific Marine Environmental Laboratory
POSEIDON	Pacific Orient Seismic Digital Observation Network
PTWC	Pacific Tsunami Warning Center
THRUST	Tsunami Hazard Reduction Utilizing System Technology
TWS	Tsunami Warning System

IOC Workshop Reports

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No.	Title	Languages
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2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (UNESCO Technical Paper in Marine Sciences, No. 20).	E (out of stock) S (out of stock)
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5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975.	E (out of stock) S
6	Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975.	E
7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO(IOFC)/UNESCO/EAC, Nairobi, Kenya, 25 March-2 April 1976.	E, F, S, R
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	E (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	E, F, S, R
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	E, F, S (out of stock) R
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11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	E (out of stock), S
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique, 28 November-2 December 1977.	E, F, S
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	E, F
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	E (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	E, F, R
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	E
17 Suppl.	Papers submitted to the Joint IOC/WMO *Seminar on Oceanographic Products and* the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (UNESCO reports in marine sciences, No. 4, published by the Division of Marine Sciences, UNESCO)	E (out of stock), F, S (out of stock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indon- a, 17-21 October 1978.	E
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	E, F, S, R
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	E, F, S, R
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27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	E
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes, Lima, 20 April-5 May 1980.	E
29	WESTPAC Workshop on Marine biological methodology, Tokyo, 9-14 February 1981.	E
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience, Heidelberg, 19-24 July 1982	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	E, F, S
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41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985	E
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44 Suppl.	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities *Submitted Papers*, Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	E
45	IOCARIBE Workshop on Physical Oceanography and Climate Cartagena, Colombia, 19-22 August 1986	E
46	Reunión de Trabajo para Desarrollo del Programa «Ciencia Oceanica en Relación a los Recursos No vivos en la Región del Atlantico Sudoccidental, Porto Alegre, Brazil, 7-11 de Abril de 1986	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence Townsville, 1-6 December 1986	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on "Ocean Science in Relation to Non-Living Resources (OSNLR)" Havana, Cuba, 4-7 December 1986	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on "El Niño" Guyaquil, Ecuador, 27-31 October 1986	E
50	CCAMLR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR) Paris, France, 2-6 June 1987	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations, Lae, Papua-New Guinea, 1-8 October 1987	E
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere, Paris, 6-10 May 1985	E
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