DATA COLLECTION SURVEY
ON THE OBSERVATION CAPACITY OF
EARTHQUAKES AND TSUNAMI
IN
CENTRAL AMERICA

FINAL REPORT

MARCH 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

JAPAN METEOROLOGICAL
BUSINESS SUPPORT CENTER

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ABBREVIATIONS

Abbreviations	Spanish	English
Nicaragua		
CODE	Centro de Operaciones de Desastres	Disaster Operation Center
CODEPRED	Comités Departamental de Prevención, Mitigación y Atención de Desastres	Departmental Disaster Prevention Committee
COLOPRED	Comités Locales de Prevención y Desastres	Local Disaster Prevention Committee
COMUPRED	Comités Municipales de Prevención, Mitigación y Atención de Desastres	Municipal Disaster Prevention and Reduction Committee
CNC	Cámara Nicaragüense de la Construcción	Society of Construction Industry of Nicaragua
INETER	Instituto Nicaragüense de Estudios Territoriales	Nicaraguan Institute of Territorial Studies
MINED	Ministerio de Educación	Ministry of Education
MTI	Ministerio de Transporte e Infraestructura	Ministry of Transport and Infrastructure
Co-Direcciones de SINAPRED	Co-Direcciones de Sistema Nacional para la Prevención, Mitigación y Atención de Desastres en Nicaragua	Co-Directions National System for Prevention, Mitigation and Attention of Disasters in Nicaragua
SINAPRED	Sistema Nacional para la Prevención,Mitigación y Atención de Desastres en Nicaragua	National System for Prevention, Mitigation and Attention of Disasters in Nicaragua
SNIP	Sistema Nacional de Inversión Pública	National public investigation system
UNAN	Universidad Nacional Autónoma de Nicaragua	National Autonomous University of Nicaragua
UNAN/CIGEO	Universidad Nacional Autónoma de Nicaragua,-Centro de Investigaciones Geocientíficas	National Autonomous University, Center for Geosciences Research
UNI	Universidad Nacional de Ingeniería	National University of Engineering
El Salvador		
ACODES	Asociación de Consultores de El Salvador	Consultants Association of El Salvador
CCPC	Comision Comunal de Proteccion Civil	Community Civil Protection Committee
CDPC	Comision Departmental de Proteccion Civil	Departmental Civil Protection Committee
CEL	Comisión Ejecutiva Hidroeléctrica del Río Lempa	Hydroelectric Executive Committee of the Lempa River
CMPC	Comision Munincipal de Proteccion Civil	Municipal Civil Protection Committee
DACGER/MOP	Dirección de Adaptacion al Cambio Climatico y Gestión Estratégica del Riesgo, Ministerio de Obras Públicas, Transporte Vivienda y Desarrollo Urbano	Directorate for Climate Change Adaptation and Strategic Risk Management, Ministry of Public Works, Transport, Housing and Urban Development
DGOA/MARN	Dirección General del Observatorio Ambiental, Ministerio de Medio Ambiente y Recursos Naturales	Ministry of Environment and Natural Resources / Environmental Monitoring Division
DGPC	Dirección General de Protección Civil	General Directorate for Civil Protection
FUNDASAL	Fundación Salvadoreña de Desarrollo y Vivienda Mínima	Salvadoran Foundation for Development and Minimum Housing
ISC	Instituto Salvadoreño de la Construcción	Salvadoran Institute of Building Construction
ISDEM	Instituto Salvadoreño de Desarrollo Municipal	Salvadoran Institute for Municipal Development
MARN	Ministerio de Medio Ambiente y Recursos Naturales	Ministry of Environment and Natural Resources
MOPTVDU	Ministerio de Obras Públicas, Transporte Vivienda y Desarrollo Urbano	Ministry of Public Works, Transportation, Housing and Urban Development
SAV	Secretaría de Asuntos de la Vulnerabilidad	Secretariat of Vulnerability Affairs

UCA	Unversidad Centroamericana	Central American University
UES	Unversidad de El Salvador	University of El Salvador
VMVDU	Ministerio de Obras Publicas, Vice Ministeriode Vivienda y Desarrollo Urbano	Ministry of Public Works, Vice Ministry of Housing and Urban Development
Guatemala		
CEDESYD	Centro de Estudios de Desarrollo Seguro y Desastres	Center for the Study of Safe Development and Disasters
CESEM	Centro de Estudios Superiores en Energía y Minas	Center for Advanced Studies in Energy and Mines
CIG	Colegio Ingenieros de Guatemala	Guatemala Professional Engineers Association
CNEE	Comisión Nacional de Energía Eléctrica	National Commission for Electric Energy (Power)
COLRED	Local de Coordinación Institucional para la Reducción de Desastres	Institutional Coordination for Disaster Reduction
CONAP	Consejo Nacional de Areas Pretegidas	National Council for Protected Areas
CONRED	Coordinadora Nacional para la Reducción de Desastres	National Coordinator for Disaster Reduction
CORRED	Regional de Coordinación Institucional para la Reducción de Desastres	Regional Institutional Coordination for Disaster Reduction
COMPRED	Municipal de Coordinación Institucional para la Reducción de Desastres	Municipal Institutional Coordination for Disaster Reduction
ECORED	Equipamiento de la Comunidad para Reducción de Desastres	Community Equipment for Disaster Reduction
INAB	Instituto Nacional de Bosques	National Institute of Forests
INFOM	Instituto de Fomento Municipal	Municipal Development Institute
INSIVUMEH	Instituto Nacional de Sismología,Vulcanología, Meteorología e Hidrología	National Institute of Seismology, Volcanology, Meteorology and Hydrology
MAGA	Ministerio de Agricultura, Ganadería y Alimentación	Ministry of Agriculture, Livestock and Food (Feeding)
MEM	Ministerio de Energía y Minas	Ministry of Energy & Mines
MICIVI	Ministerio de Comunicaciónes, Infraestructura y Vivienda	Ministry of Communications, Infrastructure and Housing
MICUDE	Ministerio de Cultura y Deportes	Ministry of Culture & Sports
MINEDUC	Ministerio de Educación	Ministry of Education
MINGOB	Ministerio de Gobernación	Ministry of the Interior
MP	Ministerio Público	Public Ministry (Office of the Attorney General)
MSPAS	Ministerio de Salud Pública y Asistencia Social	Ministry of Public Health & Social Welfare
SCEP	Secretaría de Coordinación Ejecutiva de la Presidencia	Secretariat of the Executive Coordination of the Presidency (Office of the President)
SE-CONRED	Secretaría Ejecutiva - Coordinadora Nacional para la Reducción de Desastres	Executive Secretariat-National Coordinating Agency for Disaster Reduction
SEGEPLAN	Secretaría de Planificación y Programación	Economic Planning Agency
SESAN	Secretaría de Seguridad Alimentaria y Nutricional	Secretariat of Food & Nutritional Security
SOSEP	Secretaría de Obras Sociales de la Esposa del Presidente	Secretariat for Social Works of the Wife of the President
UNIRIOS	Unidad de Manejo de Ríos y Canales, Dirección General de Caminos, Ministerio de Comunicaciones, Infraestructura y Vivienda	Unit of River and Road, Directorate General Road, Ministry of Communications, Infrastructure and Housing
USAC	Universidad de San Carlos	University of San Carlos
Costa Rica		
CCE	Comités Comunales de Emergencia	Public Emergency Committee
CFIA	Colegio Federado de Ingenieros y Arquitectos	Federated Association of Engineers and Architects
CLE	Comité Local de Emergencia	Local Emergency Committee

CME	Comité Mnicipal de Emergencia	Municipal Emergency Committee
CNE	Comisión Nacional de （Prevención de Riesgos y Atención de） Emergencias	National Emergency Commission (Risk Prevention and Attention)
CONARE	Consejo Nacional de Rectores	National Chancellor Council
CRE	Comités Regionales de Emergencia	Regional Emergency Committee
DINADECO	Dirección Nacional de Desarrollo de Comunidades	National Directorate of Community Development
ICE	Instituto Costarricense de Electricidad	Institute of Electricity Costa Rica
IFAM	Instituto de Fomento y Asesoría Municipal	Institute of Municipal Development and Assistance
INVU	Instituto Nacional de Vivienda y Urbanismo	National Institute of Housing and Urban Planning
ITCR	Instituto Tecnologico de Costa Rica	Technology Institute of Costa Rica
LIS	Liboratorio de Ingeneria Sismica	Seismic engineering laboratory
MEP	Miusterio de Educacion Publica	Ministry of Public Education
MIDEPLAN	Ministerio de Planificación Nacional y Política Económica	Ministry of National Planning and Economic Policy
MINAE	Ministerio de Ambiente y Energia	Ministry of Environment and Energy
MIVAH	Ministerio de Vivienda y Asentamientos Humanos	Ministry of Housing and Human Settlements
MOPT	Ministerio de Obras Públicas y Transportes	Ministry of Public Work and Transportation
FNE	Fondo Nacional de Emergencia	National Emergency Fund
OVSICORI(UNA)	Observatorio Vulcanológico y Sismológico de Costa Rica （Universidad Nacional de Costa Rica）	Volcanological and Seismological Observatory of Costa Rica (National University of Costa Rica)
PREVENTEC	Programa de Información Científica y Tecnológica Satelital al Servicio de la Prevención y Mitigación de los Desastres, Universidad de Costa Rica	Scientific and Technological Satellite Information Program at the Service of Disaster Prevention and Mitigation, University of Costa Rica
PRUGAM	Planificación Regionall Urbana del Gran Área Metropolitana	Planning of Regional Urban of Metropolitan Area
RSN	Red Sismologica Nacional	National Seismological Network
SINAMOT(UNA)	Sala de Monitoreo de Tsunami	Tsunami Monitoring Room
SNGR	Sistema Nacional de Gestión de Riesgos	National Risk Management System
UCR	Universidad de Costa Rica	University of Costa Rica
UNA	Universidad Nacional de Costa Rica	National University of Costa Rica
UNED	Universidad Estatal a Distancia de Costa Rica	Estate Correspondence Education University of Costa Rica
UNGL	Unión Nacional de Gobiernos Locales	National Union of Local Governments
Panama		
ACP	Authoridad del Canal de Panamá	Panama Canal Authorities
AMP	Autoridod Maritima de Panama	Panama Maritime Authorities
ANAM	Autoridad Nacional del Ambiente	Panama Environment Authorities
CONAMA	Comisión Nacional del Medio Ambiente	Panama Canal Authorities
ETESA	Empresa de Transmisión Eléctrica, S.A.	Electric Transmission Company, Inc.
IGC-UPA	Universidad de Panamá, Instituto de Geociencias	University of Panama, Institute of Geosciences
SINAPROC	Sistema Nacional de Protección Civil	National Civil Protection System
SE-SINAPROC	Secretaría Ejecutiva - Sistema Nacional de Protección Civil	Executive Secretariat - National Civil Protection System
SENACYT	Secretaría Nacional de Ciencia, Tecnología e Innovación	National Secretariat of Science,Technology and Innovation
SPIA	Sindicato Panameño de Ingenieros y Arquitectos	Panamanian Union of Engineers and Architects
UDELAS	Universidad Especializada de las Américas	Specialize University of the Americas
UMIP	Universidad Marítima Internacional de Panamá	International Marine University of Panama
UNACHI	Universidad Autónoma de Chiriquí	Chiriquí Autonomous University
UP	Universidad de Panamá	Panama University

UTP	Universidad Tecnológica de Panamá	University of Technology of Panama
Honduras		
AMHON	Asociación de Municipios de Honduras	Association of Municipalities of Honduras
CICH	Colegio de Ingenieros Civiles de Honduras	College of Civil Engineers of Honduras
CODEL	Comité de Emergencia Local	Local Emergency Committee
CODEM	Comité de Emergencia Municipal	Municipal Emergency Committee
COPECO	Comisión Permanente de Contingencias	Permanent Commission of Contingencies
FHIS	Fondo Hondureño de Inversión Social	Honduran Social Investment Fund
FONAPRE	Fondo Nacional de Preparación y Respuesta a Emergencias	National Fund for Emergency Preparation
IGH	Instituto de Geociencia de Honduras	Honduras Institute of Geoscience
SEPLAN	Secretaría Técnica de Planificación y Cooperación Externa	Ministry of Planning and International Cooperation
SERNA	Secretaría de Recursos Naturales y Ambiente	Ministry of Natural Resources and Environment
SINAGER	Sistema Nacional de Gestión de Riesgo	National System for Risk Management
SMN	Servicio Meteorológico Nacional	National Weather Service of Honduras
SOPTRAVI	Secretaría de Obras Públicas, Transporte y Vivienda	Ministry of Public Works, Transportation and Housing
UNAG	Universidad Nacional de Agricultura	National University of Agriculture
UNAH/IHCIT	Universidad Nacional Autónoma de Honduras / Instituto Hondureño de Ciencia de la Tierra	National Autonomous University of Honduras / Honduran Institute of Earth Science
UPI	Universidad Politécnica de Ingenieria	Honduras University of Engineering
UPNFM	Universidad Pedagógica Nacional Francisco Morazan	National Education University of Francisco Morazan
International Organization		
DIPECHO	Programa de Preparación antes los desastres de ECHO （El Departamento de Ayuda Humanitaria de la Comisión Europea）	Disaster Preparedness Program of the European Commission
EC	Comisión Europea	European Commission
ECHO	El Departamento de Ayuda Humanitaria de la Comisión Europea	European Commission's Humanitarian Aid Department
ECLAC(CEPAL)	Economic Commission for Latin America and the Caribbean （Comisión Económica para América Latina y el Caribe）	Economic Commission for Latin America and the Caribbean
EU	Unión Europea	European Union
FAO	Fondo de las Naciones Unidas para la Agricultura y la Alimentación	Food and Agriculture Organization
GFDRR	Facilidad Global para la Reducción y Recuperación de Desastres	Global Facility for Disaster Reduction and Recovery
ICG/PTWS		Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System
IDB	Banco Interamericano de Desarrollo	Inter-American Development Bank
NOAA	Administración Nacional de Océano y Atmósfera	National Oceanic and Atmospheric Administration
OAS	Organización de Estados Americanos / Organization of American States	Organization of American States
OCHA	United Nations Office for the Coordination of Humanitarian Affairs	United Nations Office for the Coordination of Humanitarian Affairs
PAHO	Organización Salud de PanAmerican	Pan American Health Organization
PASB	Buró Sanitario de PanAmerican	Pan American Sanitary Bureau
UNDP	Programa de las Naciones Unidas para el Desarrollo	United Nations Development Program
UNDESCO	Organización de las Naciones Unidades para la Educación, Ciencias y Cultura	United Nations Educational, Scientific and Cultural Organization

UNESCO/IOC	Organisation des Nations unies pour l'éducation, la science et la culture Commission océanographique intergouvernementale	Intergovernmental Oceanographic Commission UNESCO
UN-HABITAT	Programa de Naciones Unidas para los Asentamiento Humanos	United Nations Human Settlements Program
UNICEF	Fondo de las Naciones Unidas para la Niñez y la Infancia	United Nations International Children/s Fund
UN-ISDR	Plataformas Nacionales Para la Reducción del Riesgo de Desastres	United Nations - International Strategy for Disaster Reduction
WB	Banco Mundial	World Bank
WHO	Organización Mundial de la Salud	World Health Organization
Central American and Caribbean Regional Institute/Organization		
BCIE	Banco Centroamericano de Integración Económica	Central American Bank for Economic Integration
CCAD	Comisión Centroamericana de Amobiente y Desarrollo	Central American Commission on the Environment and Development
CCJ	Corte Centroamericana de Justicia	Central American Court of Justice
CCP	Centro Centroamericano de Población	Central American Population Center
CNEPROMYPE	Convenio Constitutivo del Centro para la Formación de la Micro y Pequeña Empresa en Centroamérica	Central American Agreement for Micro and Small Enterprise
CFR-SICA	Consejo Fiscalizador Regional	Regional Prosecution Council
CRRH	Comité Regional de Recursos Hidrálicos	Central American Commission on Water Resources
CCHAC	Comité de Cooperación de Hidrocarburos de América Central	Committee for Cooperation on Hydrocarbon in Central America
CCVAH	Consejo Centroamericano de Vivienda y Asentamientos Humanos	Central American Council of Housing and Urban Settlements
CDEMA	Agencia para el Manejo de Emergencias de Desastres en el Caribe	Caribbean Disaster Emergency Management Agency
CEAC	Consejo de Electrificación de América Central	Central American Council of Electrification
CECC	Central American Education and Cultural Coordination	Central American Education and Cultural Coordination
CENTROESTAD	Comisión Centroamericana de Estadística del SICA	Central American Statistical Commission of SICA
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central	Coordination Center for Natural Disaster Prevention in Central America
CISSCAD	Consejo de Institutos de Seguridad Social de Centroamérica y República Dominicana	Council of Social Security Institutions in Central America and the Dominican Republic
COCATRAM	Comisión Centroamericana de Transporte Marítimo	Central American Commission of Marine Transport
COCESNA	Corporación Centroamericana de Servicios de Navegación Aérea	Central American Aerial Navigation Services Corporation
CODIADER	Consejo del Istmo Centroamericano de Deportes y Recreación	Central American Council of Sports and Recreations
CONCADECO	Consejo Centroamericano de Protección al Consumidor	Central American Council of Consumer Protection
COMISCA	Consejo de Ministros de Salud de Centroamérica	Council of Ministers of Health of Central America
COMTELCA	Comisión Técnica Regional de Telecomunicaciones de Centro América	Central American Regional Technical Commission of Telecommunication
COSEFIN	Consejo de Ministros de Hacienda o Finanzas de Centroamérica	Minister of Treasury and Finance Council of Central America
CRID	Centro Regional de Información sobre Desastres para América Latina y El Caribe	Regional Center for Disaster Information Latin America and the Caribbean
CRIE	Coordinadora Regional de Investigaciones Economicas y Sociales	Regional Coordinator of Economics and Socials Investigation
CSUCA	Consejo Superior Universitario Centroamericano	Central American University Superior Council

CTCAP	Comisión para el Desarrollo Científico y Tecnológico de Centro América y Panamá	Commission of Science and Technology Development of Central America and Panama
CTPT	Comisión Trinacional del Plan Trifinio	Tri-national Commission of El Salvador, Guatemala and Honduras
EOR	Ente Operador Regional	Regional Operator Entity
FOCAR-APS	Fondo Centroamericano y República Dominicana de Agua Potable y Saneamiento	Central American and Dominican Republic Potable Water and Sanity Fund
ICAP	Instituto Centroamericano de Administración Pública	Central American Institute of Public Administration
INCAP	Instituto de Nutrición de Centro América y Panamá	Central American and Panama Institute of Nutrition
OCAM	Comisión Centroamericana de Directores de Migración	Central American Organization for Migration
OSPESCA	Organización del Sector Pesquero y Acuícola del Istmo Centroamericano	Fisheries and Aquatic Organization of Central America
PARLACEN	Parlamento Centroamericano	Central American Parliament
SE-CCAD	Comisión Centroamericana de Ambiente y Desarrollo	Executive Secretariat - Central American Commission of Environment and Development
SE-CEPREDENAC	Secretaría Ejecutiva del Centro de Coordinación para la Prevención de los Desastres Naturales en América Central	Executive Secretariat of the Coordination Center for the Prevention and Mitigation of Natural Disasters in Central America
SE-CMCA	Secretaría Ejecutiva del Consejo Monetario Centroamericano	Executive Secretariat of Central American Currency Council
SG-CECC	Secretaría General de la Coordinación Educativa y Cultural Centroamericana	General Secretariat of Central American Education and Culture
SG-SICA	Secretaría General del Sistema de la Integración Centroamericana	General Secretariat of the Central American Integration System
SICA	Sistema de la Integración Centroamericana	Central American Integration System
SIECA	Secretaría de Integración Económica Cetroamericana	Secretariat of Central American Economic Integration
SISCA	Secretaría de la Integración Social Centroamericana	Secretariat of Social Integration of Central America
SITCA	Secretaría de Integración Turística Centroamericana	Secretariat of Tourist Integration for Central America
Bilateral Donors		
AECID	Agencia Española de Cooperación Internacional para el Desarrollo	Spanish Agency for International Development
AOS	Ayuda Obrera Suiza	Swiss Labour Assistance
COSUDE	Agencia Suiza para el Desarrollo y la Cooperación	Swiss Agency for Development and Cooperation
DANIDA	Danish International Development Agency	Danish International Development Assistance
DFID	Departamento de Desarrollo Internacional del Reino Unido	The Department for International Development, UK
GIZ	Agencia Alemana de Cooperación Internacional	Die Deutsche Gesellschaft für Internationale Zusammenarbeit
JICA	Agencia de Cooperación Internación del Japón	Japan International Cooperation Agency
NORAD	Agencia Noruega para la Cooperación al Desarrollo	Norwegian Aid Agency
OFDA	Oficina de los Estados Unidos de Asistencia para Desastres en el Extranjero	Office of US Foreign Disaster Assistance
USAID	Agencia para el Desarrollo Internacional de los Estados Unidos	U.S. Agency for International Development
International Earthquake and Tsunami Observation Organization		
GEOFON		Global Seismological Broad-band Network
GFDRR		Global Facility for Disaster Reduction and Recovery

GFZ		German Research Centre for Geosciences
IRIS		Incorporated Research Institutions for Seismology
NOAA/NGDC		National Oceanic and Atmospheric Administration National Geophysical Data Center
NWPTAC		Northwest Pacific Tsunami Advisory Center
PDC		Pacific Disaster Center
PTWC		Pacific Tsunami Warning Center
USGS		US Geological Survey
Definition of terms of tsunami		
Local Tsunami	A tsunami in which its destructive effects are confined to the coast of country within 5 to 30 minutes from the time of the nearby event source	
Regional Tsunami	A tsunami capable of destructive effects which are confined to the coasts within 30 minutes to 2 hours from the time of the event offshore of Central America.	
Distant Tsunami	A tsunami capable of destructive effects which are confined to the coasts more than 2 hours from the time of event outside of Central America.	

1. Summary of the Survey

1.1. Background of the Survey

The Central America region (Nicaragua, El Salvador, Guatemala, Costa Rica, Panama, and Honduras) is located in the south-western limit of the Caribbean Plate, is frequently impacted by earthquakes as the Cocos Plate subducts under the Caribbean Plate, While the region is adjacent to the northern edge of South American Plate.

Additionally, there are concerns of local or Regional Tsunamis since the plate boundary is close to the region. In the past two decades, an earthquake of Magnitude(M) 7.0 occurred inshore of Nicaragua in 1992, a tsunami was created which caused many deaths and missing people, and serious economic damage, while another earthquake of M6.9 occurred in El Salvador which also caused serious economic damage.

Consequently, Nicaragua proposed the establishment of the Central American Tsunami Alert Center (CATAC) in the Nicaraguan Institute of Territorial Studies (INETER) on the occasion of a meeting of the Regional Working Group for Central America of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) which is a subordinate of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and has been coordinating toward its realization.
In this situation, the government of Nicaragua requested the technical cooperation project of the Japanese Government for the purpose in which INETER becomes an exhibit as an appropriate function as CATAC

On the other hand, the government of El Salvador has proposed the dispatch of JICA experts to strengthen the analysis capacity of the personnel of Environmental Monitoring Division in Ministry of Environment and Natural Resources (MARN/DGOA) while the seismic and tide gauge system was improved utilizing the Japanese grant aid"The Project for the Improvement of Equipment for Disaster Risk Management".

For the purpose of the capacity development for analysis of earthquake sand tsunamis proposed by the two countries above, the coordination for an information sharing system is required in the Central American region, since it is necessary to collect the data regionally. Additionally, in performing the project being proposed above, it is necessary to effectively and efficiently corporate considering the basic principles that are beneficial to adjoining countries, since the Japanese human resources in this field of earthquake and tsunami observation is limited.

Thereby, this research was conducted to survey the situation and issues on the observation capacity of earthquakes and tsunamis considering the expectation to CATAC of six Central American countries including Nicaragua and El Salvador to consult the contents of cooperation.

1.2. Purpose of the Survey

To consult the project formation of technical cooperation to Nicaragua and El Salvador, the objectives of this research targeting six counties, are i) to grasp a framework of data sharing and monitoring, ii) to grasp an actual system and issues in terms of dealing with data collection, analysis, issuance, and iii) to grasp technical issues in terms of data sharing for earthquake parameters (hypocenter and magnitude) and tidal waves.

1.3. Subject Organization of Investigation

CATAC is required to cooperate and coordinate with the Focal Point (FP) in each country of Central America that is appointed by UNESCO/IOC.

On the other hand, CEPREDENAC and National Contact (NC), which is in charge of disaster management administration in each country, are summarized in the framework of SICA.

From above, the JICA Expert Team had contact with the FP from the beginning of the investigation, explained about the project, and asked about earthquake and tsunami observation methods and systems. In addition, the JICA Expert Team asked NP about the current condition of a comprehensive disaster management and warming system.

Conditions of earthquake and tsunami observation facilities and warning and its communication with local governments were also examined. Furthermore, the JICA Expert Team interviewed SE-CEPREDDENAC, which is in Guatemala City and the coordinating network between the six countries, about the communication and coordination system.

Table 1.3.1 Disaster Management Related Organization of Each Country

Country	Organization
Nicaragua	FP:Instituto Nicaragüense de Estudios Territoriales (INETER) NC : Co-Direcciones de Sistema Nacional para la Prevención Mitigación y Atención de Desastres(Co-Direcciones de SINAPRED) The name was changed from Secretaría Ejecutiva to Co-Direcciones in 2014, the role is not changed dramatically)
El Salvador	FP : Ministerio del Ambiente y Recursos Naturales, Directora General del Observatorio Ambiental(MARN-DGOA) NC : Ministerio de Gobemación, Dirección General de Proteccion Civil y Prevención y Mitigación de Desastres(DGPC)
Guatemara	FP : Instituto NacionaI de Sismología, Vulcanología, Meteorología e Hidrología(lNSIVUMEH) NC : Secretaría Ejecutiva de la Coordinadora Nacional para La Reducción de Desastres (SE-CONRED)
Costa Rica	FP : MINAE,Sala de Monitoreo de Tsunamis(SINAMOT) (Related Organization: Observatorio Vulcanológico y Sismológico de Costa Rica(OVSICORI), Red Sismólogica Nacional(RSN), Laboratorio de Ingeniería Sísmica(LIS)) NC : Comisión Nacional de Prevención de Riesgos y Atención de Emergencias(CNE)
Panama	FP : Autoridad Marítima de Panamá(AMP) ,Unidad Ambiental, Instituto de Geosciencias de la Universidad de Panama NC: Secretaría Ejecutiva del Sistema Nacional de Proteccion Civil :(SE-SINAPROC)
Honduras	FP : Comision Permanente de Contingencias(COPECO) NC : COPECO
Central America	Secretaría Ejecutiva del Centro de Coordinación para la Prevención de los Desastres Naturales en América Central(SE-CEPREDENAC)

1.4. Member of JICA Expert Team

Members of the JICA Expert Team are shown on Table 1.4.1.

Table 1.4.1 Member of JICA Expert Team

Name	Charge	Company
Kiyotaka Owada	Project Manager／Warning System	Oriental Consultants Global Co., Ltd.
Shigeo Mori	Tsunami Observation	Japan Meteorological Business Support Center
Kempei Kojika	Earthquake Observation	Oriental Consultants Global Co., Ltd.

1.5. Schedule

Work in Central America was implemented between 16 November to 22 December 2014, and the JICA Expert Team visited Nicaragua, El Salvador, Guatemala, Costa Rica, and Panama. In each country, the FP, NC, Seismological and Tidal Observatory, and local disaster management organizations were investigated.

Table 1.5.1 Schedule

Date		Visited Organization, Activities
Work in Japan1 12 -15 November 2014		
Work in Central America1 16 November -22 December 2014		
Nicaragua 16-22 November 2014		
November	16(Sun)	Moving (Narita-Houston-Managua)
	17(Mon)	JICA Nicaragua Office
		FP: INETER
	18(Tue)	San Rafael del Sur Municipal Office (Alcaldía Municipal de San Rafael del Sur)
		NC: Co-Direcciones de SINAPRED Defensa Civil - CODE -
	19(Wed)	INETER
		Seismological observatory(Mt. MASAYA)
	20(Thu)	Tidal observatory（Corinto Port） Corinto Munincipal Office(Alcaldía Municipal de Corinto)
		Leon Munincipal Office(Alcaldía Municipal de Leòn)
	21(Fri)	San Rafael del Sur Municipal Office
		INETER, JICA Nicaragua Office
	22(Sat) 23(Sun)	Organizing materials, survey , Moving (Managua- San Salvador)
El Salvador 23-30 November 2014		
November	24(Mon)	JICA El Salvador Office FP: MARN/DGOA
	25(Tue)	University of El Salvador, School of Civil Engineering, Faculty of Architecture (Universidad de El Salvador , Escuela de Ingeniería Civil, Facultad de Ingeniería y Arquitectura)
	26(Wed)	Jiquilisco Municipal Office(Alcaldía Municipal de Jiquilisco) , CDPC, CMPC, CCPC, MARN/DGOA
	27(Thu)	NC: DGPC
		University of Central America, Department of Structural Mechanics, Faculty of Engineering (Universidad Centroamericana, Departamente de Mecanica Estructural, Facultad de Ingeniería)
	28(Fri)	Seismological Observatory（Laboratory in San Andrés） Tidal Observatory(La Libertad)
		MARN/DGOA, JICA El Salvador Office
	29(Sat) 30(Sun)	Organizing materials, survey, Moving (San Salvador- Guatemala City)
Guatemala 30 november-7 December 2014		
December	1(Mon)	JICA Guatemala Office
		FP: INSIVUMEH

	2(Tue)	Seismological Observatory（Mt. PACAYA） INSIVUMEH
	3(Wed)	NC: CONRED
	4(Thu)	INSIVUMEH
	5(Fri)	CEPREDENAC
		Santa Rosa Region Chiquimulilla City Placetas District
	6(Sat) 7(Sun)	Organizing materials, survey, Moving (Guatemala City- San Hose)
Costa Rica 7-11 December 2014		
December	8(Mon)	NC:CNE
		UNESCO/IOC
		MINAE
	9(Tue)	PREVENTEC
		RSN
		LIS
	10(Wed)	Tide gauge, Seismometer (Los Sueños) Puntarenas City Chacarita District
	11(Thu)	FP: SINAMOT, OVSICORI
		JICA Costa Rica Office Moving (San Hose- Panama City)
Panama 11-14 December 2014		
December	12(Fri)	FP: IGC-UPA
	13(Sat) 14(Sun)	Organizing materials, survey
	15(Mon)	FP:AMP
	16(Tue)	NC: SINAPROC
	16(Tue)	JICA Panama Office Moving (Panama City- Managua)
Nicaragua 17-20 December 2014		
December	17(Wed)- 19(Fri)	INETER
	20(Sat)- 22(Mon)	Moving (Managua-Houston-Narita)
Work in Japan2 23 December 2014- 10 January 2015		
Work in Central America 2 11-22 January 2015		
Honduras 11-18 January 2015		
January	11(Sun)	Moving(Haneda-Tegucigalpa)
	12(Mon)	JICA Honduras Office
		FP,NC: COPECO
	13(Tue)	Tegucigalpa City CODEM
		UNAH/IHCIT
	14(Wed)	Marcovia City Cedeño District Tide Gauge (San Lorenzo)
	15(Thu)	COPECO Seismological Observatory(Residencial Santa Cruz)
		CICH
	16(Fri)	COPECO
		JICA Honduras office
	17(Sat)	Organizing materials, survey
	18(Sun)	Moving (Tegucigalpa- San Sarvador)
El Salvador 18-21 January 2015		
	19(Mon)	MARN/DGOA、DGPC
	20(Tue)	Seismological Observatory (San Andrés) Tidal Observatory(La Libertad)
		MARN/DGOA
Nicaragua 21-24 January 2015		
	21(Wed)	Moving (San Salvador- Managua) Co-Direcciones de SINAPRED
	22(Thu)	INETER
	23(Fri)	Seismological Observatory(Mt. MASAYA) INETER
	24(sat), 25(Sun)	Moving (Managua –Haneda)
Work in Japan3 26 January -31 March 2015		

Figure 1.5.1 Map Showing Visited Place in Central America

2. Situation of Disaster Prevention System and Measures for Earthquake-Tsunami on the Central American Region

2.1. Nicaragua

2.1.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of Nicaragua is shown in the following table:

Table 2.1.1 Basic Information of Nicaragua

Area	Contents	Source
Population	6.08 million	2013, World Bank
GDP	11,26 billion USD	2013, World Bank
Area	130,370 ㎢ (Land Area: 119,990 ㎢) (landuse:Arable 14.57%、Cropland 1.76%、Other 83.66%)	2011, CIA World Fact Book
Administrative	15 Departments , Autonomous Regions	CIA World Fact Book
Geography	Flat terrain of volcanic origin on the Pacific Ocean side. Lowland of rainforest and pine forest in the Caribbean side Highland in central range (higher in the northern area)	Library of Congress Country Studies
Climatology	Basically high temperature and humidity. Pacific side has better weather than Caribbean side. The rainy season is from May to October, storms and hurricanes occur in July-October, especially on the Caribbean side.	Library of Congress Country Studies

(2) Basic Information of Natural Disasters

The Central America region is located on the western limit of the Caribbean Plate, surrounded by the North American, Cocos, Nazca and South American Plates. As the Cocos plate subducts under the Caribbean plate, and relative displacement has been occurring between the Caribbean Plate, the North American Plate, the South American Plate and the Nazca plate with each other, there is a high possibility of a huge earthquake and tsunami(Fig.2.1.1).

The North American-Caribbean Plates, the Cocos-Nazca Plates and the Caribbean-South American Plates plate are bounded by transcurrent faults respectively, and the Cocos Plate subducts under the Caribbean Plate, so that large quake occurs in the ocean which means there is a high possibility of causing a tsunami .

Many earthquakes in the region occur in the volcanic chain fault systems formed by plate subduction along the Pacific coastal range.

Nicaragua has been exposed to a variety of natural hazards such as earthquake-tsunamis, volcanic eruptions, floods, landslides, et.al.

Several destructive earthquakes in Nicaragua occurred in the past few decades, such as the 1972 Managua M6.2 earthquake which caused serious damages in Managua, and the 1992 M7 earthquake which occurred off the coastal area of the Pacific Ocean in Nicaragua and caused a tsunami at a height of about 10m that ran up to about 1km inland.

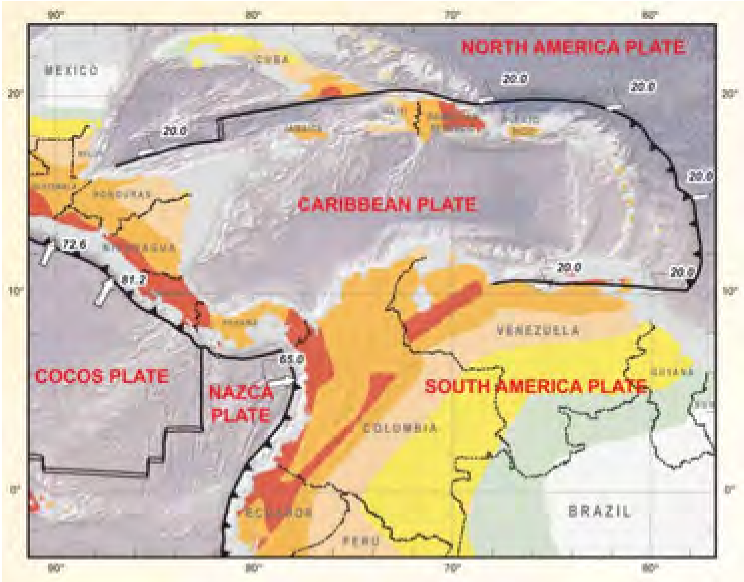

Figure 2.1.1 Tectonic map of Central America（Source： USGS）

Table 2.1.2 List of major earthquakes in the history of Nicaragua （Source：CRED /EM-DAT、NOAA/NGDC）

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)
1898/4/29	7.9	-	-	-	-
1906/2/4	-	Masaya	1,000	-	-
1931/3/31	5.6	Managua	1,000	-	15,000
1951/8/	-	-	500	-	-
1968/1/4	-	Managua	-	2,000	2,000
1972/12/23	6.2	Managua	10,000	720,000	845,000
1990/4/3	6.4	Rivas, Managua	-	-	-
1992/9/1	7.0	San Martin	179	6,179	25,000
1998/3/25	4.4	Ticuante area	-	238	-
2000/7/6	5.1	Laguna de Apoyo	7	7,477	-
2014/4/10	6.1	Managua	-	-	-

- means data is not available

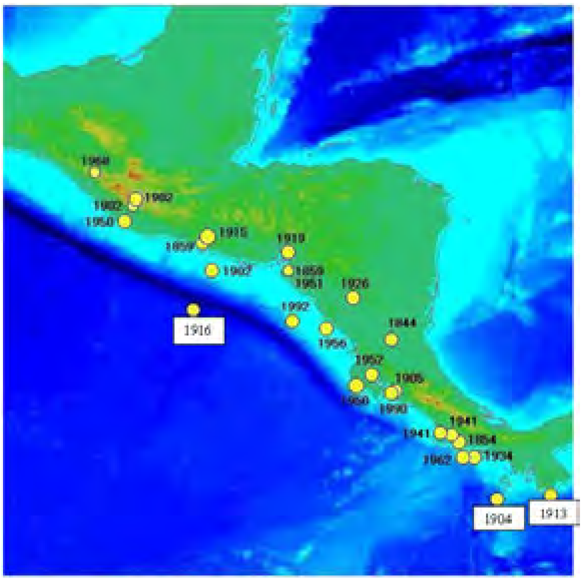

Figure 2.1.2 Epicenter of major earthquakes on the history of Nicaragua（Source：INETER）

2.1.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management(Policy, Organization)

1) Policy Framework on Disaster Management

Policy Framework on Disaster Management in Nicaragua is shown in the following table.

Table 2.1.3 Policy Framework on Disaster Management in Nicaragua

Category	Name	Contents
Policy	The National Policy Integrated Risk Management of Nicaragua	The policy indicates general principles of risk management countermeasures aiming at reducing the threat of natural phenomena, man-made and climate change affecting the security of citizens.
Law	Law 337	The law stipulates a National System for Prevention, Mitigation and Attention of Disasters (SINAPRED), and indicates the role and responsibility of organizations regarding prevention, mitigation, response and recovery as well as a function of SINAPRED as coordinator.
Plan	National Integrated Risk Management Plan (2010)	The plan is composed of risk analysis/management, prevention, information, land management, training/education, is under review in regard to add earthquakes and tsunamis to risk analysis, and the co-operation of inter-organization, between departments and municipalities.
	National Response Plan(2008)	The plan is composed of the responsibility of national and local organizations, response policy, coordination policy, is under review as a response plan for each disaster including earthquakes and tsunamis because it is not in correspondence of each disaster.

2) Framework of Disaster Prevention Organization

【1】Framework of Organization System

INETER implements the dissemination of disaster information, the formulation of hazard maps, and the collection of disaster information.

On the national level, the Co-Directions National System for Prevention, Mitigation and Attention of Disasters in Nicaragua (Co-Direcciones de SINAPRED) carry out the implementation of disaster management measures, the formulation of a national plan and the dissemination of warning on the national level, and the Defensa Civil covers the communication of disaster information and dissemination of alerts based on the law 337. The Defensa Civil covers emergency response as well. On the local level, the Departmental Committee of Prevention, Mitigation and Attention of Disasters (CODEPRED), Municipal Committee of Prevention, Mitigation and Attention of Disasters (COMUPRED), and Local Committee of Prevention, Mitigation and Attention of Disasters (COLOPRED) carry out disaster management measures on the department level, the municipality level, and the community level, respectively.

【2】Sharing Responsibility for Earthquake and Tsunami Disaster Prevention

INETER carries out observation on earthquakes and tsunamis, and formulate a hazard map of earthquakes and tsunamis.

As for alerts, the office of the president assesses the category of alerts, the Co-Direcciones de SINAPRED issues category of alert through the Disaster Operation Center（CODE：belongs to Defensa Civil）.

The Ministry of Transport and Construction (MTI) cover the enactment of standards for quake resistant construction.

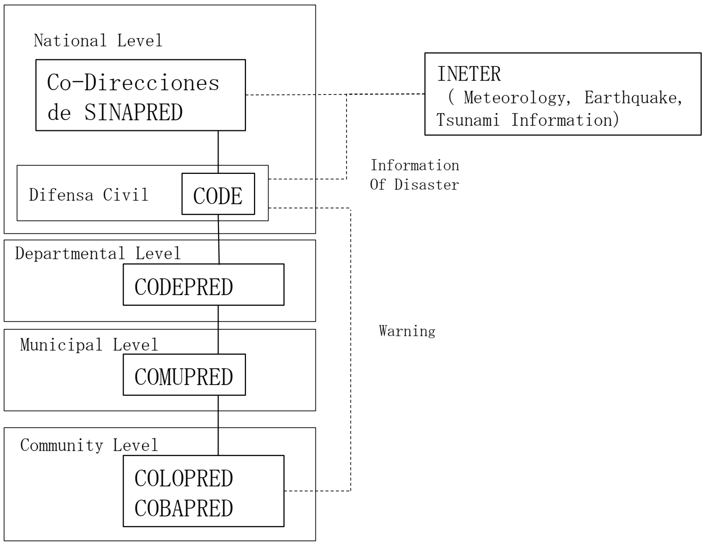

Figure 2.1.3 Structure of Relevant Organization of Disaster Prevention（Nicaragua）

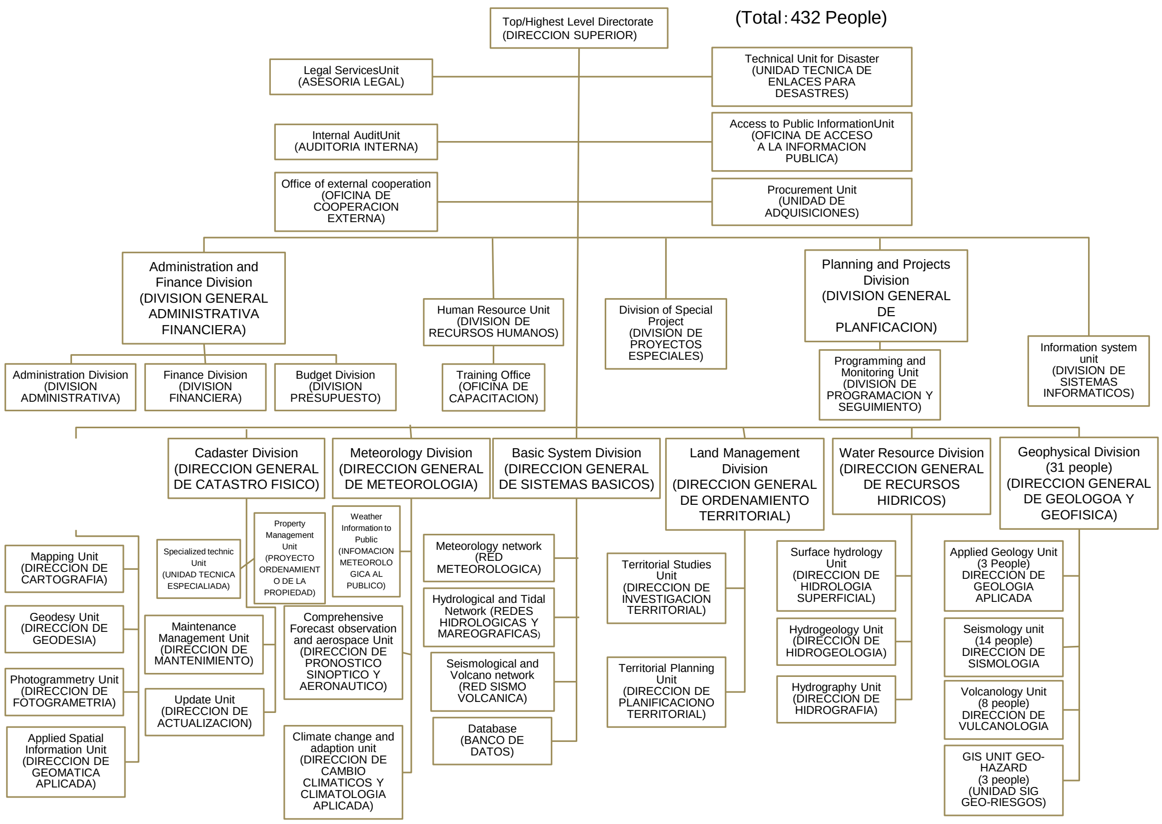

Figure 2.1.4 Organization Chart of INETER

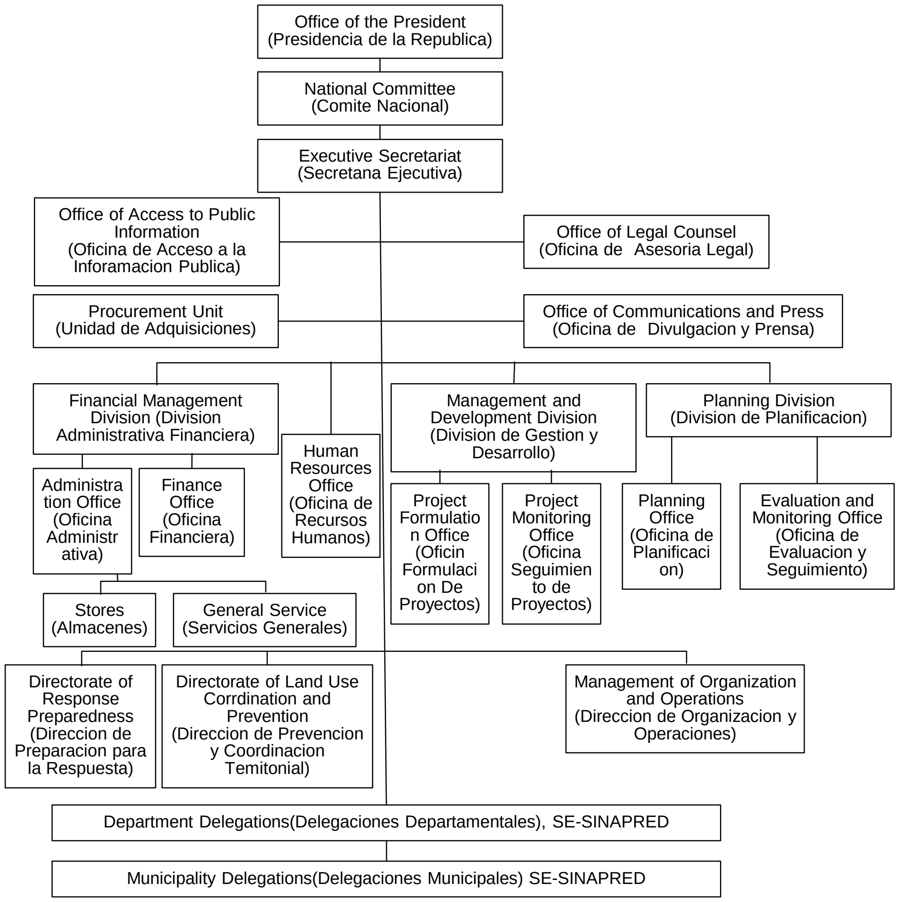

Figure 2.1.5 Organization Chart of Co-Direcciones de SINAPRED

【３】Expectation to CATAC

INETER is supposing that the function of INETER will improve the monitoring capacity of Regional Tsunamis as a function of CATAC from the view of observation experience for 20 years. The technical environment for the monitoring network was assumed in place because the system of data processing of seismic observation was already uniform; SeisComP had already been introduced, and data format was already unified.

INETER is planning to set up an “Earthquake Monitoring Network of Central America” and to use this function for CATAC.

INETER is also hoping to be in charge of similar role in CATAC as Japan Meteorological Agency in NWPTAC.

(2) Priority and Significance on Relevant Law of Earthquake and Tsunami on the National-level

The sense of crisis has been raised in Nicaragua because there several large tsunamis causing serious damage in Indonesia, Chile and Japan have occurred in recent decades, in addition to this, there an earthquake in El Salvador that brought a Regional Tsunami struck on August 2012. As the tsunami response plan is to be formulated in the review of the National Disaster Management Plan, while installation of sirens and enlightenment of tsunami awareness are promoted intensively, the priority of measures for earthquake and tsunami warning can be considered high.

(3) Situation of Allocation of Budget for Disaster Prevention

The budget of INETER was approximately 240million Córdoba (approximately 9million USD) in 2014. The allocation of employment amounted about 92%, and the total of maintenance, postage and consumable article amounted about 7%. The budget of equipment, maintenance and inspection that can be appropriated to the maintenance for observation equipment was approximately 1.1 million Córdoba (approximately 410 thousand USD).

(4) Situation of Activities for Disaster Prevention on the Community-level

Activities of disaster prevention on the community-level are to be covered by COLOPRED with assistance from COMPURED . The following activities were implemented by using the cooperation of donors and NGOs.

- Project on Capacity Development for Disaster Risk Management "BOSAI": Technical Cooperation to strengthen the disaster response capability of early warning was implemented in Las Peñitas of León City with León Municipality and Ministry of Education as counterparts.

- Project for Disaster Risk Management to Tsunami: Capacity development for disaster risk management by an early warning system for tsunamis was implemented in San Rafael del Sur, Masachapa and Pochomil by using financial assistance of COSUDE with INETER and Red Cross as counterpart.

- Project of Risk Management to Earthquake, Volcanic Eruption and Landslide: Activities on the enhancement for disaster risk management from earthquakes, volcanic eruptions and landslides were implemented in Ometepe Island by using financial assistance from DIPECO with Co-Direccions de SINAPRED as counterpart.

- Project of Capacity Development of Community Response to Earthquake, et al.: Capacity development of the community response by early warning system was implemented in five communities in Managua with INETER, Red Cross, Ministry of Education and Managua Municipality as counterparts.

(5) Situation of Disaster Prevention Education for Earthquake and Tsunami on Educational Institutes

Ministry of Education (MINED) created the 30 hours curriculum in which the theme is disaster prevention in mathematics and language, and implemented the class for disaster psychology and early warning including tsunami measures as a target based on the guideline that was formulated with the technical cooperation of donors. The staffs of COMUPRED and COLOPRED are instructing the class in terms of disaster prevention.

2.1.3. Earthquake Observation and Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

The responsible organization for earthquake observation in Nicaragua is INETER. Co-Direcciones de SINAPRED is responsible for the early warning information dissemination through CODE.

(2) Earthquake Observation Capability

1) Seismic Observation Operation

The earthquake observation operation and management is conducted by the Earthquake Section, the Department of Geology and Geophysics, INETER, since 1992 in a 24/7 manner. The department has 25 staff with fourteen regular employees and eleven interns as shown in Figure 2.1.6. The regular staff includes two advisers, seven earthquake experts, two for information and three for electronics. Earthquake monitoring and analysis is carried out by seven regular staff and two interns during the regular working hours and, one technical staff of INTER and one staff from the President’s office out of the working time. The intern means the undergraduates who participate in social work for a period of several months for their credits.

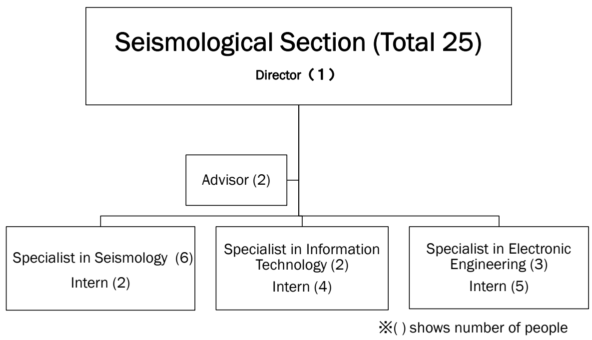

Figure 2.1.6 Staff Number of Earthquake Section, INETER (Source：INETER)

Table 2.1.4 is the staff list of the Earthquake Section who is in the shift of earthquake and tsunami monitoring. One electronics staff and one intern who belong to the other section are not in the list.

Table 2.1.4 Staff List of Earthquake Section, INETER(as of Tan. 2015 Source:INETER)

Educational Background	Title or Duty	Age layer	Monitoring shift	Training experience in foreign countries
Bachelor(Physics)	Director (Seismological Section)	40-50		Y
Bachelor(Physics)	Leader for seismic monitoring center		○	Y
Bachelor(Physics)	Geophysics field		○	Y
Bachelor(Physics)	Geophysics field	20-30	○	Y
Master(Seismology)	Seismic monitoring		○	Y
Bachelor(Information engineering)	Seismic monitoring		○	N
Under graduate (Information engineering)	Seismic monitoring		○	N
Bachelor(Information engineering)	Electronic engineering field	40-50	○	Y
Diploma (Electronic engineering)	Leader for seismic observation network			N
Diploma (Electronic engineering)	Electronic engineering field	20-30		Y
Master(Seismology)	Advisor for seismology	60		Y
Doctor (Seismology)	Advisor for earth science in INETER			
Doctor (Seismology)	Professor in physics education media			
Intern				
Bachelor(Geology)	Seismic monitoring	20-30	8	N
Bachelor(Mathematics)	Seismic monitoring		9	N
Bachelor(Electronic engineering)	Electronic engineering field			
Bachelor(Electronic engineering)	Electronic engineering field			
Bachelor(Electronic engineering)	Electronic engineering field			
Fifth grade (Electronic engineering)	Electronic engineering field			
Diploma(Information engineering)	System engineer			
Diploma(Information engineering)	System engineer			
Diploma(Information engineering)	Computer engineer			
Diploma(Information engineering)	Computer engineer			
Support for technology of observation system				
Diploma(Information engineering)	Information engineer	20-30		
Diploma(Information engineering)	System engineer			

Table 2.1 .5 shows the total staff number of the Department of Geology and Geophysics. The total is 31 with fourteen in the earthquake section, three in applied geology, eight in the volcanic section and three in GIS Hazard section.

Table 2.1.5 Number of Staff in the Department of Geology and Geophysics, INETER(Source:INETER)

	Regular Employee				Intern	Total
	Total	Advisor	Specialist	Technical/administrative Official		
INETER	432					
Department of Geology and Geophysics						
Director Office	3	0	1	2	0	3
Applied Geology Section	3	0	3	0	0	3
Earthquake Section	14	2	10	2	11	25
Volcanic Section	8	0	6	2	0	8
GIS Hazard Section	3	0	3	0	4	7
Total	31	2	23	6	15	46

2) Earthquake Observation Network

There are three types of seismic observation instruments depending on the purpose of the observation, i.e. short period, broadband and strong motion seismometer, shown in Figure 2.1.7. The short period seismometer is capable to detect microscopic tremors in the ground and is used to determine the local earthquake source. The broadband seismometer can catch the low frequency signals of remote big earthquakes and can be used for focal mechanism analysis, which is an important factor for tsunami early warning. Due to its high sensitivity of the broadband seismometer to temperature and air pressure, the condition of installation of the instrument usually needs special care. The strong motion seismometer (accelerometer) can record the strong ground motion, which is necessary for seismic design. In general, short period and broadband seismometers record the ground velocity, while strong motion accelerometer records ground acceleration.

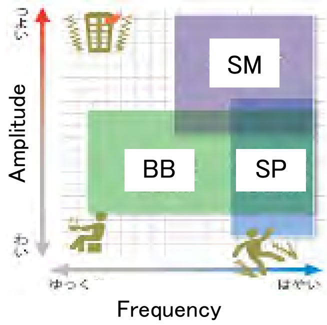

Figure 2.1.7 Seismometer Types and their application (Source: NIED: http://www.seis.bosai.go.jp/seis-portal/)

The earthquake observation in Nicaragua begun in 1975 with fourteen seismometers, shown in Figure 2.1.8, provided by the United States Geological Survey (USGS) after the 1972 earthquake. Now the observation network has 90 seismometers as shown in Figure 2.3.9, including 21 broadband seismometers, 45 short period seismometers and 24 accelerometers that are primarily located along the volcanic belt.

In addition to the seismometers of INETER, the seismometers from the Incorporated Research Institutes for Seismology (IRIS) and German Research Centre for Geosciences (GFZ) and the other Central America countries are also used for the determination of source parameters. Currently, there are 347 seismometers in Central America, shown in Figure 2.10.10, covering the all three types of seismometers.

The waveforms from 322 seismometers are used for the calculation of epicenter and magnitude. The seismometers are 79 from the INETER network whose data can be collected in real time, 71 from other countries of Central America and 172 from over the world through IRIS. The data sharing among the Central American countries has lasted for more than 20 years, although the data sharing agreements does not exist.

The seismic waveform are collected by digital radio, internet or optic fiber owned by the state-owned distribution company for the seismometers within Nicaragua. Commercial internet lines collect the data from IRIS and the other Central American countries, see Table 2.1.6.

An example of the installation of seismometers, one short period and one broadband located inside of INETER office building is shown in Figure 2.6.11. The instrument is installed in the computer server room with an isolated two-meter deep concrete foundation.

The maintenance of the earthquake observation network is costly and a large portion of the budget is spent on it. The regular maintenance is three times a month. It usually needs five to six extra maintenance sessions per month due to the disorder of the instruments. The main causes of the disorder are as below:

① Power loss of backup battery due to the lack of sunshine

The periodic replacement of a battery is needed for its aging deterioration and recharging. Since the budget is only about 60% of the required amount, some of the batteries could not be replaced. For example, the battery of Masaya needs replacement of five or six times a year and that in Telica it is needed eight times per year due to the lack of sunshine.

② Connector Connection failure

The cable connecting to the connector needs regular replacement due to corrosion. However, the budget cannot be secured for the necessary replacement.

③ Internet system failure

The internet failure occurred due to a program bug from the internet company.

④ Interference of optic fiber

The optic fiber owned by the distribution company is used with other organizations and the data could interfere with each other. Data collection delay has happened due to the interference.

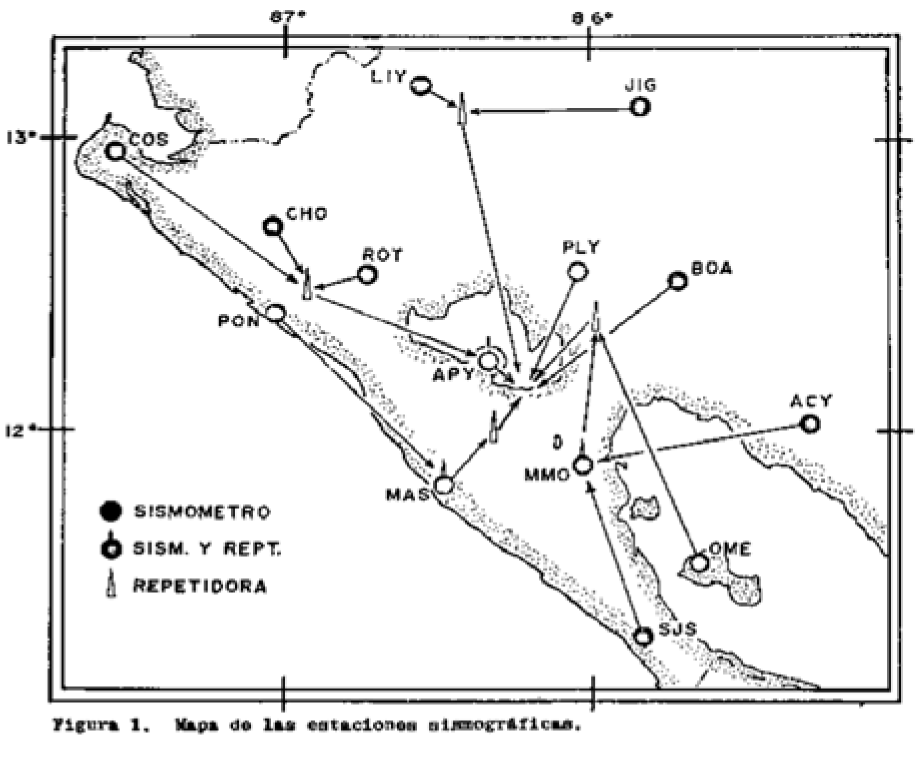

Figure 2.1.8 Seismometers of Nicaragua in 1975 (Source: INETER)

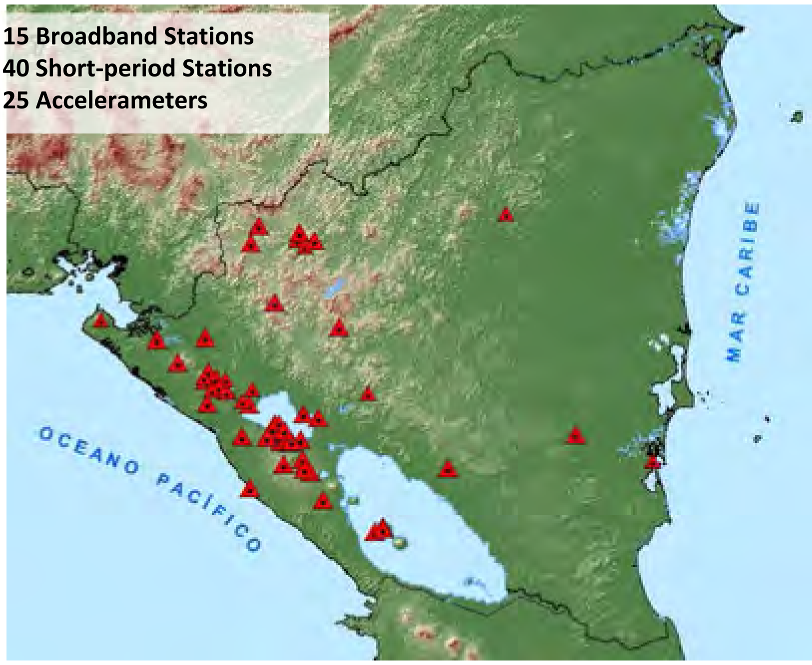

Figure 2.1.9 Locations of Seismometer of Nicaragua (Source：INETER)

Figure 2.1.10 Locations of Seismometers of Central America (Source：INETER)

Table 2.1.6 Seismometer and Data Collection Means

Seismometer		Total	Data Collection Means				
Type	Format		Radio	Optic fiber	Radio and Optic fiber	Internet	On site
Short period	Digital	40	10	2	12	14	2
	Analogue	5	5				
Broadband	Digital	21	6	3	7	4	1
Accelerometer	Digital	24				24	
Total		90	21	5	19	42	3

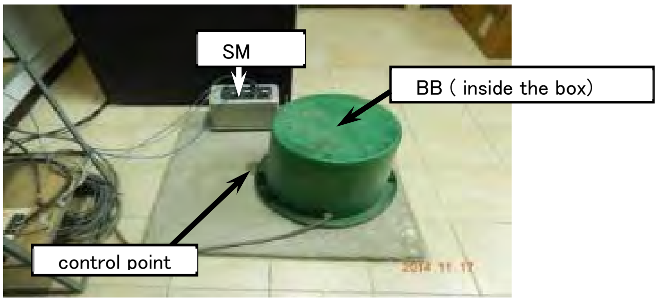

Figure 2.1.11 Short Period and Broadband Seismometers inside INETER Office Building

3) Seismic Data Processing

The seismic data processing of INETER is performed by the software of Seisan or Earthworm from 20 years ago. In 2004, the software SeisComP was introduced, which made the use of seismic observation data form IRIS and GFZ possible. The SeisComP, developed by GFZ, can automatically collect the seismic observation data, calculate the location and epicenter of the earthquake and disseminate the processing results. The latest version is SeisComP 3. In 2012, SeisComP was introduced by the six countries of Central America. INETER switched from Seisan to SeisComP in 2013. The reason is that the SeisComP is faster than Seisan and the data can be easily shared among the organizations who installed the software. In Central America, ten organizations have installed the SeisComP as shown in Figure 2.112. In Nicaragua, CODE also introduced SeisComP, but it is just the mirror of INETER, without any analysis.

Prior to the software switch, Earthworm was used for the detection of local earthquakes (within Nicaraguan territory) and regional earthquakes (in the Central American region) and Seisan was employed for the location and magnitude analysis. After the switch, SeisComP was used for the automatic detection and analysis of local, regional and remote earthquakes. The results can also be automatically sent to pre-registered organizations. In case of a big earthquake, Seisan and Earthworm are used for manual analysis and for the results of USGS, PTWC will be used for confirmation. The flowchart of data collection and process is shown in Figure 2.1.13. A screen shot for the results display of SeisComP is given in Figure 2.1.14. There are two severs now in use and one of them for backup (Figure 2.1.15). The performance of the server is satisfactory.

The data processing for occurrence time, location of epicenter (latitude and longitude), depth, and magnitude can be finished as fast as within two minutes and at worst less than five minutes. In the analysis, the regional seismic wave velocity structure model is used but the model itself is not validated. The focal mechanism analysis was performed with the initial wave, but CMT (Centroid Moment Tensor) analysis is not conducted.

The license of SeisComP for the basic function of epicenter calculation is free for research institutions and government agencies. The countries, except for Nicaragua and El Salvador, installed their SeisComP from a private company named OSOP, the official distributor headquartered in Panama.

Figure 2.1.12 The Organizations Where SeisComP Has Been Installed (Source：INETER)

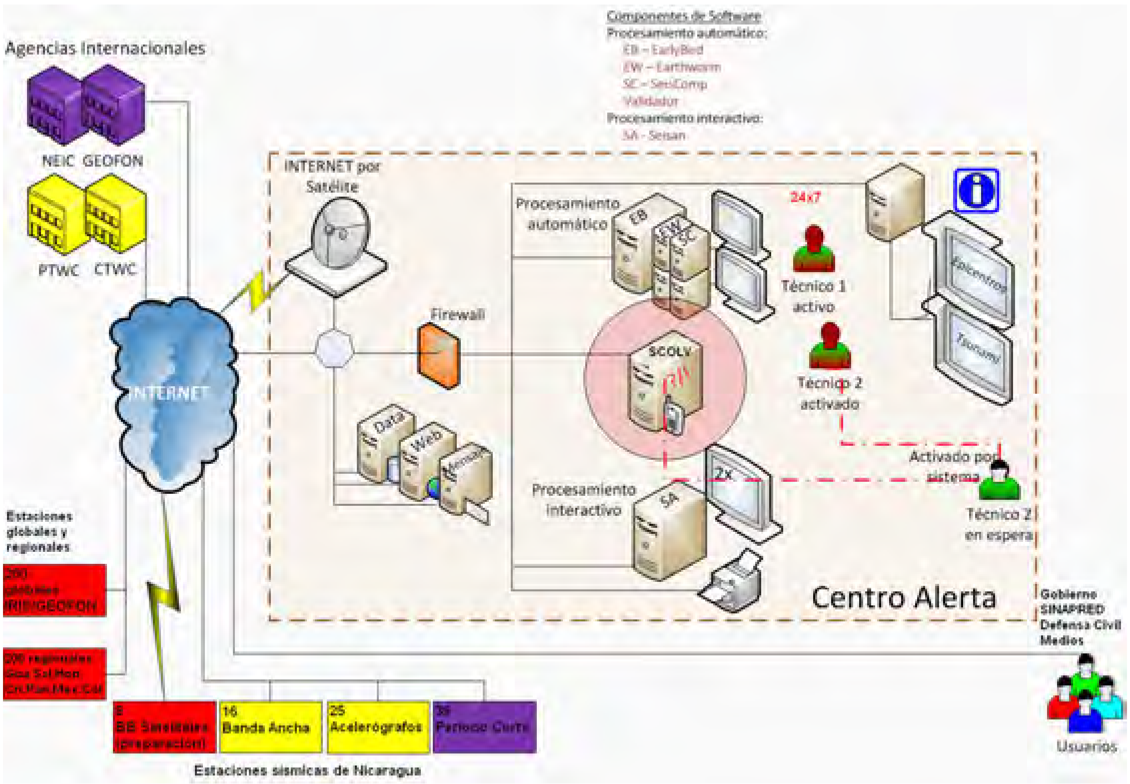

Figure 2.1.13 The Flowchart of Data Processing of INETER (Source：INETER)

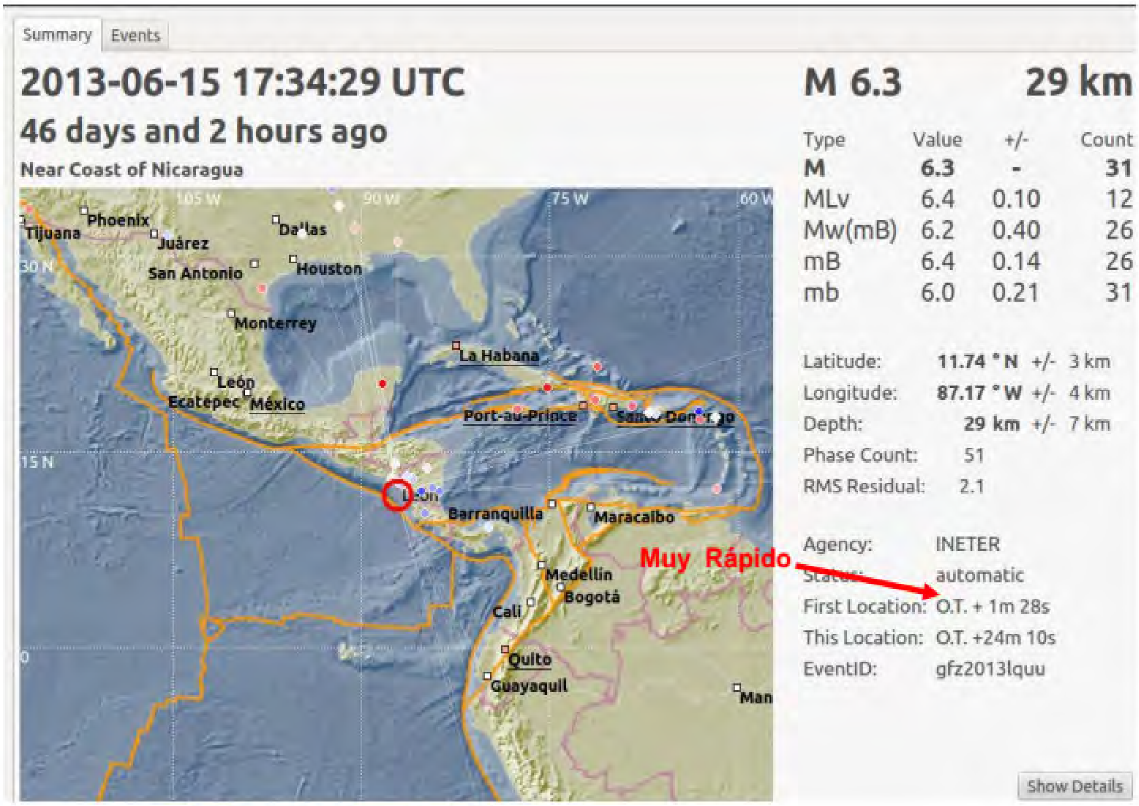

Figure 2.1.14 Screen Shot of SeisComP (Source：INETER)

Figure 2.1.15 Sever for SeisComP

The table below shows the seismic observation network of INETER.

Figure 2.1.16 Detail of Seismic Observation Network of INETER

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	43	37～43	0～6	43	43
	On Site	2	2	0		
Broadband	Real Time Telemetering	20	18～20	0～2	20	20
	On Site	1	1	0		
Strong Motion	Real Time Telemetering	24	24	0	24	24
	On Site	0	0	0		
Total	Real Time Telemetering	87	79	8	87	87
	On Site	3	3	0		

4) Earthquake information dissemination

The criteria for earthquake warning information is >M3.4 for local earthquakes, >M4.0 for regional earthquakes and >M6.0 for remote earthquakes. When an earthquake over the criteria occurs, INETER will immediately inform the occurrence to the presidential office, SINAPRED and CODE simultaneously by VHF radio or by phone. Then, the information will be sent by email to the persons at the ministry level related disaster management. SeisComP can give the results in less than five minutes at the first time and the updated information will be transmitted to the relevant authorities at the time of updating.

CODE has a SeisComp monitor and can have the same information as INETER. INETER is responsible for providing the technical information, and issuing tsunami warnings and evacuation is the responsibility of the president's office or the Co-Direcciones de SINAPRED.

The standard operation procedure (SOP) of INETER for earthquakes, tsunamis and landslides is as below:

1. Informing the Presidency of the Republic, the Seismic Monitoring Center will retransmit the same information to the - SINAPRED and National CODE in the second instance.
2. Informing the Presidency of the Republic through the co-management of monitoring natural phenomena of INETER, of the initial data of the event, the specialists of shift in the center of ongoing monitoring process the primary information obtained from the networks of national and international monitoring, in order to verify the same.
3. Completed the verification process the command is given with the UPDATE which is immediately updated in the data bank and this information is displayed on the monitor of earthquakes in the web of INETER, as well as the map that contains date, time, magnitude, coordinates, regionalization and depth. The current configuration of the process of seismic data does not allow the time, to send this information to the Presidency through the direction of observation of natural phenomena, before you update the web through the UPDATE command.

4. The results of the processing will be moved to the Presidency of the Republic in the first instance, through the co-management of monitoring natural phenomena of INETER and then the center of ongoing monitoring reports to the - SINAPRED and National CODE.
5. Moving the preliminary seismic information to a gif image, through the command COM where it is displayed the event data and is ready to be sent through the mail command. With this command, it is sent to a mailing list that in the first instance is for the Presidency of the Republic, institutions that make up the SINAPRED, municipal governments, embassies and the media.
6. The seismic bulletins are prepared and sent every six hours for the Presidency of the Republic, to the SINAPRED, CODE Address National and Co Monitoring of Natural phenomena and the directors of the surveillance area of natural phenomena. This bulletin contains a summary of the seismic activity in that period with their final calculations, which are updated immediately in the National Seismic Catalog. In the event that the parameters set in the Green Alert, yellow and red for the surveillance center for geological phenomena : tsunamis, volcanic eruptions, landslides, established in the threshold table, they will proceed in the following way:
7. The one responsible of the seismic shift in conjunction with a specialist of the event in the process will prepare and submit the technical proposal of a well justified recommendation of Alert Green, Yellow and Red Country to the Presidency of the Republic, through the co-direction of INETER natural phenomena.
8. The effect of the configuration of the software used to process the data, in the case of the earthquakes located to be processed is recorded in the database and updated on the monitor of earthquakes in the WEB page of INETER.
9. The information obtained from the preliminary data of the phenomenon monitored from the center of ongoing monitoring, this is immediately communicated to the Presidency of the Republic through the co-management of monitoring natural phenomena of INETER.
10. Informing the Presidency of the Republic, the Seismic Monitoring Center will retransmit the same information to the - SINAPRED and National CODE.
11. Then the one responsible for the seismic shift in conjunction with the specialists of the event in the process will analyze and process the primary information obtained from the national surveillance networks, in order to verify the same, and this is conveyed in the first instance to the Presidency of the Republic, through the Direction of Natural phenomena, and the Monitoring Center to the SINAPRED and National CODE.
12. After the alert is recommended as Green, Yellow or Red the information to be published will be releases the Vulcan, tsunami and landslides, authorized by the Presidency of the Republic

The technical criteria for earthquake warning are as below.

<table>
<tr><th>Category of Alert</th><th>Magnitude of Earthquake</th><th>Information Dissemination</th></tr>
<tr><td rowspan="1">Green</td><td>Occurrence of 3 earthquakes with magnitudes less than 3.5 in less than 12 hours in or near the city of Managua. (Note: this occurrence can be very rapid, within a few minutes)

Registration of at least 10 earthquakes with magnitudes less than 3.5 on a day in the rest of the national territory</td><td>The specialist for 24x7 shifts immediately sends a recommendation for a Green alert to the Presidency of the Republic, Co Address of natural phenomena, SINAPRED and CODE.

(The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of this condition).

Briefing notes will be issued on the development of the activity to the presidency of the Republic, SINAPRED and CODE, through the co-direction of INETER natural phenomena.</td></tr>
<tr><td rowspan="3">Yellow</td><td>Managua and surrounding areas:
1. Occurrence of 10 earthquakes with magnitudes less than 3.5 in less than 12 hours

2. Occurrence of 3 earthquakes with magnitudes less than 4.9 in less than 24 hours.</td><td rowspan="3">The specialist for 24x7 shifts immediately sends a recommendation for a Yellow alert to the Presidency of the Republic, Co Address of natural phenomena, SINAPRED and CODE.

(The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of this condition).

Briefing notes will be issued on the development of the activity to presidency of the Republic, SINAPRED and CODE, Co Address of natural phenomena of INETER.</td></tr>
<tr><td>Rest of the national territory: record of at least 5 earthquakes with magnitudes less than 4.5, during a day.</td></tr>
<tr><td>Earthquake with magnitude greater than 6 in the border countries borders of Honduras, El Salvador, or Costa Rica.</td></tr>
<tr><td rowspan="4">Red</td><td>Managua and surrounding areas:
Occurrence of at least an earthquake with magnitude greater than 4.5.</td><td rowspan="4">The specialist for 24x7 shifts immediately sends a recommendation for a Red Alert to the Presidency of the Republic, Co Address of natural phenomena, SINAPRED and CODE.

(The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of this condition).

Briefing notes will be issued on the development of the activity to presidency of the Republic, SINAPRED and CODE, through the co-direction of INETER natural phenomena.</td></tr>
<tr><td>Occurrence of an earthquake with magnitude greater than 4.5 in the municipal seats.</td></tr>
<tr><td>Occurrence of an earthquake with magnitude greater than 5.5 in the interior of national territory.</td></tr>
<tr><td>Occurrence of an earthquake with sudden intensity destructive in the national territory.</td></tr>
</table>

(3) Approach and Current Status of Seismic Risk Assessment

In 2004-2005, under the financial support of WB, SINAPRED and INETER jointly performed a project of Earthquake Vulnerability Assessment for Managua. The project was eventually carried out by DRM, a company of USA, and the result is linked on the INETER Webpage (http://webserver2.ineter.gob.ni/geofisica/proyectos/vulsismana/index.html). The risk assessment was carried out by a stochastic approach. The damage to buildings and the number of victims were evaluated for the scenario earthquakes with the return period of 100 and 500 years and the magnitude same as the event of 1972. However, since the inventory of the building is not complete and the vulnerability curve of Nicaragua does not exist, the result of risk was deemed to have high uncertainty. In addition, the fault plane was not designated due to the lack of data. An example of building damage distribution is shown in Figure 2.1 16.

During 2008-2009, the risk assessment project (Central American Probabilistic Risk Assessment: CAPRA) was carried out for the six Central American countries with financial aid from the Central American and Caribbean Fund of Spain, Australia Foreign Affairs and Trade Ministry and GFDRR and the cooperation of WB UN/ISDR and IADB. CAPRA developed a GIS based software, which can make risk assessment not only for earthquake but also for tsunamis, landslides, floods and typhoons. The flowchart of CAPRA is shown in Figure 2.1 17.

Nicaragua and Costa Rica participated the CAPRA program as the pilot countries. For the application of the risk assessment software, a regional technical workshop was held in Nicaragua in 2008 for the experts of Costa Rica and Nicaragua. Since the seismic risk assessment requires seismic hazard, structure type of the building, vulnerability curve, etc., CAPRA has not being applied in Nicaragua due to the insufficiency of information.

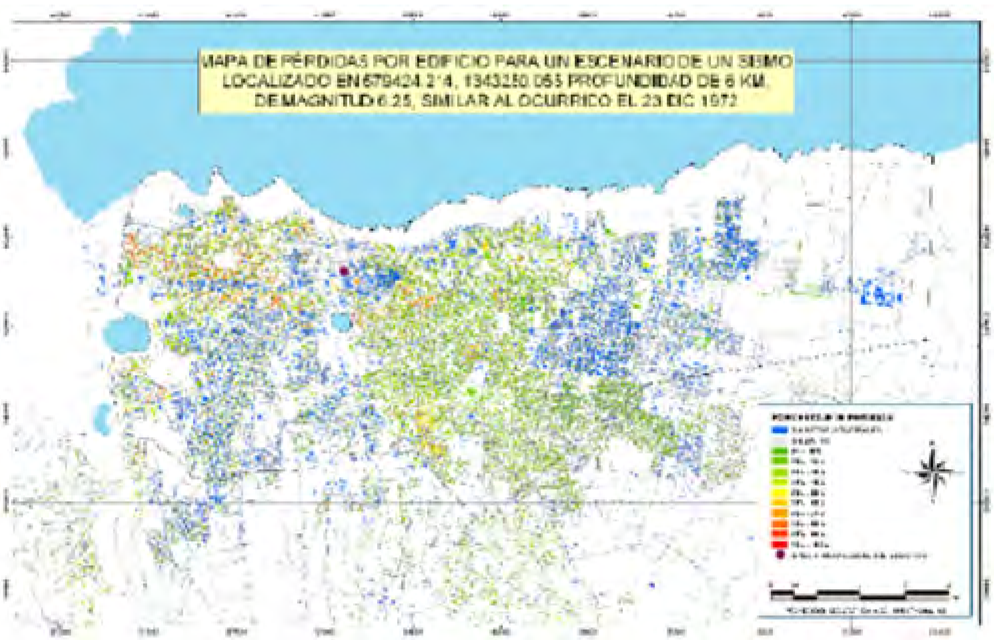

Figure 2.1.17 Building Damage Distribution of Managua (M6.25) (Source:INETER)

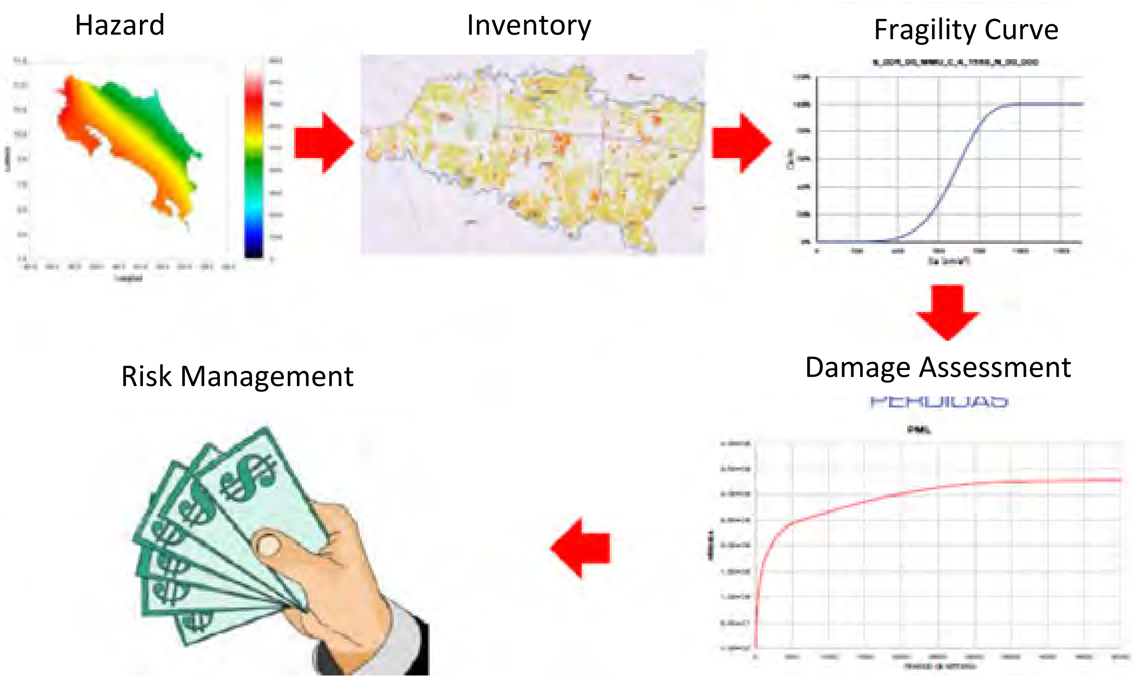

Figure 2.1.18 Flow Chart of Risk Assessment of CAPRA (Source: CAPRA)

(4) Development and utilization of seismic hazard map

Seismic hazard was estimated in Nicaragua both at the country level and at local level. An example of the local seismic hazard assessment is the JICA project named disaster prevention map and information infrastructure development project for Nicaragua (2006). In the project, the seismic hazard for Managua was evaluated for four scenario earthquakes by a deterministic approach, which is shown in Figure 2.6.18.

The seismic hazard analysis for the whole country is carried out by the project of Earthquake Risk Reduction in Central America (RESIS II) with the financial support of the Norway Cooperation Agency (NORAD). The main target countries of the project are Nicaragua, Guatemala and El Salvador, which have high seismic risk, but Costa Rica, Panama and Honduras also participated the project. The experts from all of the above-mentioned six countries participated the project and the seismic hazard was assessed for the six countries. The project took into account the latest knowledge of Seismology and Earthquake Engineering for the seismic hazard analysis by a stochastic method. The earthquake source in plate, subduction zone and the deep earthquakes were considered. As an example, the earthquake source in plates is shown in Figure 2.1 19. The logic tree was used for the consideration of the uncertainties, which is given in Figure 2.1.20). The results are the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with a 500 year return period in Nicaragua is shown in Figure 2.1.21 and the hazard curve of Managua is shown in Figure 2.1 22. The utilization of the result is highly expected in the future.

Figure 2.1.19 Seismic Hazard of Managua for a Scenario Earthquake (Source：INETER)

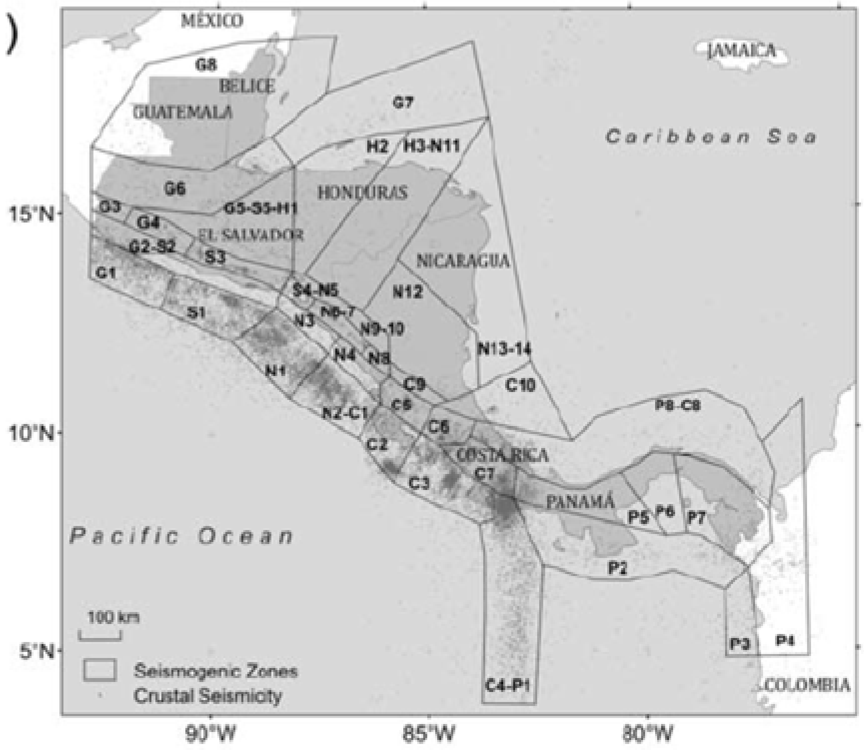

Figure 2.1.20 Earthquake Source used in RESIS II for Seismic Hazard Analysis(Source：RESIS Ⅱ Report)

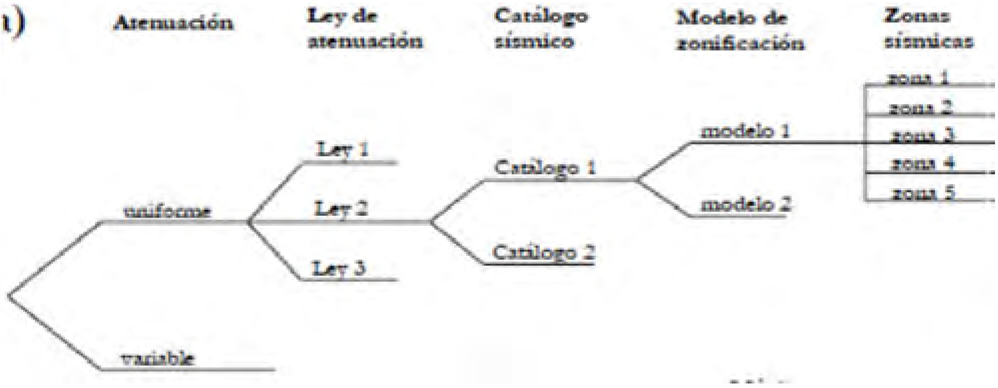

Figure 2.1.21 An example of Logic Tree Used in RESIS II (Source：RESIS Ⅱ Report)

Figure 2.1.22 Seismic Hazard of Nicaragua by RESIS II (PGA、Return Period 500years) (Source：RESIS Ⅱ Report)

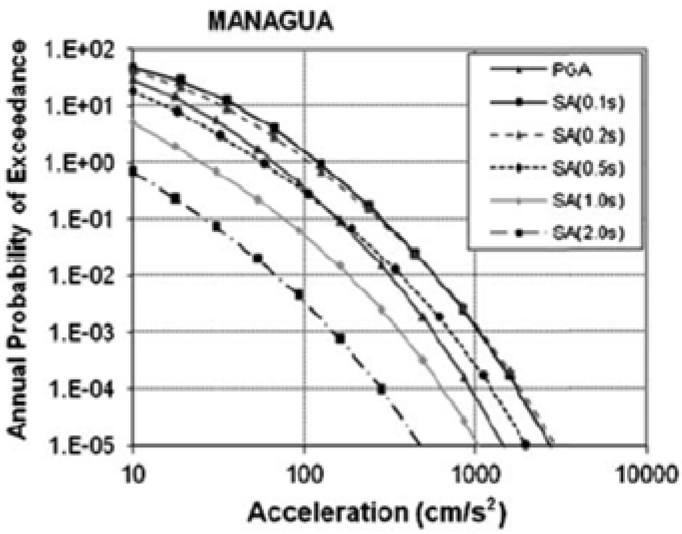

Figure 2.1.23 Seismic Hazard Curve of Managua by RESIS II (Source：BSSA,Vol.102, No.2,2012)

(5) Development of seismic code and the implementation

The first seismic code of Nicaragua was established in 1983 and it was last revised in 2007 (Reglamento Nacional de Construccion: RNC-07). According to the code, the seismic force can be calculated by three ways: Static seismic force (only first vibration mode is considered), dynamic seismic force: (considering more than one vibration mode) and equivalent static seismic force (without considering the response spectrum). The basic formula for calculating horizontal seismic force is

$$F=CW$$

Where: F is the horizontal seismic forces.

C is the coefficient, depending on the calculation method.

W is the total weight of the building.

The distribution of acceleration for seismic design is shown in Figure 2.1.23, and the shape of the response spectrum is shown in Figure 2.1.24. The seismic hazard of Pacific Ocean side (0.32g) is higher than that of Caribbean Sea side (0.10g).

All of the new buildings have to be checked and receive permission from the building safety office of the municipality. The Housing Agency has made the easy-to-understand brochure for the local construction companies to promote the implementation of the seismic code.

The buildings for schools, hospitals and the other important structures built after 2007, based on the new seismic code, is considered safe. There were projects to make seismic diagnosis for hospital buildings of more than two floors and have performed the seismic strengthening funded by the Pan American Health Organization (PAHO). The university and the structural commission of SINAPRED provide technical support for the vulnerability assessment. There is not an integrated national policy for the promotion of improving the seismic performance of old buildings as well as the transportation and lifeline infrastructures. But for the construction of public works, the Ministry of Finance requires the utility company to make proper risk management though its Public Investment Fund Management (SNIP) program.

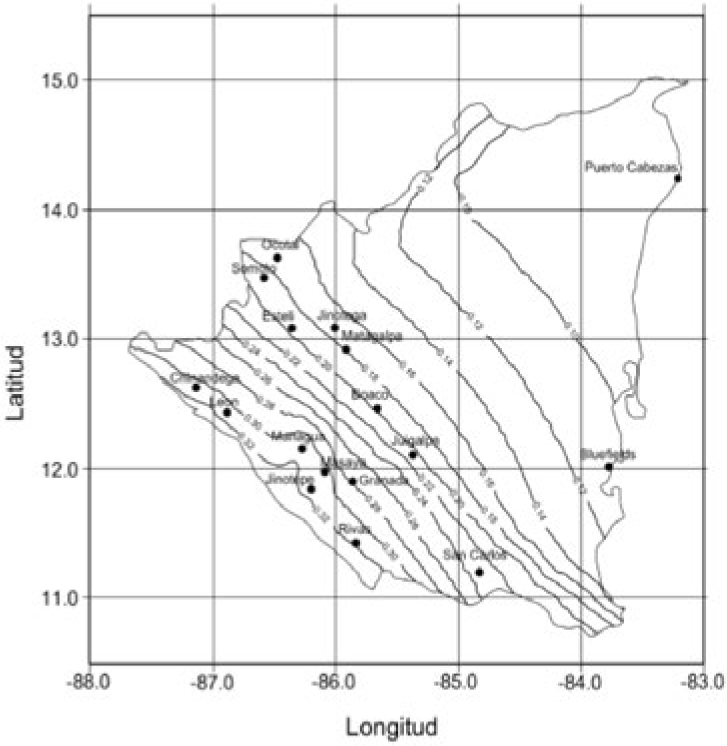

Figure 2.1.24 Acceleration Distribution of Nicaragua Seismic Code (Source:Nicaragua Seismic Code)

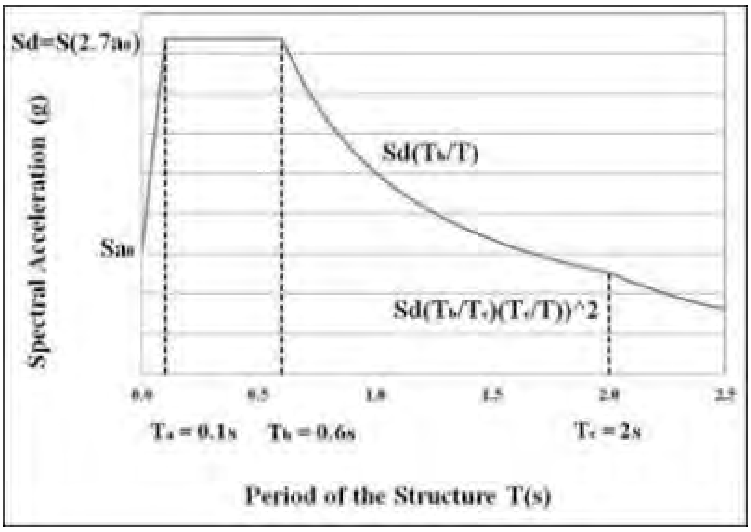

Figure 2.1.25 Shape of Response Spectrum of Nicaragua Seismic Code (Source:Nicaragua Seismic Code)

(6) Activities of University Institutes and NGOs for Disaster Prevention

The innovation center of Nicaragua National Polytechnic University (UNI) has a postgraduate program for Master's degree in the field of natural hazard, human hazard, risk management and land use planning. Some of the staff of SINAPRED and INETER attended the program. Their research also covers the selection of safe construction sites and has developed a residential area-planning manual.

The earth science research center of Nicaragua National Autonomous University (UNAN/CIGEO) has a Master's course related to disaster prevention. The center conducts researche in the field of Geology, Geophysics and earthquake disaster prevention.

2.1.4. Tsunami-Monitoring and Tsunamis-Disaster prevention efforts

(1) National organizations responsible for Tsunami-Disaster prevention and relevant organizations

The INETER has the responsibility for technical judgments on generations of scared tsunamis. On the other hand, the Co-Direcciones de SINAPRED has the responsibility for issuing Tsunami Warnings based on the information provided by INETER and according to the indication from the office of the president; the action is implemented as administrative measures; it would thus mean ordering the population to evacuate from disastrous coastal areas. The CODE should issue the warnings. In addition, the CODE is always monitoring information prepared by the INETER; and regarding Distant Tsunamis, it should check and monitor information prepared by PTWC. Moreover, regarding events larger than M6.8, after receiving any information from INETER, the CODE should check information shown on the web sites of PTWC, GEOFON, MARN of El Salvador and the other nearby countries.

Note: The organizations responsible for tsunami monitoring, and ones responsible for issuing an official tsunami warning have been validated through diplomatic channels and are approved by IOC as Tsunami warning focal points (TWFP) or Tsunami National Contact (TNC). IOC approves the INETER as TWFP and TNC; the Co-Direcciones de SINAPRED is approved as alternate TNC; Defensa Civil, who manages CODE, is approved as alternate TWFP.

(2) Monitoring System relevant to tsunami

1) Tsunami Monitoring System

Tsunami monitoring is implemented by two “7x24 contact” members of staff of Seismic Section of Geology and Geophysics Department in INETER.

2) Tsunami Observation Network

Tsunami Observations are handled with four tidal stations for the Pacific coast; those are Corinto, San Juan del Sur, Masachapa and Sandino (Table 2.1.7, Fig.2.1.25). The sampling rate is ten min, and transmission interval is one hour; that means the current observation conditions are not appropriate for tsunami monitoring. Moreover, the stations at San Juan del Sur and Masachapa are currently out of order due to the shortage of the necessary components for repair. Tidal data observed at stations of nearby countries, like Costa Rica, Mexico and Ecuador (Galapagos), are also telemetered with a low-functional system.

Table 2.1.7 Tidal Gauge Stations

Device Type	Station Name (Station Code)	Coordinates		Sampling Rate	Transmission Interval	Means for Data Collection	Power	Observation Componets	Responsible Institution	Inspection Interval Current Satatus
Presusre	Puerto Corinto (cori)	12° 29' 00'	87° 10 ' 03"	10 Min	1 Hour	Satellite transmission	Solar	Sea level (m)	INETER/DGRH	6 Months Under Operation
				30Min	1 Hour			Water Temperature	INETER/DGRH	
				10 Min	1 Hour			Wind speed & direction.	INETER/DGRH	
				10 Min	1 Hour			Precipitation	INETER/DGRH	
Pressure	Puerto Corinto	12° 29' 00'	87° 10 ' 03"	1 Min	5 Min	Satellite transmission	Solar	Sea level (m)	INETER/DGGG	6 Months Start from 2003 Currently Interrupted
Pressure	Puerto San Juan del Sur (sjds)	11° 15 ' 04'	85° 52' 30"	10 Min	1 Hour	Satellite transmission	Solar	Sea level (m)	INETER/DGRH	6 Months Currently Interrupted
				30 Min	1 Hour			Water Temperature	INETER/DGRH	
				10 Min	1 Hour			Wind speed & direction.	INETER/DGRH	
				10 Min	1 Hour			Precipitation	INETER/DGRH	
					1 Hour				INETER/DGRH	6 Months
Presusre	Puerto Sandino (psdn)	12° 12 ' 04'	86° 45' 52"	10 Min	1 Hour	Satellite transmission	Solar	Sea level (m)	INETER/DGRH	6 Months Under Operation
				30 Min	1 Hour			Water Temperature	INETER/DGRH	
				10 Min	1 Hour			Wind speed & direction.	INETER/DGRH	
					1 Hour				INETER/DGRH	6 Months
Pressure	Corn Island (cois)	12° 19 ' 38'	83° 04' 04"	10 Min	1 Hour	Satellite transmission	Solar	Sea level (m)	INETER/DGRH	6 Months Under Operation
				30 Min	1 Hour			Water Temperature	INETER/DGRH	
Pressure	Masachapa	Located between Purero Sandin and Port San Juan del		1 Min	1 Min	WIFI	Solar	Sea level (m)	INETER/DGGG	6 Months Start 2007 Currently Interrupted

Figure 2.1.26 Locations of Tidal Gauge Stations (Source: INETER)

3) Analysis of tsunami generation

The areas shown in Fig.2.1.26 and Fig.2.1.27 are set beforehand as targets of seismic activity monitoring or tsunami warning.

Figure 2.1.27 The Area for Monitoring Seismic Activity and Seismic Stations used for its Monitoring (Source: INETER)

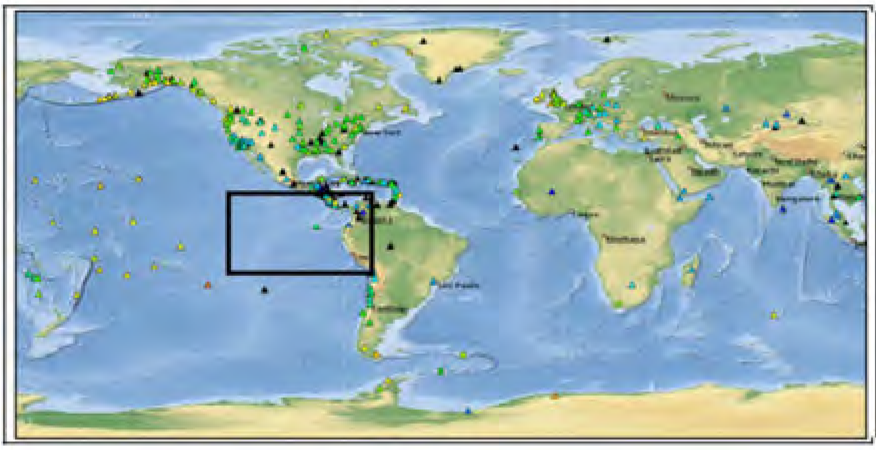

Figure 2.1.28 The Global Area for Monitoring Seismic Activity and Seismic Stations used for its Monitoring (Source: INETER)

Seismic data analysis for judgment on tsunami generation is handled with SeisComP as mentioned in the section, Seismic Data Analysis; the software can also handle the seismic data from other countries in Central America; the speedy analysis for the judgment on tsunami generation is well implemented. The software, SeisComP, has the functions of collecting real time data, automatic seismic waveform data analysis, distributing data and results of analysis, which are Origin Time, Hypocenter and M obtained within 2-5 min. The analysis of focal mechanism with initial motion polarity is implemented, but its result is not used for tsunami judgment analysis. The licenses for modules on these functions are provided free because INETER is one of the official organizations allowed to do so; however, the one for the CMT analysis module is not free and has not yet been purchased; the analysis is thus not yet implemented.

INETER will monitor the analyzed results of USGS, PTWC, GEOFON and others in the case that the event should be judged as large enough to have any potential of generating tsunamis.

Accurate tsunami generation judgment depends on the accuracy of the hypocenter and M; particularly M of earthquakes in the coastal area of Nicaragua should be sometimes underestimated because of the area's seismological feature and the used M-analysis method; the current monitoring conditions should be improved. In order to improve the accuracy of hypocenter determination, seismic velocity structure model for the calculation should be tailored to the area; although the current monitoring uses the model having local features, the idea is not commonly recognized.

Note: the current automatic analysis system starts its calculation of hypocenter determination after having collected enough number of analyzed phases and finishes it within 1-5 min; in order to improve the accuracy, though, it should be necessary to use more phases or data from more stations; data from Canada and South America are sometimes used; that brings around 5 min for obtaining the calculation results that have accuracy higher than the level requested generally (Table 2.1.8).

The contents of information provided by INETER are hypocenter, M and comments that tell the hypocenter shows that the event is the type of inland active-faults or the type of plate boundary.

Note: The information released from INETER would be able to be monitored with SeisComP by TWFPs of the Central America.

Moreover, manual analysis will provide hypocenters that are more accurate and M; in the case the results are sent to TWFP of the countries in the Central America, office of the president, SINAPRED, CODE and mass media with emails.

Note: INETER will not monitor information issued from CODE.

PTWC provides information on tsunamis for all countries located around the Pacific Ocean; the information should thus be a sort of an "average" of a wide area, and sometimes too rough to use as a tsunami warning judgment for a region; that means the accuracy is not enough for handling any regional earthquakes. In that context, INETER, however, does not estimate height of tsunami and arrival time of tsunami on its own at present; it thus has no criteria for the cancellation of a tsunami warning. Furthermore, it does not assess hypocenters and M issued from PTWC and does not use station corrections except for altitude. In order to optimize the seismic velocity structure model, INETER is considering that the crustal structure investigation, which has been implemented until now, should include "development of structure related to tsunami"as its purpose. On the other hand, against Distant Tsunami, INETER relies on PTWC.

Regarding the computer system that should be used for the judgment on tsunami generation, there are three computers like a work-station with a SeisComP of the former version, two servers (Master and Slave) with a SeisComP of the latest version, a server with an Earthworm and an Earlybird; these are connected online mutually and configured to establish a backup system.

Table 2.1.8 Tsunami Warning Operations

Procedures	Operations				Issuing results			Required time	Lapse
	Contents	Handling	Staff	Reference information	Results	Destination	tools	(min)	(min)
1	Automatic analysis with SeisComP	Automatic	・Seismic Section 1 (technical issues) ・Presidential Office 1 (liaison)	・Output from Earlybird ・Output from Earthworm ・PTWC ・Countries in Central America(SeisComP) ・USGS ・GEOFON	Hypocenter and M	Presidential Office, SINAPRED, CODE (3 disaster prevention organizations)	・E-mail through commercial Internet	Target 2～3	Target 2～3
2		Manual					・Cellphone ・Radio communication		
3	Manual analysis with Seisan	Manual	・ditto ・Support staff (gathering with any felt earthquakes)		・ditto ・Type of earthquakes (Inland or Plate boundary)	3 disaster prevention organizations, Mass Media, countries in Central America	・E-mail through commercial Internet	Tentative 5	Tentative 7～8
4	Inner consultations, recommendations to 3 disaster prevention organizations	Manual			Hypocenter and M	3 disaster prevention organizations	・Cellphone ・Radio communication	Depends	

Regarding a monitoring system for judgment on tsunami generation, related to having sufficient human resources for the work, the government has an intensity to strengthen seismic, volcanic and mechanics specialists; the government has thus started a seismic training course at UNAM. INETER has dispatched four members of staff of the Seismic Section in charge of tsunami monitoring and ten interns to the seismic course in order to keep or strengthen the ability of seismic and tsunami monitoring staff at a sufficient level; there are members of staff who are not taking the course, even though they are satisfied with the participation conditions in the course. The course does not include focal mechanism analysis and tsunami generation analysis.

4) Issuing tsunami information

The criteria for tsunami generation is that the M is larger or equal to 6.8 and that the hypocenter is shallower or equal to 60 ㎞. When the staff in the Earthquake Monitoring Center notices any information satisfying the criteria, the staff should immediately issue the information to office of the president, SINAPRED and CODE simultaneously with VHF-radio, telephone and E-mail. CODE is able to monitor the web sites of INETER through the Internet. The procedures of issuing tsunami information from INETER are the same as the ones of seismic one.

Note: If any results of hypocenters and M obtained with manual analysis are thought to be reliable, they should be provided to office of the president, SINAPRED, CODE, mass media and TWFP in Central America.

The technical criteria on issuing recommendations of tsunami warning is as follows:

Category of warning	Tsunami	Issuing information
Green	Occurrence of an earthquake of M greater than or equal to 7.0 in the basins of the Pacific Ocean and Caribbean Sea, far from the coastal zone of Central America. Issuing a potential tsunami by the PTWC	The specialist for 24x7 shifts immediately issues a recommendation for a Green Alert to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE. The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of these actions.) The specialist for 24x7 shifts periodically receives and analyzes the information obtained from the PTWC, and immediately issues the results to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE, until its cancellation.
Yellow	Arrival of tsunami at the coastal areas of countries in Central America, with wave heights likely between 30cm and 1m, generated by a distant earthquake. Occurrence of an earthquake with M greater than 6.8 near the coasts of Central America in the Pacific Ocean and Caribbean Sea. Issuing a potential tsunami by the PTWC on regional earthquake in the Pacific Ocean and Caribbean Sea.	The specialist for 24x7 shift immediately issues a recommendation for a Yellow Alert to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE. The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of these actions.) The specialist for 24x7 shifts periodically receives and analyzes the information obtained from the PTWC or similar organizations in Central America, and immediately issues the results to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE, until its cancellation.
Red	Arrival of tsunami at the coastal areas of countries in Central America, with height of waves likely larger than 1m, generated by a regional or distant earthquake. Occurrence of an earthquake in the subduction zone of El Salvador, Honduras, Nicaragua and Costa Rica with M greater than 6.8 with shallower than 60km. Occurrence of an earthquake in the Caribbean Sea with magnitude greater than 6.8, close to the Nicaraguan coast. Issuing a potential tsunami by the PTWC, on earthquake in the Pacific Ocean and Caribbean Sea, from a local earthquake.	The specialist for 24x7 shifts immediately issues a recommendation for a Red Alert to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE. The CODE of SINAPRED/Civil Defense provides information in real time by means of screens of SeisComP3 and web page. (Note: a program can automatically inform on the fulfillment of these actions.) The specialist for 24x7 shifts periodically receives and analyzes the information obtained from the PTWC or similar organizations in Central America, and immediately issues the results to office of the president, Co-Direcciónes de SINAPRED, SINAPRED and CODE, until its cancellation.

5) Specific examples of analysis of tsunami generation and issuing tsunami information

Regarding the earthquake off El Salvador in August of 2012, INETER obtained and accepted 5.7 as M at the beginning, 6.6 at the next timing, 7.3 provided from USGS lastly (Note: USGS informed 6.8 at the beginning.) ; INETER issued the information mentioning the potential of a tsunami according to the protocol. Furthermore, INETER analyzed the tidal data of nearby stations and issued a cancellation of the information of a potential tsunami based on the analysis results of no tsunami wave found; when the cancellation with the safety side judgment was issued, three hours passed since the issuance of tsunami warning.

(3) Tsunami Infrastructure Development Situation

Because of the high risk of a tsunami striking the coastal area of the Pacific Ocean, Co-Direcciones de SINAPRED has a plan of evacuation of 0.1 million people from the hazardous area within 45 min with introducing sirens there. There were eighteen sirens having 500m-perceived-range installed by the Civil Defense (Defensa Civil) and two sirens installed by JICA until 2013; but 60 sirens having 1km or 3 km-perceived-range were additionally installed until August of 2014; the action makes 80 sirens working now.

These sirens will be able to be remotely used by CODE when office of the president or Co-Direcciones de SINAPRED has judged that any evacuation from tsunami should be implemented and CODE orders the population to take the action. All the sirens should sound together according to the remote operations; they can be used like loudspeakers of voices set provisionally in the sire-system if necessary; in addition, CODE can remotely confirm if all sirens have worked.

Regarding the tsunami protection for the facility, though there is a bank separate from the coast at Corinto for a fostering beach, coastal levees have not been constructed until now.

Regarding setting evacuation roots, there is nothing on the national level, but there in an evacuation plan and a tsunami hazard map in the community.

Figure 2.1.29 Example of Setting Evacuation Root(→) (Response Plan for Masachapa in San Rafael del Sur)

(4) Tsunami Alert and Evacuation System

1) Warning Distribution System

CODE managed by DEFENSA CIVIL should receive and distribute tsunami information with 24x7 shift（Fig. 2.1.28）.

2) Warning Distribution Procedures

INETER issues the judgment of tsunami generation to office of the president and Co-Direcciones de SINAPRED simultaneously. The president decides on the issuance of tsunami warnings and orders SINAPRED to issue warnings with cellphone or radio, and warnings should be actually issued to related areas.

On the other hand, events of M7.0 of the Pacific coast area in Central America are handled without indication from the president by Co-Direcciones de SINAPRED based on its own judgment. This idea of handling comes from the experience at the event on 13 of October in 2014; at that time cellphone never connected to the president due to congestion. With that experience, the president has indicated the idea, which is just an inner regulation now.

In the case that the office of the president or Co-Direcciones de SINAPRED has the results of the assessment that an evacuation should be implemented, the sirens mentioned above should be used and mass media should broadcast the warnings.

CODE should also issue the information with radio to all City CODE and all COLOPRED together; then City CODE will issue the information to the leaders of communities with radio or cellphone. Radio equipment is well distributed to the communities located on the Pacific coastal areas (the exact number is not clarified at present.); the cancellation is distributed with the same procedures.

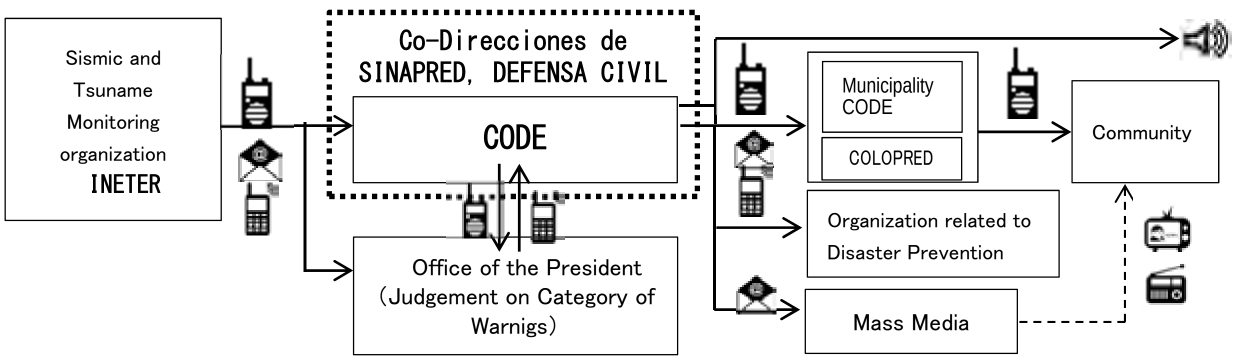

Figure 2.1.30 Tsunami Warning Issuance System

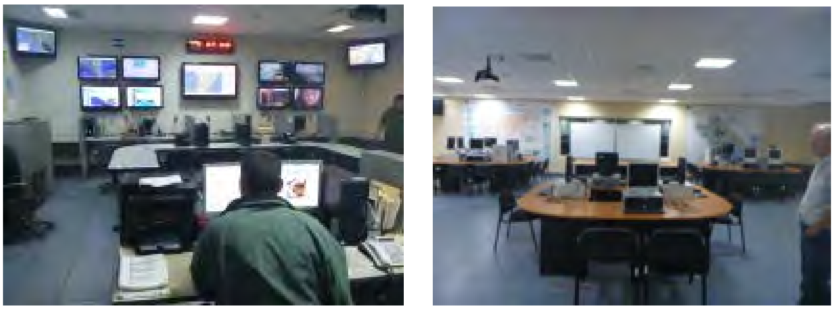

Figure 2.1.31　CODE（left）、Meeting Room for Committees for each event-type（right）

3) Tsunami Evacuation System

Tsunami evacuation plans have been developed at the community level; almost all communities located in coastal areas have finished the development; evacuation drills have been implemented twice a year according to the plans.

(5) Tsunami Risk Assessment Technique and its Present Situation

There are figures showing the inundation areas estimated by INETER and SINAPRED; but the figures show only the altitudes of the Pacific coastal area with 1/250 thousands scale, and the tsunami risk has not been assessed yet.

Figure 2.1.32　Tsunami Inundation Concerning Area Map

(6) Development on Hazard Map against Tsunami and its Utilization

Regarding a hazard map for tsunamis, there is one for four locations on the Pacific coast at 1/50 thousands scale with support from JICA, but nothing for other areas.

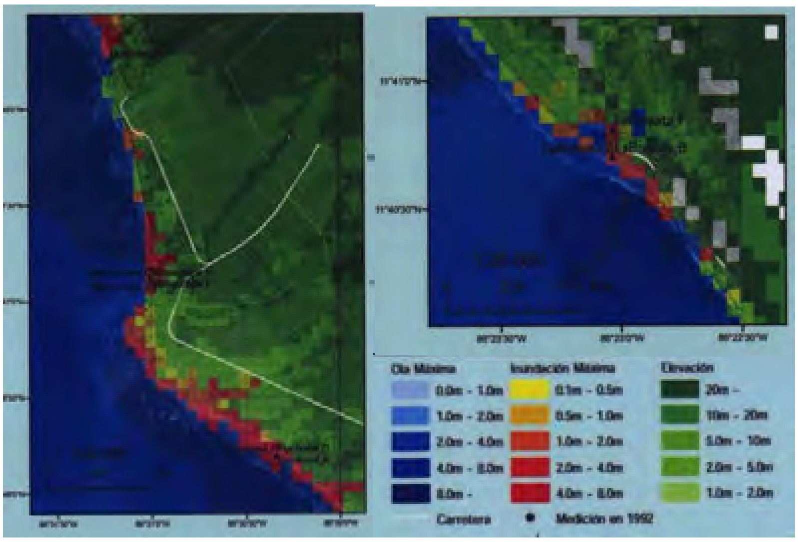

Figure 2.1.33 An Example of Hazard Map against Tsunami (Masachapa area) (Source: INETER)

(7) Effort for Tsunami Disaster Prevention at Research Institute like University and NGO

Universidad Nacional Autónoma de Nicaragua (UNAM) and INETER are now opening a seismic training course with the support from Swiss Agency for Development and Cooperation (COSUDE). The capacity of trainees is 30; the conditions of trainees are graduates or interns in the field of physics, geology and mathematics; the training continues for one year and eight hours a week. Trainers come from Cuba and Mexico; and members of staff of INETER who has experienced the training in Japan take the role. The training is expected to contribute to the improvement of earthquake analysis ability; but some items for improvement of the ability of monitoring shift is not included in the course; the items are seismic and tsunami monitoring, and their analysis.

As NGOs, Save the Children、Plan Nicaragua and Grace Baptist Church (GBC) are taking actions in the field of emergency, fire prevention and others as disaster prevention for children.

2.1.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects of Japan's cooperation to earthquake and tsunami disaster in Nicaragua are shown in the following table:

Table 2.1.9 Japan's Corporation Projects to Earthquake and Tsunami Disaster in Nicaragua

Scheme	Project Name		Period
Development Study	The Study on Vulnerability Reduction for Major Roads in the Republic of Nicaragua		2002-2003
Training Program	Countermeasure for Disaster in Central America		2003
Development Study	Study on Hazard Mapping and Information Infrastructure Development in the Republic of Nicaragua		2003-2006
Technical Cooperation	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" (Technical Corporation with León Municipality and ministry of education to strengthen the disaster response capability (Early Warning) of Las Peñitas of León City, Salinas Grandes, and Poneloya. However, community disaster management activities have been continued by COLOPRED, issues of lack of budget and limited good practices remain. 3 communities established NGO called "POPESAL", and it fundraises by itself and develops the activities.		2007-2012
Technical Cooperation	Improvement of the Earthquake-Resistant Housing Construction Technology.		2010-2013
Training Program (2010-2014)	Recovery Policy of Earthquake disaster/earthquake resistance		2010-2013
	Community based Disaster Risk Management	(2)	2014
	Seismology, Earthquake Engineering and Disaster Management Policy	(1)	2010
	Seismology, Earthquake Engineering and Disaster Recovery Management Policy	(6)	2012-2014
	Enhancement and Dissemination of Earthquake resstant Technology for Building in Latin American Countries	(4)	2014
	Disaster Management in Central American Countries	(15)	2010-2014
	Tsunami Disaster Mitigation	(1)	2014
	Disaster Risk Reduction Strategy for Urban Earthquake	(2)	2010
Dispatch of Science and Technology Researchers	Evaluation of Multi-hazards in the South Basin of Lake Managua, Nicaragua; The researchers for Landslides Risk Evaluation Model, Earthquake Risk Evaluation System and Ground Response Analysis Method were dispatched the Japanese researchers to the Center for Geosciences Research, National Autonomous University for the capacity development of human resources who contributed to reduce the risk of multi-hazards.		2010-2012

*Numbers in ( ) of Training Program indicate number of participants

(2) Situation of Key Donor's Cooperation

Projects of Key Donor's cooperation to earthquake and tsunami disaster in Nicaragua are shown in the following table:

Table 2.1.10 Key donor's Projects to Earthquake and Tsunami Disaster in Nicaragua

Funding Agency	Project Name / Project Outline	Project Sight	Implementing Body	Budget (USD)	Period
World Bank	Nicaragua Disaster Vulnerability Reduction Project Six components of capacity development for central and local government, including SE-SINAPRED were implemented to strengthen the disaster management capability.	N/A	Central and local government	10 million	2001-2009
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation to Honduras, Costa Rica and Panama Earthquake hazard map of the whole country was created based on the concept "learning by doing" for hazard, vulnerability and risk analysis with INETER as counterpart.	Entire Nicaragua	INETER	2.4 million	2007-2010
DIPECO	Disaster Risk Management for Volcanic and Landslide Hazards in Ometepe Island Project of enhancement for disaster risk management to earthquake, volcanic eruption and landslide was implemented in Ometepe Island.	Ometepe Island	INETER	520,000	2008-2011
COSUDE	Disaster risk reduction program for Nicaragua Project for disaster risk management including the development of early warning system.	San Rafael del Sur, Masachapa and Pochomil	INETER Care International	2.2 million	2008-2012
World Bank	Development of a Risk Assessment Platform for Nicaragua(CAPRA) Technical workshop to apply CAPRA software was implemented with INETER as counterpart.	Managua	N/A	350,000	2009-2010
DIPECHO	Technical assistance for vulnerability reduction and response in Nicaragua Project of capacity development of community response to earthquake, et al. by early warning was implemented in five communities in Managua with INETER, Red Cross, Ministry of Education and Managua Municipality as counterpart.	4 district in Managua	INETER, Red Cross, MoE. Managua city	N/A	-
IDB, UN,ISDR	Phase Ⅱ in the development of a Risk Assessment Platform for Nicaragua Project of enhancement to analyze disaster risk was implemented with INETER as counterpart.	N/A	INETER	600 ,000	2009-2010

2.1.6. Items to be Improved

(1) Seismic and Tsunami Monitoring and Analyzing Ability Improvement

1) Seismic analyzing ability improvement through hypocenter determination improvement

In order to improve the reliability of judgment on tsunami generation, improvement of the accuracy of hypocenter and M determination at first. Therefore, the following measures should be taken: a) regarding seismic velocity structure model for hypocenter determination, INETER is using a local model, which is not yet evaluated for optimizing it; INETER should therefore evaluate it through obtaining any seismic velocity structure with results from the crustal structure research implemented until now, and should include the evaluation results into the hypocenter determination system; b) regarding the selection of seismic stations to be used for hypocenter determination in tsunami generation judgment, its criteria is not well established; INETER should obtain the method for optimizing the selection action through clarifying the criteria.

2) Introducing focal mechanism analysis technique

In order to improve the reliability of tsunami generation judgment, it is necessary to estimate and understand the focal mechanisms like normal-reverse type or strike-slip type immediately after the occurrence of any event. Therefore, at first, introducing the real time initial motion analysis for focal mechanism into the current official procedures of tsunami generation judgment to INETR. The accuracy of initial motion analysis is not so high for large earthquakes; INETER should obtain the technique of CMT analysis having high accuracy as the nest step; in order to do so, INETE should learn the algorithms of the software in any case.

Note: the CMT analysis function is included one of SeisComP modules; the license for using the module is not free, though. The CMT analysis will produce moment magnitude (Mw) in high accuracy.

3) Acquisition of Technique of Tsunami Generation Judgment

In order to improve the reliability of tsunami generation judgment, in addition to introducing focal mechanism analysis, it is essential to improve the accuracy of M. For example, the earthquake in August of 2012, INETER obtained and accepted 5.7 as M at the beginning, 6.6 at the next timing, 7.3 provided from USGS lastly (Note: USGS informed 6.8 at the beginning.) ; therefore, as for SeisComP to be used for automatic hypocenter determination, it is necessary that a) the station selection for accurate M estimation method should be re-evaluated; b) the station correction method should be optimized. ; and as the next step, CMT analysis for getting more accurate M is needed as mentioned above.

4) Introducing procedures of estimation of tsunami height and tsunami arrival time and criteria for tsunami warning cancellation

PTWC provides information on tsunamis for all countries located around the Pacific Ocean, the information should thus be a sort of "average" of a wide area, and is sometimes too rough to use for tsunami warning judgment for a region; that means the accuracy is not enough for handling any regional earthquakes.

In that context, INETER should acquire the ability of the estimation of tsunami height and tsunami arrival time gradually. Namely, as for estimation of the tsunami arrival time INETER should acquire a) the ability of an outline or approximate estimation with the current sea depth data, b) the one of improving the estimation with the latest progress in the sea depth research; as for estimation of tsunami height, a) the one of tsunami generation analysis with focal mechanism, b) the one of approximate but quantitative estimation with the current sea depth data, c) the one of tsunami generation judgment with CMT analysis, d) the one of improving the estimation with the latest sea depth data, and e) the one of improving height estimation with coastal geography. In addition, INETER should acquire the technique for earlier tsunami warning cancellation with keeping reliability.

5) Newly Installing Tidal Gauge Stations and others

In order to improve the accuracy of tsunami warning, a tidal gauge observation network should be improved step by step as follows: a) establishment of the system for stable operations of tidal gauges; b) optimization of data acquisition or data transmission configuration; c) optimization or reinforcement of the network of tidal gauge observation network from the view point that real time tidal data monitoring should be essential for the improvement of tsunami warning reliability and for the update of a tsunami warning category, and d) the reinforcement of networks of the type of "Deep-ocean Assessment and Reporting of Tsunamis (DART) ".

Note: DART_type tidal gauge was developed by NOAA; it is a real-time observation system and is composed of buoys and ocean bottom sensors.

(2) Improvement of the Distribution of Tsunami Information on Local Tsunamis

In recent years sirens of CODE have been installed at communities located on coastal areas of the Pacific Ocean; those contribute a lot to the rapid distribution of tsunami warnings; Co-Direcciones de SINAPRED mentions that the distribution of warnings to communities should be completed within 3-5 min; INETER or CATAC should thus have to shorten the time for tsunami generation judgment through simplifying judgment procedures and the automation of a warning issuance procedure.

(3) Promotion Policy on Seismic and Tsunami Disaster Prevention

1) Archive of seismic risk assessment data

CAPRA Project has provided a tool for risk assessment; it is not well utilized, though. The cause of it is that essential data, like building and infrastructure, to be processed in the tool have been not well archived; therefore, archiving this kind of data should be promoted.

2) Implementing Assessment of Seismic Risk

The area of Central America has high seismic risk. In order to help seismic disaster mitigation, it is essential to make buildings or infrastructures, which are earthquake–proof; and it is important to assess the present risk through establishing any seismic disaster prevention measures.

2.2. El Salvador

2.2.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of El Salvador is shown in following table.

Table 2.2.1 Basic Information of El Salvador

Area	Contents	Source
Population	6.34 million	2013, World Bank
GDP	24.26 billion USD	2013, World Bank
Area	21,041 ㎢ (Land Area 20,721 ㎢) (land use: Arable 31.61%、Cropland 10.93%、Other 57.46%)	2011, CIA World Fact Book
Administrative	14 Departments	CIA World Fact Book
Geography	Mostly mountains with narrow coastal belt and central plateau.	Library of Congress Country Studies
Climate	Tropical; rainy season (May to October); dry season (November to April); Tropical on coast; Temperate in uplands	Library of Congress Country Studies

(2) Basic Information of Natural Disasters

Nicaragua has been exposed to a variety of natural hazards such as earthquake-tsunami, volcanic eruption, hurricane induced heavy storm, landslide et.al. There have been damaging earthquakes which have caused more than 100 victims seven times(1902、1917、1936、1951, 1965、1986、2001) in the last 100 years.(Table 2.2.5). The earthquake in 1986 caused 1500 victims and housing lost in San Salvador. The earthquake in 2001 induced many landslides that caused many victims. As for tsunami, the earthquake in October 2014 a tsunami occurred in La Union, but it was low impact.

Table 2.2.2 List of major earthquakes in the history of El Salvador (Source: MARN. CRED/EM-DAT)

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)	Date
1524	-	San Salvador	-	-	-	First damage reported
1576/05/23	-	San Marcos	-	-	-	Total destruction.
1593	-	San Salvador	-	-	-	Severe damage
1625	-	San Salvador	-	-	-	Severe damager
1650	-	San Salvador	-	-	-	
1659/09/30	-	-	-	-	-	
1707	-	San Salvador	-	-	-	Eruption of Boquerón volcano. Complete destruction of San Salvador
1719/03/05	7.4	San Salvador	-	-	-	
1730	5.5	San Salvador	-	-	-	Severe damage
1733	7.2	Santa Ana	-	-	-	
1765/4	5.7	Ilopango	-	-	-	
1769	-	Izalco	-	-	-	Damage of the Churches
1773/07/29	7.5	-	-	-	-	Damage in Ilopango, St. Martin, etc.

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)	Date
1783/11/29	6.6	San Vicente	-	-	-	Damage in Izalco
1798/02/02	5.4	San Salvador	-	-	-	Severe damage San Salvador
1815/08/20	6.1	San Salvador	-	-	-	Damaged in villages
1831/02/07	7.1	San Salvador	-	-	-	Damaged in San Vicente de Austria
1838/12	-	San Miguel	-	-	-	
1839/03/21	6.2	San Salvador	-	-	-	r
1847/06/23	5.9	Balsamo	-	-	-	Damage of Churches
1854/04/16	6.5	San Jacinto	-	-	-	Severe damage
1854/06/11	6.3	San Vicente	-	-	-	Complete damage
1854/06/18	-	San Miguel	-	-	-	Damage in San Salvador and neighboring towns
1859/08/25	7.1	La Unión	-	-	-	Damage in Balsamo, etc.
1859/12/08	7.3	San Salvador	-	-	-	Severe damage
1860/06/21	5.8	San Vicente	-	-	-	
1860/12/03	7.1	San Salvador	-	-	-	Damage of church
1867/06/30	7.1	San Salvador	-	-	-	Landslide occurred
1872/12/29	5.4	San Vicente	-	-	-	
1873/03/19	7.1	San Salvador	-	-	-	
1891/09/09	7.1	San Salvador	-	-	-	
1892/10/18	-	La Unión	-	-	-	Tsunami in Acajutla
1893/01/02	5.6	San Salvador	-	-	-	
1899/03/25	5.7	San Vicente	-	-	-	Damage around San Salvador
1902/4/18	7.9	-	185	-	-	Damage of Church
1912/7/19	5.9	-	-	-	-	Damaged in San Salvador, etc.
1917/6/8	6.5	San Salvador	100<	-	-	Damage in St. Vincent
1936/12/20	6.1	San Vicente	100-200	-	-	
1951/5/6	6.2	Jucuapa	1,000	-	23,000	Severe damage
1961/4/12	5.95	-	-	-	-	Damage around Lake Ilopango
1965/5/3	6.0	San Salvador	125	139,720	35,000	Strong earthquake destroyed some walls in San Salvador at 8:10 am
1982/6/19	7.0	-	20	32,500	-	
1986/10/10	7.5	San Salvador	1,500	770,000	1,500,000	Severe damage
1999/3/1	4.6	San Vicente	-	-	-	Severe damage
1999/4/3	5.3	-	-	-	-	Severe damage
2001/1/13	7.6	-	944	1,334,529	1,500,000	
2001/2/13	6.6	San Vicente	315	256,201	348,000	Tsunami occurred
2001/2/17	5.1	San Salvador	-	-	-	
2005/5/5	4.9	Apaneca	1	751	-	
2006/12/17	-	San Lorenzo	-	16,470	-	
2012/8/26	6.7	San Juan del Gozo	-	-		
2014/10/13	7.3	La Union	-	-	-	Tsunami alert

Note : - means data is not available

2.2.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management (Policy, Organization)

1) Policy Framework on Disaster Management

The Policy Framework on Disaster Management in El Salvador is shown in the following table.

Table 2.2.3 Policy Framework on Disaster Management in El Salvador

Category	Name	Contents
Policy	The National Policy Integrated Risk Management	The policy indicates a general principle forth reduction of damage in emergencies and disasters.
Law	Law 777 (2005):Disaster prevention and mitigation	The law stipulates the role of the General Directorate for Civil Protection (DGPC) , a disaster prevention system and planning on the national-level, alert issuance and provisions of penalties of law violation.
Plan	National Five-year Development Plan 2010-2014	The highest level national plan which indicates the vision of development and strategy, stipulating "Development of civil protection, early warning and risk management" as one of the purposes of the plan
	National Plan of Protection Civil	The plan is composed of risk reduction, promotion of assessment, risk analysis, disaster prevention education and an information system, is under review to add risk analysis of earthquake and tsunami and measures for prevention and mitigation.

2) Framework of Disaster Prevention Organization

【1】Framework of the Organization System

MARN/DGOA implements the observation of weather, volcanoes, air pollution in addition to earthquakes and tsunamis, also performing the dissemination of disaster information, creation of hazard maps, risk assessment and collection of disaster inventory.

On the national level, DGPC carries out measures of disaster prevention, formulation of the national plan and dissemination of warnings on the national level based on the law 777. On the local level, Commission Departmental de Proteccion Civil(CDPC) , Commission Municipal de Proteccion Civil (CMPC), and Comision Comunal de Proteccion Civil (CCPC) carry out disaster management measures on a departmental level, municipality level, and community level, respectively.

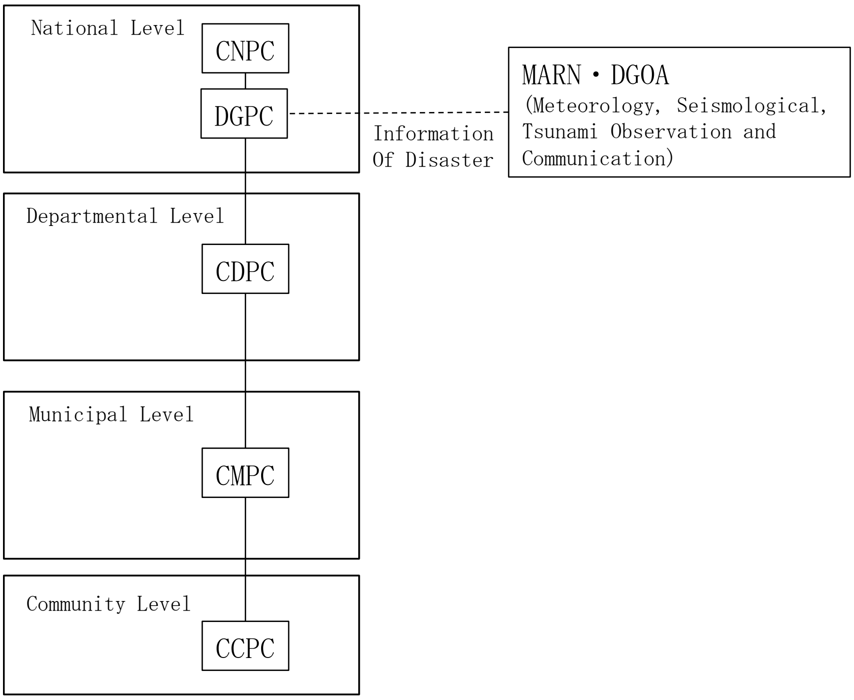

Figure 2.2.1 Structure of Relevant Organization of Disaster Preventing(El Salvador)

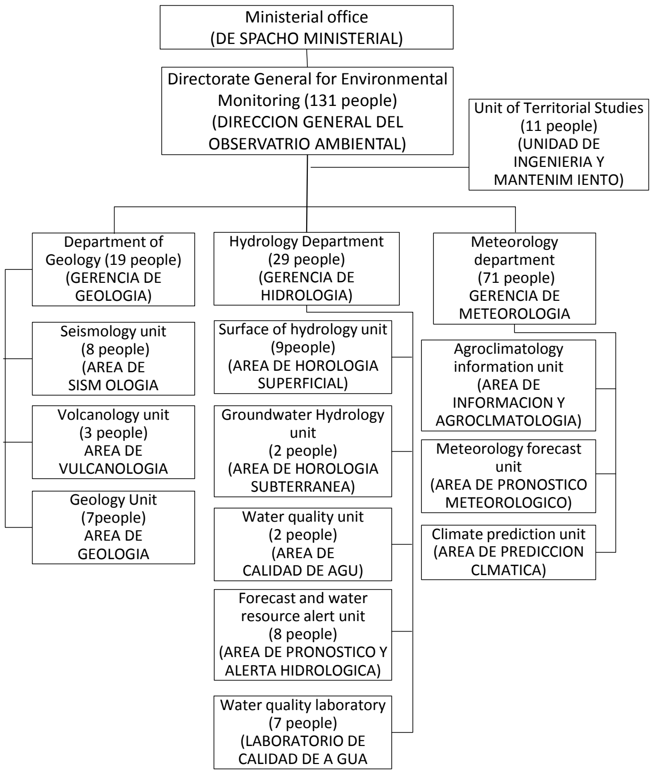

Figure 2.2.2 Organization Chart of MARN /DGOA

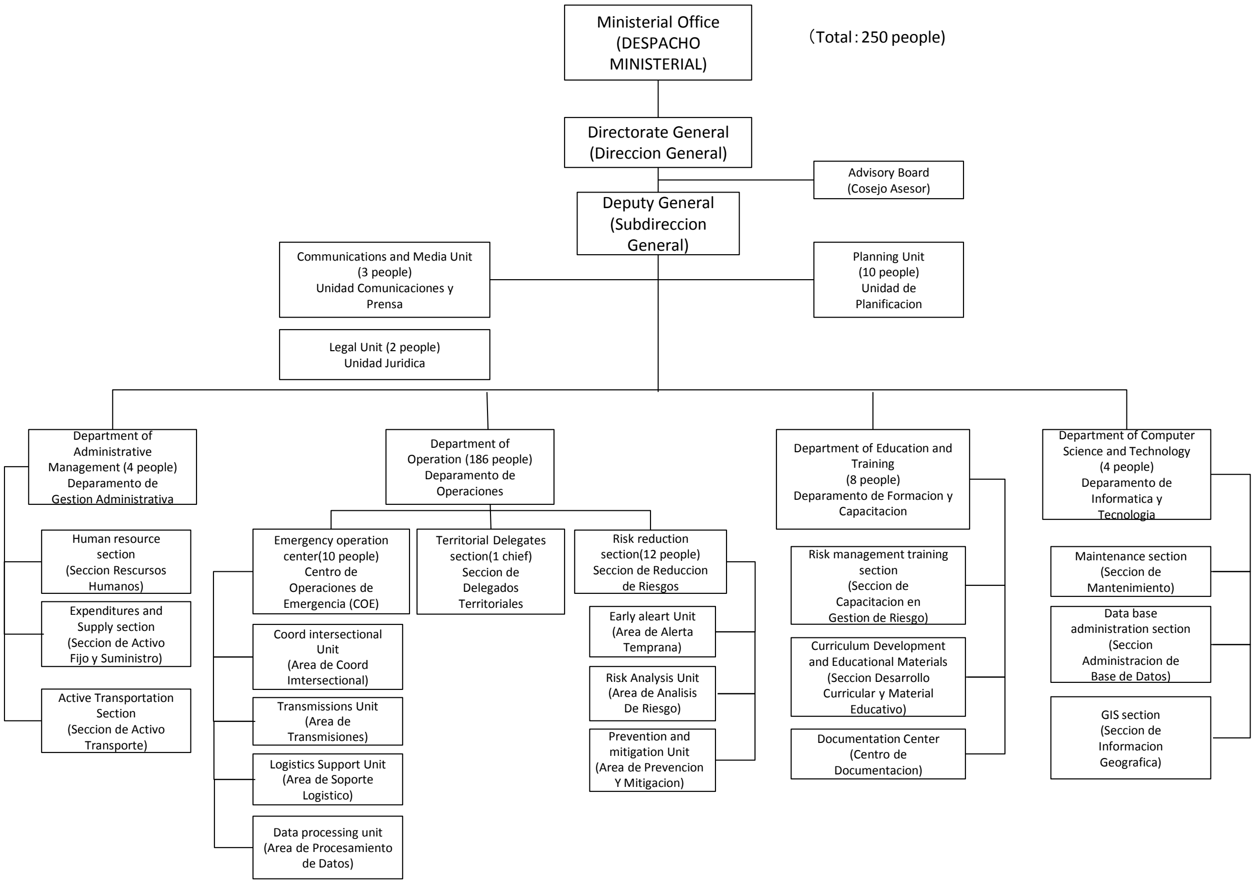

Figure 2.2.3　Organization Chart of DGPC

【２】Sharing Responsibility for Earthquake and Tsunami Disaster Prevention

MARN/DGOA carries out monitoring, creation of hazard map and risk assessment of earthquake and tsunami. MARN/DGOA issues technical information of earthquake and tsunami to Emergency Operation Center in DGPC, then DGCP judges the category of alert by the director of DGPC and issues through Disaster Operation Center

【３】Expectation to CATAC

MARN/DGOA expects CATAC to consult a reliable judgment for an alert of a tsunami due to inexperience in tsunami observation and alert issuance, even though they have made them in the past. Additionally, MARN/DGOA has an expectation of working CATAC as a backup system of observation function.

(2) Priority and Significance on Relevant Laws of Earthquake and Tsunami on National-level

DGPC used to monitor floods and volcanoes in particular, but earthquake monitoring is a big issue recently because lately there is a tendency that earthquakes, including insensible, have occurred more than five thousand times in one year. Thereby, DGPC has conducted a review of the National Plan of Protection Civil with adding risk analysis of earthquake and tsunami, and with revising measures for prevention and mitigation.

(3) Situation of the Allocation of a Budget for Disaster Prevention

The budget of MARN was approximately USD 26 million in 2014. The allocation of employment amounted to about 38%, and total of maintenance and postage amounted to about 24%, and consumable article amounted to about 24%. There is a fund for disaster prevention called "Disaster Prevention and Mitigation Fund (Fondo de Prevención y Mitigación de Desastres :FOPOMID)" of USD 400 million a year. The fund is administered separately from the budget of each organization involved in disaster risk reduction and is used as a supplementary budget.

(4) Situation of Activities for Disaster Prevention on the Community-level

Activities of disaster prevention on the community-level are to be covered by CCPC with assistance from CMPC. The following activities were implemented utilizing the cooperation of donors and NGOs.

- National Disaster Prevention Program : Training of basic knowledge of, response to and preparation for disasters, and analysis of the vulnerability of residents were implemented by MARN in San Salvador between 2010 and 2012 with the assistance of the Inter-American Development Bank(IDB) and Central American Bank for Economic Integration(BCIE)..
- Project for Disaster Prevention Education : DGOA/MARN provides observation data and implements education activities in disaster mitigation in rural areas together with NGOs including the Red Cross-Spain, the Red Cross-El Salvador, Swiss Labor Assistance (AOS: Ayuda Obrera Suiza) and Oxfam.
- participates in the implementation of the collaborative project with DIPECHO with the funding of USD 3 million for two years from the EU, DGOA/MARN is implementing educational activities in disaster risk reduction in rural areas together with NGOs including the Red Cross-Spain, the Red Cross-El Salvador, Swiss Labor Assistance (AOS: Ayuda Obrera Suiza) and Oxfam.
- Project for Disaster Prevention Education: These community disaster prevention projects have been implemented in 61 municipalities in five departments; San Salvador, Cabañas, La Libertad, Chalatenango, and Cuscatlán from 2011. The project which is based on the theme of "protecting the rights of children and living in a community with resilience.", has been implemented by Plan International in collaboration with MARN, Ministry of Education, DGPC, et.al. The project is aiming for; "Safety of school","Supply of information to children", and"Fulfillment of disaster risk reduction concepts for disaster mitigation".

(5) Situation of Disaster Prevention Education for Earthquake and Tsunami on Educational Institutes

- The Ministry of Education（MINED）implements disaster prevention education to 1,500 of 5,000 national and public schools, which targets school teachers, students and families. Considering that the disasters of this project are sediment disasters, volcanic eruptions and landslides, this disaster prevention education is insufficient in terms of earthquakes and tsunamis.

2.2.3. Earthquake Observation and Promotion of Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

Earthquake observation in El Salvador is carried out by MARN/DGOA. DGPC is responsible for earthquake warning information dissemination and emergency response. The development of seismic code is within the responsibility of the Ministry of Public Works (MOP).

(2) Earthquake Observation Capability

1) Seismic Observation Operation

The earthquake observation is conducted by the Section of Geology, MARN /DGOA, which has five people on staff, in a 24-hour manner with one shift per one person.

2) Earthquake Observation Network

The earthquake observation network has eighteen analog short period seismometers, 25 digital short period seismometers, eleven broadband seismometers and 42 accelerometers. The total is 96, shown in Table 2.2.4 and figure 2.2.4. The seismometers are mainly deployed along the volcanic belt and around the metropolitan area of San Salvador. 75 seismometers, where the data can be collected in real time, are used for the calculation of the epicenter and magnitude of an earthquake. 21 accelerometers are used for the calculation of Modified Mercalli Intensity, MMI, by the software of SHAKEMAP. Both the source parameter and intensity can be obtained in a few minutes.

The University of Central America (UCA) installed ten accelerometers in the 1990s in an EU project and has continued to be used up to now. The University of El Salvador (UES) has two accelerometers installed in the first floor and third floor, separately, of a 3-story building. None of the accelerometers in the two universities has the telemetry function. In addition, the Lempa hydroelectric power committee (CEL) has seismic observations for its dam monitoring, but the data are not routinely provided to DGOA.

In the calculation of the source parameter and magnitude, the data from INTER, Nicaragua, and INSIVUMEH, Guatemala, and IRIS are used for a better estimation especially for the events around the boundary.

Table 2.2.4 Seismometers and Data Collection Means of El Salvador

Seismometer		Total	Data Collection							
Type	Record format		Analogue radio	Digital radio	Microwave radio	Internet	Wireless internet	Satellite internet	Public network	On site
Short period	Analog	18	18							
	Digital	25		6	3	14	2			
Broadband	Digital	11		5	1	2	1	2		
Accelerometer	Digital	42				20	1		9	12
Total		96	18	11	4	36	4	2	9	12

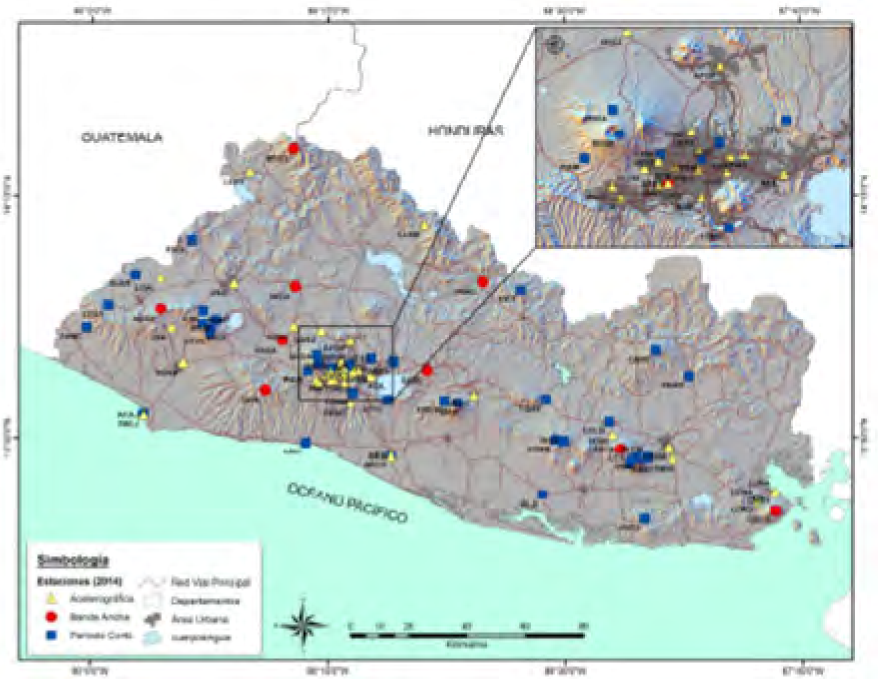

Figure 2.2.4　Location of Seismometers in El Salvador（Source：MARN）

The table below shows the seismic observation network of MARN/DGOA..

Figure 2.2.5　Detail of Seismic Observation Network of MARN/DGOA

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	43	43	0	43	43
	On Site	0	0	0		
Broadband	Real Time Telemetering	11	11	0	11	11
	On Site	0	0	0		
Strong Motion	Real Time Telemetering	30	30	0	30	30
	On Site	12	12	0		
Total	Real Time Telemetering	84	84	0	84	84
	On Site	12	12	0		

3) Seismic Data Processing

SeisComP is used for automatic data processing and the occurrence time, epicenter location (longitude, latitude), and the focal depth and magnitude of the earthquake are automatically calculated. The automatic data processing needs about two minutes after the detection of the event. The official results after the manual confirmation will be released in about fifteen minutes. The regional shear wave velocity model is used for the　calculation.

4) Earthquake information dissemination

When an earthquake, larger than the warning criteria, see Figure 2.2.5, is detected, DGOA will immediately inform DGPC the occurrence of the event. The information (Figure 2.2.6) will also appear on the DGOA homepage in five to fifteen minutes. In case of a big earthquake, intensity (MMI) will also be provided on the home page, shown in Figure 2.0.7. The flowchart of data collection, processing, and dissemination is shown in Figure 2.2.8.

Zona	Criterios para reporte sismo
1	Magnitud ≥ 2.5
2	Magnitud ≥ 3.5
3	Magnitud ≥ 4.0
4	Magnitud ≥ 5.0

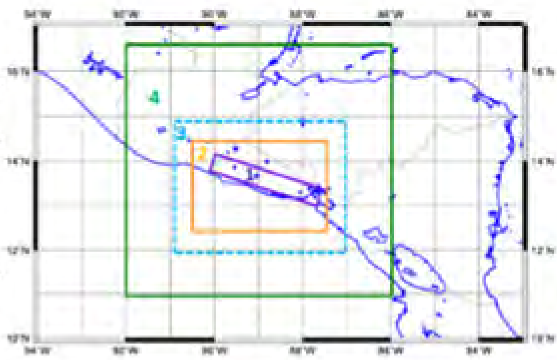

Figure 2.2.6 Criteria for Earthquake Warning (Source: MARN)

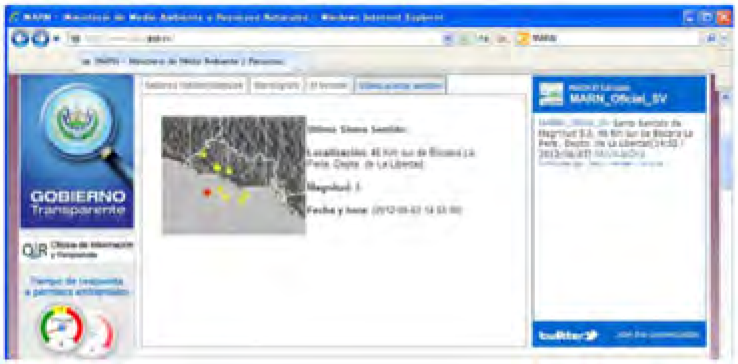

Figure 2.2.7 Screen shot of Earthquake Information of DGOA (Source: MARN)

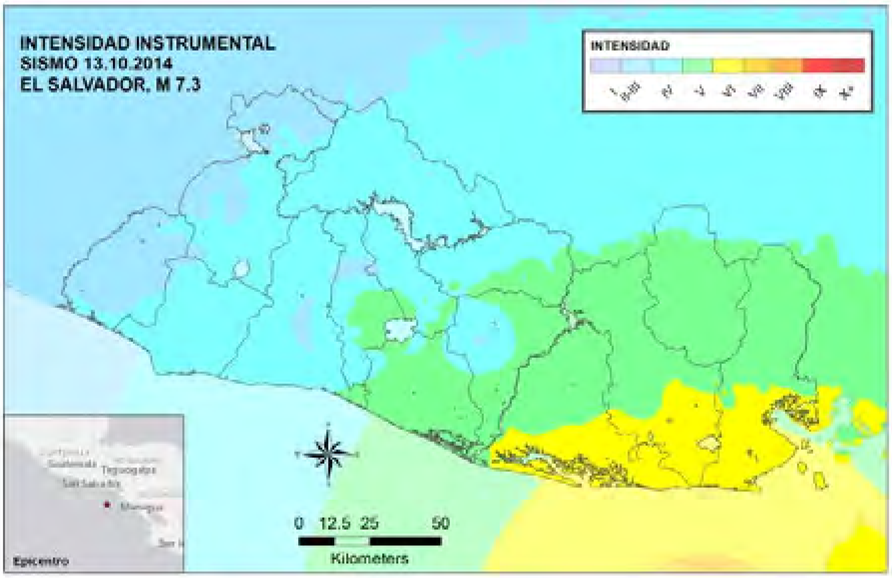

Figure 2.2.8 Screen shot of Intensity Distribution of DGOA（Source：MARN）

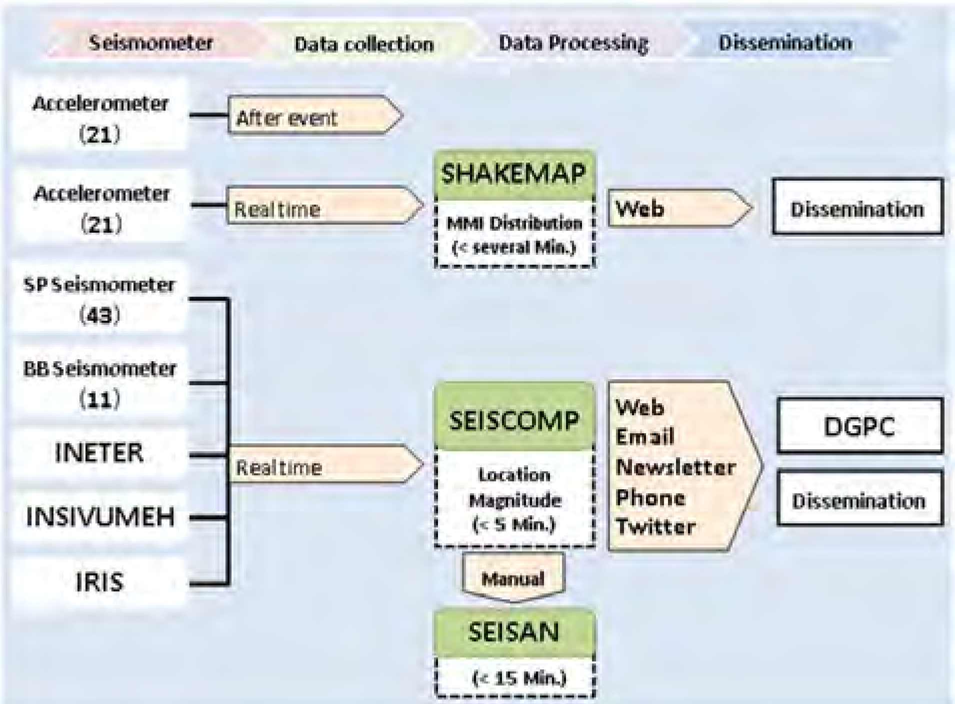

Figure 2.2.9 Flowchart of Earthquake Observation data Collection, Processing and Results Dissemination of DGOA

(3) Approach and Current Status of Seismic Risk Assessment

In 2012, in El Salvador the CAPRA platform was utilized for the seismic risk assessment for the hospitals, schools and government buildings in the Sal Salvador metropolitan area. The risk assessment for a total of 1,550 buildings was performed, where the seismic performance of each type of structure was investigated and their vulnerability curve was evaluated. The risk assessment was carried out by a stochastic approach and the results are expressed by annual expected loss. Through the risk assessment results, the buildings which will have severe damage and that should prioritize for seismic retrofitting were identified. As an example, the risk assessment results for a scenario earthquake with the same magnitude as the 1986 earthquake, which caused significant damage in El Salvador, is shown in Figure 2.2.8. The next challenge would be the extension of risk assessment to residential houses.

The University of El Salvador (UES) is conducting a UNESCO pilot project, Safe School, where 100 schools out of the total 5,200 public schools were targeted. The project is in its final stage at the time of December 2014. The seismic hazard from MARN was used for the risk assessment and vulnerability curves for the adobe, concrete blocks, reinforced bricks and reinforced concrete structures that were evaluated. The software of VISIS was applied for the assessment, which has the functions for the risk assessment for earthquakes, tsunamis, landslides and volcanoes as well as the cost estimation required for strengthening their seismic performance.

In addition, there is a project currently in progress, for risk assessment for the San Salvador metropolitan area and Santa Tegla City by UES making use of the WB fund. In order to make the vulnerability curve, 2,600 houses were surveyed for the material (adobe or brick) and structure type (with or without strengthening) and they were divided into 41 types. The vulnerability curve was evaluated by FEM analysis with considering the material characteristics, construction methods (under the current seismic code (1997 and later) or the old code (Between 1996 and 1997)). The seismic hazard results from MARN were used. It should be noted that the soil amplification by the surface soil was not taken into account in the analysis because of the unavailability of the data. As a result, the damage extent of the building, such as collapse, severe damage and medium damage was provided and it is expected to be used in the disaster prevention plan.

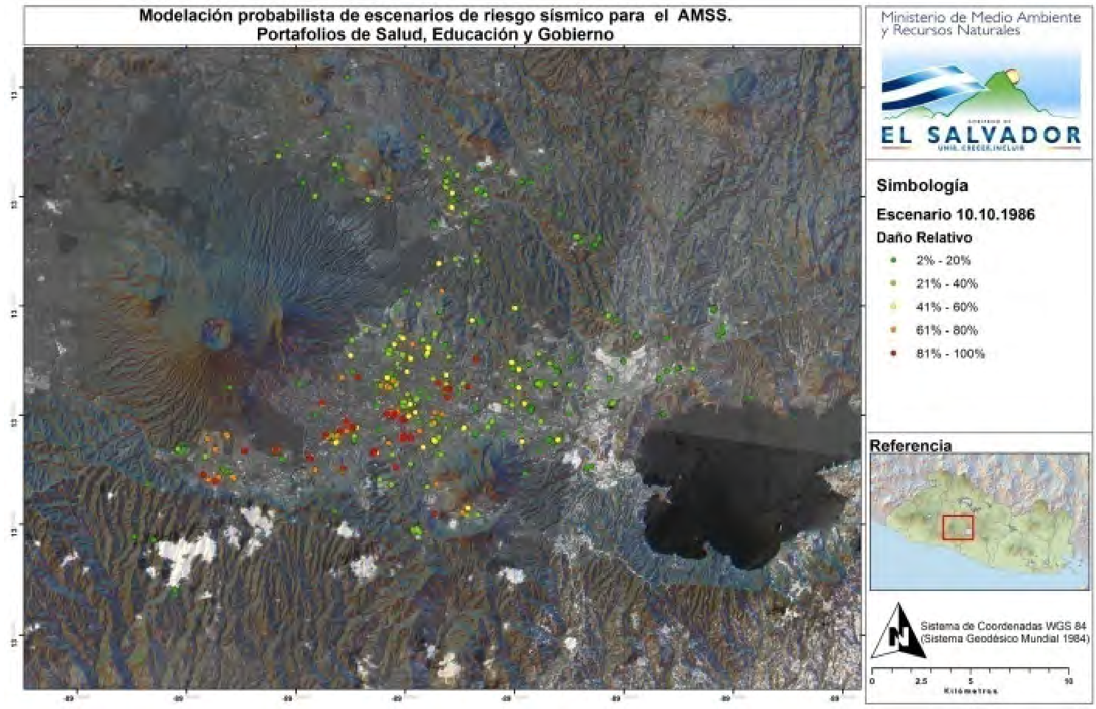

Figure 2.2.10 Risk Assessment for a Scenario Earthquake of the 1986 Magnitude (Source：MARN)

(4) Development and utilization of a seismic hazard map

The evaluation of the seismic hazard of El Salvador was conducted in the above-mentioned project and in the project of Earthquake Risk Reduction in Central America (RESIS II). The seismic hazard of RESIS II covers the whole territory of El Salvador. The results are given by the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with a 500 year return period in Nicaragua is shown in Figure 2.2.10 and the hazard curve of Managua is shown in Figure 2.2 11. For large earthquakes, the intensity will be estimated by SHSKEMAP and its distribution will be published on the MARN web site.

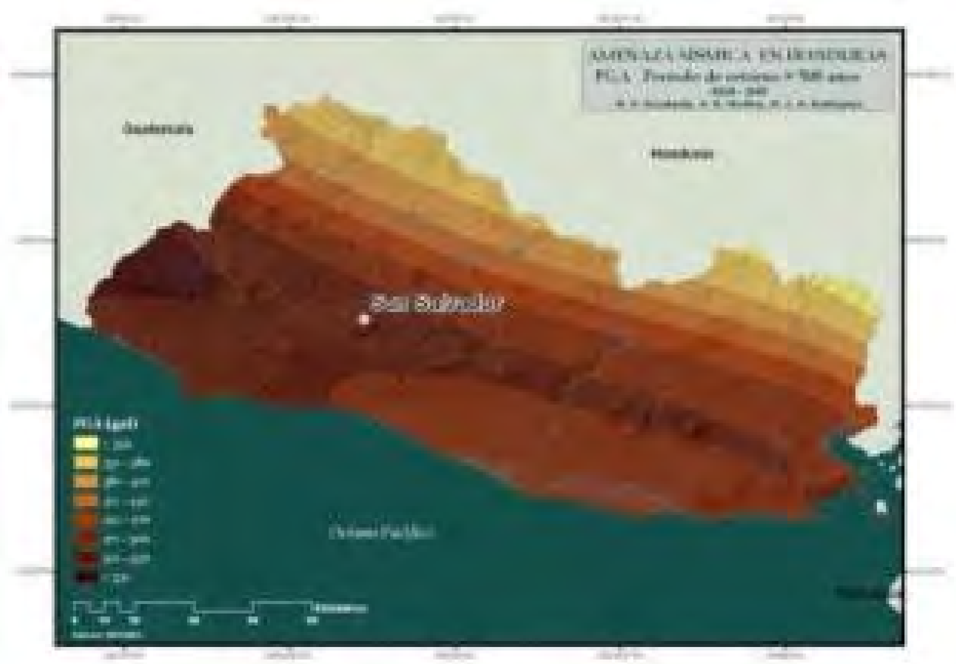

Figure 2.2.11 Seismic Hazard of El Salvador by RESIS II (PGA、Return Period 500years) (Source：RESIS Ⅱ Report)

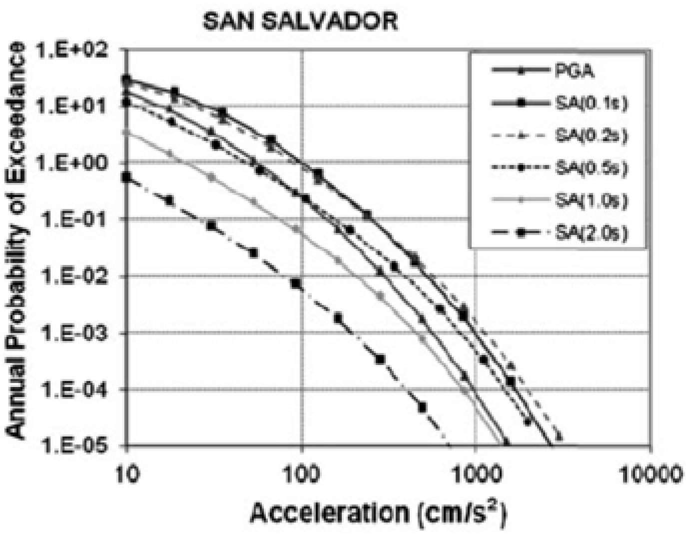

Figure 2.2.12 Seismic Hazard Curve of San Salvador by RESIS II (Source：BSSA,Vol.102, No.2,2012)

(5) Development of a seismic code and its implementation

El Salvador is an earthquake prone country and its seismic code was developed in 1965, and then revised in 1989 and 1994. The current code (NTDS) is that which was revised in 1997, with the reference to the UBC-97 (Uniform Building Code, 1997) of America. The seismic force, according to the code, can be calculated by either static seismic force (only first vibration mode is considered) or dynamic seismic force (considering more than one vibration mode). The buildings with a regular plane shape and which were less than 70m high and those with an irregular plane shape but lower than 20m could apply the static seismic force. The dynamic seismic force is required for the other buildings. The basic formula for the calculation of horizontal seismic force is

$$V=CW$$

Where: V is the horizontal seismic forces.

C is the coefficient with considering the ground motion zonation (Figure 2.2.12).

W is the total weight of the building.

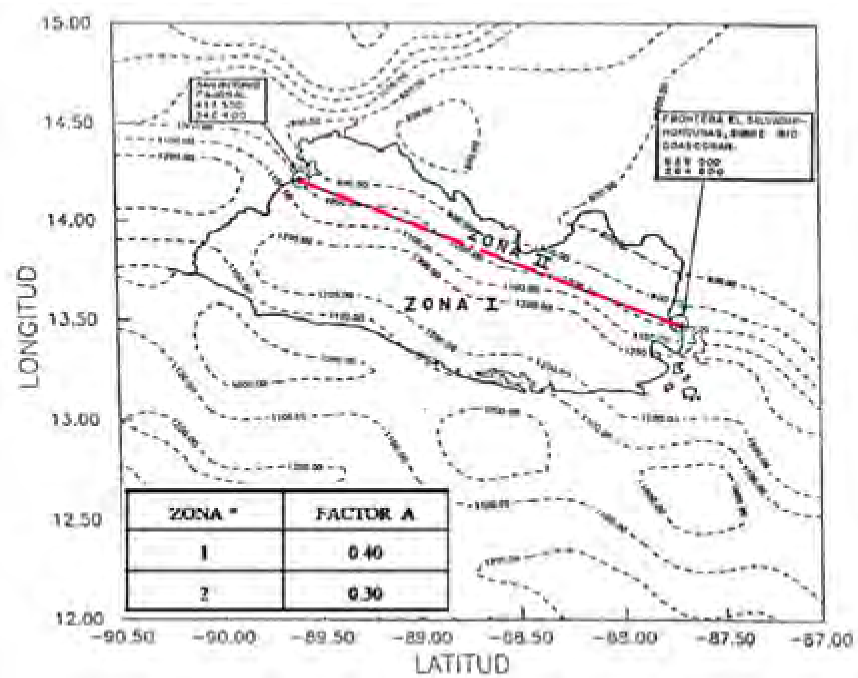

Figure 2.2.13 Ground Motion Zonation of Seismic Code of El Salvador (Source: El Salvador Seismic Code)

It should be noted that although the current seismic code was authorized by the president 1997, but was not approved by the congress, so that it has no legal power. According to the code, it should be revised every six years, but this does not function in reality. There is recognition among the experts that the current code, created in 1997, needs to be revised. The experts had made the proposal to the Housing and Urban Development Bureau, Ministry of Public Works, but the expert in the Bureau is not sufficient to respond to the revision. The code stimulated the establishment of a structure safety committee. Although the committee was created in 2001, it has not been active from the beginning.

There are different cases for building permission. The authority of building permission for the San Salvador metropolitan area is OPAMOS, which is specially established for the area because of the large volume of applications. OPAMOS is responsible for the review of drawings and structure calculations according to the guidelines made by the Ministry of Public Works. The construction of buildings needs, at first, the examination from the point of view of urban planning and then the structure design. In all other regions, the Housing and Urban Development Bureau, a joint organization of plural municipalities or the municipality alone, makes the inspection and permission. The permission for seismic design is based on the El Salvador seismic code for seismic load, the American standards for RC structure and Mexican standards for brick structures.

From the 2001 earthquake, which had caused significant damage to houses, it was recognized that the seismic strengthening for old buildings is necessary. However, a promotion policy has not yet been implemented. Although there were individual cases for seismic strengthening for RC hospitals with international support, the promotion including the government and professional bodies is necessary.

JICA has performed a project of the Enhancement of Technology for the Construction of Earthquake-Resistant Popular Housing (also known as "TAISHIN" project) in 2003-2008, and a project of the Enhancement of the Construction Technology and Dissemination System of the Earthquake-Resistant "Vivienda Social" in 2009-2012. As the results of the "TAISHIN" project, the seismic design criteria for the adobe structures of one-floor and the area less than 50m2 buildings was created. The application of the criteria needs the understanding of the criteria by the officials in charge of the building permission. The criteria for the two-floor buildings are under development from the fund from the Ministry of Public Works.

There has been no earthquake damage for roads and bridges in the past. The design of bridges is made with reference to the American standards of AASHTO. There is a special policy for the promotion of improving the seismic performance of transportation infrastructure and lifeline facilities, such as roads, bridges, electricity, water, etc.

(6) Activities of University Institutes and NGOs for Disaster Prevention

The Department of Civil Engineering, Faculty of Engineering and Architecture, University of El Salvador (UES) is the counterpart of the JICA project of the Enhancement of the Construction Technology and Dissemination System of the Earthquake-Resistant "Vivienda Social" (2009-2012). The Department was also involved in the above-mentioned UNESCO pilot project of Safe School and the WB funded the seismic risk assessment project for the San Salvador metropolitan area and Santa Tegla City.

The University of Central America (UCA), together with UES, is also the counterpart of the JICA project of the Enhancement of the Construction Technology and Dissemination System of the Earthquake-Resistant "Vivienda Social" (2009-2012). The university has experts in the field of earthquake resistant structures, and created a program of a Master's degree in earthquake engineering in 2013. They also have contributed to the dissemination of the seismic technology.

2.2.4. Tsunami-Monitoring and Tsunamis-Disaster prevention efforts

(1) National organizations responsible for Tsunami-Disaster prevention and relevant organizations

The MARN has the responsibility for technical judgments on generations of scared tsunamis. On the other hand, DGPC has the responsibility for issuing Tsunami Warnings based on the information provided by MARN.

Note: The MARN is approved as TWFP and TNC by IOC.

(2) Monitoring System relevant to Tsunamis

1) Tsunami Monitoring System

One "7x24 contact" member of a team having five people from the Geological Section of DGOA implements tsunami monitoring.

MARN allocates "7x24 contacts" monitoring staff in charge of floods or weather together with the geological staff for earthquakes and tsunamis. Under this context, in order to improve the warning issuance protocol, that the geological staff should be supported by the staff for floods or weather when handling tsunami warnings or strong motions is under consideration. In addition, in order to assess and improve tsunami generation judgment, methods for the drills of the assessment are being developed. However, it is essential for implementing the appropriate judgment that the monitoring staff should have the basic knowledge on earthquake and tsunami, even though MARN has a shortage of the staff having it. MARN has thus introduced the Intern System, and has started it with four "students" in 2014 considering the long-term human resources in the field of judgment on tsunami generation.

2) Tsunami Observation Network

Tsunami observations are handled with three tidal stations located at Acajutla, La Libertad and La Unión, and with two monitoring video-cameras at Acajutla and La Liberta, which view the tidal stations (Table 2.2.5).

Table 2.2.5 Tsunami Observation Stations in El Salvador (Source: MARN)

Equipment Type (Device Type)	Station Name (Station Code)	Coordinates	Sampling Rate / Transmission Interval	Means for Data Collection	Power	Responsible Institution	Inspection Interval	Observation Period
Tidal Gauge (radar (main) and pressure)	Acajutla (acaj)	N 13.573836° 89.838221° W	1 Second (1 min average) / 5 min	Satellite transmission	Solar	MARN/DGOA	3 Months	1971-2001 and August/2010~
Tidal Gauge (ultrasonic)	La Libertad	N 13.485180° 89.319016° W	1 Second (1 min average) / 5 min	Satellite transmission	Solar	MARN/DGOA	3 Months	August/2014~
Tidal Gauge (pressure)	La Union (laun)	N 13.332908° 87.818101° W	1 Second (1 min average) / 5 min	Satellite transmission	Solar	MARN/DGOA	3 Months	1956-1986 and October/2010~
Current meter	Acajutla	N 13.578520° 89.852328° W	N/A	Radio-archive in PC-data collection software (TEAMVIWER)-Internet	Solar	MARN/DGOA	3 Months	September /2012~
Current meter	La Union	N 13.314559° 89.775779° W	N/A	Radio-archive in PC-data collection software (TEAMVIWER)-Internet	Solar	MARN/DGOA	3 Months	September /2012~
Camera	Acajutla	N 13.575152° 89.833700° W	N/A	Internet	Solar	MARN/DGOA	3 Months	August/2014~
Camera	La Libertad	N 13.487091° 89.319328° W	N/A	Internet	Solar	MARN/DGOA	3 Months	August/2014~

3) Analysis of Tsunami Generation

MARN implements analysis for tsunami generation judgment with results obtained from the automatic hypocenter calculation, the California Integrated Seismic Network (CISN) and tsunami information provided by PTWC through emails, SMS or fax.

Note: Tsunami simulation is not used in real time procedures because MARN has no tool for real time handling of the simulation, though it is used in a review process at later time.

MARN starts tsunami generation judgment at the time when MARN realizes that the M of the event is larger than or equal to 6.5 or when MARN receives estimations on tsunami height or arrival time from PTWC. In addition, MARN judges the tsunami generation according to the criteria shown in Table 2.2.6.

Note: MARN has no criteria on the cancellation of a tsunami warning. In addition, it will not check the status of a tsunami warning dissemination to the population.

It is noticed that as for hypocenter determination for a judgment on tsunami generation, Nicaragua and El Salvador use different methods for selecting stations to be used in the calculation.

MARN does not use information issued from other countries in Central America. On the other hand, seismic waves observed at stations in El Salvador and information related to a tsunami warning issued from MARN is opened in MARN's web site to the public. Thus, they will be able to be monitored by other countries in Central America.

Note: MARN sends information related to tsunami warning issued from MARN to Honduras by email.

MARN will use seismic waveform data observed in foreign countries, but in order to enhance the reliability of tsunami generation judgment, it is necessary to strengthen the action or increase the numbers of stations to be used.

As for cooperation with other countries in Central America, El Salvador and Honduras worked together in reading the phases of the aftershocks of an event that occurred at the boundary area between them. Furthermore, once Guatemala had to turn the power off its observation system for three or four days. At that time, MARN provided seismic and tsunami related information to Guatemala in order to support their judgment on the generation of tsunamis.

Table 2.2.6 Criteria on Tsunami Generation judgment

Type of Tsunami	Seismic Parameter for the Criteria	Estimated Hours for Tsunami Arrival to Coasts of El Salvador	Category of Tsunami Information	Information for local observers
Near	$M \geq 7.0$	Less than 1 hour	Tsunami Warning	It will be recommended to the population to immediately move away from the coast and to address themselves to the recommendations of PC for return
Regional	$7.0 \leq M \leq 7.9$	3 or 4 hour	Tsunami Advisory	It will be recommended to the population to orderly move away from the coast and to address themselves to the recommendations of PC for return
	$M \geq 8.0$		Tsunami Warning	
Distant	$8.0 \leq M \leq 9.0$	Longer than or equal to 8 hours	Tsunami Advisory	Recommendation to the population that follows the recommendations of PC
	$M > 9.0$		Tsunami Warning	

4) Issuing Tsunami Information

MARN analyzes the results of the hypocenter and M calculation automatically and issues the analysis results. Although those results are obtained within about two minutes, MARN waits for updated automatic analysis results during an additional three minutes in order to have and issue results that are more reliable to DGPC. As for the final information, MARN adopts the results obtained fifteen minutes later from the occurrence of the event. The final one is issued to the "7x24 contact" emergency operation center of DGPC with VHF-radio, fax, telephone and email. The hypocenter obtained from automatic analysis is publicized on the web-site. Publication of it is implemented based on the earlier timing than that of the one manually evaluated.

The emergency operation center of DGPC has 40 members of staff, and two "7x24 contact" people, who monitor the MARN web site to the public, conduct its function in the monitoring room.

In DGPC, its director-general judges the category of tsunami warning according to the protocol based on information provided by MARN.

As for the earthquake on the coastal area of its own country or of nearby countries, MARN starts its action of judgment on tsunami generation when the M of the event is thought to be tentatively greater than or equal to 6.5. MARN also issues the analysis results to DGPC. In addition, MARN issues seismic information with twitter, and checks PTWC estimations on tsunami height and tsunami arrival time. In the case that the generation of a tsunami is not identified, the tsunami warning is canceled several hours later from the estimated arrival time of the first tsunami.

5) Specific Examples of Analysis of Tsunami Generation and Issuing Tsunami Information

On 13 October in 2014, at 9:51PM (El Salvador Time, the same hereafter in this section), an event of M7.3 caused a tremor of 45 seconds duration in San Salvador. MARN publicized the potential of a tsunami warning with twitter at 10:08PM and issued the information to DGPC with radio. In addition, MARN judged that a tsunami would be generated and issued the information mentioning that the tsunami alert should be maintained until 6 o'clock the following morning as a preventive measure at 10:40PM. The alert was canceled at 06:00AM the following morning.

On the other hand, PTWC issued its origin time, hypocenter and M as tsunami information by email at 10:08PM to all organizations, who participate in IOC, and MARN received it at 10:27PM. In addition, PTWC issued specific tsunami information to the TWFP of El Salvador (MARN), and MARN received it at 10:13PM. Its contents tell that "BASED ON THE PRELIMINARY EARTHQUAKE PARAMETERS... HAZARDOUS TSUNAMI WAVES ARE POSSIBLE FOR COASTS LOCATED WITHIN 300 KM OF THE EARTHQUAKE EPICENTER" and "ESTIMATED TIMES OF ARRIVAL -ETA- OF THE INITIAL TSUNAMI WAVE is 11:09PM at ACAJUTLA". Furthermore, PTWC issued tsunami information to MARN, which told, "the threat from the earthquake has now mostly passed away", and MARN received it at 10:40PM. Although PTWC canceled it warning, MARN maintained their warning until 6 o'clock. This is because MARN was not able to deny the idea of the arrival of any coda tsunami from the safety view under the condition of only the second experience in tsunami generation judgment.

In this event, at DGPC, the director-general was not informed of it, the planning unit decided to issue the tsunami warning without any indication from the director-general, and disseminate it to communities through relevant cities. It took less than 1 hour to disseminate it.

Note: There were no reports of tsunami damage on the coastal area, though there was one victim and some building damage by strong motion (Source: the national radio El Salvador shown in JMA document).

On 26 August in 2012, at 10:37PM, with an earthquake event of M6.7, MARN had difficulties in reading the phases. The M calculated immediately after the occurrence was 5.7, which was much smaller than the final calculation. Under this condition, it was at 11:30PM, 50 minutes after the occurrence, before it was judged to be "M6.7 and tsunami threat", and to tell the judgment to DGPC. It was at 11:56PM, another 20 minutes more, before it was issued to the public. Even at that moment, the calculated epicenter was different from the ones made by other organizations as shown in Figure 2.2.14. Regarding this event, PTWC issued seismic information eight minutes after the occurrence, and upgraded its judgment to a tsunami warning thirteen minutes later for the Central American area. MARN first received the tsunami information that the M was 7.4 at 10:46PM (Figure 2.2.13), and it received the specific tsunami warning for El Salvador at 11:05PM.

Note: The tsunami generated by the event of 2012 was 6m at its maximum height, and was 40km wide as for its inundation of the coastal area. The inundation reached 300m inland in some areas. PTWC canceled its tsunami warning at 00:27AM on the 14th, which was 2 hours after the earthquake occurred, and MARN received the information at 00:30AM.

The First Tsunami Information on the Event of 26 August in 2012 (Local Time) from PTWC

TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT [illegible] 27 AUG 2012

THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC OCEAN AND ADJACENT SEAS...EXCEPT ALASKA...BRITISH COLUMBIA...
WASHINGTON...OREGON AND CALIFORNIA.

... TSUNAMI INFORMATION BULLETIN ...

THIS BULLETIN IS FOR INFORMATION ONLY.

THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND ANY ACTIONS TO BE TAKEN IN RESPONSE.

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - [illegible] 27 AUG 2012
COORDINATES - 12.2 NORTH [illegible] WEST
DEPTH - [illegible] KM
LOCATION - OFF COAST OF CENTRAL AMERICA
MAGNITUDE - 7.4

EVALUATION

NO DESTRUCTIVE WIDESPREAD TSUNAMI THREAT EXISTS BASED ON HISTORICAL EARTHQUAKE AND TSUNAMI DATA.

HOWEVER - EARTHQUAKES OF THIS SIZE SOMETIMES GENERATE LOCAL TSUNAMIS THAT CAN BE DESTRUCTIVE ALONG COASTS LOCATED WITHIN A HUNDRED KILOMETERS OF THE EARTHQUAKE EPICENTER. AUTHORITIES IN THE REGION OF THE EPICENTER SHOULD BE AWARE OF THIS POSSIBILITY AND TAKE APPROPRIATE ACTION.

THIS WILL BE THE ONLY BULLETIN ISSUED FOR THIS EVENT UNLESS ADDITIONAL INFORMATION BECOMES AVAILABLE.

THE WEST COAST/ALASKA TSUNAMI WARNING CENTER WILL ISSUE PRODUCTS FOR ALASKA...BRITISH COLUMBIA...WASHINGTON...OREGON...CALIFORNIA.

Figure 2.2.14 The First Tsunami Information on the Event of 26 August in 2012 (Local Time) from PTWC

Figure 2.2.15 Initial hypocenters issued from PTWC, USGS and MARN of the Event of 26 August in 2012 (Local Time)

(Source: MARN)

(3) Tsunami Infrastructure Development Situation

There are no tsunami protection facilities, like coastal levees, though there is an idea of the construction of a 900m-bank for coastal protection together with the repair-work of the La Union fishing port.

Regarding the setting of evacuation routes, the routes against tsunami are set in the tsunami evacuation plans of coastal communities.

Figure 2.2.16 Example of Setting Evacuation Route (→)

(Source: Strengthening Plan of Isla de Mendez in Jiquilisco)

(4) Tsunami Alert and Evacuation System

1) Warning Dissemination System

The DGPC Operation Center should receive and disseminate tsunami information with two out of 40 members of staff in 24x7 shifts in the monitoring room.

2) Warning Dissemination Procedures

Once an earthquake occurs, the DGPC emergency operation center receives the hypocenter parameters from MARN/DGOA within ten or fifteen minutes by radio, fax, cellphone and email. The information is publicized on the web site of MARN.

The director-general of DGPC should decide if the DGPC should disseminate a tsunami warning according to the protocol.

When warnings should be disseminated, DGPC does so to departments, to municipal governments simultaneously, with radios. Then, the departments should do so as well to municipal governments, and the governments should do so to communities. In addition, warnings and related information should be broadcasted by mass media like TV or radio according to the indication from DGPC. The communication tools for these procedures from DGPC through to municipal governments have been established. Furthermore, ones from the governments to communities have not yet been done; but JICA supported, under the Project for Improvement of Equipment for Disaster Risk Management, the installation of five repeaters, 43 base-radios, and 500 mobile-radios at coastal areas, and this action has improved communications in eight departments out of a total of fourteen, 29 municipal governments out of a total of 262, and 143 communities. On the other hand, reliable communication systems to the population like siren-systems are not yet established, though they have been partially done.

DGPC has three regional operation centers in addition to the emergency operation center in San Salvador, and warnings are disseminated to these centers as well.

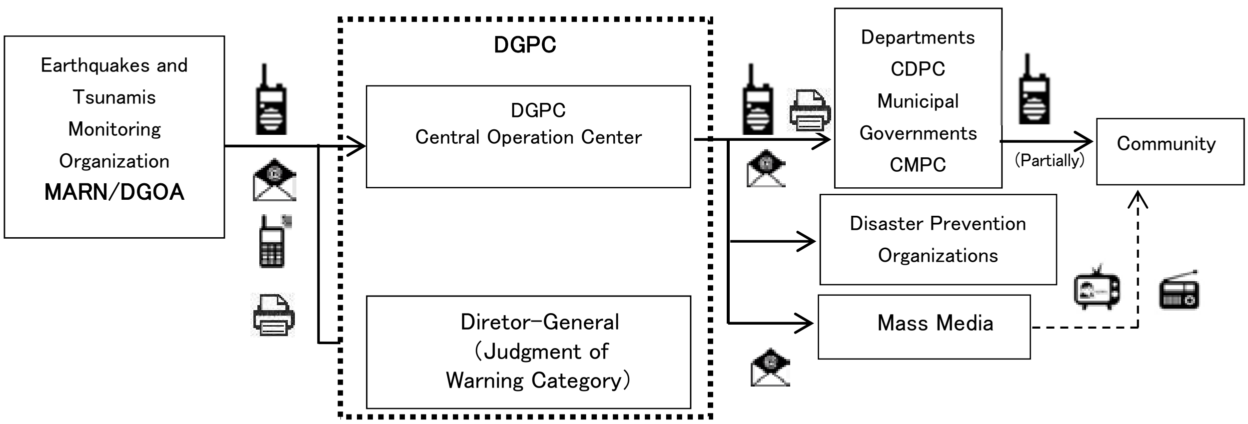

Figure 2.2.17 Tsunami Warning Dissemination System

Figure 2.2.18 DGPC Emergency Operation Center, Facility Whole View (Left), Inner View (Right)

3) Tsunami Evacuation System

As for tsunami evacuation, its plans have been developed at all communities located at coastal areas, and evacuation drills have been implemented.

(5) Tsunami Risk Assessment Technique and its Present Situation

In December of 2012, El Salvador developed a series of maps and catalogs for tsunami hazard, vulnerability and risk on the coastal areas of El Salvador. These were done through establishing a global database on earthquakes which created tsunamis which struck El Salvador, and through getting sea floor geographies and a shallow water wave propagation model. Figure2.2.18 shows one of the tsunami risk figures.

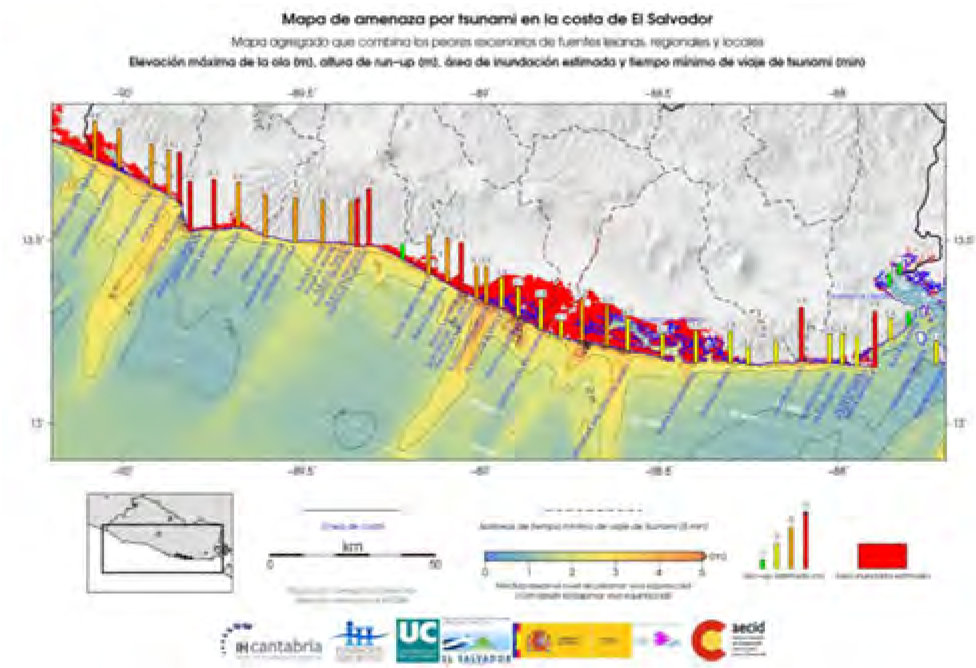

Figure 2.2.19 Tsunami Risk Map (Source: MARN)

(6) Development on a Hazard Map against Tsunami and its Utilization

MARN has made tsunami hazard maps for the regional and national levels. Those maps were used for analyzing evacuation routes for each community through considering the vulnerability of the areas with indexes like population density. The tsunami hazard for the national level is show in Figure 2.2.19.

Figure 2.2.20 Tsunami Hazard Map (Source: MARN)

(7) Effort for Tsunami Disaster Prevention at Research Institute like Universities and NGOs

As activities of NGOs handling national issues, OXFAM in Belgium is taking action for disaster prevention, not specifically against tsunami though, for pupils in primary schools and the youth mainly of agricultural areas in San Salvador and in La Liberta; the action is dealing mainly with the appropriate responses when earthquakes, floods or inundations occur. Save the Children and Plan International are also supporting disaster prevention activities in communities or schools. These NGOs will support the activities inevitably against tsunamis in the case of communities or schools, which are located in coastal areas.

Note: There are SEPRODE、Comand de Salvamento and FUSAKPRDESE, who are supporting communities to make any plans or to implement drills according to requests from them through municipal governments.

2.2.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects of Japan's cooperation to earthquake and tsunami disaster in El Salvador are shown in the following table:

Table 2.2.7 Japan's Corporation Projects to Earthquake and Tsunami Disaster in El Salvador

Scheme	Project Name		Period
Grant Aid	Earthquake Reconstruction Plan		1996
Technical Cooperation	Project on improvement of building promotion technology for earthquake-resistant housing		2003-2008
Technical Cooperation	Project on improvement of building technology for a seismic house to low- and middle-income earners		2009-2012
Technical Cooperation	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" The activities on capacity development was implemented in the city of La Liberta region Nuevo Cuscatlancity, Zaragoza city, San Jose Villanueva city, La Paz region San Luis Talpacity San Pedro Masahuat. Some community has continues activities but others are not. Setting up of rain gages has been prepared in other areas, and people evacuated effectively when tropical cyclone 12E attacked.		2007-2012
Grant Aid	Project for Improvement of Equipment for Disaster RiskManagement In the project, five broadband seismic observation systems, eight strong motion seismometer systems, three GPS systems, one tidal gauge systems and two tsunami monitoring cameras have been installed. That has improved the function of monitoring of earthquakes and tsunamis. Furthermore, repeaters, base-radios and mobile-radios at coastal areas have been installed. That has improved communications among prefectures (departments), municipal governments, and communities.		2012-2014
Training Program (2010-2014)	Disaster Management on Infrastructure (River, Road, Port)	(2)	2014
	Prevention, Mitigation and Recovery of Infrastructure (River, Road, Port) on Natural Disasters	(2)	2012-2013
	Community based Disaster Risk Management	(4)	2010-2013
	Bridge Enhancement and Disaster management	(6)	2012
	Disaster management of Buildings (against Earthquake, Tsunami, and Fire)	(5)	2013-2014
	Comprehensive Disaster Risk Management	(1)	2013
	Seismology, Earthquake Engineering and Disaster Management Policy	(4)	2010-2011
	Seismology, Earthquake Engineering and Disaster Recovery Management Policy	(4)	2012-2014
	Disaster Management of the ground	(6)	2012
	Enhancement and Dissemination of Earthquake resistant Technology for Building in Latin American Countries	(6)	2014
	Disaster Management in Central American Countries	(15)	2010-2014
	Recovery Process of Great East Japan Earthquake	(3)	2013

*Numbers in ( ) of Training Program indicate number of participants。

(2) Situation of Key Donor's Cooperation

Projects of Key Donor's cooperation to earthquake and tsunami disaster in El Salvador are shown in the following table:

Table 2.2.8 Key donor's Projects to Earthquake and Tsunami Disaster in El Salvador

Funding Agency	Project Name / Project Outline	Project Sight	Implementing Body	Budget (USD)	Period
EU	Information System, Monitoring and Early Warning for Southern Ahuachapán	Ahuachapán	Defensa Civil	N/A	2008
	The training of the formulation of The protection Civil Plan was implemented to one hundred communities and municipalities in the Department of San Salvador and Chalatenango in cooperation from DIPECHO.				
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation to Honduras, Costa Rica and Panama	Entire El Salvador	MARN/DGOA	2.4 million	2007-2010
	An earthquake hazard map of the whole country was created based on the concept of "learning by doing" for hazard, vulnerability and risk analysis with MARN/DGOA as counterpart				
IDB	Central American Probabilistic Risk Assessment (CAPRA)	San Salvador Metropolitan Area	MARN/DGOA	2.4 million	2007-2010
	The seismic risk assessment was implemented with MARN/DGOA as counterpart.				
AECID	Institutional Strengthening for Watershed Management, Protected Area management, and Natural Disaster Risk Management in El Salvador Phase2	Acajutla, La Liberta, Jiquilisco, and other twenty-nine municipalities	N/A	480 thousand	2011-2012
	The assessment of vulnerability and the creation of risk map were implemented .				
WB	Seismic Risks in San Salvador Metropolitan Area	San Salvador Metropolitan Area	MARN/DGOA	N/A	20012
	The assessment of seismic performance of hospitals, schools and other significant buildings was implemented with MARN/DGOA as counterpart.				

2.2.6. Items to be Improved

(1) Seismic and Tsunami Monitoring and Analyzing Ability Improvement

1) Seismic analyzing ability improvement through hypocenter determination improvement

In order to improve the reliability of judgment on tsunami generation, improvement of the accuracy of hypocenter and M determination at first. Therefore, the following measures should be taken: a) regarding seismic velocity structure model for hypocenter determination, INETER is using a local model, which is not yet evaluated for optimizing it; INETER should therefore evaluate it through obtaining any seismic velocity structure with results from the crustal structure research implemented until now, and should include the evaluation results into the hypocenter determination system; b) regarding the selection of seismic stations to be used for hypocenter determination in tsunami generation judgment, its criteria is not well established; INETER should obtain the method for optimizing the selection action through clarifying the criteria.

2) Introducing focal mechanism analysis technique

In order to improve the reliability of tsunami generation judgment, it is necessary to estimate and understand the focal mechanisms like normal-reverse type or strike-slip type immediately after the occurrence of any event. Therefore, at first, introducing the initial motion analysis for focal mechanism into the current official procedures of tsunami generation judgment. The accuracy of initial motion analysis is not so high for large earthquakes; INETER should obtain the technique of CMT analysis having high accuracy as the nest step; in order to do so, INETER should learn the algorithms of the software in any case.

Note: the CMT analysis function is included one of SeisComP modules; the license for using the module is not free, though. The CMT analysis will produce moment magnitude (Mw) in high accuracy.

3) Acquisition of Technique of Tsunami Generation Judgment

In order to improve the reliability of tsunami generation judgment, in addition to introducing focal mechanism analysis, it is essential to improve the accuracy of M. For example, the earthquake in August of 2012, INETER obtained and accepted 5.7 as M at the beginning, 6.6 at the next timing, 7.3 provided from USGS lastly (Note: USGS informed 6.8 at the beginning.) ; therefore, as for SeisComP to be used for automatic hypocenter determination, it is necessary that a) the station selection for accurate M estimation method should be re-evaluated; b) the station correction method should be optimized. ; and as the next step, CMT analysis for getting more accurate M is needed as mentioned above.

4) Introducing procedures of estimation of tsunami height and tsunami arrival time and criteria for tsunami warning cancellation

PTWC provides information on tsunamis for all countries located around the Pacific Ocean; the information should thus be a sort of “average” of a wide area, and is sometimes too rough to use for tsunami warning judgment for a region; that means the accuracy is not enough for handling any regional earthquakes.

In that context, INETER should acquire the ability of the estimation of tsunami height and tsunami arrival time step by step. Namely, as for estimation of the tsunami arrival time INETER should acquire a) the ability of an outline or approximate estimation with the current sea depth data, b) the one of improving the estimation with the latest progress in the sea depth research; as for estimation of tsunami height, a) the one of tsunami generation analysis with focal mechanism, b) the one of approximate but quantitative estimation with the current sea depth data, c) the one of tsunami generation judgment with CMT analysis, d) the one of improving the estimation with the latest sea depth data, and e) the one of improving height estimation with coastal geography. In addition, INETER should acquire the technique for earlier tsunami warning cancellation with keeping reliability.

5) Newly Installing Tidal Gauge Stations and others

In order to improve the accuracy of tsunami warning, a tidal gauge observation network should be improved step by step as follows: a) establishment of the system for stable operations of tidal gauges; b) optimization of data acquisition or data transmission configuration; c) optimization or reinforcement of the network of tidal gauge observation network from the view point that real time tidal data monitoring should be essential for the improvement of tsunami warning reliability and for the update of a tsunami warning category, and d) the reinforcement of networks of the type of "Deep-ocean Assessment and Reporting of Tsunamis (DART) ".

Note: DART_type tidal gauge was developed by NOAA; it is a real-time observation system and is composed of buoys and ocean bottom sensors.

(2) Improvement of the Distribution of Tsunami Information on Local Tsunamis

In recent years sirens of CODE have been installed at communities located on coastal areas of the Pacific Ocean; those contribute a lot to the rapid distribution of tsunami warnings; Co-Direcciones de SINAPRED mentions that the distribution of warnings to communities should be completed within 3-5 min; INETER or CATAC should thus have to shorten the time for tsunami generation judgment through simplifying judgment procedures and the automation of a warning issuance procedure.

(3) Promotion Policy on Seismic and Tsunami Disaster Prevention

1) Archive of seismic risk assessment data

CAPRA Project has provided a tool for risk assessment; it is not well utilized, though. The cause of it is that essential data, like building and infrastructure, to be processed in the tool have been not well archived; therefore, archiving this kind of data should be promoted.

2) Implementing Assessment of Seismic Risk

The area of Central America has high seismic risk. In order to help seismic disaster mitigation, it is essential to make buildings or infrastructures that are earthquake–proof; and it is important to assess the present risk through establishing any seismic disaster prevention measures.

2.3. Guatemala

2.3.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of Guatemala is shown in the following table:

Table 2.3.1 Basic Information of Guatemala

Area	Contents	Source
Population	15.08million	2013, World Bank
GDP	53,80 billion USD	2013, World Bank
Area	108,889 ㎢ (Land Area 107,159 ㎢) (Land Use: Arable13.78%、Cropland d8.68%、Other 77.55%	2011, CIA World Fact Book
Administrative	22 Departments	CIA World Fact Book
Geography	mostly mountains with narrow coastal plains and rolling limestone plateau	CIA World Fact Book
Climate	tropical; hot, humid in lowlands; cooler in highlands	CIA World Fact Book

(2) Basic Information of Natural Disasters

Guatemala is located on the border of the North American, Caribbean and Cocos Plates, which move relatively, so that earthquakes occur frequently and volcanoes are very active, as shown in Figure2.3.1.

Figure 2.3.1 Tectonic map around Guatemala (Source: INSIVUMEH)

Table 2.3.2 List of major earthquakes in the history of Guatemala (Source: CRED/EM-DAD, NOAA/NGDC)

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)
1565/8	-	Antigua	-	-	-
1566/5	-	Antigua	-	-	-
1586	-	Antigua	-	-	-
1766	-	Chiquimula, Quetzaltepeque	-	-	-
1773/6/3	-	St. Jago	8,000	-	-
1773/7/29	-	Antigua	100	-	-
1791	-	San Marcos	-	-	-
1816/7/22	7.5	Soloma	23	-	-
1874/9/3	-	Antigua, Chimaltenango	300	-	-
1902/1/18	6.3	San Martin, Quezaltenango	-	-	-
1902/4/18	7.5	Quezaltenango	2,000	-	-
1917/12/29	-	Guatemala City	2,650	-	-
1918/1/4	-	Guatemala City	-	-	-
1921/2/4	7.5	-	-	-	-
1942/8/6	7.9	Near South Coast	-	-	-
1950/10/23	7.5	San Marcos	-	-	-
1976/2/4	7.5	Guatemala city	23,000	4,993,000	1,000,000
1979/10/9	5	Santa Rosa	-	2,040	-
1982//	6.9		20	-	5,000
1985/10/11	7.5	Tierra Blanca	-	5,000	-
1986/2/3	4.7	Ixchiguan	-	2,500	-
1988/10/15	-	Chamaltenango area	-	1,550	-
1988/11/3	5.6	South	5	500	-
1991/9/18	5.3	Escuintla	14	23,890	-
1999/7/11	6.5	San Pedro Sula	2	280	-
2001/1/13	7.9	Jutapia Department	6	152	50
2011/9/19	5.8	Cuilapa, Santa Rosa	3	400	-
2012/11/7	7.2	San Marcos	44	1,321,742	210,000
2013/9/6	6.6	Ciudad Tecun Uman	1	572	-

Note : - means data is not available

2.3.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management (Policy, Organization)

1) Policy Framework on Disaster Management

Policy Framework on Disaster Management in Guatemala is shown in the following table:

Table 2.3.3 Policy Framework on Disaster Management in Guatemala

Category	Name	Contents
Policy	The national Policy for Disaster Risk Reduction	The policy indicates the general principles of monitoring and early warning, risk identification, improvement of capacity of risk assessment, disaster prevention education and measures for risk reduction and mitigation.
Law	Law109-96 : (commonly called "CONRED Law")	The plan stipulates the responsibility and cooperation between national and local organizations on the stage of before, immediately before, during and after the event of an emergency such as disasters.
Plan	National Response Plan	The plan is composed of the emergency response system, responsibility of relevant organizations, departments and municipalities. The particular response to earthquake and tsunamis are not indicated.

2) Framework of Disaster Prevention Organization

【1】Framework of the Organization System

INSIVUMEH implements the observation of earthquakes, meteorology and hydrology, and also performing the dissemination of disaster information, damage assessment on a disaster and provision of technical information for disaster response to the relevant organizations.

On the national level, SE-CONRED carries out the measures of disaster prevention, the formulation of a national plan and the dissemination of warnings on a national level based on the law 109-96. On the local level, Regional Institutional Coordination for Disaster Reduction (CORRED), Commission Departmental de Protection Civil(CODDRED) , Municipal Institutional Coordination for Disaster Reduction (COMRED), and Local Institutional Coordination for Disaster Reduction (COLRED) carry out disaster management measures on the regional level, department level, municipality level, and community level, respectively.

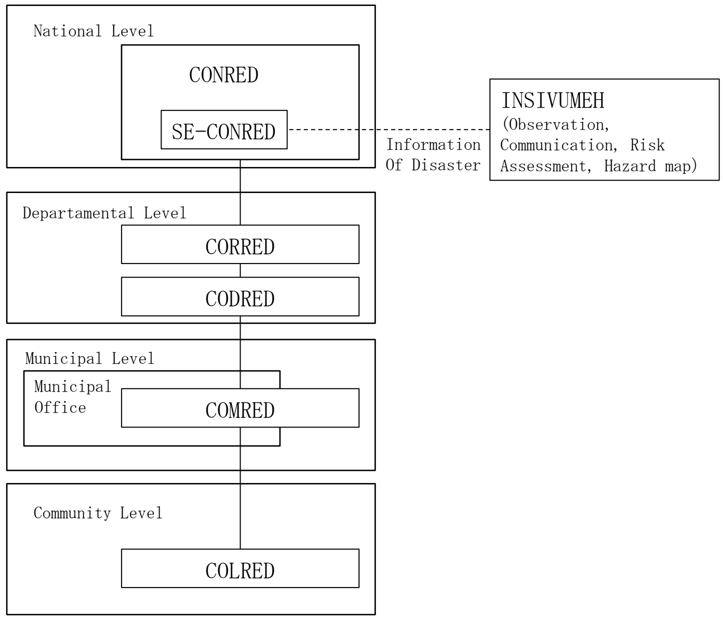

Figure 2.3.2 Structure of Relevant Organization of Disaster Prevention (Guatemala)

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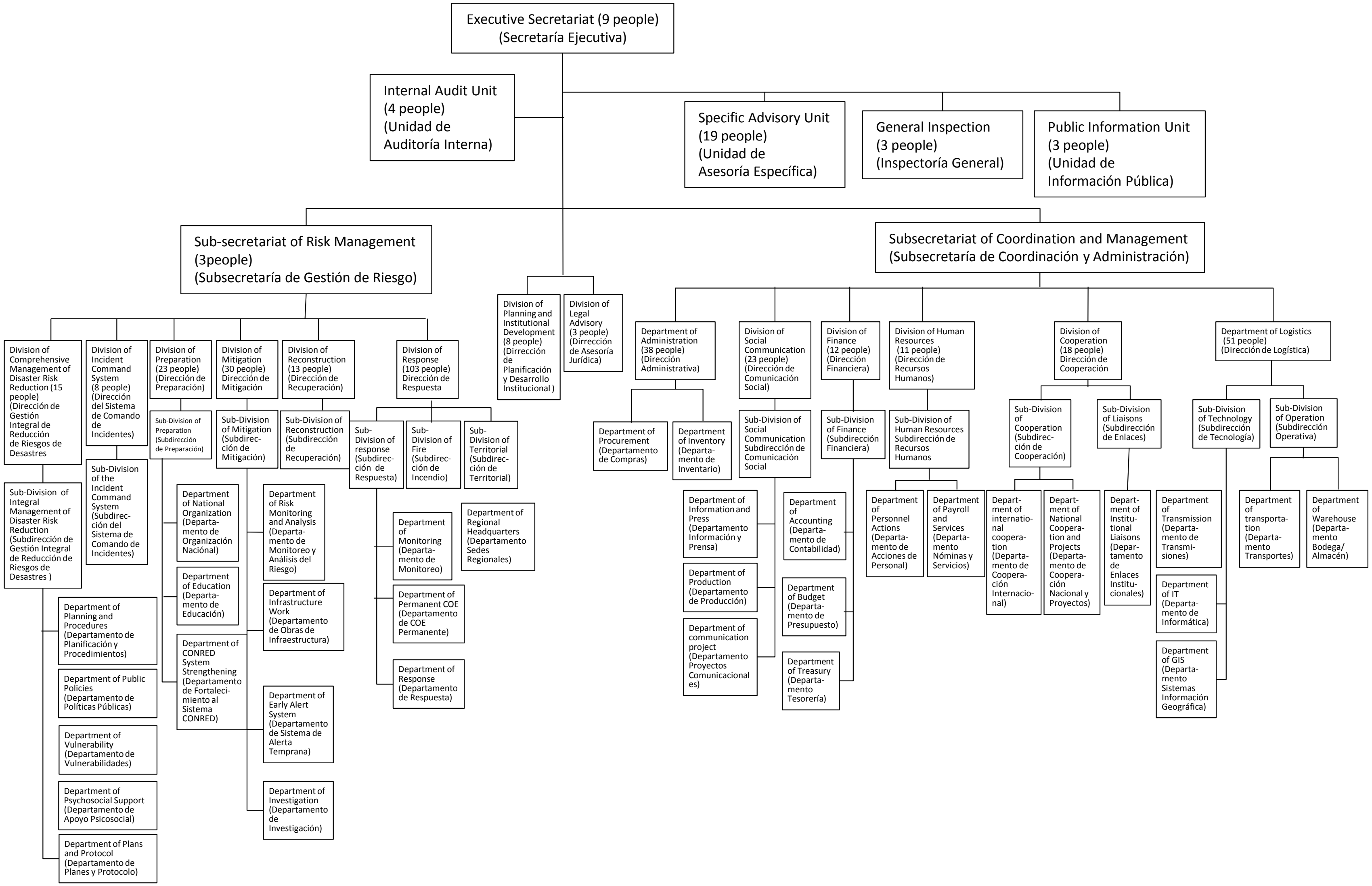


Figure 2.3.3 Organization Chart of SE-CONRED

【2】<u>Sharing Responsibility for Earthquake and Tsunami Disaster Prevention</u>

INSIVUMEH carries out the monitoring, creation of hazard map and risk assessment of earthquakes and tsunamis, and issues technical information to the Emergency Information Center of SE-CONRED through ALFA that covers the dissemination of disaster information. SE-CONRED makes a decision on the issuance category of alert, and then disseminates the warning to relevant organizations.

【3】<u>Expectation to CATAC</u>

INSIVUMEH expects the information of Regional Tsunamis from CATAC because INSIVUMEH relies on automatic calculation for the analysis of seismic data, and it all depends on PTWC for the judgment of tsunami generation. INSIVUMEH also expects a training program of tsunami analyzing methodology that is supposed to be conducted by CATAC.

(2) Priority and Significance on the Relevant Law of Earthquake and Tsunami

The priority of tsunami is not so high so far, because the active volcanic eruption and associated lahar and sediment disasters with heavy rain have been urgent issues. However, the response division of SE-CONRED recognizes that the information of tsunami generation is one of the most important because serious damage will happen once a tsunami occurs.

(3) Situation of Allocation of Budget for Disaster Prevention

The budget of SE-CONRED was approximately 75 million Quetzal (approximately 9.8 million USD) in 2014, of which foreign sources constituted about 13 % .

(4) Situation of Activities for Disaster Prevention on the Community-level

Activities of disaster prevention on the community-level are to be covered by COLRED with assistance from COMURED. The following activities were implemented by using the cooperation of donors and NGOs:

- Project for Capacity Development of Local Disaster Prevention Organization: The establishment of early warning and enhancement of the ability for disaster prevention system in the community have been implemented in Escuintla and Isabela, et.al. with assistance of Red Cross and OXFARM utilizing support from DIPECHO.

- Project on Capacity Development for Disaster Risk Management "BOSAI": Technical Cooperation to strengthen the disaster response capability of vulnerable communities was implemented in Fuego Volcanoes.

- Project for Facilities and Equipment Development for Communities: Disaster prevention education programs were implemented in 104 communities in eight departments including Santa Rosa up to 2012

(5) Situation of Disaster Prevention Education for Earthquakes and Tsunamis in Educational Institutes

The curriculum of disaster Prevention Education was promoted to the school with the cooperation of the Ministry of Education (MINEDUC) and SE-CONRED.

2.3.3. Earthquake Observation and Promotion of Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

The earthquake observation and analysis in Guatemala is carried out by INSIVUMEH. SE-CONRED is responsible for issuing earthquake warning information and emergency response. The development of a seismic code is within the responsibility of the Earthquake Engineering Association (AGIES).

(2) Earthquake Observation Capability

1) Seismic Observation Operation

The earthquake observation and analysis is conducted by five people of the Department of Geophysics Investigation and Service, INSIVUMEH during working hour.

2) Earthquake Observation Network

Earthquake observation in Guatemala began in 1925 with a mechanical seismograph, see Figure 2.3.4, which was manufactured in 1904 and was used until 1975. In the late 1970s, six electromagnetic seismographs were installed to monitor the activity of volcanos as a part of USGS project. The INSIVUMEH was founded as the result of a 1976 earthquake and promoted the national earthquake observation since then. The current earthquake observation network is composed of an analog seismic observation network, having eight analog seismometers shown in Figure 2.3.5), and a newly developed digital seismic observation network, having ten broadband seismometers shown in Figure 2.3.6. Some of the seismometers are for monitoring volcanic activity.

The observation data of the analog seismometers is transmitted by UHF to the data processing center in real time and automatically digitized, which is then sent to Earthworm for the earthquake location and magnitude calculation by Seisan. The observation data of broadband seismometers are collected by digital satellites and/or the Internet in real time and are processed by SeisComP.

A digital earthquake observation network began in 2014. In addition to the ten broadband seismometers, there are twelve short period seismometers under installation. Locations of the short period seismometers are shown in Figure 2.3.6. There are five accelerometers, which are installed at the same location as the broadband seismometers. The observation data of the broadband seismometer and accelerometer are transmitted to the data processing center.

3) Seismic Data Processing

The observation data of the digital seismometers are collected the data processing center of INSIVUMEH and is saved in the Sedlink server. SeisComP uses the collected data, together with the data around the world collected by IRIS, for automatically processing each earthquake location and magnitude. For events larger than M3.5, the automatic results will be manually confirmed with Seisan. The confirmation will be made in the office during official hours and at home out of the official hours. The flow chart of the data processing is shown Figure 2.3.7.

The table below shows the seismic observation network of INSIVUMEH.

Figure 2.3.4 Detail of Seismic Observation Network of INSIVUMEH

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	8	8	0	8	8
	On Site	0	0	0		
Broadband	Real Time Telemetering	10	9	1	10	10
	On Site	0	0	0		
Strong Motion	Real Time Telemetering	5	5	0	0	0
	On Site	0	0	0		
Total	Real Time Telemetering	23	22	1	18	18
	On Site	0	0	0		

4) Earthquake information dissemination

The ALFA office of INSIVUMEH is responsible for the disaster warning information dissemination for all kinds of natural disasters, such as earthquakes, tsunamis, floods, etc. There is one person in the ALFA office on duty for 24-hours a day. The results can be obtained in 1-2 minutes by automatic data processing and it will be informed to CONRED by fax and e-mail and displayed on the INSIVUMEH web site for the public. After the analysis of the automatic results by the earthquake experts, the formal earthquake information will be announced for CONRED, mass media and the public.

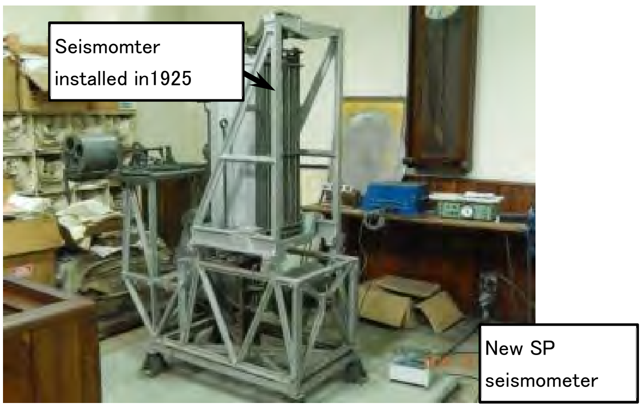


Figure 2.3.5 Seismometer Inside the IVSIVOMEH Office building

Figure 2.3.6 Location of Analogue Seismometers of INSIVUMEH（Source：INSOVUMEH）

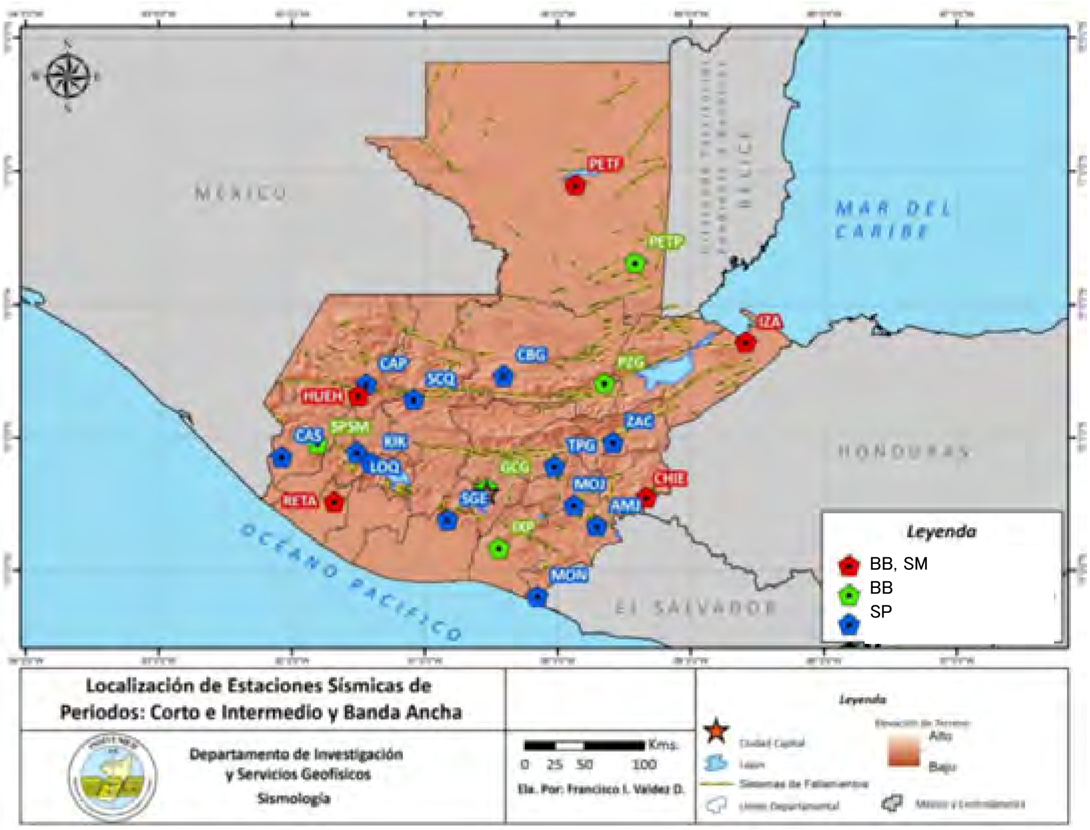


Figure 2.3.7 Location of Digital Seismometers of INSIVUMEH（Source：INSOVUMEH）

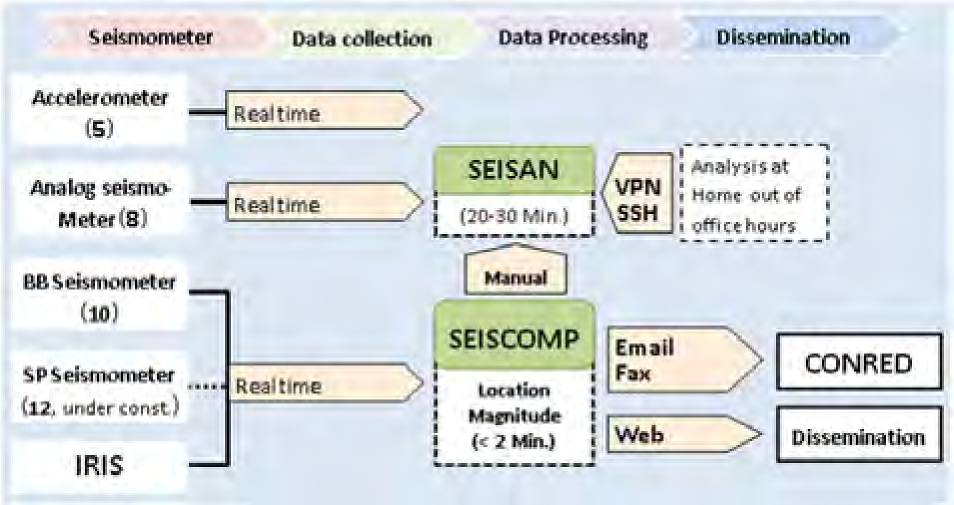


Figure 2.3.8 Flowchart of Seismic Observation Data Processing of INSIVUMEH

(3) Approach and Current Status of Seismic Risk Assessment

Risk assessment software applying to multi-hazards has been developed within the framework of the project CAPRA for Central America. Since the seismic risk assessment requires seismic hazards, inventory of the buildings, vulnerability curves, etc., CAPRA has not been applied in Guatemala due to the insufficiency of data. Basic data collection and accumulation is necessary to take advantage of this risk assessment tool for seismic risk assessment.

(4) Development and utilization of a seismic hazard map

From the JICA project of The Study for the Establishment of Base Maps and Hazard Maps for GIS in the Republic of Guatemala (2001 - 2003), the earthquake hazard (five cities), volcanic hazard (four volcanoes), landslide hazard (three cities and two regions) and flood hazard (four river basins) were estimated. The seismic hazard for intensity and liquefaction of a part of Guatemala City is shown in Figure 2.3.8, which has been used for the determination of the evacuation shelters, evacuation routes and community based disaster prevention. The seismic hazard for the whole of Guatemala has been evaluated by the project of RESIS II. The results are the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with a 500 year return period in Guatemala is shown in Figure 2.3.9 and the hazard curve of Guatemala City is shown in Figure 2.3 10. The utilization of the result is highly expected in the future.

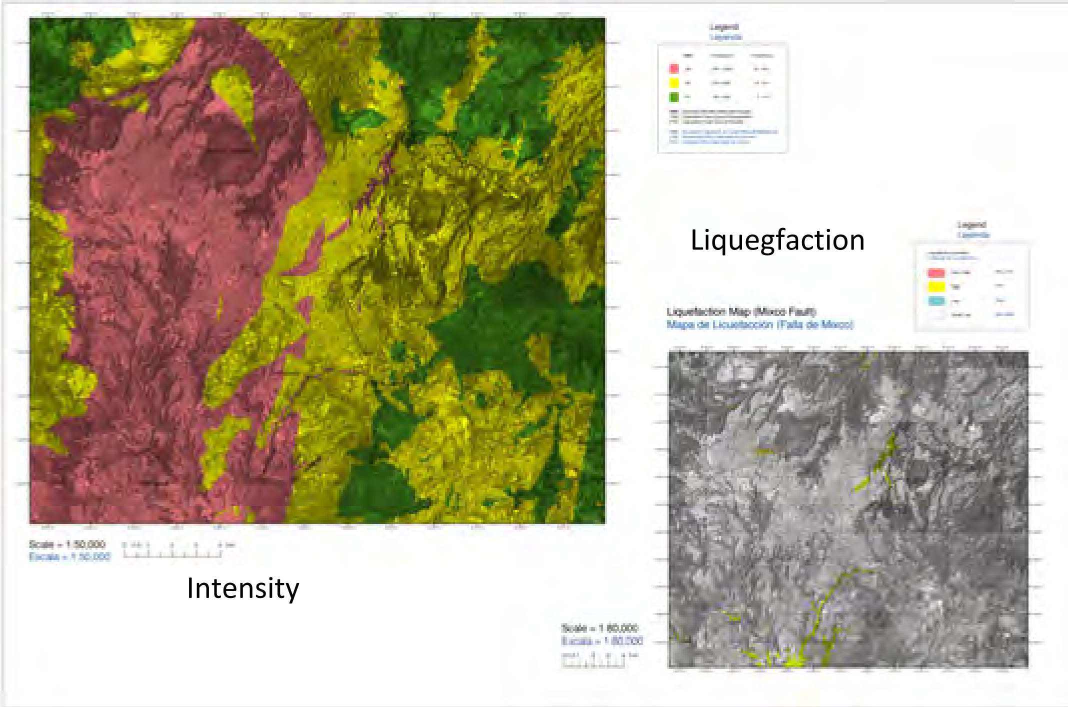


Figure 2.3.9 Seismic Hazard of Part of Guatemala City（Source:INSIVUMEH HP）

Figure 2.3.10 Seismic Hazard of Guatemala by RESIS II (PGA、Return Period 500years) (Source:RESIS Ⅱ Report)

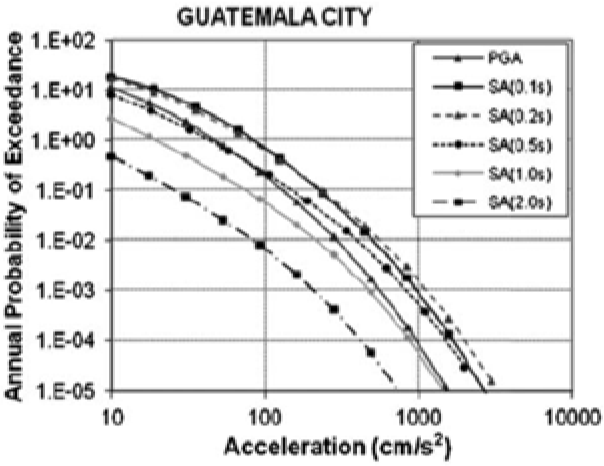


Figure 2.3.11 Seismic Hazard Curve of Guatemala City by RESIS II (Source: BSSA,Vol.102, No.2,2012)

(5) Development of seismic code and the implementation

The seismic code (NR - 1) of Guatemala was created in 1996. It has been revised in 2002 and 2010. The current code is the 2012 version (AGIES NSE 2- 10), which was developed by referring to the Uniform Building Code of America (UBC – 97) and International Building Code (IBC-2009). The buildings are classified into critical, important and general. The design ground motion for critical and important buildings is that with a 5% of exceedance of probability in 50 years, while the ground motion for general buildings is that with a 10% of exceedance of probability in 50 years. The seismic zonation for seismic design is shown in Figure 2.3 11. It should be noted that a number of general residential houses and buildings outside of Guatemala City does not follow the code because of the lack of technical knowledge. There is no policy for the strengthening of existing critical buildings, infrastructures and lifeline facilities.

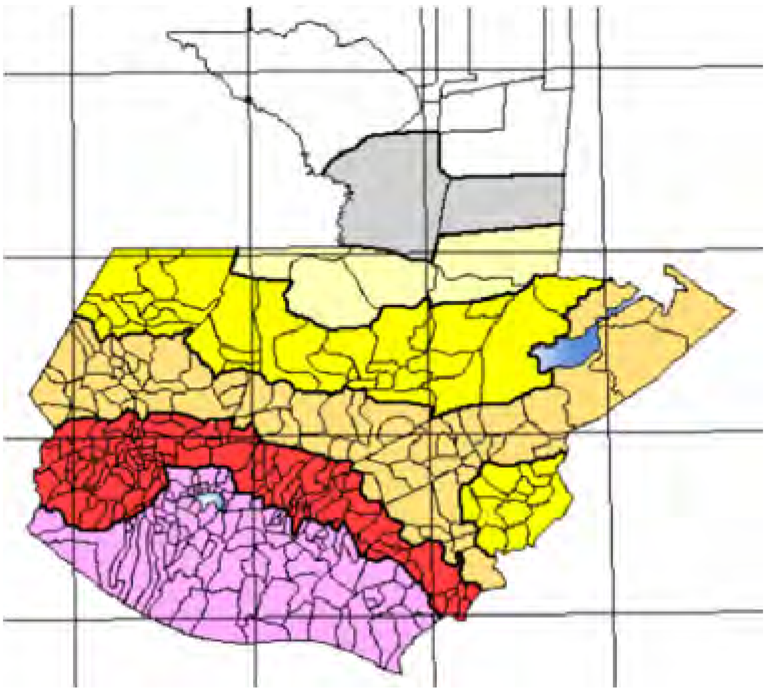


Figure 2.3.12 Ground Motion Zonation of Seismic Code of Guatemala (Source: Seismic code of Guatemala)

(6) Activities of University Institutes and NGOs for Disaster Prevention

The San Carlos University established a secure development and disaster prevention research center (USAC/CEDESYD) in 2008 for improving the safety of USAC, but the activities of the center are not limited within the university. Within the campus, the center promotes awareness, emergency evacuation drills, etc. Out of the campus, they perform community disaster prevention drills as one of the graduation exercises. Every year about 100 students will participate the real community disaster prevention activities, making use of the disaster management manual.

The Energy and Mining Senior Research Center (USAC/CESEM) of the San Carlos University disseminates and shares its information on disaster education and disaster prevention technology, playing the role of a communication network among the technicians and researchers. The members of center are not only the university persons, but also that from INSIVUMEH, SE-CONRED, government officials and private sector.

After the San Marcos earthquake, the NGO of Tricaire was established. The activities of Tricaire are supporting the seismic performance assessment and community disaster prevention activities with technical assistance from the University of Mariano Galvez.

2.3.4. Tsunami-Monitoring and Tsunamis-Disaster Prevention Efforts

(1) National Organizations Responsible for Tsunami-Disaster Prevention and Relevant Organization

IOC approves INSIVUMEH as TWFP and TNC.

The INSIVUMEH has the responsibility for technical judgments on the generation of tsunamis. On the other hand, the CONRED has the responsibility for issuing Tsunami Warnings based on the information provided by INSIVUMEH. The Emergency Operation Center (COE) should issue the warnings and disseminate indications of evacuations and others. In addition, the COE should monitor information prepared by the INSIVUMEH. The protocols for how to manage earthquakes, volcanic activities, floods, hydrological phenomena and severe weather are established. As for earthquakes and tsunamis, It is prescribed that INSIVUMEH should provide technical information to CONRED in the protocol.

(2) Monitoring System Relevant to Tsunami

1) Tsunami Monitoring System

Technical issues on tsunamis are managed by INSIVUMEH like earthquakes. Namely, the seismic specialists group and ALFA, which is a center for information issuance and public relations, should deal with the issuance of tsunami information. The group works only on weekdays, but the member of the day should handle the emergency issues at home during non-working-hours.

ALFA, which has the responsibility for the issuance of tsunami information, is managed by one "7x24 contact" member of staff in the hydrological field of INSIVUMEH.

Note: INSIVUMEH once had one oceanology specialist, whose knowledge is essential to understand or analyze tsunami propagation, but there is none of the specialists as of 2014.

2) Tsunami Observation Network

Tidal gauges are located at one coastal site on the Caribbean Sea and the Pacific Ocean (Figure 2.3.12) .

The one on Pacific Ocean coast is located at Puerto Quentzal, and was installed by INSIVUMEH with its own fund in 2010; its device type is radar, MAUS301 of the Vaisala Company. The observed data are sampled each one minute, and the sampled data are averaged every five minutes. The averaged data are transmitted every five minutes. The power for them is commercial power with floating manner. Means for data collection is GOES Satellite to PTWC with DCP. They can be seen at the IOC web site and have been used for real time tsunami monitoring. Inspections at stations have been implemented twice or three times a year. However, currently the radar sensor itself has some problem and the station is out of order now. The sensor is so old that the component for repair is no longer produced by the manufacturer. In addition, INSIVUMEH does not have the funds for its repair. Its recovery during 2016 is expected even without any prospects.

Note: The station has a sea level ruler, which is used for the manual recording of the sea level with the action or reading of the ruler by the port caretaker. It also has a set of meteorological instruments for observing wind-direction, wind-speed, precipitation and intensity of radiation (actinometer).

The one on the Caribbean Sea coast is located at Puerto Barrios, and was installed with the help from NOAA and IOC and has started observation in December of 2013. It has sensors of radar and pressure. The observed data are sampled every minute, and the sampled data are averaged every five minutes. The averaged data are transmitted every five minutes. The power is solar panel. The exact location is in the basement of the navy. The station is thus maintained by the navy. The means for data collection is the GOES Satellite to PTWC with DCP. They can be seen at the IOC web site and have been used for real time tsunami monitoring.

Note: The initial location of the station was at a quay, but is now at the tip of a pier.

INSIVUMEH does not have specific tsunami monitoring equipment at present. It thus has to monitor the data collected and shown on the web-site by NOAA as mentioned above.

As for oceanic information for the public, INSIVUMEH analyzes the tidal data by the global model of NOAA and publicizes the results like current speed, sea temperature and oceanic waves on its own web site.

Figure 2.3.13 Locations of Tidal Gauge Stations
(Yellow symbols show the locations. Red circles are seats of department governments. Source: INSIVUMEH)

3) Analysis of Tsunami Generation

In tsunami generation analysis, the hypocenter is one of the most important elements. In the analysis, the seismic specialist group mainly uses hypocenters produced from automatic calculation by the SeisComP. The current issues to be handled in order to improve the accuracy of the hypocenters are as follows: a) introducing an appropriate local seismic velocity structure model, b) introducing station corrections in addition to altitude corrections, c) evaluating hypocenter depths (Note: INSIVUMEH refers to and uses the distribution of USGS hypocenters in a cross section. Figure Figure 2.3.14).

As for the judgment of tsunami generation, in the case of a Distant Tsunami, it is implemented based on information provided by PTWC and observed data at DART-buoy 320km off from coasts of Guatemala; if necessary, information provided by the Mexico Tsunami Warning Center are also referred to. In the case of a Local Tsunami, the judgment is implemented based on the local seismic information through referring to the DART-buoy (Note: The distance between the epicenters concerned and the coasts is shorter than the one between the epicenters and the DART-buoy; namely, the results of observation of the DART-buoy will not be in time for warnings.). The trigger of taking the above actions by the staff in charge of the day perceives seismic motions or receiving emails with information on an occurrence of greater than or equal to M5.0; the emails should be sent from SeisComP automatically. In the case that INSIVUMEH notices any event having greater than or equal to M7.8 and located at coastal areas of Guatemala even without any additional information for evaluating the event, INSIVUMEH should issue tsunami warnings because the M satisfies with the criteria for the issuance of tsunami warnings.

Regarding M., SeisComP calculates the local magnitude (ML), body-wave magnitude (M b) and surface-wave magnitude (Ms). INSIVUMEH uses ML for Near Earthquakes and Mb or MS for Far Earthquakes as M for issuance.

INSIVUMEH issues its own hypocenters and M in principle except for distant earthquakes. However, CONRED calls M provided by INSIVUMEH "Richter Magnitude".

When the members of the seismic specialists group receive information from PTWC and other sources at home, they can analyze them for judgment of tsunami generations because they have the environment that are needed in the duty work. The analyzed results should be sent to ALFA, who receives and issues them to organizations according to the protocol. The time between events occurrence and the issuance is expected to be around or less than ten minutes.

Although El Salvador made sea depth surveys, Guatemala has not yet done so.

4) Issuing Tsunami Information

The criteria on the judgment of tsunami generation were established through following the ones of PTWC. The tsunami information issuance procedures are not established yet. However, in the National Response Plan, as for geological and meteorological phenomena, the protocol of warning dissemination procedures is established as follows: a) monitoring the phenomena should be handled by INSIVUMEH, b) judgment on category of Warning should be done based on the information from INSIVUEH, and c) INSIVUMEH should issue the analyzed results with radio.

The member in charge of the day from the seismic specialist group should take actions as follows: a) evaluate the accuracy of hypocenters and M provided by PTWC or from SeisComP as automatic calculation results, b) reading the P-phases or S-phases, calculating hypocenters, and correcting hypocenters and M, c) issuing the evaluated results to ALFA, the Director-General and the secretary for him with fax and email. On the other hand as for cancellation of the judgment is done following the PTWC Information.

The information from PTWC is received from the Internet at 10MB/s-speed. In addition, INSIVUMEH as TWFC can take information with the SMS of cellphones. The information from PTWC has a figure of the epicenter. The PTWC information is sent to all TWFP in Central America and is received within 10-15 minutes after the occurrence of the earthquake. The public cannot see the information.

ALFA should issue automatic calculation results as the first seismic information by fax, public-telephone, email and twitter to CONRED usually within one or two minutes after the occurrence of events. The fax transmission should be prioritized with confirmation of reception by radio. It should also pass the information to mass media and the public through the web site. The first seismic information includes the comment that the contents have not yet been checked by seismic specialists. ALFA issues the second information to related organizations twenty or thirty minutes later from the issuance of the first one after communicating with seismic specialists and getting any information from them. The second one includes information from them and expresses "tsunami will be expected." ALFA will have to respond to enquiries from the public when the event is a felt earthquake.

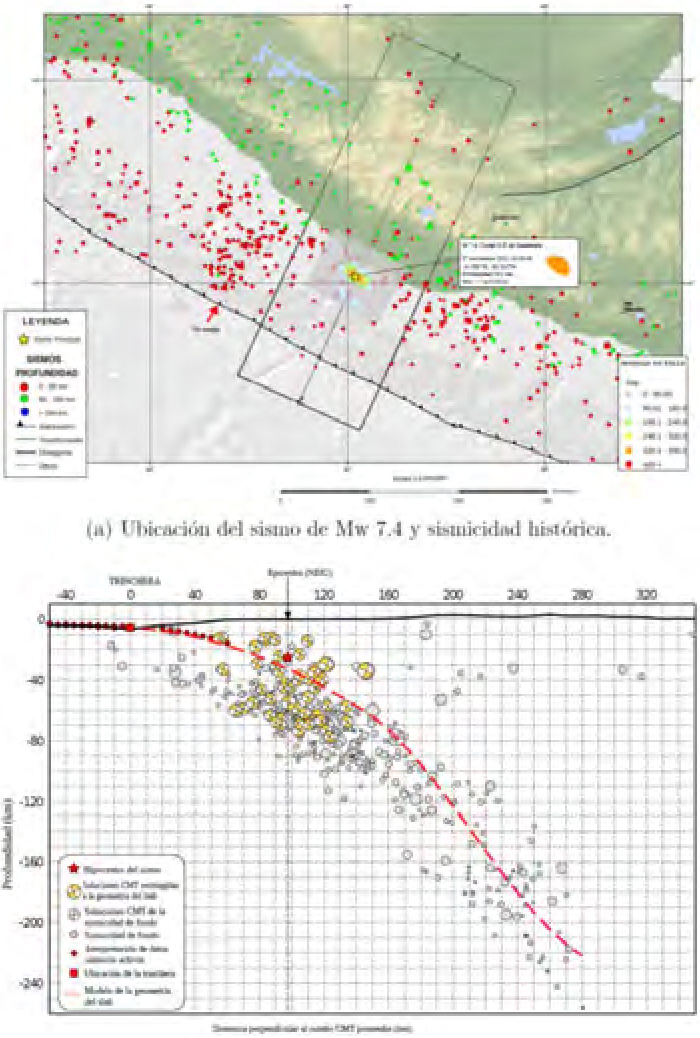
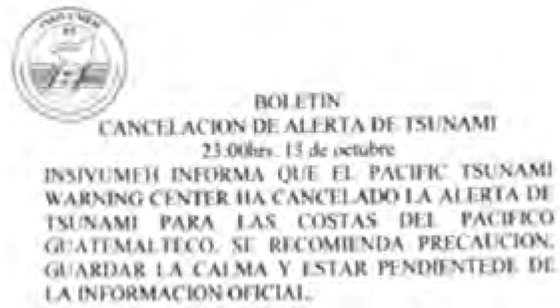


Figure 2.3.14 Hypocenter of 7th of November in 2012
(Upper: plain figure. Lower: cross section figure. Background shows hypocenters of historical events from USGS. Sauce: INSIVUMEH)

5) Specific examples of the analysis of tsunami generation and issuing tsunami information

As for the event of 7th of November in 2012 called the San Marcos Earthquake M7.2, whose epicenter was 160km away from coastal areas of Guatemala (After USGS ; Figure 2.3.13), INSIVUMEH issued the information having made the judgment of no effect to Guatemala before getting any information from PTWC because of the 10cm record of DRAT-Buoy.

As for the event of 13th of October in 2014 at 09:51PM (Local Time), M7.3, whose epicenter was off El Salvador , INSIVUMEH issued the judgment of tsunami generation, and furthermore issued the information of cancellation one hour later from the occurrence of the event (Figure 2.3.14).



BOLETIN
CANCELACION DE ALERTA DE TSUNAMI
23:00hrs. 13 de octubre
INSIVUMEH INFORMA QUE EL PACIFIC TSUNAMI WARNING CENTER HA CANCELADO LA ALERTA DE TSUNAMI PARA LAS COSTAS DEL PACIFICO GUATEMALTECO. SE RECOMIENDA PRECAUCION. GUARDAR LA CALMA Y ESTAR PENDIENTEDE DE LA INFORMACION OFICIAL.

Bulletin: Cancellation of Tsunami Warning
23:00 13th of October
INSIVUMEH informs that PTWC has cancelled the tsunami warning to the Pacific coast of Guatemala and recommends to remain precautious and calm and to take care of official information.

Figure 2.3.15 The Information on Cancellation of Tsunami Warning for Event of 13th October in 2014
(Source: INSIVUMEH)

(3) Tsunami Infrastructure Development Situation

There is no information on a warning dissemination system like sirens that can be used for the dissemination. There is also no information on the actual construction of a tsunami prevention facility. As for setting evacuation routes, there is no information on any action on the national and community levels.

(4) Tsunami Alert and Evacuation System

1) Warning Dissemination System

The COE Emergency Information Center of CNRED manages receipts and the dissemination of tsunami information with two or three “24x7 contact” members from seven members having three groups. The shift is managed with 24 hours duty and forty-eight hours off. The members in charge of the duty in the Center should be trained of the required items beforehand.

When an earthquake occurs, COE should monitor the web sites of USGS and INSIVUMEH. COE should assess the information of “tsunami will be expected” in the second information from ALFA, and COE should disseminate the result of the assessment (after a decision of the President if necessary).

In the case that it is difficult for SE-CONRED to assess or judge, it holds the Scientific Committee, which is constituted under CONRED. The president of the committee is the Director-General of INSIVUMEH. The committee should consider the technical issues in the information to be disseminated from SE-CONRED.

(Note: A drill of the procedures for the dissemination shows that the time between the first dissemination of information from COE and the start of the committee is around ten minutes.)

As for distant earthquakes, SE-CONRED depends on international organizations. However, for near earthquakes that are larger or equal to M6.0, it disseminates tsunami warnings based on its own criteria without depending on international organizations.

Furthermore, as for seismic activities not related to tsunami, INSIVUMEH (ALFA) should inform only the analysis results to SE-CONRED and disseminate it to the public. COE has established an emergency disaster information management system with the software, Lotus note.

(Note: At present, there is only one COE, but CONRED has a vehicle taking the role of mobile COE. In addition, CONRED has a plan of establishing two more COEs.)

2) Warning Dissemination Procedures

The technical information or disaster information provided by INSIVUMEH・ALFA should be received at the Emergency Information Dissemination Center of COE. The responsible staff of CONRED should make the judgment on the selection of category from yellow, orange or red according to the National Disaster Response Plan. The judgment result is disseminated to COMRED on the municipal government level with VHF based radio, email, or cellphone, and to mass media with email. The Caribbean area is partially covered voluntarily by HF amateur radios. As for the dissemination from the municipal level to the community level, radios are partially introduced as early warning dissemination tools for the areas having a high risk for floods or volcanic activities.

On the other hand, COE is usually monitoring disasters. It thus monitors the videos of cameras for volcanoes, the web site of NOAA for meteorological information and the ones of PTWC; but CONRED has no procedures for tsunami warning dissemination. It should follow the idea mentioned by ALFA and should disseminate it. CONRED is considering an automatic tsunami warning dissemination system for the events larger than M6.0.

As for the dissemination system of tsunami warnings from the municipal government at coastal areas to communities, the tools are only cellphones or direct communication. Therefore, the mass media like TV or the radio is important tools.

(Note: At the time of the tsunami of Japan in 2011, the Disaster Mitigation National Consultative Committee was called. In addition, it examined the tsunami arrival and judged there would be no risk based on the PTWC estimation of 10 cm at most.)

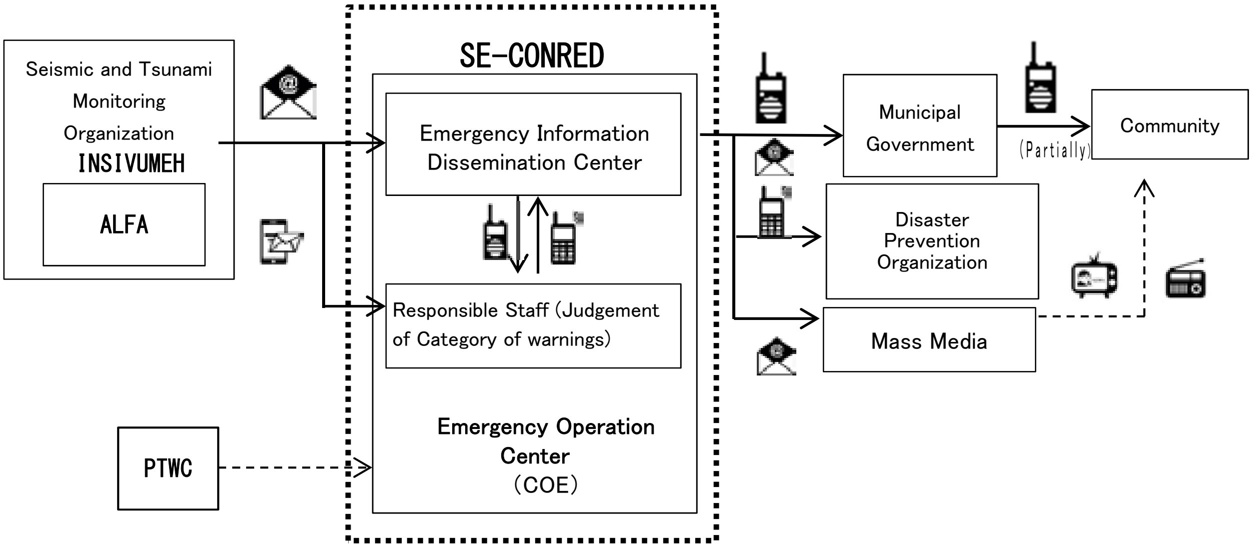


Figure 2.3.16 Tsunami Warning Dissemination System

Figure 2.3.17 Emergency Information Dissemination Center (Left), Emergency Operation Center (Right)

3) Tsunami Evacuation System

As for evacuations, the communities having a high risk of floods or volcanic eruptions have evacuation plans and have implemented the drills. However, regarding tsunamis, the evacuation plans or the drills are not handled systematically.

(5) Tsunami Risk Assessment Technique and its Present Situation

As for tsunami risk for Guatemala, a tsunami hazard map shows Guatemala will have 7.9m at the highest, El Salvador 8.1m and Mexico 8.2m. The map was made with the records retained in El Salvador. Namely, 37 tsunamis have struck Central America, and eleven out of them had an impact on the area.

(6) Development on a Hazard Map against Tsunami and its Utilization

There is a disaster data management system in INSIVUMEH. The system has hazard maps for earthquakes, volcanic activities, landslides, floods and sea waves. It also has real disaster information. However, it has no tsunami items.

(7) Effort for Tsunami Disaster Prevention at Research Institute like University and NGO

There are no universities to be handled in this section. On the other hand, as for the activities of NGOs, the Plan International has worked in supporting 138 primary schools establishing disaster response plans until 2014. The Save the Children is establishing a system of provision for three days of necessities after the occurrence of disasters. Both NGOs include communities located at coastal areas as the region of their activities.

2.3.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects of Japan's cooperation toward earthquake and tsunami disaster prevention in El Salvador are shown in the following table:

Table 2.3.4 Japan's Cooperation Projects toward Earthquake and Tsunami Disaster in Guatemala

Scheme	Project Name	Period
Development Study	The Study for the Establishment of Base Maps and Hazard Maps for GIS	2000-2003
Grant Aid	Outline Design Survey for Disaster Reconstruction Grant Aid in Guatemala	2006
Technical Cooperation	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" Capacity development project of Disaster Management in San Pedro Yepocapa city Sangre de Cristo, El Provenir, Santa Sofia, Yucales, Morelia, Panimache,and San Juan Alotenango city and El Provenir Siquinala city Las Palmas, and Lucernas Escuintla CONRED continuously support local activities for disaster management.	2007-2012
Training Program (2010-2014)	Global Seismological Observation (2)	2010-2011
	Community based Disaster Risk Management (15)	2010-2014
	Disaster Management in Central American Countries (28)	2010-2014

*Numbers in ( ) of Training Program indicate number of participants

(2) Situation of Key Donor's Cooperation

Projects of Key Donor's cooperation toward earthquake and tsunami disaster prevention in Guatemala are shown in the following table:

Table 2.3.5 Key donor's Projects toward Earthquake and Tsunami Disaster in Guatemala

Funding Agency	Project Name / Project Outline	Project Sight	Implementing Body	Budget (USD)	Period
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation for Honduras, Costa Rica and Panama	Entire Guatemala	INSIVUMEH	2.4 million	2007-2010
	Earthquake hazard map of the whole country was created based on the concept "learning by doing" for hazard, vulnerability and risk analysis with INSIVUMEH as counterpart				
IDB	Development and application of a Risk Assessment Platform for Guatemala (CAPRA)	N/A	INSIVUMEH	350 thousand	2009-2010
	Project of enhancement of platform for risk analysis was implemented with INSIVUMEH as counterpart.				
UNDP	Institutional support to technical groups related with risk reduction	Entire Guatemala	Council of system science with coordination of INSIVUMEH	90,000	2009
	The Council for System Science (coordinated by INSIVUMEH) implemented the project of extracting risk zones of natural hazards in the whole country.				

2.3.6. Items to be Improved

(1) Seismic analyzing ability improvement through hypocenter determination improvement

1) Seismic analyzing ability improvement through hypocenter determination improvement

In order to improve the reliability of judgments on tsunami generation, improvement of the accuracy of hypocenter and M determination is essential.

Therefore, the following measures should be taken: a) regarding the seismic velocity structure model for hypocenter determination (but, promoting the revision of the temporary model, and reflecting the calculation immediately), b) regarding the selection of seismic stations to be used for hypocenter determination in tsunami generation judgment, its criteria is not well established, INSIVUMEH should obtain the method for optimizing the selection action through clarifying the criteria, c) the station correction method should be optimized, and d) it is necessary to obtain the cross section showing the distribution of the hypocenter to assess the accuracy of the depth of hypocenter. It is also necessary to introduce Mw in the near future in order to obtain reliable assessments.

2) Introducing the focal mechanism analysis technique

In order to improve the reliability of a tsunami generation judgment, it is necessary to estimate and understand the focal mechanisms such as the normal-reverse type or strike-slip type immediately after the occurrence of any event. Therefore, at first, introducing the initial motion analysis for focal mechanisms into the current official procedures of tsunami generation judgment should be done. The accuracy of the initial motion analysis is not so high for large earthquakes; INSIVUMEH has obtained the technique of CMT analysis having high accuracy as the next step; in order to do so, INSIVUMEH should learn the algorithms of the software in any case.

3) Acquisition of the Technique of Tsunami Generation Judgment

In order to improve the reliability of tsunami generation judgment, in addition to basic knowledge and skills, it is essential to acquire "the accumulation of improvement on actual work" and to put this experience into a manual.

In addition, INSIVUMEH should acquire the technique for earlier tsunami warning cancellation while keeping quick reporting and reliability by referring to the advanced Introduction procedures on the estimation of tsunami height and tsunami arrival time.

PTWC provides information on tsunamis for all countries located around the Pacific Ocean; the information should thus be a sort of "average" for a wide area, and is sometimes too rough to use for a tsunami warning judgment for a region; that means the accuracy is not enough for handling any regional earthquakes.

In that context, INSIVUMEH should acquire the ability of estimating tsunami height and tsunami arrival time step by step. Namely, as for the estimation of the tsunami arrival time INSIVUMEH should acquire the ability a) of making an outline or approximate estimation with the current sea depth data, b) of improving the estimation with the latest progress in the sea depth research; as for estimation of tsunami height, it should have the ability a) of tsunami generation analysis with focal mechanism, b) of approximate but quantitative estimation with the current sea depth data, c) of tsunami generation judgment with CMT analysis, d) of improving the estimation with the latest sea depth data, and e) of improving height estimation with coastal geography.

In addition, INSIVUMEH should acquire the technique for earlier tsunami warning cancellation while keeping reliability.

Newly Installing Tidal Gauge Stations and others

In order to improve the accuracy of tsunami warnings, a tidal gauge observation network should be improved step by step as follows: a) the establishment of a system for stable operations of tidal gauges; b) the optimization of data acquisition or data transmission configuration; and c) the optimization or reinforcement of the network of the tidal gauge observation network from the view point that real time tidal data monitoring should be essential for the improvement of tsunami warning reliability and for the update of a tsunami warning category.

(2)Improvement of the Dissemination of Tsunami Information on Local Tsunamis

1) Improvement of the Dissemination of Tsunami Information

INSIVUMEH should shorten the time for a tsunami generation judgment through simplifying the judgment procedures and the automation of a warning issuance procedure in order to respond to Local Tsunamis, which is likely to occur.

2) Ensure the warning dissemination route

It is necessary to ensure the dissemination route to the residents in vulnerable areas especially along the coastal area of the Pacific Ocean, even though there are a few stable communication tools between the municipalities and communities.

3) Promotion Policy on Seismic and Tsunami Disaster Prevention Archive of seismic risk assessment data

It is necessary to develop essential data, such as building inventories of building structures and the fragility curve for risk assessment of earthquakes.

4) Promotion of an Earthquake–proof Policy

The results from RESIS II and SAPRA Projects should be used for risk assessment and design for earthquake proofing, the promotion of people's intention of reinforcement for earthquake–proofing and supporting community activity for disaster prevention.

5) Creation of Tsunami Hazard Map on the Community-level

Organizing community disaster prevention has been implemented in particular areas which are prone to the occurrence of floods and volcanic hazards, and the necessary tools are quite few, for example, tsunami hazard maps which are made only for a particular part of coastal areas. It is thus necessary to make maps to cover all coastal areas in order to realize reliable evacuation for all.

2.4. Costa Rica

2.4.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of Costa Rica is shown in the following table:

Table 2.4.1 Basic Information of Costa Rica

Area	Contents	Source
Population	4.87million	2013, World Bank
GDP	49.62 billion USD	2013, World Bank
Area	51,100 ㎢ (Land Area 51,060 ㎢) (Land Use:Arable4.89%、Cropland6.46%、Other88.65%	2011, CIA World Fact Book
Administrative	7 Province	CIA World Fact Book
Geography	Coastal plains separated by rugged mountains including over 100 volcanic cones, of which several are major volcanoes	CIA World Fact Book
Climate	Tropical and subtropical; dry season (December to April); rainy season (May to November); cooler in the highlands	CIA World Fact Book

(2) Basic Information of Natural Disasters

Costa Rica has been exposed to a variety of natural hazards such as earthquake-tsunamis, hurricanes, landslides et.al. Several destructive earthquakes in Costa Rica have occurred in the past few decades, such as the 1991 M7.6, the 2009 M6.1 earthquake, which caused serious damage, and recently the 2012 M7.6 earthquake, which occurred off the coast of the Nicoya Peninsula and caused a tsunami.

Table 2.4.2 List of major earthquake in the history of Costa Rica (Source:CRED /EM-DAT、NOAA/NGDC)

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)	Date
1904/12/20	7.8	-	-	-	-	
1905/1/20	-	Central Pacific	-	-	-	
1910/4/13	-	Cartago	1,750	-	-	
1973/4/14	6.5	South Laguna Arenal	21	3,745	200	
1983/4/2	7.2	S.E. San José	10	475	1,000	
1983/7/3	6.1	San Jose province	2	5,060		
1990/12/22	5.8	Alajuela, Heredia	1	14,299	19,500	
1990/3/25	6.8	Puntarenas	-	310	-	
1991/4/22	7.6	Bribri, Matina	47	10,419	100,000	
1991/5/4	5.6	Limon area	-	-	-	
1991/8/9	4.9	San José	-	150	-	
1993/7/10	4.4	Cartago, Turrialba	3	240	-	
2003/12/25	6.5	Puerto Muelles	2	135	-	
2004/11/20	6.4	San Jose	8	280	-	
2009/1/8	6.1	Barva, Santa Barbara	31	128,618	200,000	
2012/9/5	7.6	Guanacaste	2	762	45,000	
2012/10/13	7.3	Off shore	-	-	-	Tsunami alert
2012/10/24	6.5	-	-	-	-	Small tsunami at Coco island

- means data is not available

2.4.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management (Policy, Organization)

1) Policy Framework on Disaster Management

The Policy Framework on Disaster Management in Costa Rica is shown in following table:

Table 2.4.3 Policy Framework on Disaster Management in Costa Rica

Category	Name	Contents
Policy	Not yet	
Law	Law 8488 (2006)	The law stipulates a disaster management system, roles and responsibilities, emergency response process and financial resources (the transfer of 3% of tax revenue to the national financial response fund) for CNE and local commission.
	Law 7914	The law stipulates the roles and responsibilities of the government, municipalities and private sectors in emergencies, and participation in the activities for risk reduction.
Plan	National Risk Management Plan (2010-2015)	The plan is composed of the risk assessment, strategic framework of disaster prevention and mitigation plan with public-private partnership, and is under review as a response plan for each disaster including earthquakes and tsunamis because it is not in correspondence of each disaster.

2) Framework of Disaster Prevention Organization

【1】Framework of Organization System

On the national level, the National Emergency Commission for Risk Prevention and Attention (CNE) carries out the implementation of measures on disaster prevention, the formulation of a national plan and the dissemination of warnings on the national level based on Law8488. On the local level, the Departmental Committee of Prevention, Mitigation and Attention of Disasters (CODEPRED), Municipal Committee of Prevention, Mitigation and Attention of Disasters (COMUPRED), and Local Committee of Prevention, Mitigation and Attention of Disasters (COLOPRED) carry out disaster management measures on the departmental level, the municipality level, and the community level, respectively.

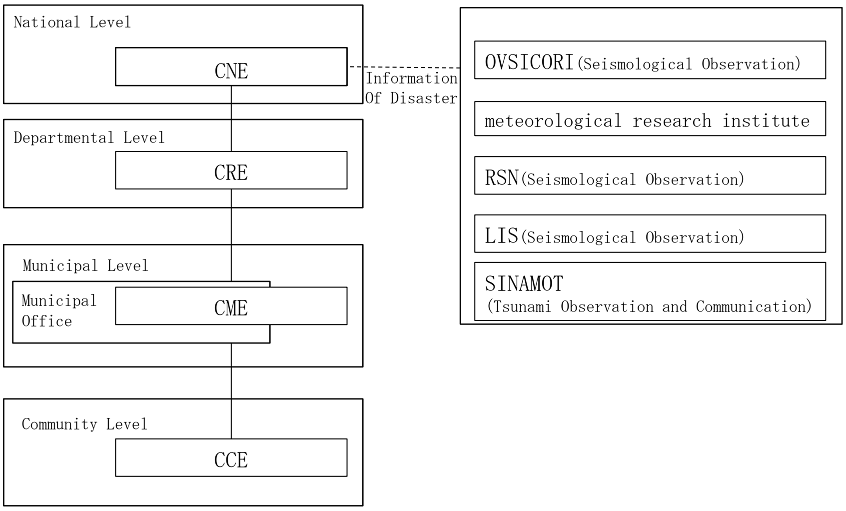


Figure 2.4.1 Structure of Main Organization of Disaster Prevention (Costa Rica)

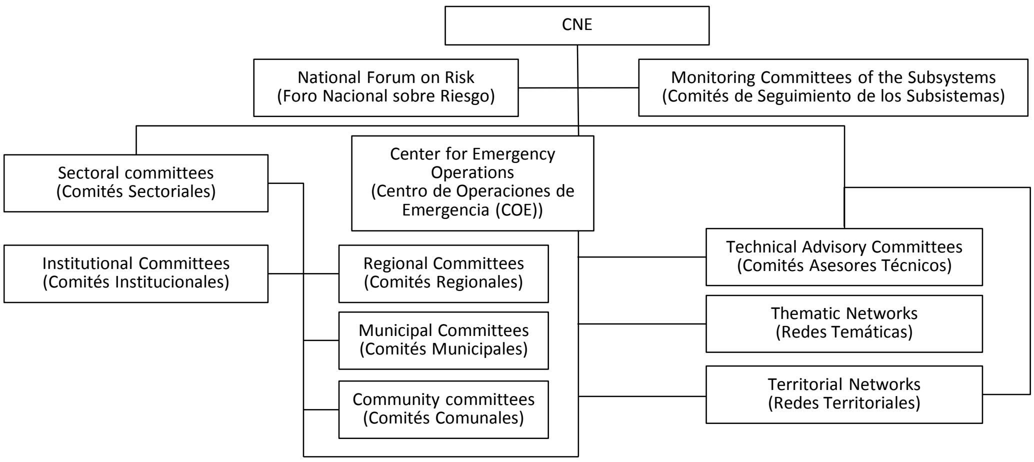


Figure 2.4.2 Structure of Relevant Organization of Disaster Prevention (Costa Rica)

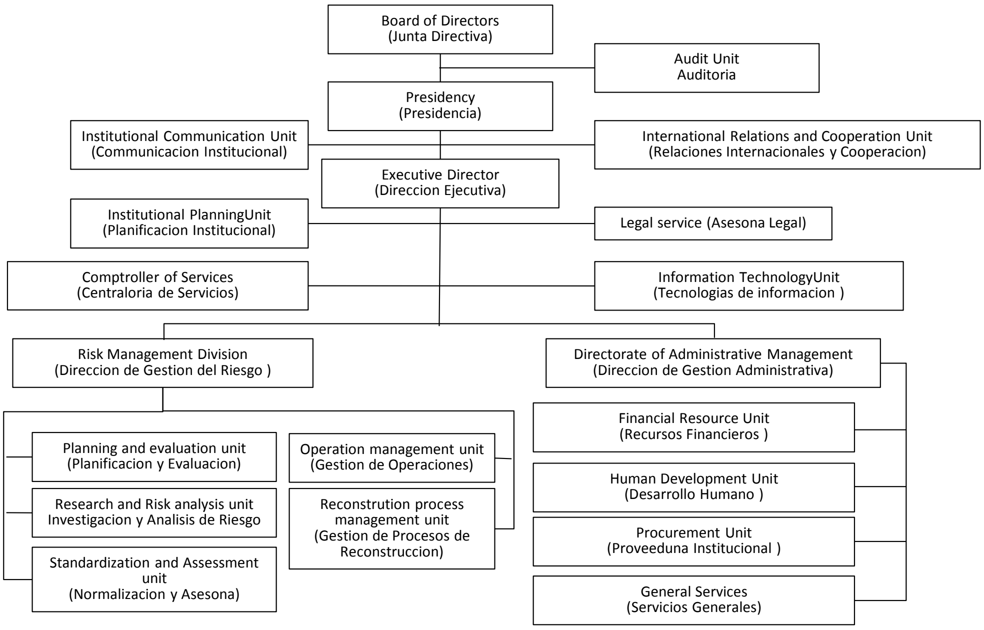


Figure 2.4.3 Organization Chart of CNE

【２】Sharing Responsibility for Earthquake and Tsunami Disaster Prevention

Earthquake monitoring and the dissemination of earthquake information are implemented by the National Seismological Network of the University of Costa Rica (RSN), the Seismic engineering laboratory of the University of Costa Rica (LIS) and the Volcanological and Seismological Observatory of Costa Rica of the National University of Costa Rica (OVSICORI) which has their own observatory network. As for the dissemination of tsunami information, the Tsunami Monitoring Room of the National University of Costa Rica (SINAMOT) assesses tsunami generation based on the information from the above-mentioned organizations and PTWC, and then disseminates the tsunami technical information to CNE.

CNE judges the alert level and disseminates the alert to the relevant organizations such as municipalities, et al.

【３】Expectation to CATAC

SINAMOT expects the information of Regional Tsunamis from CATAC because all of the organizations above rely on the automatic calculation for the analysis of seismic data, and it all depends on PTWC for the judgment of tsunami generation. In addition to this, SINAMOT also expects a training program, which covers the role of CATAC, promising information and the limitation of disseminated information.

(2) Priority and Significance on the Relevant Laws on Earthquake and Tsunami Disasters on the National-level

The measures for tsunamis have become an urgent issue because of the earthquake and Local Tsunami which occurred on the Nicoya Peninsula, a regional earthquake which occurred offshore of El Salvador and a high possibility of tsunami induced by an earthquake which occurred offshore of Colombia or Ecuador. Thereby, CNE has conducted a review of the National Risk Management Plan with adding an emergency response for tsunamis.

(3) Situation of the Allocation of a Budget for Disaster Prevention

There is no specific allocation for tsunami observation in any of the four organizations for earthquake and tsunami observation because those are operated under the budget allocation for education and study. As for OVSICORI, it is supposed that the budget of the observation was about 100,000 USD in 2014.

(4) Situation of Activities for Disaster Prevention on the Community-level

The disaster prevention organization on the community-level is stipulated that CME and CCE have a role, but the establishment of those have not been promoted yet. Consequently, a number of community activities have been supported by CNE or the Japanese project "BOSAI" in the Nicoya Peninsula where an earthquake and tsunami are could occur in the near future. The Scientific and Technological Satellite Information Program at the Service of Disaster Prevention and Mitigation, University of Costa Rica (PREVENTEC) have implemented the project to support the community for the disaster prevention education on tsunamis in the Municipality of Puntarenas.

(5) Situation of Disaster Prevention Education for Earthquakes and Tsunamis in Educational Institutes

The Ministry of Public Education (MEP) stipulates the effort for disaster prevention education in the school curriculum and has the responsibility for implementation.

2.4.3. Earthquake Observation and Promotion of Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

Earthquake observation in Costa Rica is conducted by RSN, OVSICORI and LIS independently. The legal institutes for the announcement of earthquakes are not specified. CNE is responsible for issuing earthquake and tsunami warnings and emergency response. The Association of Engineers and Architects of Costa Rica (CFIA) develop the seismic code.

(2) Earthquake Observation Capability

1) Seismic Observation Operation

Not all three of the observation institutes have an official system for response 24 hours a day. As RSN OVSICORI's observation is primarily from the perspective of seismology, focusing on the determination of earthquake parameters, LIS's observation is mainly for earthquake engineering for the attenuation of ground motion and ground amplification. The records of broadband and short period seismometers usually calculate the earthquake source parameters, but LIS calculates the parameters by the records of accelerometers. The three institutes announce their results independently.

2) Earthquake observation network, data processing and dissemination

【1】RSN

RSN began its seismic observation from 1973. The current seismic observation network has 21 seismometers from UCR and fourteen from the Costa Rica Electric Power

Company (ICE) as shown in Figure 2.4.4. The data of ICE is collected in real time by optic fiber and the others are collected by the Internet. There is one broadband seismometer installed on Coco Island, about 500 km away from the coast, which is useful for improving the accuracy of calculation for the events between the mainland and the island. 86 seismometers, including those from Nicaragua, Panama and IRIS, are used for the calculation. RSN is planning to deploy 90 short period seismometers to improving its observation network, which will be finished in 2015. The locations of the 90 seismometers are shown in Figure 2.4.5.

The calculation for the epicenter and magnitude is performed by SeisComP automatically. For the relatively large earthquakes, which occur in Costa Rica, the automatic result will be confirmed by manual processing with Earthworm. The regional shear wave velocity model is considered in the calculation. If more than five seismometers are triggered, the automatic calculation will begin. The result will be automatically sent to the observation staff by mobile mail and the person on duty will decide if it needs immediate manual confirmation. The focal mechanism by initial wave is analyzed but not included in the preliminary announcement. CMT analysis is not carried out. Automatic calculation takes approximately one to three minutes and the manual confirmation needs at least seven minutes.

The manual processing results, as preliminary information, will be transmitted to CNE, all of the municipalities and the mass media by email with the link of the epicenter location map. About 150 thousand people are registered to the RSN Facebook page and about 50 thousand people are registered to the RSN twitter feed.

Figure 2.4.4 Location of the Current Seismometers of RSN (Source: RSN)

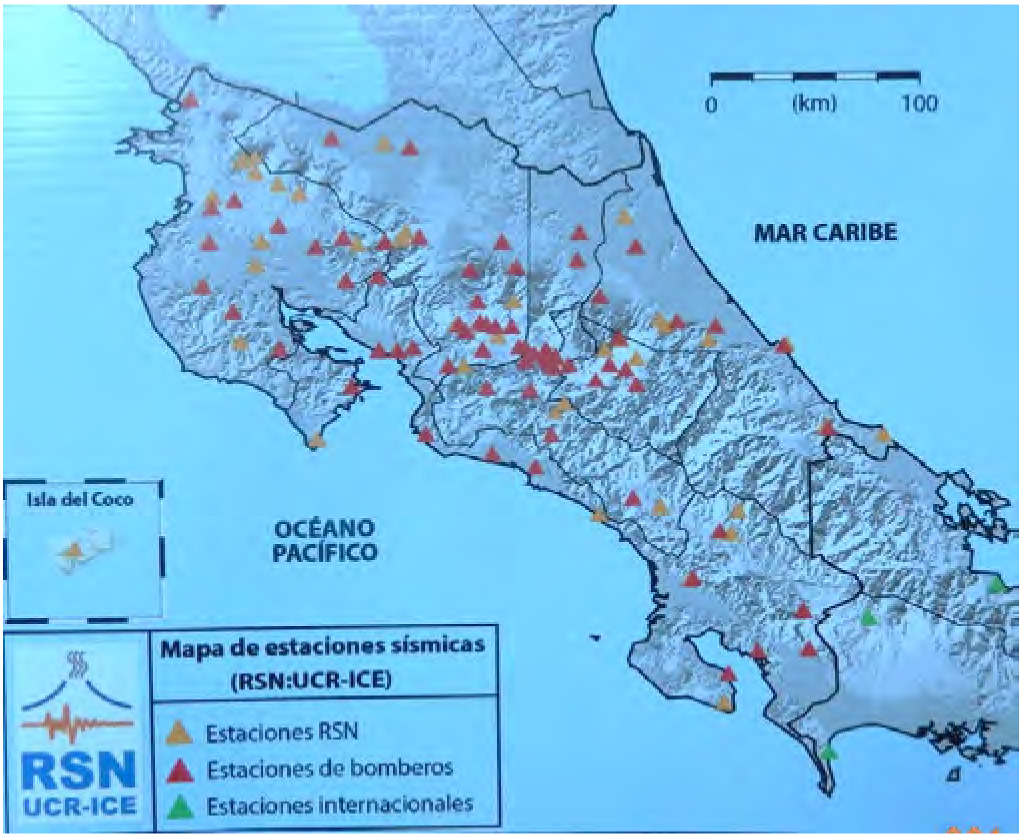


Figure 2.4.5 Location of Planned Seismometers of RSN (Source：RSN)

【２】OVSICORI

OVSICORI was established in 1973 as a research institute for volcano. The seismic observation began in the wake of the 1983 Central Costa Rica earthquake with the support of University of California. The current seismic observation network has about 80 seismometers, including broadband, short period seismometers and accelerometers, as shown in Figure 2.4.6. The data from about 50 seismometers are collected in real time and used for earthquake source calculation. For the remaining seismometers, their data will be collected on site approximately once every 2 months.

The current data processing software used by OVSICORI is Antelope, which can automatically collect data, process and disseminate information as well as operated manually. SeisComP has been installed and it will be used in 2015 instead of Antelope. The manual confirmation is not for the epicenters out of Costa Rica. In the calculation, the shear wave velocity model of Costa Rica is used. Focal mechanism by initial wave is analyzed but CMT analysis does not been carried out. There are two servers for the analysis, and one for backup.

Figure 2.4.6 Location of Seismometers of OVSICORI (Source: OVSICORI)

【3】LIS

The seismic observation of LIS began from 1982 with 40 accelerometers by the support of USAID. The observation network now has 100 accelerometers installed in 93 sites, in which about 70 are placed on the free field and the remaining is installed on buildings. The locations of the accelerometers are shown in Figure 2.4.7. The data has been collected in real time over the Internet since 2010.

The acceleration records are used to calculate the epicenter location and magnitude. In addition, the distribution of the intensity and response spectrum are also calculated. All of the results are opened through WEB, Facebook and Twitter. Only the data of free field are used for calculation and the data of other institutes are not used. The software used is open source software of Sisloc 8. The shear wave velocity model of Costa Rica, used by RSN and OVSICORI, is used for the calculation. After an earthquake occurs, the data will be automatically processed and the result will come out in about three minutes. Then the manual review will be conducted if necessary. LIS has no 24-hour response system. The manual confirmation is usually done during the work hours, except for extreme earthquakes. LIS has three experts (among them one a civil engineering expert and one a seismology expert) and 2 - 3 research assistants.

LIS provides the earthquake information to CNE the same as that which is opened on its WEB site. The Fourier spectrum of acceleration records are used for calculating magnitude. Since the accelerometer has a low capability to record the small ground motion and long period component of seismic waves, the accurate magnitude that LIS can provided is deemed to be in the range of 3.0 - 6.7.

LIS is also commissioned by other organizations for strong motion data collection and processing. For example, the management and data processing for five accelerometers installed in a 29-story building (the tallest building in San Jose) are entrusted. They will report to the originator when there is an earthquake. LIS has the intention to perform the seismic risk assessment, but it cannot be realized because of the lack of human resources. The situation may change in the future because one person is attending the doctoral program in Spain for the study of structural vulnerability. It will be possible for seismic risk assessment when he is back.

The flowchart of RSN, OVSICORI and LIS for data collection, processing, and information dissemination is shown in Figure 2.4 8.

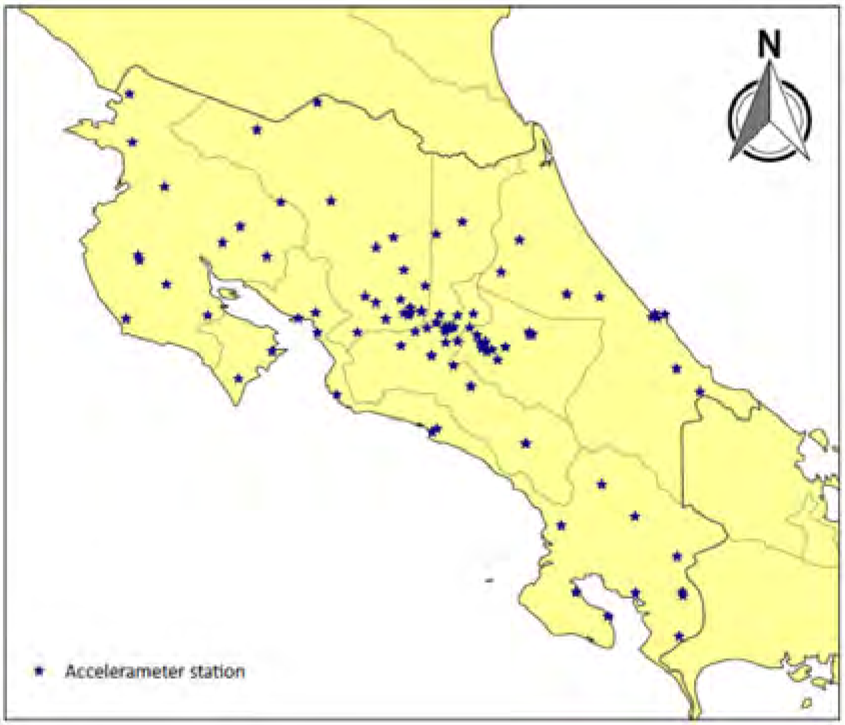


Figure 2.4.7 Location of Seismometers of LIS (Source: LIS data)

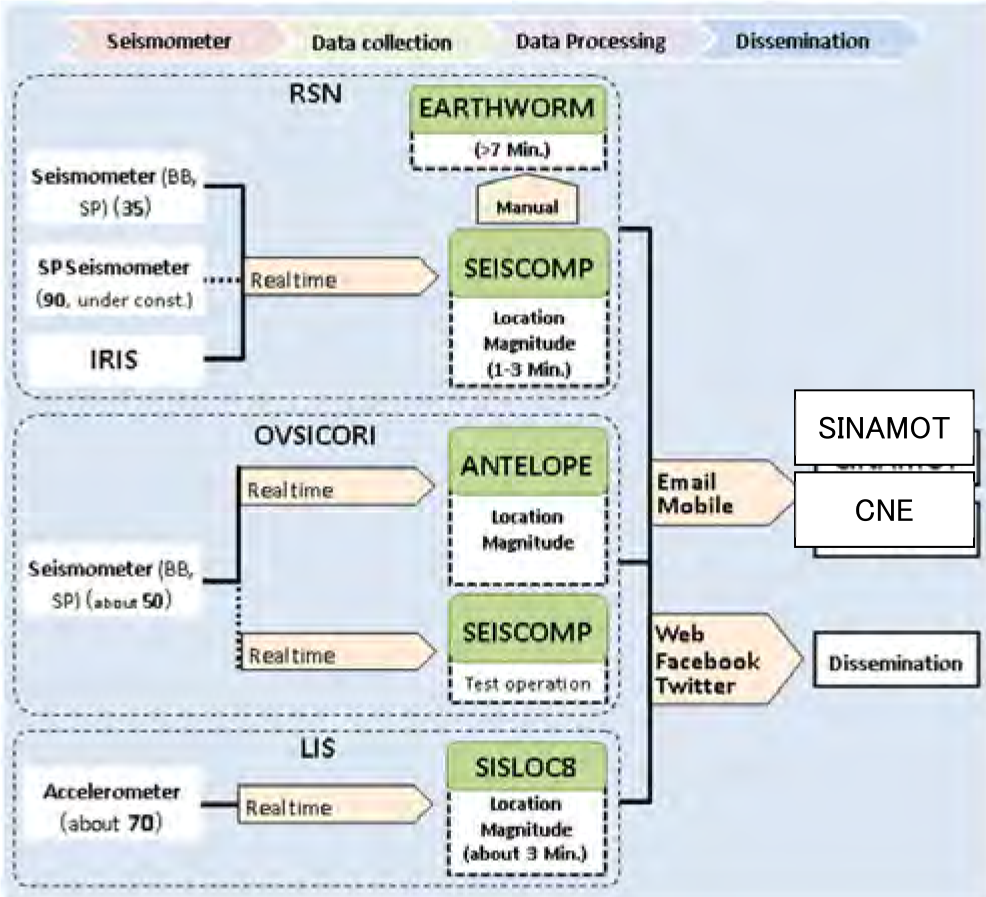


Figure 2.4.8 Flowchart of Data Collection, Processing and dissemination of RSN、OVSICORI、LIS

The table below shows the seismic observation network of Costa Rica.

Figure 2.4.9 Detail of Seismic Observation Network of Costa Rica

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	55～79	55～79	0	55～79	55～79
	On Site	20～30	20～30	0		
Broadband	Real Time Telemetering	6～30	6～30	0	6～30	6～30
	On Site	0～10	0～10	0		
Strong Motion	Real Time Telemetering	70	70	0	0	0
	On Site	0	0	0		
Total	Real Time Telemetering	155	155	0	85	85
	On Site	30	30	0		

(3) Approach and Current Status of Seismic Risk Assessment

In Costa Rica, as the pilot country of the CAPRA project, the seismic risk assessment for five districts of San Jose was conducted in 2014. The assessment was performed for residential houses, schools, and hospitals. As for houses, since the complete data is not available, only the existing data were used. Several scenario earthquakes were considered. For example, an earthquake beneath San Jose with a magnitude of 6.34 (Figure 2.4.8) and that may have occurred along the coast having a magnitude of 7.38. The seismic risk assessment requires the detailed information of each individual building, such structure type, material, construction year, height, etc. and the insufficient data is a common issue in Central American countries. The preparation of a building inventory is necessary for the utilization of CAPRA.

Figure 2.4.10 Example of the Seismic Hazard of San Jose (Source: CNE)

(4) Development and utilization of seismic hazard map

Costa Rica participated the project RESIS II and the seismic hazard map for the whole territory of Costa Rica has been made. The hazard is given by the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds, corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with a 500 year return period of Costa Rica is shown in Figure 2.4.9 and the hazard curve of San Jose is shown in Figure 2.4 10. The utilization of the hazard map is expected.

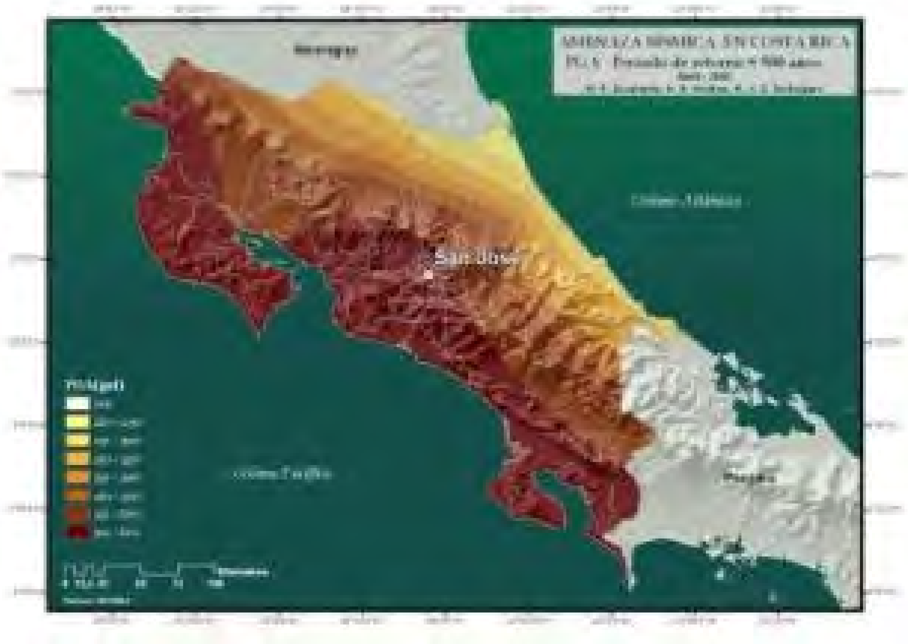


Figure 2.4.11 Seismic Hazard of Costa Rica by RESIS II (PGA、Return Period 500 years) (Source：RESIS Ⅱ Report)

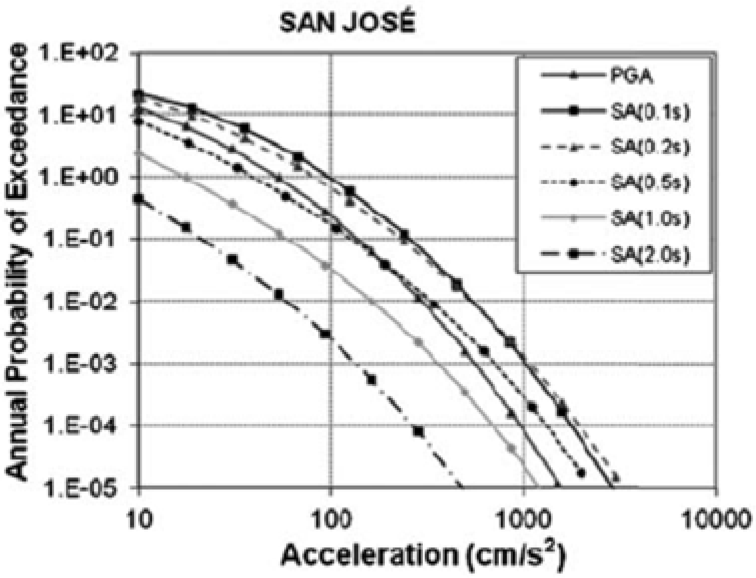


Figure 2.4.12 Seismic Hazard Curve of San Jose by RESIS II (Source：BSSA,Vol.102, No.2,2012)

(5) Development of seismic code and the implementation

The seismic code of Costa Rica was created in 1974 and was revised in 1986, 2002, and 2010. The ground motion zonation of the code is shown in Figure 2.4 11. The design ground motion is calculated according to the ground condition and ground motion zonation as shown in Table 2.4.5. In addition to the seismic code for buildings, a seismic design standard for bridges was also established.

The Association of Engineers and Architects of Costa Rica (CFIA) create the seismic code. CIFA also performed a vulnerability survey and provided advice to the government authorities in relation to the building construction quality check. It is the responsibility of the ministry in charge for the vulnerability assessment and seismic strengthening of important buildings, infrastructure and lifeline facilities.

Table 2.4.4 Design Acceleration of Costa Rica (Source: Costa Rica Seismic Code)

Tipo de sitio	Zona II	Zona III	Zona IV
S_1	0.20	0.30	0.40
S_2	0.24	0.33	0.40
S_3	0.28	0.36	0.44
S_4	0.34	0.36	0.36

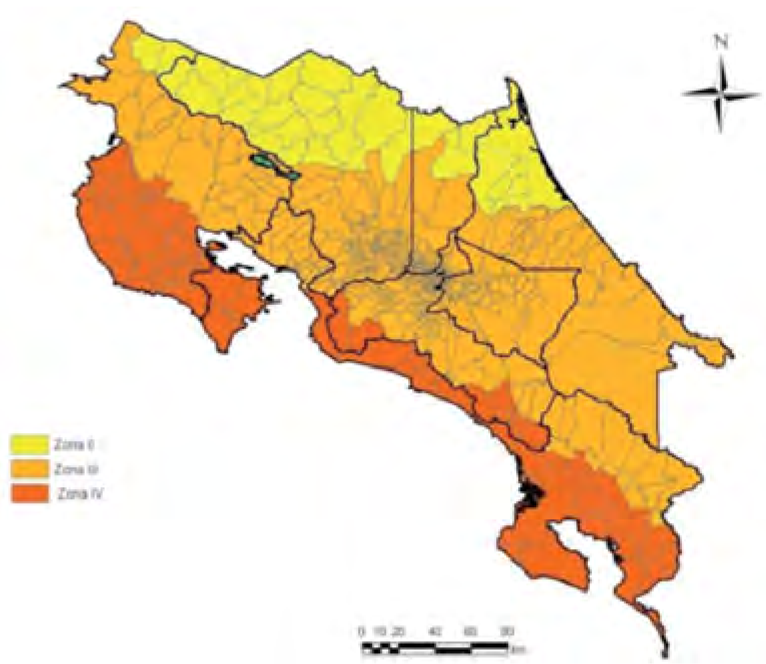


Figure 2.4.13 Ground Motion Zonation of Costa Rica Seismic Code (Source: Costa Rica Seismic Code)

(6) Activities of University Institutes and NGOs for Disaster Prevention

The Disaster Prevention Research Institute of UCR (PREVENTEC) was established in 2007 aiming at the management of satellite disaster images. Experts and researchers in a variety of areas participated the research program related to the disaster prevention plan of the institute. The institute has the research on the utilization of satellite images for disaster prevention and has provided the satellite images and analysis results of damage from the earthquake that occurred in January of 2009 to CNE. In recent years, PREVENTEC provides support for elementary school's activities for disaster prevention planning and education.

The Red Cross, as a member organization of CNE, promoted the community based disaster prevention activities for sediment-related disasters. During the earthquake of January 2009, it dispatched volunteers from the psychological social support team give assistance to those affected by the earthquake.

2.4.4. Tsunami-Monitoring and Tsunamis-Disaster prevention efforts

(1) National Organizations responsible for Tsunami-Disaster prevention and relevant organizations

IOC approves the CNE as TWFP accordingly. On the other hand, the IOC approves the Ministry of Environment and Energy (MINAE) as TNC, although it has no relation with tsunami warnings except that the deputy Minister is a member of CNE when any disaster occurs, and that a member of its staff is a member of the Oceanic Technology Committee of CNE.

SINAMOT comes from a part of the RONMAC（Water Level Observation Network for Latin America）project. It is a joint organization of UNA and UCR. It handles only tsunamis and not earthquakes. Namely, it implements analyzing tsunami issues with the seismic information provided from LIS, RSN and OVSICORI, and issues the results from the analysis to CNE. During the off period, it handles issues at home like the seismic institutes. On the other hand, CNE has the responsibility for disseminating tsunami warnings. CNE can inquire any questions not only to SINAMOT but also to the other institutes according to the related laws.

CNE has established a regular Communication Center that should have a "24x7 contact" as a disaster information dissemination organization. The center has two or three members of staff in charge of the duty of the center in a shift of twenty-four hours with forty-eight hours off. The center is managed with nine members, who have experience in security or communications. The center should also coordinate the activities of firefighting, police, and the Red Cross. Firefighters have the function of search and rescue with ambulances; the Red Cross also has ambulances.

(2) The Monitoring System relevant to Tsunami

1) Tsunami Monitoring System

The tsunami warning system is managed with CNE as a provider of funds for computers, software and related items and with SINAMOT as a provider of human resources. Note: the intermediate products in tsunami warning dissemination procedures like those that GIS information is used by CNE.

SINAMOT uses information provided one after another by LIS, RSN and OVSICORI for analyzing tsunami generation. The provision is done in this order in normal cases. The information from RSN has a map figure of the epicenter; those from OVSICPRI have a comment on the tectonic context of the epicenter.

(Note: CNE is considering the introduction of CISN software, which can be expected to contribute to effective tsunami monitoring. The software can be easily installed and can be permitted for TWFP and researchers to use it without payment.

2) Tsunami Observation Network

On the coast of the Pacific Ocean, the tidal gauge located at Los Suenos is the only one that works as of 10th of December in 2014 (Table Table 2.4.5 and Figure 2.4.14). Later, not showing in Figure 2.4.13, a gauge has been re-installed at Papagayo on the Pacific Coast in

December of 2014. The one at Quepos on the Pacific Coast was installed by the University of Hawaii Sea Level Center (UHSLC) was being used for observations. However, it was removed due to port repairs, and it is expected, as of 14th of February in 2015, to be reinstalled in April of 2015. In addition, there is a possibility that a gauge will be installed on Coco Island with support from Spain in 2015.

The tidal data are sent through GOES Satellite to PTWC with DCP. SINAMOT improves the accuracy of tsunami observation results through estimating the tide with the past observed data. The estimation is implemented with the Tide Tool software provided free by PTWC. SINAMOT uses Google Earth for more effective tsunami monitoring.

Table 2.4.5 Tidal Gauge Station in Cost Rica (Source:: SINAMOT)

Device Type	Station Name (Station Code)	Coordinates	Sampling Rate / Transmission Interval	Means for Data Collection	Power	Responsible Institution	Observation Period Inspection Interval
Pressure and Radar	Limón (limn, limon)	10°N, 83.033°W	1min 5min	Satellite transmission	Solar	UHSLC (installation) & RONMAC	Oct 2009 Operation 3 times a year
Pressure and Radar	Quepos (quepo)	9.4°N, 84.167°W	1min 5min	Satellite transmission	Solar	UHSLC (installation) & RONMAC	Oct 2009 Stop 3 times a year
Bubble and Pressure	Los Sueños (losu)	9.6499°N, 84.6663611° W	1min 5min	Satellite transmission	Solar	RONMAC (Campbell (installation) CNE(fund))	May 2013 Operation 3 times a year
Bubble and Pressure	Papagayo Marina (papa)	10.6420278° N 85.656°W	1min 5min	Satellite transmission	Solar	RONMAC (Campbell (installation) CNE(fund))。	Dec 2014 Operation 3 times a year

Figure 2.4.14 Location of Tidal Gauges (Source: SINAMOT)

3) Analysis of Tsunami Generation

SINAMOT should analyze tsunami generations only for the earthquakes that satisfy certain conditions on M, hypocenter and tectonic mechanism. It checks only the information received as the trigger for starting the analysis. This way of handling has the concern of oversight of important information. Therefore, SINAMOT wants to obtain alarm software that will make a sound or display for perceiving a large event occurrence like M6.1.

The first of the conditions mentioned above is that the Mw should be larger than or equal to Mw6.5. This comes from PTWC.

The second of them is that the hypocenter should be at coastal areas of Costa Rica or within 300km of Costa Rica. (Note: PTWC provides estimations of tsunami height to the Sections that are set at all coastal areas of Pacific Ocean. There is only one Section for Costa Rica.

The third of them is that the tectonic mechanism should be the Subduction-Zone type or the Outer-Rise type.

SINAMOT analyzes only the information from PTWC for near earthquakes. The information on estimations of tsunami height will be sent individually to the TWFP and TNC of the countries that have a high possibility of being affected by tsunami; the information reaches them usually within thirty minutes after the occurrence of the event. The information is also sent to all organizations participating in the IOC.

SINAMOT depends also on PTWC for the estimations of tsunami arrival times. As for near earthquakes, that means there is a concern that a tsunami warning issuance might not be in time to order evacuations from a tsunami strike. (Note: the software Tide Tool for the estimation of tides will be used for rough estimations of tsunami arrival times.)

The categories of tsunami warnings from CNE show tsunami arrival times (Figure 2.4.14). This demands high reliability in estimations of arrival times and swiftness of the action.

Regarding estimates of tsunami height, the software Twave, which is provided by NOAA only to TWFP, has this function. Therefore, SINAMOT has already obtained it and is asking permission of its use according to the formal procedures as of December 2014.

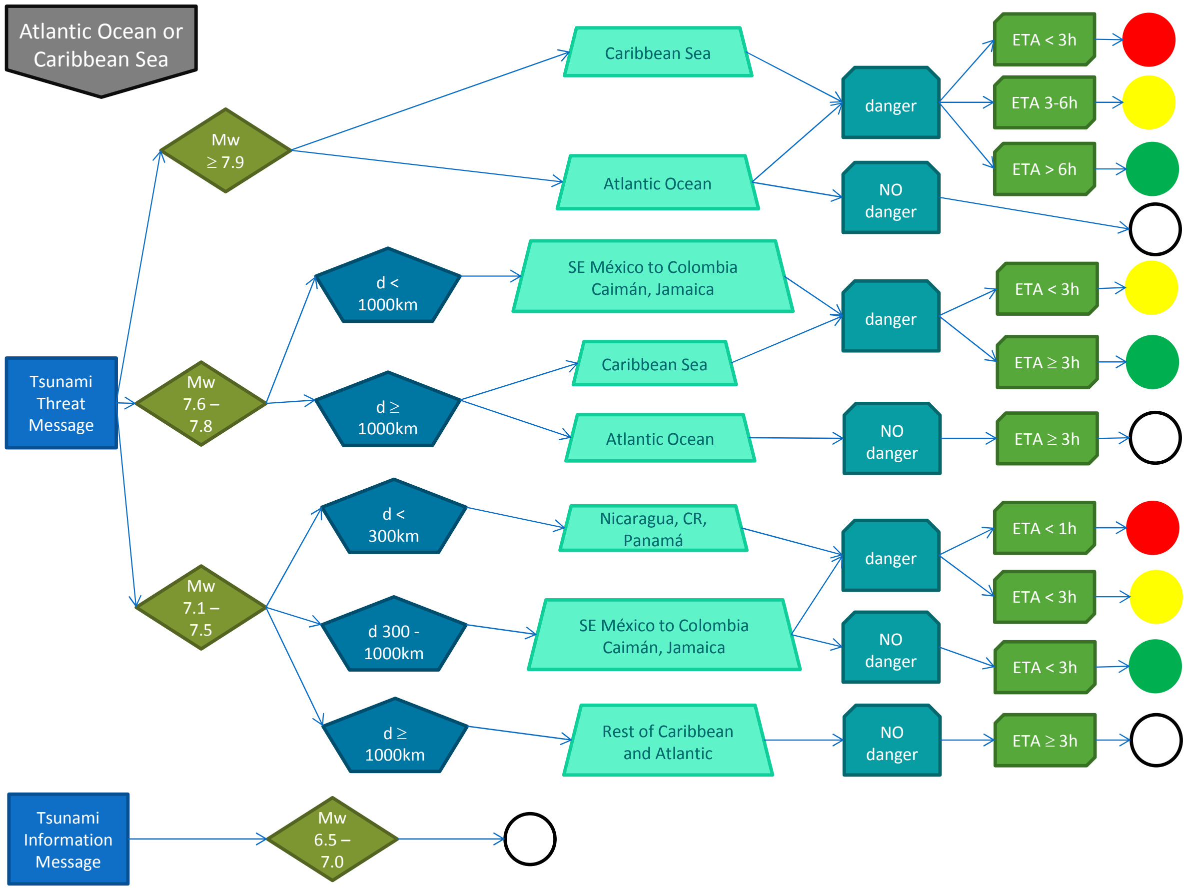


Figure 2.4.15 Categories of Tsunami Warning in the Case of no Tsunami Height Estimations
("d": Distance. ETA: Estimated of Tsunami Arrival Time. Source: SINAMOT)

4) Issuing Tsunami Information

The criterion on tsunami generation judgment is established as mentioned above. The procedures of issuance of tsunami information are also established in the inner protocol such as SINAMOT should issue the analyzed results to CNE and a part of the information should be publicized to mass media and the public. According to the protocol, in the case of felt earthquakes, CNE should call the designated person of SINAMOT. Four people are designated and shown in a list. The order in the list is the order of calling; the order is the tsunami specialist of UNA, the sea wave specialist of UNA, the sea wave specialist of UCR and another sea wave specialist of UCR. Even though three of them are not tsunami specialists, they have taken tsunami-training courses.

5) Specific Examples of Analysis of Tsunami Generation and Issuing Tsunami Information

As for the earthquake felt at San Jose on 8 December in 2014, SINAMOT received emails from three seismic observation institutes, and then received information from PTWC. CNE also sent an email to the person on the top of the list and called the person. The person was told as follows: LIS M6.1, RSN M6.4, OVSICORI M6.8, USGS M6.7 and PTWC "no tsunami". The epicenter was at the boundary of the Cocos Plate and the Nazca Plate; therefore, SINAMOTO judged the event as a strike slip type and no tsunami would occur. There are no communities on the coasts near the epicenter.

As for the Mw7.3 earthquake at 09:51PM (Local Time) on 13th of October in 2014, the epicenter was near El Salvador. There were two events within one hour. The first one occurred at 08:50PM and was around M4. PTWC announced the second one as M7.4, and Listels as M6.1. In this case, the first one disturbed the automatic calculation of the second one.

As for the Mw6.5 (USGS) earthquake on 24th of October in 2012, the epicenter was off Costa Rica, and a strong motion was felt on Coco Island and a small tsunami arrived at the island.

As for the M7.6 called the Nicoya earthquake on 5th (Local Time) of September in 2012, the epicenter was off Costa Rica、 and a tsunami of 2-5 meters height arrived at the north part of the Pacific coast within 5-8 minutes after the event occurred.

(3) Tsunami Infrastructure Development Situation

CNE will deploy sirens at Puntarenas located on coasts at risk from tsunamis with the 2014 budget of CNE. Regarding the tsunami prevention facility, there are no structures like a bank as coastal levees, though there is a pier for fostering the beach and its subsidiary seawall at Puntarenas. There is no information on setting evacuation routes.

(4) Tsunami Alert and Evacuation System

1) Warning Dissemination System

The Communication Center of CNE should manage the reception and dissemination of tsunami information and tsunami warnings. It has nine members and two or three members should be in charge of the duty in a shift of twenty-four hours on duty and forty-eight hours off.

CNE will receive earthquake information from SINAMOT and three seismic institutions (LIS, RSN and OVSICORI) as well. In the case of earthquakes having any concern for CNE, CNE will call the top of the list in about ten minutes after the event. The member of the Communication Center should take training of the 911-system, which is one of the important commutation tools, beforehand.

2) Warning Dissemination Procedures

Technical sources for tsunami warnings in CNE are PTWC as for Distant Tsunamis. On the other hand, as for Local Tsunamis, USGS and the institutes in Costa Rica, LIS, RSN and OVSICORI are the sources; the time for the receipt of any information from them after the occurrence of an event is one or two minutes due to the high density of the observation network. Once it took twenty minutes. LIS will take one minute, and OVSICORI will take five minutes including the indication of the focal mechanism. The M of RSN is all Mw.

CNE should disseminate earthquake information in the case of events that occur inside the country and are larger than or equal to Mw6.1. Usually after the dissemination, the tsunami arrival information will come by emails sent to cellphones or to PCs.

As for Distant Tsunamis, tsunami information should come to the CNE Communication Center and the person in charge of emergency response from SINAMOT by emails sent to cellphones and PCs. With the information, the person should make a judgment on disseminating the indications on evacuation, and does so through the Communication Center by emails and VHF radio to municipal governments, mass media and relevant organizations in the nation all together. Twitter and Facebook are also used, but SMS is no longer in use.

Tsunami information is sent from CNE to each municipal government due to almost no installation of CME. The dissemination tools from the municipal level to the community level have not yet been established; the current arbitrary “tool” is cellphones or direct communication. As for near earthquakes, each community should make an inquiry to the municipal government or monitor mass media, and should take action according to its own judgment.

Note: ICE is now trying to introduce digital television broadcast (The Japanese way has been decided already). When it is accomplished, text or voice information will be disseminated through the 911 system. In addition, EUVR COM (private carrier company) might start the service of messages having voice-text through telephones.

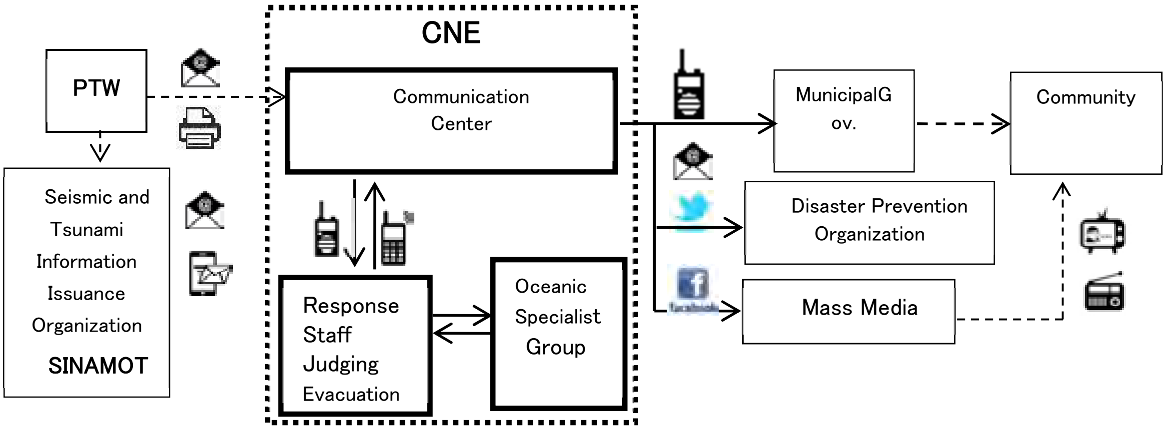


Figure 2.4.16 Tsunami Warning Judgment and Dissemination System

Figure 2.4.17 CNE Communication Center

3) Tsunami Evacuation System

The occurrence of a Local Tsunami at Nicoya Peninsula is feared. JICA (BOSAI) and PREVENTEC have activities in disaster prevention for schools and communities. They contribute to perceiving tsunami risk, establishing evacuation places, enlightening evacuation action and evacuation drills.

CME is not installed at many municipal areas. In addition, CCE is not well organized except in the pilot areas of the BOSAI project. Therefore, not almost all communities have established an evacuation system.

(5) Tsunami Risk Assessment Technique and its Present Situation

There is no consideration on tsunami risk. However, as for the Pacific Coast, the assessment of tsunami risk is thought to be needed for the following areas: a) Nicoya Peninsula due to its vulnerability from tsunamis, b) Coco island due to its vulnerability from tsunamis and National Park sightseeing, c) the southern area of the country due to its vulnerability for tsunami and the possibility of a large earthquake in the near future, d) the whole of the country with the concern on tsunamis generated by earthquakes located off of Colombia and Ecuador like the M8.8in 1906, and e) a tsunami generated at Tonga (which would affect the whole country).

(6) Development on Hazard Map against Tsunami and its Utilization

Seismic hazard is studied at RSN and OVSICORI. They will publicize seismic hazard maps on GIS on the websites. CNE is expected to make tsunami hazard maps.

(7) Effort for Tsunami Disaster Prevention at Research Institutes like Universities and NGOs

PREVENTEC is making efforts on the spread of tsunami disaster prevention education on the national level together with the educational ministry through making tsunami disaster prevention plans and implementing tsunami disaster prevention activities. PREVENTEC is developing a warning system for rivers together with the Science and Technology Ministry.

2.4.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects of Japan's cooperation to earthquake and tsunami disaster in El Salvador are shown in the following table.

Table 2.4.6 Japan's Cooperation Projects to Earthquake and Tsunami Disaster in Costa Rica

Scheme	Project Name		Period
Technical Coordination	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" The activities on capacity development was implemented in Cañas, Nicoya, Santa Cruz, Carrillo Consejo de Distrito de Cobano as pilot areas. In the Cobano city, the game style classes for students, schoolteachers and parents, ware put into action that it was called the school of disaster prevention in Cobano. After the project, the movement of the school of disaster prevention has spread to another 3 schools.		2007-2012
Training Program (2010-2014)	Comprehensive Disaster Risk Management	(2)	2014
	Operating Management of Earthquake, Tsunami and Volcano Eruption observation system	(3)	2011-2013
	Disaster Management in Central American Countries	(20)	2010-2014

*Numbers in ( ) of Training Program indicate number of participants

(2) Situation of Key Donor's Cooperation

Projects of Key Donor's cooperation toward earthquake and tsunami disaster prevention in Costa Rica are shown in the following table:

Table 2.4.7 Key donor's Projects toward Earthquake and Tsunami Disaster in Costa Rica

Funding Agency	Project Name Project Outline	Project Sights	Implementing Body	Budget(USD)	Period
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation to Honduras, Costa Rica and Panama Earthquake hazard map of the whole country was created based on the concept "learning by doing" for hazard, vulnerability and risk analysis with OVSICORI as counterpart	Whole of the country	UCR、ICE	2.4 million	2007-2010
World Bank	Probabilistic Risk Measurement for Central America(CAPRA) The risk assessment was implemented with several scenarios of earthquakes including the earthquake in San Jose city and one in coastal area.	5 communities	CNE	360,000	2008-2011
World Bank	Integration of Disaster Risk Information in Costa Rica planning System The optimization of disaster information was implemented in the planning system. Capacity development of CNE and other disaster related organizations are prepared with reactivation of DRM Technical Advisory Committees, promotion of CAPRA, and so on.	San Jose	CNE	450,000	2009-2012

2.4.6. Items to be Improved

(1)Seismic analyzing ability improvement through hypocenter determination improvement

1) Acquisition of Technique of Tsunami Generation Judgment

In order to improve the reliability of judgments on tsunami generation, improvement of the accuracy of hypocenter and M determination is essential.

The technical judgments of tsunami generations depend on SINAMOT, but SINAMOT does not work in 24 hours but works in the out of office at off duty. The manual processing of seismic data from the network of the county is to be implemented in the out of office even though the result of assessment would be utilized for the judgments of tsunami generation. Therefore, the system does not function for the steady judgments no matter what the timing of generation of tsunami is.

Therefore, the following measures should be taken accordingly: a) installing CISN software to CNE which is functioning 24hours, to develop an observatory function, then feedback the result of the observation in order to improve efficiency of tsunami observation, b) introducing the information system for informing the earthquake data to a personnel of SINAMOT in case of a magnitude more than 6.1 is observed.

In addition, OVSICORI should acquire the technique for earlier tsunami warning cancellation while keeping quick reporting and reliability by referring to the advanced Introduction procedures on the estimation of tsunami height and tsunami arrival time of PTWC or the country that already introduced tsunami alert system...

2) Introducing the focal mechanism analysis technique

In order to improve the reliability of tsunami generation judgment, it is necessary to estimate and understand the focal mechanisms like normal-reverse type or strike-slip type immediately after the occurrence of any event. Therefore, at first, introducing the initial motion analysis for focal mechanism into the current official procedures of tsunami generation judgment. The accuracy of initial motion analysis is not so high for large earthquakes; RSN or OVSICORI should obtain the technique of real time CMT analysis having high accuracy as the next step.

3) Introducing procedures of estimation of tsunami height and tsunami arrival time

PTWC provides information on tsunamis for all countries located around the Pacific Ocean; the information should thus be a sort of "average" of a wide area, and is sometimes too rough to use for tsunami warning judgment for a region; That means the accuracy is not enough for handling any regional earthquakes.

In that context, RSN or OVSICORI should acquire the ability of the estimation of tsunami height and tsunami arrival time gradually by utilizing Tide Tool or Twave software. In addition, SINAMOT should acquire the ability of analysis considering the results of the initial motion analysis for focal mechanism and CMT analysis.

4) Improvement of Stable Operation of Tidal Gauges

In order to improve the reliability of tsunami generation judgment, it is necessary to improve the system for a steady operation of the existing tidal gauges in the coast. In addition, it is necessary to consult optimization of tidal gauge arrangement.

(2) Improvement of the Dissemination of Tsunami Information on Local Tsunamis

1) Improvement of the Dissemination of Tsunami Information on Local Tsunamis

SINAMOT should shorten the time for a tsunami generation judgment through simplifying the judgment procedures and the automation of a warning issuance procedure in order to respond to Local Tsunamis that is likely to occur.

2) Ensure the warning dissemination route

It is necessary to ensure the dissemination route to the residents in vulnerable areas especially along the coastal area of the Pacific Ocean, because there is no stable communication tool between municipalities and communities even though the direct route of alert dissemination between the communication center of CNE and municipalities by VHF radio have been already secured.

(3) Promotion Policy on Seismic and Tsunami Disaster Prevention

1) Archive of seismic risk assessment data

It is necessary develop essential data, like the building inventory of building structures and the fragility curve for risk assessment of earthquakes.

2) Promotion of Earthquake –proof Policy

The results from RESIS II and SAPRA Projects should be used for risk assessment and design for earthquake–proof structures, promotion of people's intention of reinforcement for earthquake–proof, and supporting community activities for disaster prevention.

3) Ensure the Tsunami Disaster Prevention System on Community-level

Local or Regional Tsunamis are feared to occur because the tsunami occurred on the Nicoya Peninsula, which occurred in reality with the magnitude 7.6 on the September 2012. It is required to make maps to cover all coastal areas to realize reliable evacuation in order to respond to local or Regional Tsunamis.

2.5. Panama

2.5.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of Panama is shown in the following table.

Table 2.5.1 Basic information of Panama

Area	内容	出典
Population	3.86million	2013, World Bank
GDP	42.65 billion USD	2013, World Bank
Area	75,420 ㎢ (Land Area 74,340 ㎢) (Land Use: Arable 7.16%、Cropland2.51%、Others90.33%	2011, CIA World Fact Book
Administrative	10 Province and 3 Indigenous Territories	CIA World Fact Book
Geography	Interior mostly steep, rugged mountains and dissected, upland plains; coastal areas largely plains and rolling hills.	CIA World Fact Book Library of Congress Country Studies
Climate	Tropical maritime; hot, humid, cloudy; prolonged rainy season (May to January), short dry season (January to May)	CIA World Fact Book Library of Congress Country Studies

(2) Basic Information of Natural Disasters

Panama has been exposed to a variety of natural hazards such as earthquake-tsunamis, floods induced by heavy rain and log rain. There haven't been many records of earthquakes in the past, but destructive earthquakes have occurred (Table2.5.2), such as the 1882 M7.9 earthquake which caused a tsunami with the height of about 3m, which killed 100 victims along the San Bias Coast on the Caribbean side.

Table 2.5.2 List of major earthquake in the history of Panama (Source: CRED/EM-DAD, NTAA/NGDC)

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)
1882/09/07	7.9	San Blas Coast	100	-	-
1884/11/5	7.5	Aquadas	--	-	-
1904/12/20	7.2	Bocas del Toro	-	-	-
1934/7/18	7.7	-	-	-	-
1962/7/26	7.4	-	-	-	-
1979/7/1	6.5	Puerto Armuelles	-	-	-
1991/4/22	7.2	Bocas Del Toro	30	18,060	-
1991/5/4	5.6	Changuinola, Almirante	-	2,036	-
2000/11/8	6.5	Jurado	-	-	-
2002/7/31	6.5	Baru, Alanje	-	-	-
2003/8/13	5.3	Colon, Panama city	-	340	-
2003/12/25	6.5	Puerto Armuelles	2	1,075	-
2004/2/4	6.1	Chiriqui	-	-	-
2006/5/4	4.5	Boquete	-	-	-
2008/5/26	5.6	-	-	-	-
2008/11/19	6.1	Paso, Canoa, David	-	-	-
2009/7/4	6.0	Panama City	-	-	-
20012/12/8	6.4-6.8	Panama City	-	-	-

- : data is not available

2.5.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management (Policy, Organization)

1) Policy Framework on Disaster Management

The policy framework on Disaster Management in is shown in the following table.

Table 2.5.3 Policy Framework on Disaster Management in Panama

Category	Name	Contents
Policy	The National Policy of Integrated Risk Management (2010)	The policy indicates general principles, responsibility, and guidelines in short and middle periods for the reduction of vulnerability, protection from disaster and mitigation.
Law	Law No.7	The law stipulates the organization and role of the National Civil Protection System (SINAPROC), the responsibility of municipalities and residents, activities for disaster prevention, risk management, disaster prevention education and humanitarian activities.
Plan	National Disaster Management Plan 2011-2015	The plan, which is composed of the activities for risk assessment and risk reduction, and the responsibilities of relevant organizations, is under review as an integrated risk management plan in addition to a national emergency plan including a response to tsunamis.

2) Framework of Disaster Prevention Organization

【1】<u>Framework of Organization System</u>

On the national level, the Executive Secretariat - National Civil Protection System (SE-SINAPROC) carries out the implementation of measures on disaster prevention, the formulation of a national plan and the dissemination of warnings on the national level based on Law 8. On the local level, the ten regional offices of SINAPROC carries out the dissemination of warnings and emergency response on a provincial-level, but the disaster management system on the city-level and community-level has been stipulated but very little has been established.

SE-SINAPROC puts effort into the operation of disaster prevention training and education by operating the academy of disaster prevention and has registered 1,500 volunteers for emergency response and activities in normal time.

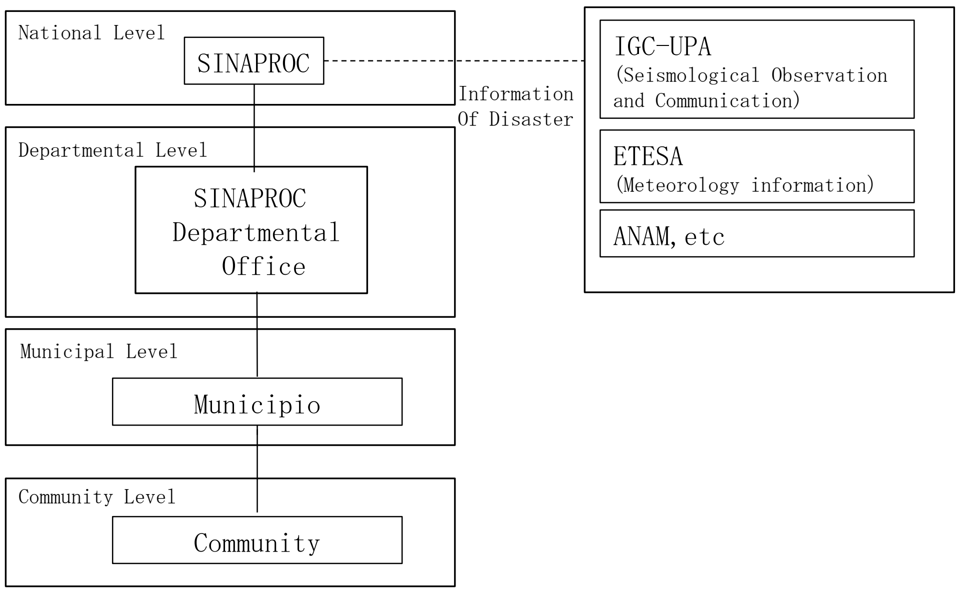


Figure 2.5.1 Structure of Relevant Organization of Disaster Prevention (Panama)

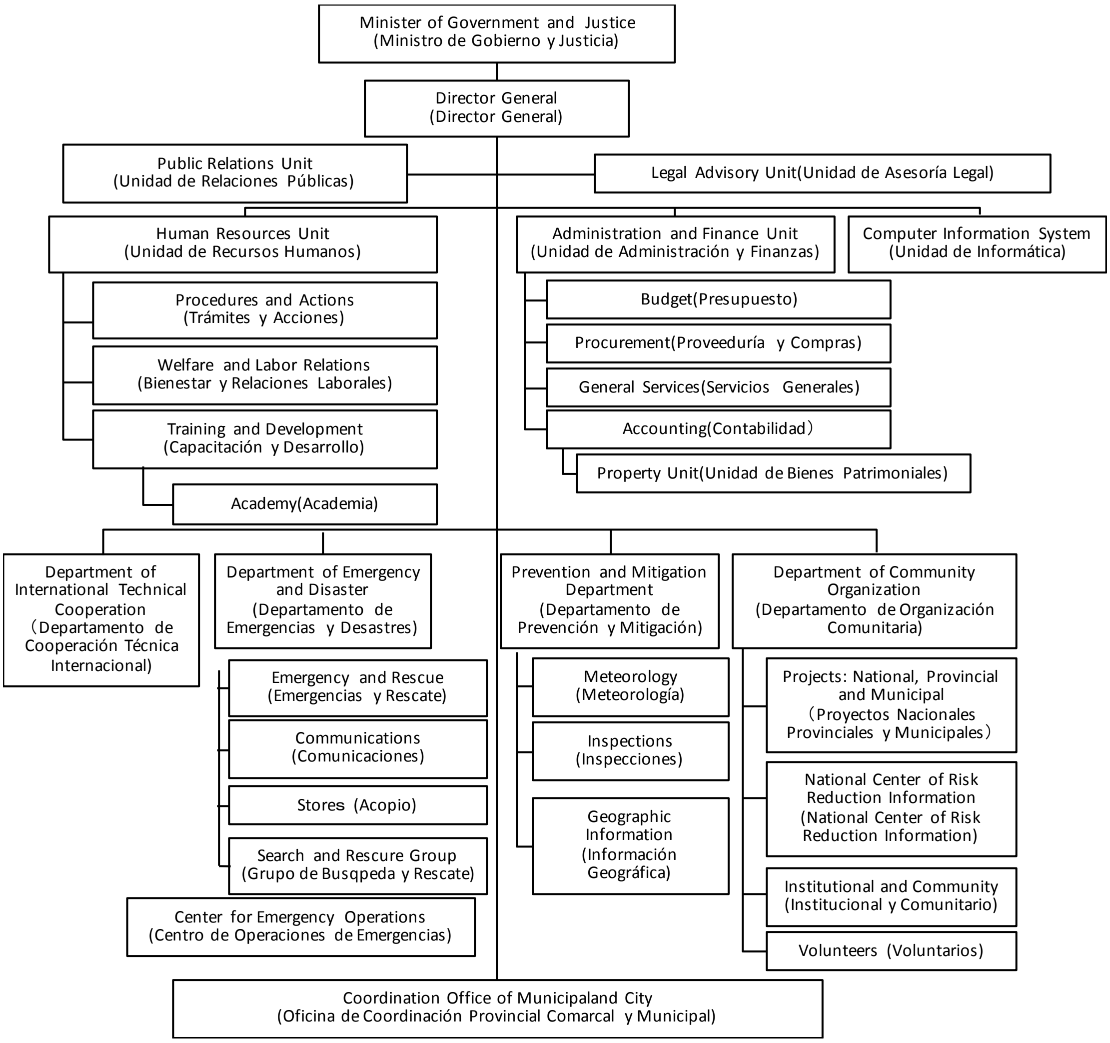


Figure 2.5.2 System of SE-SINAPROC (Panama) (Source: SINAPROC)

【２】Sharing Responsibility for Earthquake and Tsunami Disaster Prevention

The University of Panama, Institute of Geosciences (IGC-UPA) by utilizing an automatic processing system for seismic data, implements earthquake monitoring and the dissemination of earthquake information. SINAPROC judges the alert level and disseminates the alert to the relevant organizations such as municipalities, et al. The Panama Maritime Authorities (AMP) carries out the information transmitting/receiving of tsunamis in terms of securing the safety for ships.

【３】Expectation to CATAC

IGC-UPA agreed on the establishment of CATAC in NETER which has vast experience in earthquake and tsunami observation. In addition to this, IGC-UPA also expects a training program which covers the Japanese experience for the improvement of reliable tsunami prediction and shortening the time of alert dissemination.

SE-SINAPROC which has the responsibility of tsunami alert, expects CATAC to provide the tsunami information on a 24-hours a day basis because IGC=UPA is not on duty for 24-hours a day.

In addition to this, SE-SINAPROC also expects a training program which covers the basic tsunami alerts, a way of understanding websites and the information from CATAC.

(2) Priority and Significance on the Relevant Laws on Earthquakes and Tsunamis on the National-level

Floods and landslides have become an urgent issue because of the recent tendency of an increasing amount of precipitation, and earthquakes and tsunamis are not so urgent an issue so far. However, the tsunami alert system has gradually become an urgent issue because SE-SINAPROC could not communicate with IGC-UPA when the 2014 earthquake in Chile occurred. The development of an earthquake and tsunami disaster plan is being discussed in the formulation process of the National Response Plan

(3) Situation of the Allocation of a Budget for Disaster Prevention

IGC-UPA consigns the maintenance of seismographs to OSOP on about USD30, 000 per year in the budget of the study and education.

(4) Situation of Activities for Disaster Prevention in on the Community-level

The countermeasures for disasters have been mainly intended for emergency responses led by SE-SINAPROC so far. The development of community based disaster management is an urgent subject for strengthening the ability for disaster prevention on the local-level.

(5) Situation of Disaster Prevention Education for Earthquake and Tsunami in Educational Institutes

The ministry of education (MEDUCA) has the responsibility of disaster prevention education, but does not have any school curriculum for disaster prevention so that it entrusted to each school.

2.5.3. Earthquake Observation and Promotion of Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

The earthquake observation in Panama is conducted by the Institute of Geoscience of Panama University (IGC-UPA), which is not a legal institute responsible for earthquake information. SE-SINAPROC is responsible for issuing earthquake and tsunami warnings and making emergency responses.

(2) Earthquake Observation Capability

1) Seismic Observation Operation

Five people in charge with one on duty perform the earthquake monitoring of IGC-UPA during the working hours. The automatic results are sent to the five people by email. For the big events, which occur, outside of working hours and when the manual confirmation is needed, the person on duty will go to the university. At present, it is not accessible to the server of the university at the home of the earthquake monitors for security reasons.

The observation data are collected in real time by commercial communication satellites, commercial Internet, or the exclusive internet line of the university. To ensure the accuracy of the epicenter, the density of the seismometer is not a problem for the western part of panama, but the number of seismometers in the eastern part is not sufficient. From 2010, the data have been changed from analogue to digital. The maintenance of the instruments is entrusted to OSOP, which will be performed three times a year.

The Authority of Panama Canal (ACP) has six short period seismometers and accelerometers. The data is transmitted to IGC for processing. From neighboring countries, five broadband seismometers' data from Colombia and six broadband seismometers' data from Costa Rica are received through the Internet by an agreement. The data from Colombia is linked to Earthworm and the others are connected to SeisComP. In addition, global data is used through IRIS.

The Panama Technical University has conducted strong motion observation for buildings. Approximate 200 accelerometers are installed in Panama City. The data collection is on site collection. The purpose of the observation is for understanding the building behavior during an earthquake and the research for the seismic response of the building, not for the calculation of the earthquake source parameters.

2) Seismic Data Processing

SeisComP does the data processing automatically. In principle, Mw is usually calculated. However, in case of poor accuracy for a small earthquake, the Mc will be calculated. The focal mechanism analysis by initial wave is not conducted. The automatic data processing can be finished in less than 5 minutes. In the case of manual processing by Seisan, the results can be obtained within 10 minutes. Some of the key observation sites for automatic calculation have been previously decided. The shear wave velocity model of Panama is used for calculation. The events, which occur outside of Panama, will not be processed. There are two servers for the backup, one in the United States and another in Europe.

3) Earthquake information dissemination

The results from automatic analysis will be sent to the earthquake monitoring staff and SE-SINAPROC automatically by SMS. If the manual process has a different result, the information will be updated. There will be no information released for the events outside of Panama except by special request from a disaster prevention agency. The flowchart of data collection, processing, and information dissemination is given in Figure 2.5.5.

The table below shows the seismic observation network of IGC-UPA.

Figure 2.5.3 Detail of Seismic Observation Network of IGC-UPA

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	69～72	69～72	0	69～72	69～72
	On Site	0	0	0		
Broadband	Real Time Telemetering	10	10	0	10	10
	On Site	0	0	0		
Strong Motion	Real Time Telemetering	15～18	15～18	0	0～3	0～3
	On Site	0	0	0		
Total	Real Time Telemetering	97	97	0	82	82
	On Site	0	0	0		

4) Earthquake information dissemination

The results from automatic analysis will be sent to the earthquake monitoring staff and SE-SINAPROC automatically by SMS. If the manual process has a different result, the information will be updated. There will be no information released for the events outside of Panama except by special request from a disaster prevention agency. The flowchart of data collection, processing, and information dissemination is given in Figure 2.5.5.

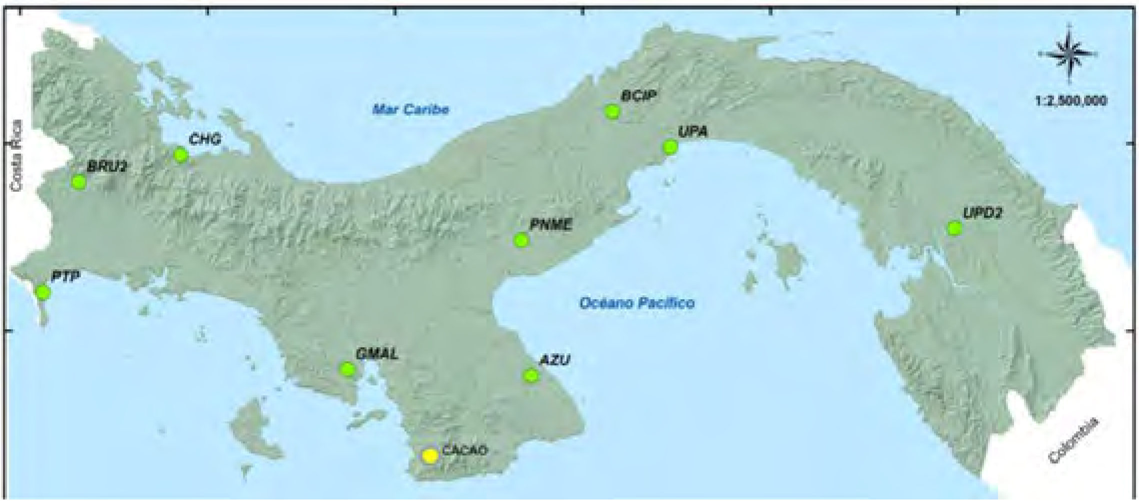


Figure 2.5.4 Location of Broadband Seismometers of Panama (Source:IGC)

Figure 2.5.5 Location of Short Period Seismometers of Panama (Source: IGC)

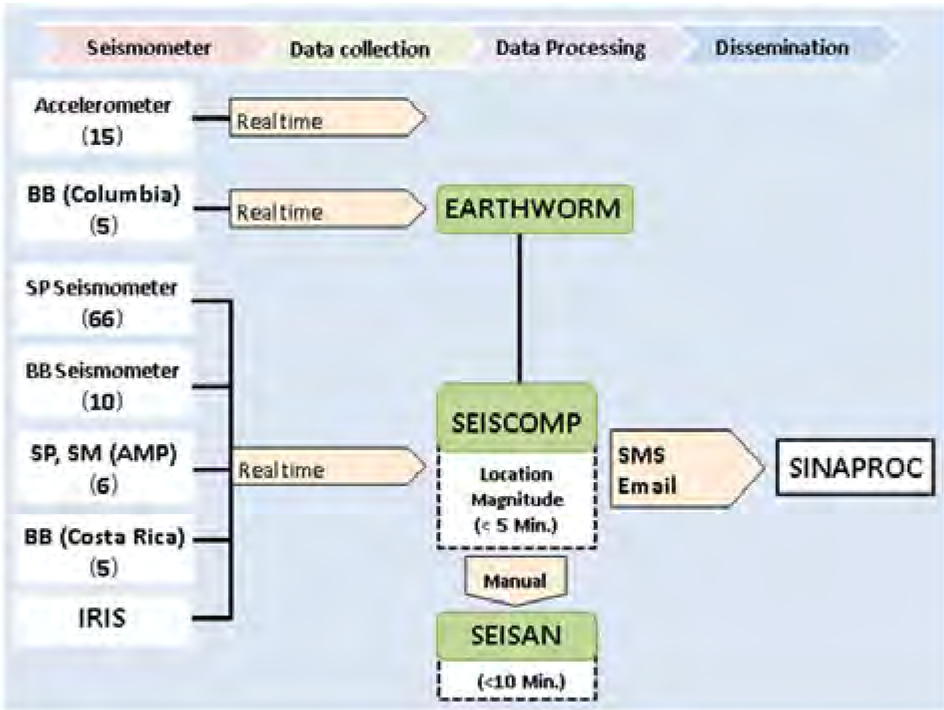


Figure 2.5.6 Flowchart Data Collection, Processing and Information Dissemination of IGC

(3) Approach and Current Status of Seismic Risk Assessment

As a pilot area of the CAPRA project, the seismic risk assessment for David was conducted in 2012. David is the third largest city in Panama and is the financial and commercial center in the western part of Panama. The risk assessment was performed by IGC for residential houses, schools and hospital buildings. In the risk assessment, multiple scenarios of earthquakes were considered. As an example, the risk assessment results of houses for an M 7.1 earthquake is shown in Figure 2.5.5. The risk assessment is planned for Panama City in next. Since there are a large amount of houses in Panama City, which will take a lot time for investigation to get the building information, schools and hospitals will be evaluated first. The ground micro zonation has finished, as shown in Figure 2.5.6. The building inventory is under preparation.

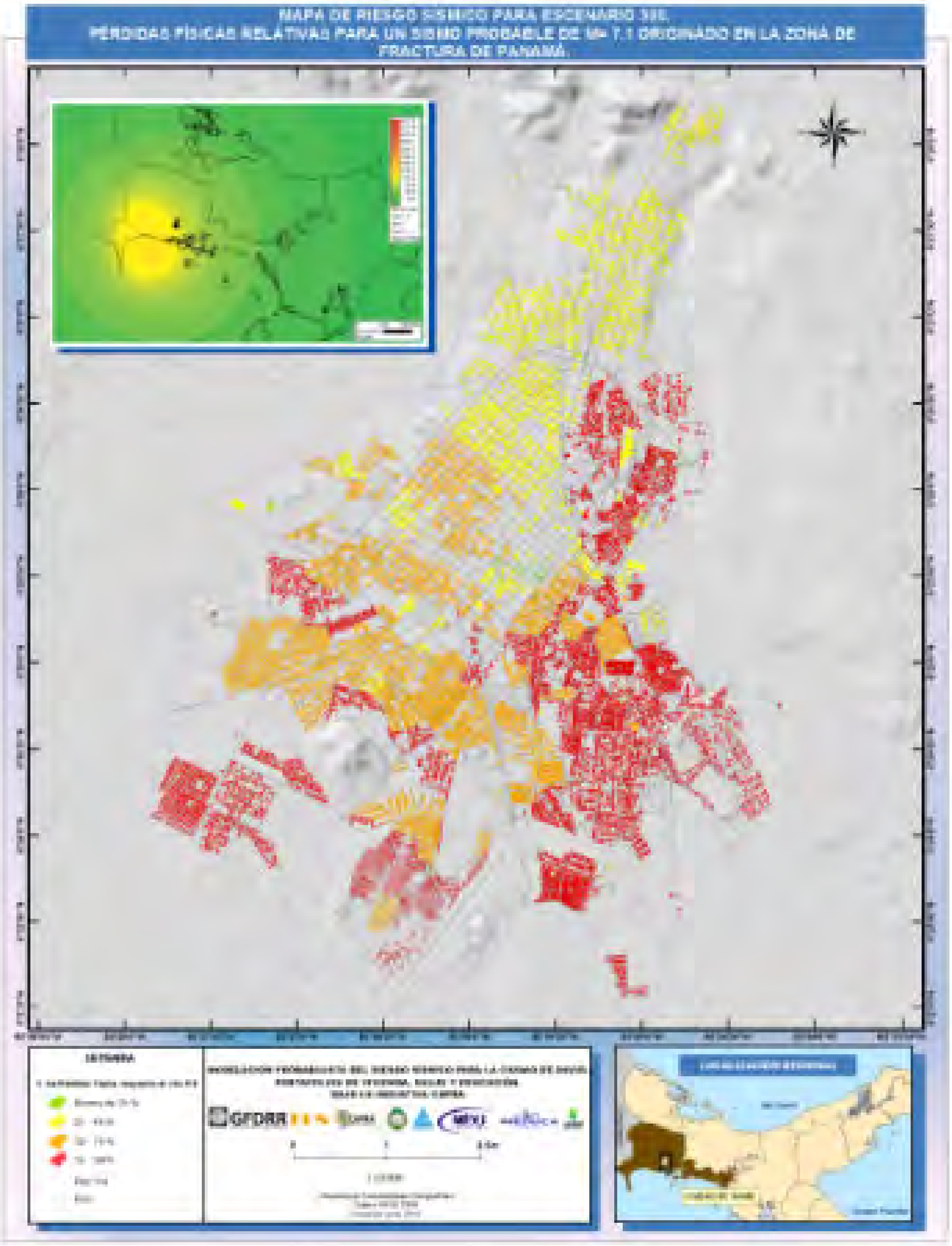


Figure 2.5.7　Seismic Risk Assessment Results of Dabid by CAPRA (Source: IGC)

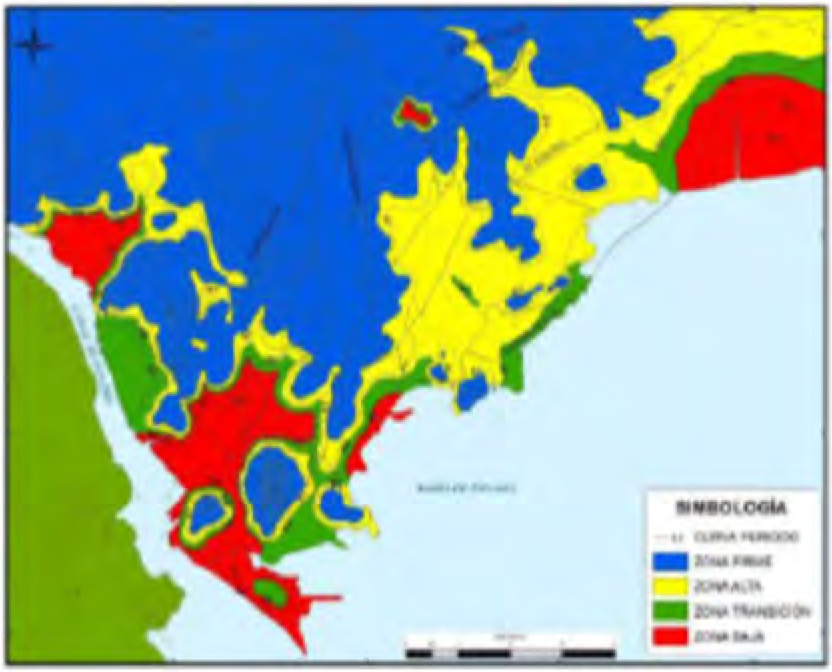


Figure 2.5.8 Ground Micro Zoning of Panama City (Source : IGC)

(4) Development and utilization of a seismic hazard map

The seismic hazard map for the whole territory of Panama has been made by the project RESIS II. The hazard is given by the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds, corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with a 500-year return period for Panama is shown in Figure 2.5.8 and the hazard curve of Panama City is shown in Figure 2.5.9. This latest results were referred to in the revision of Panama seismic code.

Figure 2.5.9 Seismic Hazard of Panama by RESIS II (PGA、Return Period 500 years) (Source : RESIS Ⅱ Report)

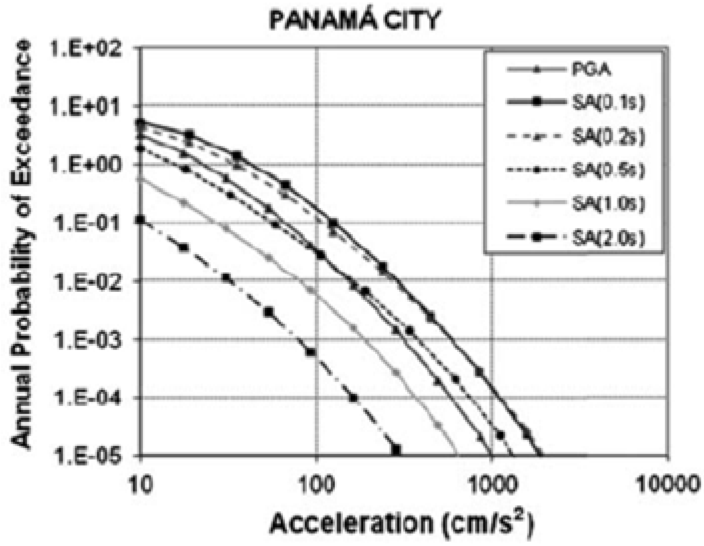


Figure 2.5.10 Seismic Hazard Curve of Panama City by RESIS II (Source：BSSA,Vol.102, No.2,2012)

(5) Development of a seismic code and its implementation

The seismic code of Panama was first created in 1984 and was revised in 1994 (REP - 1994) and in 2004 (REP - 2004). It is stipulated that the code should be revised every ten years and the technical revision for the 2014 edition has been completed, and is in the process of deliberation and approval procedures. The seismic code does not give the ground motion zonation, but, instead, the design acceleration for each city directly as shown in Table 2.5.2. the design seismic force V (base share) will be computed by

$$V = Cs\ W$$

Where Cs is the coefficient, depending on the design ground motion, natural period and structure type etc.

W is the total weight of structure.

It has been said that the new design ground motion will be larger than that of 2004. If the design ground motion is changed, it is needed for the seismic performance assessment for the existing buildings according to the new code. The countermeasure for the high-rise buildings, infrastructures and lifelines may be necessary.

Table 2.5.4 Design Ground Motion of Panama (Source：Panama seismic code)

Effective Peak Acceleration Coefficients A_a and A_v					
City	A_a	A_v	City	A_a	A_v
Aguadulce	0.14	0.14	David	0.21	0.27
Aligandi	0.19	0.19	El Real	0.22	0.27
Almirante	0.21	0.22	El Valle	0.12	0.14
Bocas del Toro	0.21	0.21	Jaqué	0.22	0.28
Boquete	0.18	0.20	La Palma	0.21	0.27
Changuinola	0.24	0.28	Las Tablas	0.17	0.20
Chepo	0.20	0.28	Panamá	0.15	0.20
Chiriquí Grande	0.18	0.20	Penonomé	0.11	0.14
Chitré	0.15	0.15	Portobelo	0.17	0.19
Chorrera	0.13	0.15	Puerto Armuelles	0.25	0.34
Colón	0.15	0.20	Puerto Obaldía	0.21	0.22
Concepción	0.22	0.28	Santiago	0.15	0.18
Coronado	0.12	0.15	Soná	0.17	0.19

(6) Activities of University Institutes and NGOs for Disaster Prevention

The Civil Engineering Department of the Panama Technical University (UTP) has conducted the research on hazard maps, seismic vulnerability and ground surveys in the past. However, there is no program or activities for disaster prevention in the university now.

As the members of SINAPROC, the Red Cross has promoted for the awareness and capacity building on floods and wildfires.

FUNDAVISP, a NGO and the partnership of DFRDD, has participated in the projects for earthquake and flood risk assessment.

2.5.4. Tsunami Monitoring and Tsunami Disaster Prevention Efforts

(1) National organizations responsible for Tsunami Disaster prevention and relevant organizations

IOC approves the IGC-UPA as TWFP, and SINAPROC is the TWFP alternate and TNC. Furthermore, AMP is the TNC alternate.

The purpose of the establishment of IGC-UPA is to do a research study on hazards like earthquakes, volcanic activities and landslides. Only IGC-UPA has an earthquake-monitoring network in Panama. For this reason, although there is no obligation for them to handle tsunami-warning issues, they handle the job as volunteer activities. Note: the establishment of the IGC-UPA was in 1979, which is earlier than SINAPROC establishment.

(2) The Monitoring System relevant to Tsunamis

1) Tsunami Monitoring System

Five staff members carry out monitoring in IGC-UPA only during working hours. After hours, the automatic processing result is issued to them by e-mail. They then come to the university to perform the tsunami monitoring process. To serve as TWFP, IGC-UPA is negotiating with the Department of the Interior to establish a "24x7 contact" system through increasing the number of the staff for tsunami warning work.

All of the monitoring staff has taken the one-week training at PTWC in order. Its contents were the software to monitor the tide, warning issuance and monitoring work, and sometimes including the items related to software Tide Tool and Twave.

The backup power supply for the IGC-UPA seismic and tsunami analysis system is underdeveloped. Therefore, in order to maintain the stable usage of the system they have the backup mirror-sites in the USA and in Europe.

Note: the contents of the monitoring screen in IGC-UPA can be seen at OSOP who is entrusted with maintaining the earthquake observation stations. In addition, Panama Canal Authorities (ACP) can see the contents, though it will not process the data.

2) Tsunami Observation Network

IGC-UPA has only one tidal gauge at Porvenir on the Caribbean side. IGC-UPA will monitor the data if necessary, for example, an occurrence of an earthquake. The station was established with the assistance of IOC. The data are transmitted to the IOC by DCP (via GOES). IGC-UPA utilizes the software, Twave and Tide Tool for advanced usage of the tidal data. The latter is used for the estimation of tsunami heights.

Note： The Smithsonian Institute has a tide gauge on the colon (Colon) island of the Caribbean side for the purpose of climate change monitoring. The data from the station are also transmitted to the IOC with the DCP (via GOES), and are seen on the website of IOC. In addition, the institute once had another tide gauge on the Caribbean side.

These sensors are radio type, powered by solar panels. Data are sampled every five seconds, and are averaged every 60 seconds. The averaged data are sent every fifteen minutes or five minutes. Estimated tidal levels are calculated at IOC. However, these tidal gauges have been installed recently, and real-time collection by the IGC-UPA is not performed yet.

Note: the University of Hawaii has an additional tidal gauge installed on San Blás Island, but operation staff of the SE-SINAPROC cannot monitor its data.

3) Analysis of Tsunami Generation

IGC-UPA performs seismic data automatic processing in SeisComP. It uses the moment magnitude as magnitude. However, accuracy of moment magnitude is not good in small earthquakes; the coda magnitude is thus used for small earthquakes. As for focal mechanism analysis with initial motion polarity data, the module for the analysis has not yet been obtained, and so the analysis is not performed. By the way, automatic calculation of epicenters and magnitudes will be obtained within five minutes from the occurrence of an earthquake. The key stations for performing well in calculation of hypocenters and magnitudes are selected as important stations in advance. Currently the important stations are all broadband seismometer stations. As for the seismic wave velocity structure to be used in the hypocenter calculation, IGC-UPA are using a Panama model.

IGC-UPA has a system that the results of automatic seismic data processing should be issued to the staff of the organization with the SMS and Emails. In addition, verification of the accuracy of the results is carried out manually using the Seisan. This verification would improve the hypocenters and the magnitudes to be issued to SE-SINAPROC. The works mentioned above will usually be completed within ten minutes from the occurrence of the earthquake. However, manual data processing will not be implemented for the earthquake that occurred outside the country.

PTWC has started a new style information issuance for TWFP. The information shows tsunami heights with a map.

4) Issuing Tsunami Information

The criterion for tsunami generation judgment is not yet established. However, as for procedures for tsunami information issuance, those of floods should be applied to tsunamis as described below.

If it was validated that the results of automatic processing seismic data were proper, only the automatic results should be issued and publicized, and manual results should not be. On the other hand, in some cases of verifications and manual processing results, the issued magnitude should be updated. Manual processing results should be issued and publicized by the tools like terrestrial radios and websites in addition to the tools used for the issuance of automatic processing results. For issuance to the SE-SINAPROC satellite radios are also used. Note: If there is a request from SINAPROC, IGC-UPA will explain the information and related items.

5) Specific Examples of Analysis of Tsunami Generation and Issuing Tsunami Information

Regarding the Chiriquí earthquake of magnitude 6.4-6.8 on 8 December in 2014, it occurred at around 4:00 (Panama time) and was felt in San Jose in Costa Rica. The occurrence time was "off time" for the staff of TWFP (IGC-UPA). PTWC tried to contact the TWFP but failed; it then tried to contact the TNC (AMP) and succeeded. PTWC was able to contact with TWFP through TNC. The start of communication between PTWC and the TWFP were delayed.

Regarding the Nicoya earthquake of magnitude 7.6 on 5 September (local time) in 2012, it occurred in the Nicoya Peninsula of Costa Rica. PTWC issued a tsunami warning to Panama.

(3) Tsunami Infrastructure Development Situation

In Panama, since the tsunami disaster in 1882 on the Caribbean side, there has been no one to remember the devastation, and so no need for protection. For this reason, tsunami infrastructures like seawalls, sirens and evacuation paths have not yet been established. However, based on the unexpected tsunami disaster in Japan, the 2011 Great East Japan Earthquake, interest in tsunami infrastructures has become a high priority for the Panama Canal management.

(4) Tsunami Alert and Evacuation System

1) Warning Dissemination System

Regarding tsunami information handling at SE-SINAPROC, one member of the staff in charge of the duty is responsible for receiving tsunami information from IGC-UPA. Each shift is eight hours with three shifts. Three people constitute a team, and there are two teams. Each team works one week and takes turn in the duty. The information dissemination is handled by two members of the staff in charge of the duty, in the Communication Center, which has the "24x7 contact" with three shifts.

2) Warning Dissemination Procedures

Information from IIGC-UPA comes to the operation staff room via email. The staff in charge of the duty in the room should disseminate, based on the information in the email or others, the seismic intensity (MMI at staff discretion), the magnitude and the hypocenter (information gained from websites or provided by IGC-UPA) to the Director-General of SE-SINAPROC and the Emergency Response Responsible Officer via cellphone or VHF radio. The categories of warnings for floods are three types, namely green, yellow and red. The Director-General should decide the category of the event. If the Director-General is not being able to be contacted, the Emergency Response Responsible Officer should do so. As for floods, the Emergency Response Responsible Officer should decide whether humanitarian aid should be carried out or not, and the decision should be informed to the Director-General and the staff in the Operation Staff Room. Regarding tsunamis, how to handle the issue should be followed in the same way of floods. The staff in the Operation Staff Room should convey the above results of the decision to the Communication Center, and the Communication Center should disseminate it to the SINAPROC regional offices with cellphones, telephones, or radios. Furthermore, it should be disseminated to mass media by emails. The regional SINAPROCs have sirens, but the information should be disseminated with cellphones, telephones or emails. There are no radio communication tools between provinces and municipal governments. As for the contact tools from municipal governments to communities, there is no designated ones to be used, although radios are partially used.

In the Operation Staff Room, the staff monitors the website of the USGS and should receive information from PTWC as TWFP alternate. Based on such information, SE-SINAPROC judges tsunami generation by itself in the case that there is no information from IGC-UPA.

SINAPROC has the Tsunami Committee, which is made up of twenty-five or thirty people from organizations related to tsunamis like Labor or Transportation from official ones, Telephone Company from private companies. The committee will receive reports from IGC-UPA and discuss about the improvement of the existing system or others if necessary.

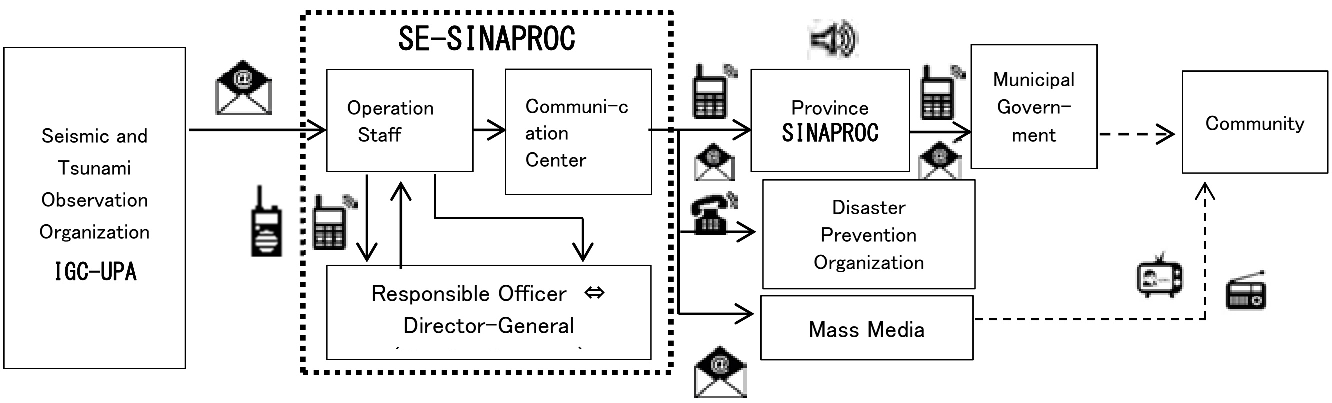


Figure 2.5.11 Tsunami Warning Judgment and Dissemination System

Figure 2.5.12 Operation Staff Room, Communication Room, Operation Room (From left)

3) Tsunami Evacuation System

There is no information on evacuation plans for tsunamis and others.

(5) Tsunami Risk Assessment Technique and its Present Situation

Research based on the tsunami scenario has been implemented, but tsunami inundation mapping or the risk assessment has not been done yet. In addition, as for earthquakes that are considered necessary to tsunami risk assessment for the Pacific Coast, Panama have those near Columbia and Ecuador. Moreover, for the Caribbean side, it should be noted that the side would have tsunamis by reincarnation of the earthquake that occurred in 1882. Therefore, there is a plan to undertake tsunami response training at Caribbean coastal areas in March 2015 through taking into account the more than 100 victims at the event in 1882.

It should be noted that, in relation to the risk evaluation, there are the following facts: an earthquake of magnitude 7.6 occurred near the David in July 17, 1934. Disastrous earthquakes occurred near David periodically (thirty years interval) like the one in 1945, the one in 1979 and the one in 2003. Namely, they have occurred with 30-year intervals.

(6) Development on a Hazard Map against Tsunami and its Utilization

A tsunami hazard map is not yet been created. There are plans to create tsunami inundation maps in the future with tools provided by IOC, but in that case, the Bureau of Statistics is responsible instead of SINAPROC.

(7) Effort for Tsunami Disaster Prevention at Research Institutes like Universities and NGOs

IGC/UPA will implement the enforcement of tsunami observations. IGC/UPA is thus now considering increasing the number of staff accordingly.

2.5.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects undertaken with Japan's cooperation on earthquake and tsunami disaster prevention in Panama are shown in the following table:

Table 2.5.5 Japan's Cooperation Projects toward Earthquake and Tsunami Disaster Prevention in Panama

Scheme	Project Name	Period
Technical Cooperation	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" The activities on capacity development was implemented in Almendro, Acueducto of Baru city, Cascajillos of Baco Maria city, Tres Hermanas of Varadero Capira city, Los Faldare of Varadero Capira city as pilot areas. After the project, the activities are continuing in the Tres Hermares are, but have not taken hold in other places. On the other hand, "Kaerucaravan " has spread to all over the country.	2007-2012
Training Program (2010-2014)	Disaster Management in Central American Countries (10)	2010-2014

*Numbers in ( ) of Training Program indicate number of participants。

(2) Situation of Key Donor's Cooperation

Projects undertaken with Key Donor's cooperation toward earthquake and tsunami disaster prevention in Panama are shown in the following table:

Table 2.5.6 Key donor's Projects toward Earthquake and Tsunami Disaster Prevention in Panama

Funding Agency	Project Name Project Outline	Project Sight	Implementing Body	Budget (USD)	Period
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation to Honduras, Costa Rica and Panama An earthquake hazard map of the whole country was created based on the concept "learning by doing" for hazard, vulnerability and risk analysis	Whole of the country	IGC-UPA	2.4 million	2007-2010
Universities, Ministry of France	Support for the development of a Risk Assessment platform (CAPRA) for Panama The risk assessment of earthquake was implemented reflecting several scenarios.	David City	IGC-UPA	500,000	2009-2011

2.5.6. Items to be Improved

(1) Seismic Analyzing Ability Improvement through Hypocenter Determination Improvement

1) Strengthening the Seismic Observation Network

It is necessary to create an observatory in the appropriate place because there is difficulty in identifying hypocenters due to missing observation areas around the border on both the eastern and western sides.

2) Seismic Analyzing ability Improvement through Hypocenter Determination Improvement

In order to improve the reliability of judgments on tsunami generation, improving the accuracy of hypocenter and M determination first is important.

Therefore, it is necessary to clarify and optimize the criterion of selection and adjustment of observation points for tsunami generation judgment. It is also necessary to introduce the real time CMT-analysis in the near future in order to obtain reliable Mw.

3) Introducing the focal mechanism analysis technique

In order to improve the reliability of tsunami generation judgment, it is necessary to estimate and understand the focal mechanisms like normal-reverse type or strike-slip type of earthquake immediately after the occurrence of any event. Therefore, at first, introducing the initial motion analysis for focal mechanism into the current official procedures of tsunami generation judgment is key point. The accuracy of the initial motion analysis is not so high for large earthquakes, IGC-UPA has to obtain the technique of CMT analysis having high accuracy as the next step; in order to do so, IGC-UPA should learn the algorithms of the software in any case.

4) Acquisition of the Technique of Tsunami Generation Judgment

In order to improve the reliability of tsunami generation judgment, in addition to the introduction of focal mechanism analysis, it is essential to improve the accuracy of magnitude calculation. Thus, the calculation of hypocenter and magnitude can be made in the following ways: a) revision the method to select criterion of observation points used in the magnitude calculation and b) optimization of the station correction. As a next step, it is necessary to have the introduction of CMT analysis mentioned above to obtain a high moment magnitude accuracy.

In addition, IGC-UPA should acquire the technique for earlier tsunami warning cancellation with keeping quick reporting and reliability by referring to the advanced example and optimizing the procedures.

The technical judgment of tsunami generation depends on IGC-UPA, but IGC-UPA does not work in 24-hours shifts but works out of the office during off duty hours. It is necessary to improve this situation. In addition, it is necessary to respond to the earthquakes which occur abroad as though they occurred locally.

In addition, it is necessary to respond to the earthquakes that occur abroad as though they occurred locally.

5) Introducing Procedures on the Estimation of Tsunami Height and Arrival Time

PTWC provides information on tsunamis for all countries located around the Pacific Ocean; the information should thus be a sort of "average" for a wide area, and is sometimes too rough to use for a tsunami warning judgment for a region; that means the accuracy is not enough for handling any regional earthquakes.

In order to improve the accuracy of tsunami warnings, a tidal gauge observation network should be improved step by step.

As for estimation of tsunami height, the estimates can be made in the following ways: a) the one of tsunami generation analysis with focal mechanism, b) the one of approximate but quantitative estimation with the current sea depth data, c) the one of tsunami generation judgment with CMT analysis, d) the one of improving the estimation with the latest sea depth data, and e) the one of improving height estimation with coastal geography. In addition, IGC-UPA should acquire the technique for earlier tsunami warning cancellation while keeping reliability.

6) Newly Installing Tidal Gauge Stations and Others

In order to improve the accuracy of tsunami warnings, a tidal gauge observation network should be improved step by step as follows: a) the establishment of a system for stable operations of tidal gauges; b) the optimization of data acquisition or data transmission configuration; and c) the optimization or reinforcement of the network of the tidal gauge observation network from the view point that real time tidal data monitoring should be essential for the improvement of tsunami warning reliability and for the update of a tsunami warning category.

(2) Improvement of the Dissemination of Tsunami Information on Local Tsunamis

1) Improvement on the Dissemination of Tsunami Information

IGC-UPA should shorten the time for a tsunami generation judgment through simplifying the judgment procedures and the automation of a warning issuance procedure in order to respond to Local Tsunami that is likely to occur.

2) Ensure the Warning Dissemination Route

There are a few stable communication tools between municipalities and communities while the dissemination route between SINAPROC and provincial SINAPROC, provincial SINAPROC and municipalities have been ensured by using VHF radio. It is necessary to ensure the dissemination route to the residents in vulnerable areas especially along the coastal area of both the Pacific Ocean and the Caribbean Ocean.

(3) Promotion Policy on Seismic and Tsunami Disaster Prevention

1) Promotion Policy on Seismic and Tsunami Disaster Prevention

It is necessary develop essential data, like the building inventory of building structures and the fragility curve for risk assessment of earthquakes.

2) Promotion of Earthquake–proof Policy

The results from RESIS II and SAPRA Projects should be used for risk assessment and design for earthquake–proof structures, the promotion of people’s intention of reinforcement for ensuring earthquake–proof structures, and supporting community activities for disaster prevention.

3) Ensure the System of Tsunami Disaster Prevention System on the Community-level

Organizing community disaster prevention has been almost terminated, but there are quite a few of the necessary tools available; for example, tsunami hazard maps which are made only for a particular part of coastal areas. It is thus necessary to make maps to cover all coastal areas to realize reliable evacuation.

2.6. Honduras

2.6.1. Basic Information

(1) Basic Information of the Country

Basic information on the territory of Honduras is shown in the following table:

Table 2.6.1 Basic Information of Honduras

Area	Contents	Source
Population	8.09million	2013, World Bank
GDP	18.55 billion USD	2013, World Bank
Area	112,090 ㎢ (Land Area 111,890 ㎢) (Land Use:Arable9.07%、Cropland3.91%、Others87.02%	2011, CIA World Fact Book
Administrative	18 Department	CIA World Fact Book
Geography	Mostly mountains in the interior, narrow coastal plains	CIA World Fact Book Library of Congress Country Studies
Climate	Subtropical in lowlands, temperate in mountains, rainy season(May to September)。	CIA World Fact Book Library of Congress Country Studies

(2) Basic Information of Natural Disasters

Honduras has been exposed to a variety of serious natural hazards such as floods, landslides and mudflows induced by hurricanes or tropical depressions.

There have been fewer serious earthquakes in comparison to Nicaragua and Guatemala. Several damaging earthquakes have occurred in recent years such as the 2009 M7.1 earthquake that caused damage to more than one thousand buildings, damage to bridges as well as soil liquefaction.

Table 2.6.2 List of major earthquakes in the history of Honduras (Source：CRED/EM-DAD, NOAA/NGDC)

Date	Magnitude (Richter)	Affected Area	Dead	Affected People	Economic Damage (thousand USD)
1915/12/26	6.3	Gracias A Dios	-	-	-
1934/12/3	6.2	-	-	-	-
1980/8/9	6.1	North Honduras	2	-	-
1982/4/27	5.4	Comayagua area	-	500	-
1982/9/29	5.6	-	-	-	-
2007/9/15	5.5	El Progresso	-	1,883	-
2009/5/28	7.1	Roatan	7	50,136	100,000

- means data is not available

2.6.2. Policy, Planning and Organization of Disaster Management

(1) Situation of Disaster Management (Policy, Organization)

1) Situation of Disaster Management (Policy, Organization)

Policy Framework on Disaster Management in Nicaragua is shown in the following table:

Table 2.6.3 Policy Framework on Disaster Management in Honduras

Category	Name	Contents
Policy	The National Policy Integrated Risk Management of Honduras2013)	The policy indicates the strategic principle of risk reduction, prevention, response, enlightenment and training for the enhancement of the resilience.
Law	SINAGER Law (Law151-2009)	The law stipulates the function of the Permanent Commission of Contingencies (COPECO) as coordinator, and the plan for preparedness, emergency response, recovery and reconstruction, the budget and the compensation.
Plan	Not yet	

2) Framework of Disaster Prevention Organization

【1】<u>Framework of Organization System</u>

On the national level, the Permanent Commission of Contingencies (COPPECO) carries out the implementation of measures of disaster prevention, the formulation of a national plan and the dissemination of warnings on the national level, in addition to these, covers the monitoring of earthquakes, tsunamis and weather based on the SINAGHER law. On the local level, the Regional COPECO, the Municipal Emergency Committee (CODEM) and Local Emergency Committee (CODEL) carry out disaster management measures on the regional level and the municipality level, and the community level, respectively.

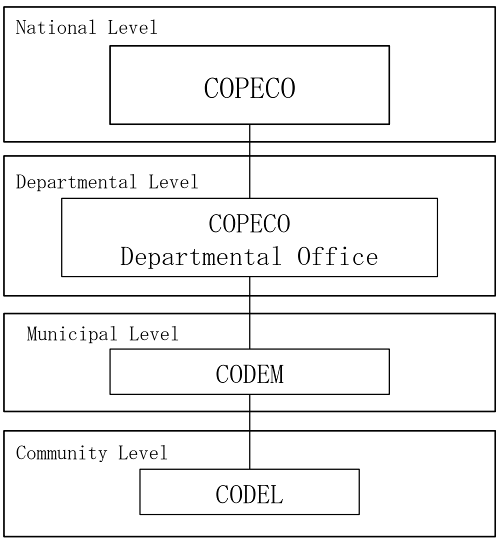


Figure 2.6.1 Structure of Relevant Organization of Disaster Prevention (Honduras)

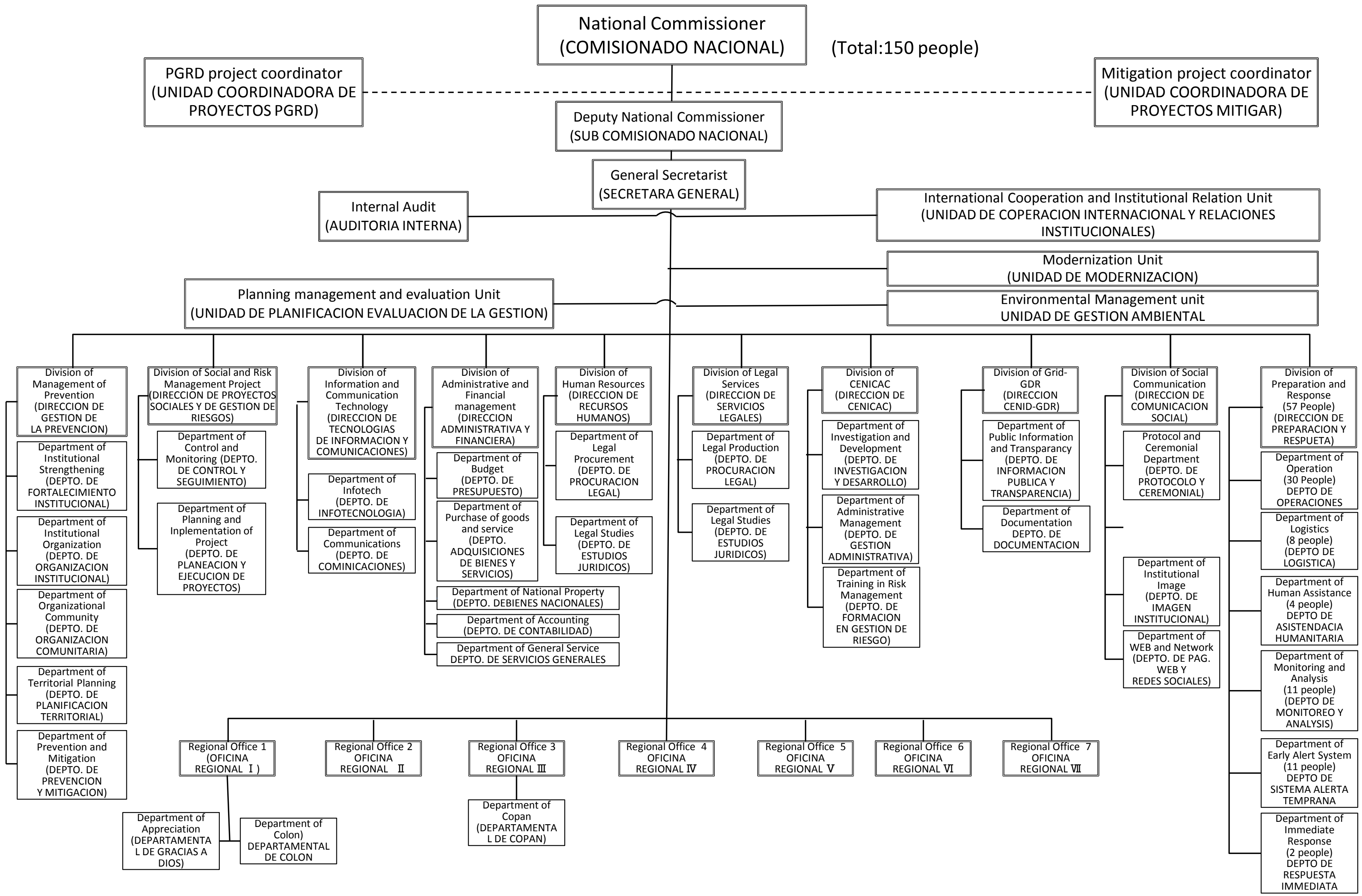


Figure 2.6.2 Structure of COPECO

【２】Sharing Responsibility for Earthquake and Tsunami Disaster Prevention

COPECO carries out monitoring on earthquakes and tsunamis, judges the alert level, and disseminate the technical information of earthquake and tsunami to relevant organizations.

【３】Expectation to CATAC

COPECO expects to obtain the prompt earthquake and tsunami information for the judgment of tsunami generation since COPECO has an intention to get out of PTWC dependence in terms of local and Regional Tsunamis. COPECO also expects a training program that covers the methodology of earthquake parameter calculation, the way of maintenance of seismographs and the utilization of information from CATAC.

(2) Priority and Significance on the Relevant Law of Earthquake and Tsunami

Although the main target disasters were landslides and floods in COPECO so far, tsunamis have come to be considered inevitable events because once it occurs, it causes serious damage especially to the Pacific Ocean side.

(3) Situation of the Allocation of a Budget for Disaster Prevention

The budget of COPECO was approximately 81 million lempira (HNL)(approximately 3.8millionUSD) in 2014. The allocation of employment amounted to about 42%, and the total of maintenance and postage amounted to about 48%, and consumable articles amounted to about 4%. The budget of equipment, maintenance and inspection that can be appropriated to the maintenance for observation equipment was approximately 50,000 HNL (approximately 2,300 USD).

(4) Situation of Activities for Disaster Prevention on the Community-level

Activities of disaster prevention on the community-level are to be covered by CODEL based on SINAGER Law. The following activities were implemented utilizing the cooperation of donors and NGOs:

- The countermeasures to landslides were implemented for the two pilot sights (El Berrinche and El Reparto) in Tegucigalpa city with Tegucigalpa CODEM utilizing the cooperation of a JICA Grant Aid. Regarding this project, the landslide risk maps for the communities were formulated as a part of disaster prevention education. The project referred to the result of the research for landslides that was implemented by JICA.

- The Plan International with CODEM as counterpart implemented a community support program.

(5) Situation of Disaster Prevention Education for Earthquakes and Tsunamis in Educational Institutes

The Ministry of Education formulated the school curriculum of Social Science including disaster prevention; the training for teachers was implemented with 30% of the performance.

2.6.3. Earthquake Observation and Promotion of Disaster Prevention

(1) Authorities for Earthquake Disaster Prevention

The responsibility of earthquake observation and dissemination of earthquake warning information in Honduras is COPECO, which monitors both natural and human disasters 24 hours a day. It also has the function for coordinating among the governmental organizations in an emergency case. The Civil Engineers Association (CICH) developed the seismic code.

(2) Earthquake Observation Capability

1) Seismic Observation Operation

The earthquake observation is conducted by the National Monitoring Center within COPECO. There are nine people for three shifts, i.e. from 9 to 17, 17 to 21 and 21 to 9 the next day, with two people on each shift. At present, COPECO has no earthquake information of its own but is monitoring the earthquake information of INETER of Nicaragua, MARN of El Salvador and USGS through the CISN earthquake warning system.

2) Earthquake Observation Network

Earthquake observation in Honduras began in 2000 with the support of USGS, which installed one broadband seismometer. During 2002-2005, six short period seismometers were installed with the aid of DIPECHO. In 2012, another ten short period seismometers and the automatic data processing software SeisComP were introduced by the 20 million Euro financial supports from the Spain Cooperation Agency (AECID). The installation and the maintenance of the instruments and SeisComP for two years were entrusted to OSOP. The maintenance contract terminated in 2014. Since there is no proper maintenance, some of the seismometers and SeisComP do not function well right now. The current earthquake observation network has ten short period and two broadband seismometers, as shown in Figure 2.6.2. The data of these seismometers were transmitted to COPECO in real time, by which the epicenter and magnitude was calculated.

Another ten seismometers are planned in a WB project. COPECO wants eight short period and two broadband seismometers. The broadband seismometer has not been decided yet because of the budget. The national monitoring center has the environment to access the observation data from other countries over the Internet.

3) Seismic Data Processing

The automatic data processing is done by SeisComP. At present, SeisComP cannot function correctly because of the lack of maintenance. It means SeisComP cannot calculate the epicenter and magnitude of earthquakes at present. It is an urgent issue to secure the maintenance budget or obtain the operation technology of SeisComP.

The table below shows the seismic observation network of COPECO.

Figure 2.6.3 Detail of Seismic Observation Network of COPECO

Type	Dta Collecion Method	Total Number	Under operation	Interrupted	Real Time Monitoring	Expected Number to be used at CATAC
Short Period	Real Time Telemetering	10	10	0	10	10
	On Site	0	0	0		
Broadband	Real Time Telemetering	1	1	0	1	1
	On Site	0	0	0		
Strong Motion	Real Time Telemetering	0	0	0	0	0
	On Site	0	0	0		
Total	Real Time Telemetering	11	11	0	11	11
	On Site	0	0	0		

4) Earthquake Information Dissemination

Earthquake information from INETER, MARN and USGS is utilized in Honduras now. For an event, which may affect the country, the National Monitoring Center will inform the early warning department (SAT) the location of the earthquake, magnitude and the name of the nearest village by phone and email. SAT will consult the experts in geoscience at the research institute of National Autonomy University of Honduras (UNAH-IHCIT). If necessary, the early warning committee will be called for the judgment of an earthquake warning.

COPECO has made clear the criteria for earthquake warnings, as shown in Table 2.6 4. In case of an earthquake, which may result in a red alarm, the director of preparation and response department will convene the warning committee to make the judgment for the warning level. The members of the warning committee are the director of preparation and response department, the director of disaster prevention department, the national operations center chief, the SAT chief and the director of the legal department with the director of preparation and response department serving as the chairperson. The results of the committee will be reported to the director of COPECO, who will make the final judgment. If the earthquake warning will be announced, the chairperson and the spokesperson will send the information to the COPECO local office and mass media with the support of the national monitoring center.

Table 2.6.4 Criteria for Earthquake Warning (Source: COPECO)

Green	- Occurrence of a seismic swarm with more than ten events of magnitude above 3.5 on the Richter scale in the Pacific region of Honduras, by more than a day. - Occurrence of an earthquake with a magnitude above 7.5 on the Richter scale in a distance of less than 300km from a municipality or prefecture in Honduras
Yellow	- Occurrence of a seismic swarm with more than five events above magnitude 3.5 for one hour in a radius of 10km from one of the big cities in Honduras. - Occurrence of an earthquake above magnitude 7 in Costa Rica, Nicaragua or El Salvador, in the border area with Honduras
Red	- Occurrence of an earthquake above 7 on the Richter scale on the Pacific Ocean side of Honduras. - Occurrence of an earthquake with magnitude above 6 on the Richter scale throughout Honduras. Occurrence of an earthquake with a magnitude above 5 on the Richter scale in the departments of the Pacific of Honduras. - Earthquake with magnitude above 4.5on the Richter scales in a radius of 10km from any prefecture in Honduras. - Occurrence of accelerations of over 0.1 in one of the departmental capitals detected by digital–accelerometers.

Figure 2.6.4 Location of Seismometers of Honduras (Source: COPECO)

As an example, the earthquake information announced by SAT for the earthquake of September 2014 is shown in Figure 2.6.4. The opinion of UNAH is included.

Comisión Permanente de Contingencias
Dirección de Comunicación Social
BOLETÍN INFORMATIVO

Boletín Informativo No. 083-2014

SISMO DE 4.8 GRADOS RICHTER EN EL NORTE DEL PAIS NO PROVOCO DAÑOS HUMANOS NI MATERIALES

Los datos preliminares acerca del movimiento telúrico del cual no se reporta hasta el momento daños humanos o materiales que lamentar, son los siguientes:

Localización:	HONDURAS
Magnitud	4.8
Fecha:	08 Septiembre del 2014
Hora Local	13:45 Horas
Coordenadas	15.70 N -87.18 W
Profundidad (Km)	10
Fases	9
Puntos de Referencia	
4.8 km al Sur de la Ensenada Atlántida	
11.9 km al Nor - Este de San Juan Pueblo Atlántida	
11.8 km al Nor - Oeste de la Másica Atlántida	

Información analizada por sismógrafo de Copeco.

Según José Jorge Escobar de la Facultad de Física de la UNAH el movimiento sísmico podría obedecer a una falla local en la depresión central.

Las principales recomendaciones en caso de actividad sísmica son las siguientes:

ANTES:

- Tenga siempre un botiquín de primeros auxilios, linternas, radio y baterías.
- Mantenga suministros de agua y comida.
- Elabore un plan para saber qué hacer y dónde reunirse después que haya dejado de temblar.
- Localice los lugares más seguros en su vivienda: bajo mesas sólidas y bajo marcos de puertas.

DURANTE

- Mantenga la calma. No corra.
- Aléjese de las ventanas de vidrio.

Aldea el Ocotal 500m. adelante del Hospital Militar, Carretera a Mateo
Tel.: (504) 2229-0606/ Fax. 2229-0616.
Comayagüela Honduras Centroamérica

www.copeco.gob.hn

Preliminary report
Report No. 083 – 2014
An earthquake of M4.8 occurred in the northern part of the country. There was no life loss and structural damage.
・There is no earthquake records which will result in life and property loss.

2014.9.8 13:45	
Source	Honduras
M	4.8
Date	2014.9.8
Time	13:45
Latitude and Longitude	15.70N 87.18W
Depth	10
“Phase” used	9
Remarks	
(Distance from epicenter to major cities)	

・This information is based on the seismic records of COPECO.
・According to Prof. Jose Jorge Escobar, Physics Department of UNA, the quake was caused by the fault in the compression field of inland.

Figure 2.6.5 Example of Earthquake Information (Source:COPECO)

(3) Approach and Current Status of Seismic Risk Assessment

Honduras participated the CAPRA project. Because of insufficient data and budget, the seismic risk assessment has not been performed. There is a plan for a seismic risk assessment for water supply and sewerage facilities in Tegucigalpa with a WB project. However, the details have not been specified.

(4) Development and Utilization of a Seismic Hazard Map

Honduras participated the project RESIS II and the seismic hazard map for the whole territory of Honduras has been made. The hazard is given by the peak ground acceleration (PGA) and the response spectra at the period of 0.1, 0.2, 0.5, 1.0, and 2.0 seconds, corresponding to the return period of 500, 1000, and 2500 years. The distribution of PGA with 500 year return period of Honduras is shown in Figure 2.6.4 and the hazard curve of Tegucigalpa is shown in Figure 2.6 5. This hazard map was referred to for the revision of ground motion zonation of the seismic code in 2014. UNAH-IHCIT conducted an earthquake micro-zoning project with USAID's fund for Belen Gvalcho municipality of Ocotepeque prefecture, but the results have not yet been released.

Figure 2.6.6 Seismic Hazard of Honduras by RESIS II (PGA、Return Period 500 years) (Source：RESIS Ⅱ Report)

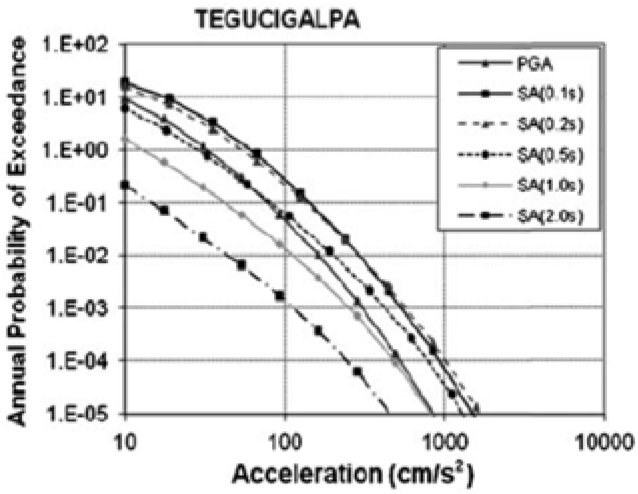


Figure 2.6.7 Seismic Hazard Curve of Tegucigalpa by RESIS II (Source：BSSA,Vol.102, No.2,2012)

(5) Development of a Seismic Code and its Implementation

The seismic code of Honduras was created in 2000 and revised in 2010. Honduras is divided into six zones according to the seismic hazard in the 2010 code. The hazard on the Caribbean Sea side is lower than that on the Pacific Ocean side. The zonation was modified in 2014 by referring to the hazard results of RESIS II. The new ground motion zonation is shown in Figure 2.6.6. Compared with the previous code, the ground motion zonation has increased from six to nine and the design ground motion of Pacific Ocean side has increased from 0.35g to 0.5g.

$$V = C_s W$$

Where Cs is the coefficient, depending on the design ground motion, natural period and structure type etc.

W is the total weight of structure.

Although the seismic code was created, it was only applied to Tegucigalpa and San Pedro Sula, the two largest cities now. The other cities were not applied because of the lack of technical capability. The construction permission is performed by the municipality. In the case of large-scale development, the environmental permission is also needed from the Ministry of Natural Resources.

There is no policy for the promotion of seismic strengthening for airports, seaports, electricity and water supply. Based on the new seismic code, the seismic performance assessment for important structures, infrastructures and lifelines will be necessary.

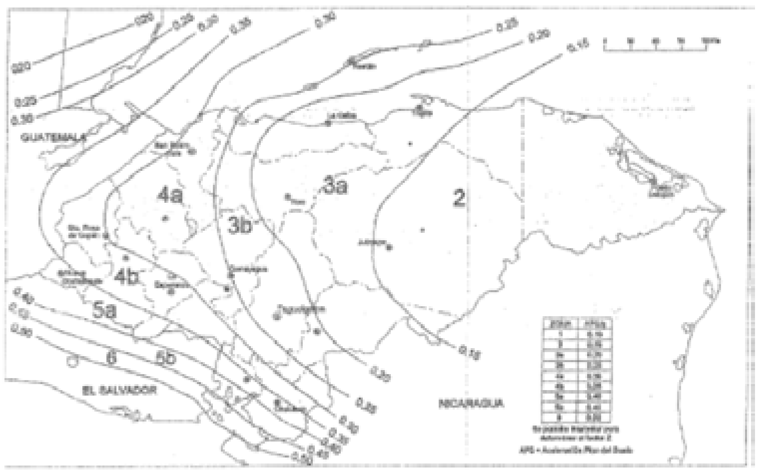


Figure 2.6.8 Ground Motion Zonation of Honduras for Seismic Design (Source: Honduras seismic code)

(6) Activities of University Institutes and NGOs for Disaster Prevention

UNAH-IHCIT has performed the research for the formation of a disaster prevention culture, disaster mechanisms and early warning. It has seven seismometers for earthquake observation. The other activities include the compiling of disaster records, creation of hazard maps and the participation of community based disaster prevention activities. As the university's curriculum, there is a master's degree course for disaster prevention.

2.6.4. Tsunami-Monitoring and Tsunamis-Disaster prevention efforts

(1) National Organizations Responsible for Tsunami-Disaster Prevention and Relevant Organizations

UNAH-IHCIT is approved as TWFP and TNC. In addition, COPECO is the TWFP alternate and TNC alternate. UNAH-IHCIT has also registered a personal name rather than the institution name as the contact destination. In order to clarify the responsibilities and to optimize the response system to tsunamis, COPECO wants that COPECO should become TWFP and that UNAH-IHCIT should change the contact destination from the personal name to institution name.

(2) The Monitoring System relevant to Tsunamis

1) Tsunami Monitoring System

Tsunami monitoring is handled with the "24x7 contact" in the COPECO National Monitoring Center like the seismic observation. However, because the seismic system is not stable in operation as described above in the "seismic observation operation" section, the tsunami monitoring system as a result is unstable as well.

Earthquake-tsunami monitoring at the National Monitoring Center is implemented by the websites of PTWC, USGS (constantly displaying and monitoring the earthquake occurrence information of USGS using the CISN Display earthquake information monitoring software), Nicaragua (INETER), El Salvador (MARN) and OSOP. It is also done by data from eleven seismic stations and ten tidal gauge stations (the Pacific Coast has three of them.). In addition, the Center obtains the results of the science and technology assessment on the event from UNAH-IHCIT and the Center uses those results in monitoring.

Note: the SAT chief and the director of preparation and response department received training in Hawaii, also the National Monitoring Center chief received training in Mexico (From 1st to 5th of April in 2014; for establishing tsunami warning procedures or the protocol for distant earthquakes and near earthquakes) and Ecuador (From 2nd to 4th of June in 2014), respectively. These training sessions were held by PTWC. Then, the National Monitoring Center chief, with the training results, has revised or improved the tsunami warning procedures; official documentation of the revision is now underway.

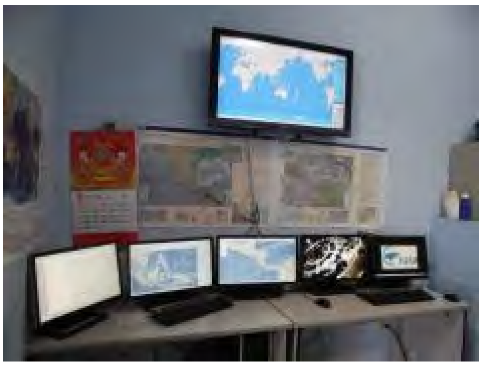


Figure 2.6.9 National Monitoring Center, the Display at Upper Shows "CISN Display" (Shown All the Time)

2) Tsunami Observation Network

There are ten tidal gauge stations currently running. Three of them are located on the Pacific Coast and seven on the Caribbean Sea Coast. The exact three locations of the Pacific Coast units are one at San Lorenzo Port and two on Tigre Island (Note that two places of Tigre Island in the figure are overlapping, Figure 2.6.9).

Data sampling is every minute for the Pacific Ocean side, every three minutes for the Caribbean side. All have bubble-type tidal gauges. The data are transmitted from the stations to the National Monitoring Center on the Internet, and are done using the GTSL (link of global communication system (GTS)) to an institute of NOAA via Puerto Rico.

It should be noted that in San Lorenzo, although there is no experience of the tsunami at the coast, there was a storm surge experienced in February 2014. The inundation height was 7 ~ 9feet (around 2.5 meters), and Marcovia had floods from the coast up to 300meters inland. UNAH-IHCIT has been observing tsunamis on the Caribbean side with a tide gauge station located at La Ceiba (one of ten locations in operation) Note: the storm surge forecast are handled now by the national weather service (Servicio Meteorológico Nacional: SMN, currently under COPECO).

Figure 2.6.10 Tidal Gauge Stations (Light Green Point) (Source: COPECO)

In addition, as COPECO is the TWFP alternate, it receives tsunami information sent from PTWC at its common email address of the National Monitoring Center. In addition, as UNAH is the TWFP, it receives tsunami information sent from PTWC. However, since the registration of TWFP is a personal name as described above, the information is sent only to a particular individual address.

Figure 2.6.11 Monitoring Display of the Tide Data Observed at the Coast of San Lorenzo on the Pacific Coast (Difference between High Tide and Low Tide is 2 meters on 16th of January in 2015)

Figure 2.6.12 Tidal Gauge View from North-West side (Left), View from East side (Middle), View from North-East Side Right))

3) Analysis of Tsunami Generation

At the National Monitoring Center, for near earthquakes and regional earthquakes, the analysis of tsunami generation should be made if the magnitude is greater than or equal to 6.0, using tsunami information provided by PTWC and information from foreign institutions mentioned in the "Tsunami Monitoring System" section. Servinet of NASA's hurricane Center is also sometimes checked.

The National Monitoring Center should analyze the information with technical assistance of UNAH-IHCIT via SAT. It should be noted that UNAH evaluates analysis results as described in the "Earthquake Information Dissemination" section; it also does the analysis of tsunami generation.

On the other hand, as for the hypocenters and magnitudes provided from international institutions, the National Monitoring Center uses the information from USGS as the highest priority, because the hypocenter determination by USGS is implemented with the data from the broadband seismic stations network with the best distribution in Central America compared to other institutions, and because the hypocenters are the most reliable.

As for near earthquakes, the time between its occurrence and the arrival time of tsunami is very short. Therefore, the results from the automatic processing by SeisComP should be used to response to the near ones. However, the processing system is currently unstable as described above. Furthermore the system cannot calculate magnitude and cannot do the hypocenter for this reason, the tsunami generation judgment should be implemented with referring to the judgment of the institutes in foreign countries like PTWC, INETER, MARN or USGS not only for Distant Tsunamis, but also for Local Tsunamis and Regional Tsunamis. However, in the case, that strong motion is observed in the coastal areas, and that there is a risk of an occurrence of Local Tsunamis, and it is expected and require the immediate action of residents in coastal areas, tsunami warnings should be disseminated without waiting for the information from the PTWC. In other words, the Tsunami Warning Committee, which will be described later, should make a goal that it takes shorter than or equal to ten minutes from calling the meeting to opening it, and the committee should disseminate a tsunami red alert immediately. This procedures, based on the training results of the PTWC held in Ecuador and Mexico, have been included in the existing protocol, which has been improved accordingly (Figure 2.6.12).

On the other hand, as for real-time updates and cancellation of tsunami warnings, it is necessary to make real time analysis of observed tidal gauge data. However, there is no platform to do so. For this reason, it is difficult now to incorporate the tsunami observation results into a real-time evaluation of the tsunami warning.

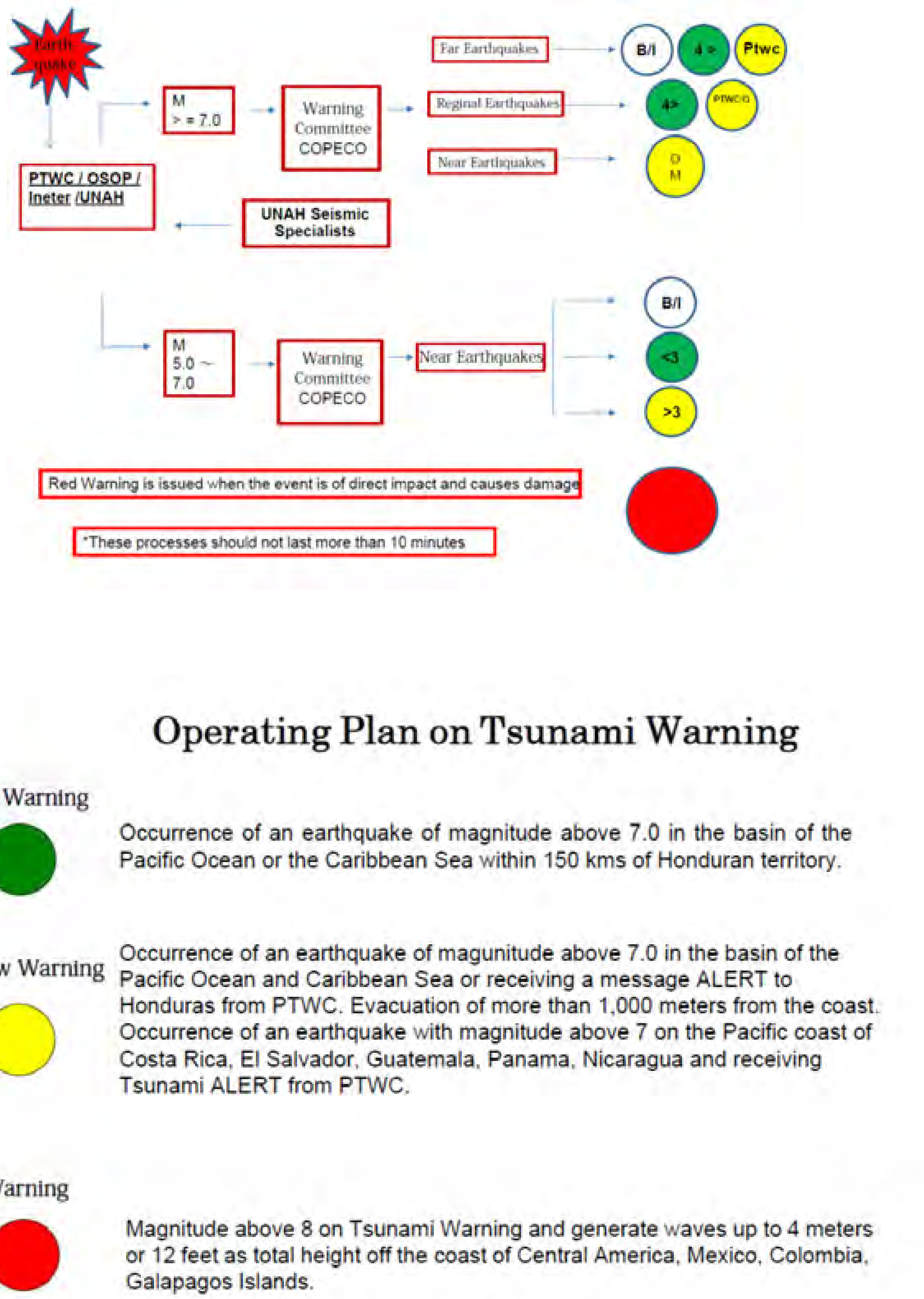


Figure 2.6.13 Protocol of Tsunami Generation Judgment and Tsunami Warning Issuance

(Upper：Flow of procedures. Lower：Warning Criteria)

4) Issuing Tsunami Information

Tsunami information made based on the collected seismic data should be issued in the same flow and procedures as earthquake information, and its dissemination should be carried out in the same transmission path as earthquake information.

The National Monitoring Center should transmit the collected information to SAT chief with cellphones or radios.

The SAT chief should send the received information to UNAH-IHCIT with cellphones and emails and ask them advices. Also, according to the protocol, described in the "Earthquake Information Dissemination", used in practical action (currently its incorporation is being handled through updating the "Corresponding Plan"), the director of preparation and response department should call the meeting of the Warning Committee in the case that there is possibility of Red warning. However, as for Local Tsunamis and Regional Tsunamis, since the time between its generation time and the arrival time of tsunami is very short, the SAT chief should disseminate red alerts, sometimes at his discretion without waiting for results of the Warning Committee meeting. Even in that case, the Committed should have responsibility on the warning appropriateness.

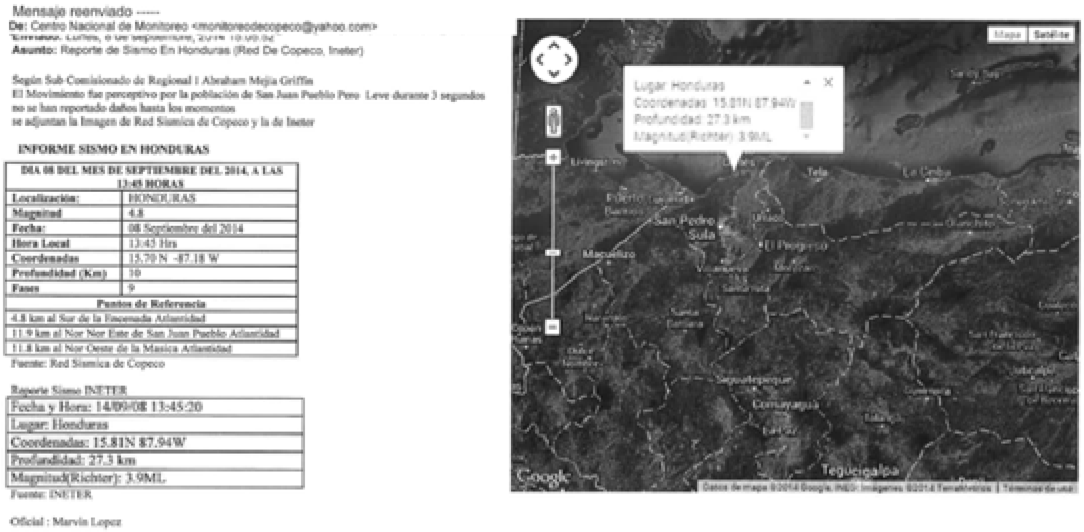
Note: UNAH-IHCIT is processing the waveform data by three systems, Earthworm, SeisComP and another. As for the seismic velocity structure model, it uses general model, not its local one. It has no criteria on tsunami generation judgment because they have no tsunami experience. They make hypocenter distribution map with the information of the USGS. In addition, they will not handle the Far Earthquakes. Though they implement focal mechanism analysis and tsunami simulation, the actions are taken for making hazard maps. Three seismic specialists of UNAH-IHCIT handle technical judgment. Furthermore, they can be contacted always, but have no administrative responsibility because they belong to Educational organization not administrative one.

5) Specific Examples of Analysis of Tsunami Generation and Issuing Tsunami Information

COPECO has no experience of tsunami in the current system.

Figure 2.6.13 is an example of seismic information about the earthquake of magnitude 4.8 that occurred in Honduras at the depth of 10km on 8 September in 2014 at 13:45 (Honduras time). An email from the National Monitoring Centre to SAT and others sent it at 15:05 (Honduras time) after about one hour later of its occurrence.

The information shows the description of "According to the Deputy Director-General of the Regional Ⅰ, San Juan Pueblo, northwest of Honduras, felt tremors. However, the minor shaking lasted three seconds. There is no report on damage until now. Additionally the seismic networks of COPECO and INETER are shown." The figure shows information on the results of automatic calculation hypocenter by COPECO and on those from Nicaragua INETER. In addition, a map showing hypocenter was attached as well.



Mensaje reenviado -----
De: Centro Nacional de Monitoreo <monitoreodecopeco@yahoo.com>
Asunto: Reporte de Sismo En Honduras (Red De Copeco, Ineter)

Según Sub Comisionado de Regional I Abraham Mejía Griffin
El Movimiento fue perceptivo por la población de San Juan Pueblo Pero Leve durante 3 segundos
no se han reportado daños hasta los momentos
se adjuntan la Imagen de Red Sísmica de Copeco y la de Ineter

INFORME SISMO EN HONDURAS

DIA 08 DEL MES DE SEPTIEMBRE DEL 2014, A LAS 13:45 HORAS	
Localización:	HONDURAS
Magnitud	4.8
Fecha:	08 Septiembre del 2014
Hora Local	13:45 Hrs
Coordenadas	15.70 N -87.18 W
Profundidad (Km)	10
Fases	9
Puntos de Referencia	
4.8 km al Sur de la Ensenada Atlántida	
11.9 km al Nor Nor Este de San Juan Pueblo Atlántida	
11.8 km al Nor Oeste de la Masica Atlántida	

Fuente: Red Sísmica de Copeco

Reporte Sismo INETER

Fecha y Hora: 14/09/08 13:45:20
Lugar: Honduras
Coordenadas: 15.81N 87.94W
Profundidad: 27.3 km
Magnitud(Richter): 3.9ML

Fuente: INETER

Oficial : Marvin Lopez

Figure 2.6.14 An Example of email having seismic and tsunami information sent from the National Monitoring Center (Source: COPECO)

Figure 2.6.14 is an example of information disseminated from SAT based on the analytical results provided from UNAH/IHCIT. The action was after receipt of Seismic Tsunami information shown in Figure 2.6.13. The information from SAT shows also the seismic waveform of the station, Yuscaran, approximately within two or three hundred kilometers away from the epicenter. The waveform in the figure shows the state of shaking visually. The interval of the vertical lines of the record is one minute.

De José Jorge Escobar: Se realizó análisis desde la Facultad de Física de la UNAH / y nos refieren que se trata de **un evento relacionado con fallamiento de tipo de Local y este episodio sismico se le atribuye a la falla de Ceiba que cruza precisamente la ciudad de Ceiba y cruza San Juan Pueblo.**

Se podrian seguir registrando eventos iguales, menores o mayores en magnitud.

José Jorge Escobar
Facultad de Física
UNAH

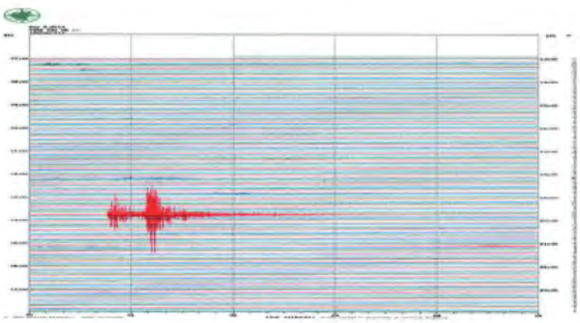
Prof. Jose Jorge Escbar : Faculty of Phyiscs in UNAH were analyzed. According to it, this earthquake is due to inland fault activity. It is an activity of the Ceiba fault that passes under the Ceiba. In addition, this fault passes also under the San Juan Pueblo.

・・・

José Jorge podrías realizar análisis de este evento e informarnos :Los datos preliminares acerca del movimiento telúrico del cual no se reporta hasta el momento daños humanos o materiales que lamentar, son los siguientes:

Localización:	**HONDURAS**
Magnitud	4.8
Fecha:	08 Septiembre del 2014
Hora Local	13:45 Horas
Coordenadas	15.70 N -87.18 W
Profundidad (Km)	10
Fases	9
Puntos de Referencia	
4.8 km al Sur de la Ensenada Atlántida	
11.9 km al Nor - Este de San Juan Pueblo Atlántida	
11.8 km al Nor - Oeste de la Másica Atlántida	

Se adjunta sismograma de Estación de Yuscaran.



Prof. Jose Jorgehas has analyzed the event and mentioned as follows: Preliminary data shows there have been no strong motion that should cause human injuries or any damage.

Location	Honduras
Magnitude	4.8
Date	08 September in 2014
Origin Time	13:45
Coordinate	15.70N 87.18W
Depth	10
Number of used Phases	9
Reference	
(*Distances between the epicenter and near towns*)	

・Attached the waveform observed at the Yuscaran Seismic Station

Figure 2.6.15 Example of Analyzed Results Provided from UNAH and Example of Information Disseminated from SAT

(Source: COPECO)

Figure 2.6.15 is an example of an earthquake of magnitude 7.4 that occurred at 21:52 (Honduras time) in the Central America coastal region on the 13th of October in 2014. It shows the tsunami information provided to the National Monitoring Center of COPECO as TWFP alternate from PTWC by an email.

Asunto: PTWC TSUNAMI THREAT MESSAGE
De: ptwc@ptwc.noaa.gov (ptwc@ptwc.noaa.gov)
Para: tsunami_bb@infolist.nws.noaa.gov;
Fecha: Lunes, 13 de octubre, 2014 22:13:14

ITIC Tsunami Bulletin Board
TSUNAMI MESSAGE NUMBER 1
NWS PACIFIC TSUNAMI WARNING CENTER EWA BEACH HI
0411 UTC TUE OCT 14 2014

...PTWC TSUNAMI THREAT MESSAGE...

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE *****

THIS MESSAGE IS ISSUED FOR INFORMATION ONLY IN SUPPORT OF THE UNESCO/IOC PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM AND IS MEANT FOR NATIONAL AUTHORITIES IN EACH COUNTRY OF THAT SYSTEM.

NATIONAL AUTHORITIES WILL DETERMINE THE APPROPRIATE LEVEL OF ALERT FOR EACH COUNTRY AND MAY ISSUE ADDITIONAL OR MORE REFINED INFORMATION.

**** NOTICE **** NOTICE **** NOTICE **** NOTICE **** NOTICE *****

PRELIMINARY EARTHQUAKE PARAMETERS
----

* MAGNITUDE 7.4
* ORIGIN TIME 0352 UTC OCT 14 2014
* COORDINATES 12.5 NORTH 88.3 WEST
* DEPTH 22 KM / 14 MILES
* LOCATION OFF THE COAST OF CENTRAL AMERICA

EVALUATION
----

* AN EARTHQUAKE WITH A PRELIMINARY MAGNITUDE OF 7.4 OCCURRED OFF THE COAST OF CENTRAL AMERICA AT 0352 UTC ON TUESDAY OCTOBER 14 2014.

* BASED ON THE PRELIMINARY EARTHQUAKE PARAMETERS... HAZARDOUS TSUNAMI WAVES ARE POSSIBLE FOR COASTS LOCATED WITHIN 300 KM OF THE EARTHQUAKE EPICENTER.

Subject : PTWC TSUNAMI THREAT MESSAGE
Date : Monday, 13 of October, 2014 22:13
(Note:about 20 minutes passed after the event occurrence)

ITIC Tsunami Bulletin Board
・・・
0411 UTC TUE OCT 14 2014

・・・

PRELIMINARY EARTHQUAKE PARAMETERS

- ・M 7.4
- ・ORIGIN TIME 0352 UTC OCT 14 2014 (*Note: 2152 13th Honduras Time*)
- ・COORDINATES 12.5N 88.3W
- ・DEPTH 22km / 14MILES
- ・LOCATION OFF THE CAST OF CENTRAL AMERICA

TSUNAMI THREAT FORECAST...UPDATED
----

* HAZARDOUS TSUNAMI WAVES FROM THIS EARTHQUAKE ARE POSSIBLE WITHIN 300 KM OF THE EPICENTER ALONG THE COASTS OF

NICARAGUA... HONDURAS AND EL SALVADOR

RECOMMENDED ACTIONS
----

* GOVERNMENT AGENCIES RESPONSIBLE FOR THREATENED COASTAL AREAS SHOULD TAKE ACTION TO INFORM AND INSTRUCT ANY COASTAL POPULATIONS AT RISK IN ACCORDANCE WITH THEIR OWN EVALUATION... PROCEDURES AND THE LEVEL OF THREAT.

* PERSONS LOCATED IN THREATENED COASTAL AREAS SHOULD STAY ALERT FOR INFORMATION AND FOLLOW INSTRUCTIONS FROM NATIONAL AND LOCAL AUTHORITIES.

ESTIMATED TIMES OF ARRIVAL
----

* ESTIMATED TIMES OF ARRIVAL -ETA- OF THE INITIAL TSUNAMI WAVE FOR PLACES WITH AN ETA WITHIN THE NEXT SIX HOURS. ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST. A TSUNAMI IS A SERIES OF WAVES AND THE TIME BETWEEN WAVES CAN BE FIVE MINUTES TO ONE HOUR.

LOCATION	REGION	COORDINATES	ETA(UTC)
CABO SAN ELENA	COSTA RICA	10.9N 86.0W	0438 10/14
CORINTO	NICARAGUA	12.5N 87.2W	0447 10/14
PUERTO SANDINO	NICARAGUA	12.2N 86.8W	0449 10/14
SIPICATE	GUATEMALA	13.9N 91.2W	0459 10/14
SAN JUAN DL SUR	NICARAGUA	11.2N 85.9W	0500 10/14
PUERTO QUEPOS	COSTA RICA	9.4N 84.2W	0502 10/14
CABO MATAPALO	COSTA RICA	8.4N 83.3W	0506 10/14
AMAPALA	HONDURAS	13.2N 87.6W	0509 10/14
ACAJUTLA	EL SALVADOR	13.6N 89.8W	0509 10/14
COCOS ISLAND	COSTA RICA	5.5N 87.1W	0510 10/14
PUNTA BURICA	PANAMA	8.0N 82.9W	0513 10/14
PUERTO MADERO	MEXICO	14.8N 92.5W	0519 10/14
SALINA CRUZ	MEXICO	16.5N 95.2W	0537 10/14
ACAPULCO	MEXICO	16.9N 99.9W	0549 10/14
PUNTA MALA	PANAMA	7.5N 80.0W	0605 10/14

・HAZARDOUS TSUNAMI WAVES FROM THIS EARTHQUAKE ARE POSSIBLE WITHIN 300 KM OF THE EPICENTER ALONG THE COASTS OF NICARAGUA, HONDURAS AND EL SALVADOR

…

…

…

ESTIMATED TIMES OF ARRIVAL (UTC)

…

・・・
AMAPALA HONDURAS 0509
ACAJUTLA EL SALVADOR 0509
・・・

Figure 2.6.16 Example of Tsunami Information Provided by PTWC to TWFP with an Email (Source: COPECO)

(3) Tsunami Infrastructure Development Situation

Seawalls have not been established.

As for evacuation routes, those reaching to the buildings designated as shelters in the vulnerability assessment study in each community (community center, hotel, church, etc.) has been set, and also evacuation systems are defined in Emergency Response Plans.

As for sirens, one is installed at Marcovia City of the Pacific side, and at the Santa Fe City of the Caribbean side. They make total two.

Figure 2.6.17 An example of setting Evacuation Roots (Source: The report of Vulnerability Analysis of the San Isidro Community , Marcovia.)

Figure 2.6.18 Evacuation Shelter (Community Center) and a Siren at Cedeño (Marcovia)

(4) Tsunami Alert and Evacuation System

1) Warning Dissemination System

Seismic and tsunami information that has been monitored in the "24x7 contact" in the National Monitoring Center of COPECO is sent to the SAT. After judging the warning category, the information should be disseminated to the region COPECO through Public Relations. Further, it is disseminated to the municipal governments.

2) Warning Dissemination Procedures

The SAT should send the warnings decided through the procedures described above to Public Relations. The PR should disseminate it to seven regional COPECO, organizations related to disaster prevention and mass media with email, Facebook and Twitter. The regional COPECO should immediately disseminate the warnings to the SAT of CODEM with emails, cellphones and radios (UHF. Deployed not to all municipal government). Each municipal government should disseminate it from CODEM ・ SAT to community CODEL chairman through the mayor's approval with

Cellphones or VHF radios (Deployed partially). CODEL members should disseminate it to each district with megaphones; the way is main now. On the other hand, as for tsunamis, the system that, according to the request from the SAT, each community should convey the visual observation information such as sea level information to the central COPECO, is established through drills.

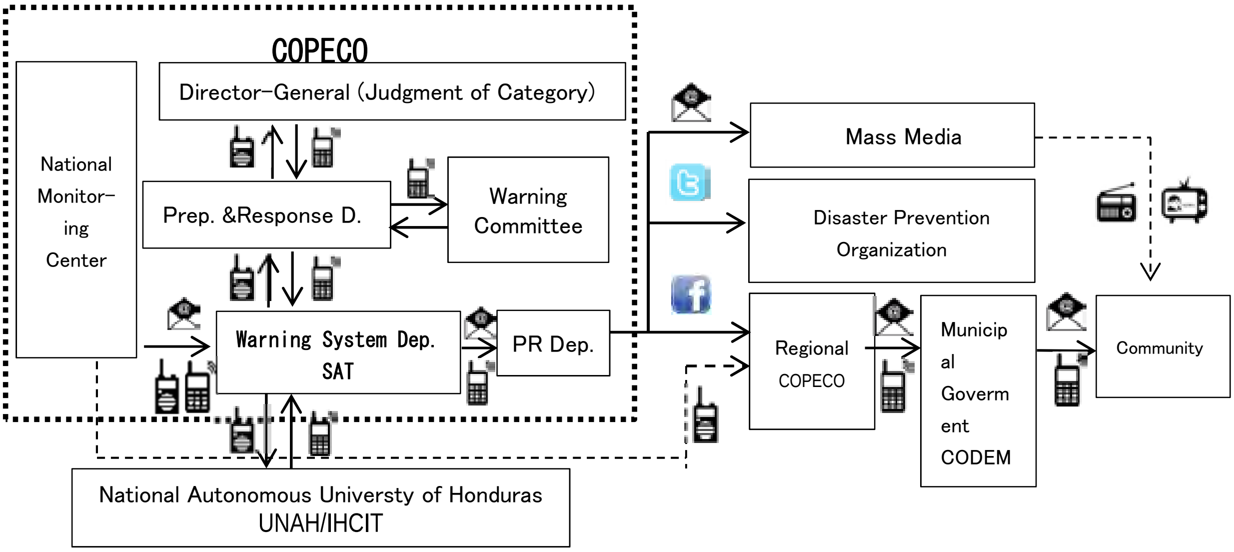


Figure 2.6.19 Tsunami Warning Dissemination System

3) Tsunami Evacuation System

In recent years, most of the communities in the Pacific coastal areas have been conducting vulnerability survey of the region and development of Emergency Response Plans with the support from the city CODEMs. In the results of the survey or the Plans, designation of evacuation places, warning dissemination and evacuation systems are defined. In addition, development of tsunami evacuation plan has been completed in most of the communities on the coastal area. Furthermore, annual evacuation drills have been carried out generally.

(5) Tsunami Risk Assessment Technique and its Present Situation

Tsunami risk assessments have not been yet made in COPECO. Note that COPECO should do vulnerability investigation according to requests from any organizations like municipalities, prefectures, private organizations. Until now, COECO has conducted the investigations for floods, landslides, and earthquakes, but not tsunamis.

(6) Development on Hazard Map against Tsunami and its Utilization

Development of tsunami hazard maps are not yet performed in COPECO. On the other hand, when carrying out the vulnerability study in CODEL, lowlands of coastal areas have been designated as vulnerable areas.

(7) Effort for Tsunami Disaster Prevention at Research Institutes like Universities and NGOs

UNA-IHCIT makes technical advice on tsunami analysis. It has a tide gauge at Ceiba of the Caribbean side and implements tsunami observation with it.

2.6.5. Situation of Cooperation of JICA and Donors

(1) Situation of Japan's Cooperation

Projects undertaken with Japan's cooperation toward earthquake and tsunami disaster prevention in Honduras are shown in the following table:

Table 2.6.5 Japan's Cooperation Projects toward Earthquake and Tsunami Disaster in Honduras

Scheme	Project Name	Period
Technical Cooperation	Project on Capacity Development for Disaster Risk Management in Central America "BOSAI" The activities on capacity development was implemented in El Ocotillo Namasigue, San Rafael Centro of Choluteca City, Matapalo Arriba of Sanra Isabel El Trinufo City, Los Llanitos, Guapino of Santa Teresa Marcovia City and Tegucigalpa City as the pilot districts. There are several districts that are on a continual action, but some others are on a one-off. The spread of these activities to other districts is one of the issues, but more than 150 sirens have been planned to be installed in Tegucigalpa	2007-2012
Training Program (2010-2014)	Community based Disaster Risk Management (6)	2011-2014
	Disaster Management in Central American Countries (20)	2010-2014
	Raising Awareness of Disaster Reduction (7)	2012-2014

*Numbers in ( ) of Training Program indicate number of participants。

(2)Situation of Key Donor's Cooperation

Projects undertaken with Key Donor's cooperation toward earthquake and tsunami disaster prevention in Panama are shown in the following table:

Table 2.6.6 Key donor's Projects toward Earthquake and Tsunami Disaster in Honduras

Funding Agency	Project Name / Project Outline	Project Sights	Implementing Body	Budget(USD)	Period
World Bank	Natural Disaster Mitigation – Additional Scale-Up Financing	81 municipalities participated	COPECO	9 million	2007-ongoing
	The project of reduction of vulnerability was implemented.				
NORAD	Earthquake Risk Reduction in Guatemala, El Salvador and Nicaragua with regional cooperation with Honduras, Costa Rica and Panama	Whole of the country	COPECO	2.4 million	2007-2010
	Earthquake hazard map of the whole country was created based on the concept "learning by doing" for hazard, vulnerability and risk analysis				

2.6.6. Items to be Improved

(1)Seismic and Tsunami Monitoring and Analyzing Ability Improvement

1) Acquisition of Techniques for Earthquake and Tsunami Generation Judgment

COPECO depends on the judgment of the generation of earthquakes and tsunamis on automatic processing by utilizing local networks, the evaluation of UNAH-IHCIT experts, PTWC and other organizations of Nicaragua and El Salvador because COPECO has no staff to do it.

Therefore, the urgent issue is that the staff of the monitoring center should acquire the ability of the basics, the focal mechanism and the tsunami generation, and in addition, COPECO should ensure they have the experts of earthquake analysis.

2) Seismic Analyzing Ability Improvement through Hypocenter Determination Improvement

The monitoring in COPECO is based on the techniques learned by experiencing things.

It is necessary to estimate and understand the focal mechanisms, then to improve the data analysis system of a tidal gauge observation in accordance to establish a system for stable operations and reliable judgment for tsunami generation.

3) Optimizing the Maintenance and Inspection of Observation Equipment

Several equipment does not work properly because of a shortage in the budget of maintenance. The number of equipment will decrease gradually if this situation continues. Moreover, there is a disabled SeisComP due to an expired contract of maintenance. Therefore, it is necessary to ensure the budget allocation for maintenance, and personnel in charge of maintenance.

4) Strengthening the Tsunami Observation Network

In order to improve the accuracy of tsunami warnings, a tidal gauge observation network should be improved for real time processing in cooperation with neighboring countries and for stable operation.

(2) Improvement of the Dissemination of Tsunami Information on Local Tsunamis

1) Improvement of the Dissemination of Tsunami Information

COPECO should shorten the time for a tsunami generation judgment through simplifying the judgment procedures and the automation of a warning issuance procedure in order to respond to Local Tsunamis which are likely to occur.

2) Ensure the Warning Dissemination Route

It is necessary to ensure the dissemination route to the residents in vulnerable areas, especially along the coastal area of the Pacific Ocean, even though there are already a few stable communication tools between the municipalities and communities, while the dissemination of an alert between the Central COPECO SAT and CODEM has been already established.

(3)Promotion Policy on Seismic and Tsunami Disaster Prevention

1) Development of an Archive for Seismic Risk Assessment Data

The result of RESIS revealed that the risk of earthquakes along the Pacific Ocean side was very high. It is necessary to develop essential data, like the building inventory of building structures especially for important buildings and the fragility curve for the risk assessment of earthquakes.

2) Promotion of an Earthquake–proof Policy

Honduras has a seismic standard, which was issued in 2012. There are many buildings built before the year of 2010. Therefore, it is necessary to promote a seismic retrofit with priority.

3) Improvement of a Community-based Tsunami Disaster Prevention System

Organizing the vulnerability assessment and emergency response plan of communities along the coast area has been almost terminated, but there are quite a few of the necessary tools available between CODEL and the communities. It is thus necessary to improve the existing dissemination system for prompt action in accordance with an alert, and to steadily implement training.

2.7. The Role of CEPREDENAC on Tsunami Alert System in the Central America

CEPREDENAC takes the following roles in the tsunami warning related issues:

・Promotion of the development of a disaster, including tsunami, response plan for the countries in Central America

Because the current response plan related to tsunamis is currently handled together with other kinds of disasters like earthquakes, volcanic activity or hurricanes, the above promotion is targeting only tsunami issues.

・Promotion of the establishment of a tsunami warning dissemination system for the countries in Central America

In Central America, there are a number of hydrological, meteorological, volcanic and earthquake experts, but there are a smaller number of experts for tsunami, so that CEPREDENAC has supported the improvement of professional skills, such as providing communication opportunities. Although hydro-meteorological experts have organized the Regional Water Resources Committee, since earthquake tsunamis such have such a professional organization, it is supposed to promote the improvement of its organizational ability.

In addition, CEPREDENAC has carried out the promotion of disaster plans regarding earthquakes and tsunamis in the past such as:

・Hosting the Representative Advisory Committee at Corinto, Nicaragua in November of 2013 with the theme "Tsunami Monitoring and Early Warning System". A conclusion of the meeting, the operation of the tsunami warning system should operate integrally rather than individually. This meets the direction of the establishment of CATAC. In this meeting, a tour of the early warning system at Corinto Port was held.

・In June of 2014, SICA, the supervisor of CEPREDENAC, held a regular meeting with the heads of state or those of government in the Republic of Dominica the Dominican Republic. At the meeting, it was agreed to the "regional cooperation on seismic observation according to the proposal from the president of Nicaragua. In addition, it was decided that "involvement in the establishment of CATAC of CEPREDENAC"should be discussed at the "Advisory Committee with representatives" of CEPREDENAC scheduled to be held in February 2015.

It should be noted, CEREDENAC is operated as a joint body of the six countries (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama) in Central America. It has the Advisory Committee with representatives from the disaster prevention organizations of the six countries. CEPREDENAC should be its secretariat, and implement decisions made by the Committee. The Committee should have regular meetings four times a year. The meetings will be held in one of the countries in turns. The main activities of CEPREDENAC are (1) the implementation of a comprehensive disaster prevention policy (PCGIR), and (2) the promotion and the familiarization of a disaster prevention culture. As the action for the latter, sharing of the related information by campaigns and "communications" on disaster prevention are to be carried out. Note: In the case of support from donors, in the case that the entire Central American region is targeted, CEPREDENAC may act as a receiver of the support depending on the content of assistance.

3. The Current Status of CATAC Establishment Plan and the Items to be Improved

3.1. The Progress of Consideration on CATAC in UNESCO/IOC- ICG/PTWS

Regarding the establishment of CATAC, UNESCO/IOC has started a full-fledged discussion on it from the meeting in 2011. The IOC Central America tsunami meeting of September 2014 aimed at strengthening the "seismic network that covers the whole area of Central America" that is required for the tsunami warning outgoing function of CATAC, and so the establishment of the " Regional Network of Seismology to Central America" has been approved. Based on this progress, IOC is supposed to support the establishment of CATAC in Nicaragua. However, how involved is left to the decision of the IOC Paris headquarters. It is to be noted that the Nicaraguan proposal of the IOC meeting of 2011 a request for technical and financial support from JICA was included.

CEPREDENAC recognizes that Nicaragua is proceeding on the technical issues of making tsunami warnings compared to the other countries of Central America. In addition, in order to establish a CATAC in Nicaragua, it became a hot topic in the Representatives Advisory Committee of 2009, however Nicaragua is a country of poor coordination in political aspects. It takes time for the establishment to be approved at CEPREDENAC. Also, although there is an agreement among TWFP · TNC of the six countries, the cooperation contents of the six countries' technological institutions has not been decided.

On the other hand, INETER, in order for a CATAC for exhibit the proper tsunami warning issuance function as it should, it has been recognized that the seismic network that covers all of Central America needs to be strengthened. For this reason, in order to promote the use of the six Central American countries of the seismic network, the establishment of a " Regional Network of Seismology to Central America" should be made. INETER proposed this suggestion to the Nicaraguan President in April 2014, and the president approved the idea. As mentioned in 2.7, in the SICA regular meeting, which was held in the Dominican Republic in June 2014, the Nicaraguan President proposed the establishment of it, and the proposal for regional cooperation on seismic monitoring has been agreed. Then, as described above, it has become part of the IOC acknowledgment and CEPREDENAC agreement.

In addition, the earthquake and tsunami experts in the six Central American countries will establish a technical committee, which should consider the " Regional Network of Seismology to Central America" and will hold a meeting concerning it. However, a location for it has not yet been decided.

The number of seismometers that will be used at the " Regional Network of Seismology to Central America" is shown in Table 3.1.1. It should be noted that it is assumed that, in the future, they will be used at CATAC.

Note: the seismic networks for a " Regional Network of Seismology to Central America" will include not only the networks in Central America but also the networks of Mexico and Colombia. The use of the data from the Mexican seismic network in Nicaragua is partially agreed between two countries. The use of the data in Nicaragua from Colombia will be started from now on.

Table 3.1.1 The Seismic Networks and the Number of Seismometers Managed by Central American countries and its vicinity Countries (Source: INETER)

COUNTRY		Institution	Quantity TOTAL APPROXIMATE
Guatemala	1	INSIVUMEH Http://www.insivumeh.gob. gt/estaciones_sismologica s.html	20
	2	UMG (Universidad Mariano Galvez) http://in3.umg.edu.gt/	20
El Salvador	3	MARN Http://www.snet.gob.sv/ver /seismology	95
Honduras	4	COPECO	20
Nicaragua	5	INETER Http://webserver2.ineter.go b.ni/geophysics/sis/monitor.h TML	75
Costa Rica	6	OVSICORI Http://www.ovsicori.una.ac. cr/systems/SAES_MAPA/pages/map.php	40
	7	RSN (UCR-ICE) http://www.rsn.ucr.ac.cr/in dex.php/seismology/network - seismic	55
	8	LIS (UCR) Http://www.lis.ucr.ac.cr/cla se_index/tv/googlemaps/e staciones_activas_v2.php	90
Panama	9	IG-UPA Http://www.panamaigc- up.com/ http://www.osop.com.pa/w p-content/uploads/ 2013/09/c ongreso_geo_2013.pdf	60
	10	Panama Canal http://micanaldePanama.c om/	10
NETWORKS OUTSIDE OF CENTRAL AMERICA			
Colombia		Geological Service Colombian http://seisan.sgc.gov.co/R CNS/index.php/network-of- stations/map-of-the- stations	70
		OSSO-Universidad del Valle http://osso.univalle.edu.co/ index.php?option=com_co ntent&view=article&id=106	15
Mexico		National Seismological Service http://www2.ssn.unam.mx: 8080/website/jsp/red_sism ologica.jsp	54
		SASMEX Http://www.cires.org.mx/sa smex_es.php	
		University of Sciences and Arts Chiapas http://www.cmvs.chiapas.g ob.mx/seismology	

3.2. Outline of Duties of CATAC Assumed and Cooperation System with Relevant Countries

El Salvador's expectations for CATAC: MARN/DGOA has the capacity for analyzing tsunami generation, but does not have so much experience in tsunami monitoring and issuing tsunami warnings. It will rely heavily on the performance of CATAC in particular for Regional Tsunamis. In addition it expects CATAC to become the backup for their seismic and tsunami monitoring system.

Guatemala's expectations for CATAC: SE-CONRED relies on the output from automatic calculation for dissemination of seismic information. It also mostly relies on the information provided by PTWC on the judgment of tsunami generation. It has expectations for the information on regional earthquakes. On the other hand it has constraints on monetary support for CATAC. In addition, regarding training at CATAC for monitoring tsunamis and earthquakes, the training themes should be a) tsunami generation theory or modeling of tsunamis, and b) extracting tsunami vulnerable areas and modeling the actions. Through the training with these themes Guatemala expects to foster seismic and oceanic specialists.

Costa Rica's expectations for CATAC: CNE relies on the output from automatic calculation for the dissemination of seismic information. It also mostly relies on the information provided by SINAMOT by telephone or PTWC in judgment of tsunami generation. SINAMOT has no "7x24 contact" that should take care of tsunami generation judgment from the technical point of view thus has expectations for the information on regional earthquakes from CATAC.、In addition, regarding the training at CATAC for monitoring tsunamis and earthquakes, the training themes should be the role of CATAC, the products for CATAC and any constraints of CATAC.

Panama's expectations for CATAC: IGC-UPA agrees with the idea that Nicaragua should take the role of CATAC because that country has sufficient experience in tsunami warning matters. If any training courses related to CATAC establishment will be planned and opened, the themes of it should be the "improvement of tsunami forecast reliability in Japan" and the "shortening the time needed for handling the issuance in Japan".

Note: the training course at PTWC in Hawaii is one week and its theme is tide data monitoring software, warning issuance, actions to be taken in monitoring turn and other.

On the other hand, SINAPROC having the responsibility for the dissemination of tsunami warnings it will be expected that CATAC will realize the judgment of tsunami generation under the condition of a "24x7 contact" because the present weak point in the tsunami warning system in Panama is that it relies on information shown on web-sites due to the current condition that IGC-UPA, who should judge tsunami generation from technical point of view, has no "24x7 contact". SINAPROC is also expecting to participate in any training course together with the staff of IGC-UPA. SINAPRCO is expecting the course will provide basic knowledge of tsunami warnings, how to monitor information in the relevant web sites and how to check the information to be provided from CATAC.

Honduras' expectations for CATAC: COPECO hopes to implement the issuance and the dissemination of tsunami warnings based on the tsunami information that has been analyzed in Central America without relying on PTWC. COPECO thus has a large expectation on the establishment of CATAC. Regarding the training at CATAC, COPECO will dispatch the staff in charge of seismic and tidal observations and the staff of TWFP and TNC to technical part of the training. The themes should be basic theories like how to interpret earthquakes and how to calculate seismic parameters, and practical items like how to maintain observation stations, how to collect seismic and tidal data and how to receive information issued from CATAC.

Based on the items to be improved in the countries and the above expectations to CATAC, the role and the function that CATAC should take or have can be notified as follows:

Note: the Figure 3.2.1 shows the potential users of information provided from CATAC. The table can be used to consider the destination of the information issued from CATAC in order to make CATAC perform its functions accordingly.

- As for Distant Tsunamis, issuance of correction information to Central America on the estimations of tsunami arrival times and tsunami heights with the information provided from PTWC.

- As for regional earthquakes that occur in the Central America region, issuance of tsunami warnings or advisories about the judgment results on the generation of a Regional Tsunami, estimation of its arrival time and the estimation on the height of the tsunami.

- As for near earthquakes (Note: tsunami warning dissemination might be not in time), the issuance of accurate hypocenter analysis and it results should be released rapidly.

At the meeting of the third ICG/PTWS held in Managua in September of 2014, INETER proposed that the tasks of CATAC should be a) real-time monitoring with a “24x7 contact”, b) automatic determination of seismic parameters within the shortest time, c) collection of sea level fluctuation data from tidal gauges and DART, and d) the calculation of the arrival times and the heights of the tsunamis. The calculation results should be issued within five minutes after the earthquake. And the CATAC should have the functions that will realize the proper implementations of the above tasks.

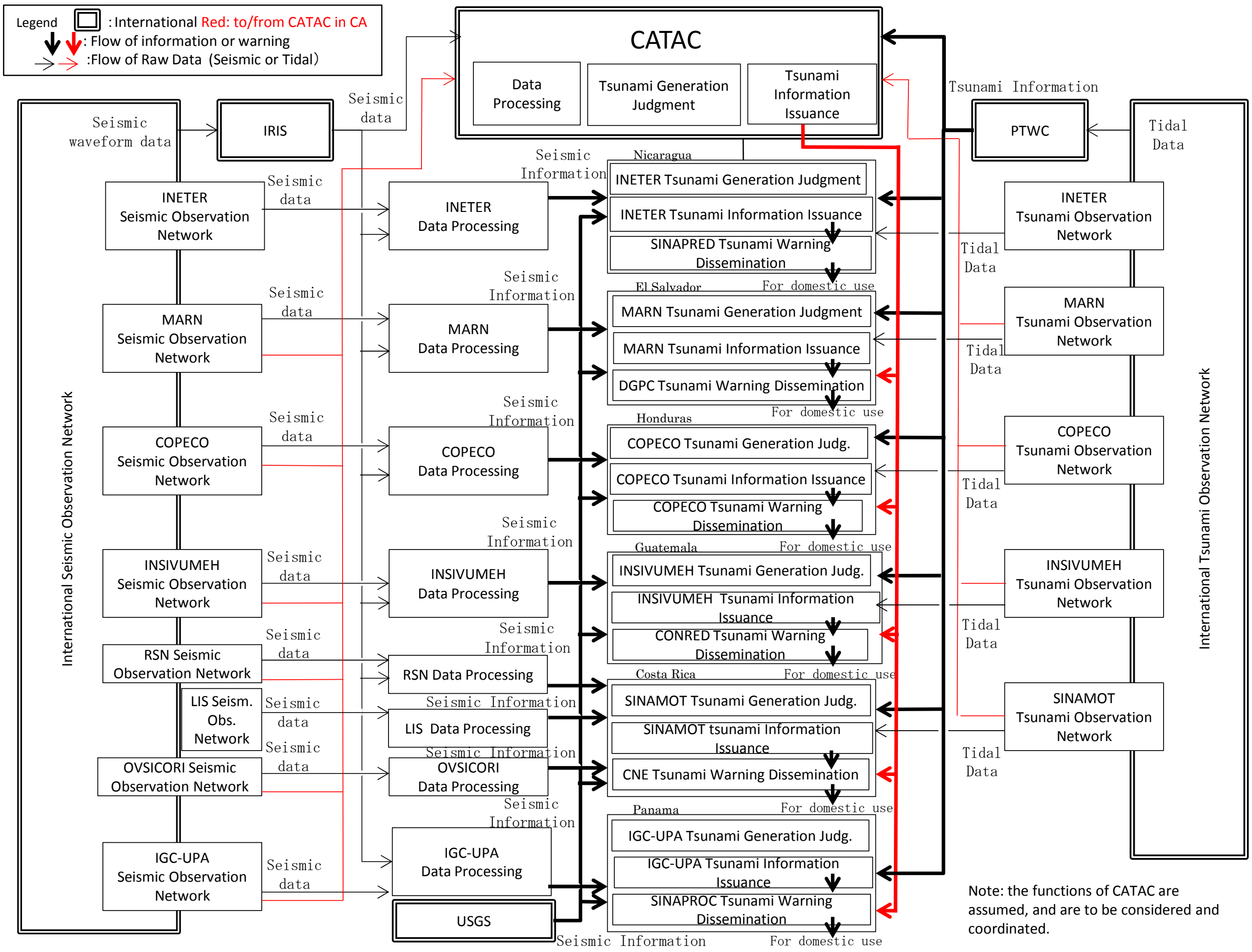


Figure 3.2.1 The Information Flow from CATAC to Relevant Organizations or Users

3.3. Management Policies of INETER for CATAC, its Organizational Structure, and its Development Status of Tsunami Warning Issuance Criteria

In the third meeting of ICG / PTWS in September 2014, INETER has shown its management policy on CATAC based on the current properties in other Regional Tsunami Warning Centers like the basic purposes, capacities, duties and products. INETER, however, has not yet designed a concrete plan.

3.4. Plans on Fostering Human Resources for Relevant Countries for the Management of CATAC

INETER has not yet designed a concrete plan.

3.5. Items to be Improved in the Management of CATAC and its Technical Capacity

The items to be improved for CATACT to exhibit the expected functions can be classified into two parts, namely the ones to be handled in the short term, such as two or three years after its establishment, and the ones to be done in the middle or long term, such as three years or longer. These are described below. Note: In INETER there are members who have already acquired any required technological skills. It should be considered to ask them to become trainers for the technologies in the training course.

3.5.1. Items to be handled in short term

(1) Improvement in Earthquake Analyzing Ability by Improvement in Hypocenter Calculation

It is necessary to improve the accuracy of hypocenter determination of earthquakes in Central America by tailoring seismic wave velocity structures to meet the regional features, and by optimizing the criteria for the selection of observation stations used in the hypocenter calculation for tsunami generation judgment according to the target area. Furthermore, by carrying out the error evaluation of hypocenters and magnitudes, it is necessary to grasp the way how to improve their reliability and accuracy.

Note: the crustal structure studies have been conducted in Nicaragua. It is desired to support the idea of the addition of "the establishment of seismic velocity structure model" to their study-purposes to have the study results used to make the reliability of the model improved.

(2) Introduction of Focal Mechanism Analysis

It is necessary to improve the accuracy of tsunami generation judgment in Central America by introducing a real-time analysis of focal mechanism with initial motion polarity data. Furthermore, since the estimation accuracy of the above technique is not high in large earthquakes, as a next step, the introduction of the CMT analysis, whose accuracy is generally high, is required.

(3) Acquisition of the Technology for Tsunami Generation Judgment

It is necessary to make an effort in improving the accuracy of the magnitude automatically estimated in the SeisComP for events in Central America by optimizing the selection of stations, with which magnitude is calculated, and optimizing station corrections as well. As a next step, it is necessary for the introduction of the CMT analysis to obtain moment magnitudes.

(4) Estimation of Tsunami Height and Arrival Time

For the tsunamis involved in the Central American region, since the estimation of tsunami heights and arrival times provided by PTWC is rough, it is thus necessary to improve the accuracy in the estimations for the region. The improvement needs information on the detailed bathymetry of Pacific Ocean throughout the coast, but the information has not been collected nor has notes been obtained. Therefore, as an immediate handling the current situation, it is necessary to bring the best sea depth information for Central America, put that information into the calculation of the estimations, and to make an effort in improving the accuracy of the estimations (calculation of tsunami propagation).

In addition, it is necessary to improve the estimations of tsunami heights for Central America by improving the ability for tsunami generation analysis (source process estimation) through using focal mechanisms or results from CMT and by analyzing coastal terrain. Furthermore, with a view to utilizing the tsunami observation results to update the estimates, after improving the source process grasping ability and tsunami propagation calculation technique, it is desirable to introduce the tsunami simulation technique into near real-time tasks. Note: Through this improvement, as for tsunami warning cancellation, it is desirable to obtain the technique for earlier judgment or issuance of the cancellation without losing reliability.

(5) Improvement of Existing Tidal Observation Facility

For the existing tidal gauges on the Pacific Ocean coast in Central America, when viewed from the point of view of tsunami observation, there are some stations, whose operation is unstable or its data is inappropriate. For this reason, the observation results are not fully contributed to improving the accuracy of forecasts of tsunami. Therefore, for the time being, it is necessary to establish stable operation systems for the existing tidal gauges, and to advance the optimization of the data acquisition and transmission systems.

(6) Optimization of a Central American Seismic and Tsunami Observation Network

Regarding the deployment of seismic and tsunami stations and data exchange in Central American countries, there is a need to make an effort in optimizing them from the following two perspectives: a) under the condition of an observation network working accordingly, hypocenters and magnitudes having necessary accuracy should be obtained for large earthquakes, and b)under the condition of an observation network having some problems due to occurrence of earthquakes or tsunamis, hypocenters and magnitudes having necessary accuracy should be obtained for aftershocks. Regarding these things mentioned above, it is desired to accomplish the mastery of technology based on the precedents of Japan or others.

(7) Improvement of the Technology on Tsunami Generation Judgment

In conjunction with the acquisition (understanding) of the technology (physics) on tsunami generation and propagation, as for regional earthquakes on the Pacific Coast in Central America, it is necessary to promote the establishment of a tsunami generation database, and to make the tsunami generation judgment efficient with help from the database. The activity should be handled through clarifying the priorities of the work to do and the procedures of them.

Note: With regard to the prioritization of the area (prioritized area should be handled earlier); the levels of tsunami possibility or levels of impact of tsunami attacks should be considered. In addition, with regard to the procedures of the works, we can imagine that schedule for the preparation work such as a) collecting resources for the establishment of a data-base like a computing environment and human resources, b) development of analysis of assumed seismic sources for the calculation, and c) ensuring the required water depth data of Pacific coastal areas in Central America.

(8) Optimization of the System for Providing the Six Countries in Central America with Seismic and Tsunami Information

It is necessary to build a system in which the six countries in Central America can share the knowledge obtained in the course of the analysis for earthquake and tsunami observations at CATAC and the Northwest Pacific Ocean Tsunami Advisory Center (NWPTAC) among them. In the process of the building the system, it is desired that the knowledge of NWPTAC, which have experience in advance, should be shared earlier among them, and they should accomplish improvement or optimization in their protocols for tsunami warning issuance together with the process of the enforcement of the functions of CATAC.

In addition, in order to verify whether the improvement of the protocols has been done properly with the actual performance in provision of information from CATAC, joint drills of the six countries should be implemented and the optimization should be evaluated.

(9) Actions to the Items to be Improved in the Six Countries in Central America

Experience and knowledge of the seismic and tsunami monitoring in CATAC will be accumulated. The accumulation should be utilized after its function has been exhibited. It is thus desired that the accumulation and the experience of predecessors like Japan should be used for the improvement of the ability in seismic and tsunami analysis of the countries with the above system established. The improvement should be handled through considering the actual features of the countries.

3.5.2. Items to be handled in Medium- and Long-term

(1) Newly Building and Increasing of Observation Facilities for Earthquakes and Tsunamis

In order to improve the accuracy of earthquake and tsunami observation in Central America, it is desired to consider the optimization of the deployment of seismic stations and take any measures to accomplish the results. In particular, to tsunami observation, it is desired to do so from the viewpoint of utilizing the observed data for real-time updates of tsunami warnings in Central America.

(2) Obtaining the Details of the Bathymetry

In order to improve the accuracy of estimations of tsunami heights or tsunami arrival times related to Central America, the detailed bathymetry of the Pacific Coast of Central America is needed. It should thus be promoted to make the coastal bathymetric survey and to arrange the results for their usage.

3.6. CATAC Approval Process

(1) Current Status

Regarding the consultation towards the establishment of CATAC, there was the third meeting of the Central America Working Group of ICG / PTWS held in Managua in September 2014. Its report only shows, "The Working Group decided to support the efforts and progress made by Nicaragua for the creation of CATAC in the support of the ICG-PTWS and ICG-CARIBBE (original Spanish)".

(2) Approval Process

The current status in the approval process is the agreement among the organizations of the working group level of the six countries. Hereafter, among the representatives of the national level (actually a representative of each country in the ICG / PTWS (TNC): Director of INETER as for Nicaragua), the issue should be agreed upon, and should be approved by the ICG / PTWS General Assembly. Lastly, UNESCO / IOC General Assembly should endorse it. After that, the information issued from CATA becomes the official one.

(3) Future Activities Required for Approval

It is ideal to follow a process of 1) holding a meeting of the Working Group again, deciding a recommendation on the establishment of CATAC, and describing the decision in the meeting report to ICG / PTWS, 2) approving this report at the General Assembly of ICG / PTWS (Hawaii) in April 2015, and lastly 3) endorsing the report of the General Assembly at the IOC general meeting of July 2015.

The following can be also considered as an option. Instead of the report of the Working Group, any agreement document signed by the person responsible in TNC or organizations involved in the tsunami warning issuance (in the case of Nicaragua, INETER and Co-Direcciones de SINAPRED) should be submitted to the ICG/PTWS General Assembly. With the submission, the above recommendations to ICG / PTWS should be implemented.

On the other hand, at the meeting of CEPREDENAC in February of 2015, "the decision at the Regional Working Group for Central America of ICG/PTWS Third Meeting in September of 2014 " has been ratified. In response to this, the Minister of Foreign Affairs of Nicaragua has requested the assistance pertaining to the resolution on CATAC issue at IOC / UNESCO General Assembly in June 2015 to the Ministers of Foreign Affairs of the countries in Central America. From these, based on this trend, while achieving consistency, it is necessary to select and implement procedures for the CATAC approval.

4. Items to be improved in the Disaster Prevention System of the Six Countries of Central America

The items to be improved that are common to the seismic and tsunami disaster prevention system of the Central American region are as follows:

(1) Establishment of Backup System for Tsunami Warning

Regarding the seismic and tsunami monitoring system to be used in the tsunami generation judgment, the Central American countries always have a concern about an operational stop caused by the following "disorders": a) system stop by planned maintenance, b) system stop by planned power maintenance, c) system failure caused by the earthquake which is located just under the system's location, and d) failure of data acquisition function by a failure of the transmission system. In order to implement steady and stable tsunami warning system, it is necessary to have a backup function for the system. Establishment of CATAC has also been expected from the above viewpoint.

(2) Securing and Fostering of Human Resources related to Tsunami Warnings

It is not so easy to secure staff related to tsunami generation judgment in the Central American countries. They are making efforts to have officials with the required ability by implementing the following steps: a) existing international training system, b) construction of training programs in the country, and c) utilizing internships. From the above viewpoint, the "tsunami warning-related training" that targets the entire area of Central America for the establishment of CATAC is also expected.

(3) Support for the Organizations without the "24x7 contact" related to Tsunami Warning

In Central America, there are organizations, which have the responsibility to disseminate tsunami warnings that operate with a "24x7 contact". On the other hand, there are many countries whose organizations having the responsibility to judge tsunami generation, which technically do not have any "24x7 contact". For this reason, such countries expect the CATAC to function in the off-hours.

5. The Direction for Future Cooperation

5.1. A proposal on the Contents of Cooperation for Capacity Development of the Analysis for Earthquakes and Tsunami, and the Alert Dissemination of CATAC

5.1.1. The review of the Direction of Cooperation with CATAC

Towards solving the items to be improved (3.5 and 4), since CATAC is required to respond promptly to Regional Tsunami, the cooperation shall be implemented in two stages, namely one is the short term; to be done in first two or three years, and the other is middle-long term; to be done after the first considering the current circumstances of INETER.

(1) Emergency Response to the Short Term Items

It is necessary to cope with a Regional Tsunami which is feared to occur offshore of Central America in the near future under the existing resources as the short-term issues.

(2) Preparation for the Medium and Long Term Items

It is desired to assist a consideration (initiation of an experience) for the optimization of the deployment of seismic and tide gauge stations

As for supporting technical cooperation, it is necessary to cover not only practical technologies but also basic theory in terms of reliable implementation in addition to real time analysis and alert dissemination because the luck of fundamental ability is concerned. Thereby, it is better to aim for effective and efficient technology transfer to divide the contents of cooperation into a basic theory which is carried out by academicians and practical technologies which covered by JMA.

The components of cooperation in terms of the above-mentioned points are shown in the table below:

Table 5.1.1 The Assessment of Components for Cooperation

Items to be improved		Direction of Cooperation		
		Theme of cooperation	Components of cooperation	
			Basic theory	Practical technologies
CATAC				
Short Term Items	Improvement in earthquake analyzing ability by improvement in hypocenter calculation	・Utilizing a local seismic wave velocity structure model for hypocenter calculation ・Selection of observation station ・Error evaluation	・Utilizing method of seismic wave velocity structure model ・Evaluation and utilizing method for the result for the model	・Evaluation on the operation of model adoption ・The experience of hypocenter calculation
	Introduction of Focal Mechanism Analysis	・Introduction of analysis of focal mechanism with initial motion polarity ・Introduction of the CMT analysis	・Basic theory of the analysis of focal mechanism with initial motion polarity data	・Operation Procedure for initial focal mechanism analysis ・Experience for the improvement of operation on initial focal mechanism analysis
	Acquisition of the Technology for Tsunami Generation Judgment	・Selection of stations ・Introduction of the CMT analysis	・Basic theory of the hypocenter calculation ・Basic theory of the CMT analysis	・Operation Procedure for the hypocenter calculation ・Operation Procedure for the Selection of stations on the hypocenter calculation ・Experience for the improvement of the selection of stations ・Operation Procedure for the CMT analysis
	Estimation of Tsunami Height and Arrival Time and Introduction of the Standard for a Cancellation Procedure	・Utilizing existing best sea depth information ・Understanding the source process ・Tsunami propagation calculation technique	・Simulation technique for tsunami generation ・Basic theory of understanding the source process ・Basic theory of tsunami propagation calculation technique	・Operation procedure of the tsunami simulations
	Improvement of Existing Tidal Observation Facility	・Development of stable operation system ・Optimizing data receiving and transmission	・Basic theory for the optimization on a seismograph network ・Supporting the implementation of optimization	・Desirable network of seismic and tsunami station network ・Supporting the implementation of optimization
	Optimization of Central American Seismic and Tsunami Observation Network	・Assessment of the deployment of seismic and tsunami stations and optimization of an exchange system of seismic and tsunami wave data	・Optimizing the seismic and tsunami observation network	・Desirable seismic observation network of Central America on the operation
	Improvement of the Technology on Tsunami Generation Judgment	・Design of tsunami generation database	・Basic theory of tsunami generation judgment DB technology	・Designing of tsunami generation DB technology for the operation
	Optimization of the System for Providing the Six Countries in Central America with Seismic and	・Consideration on building a system in which the six countries in Central America can share the knowledge obtained in the course of the analysis for	(Not Applicable)	・Handing down of NWPTAC experience

	Tsunami Information	earthquake and tsunami observations. Introduction of the results into an existing system (optimization)		
		・Consideration on the technical and economic cooperation with the PTWC and NWPTAC	(Not Applicable)	・Handing down of NWPTAC experience
	Actions to the Items to be Improved in Six Countries in Central America	・Considering the items to be improved in the Six Countries and handing down the experiences of the Countries and Japan	(Not Applicable)	・Considering on the items to be improved of the Six Countries and handing down experiences of the Countries and Japan to INETER (・Application of International tsunami training system)
		・Implementation of training	・Support for holding training and workshops	・Making advice or support for training and workshops
Medium and Long Term Items	Newly Building and Increasing of Observation Facilities for Earthquakes and Tsunamis	・Considering the optimization of the deployment of seismic stations ・Considering the optimization of the deployment of tidal gauge stations	・Basic theory of optimization of seismic and tsunami monitoring network for tsunami generation judgment	・Desirable seismic and tsunami monitoring network for the operation
	Obtaining the Details of the Bathymetry	・Promotion of making the coastal bathymetric survey and arranging the results for their usage	・Basic theory of tsunami propagation calculation technology	・How to use Tsunami simulation technology for the operation
Items to be improved in the Six Countries				
	Establishment of Backup System for Tsunami Warning	・How to exhibit the functions as the backup	(Not Applicable)	・Considering on the items to be improved in the Six Countries and handing down experiences of the Countries and Japan to INETER
	Securing and Fostering of Human Resources related to Tsunami Warnings	・Supporting human resources fostering		
	Support for the Organizations without the “24x7 contact” related to Tsunami Warning	・How to exhibit the functions for the off-hours		

5.1.2. Contents of Support for the Establishment of CATAC

In order to exhibit the CATAC function accordingly, as contests of support from Japan to INETER for its enhancement in the ability of "earthquake and tsunami information analysis and issuance of warning", it can be proposed that the above-mentioned support matter should be implemented through the following three stages from the viewpoint of a more effective technology transfer. Specific support contents for basic theories and practical techniques will be examined below.

a. Fundamental theory: "Support for the acquisition of theory by university or research institutions (examples: hypocenter calculation basic, tsunami simulation technique method developed by a university)"

b. Practical technology: "The support with experience and know-how of the practice of the Japan Meteorological Agency (examples: the experience in the operation and improvement process of operational technologies)"

<table>
<tr><th colspan="3">Direction of support contents</th></tr>
<tr><th></th><th>Fundamental theory</th><th>Practical technology</th></tr>
<tr><td colspan="3">Step1 : Implementation of training with the themes as follows. The staff acquiring the technology of ①②③ should be employed as a lecturer of the seminars held in CATAC for the six countries in order to improve the efficiency of them</td></tr>
<tr><td rowspan="10"></td><td colspan="2">① The method of utilizing a local seismic wave velocity structure model for hypocenter calculation</td></tr>
<tr><td>a Model building technique
a Evaluation of the results of model application and how to use it</td><td>b Evaluation of the results of model application in the operation</td></tr>
<tr><td colspan="2">② Knowhow on selection of stations for hypocenter calculation</td></tr>
<tr><td>a Basic theory of hypocenter calculation</td><td>b Procedures of Hypocenter calculation in the operation
b How to select stations in the operation</td></tr>
<tr><td colspan="2">③ Introduction of analysis of focal mechanism with initial motion polarity</td></tr>
<tr><td>a Basic theory of analysis of focal mechanism with initial motion polarity</td><td>b Procedures of analysis of focal mechanism with initial motion polarity in the operation</td></tr>
<tr><td colspan="2">④ Experience of improvement of the above items</td></tr>
<tr><td></td><td>b Experience of improvement of anything in the operation</td></tr>
<tr><td colspan="2">The staff acquiring the technology of ①②③ should be employed as a lecturer of the seminars held in CATAC for the six countries in order to improve the efficiency of them</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="3">Step2 : Implementation of training with the themes as follows after completion or having the outlook for completion of Step1</td></tr>
<tr><td rowspan="2"></td><td colspan="2">⑤ CMT technology and the experience of improvement of it</td></tr>
<tr><td>aBasic theory of CMT analysis
a Basic theory of mechanics of tsunami generation</td><td>bProcedures of CMT analysis in the operation
b Process of the improvement of tsunami generation judgment</td></tr>
<tr><td colspan="3">Step3 : Considering the optimization of the deployment of seismic and tidal gauge stations, and optimizing a seismic and tidal gauge waveform data exchange system</td></tr>
<tr><td rowspan="14"></td><td colspan="2">⑥Considering the optimization of the deployment of seismic and tidal gauge stations, and optimizing a seismic and tidal gauge waveform data exchange system</td></tr>
<tr><td>aBasic theory of Optimizing the seismic and tsunami observation network</td><td>b How to optimize a seismic and tsunami observation network in Central America in the operation</td></tr>
<tr><td colspan="2">⑦Use of existing sea depth information, understanding source process, and tsunami propagation calculation technology</td></tr>
<tr><td>aBasic theory of source process, basic theory of tsunami propagation technology and development of tsunami hazard map (support)</td><td>b Tsunami simulation technology in the operation (example: TSUNAMI de EXCEL developed by JMA) and procedures of using it</td></tr>
<tr><td colspan="2">⑧Optimization of Central America Seismic and Tsunami Observation Network</td></tr>
<tr><td>aBasic theory of the optimization of a seismic and tsunami observation network and implementing the optimization (support)</td><td>bHow to optimize the Central American Seismic and Tsunami Observation Network in operation and implementing the optimization (support)</td></tr>
<tr><td colspan="2">⑨Designing of tsunami generation judgment DB</td></tr>
<tr><td>aBasic theory on the technology of tsunami generation judgment</td><td>bDesigning of tsunami generation judgment DB in the operation</td></tr>
<tr><td colspan="2">⑩Consideration of the system for sharing seismic and tsunami observation results, their analysis process, and the analysis results. Use of the results in consideration of the existing system (optimization)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">⑪Technical Cooperation with PTWC and NWPTAC</td></tr>
<tr><td></td><td>bHanding down of experience of NWPTAC</td></tr>
<tr><td>⑫Response to the Items of the Six Countries</td><td>bHanding down of experience of NWPTAC</td></tr>
<tr><td></td><td>b Through considering on the items to be improved of the Six Countries (Source. Table 5.1.1), handing down the experiences of the Countries and Japan to the CATAC candidate organization</td></tr>
</table>

5.2. A proposal on the Contents of Cooperation for Capacity Development of the Analysis for Earthquakes and Tsunami of El Salvador

Based on the items to be improved for earthquake and tsunami monitoring and analysis, the following contents of cooperation can be proposed.

In a specific implementation, the contents below should be classified into “a” and “b” (described above).

<table>
<tr><th colspan="2">Direction of support contents</th></tr>
<tr><th>Fundamental theory</th><th>Practical technology</th></tr>
<tr><td colspan="2">① Analysis of the information in seismic parameters and improvement of the calculations</td></tr>
<tr><td>a Basic theory of improvement of accuracy of depth in hypocenter determination and any development (support)</td><td>b Know-how for improvement of the accuracy of depth in hypocenter determination a in the operation</td></tr>
<tr><td colspan="2">Support for the development of improvement of hypocenter depth in the determination (one week training for one developer)</td></tr>
<tr><td colspan="2">② Improvement of analysis of broadband seismometer data</td></tr>
<tr><td>a Provision of the software for CMT analysis and training on how to use it</td><td>b Know-how for CMT analysis in the operation</td></tr>
<tr><td colspan="2">Provision of the software for CMT analysis and training on how to use it (One week training for all members who should take the monitoring shift</td></tr>
<tr><td colspan="2">③ Analysis of the information for tsunami warning and disaster prevention, and its improvement</td></tr>
<tr><td>ditto</td><td>ditto</td></tr>
<tr><td colspan="2">④ Strain analysis with GPS measuring</td></tr>
<tr><td>a Training on how to analyze crustal stress information with GPS measuring and use of the information for disaster mitigation</td><td>b Training on how to analyze crustal stress information with GPS measuring and use of the information for disaster mitigation</td></tr>
<tr><td colspan="2">⑤ Understanding the system and the functions of the seismic and tsunami warning center of JMA, and the application of the functions to El Salvador as much as possible</td></tr>
<tr><td>a Candidate theme 4: The feature of seismic tectonics around Japan and its relation to seismic observation</td><td>Provision of experience of improvement in JMA
b Candidate theme 1 Shortening of the time between the occurrence of an earthquake and issuance of a tsunami warning I and the process of setting tsunami generation judgment criteria
b Candidate theme 2 How to cancel tsunami warning and its criteria
b Candidate theme 3 ”Tsunami Earthquake” and how to handle gigantic earthquakes</td></tr>
<tr><td colspan="2">Provision of experience of improvement in JM（Training：for all staff related to tsunami warnings through extracting three or four themes. Each theme should be handled by one week training.）</td></tr>
</table>

【List of collected materials】

NIcaragua

- 50 Mapas Amenaza Tsunami Nicaragua y Golfo Fonseca
- CODE　DEFENSACIVIL　PROTOCOLO　tsunami (2013)
- Evaluacion Tsunami INETER　SNET 12 NORWIN
- Exposición Simulacro General ante Tsunami code (2013)
- ICG/PTWS Twenty-fifth Session (2013)
- INFORME DE CIERRE SISMICIDAD 10 ABRIL B (2014)
- Informe Final II reunión Tsunami CA230633S (2014)
- INFORME PARA PRESIDENCIA AFECTACION DE TSUNAMI EL SALVADOR (2012)
- Informe sismo 13 octubre 2014 correduria _ seguro
- Informe-6-octubre-2AM_revLBA_96ppi (2012)
- Ley 337_SINAPRED
- Lista de personal de sismologia2014
- MANUAL DE PROTOCOLOS 300714 4pm (1) (2014)
- Presentaciones INETER (2014)
- PROTOCOLO INETER DGG (2013, 2014)
- Proyecto de Amenaza Sísmica RESIS-II
- Proyecto JICA 2006
- Red Sísmica y mareográfica
- Reglamento Nacional de la Construcción RNC- 07
- SINAPRED 210115
- Sistema adquisición y procesamiento sísmico INETER DIC 2014
- SCS/WG First Meeting (2011)
- SCS/WG Second Meeting (2012)
- TSUNAMI MAPAS

El Salvador

- amenaza-riesgo-sismico
- Amenaza-riesgo-tsunami
- 2012-08-26-sismo
- Norma　Tecnica　sismocig.ULT(1994)
- PRESUPUESTOS 2009-2014
- Protocolo-tsunami (2013)
- Recopilación de Leyes, Reglamento y Norms

Guatemala

- Boletin Sismolgia (1977)
- Communidad en la Isla de Méndez (2013, 2014)
- Informe　Especial　Alerta　Tsunami　1200 (2011)
- Network_Guatemala (2014)

Costa Rica

- Costa Rica Geologic Data
- Plan Gestión del Riesgo (for 2015)
- La Declaración del Estado de Emergencia en Costa Rica (2014)
- RSN UCR-ICE, RED SISMOLÓGICA NACIONAL
- TrainingManual　TWTools　mar14 (2008-2014)
- Tsunamis Simposio Nicoya Gino 11-12-2014
- Tsunamis Simposio Nicoya Juan Luis 11-12-2014

Panama

- El Volcan Baru lo que debemos saber de un gigante dormido
- Estaciones Sismologicas Noviembre 2014

・Instructivo Interno de Procedimeintos Red Sismica de Geociencias (2012)
・MAPA PGA
・Mapas de Aceleración
・MONITOREO SISMICO EN PANAMA (2014)
・Plan Nacional de Respuesta a Emergencias (2009)
・PLAN TSUNAMI VERSION 4 DIC.2012
・Presupuesto Geociencias 2014.
・Project Highlights Ciudad de David_Español (2012)
・Resumen Ejecutivo TAP Ciudad de David (CAPRA) (2012)
・Sistema Nacional de Protección Civil República de Panamá (Manual, 2012)
・STRI Physical Monitoring Program 2014 SINAPROC

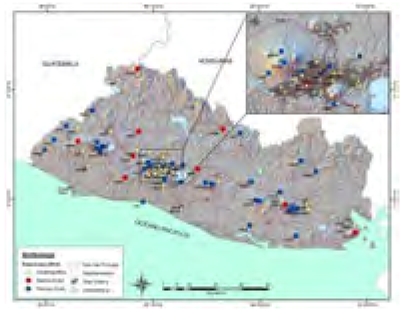
Honduras

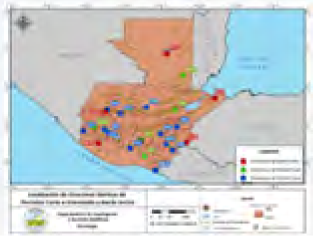
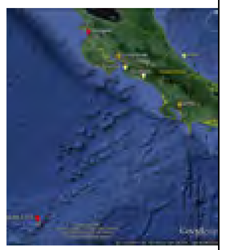
・ANE12- protocolos de respuesta CODEM DC A03 (2013)
・Coiegio de Ingenieros Civiles de Honduras (2008) Codigo Hondureno de Construccion
・Expo. Catalogo Sismico Honduras 1956-2011
・Diagnostico Análisis de Vulnerabilidades y Capacidades del Caserío de San Isidro, Marcovia.(2014)
・Diagnostico Análisis de Vulnerabilidades y Capacidades dela Comunidad de Cedeño, Marcovia. .(2014)
・Informe Catalogo Sismico de Honduras (2012)
・Informe del mes de NOVIEMBRE Proyecto Berrinche y Reparto
・Informe Microzonation Glosario (2013)
・Ley del sinager_en
・Pacific SL Stations 2013
・Presentacion de Honduras en SAT COPECO (1)
・Presentacion Red Sismica de Copeco
・PTWC Operations Manual V1.3.5 (2011)
・Tsunami hazard modeling (2013)

Appendix 1

Summary Chart of the Current Situation of the Six Countries of Central America

Appendix 1 Summary Chart of the Current Situation in the six countries of Central America

Institutes	Capacity of Earthquake and Tsunami Observation and Data Processing						Warning Information to NC		Challenge
	Operation System	Earthquake Observation	Tsunami Observation	Data Processing	Expectation on CATAC	Improvement	Current Status	Improvement	
Nicaragua Nicaraguan Institute of Territorial Studies (INETER)	・INETER has nine members of staff who are in charge of the duty in the Seismic Monitoring Center. It has the "24x7 contact" by two members in principal. ・Two members in the Center are: one from the Seismic Section of INETER and one from the Office of the President (during a special period like the Christmas Season the Office of the President dispatches two. That makes three at a time.)	・ The observation network is composed of 21 broadband (BB) seismometers, and 45 short period (SP) seismometers. ・ Monitoring 347 seismometers, including those from the Incorporated Research Institutes for Seismology (IRIS), the five other Central American countries and its own network. ・ The data from its own network are collected over digital radio, internet, or the optical fiber owed by the state-owned distribution company in real-time. The data from IRIS and the five other Central American countries are collected by commercial internet.  Seismometer Locations of Nicaragua	・ There are two tidal gauge stations located at Corinto and Sandino on the Pacific Coast. There are two more at San Juan del Sur and Masachapa on the Pacific side, but they are out of order now. ・ The sampling rate is ten minutes. That means the current observation conditions are not appropriate for tsunami monitoring.	・Data processing system: Seisan, Earthworm and SeisComP (since 2004) ・SeisComP3can handles automatic observation data collection, analysis, and issuance of the results. It calculates origin time, hypocenter, and magnitude. The calculation can be finished within two or five minutes. (Seisan is useful for batch processing.) ・The analysis of focal mechanism with initial motion polarity data is made, but the results of the analysis is not used for tsunami generation judgment systematically. CMT analysis is not handled yet. ・As for the seismic wave velocity structure, the local one is adopted, but has not yet been evaluated systematically. In the case of a large earthquake, the information of the following institutes is checked: United States Geological Survey (USGS), Pacific Ocean Tsunami Warning Center (PTWC), and Global Earthquake Network (GEOFON). ・SeisComP3 has a CMT analysis function, but the license for using the function is not free.	・ INETER is expecting that the function of CATAC will improve the capacity of monitoring Regional Tsunamis. ・ Regarding seismic observation, the system for seismic data processing has already been made uniform by introducing SeisComP, and the data format has also been unified by introducing SEED. ・ INETER is planning to set up the "Earthquake Monitoring Network of Central America" and to use this function for CATAC. (CEPREDENAC's status: in June of 2014, SICA held a regular meeting, where the regional cooperation on seismic observation was agreed according to the proposal from the president of Nicaragua. Further, the SICA decided that the subject of "CEPREDENAC's involvement in the establishment of CATAC" should be discussed at the "Advisory Committee with representatives" in coming February 2015.	・Systematical evaluation of the local seismic velocity structure model for hypocenter determination, and the adoption of the results ・Selection of seismic stations to be used for hypocenter determination ・Introducing the real time initial motion analysis for focal mechanism into the current official procedures of tsunami generation judgment ・Introduction of the CMT analysis ・ Acquisition of techniques for tsunami generation judgment ・Introducing procedures for the estimation of tsunami height and arrival time and criteria for tsunami warning cancellation ・Installing new tidal gauge stations ・Establishment of a system for the stable operation of tidal gauges ・Reinforcement of networks of the type of DART	The criteria for tsunami generation is that the M is larger or equal to 6.8 and that the hypocenter is shallower or equal to 60 ㎞. When the staff in the Earthquake Monitoring Center notices any information satisfying the criteria, the staff should immediately issue the information to the office of the President, SINAPRED and CODE simultaneously with VHF-radio, telephone and E-mail. (In the case of Earthquakes, near ones is >=3.4, regional ones M>=4.0, and distant ones M>=6.0) CODE is able to monitor the websites of INETER through the Internet. (Events of above M7.0 on the Pacific Coast area in Central America are handled without indication from the President by Co-Direcciones de SINAPRED based on its own judgment.)	・Establishment of tsunami generation judgment ・Improvement of the Warning Issuance system	Items for Enforcement of Functions of CATAC 1. **Short Term Items** (1)Improvement in earthquake analyzing ability by improvement in hypocenter calculation (2) Introduction of Focal Mechanism Analysis to tsunami generation judgment (3)Acquisition of the Technology for Tsunami Generation Judgment (4) Introduction of the Estimation of Tsunami Height and Arrival Time and the Standard of Cancellation Procedure (5) Improvement of the Existing Tidal Observation Facility (6) Optimization of the Central American Seismic and Tsunami Observation Network (7) Improvement of the Technology on Tsunami Generation Judgment (8) Optimization of the System for Providing the Six Countries in Central America with Seismic and Tsunami Information (9) Actions to the Items to be Improved in Six Countries in Central America 2. **Medium and Long Term Items** (1) Newly Building and Increasing of Observation Facilities for Earthquakes and Tsunamis (2) Obtaining the Details of the Bathymetry
El Salvador Ministry of Environment and Natural Resources / Environmental Monitoring Division (MARN/DGOA)	DGOA has five members of the staff who are in charge of the duty in the Monitoring Room. It has the "24x7 contact" by one member.	・96 earthquake observation stations (in which there are ten BB). Data exchanged with Nicaragua and Guatemala. Regional shear wave velocity model is used. Focal mechanism analysis performed with initial wave. ・ Data were collected by internet, radio and microwave.  Seismometer Locations of El Salvador	・There are three tidal gauge stations located at Acajutla, La Libertad and La Unión, and with two monitoring video-cameras at Acajutla and La Liberta. The camera can see the stations.	・ CMT analysis is not handled yet. Estimation of tsunami arrival times and tsunami height are not issued. ・ Tsunami simulation is not used in real time procedures, though it is used in a review process at later time. ・The target is set that hypocenter and magnitude should be obtained within ten minutes after the occurrence of the event, and that the information issued should reach the population through DGPC within twenty minutes. ・The automatic data processing needs about two minutes after the detection of the event. The official results after the manual confirmation will be released in about fifteen minutes. ・Estimated tide is calculated. ・ Information from the video –cameras can be monitored at DGOA.	・MARN/DGOA has sufficient ability for tsunami analysis, but its experience for monitoring and warning issuance are so small. It thus expects establishment of CATAC for Regional Tsunami. It expects CATAC as a backup monitoring system. ・The staff having knowledge about ground features are shortage. ・The themes of the training related to CATAC should be "tsunami simulation technology" and "judgment of Tsunami Earthquake".	・ Adoption of seismic velocity structure mode. ・ Selection of stations for hypocenter calculation. ・Station Correction ・Evaluation of accuracy of depth ・Introduction of initial motion focal mechanism analysis ・ Introduction of CMT analysis ・Acquisition of tsunami generation judgment technology ・Estimates of tsunami height and tsunami arrival time ・Newly installation of tidal gauge stations	Dissemination of hypocenters and magnitudes to DGPC within ten or fifteen minutes with radio, fax, cellphone and email. Publicizing at web-site at once.	・Establishment of tsunami generation judgment ・Improvement of Warning Issuance system ・Establishment of the dissemination root to the population	Items for MARN/DGOA (1)Analysis of the information of seismic parameters and improvement of the calculations (2)Improvement of the analysis of broadband seismometer data (3)Analysis of the information for tsunami warning and disaster prevention, and its improvement (4)Understanding the system and the functions of the seismic and tsunami warning center of JMA, and the application of the functions to El Salvador to the furthest extent possible (5) Strain analysis with GPS measuring

Guatemala National Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH)	・INSIVUMEH has five members of staff who are in charge of the duty in the Seismic Analysis Room. It does not have the "24x7 contact", and the staff in charge of the duty can make remote-access to the system for analysis during off-hours. Note that it has the "24x7 contact" at ALFA that should issue the tsunami information.	・ The earthquake observation network is eight analog, ten BB and twelve SP. The installation for SP was finished, waiting for communication work. ・ There are five accelerometers (SM) at the same location with BB. The data from analog seismometers are collected by radio and the others by satellite or internet.  Seismometer Locations of Guatemala	・For the Pacific Coast side, there is one tidal gauge station located at Puerto Quentzal. But it is out of order now. The one on the Caribbean Coast side, there is one at Puerto Barrios. And it has sensors of radar and pressure. The observed data are sampled every minute, and the sampled data are averaged every five minutes.	・There is no tsunami monitoring system. ・Regarding the judgment of the issuance of tsunami information for warnings, PTWC and DART data are used for distant earthquakes, and seismic information of its own is used for near earthquakes. Tsunami warning dissemination criteria is above Magnitude 7.8	・Seismic information analysis should be relied on automatic processing. And tsunami generation judgment is relied on the information from PTWC. Therefore the information from CATAC for Regional Earthquakes is expected. ・The themes of training related to CATAC should be tsunami modeling, and tsunami vulnerability modeling . ・Expectation on fostering staff about semiology or oceanology.	・Acquisition of tsunami generation judgment technology ・Introduction of initial motion focal mechanism analysis ・Estimates of tsunami height and tsunami arrival time ・Stabilizing tidal observations	ALFA disseminated seismic and tsunami information to SINAROC, and mass media with fax, telephone email, and twitter. (Tsunami judgment is done by the President of Science Committee in CONRED) Earthquakes above M7.8 are handled as tsunami warning events.	・ ・Establishment of tsunami generation judgment ・ Improvement of Warning Issuance system ・ Establishment of the dissemination root to the population	
Costa Rica National University Tsunami Monitoring Office (SINAMOT) Volcanological and Seismological Observatory of Costa Rica (National University of Costa Rica) (OVSICORI) National Seismological Network (RSN) Seismic engineering laboratory (LIS)	・There are three seismic observation institutes, OVSICORI, RSN and LIS. ・The organization for tsunami information issuance is SINAMOT. ・RSN has four members in charge of monitoring. They will do the work at home during off-hours. ・OVSICORI has twenty four members in charge of monitoring .They will also work at home during off-hours. ・SINAMOT has four members in charge of monitoring .They will also work at home during off-hours.	・ The earthquake is announced in the sequence of LIS, RSN (with epicenter map) and OVSICORI (with tectonics of event). ・ LIS has 100 SM and 80 of them are in operation. ・RSN (collaboration of ICE and UCR) uses the data from 86 earthquake observations stations (BB and SP) from domestic and abroad. 90 SP will be installed in three to four months. One BB in Coco Island, which is important for improving the accuracy of hypocenter calculation. 15 BB from IRIS is used. The data form Nicaragua and Panama is used for the calculation of Mw manually. ・ OVSICORI has 80 earthquake observations (SP and BB). The automatic data collection, processing and information dissemination was currently done by Antelope. Most of the seismometers are also connected to SeisComP, which will be used routinely in 2015. The manual processing is basically not for the events which occur outside of Costa Rica. The earthquake information is provided to CNE, but tsunami is not covered. There is cooperation with LIS but not with RSN and data exchange.  Seismometer Locations of Costa Rica	・There is only one tidal gauge station in the country. Its location is Los Suenos on the Pacific Coast side. 	・Information from PTWC is used for the judgment of tsunami warning for distant earthquakes. ・Estimation of tide is calculated. ・RSN uses the local seismic velocity structure mode. Automatic seismic data processing is handled by SeisComP. Manual processing is done by the software developed by them. The automatic results are obtained in one or three minutes for M6.0 earthquakes. The reliable results are obtained in seven minutes at the fastest. ・OVSICORI uses local seismic velocity structure model. Focal mechanism analysis with initial motion polarity data is done in the case of large earthquakes. CMT analysis is not handled yet. ・SINAMOT issues tsunami information relate to tsunami warning when the event is above Mw6.5. The warning category should be changed according to estimated tsunami arrival time. If it is less than three hours the category should be re… Tsunami simulation results are referred.	・Seismic information is relied on automatic processing. Tsunami generation judgment is relied on PTWC and SNAMOT that has no 24x7 contact. The information from CATAC for Regional Earthquakes is expected. ・The themes of training related to CATAC should be the role of CATAC.	・Acquisition of tsunami generation judgment technology ・Introduction of initial motion focal mechanism analysis ・Estimates of tsunami height and tsunami arrival time ・Stabilizing tidal observations	SINAMOT issues seismic information to CNE with telephone. Earthquakes occurred around subduction and outer-rise is handled as tsunami warning events.	・ Establishment of tsunami generation judgment ・ Improvement of Warning Issuance system ・ Establishment of the dissemination root to the population	

Panama University of Panama, Institute of Geosciences (IGC/UPA)	IGC has five members in charge of monitoring in the Monitoring Room. It does not have the "24x7 contact", but designates one member in turn. The staff will receive results of automatic analysis by emails. When they receive emails, they come to the office for handling the issue during off-hours.	・ The earthquake observation network has 66 SM and SP and nine BB. Approximately 70 are in operation. ・ The Authority of Panama Canal (ACP) has six SM and SP. The data was transmitted to IGC.  Seismometer Locations of Panama	・ There is only one tidal gauge station in the country. Its location is Porvenir on the Caribbean side.	・Automatic processing is handled by Seisan. The results are obtained within ten minutes. ・The result from automatic processing are automatically issued with SMS and e-mail. If it is evaluated as appropriate, no more issuance will be done. ・The results form manual processing are also issued. ・ As for the seismic wave velocity structure, the local one is adopted.	・Panama has several concern on large earthquakes related to Tsunami. Therefor it expects the analysis results from CATAC. ・ Nicaragua has experience. Therefore it is agreeable that CATAC is set in Nicaragua. ・The themes of training related to CATAC should be basic knowledge on tsunami warning, how to monitor web-sites and how to analyze the information from CATAC. Additionally, the item related to establishment of CATAC and experience in Japan related to tsunami warning.	・Enforcement of Seismic Observation Network ・ Improvement of Earthquake analysis ability with hypocenter calculation improvement ・Acquisition of tsunami generation judgment technology ・Introduction of initial motion focal mechanism analysis ・Estimates of tsunami height and tsunami arrival time ・Newly installation of tidal gauge stations	・ Automatic processing is handled by Seisan. ・The result from automatic processing are automatically issued with SMS and e-mail. If it is evaluated as appropriate, no more issuance will be done. ・The results form manual processing are also issued with SMS, e-mail and web-sites. If necessary with radio or satellite phone. To SINAPROC, if necessary, with satellite radio.	・ Establishment of tsunami generation judgment ・ Improvement of Warning Issuance system ・ Establishment of the dissemination root to the population	
Honduras Permanent Commission of Contingencies (COPECO)	COPECO has nine members of staff who are in charge of the duty in the Monitoring Center. It has the "24x7 contact" by two members.	・ The earthquake observation network has ten SP and one BB, connected by internet.  Seismometer Locations ofHonduras	・As for tidal gauge stations, there are ten which are currently. Three of them are located on the Pacific Coast and seven on the Caribbean Sea Coast. The exact three locations of the Pacific coast are: one at San Lorenzo port and two on the Tigre Island.	・Data processing with the national seismic network is handled only with automatic processing, not with manual processing. ・As for Near Earthquakes ad Regional Earthquakes, tsunami generation analysis for the events above M6.0, is done by the information of PTWC and foreign institutes. ・ Hypocenters and magnitude of USGS are prioritized for use among those of foreign institutes. ・ As for Near Earthquakes with strong motion felt on the coastal area, tsunami warning should be disseminated by Warning Committee held within ten minute after the occurrence.	・It is desired to handle tsunami without PTWC . The information analyzed in Central America region is desired. Thus CATAC is expected a lot. ・The themes of training related to CATAC should be basic theory and practical items.	・Acquisition of tsunami generation judgment technology ・Acquisition of seismic and tsunami information analysis technology ・ Optimization of maintenance of monitoring system ・Enforcemen tof tunai observation network	・The results of observation andanalysis at the monitoring Center are issued to SAT, through Preparation and Respons Director sent to the Director-General of CO`ECO. The SAT forwards the information to UNAH/IHCT. With the evaluation at UNAH/IHCT, The Director –General decide the category of warning. The decision is disseminate through PR office and to Regional COMECO municipal government. It disseminates the information to Communities.	・ Improvement of Warning Issuance system ・ Establishment of the dissemination root to the population	

Appendix 2

Assessment of Components for Cooperation

Appendix 2　Assessment of Components for Cooperation

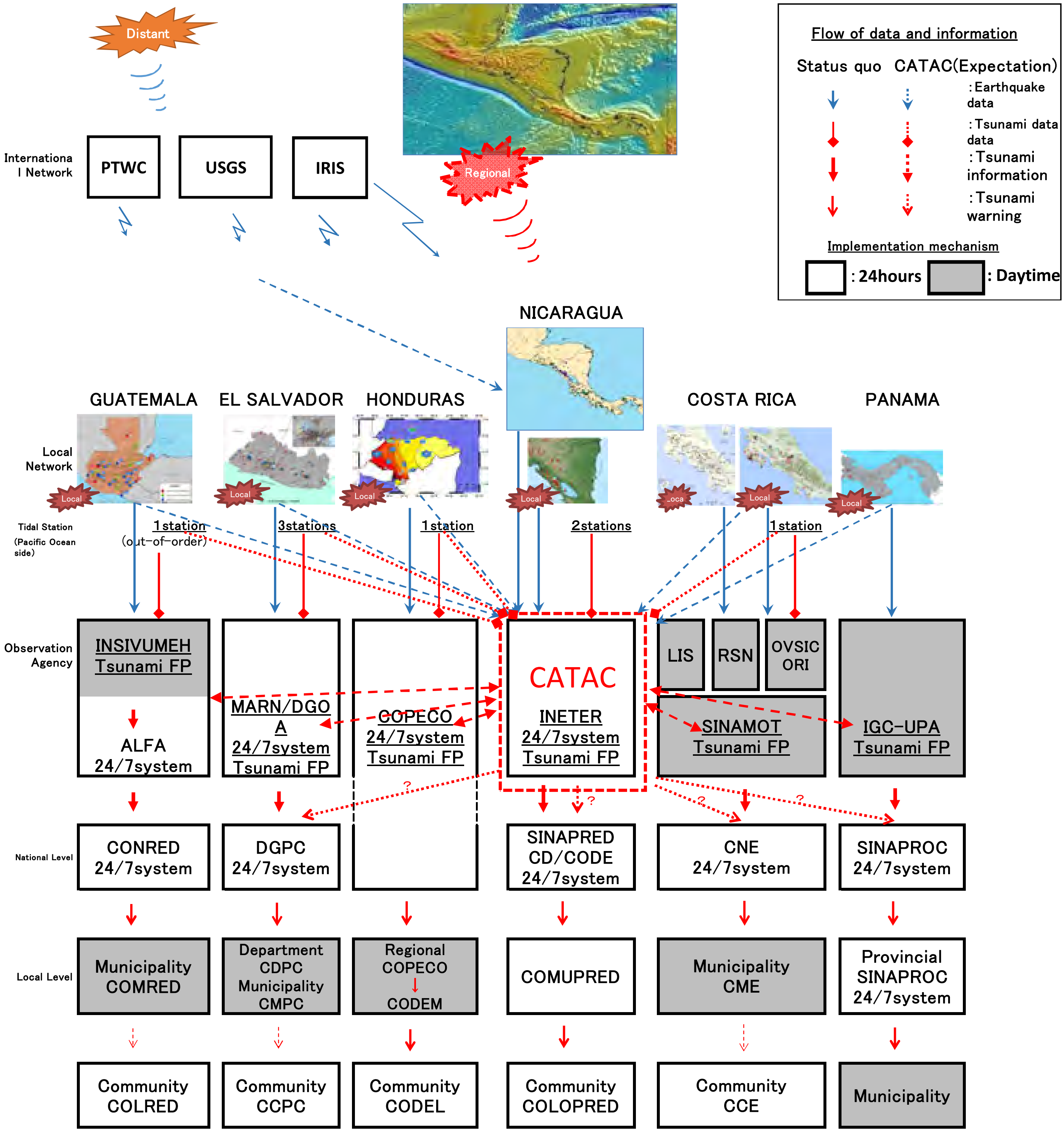
Item to be Improved			Direction of Cooperation			Abstract of Cooperation
			Necessary Item	Basic theory	Practical technologies	
Nicaragua　CATAC						
1. Short Term Items	Step1	(1) Improvement in earthquake analyzing ability by improvement in hypocenter calculation	1) Methodology of utilizing a local seismic wave velocity structure model for hypocenter calculation 2)How to select observation stations, error evaluation	・Utilizing method of seismic wave velocity structure model ・Evaluation and utilizing method for the result for the model ・Basic theory of hypocenter calculation	・Evaluation on the operation of model adoption ・The Operation Procedure of hypocenter calculation ・Operation Procedure for the Selection of stations on the hypocenter calculation	**１． Capacity Development for Seismic Parameter Analysis by Utilizing Data of Central America** 1-1Instructing the hypocenter calculation by utilizing seismic waveform data from the countries of Central America (CA) 1-2Instruction of the analysis of focal mechanism with initial motion polarity data 1-3Instruction of the CMT analysis 1-4Reflecting 1-1～3 to operation
		(2) Introduction of Focal Mechanism Analysis	3) Introduction of analysis of focal mechanism with initial motion polarity 4) Experience of improvement in operation	・Basic theory of the analysis of focal mechanism with initial motion polarity data	・Operation Procedure and experience for initial focal mechanism analysis	
	Step2	(3) Acquisition of the Technology for Tsunami Generation Judgment	5) CMT technology and the experience of improvement of it, ・Selection of stations ・Introduction of the CMT analysis	・Basic theory of the CMT analysis ・Basic theory of mechanics of tsunami generation	・Operation Procedure and experience for the CMT analysis ・Process of the improvement of tsunami generation judgment	
	Step3	(4) Introduction of the Estimation of Tsunami Height and Arrival Time, and Standard of Cancellation Procedure	6) Utilizing existing best sea depth information, Understanding the source process, tsunami propagation calculation technique	・Simulation technique for tsunami generation ・Basic theory of understanding the source process ・Basic theory of tsunami propagation calculation technique	・Operation procedure of the tsunami simulations（ex. TSUNAMI de EXCEL of JMA）	**２． Development of the Implementation System for Quantitative Prediction of Tsunami** 2-1Instructin for establishment of data base for quantitative estimation of Tsunami 2-2 Lecture of tsunami propagation simulation 2-3Reflecting 2-1,2 to operation
		(5) Improvement of Existing Tidal Observation Facility	7) Development of stable operation system, Optimizing the data receiving and transmission	・Basic theory for the optimization of seismograph network ・Supporting the implementation of optimization	・Desirable network of seismic and tsunami station network ・Supporting the implementation of optimization	
		(6) Optimization of Central America Seismic and Tsunami Observation Network	8) Assessment of deployment of seismic and tsunami stations and optimization of exchange system of seismic and tsunami waveform data	・Optimizing the seismic and tsunami observation network	・Desirable seismic observation network of Central America on the operation	
		(7) Improvement of the Technology on Tsunami Generation Judgment	9) Design of tsunami generation database	・Basic theory of tsunami generation judgment DB technology	・Designing of tsunami generation DB technology for the operation	
		(8) Optimization of the System for Providing Six Countries in Central America with Seismic and Tsunami Information	10) Consideration on building a system in which the six countries in Central America can share the knowledge obtained in the course of the analysis for earthquake and tsunami observations.	(Not Applicable)	・Handing down of NWPTAC experience	**３． Capacity Development for the Issuance of Regional Tsunami Advisory Information of CATAC** 3-1Development and revision of operation procedure of CATAC 3-2Implementation of training for the issuance of advisory information 3-3Implementation of joint training of the six countries of CA for the issuance of advisory information(TWFP) 3-4 Implementation of joint training of the six countries of CA for the issuance of advisory information(TNC) 3-5Workshop for the lessons of training and the points of improvement
			11) Consideration on the technical cooperation with the PTWC and NWPTAC	(Not Applicable)	・Handing down of NWPTAC experience	
		(9) Actions to the Items to be Improved in Six Countries in Central America ・Strengthening of warning system ・Human development ・Support to Tsunami warning organization	12) Considering on the items to be improved of the Six Countries and handing down experiences of the Countries and Japan	(Not Applicable)	・Through considering on the items to be improved of the Six Countries and handing down experiences of the Countries and Japan to the CATAC candidate organization （・Application of International tsunami training system）	**４． Building the system for development of human resources** 4-1Imprementatin of training for the countries of CA in CATAC 4-2 Workshop for revision of standard operation procedure of CATAC
			13) Implementation of training	・Support for holding trainings and workshops	・Making advices or supports for trainings and workshops	
2. Medium and Long Term Items		(1) Newly Building and Increasing of Observation Facilities for Earthquakes and Tsunamis	・Newly Building and Increasing of Observation Facilities	・Optimization of seismic and tsunami monitoring network for tsunami generation judgment	・Operation Procedure of seismic and tsunami monitoring network for the operation	（Above1,2 serves fundamental part of this components）
			・Considering the optimization of the deployment of seismic stations, Considering the optimization of the deployment of tidal gauge stations	・Basic theory of tsunami propagation calculation technology	・How to use Tsunami simulation technology for the operation	
		(2) Obtaining the Details of the Bathymetry	Promotion of making the coastal bathymetric survey and arranging the results for their usage	・Basic theory of tsunami propagation calculation technology	・How to use Tsunami simulation technology for the operation	
			・Designing of tsunami generation judgment DB	・Basic theory on the technology of tsunami generation judgment	・Designing of tsunami generation judgment DB in the operation	

El Salvador MARN/DGOA				
(1) Improvement of the analysis of the information in seismic parameters	① Improvement of the analysis of the information in seismic parameters and the calculations	・Basic theory of f seismic parameters analysis	・Provision of introduction of technology and experience	**１．Capacity Development for Observation and Analysis of Earthquake** 1-1Lecture on the seismic information analysis
(2) Improvement of analysis of broadband seismometer data	② Improvement of analysis of broadband seismometer data	・Basic theory of analysis of broadband seismometer	・Provision of introduction of technology and experience	1-2Lecture on the analysis utilizing broadband seismometer
(3) Improvement of Tsunami Warning	③ Improvement of analysis of the information for tsunami warning and disaster prevention	・Basic theory of Tsunami simulation	・Provision of experience	1-3 Lecture on the simulation of tsunami propagation
(4)Introduction of Strain analysis with GPS measuring	④ Strain analysis with GPS measuring	Training on how to analyze crustal stress information with GPS measuring and use of the information for disaster mitigation		1-4 Lecture on the analysis of crustal stress information with GPS
(5) Provision of experience of improvement in JMA	⑤ Understanding the system and the functions of the seismic and tsunami warning center of JMA, and the application of the functions to El Salvador to the extent of possible	・The feature of seismic tectonics around Japan ・Support of training	・Process of shortening of the time between occurrence of earthquakes and issuance of tsunami warning, and the process of setting tsunami generation judgment criteria ・How to cancel tsunami warning and its criteria ・"Tsunami Earthquake" and how to handle gigantic earthquakes	**２． Improvement of the Protocol for Tsunami Warning** 2-1Improvement of protocol for tsunami warning by relevant organizations of earthquake and tsunami 2-2Implementation of response training for earthquake and tsunami 2-3Evaluatin of training

Appendix 3

Flow of Earthquake and Tsunami Information in Central America

Appendix3:The Flow of Earthquake and Tsunami Information in Central America and CATAC



Local Tsunami : A tsunami which its destructive effects are confined to the coast of country within 5 to 30minutes from the time of event nearby source .
Regional Tsunami : A tsunami capable of destructive effects are confined to coasts within 30minites to 2hour from the time of event at the offsore of Central America.
Distant Tsunami : A tsunami capable of destructive effects are confined to coasts more than 2hour