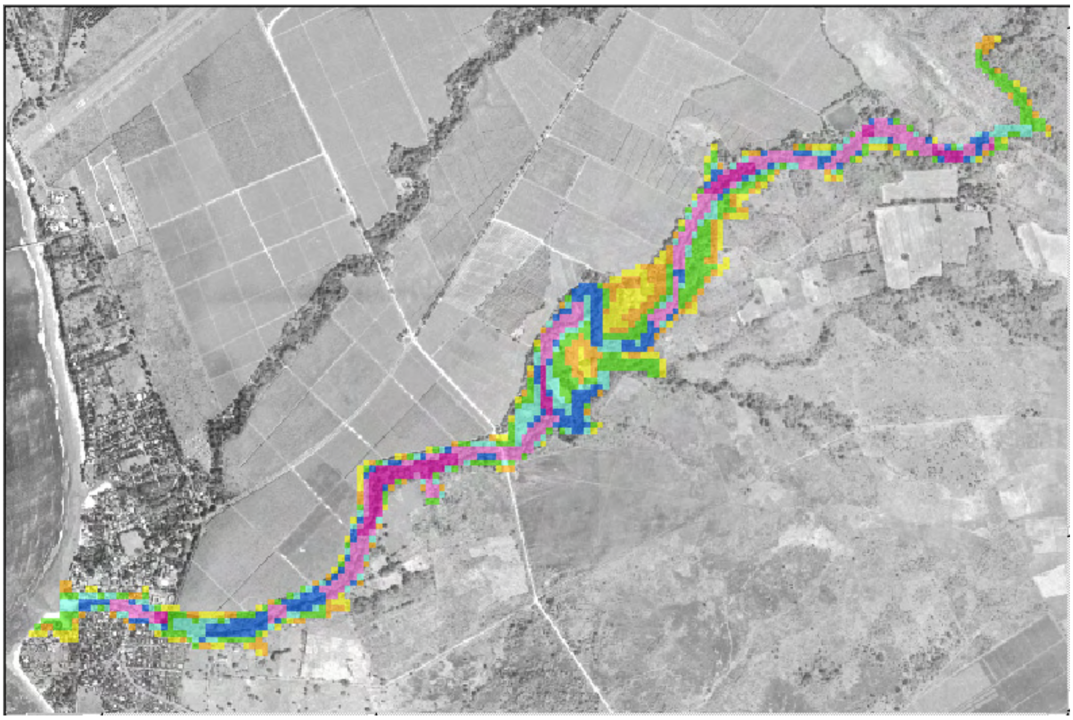


Figure 8-56 Return Period 200 Years

8-3-7 Framework of Flood Hazard Map

The results of the simulation calculation show only inundation areas at a time of flood based on the assumptions. A hazard map is an easy-to-use representation of such technological information for disaster prevention activities. It is necessary to determine the dimension of a hazard map, appearance, the contents, etc. after thorough discussions with users. Considering the situation, the Study Team created a draft of a hazard map; the counterpart and the Study Team had a series of discussions and confirmed on the contents. Then, the final draft was prepared.

(1) Presentation of the draft hazard maps

During the fifth work in Japan, the draft hazard maps were prepared; the Study Team presented the maps to the counterpart. After four or more explanation and discussion sessions, the final draft hazard maps came to an agreement.

1) Characteristics

The hazard maps are defined as the maps, which indicate information relevant to the inundation estimation areas so that disaster prevention persons in charge utilize for disaster measures. The target users are the staffs in the central government and the disaster prevention person in charge in local governments. Departments, such as the police and fire fighting, are also included and disaster prevention persons in charge do not necessarily have the knowledge of hydrology or river engineering. Therefore, we decided to consider not to include technical description; rather, the contents are intelligible. Also and are devised in a way for local residents to know and understand.

2) Contents and expressions

The specifications of the map based on the concept described are explained as follows.

(a) Format and quantity

Since a large number of people need to use simultaneously in order to use for disaster measures to survey a wide area, a large-sized map is required. A handout type needs to be prepared for local residents. Considering the two points mentioned, the Study Team has decided to prepare two kinds: type G (large A1 size) and type P (general letter size). The general size is the common letter size for documentation in Nicaragua, which can be reproduced easily using a printer or a copier.

type G (Grande) (for municipality) A1 (59.4cm * 84.1cm) size

It is the size, which can be posted on a large-sized wall, and it is targeted to be used for disaster prevention activities by disaster prevention organizations. Fifty copies were produced for mainly supplying to disaster prevention organizations.

type P (Pequeno) (for residents) Letter (8.5 inches * 11inches) size

The handouts to residents are assumed to be provided by local governments themselves. Therefore, a letter size format in black and white, which enables low cost and easy production, is suitable. Then, the data are provided in the pdf format so that even a low-spec PC would be able to manage printing. The format of the data is the letter size for the purpose of producing photocopies. The depths of water are expressed by hatching in the legend on the assumption that the output is in monochrome. We decided to provide 50 copies as sample.

(b) Expression of a flood assumption zone

Although the calculation result of a flood assumption zone was outputted later on in time for four kinds of every plan scales, what is expressed on a map presupposed that it is restricted to one case of a 200-year scale which shows the greatest range and the greatest depth of water. The classification of depth of water referred to the example of a Japanese hazard map. Since the many private house in Nicaragua are one-storied structure, the fact is taken into consideration and the classification was adopted as follows.

	0 < 0.5m	under the height of an adult's knee
	0.5 < 1.0m	under the height of an adult's waist
	1.0 < 3.0m	top of house roof
	3.0m<	over the height of houses

Figure 8-57 Criteria and Color

(c) Base Map

The base map, which displays an inundation hazard zone, was created by overlaying the ortho-photographs with a transparency rate of 50% taken in the Study onto the hill shade map. The hill shade map was created from the contour lines of the topographic maps used for creating the topographic model. The overlay had a merit of grasping landform intuitively. The scale was set at 1/7,000 to maximize the expression of the flooded areas while the contents were fitted in the map size within the boundary.

(d) Explanation

The purpose, users, conditions were described as an explanation of the map. At the same time, a caution was noted that the results were only a presentation of calculated results and that the situation, not necessarily, would become a reality in some future. The Study Team prepared a draft. The counterpart prepared the final version in Spanish after repeated discussions.

about this map

About this hazard map, the cautions, which are in charge of use, were described.

ACERCA DE ESTE MAPA

→ Este mapa de amenaza indica el área de inundación estimada.

→ El propósito de este mapa es brindar apoyo a las actividades del SINAPRED, COMUPRED y las autoridades Municipales para prevención de desastres por inundaciones. Las municipalidades locales son los usuarios finales de este mapa.

→ Las lluvias fuertes traen mucha agua, la cual se concentra dentro del río. La capacidad del río para conducir agua (capacidad del cauce), sin embargo, es limitada y, por consiguiente, el exceso de agua cubriría el área alrededor causando inundaciones.

→ Conociendo de antemano el área de inundación se pueden tomar medidas para reducir los daños.

→ Se recomienda no construir ningún tipo de edificación en el área afectada por inundaciones. Las personas que actualmente viven en esas áreas deben ser evacuadas ante el aviso de lluvias intensas en la zona.

→ El área de inundación representada en este mapa se calculó asumiendo una precipitación con un periodo de retorno de 200 años.

note

Calculation conditions etc. were described in order to offer technical information.

NOTE

1-The hydrograph of design rainfall are estimated by observed data 1987 to 2000 at July Buitrago.

El hidrograma de diseño, esta estimado en datos de lluvia observados entre 1987-2000 en la estación Julio Buitrago.

2-Daily precipitation on return period 200 years in 310.4 mm/day

La precipitación diaria para un período de retorno de 200 años es de 310.4 mm/día.

3-Rainfall-runoff conversion method is rational formula.

El método de conversión lluvia-escorrentía utilizado fue el de la fórmula racional.

4-Design peak discharge is 935.7 m^3 / seg.

El caudal pico de diseño es de 935.7 m^3 / seg.

5-Digital elevation model are based on topographic map of scale 1:5000 provided by INTUR. Calculating mesh size is 25 m.

El modelo digital de elevación esta basado en mapas topográficos a escala 1:5000 proporcionados por INTUR. La medida de la malla calculada es de 25 m.

6-This map is made by INETER in cooperation with Japan.

Este mapa fue hecho por INETER con la cooperación del gobierno de Japón

(e) Others

For non-expert uses, the image of depths of water and intensity of heavy rains were inserted as supporting illustrations for the hazard map. All the examples were used in Japan for flood hazard maps; the examples were changed to reflect situations of Nicaragua.

The image figure of depth of water

To reflect the situations of housing structure in Nicaragua, a one-story house is used as a typical house structure (three-meter high).

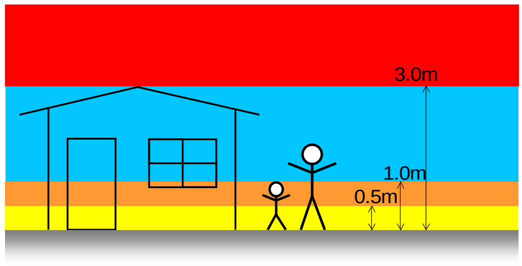
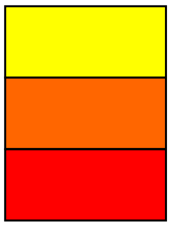


Figure 8-58 Image of Water Depth

<u>Comparison of Depths Classification and Colors</u>

It is necessary to hear opinions from users widely on the depth classification and color of legend in order to convey the danger of flood damage as imaged. The alternative plan in discussion is shown for reference.



0 < 0.5m

0.5 < 1.5m

1.5 <

Figure 8-59 Water Depth Classification and Representing Colors (Example)

The following example of the legend of the hazard maps is discussed to be finalized.

	< 0.5m	under the height of an adult's knee
	< 1.0m	under the height of an adult's waist
	< 2.0m	under the height of the eaves of the first floor
	< 5.0m	under the height of the eaves of the second floor
	5.0m<	over the height of the eaves of the second floor

Figure 8-60 Example of Legend

The legend is based on the standards used in Japan. The image is the water depths is shown as in the figure.

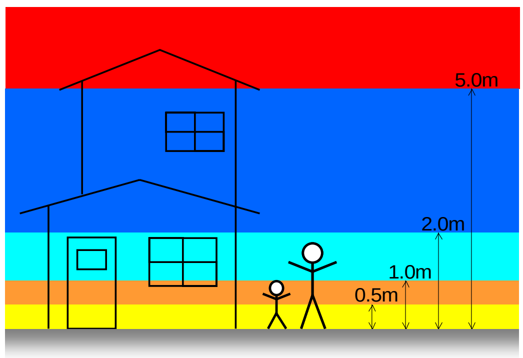
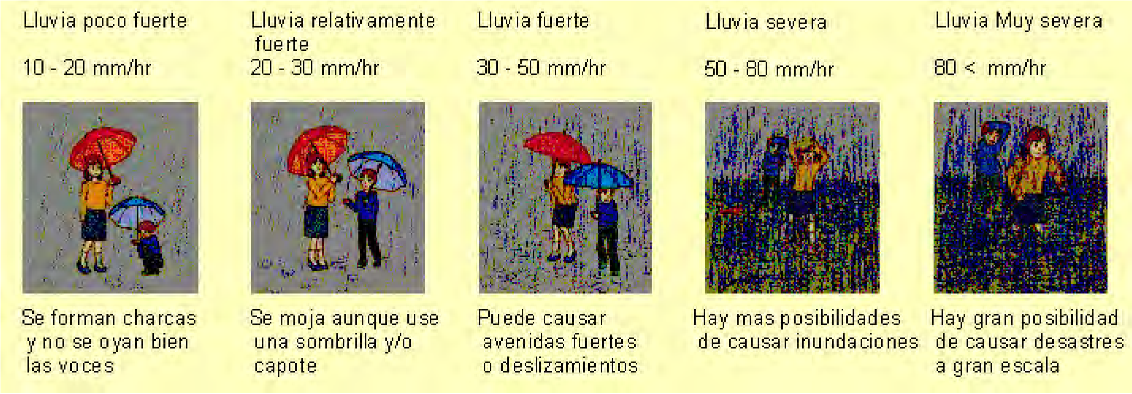


Figure 8-61 Image of Water Depths

Image of Rainfall Intensity

The illustration was quoted from the "Flood Hazard Map Preparation--Explanation and Examples of Preparation Procedure (2002)", the River Information Center Foundation with permission from the same foundation.

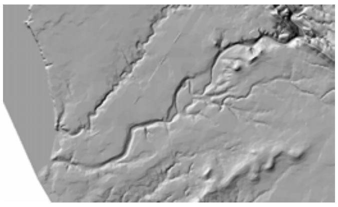


Location map

The figure shows the location of the target river.

Hill shade map

The hill shade map was included to facilitate clear imaging of the topography at the lower stream.   .



Watershed of the Maravilla river

The ortho-photograph includes the boundaries of watershed and the locations of hydrology observatories.

Logos (INETER, JICA, Oyo-international, Pasco)The logos of INETER, JICA, ODA, OYO International Corporation, and Pasco Corporation are included in the maps.

OYO INTERNATIONAL CORPORATION

PASCO

Figure 8-62 Logos

3) Preparation Method

The hazard maps as the last result were produced using GIS (ArcGIS) so that the staffs in the counterpart agency would be able to make changes and to the outputs by themselves. We decided to produce 50 copies of Type G from the plotter and Type P from the printer each. The Study Team decided to provide GIS data, the map laying-out data, and files in the pdf file format.

4) Workshop

Since Masachapa is the study area for flood and Tsunami hazards, the workshop was jointly conducted. Hurricane Beta struck the areas before the workshop; interest to the workshop was high. About 20 persons participated, actively discussed and exchanged opinions. It was felt that it was necessary to distribute as many intelligible hazard maps as possible in respect of practical uses.

5) Integration of flood and Tsunami hazard in hazard mapping

Masachapa is also the study area of Tsunami. By displaying the result with a flood hazard map, creation of a complex hazard map was attempted.

The ascension calculation of Tsunami is performed based on the 100m mesh. It is large compared with the 25 m mesh used in the flood simulation. Changing colors can express and show the difference. In this example, the shades of green express Tsunami. It can be interpreted that Masachapa City has a larger Tsunami zone than that of flood.

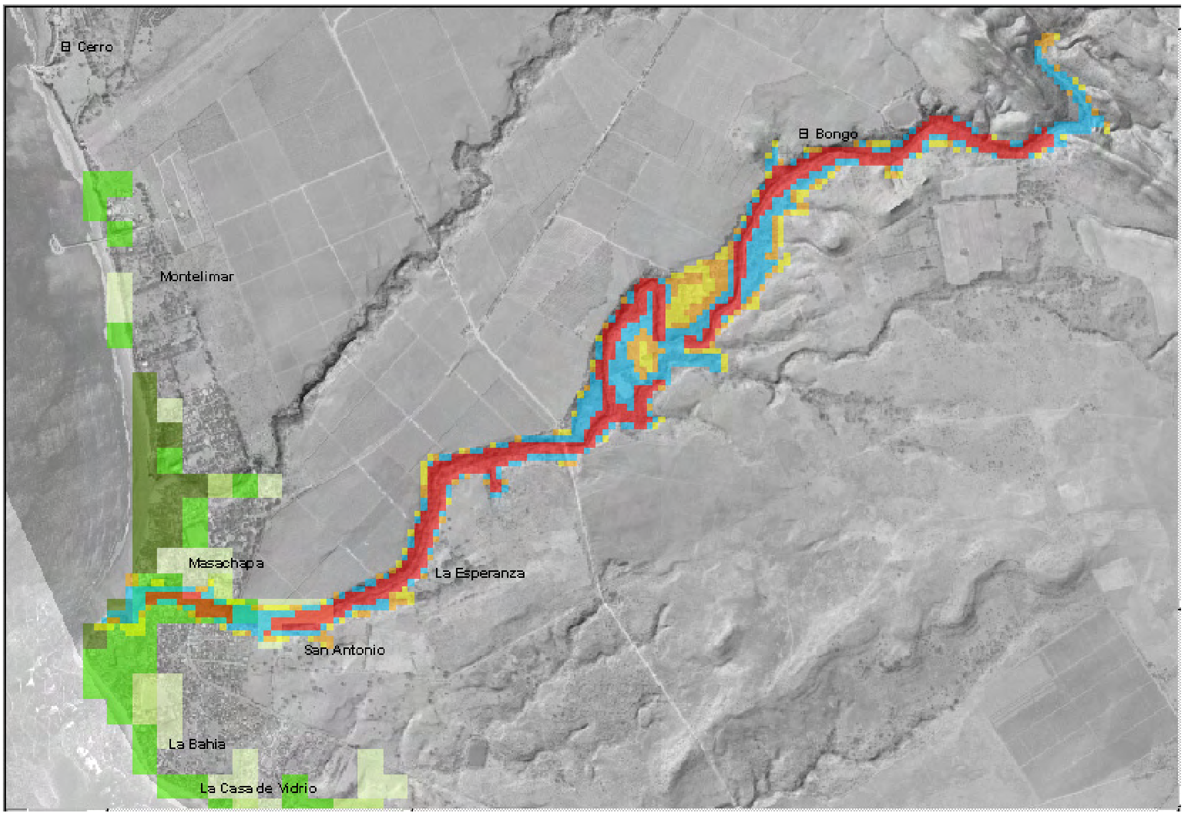


Figure 8-63 Hazard Map with Multiple Themes

8-4 Tsunami

The flowchart for mapping tsunami hazard is shown in Figure 8-64. The topography model is defined for the simulation of tsunami based on collected data. A simulation is then carried out and checked against observed data to see if the methodology and input parameters can reproduce a past event. Simulation can be made for other cases and the calculated results used to demonstrate the estimated inundation area.

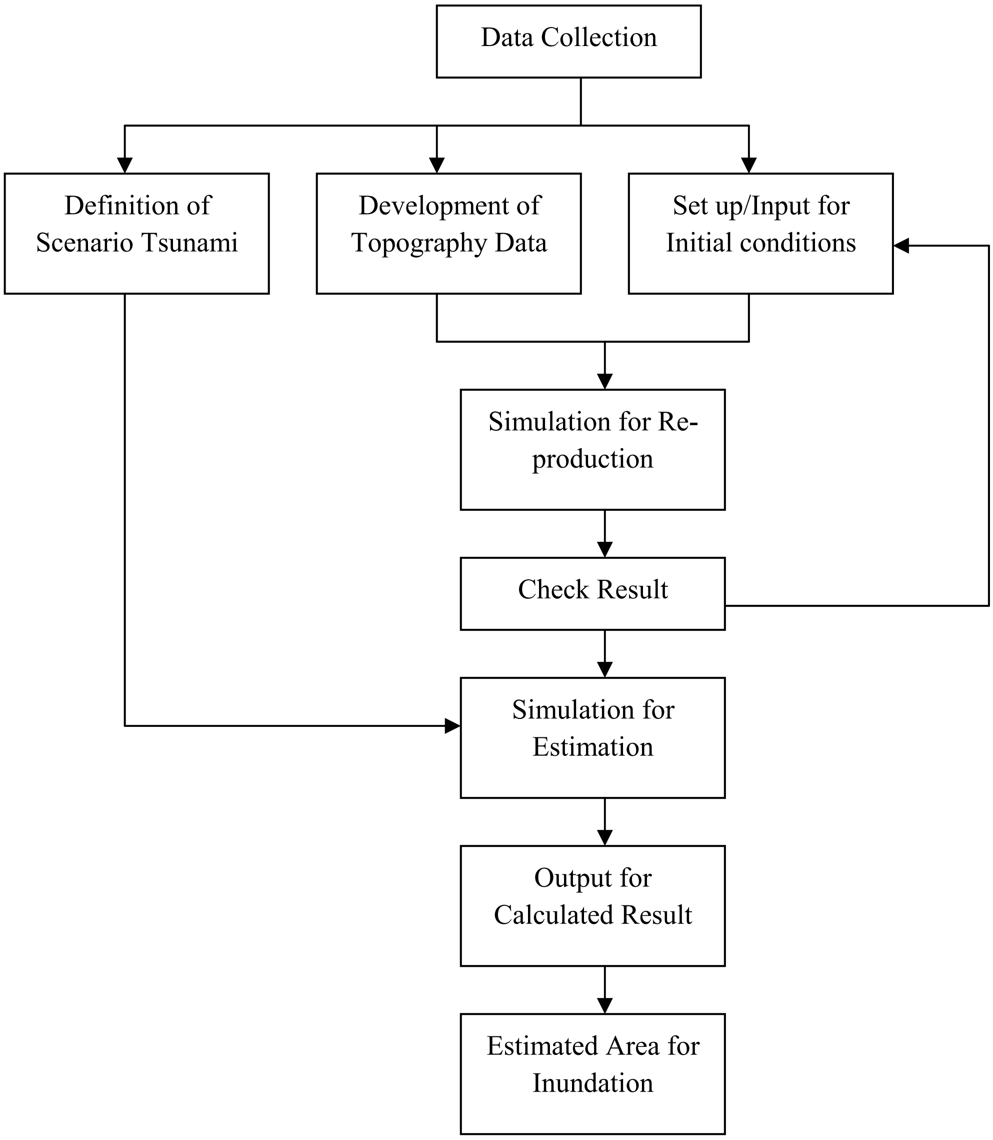


Figure 8-64 Flowchart for Inundation Estimation due to Tsunami

8-4-1 Collected Data and Information

Following data are collected for the simulation.

(1) Topography data

The topography data collected from various sources to develop a Tsunami hazard map are listed in Table 8-15. The availability of data for each study area is shown in the right hand side of the table. All required data are available at Corinto and San Juan del Sur but Puerto Sandino lacks a 1:5,000 topography map and Masachapa lacks bathymetry data close to the coast as well as a tide graph.

To complement the insufficient data a bathymetry survey was conducted off-coast at Masachapa. Aerial photos taken in the JICA study were used to generate a large-scale topography map in the Puerto Sandino area.

Table 8-15 List of Collected Data

Category	Contents	Source	Scale	Year	Availability for study area *			
					Co	PS	Ma	SJ
Tsunami catalog	Catalogue with damage	Fernandez et al.		2000				
	List of past Tsunami	NOAA						
Tsunami survey	1992 Nicaragua Tsunami	ERI		1993	Y	Y	Y	Y
	1992 Nicaragua Tsunami	USA			N	Y	N	N
Tide graph	Hourly observation data	INETER		1989-	Y	Y	N	Y
Bathymetry map	Global topography map	NOAA	2 minutes		Y	Y	Y	Y
	Navigation chart	Defense Mapping Agency	1:300,000	1984	Y	Y	Y	Y
	Navigation chart	Defense Mapping Agency	1:75,000 1:12,500	1984-1987	Y	Y	N	Y
	Channel in Corinto	EPN	1:500-2500	2004	Y			
	Channel in Puerto Sandino	EPN	1:7,500	2001		Y		
	Channel in San Juan del S.	EPN	1:2,000	2002				Y
Topography map	Topography map	INETER	1:50,000	1986-1988	Y	Y	Y	Y
	Coastal area map for development	INTOUR	1:5,000	2001-2002	Y	N	Y	Y

Note: Co: Corinto, PS: Puerto Sandino, Ma: Masachapa, SJ: San Juan del Sur, Y: Yes, N: No

(2) Tide gauge data

INETER has tide gauge observatories at three ports along the Pacific coast as shown in Table 8-16. Of those, only the tide gauges at Corinto and Puerto Sandino were in operation during the 1992 Nicaragua Tsunami. However, the record at Puerto Sandino was saturated and the peak value was not recorded. It should be noted that the 1992 Tsunami arrived when the tide was almost at the maximum level.

Table 8-16 Tide gauge operated by INETER along Pacific Coast

Site	Lat	Lon	Equipment	Period of monitoring
Corinto	12° 29' 06"	87° 10' 18"	Strip chart Water Level Recorder, analogue Type R20, Model A. OTT, made in Germany	1989-2001
Puerto Sandino	12° 12' 07"	86° 45' 22"	Strip chart Water Level Recorder, analogue Type R20, Model A. OTT, made in Germany	1989-1990, 1992
San Juan del Sur	11° 15' 04"	85° 53' 27"	Pressure sensor digital recorder Model TWG-12, Applied Microsystems, made in Canada	1999-2000

Source: INETER (2004)

(3) Tsunami History

The tsunami history on the Pacific coast near Nicaragua has been catalogued by Fernandez et al. (2000) and NOAA. Fernandez et al. (2000) documented historical tsunami for the period 1539-1996. Among them, 37 events were recorded along the Pacific coast as shown in Figure 8-65 on the topography map supplied by NOAA. Most of them were generated between the Cocos - Caribbean subduction zone. The number of historical tsunami recorded increased drastically from mid 19th century as shown in Figure 8-66, probably due to growth in the population near the coast. The damage, effects and comments related to Nicaragua are described in Table 8-17. From these historical records, the 1992 Nicaragua Tsunami was the worst tsunami to affect Nicaragua.

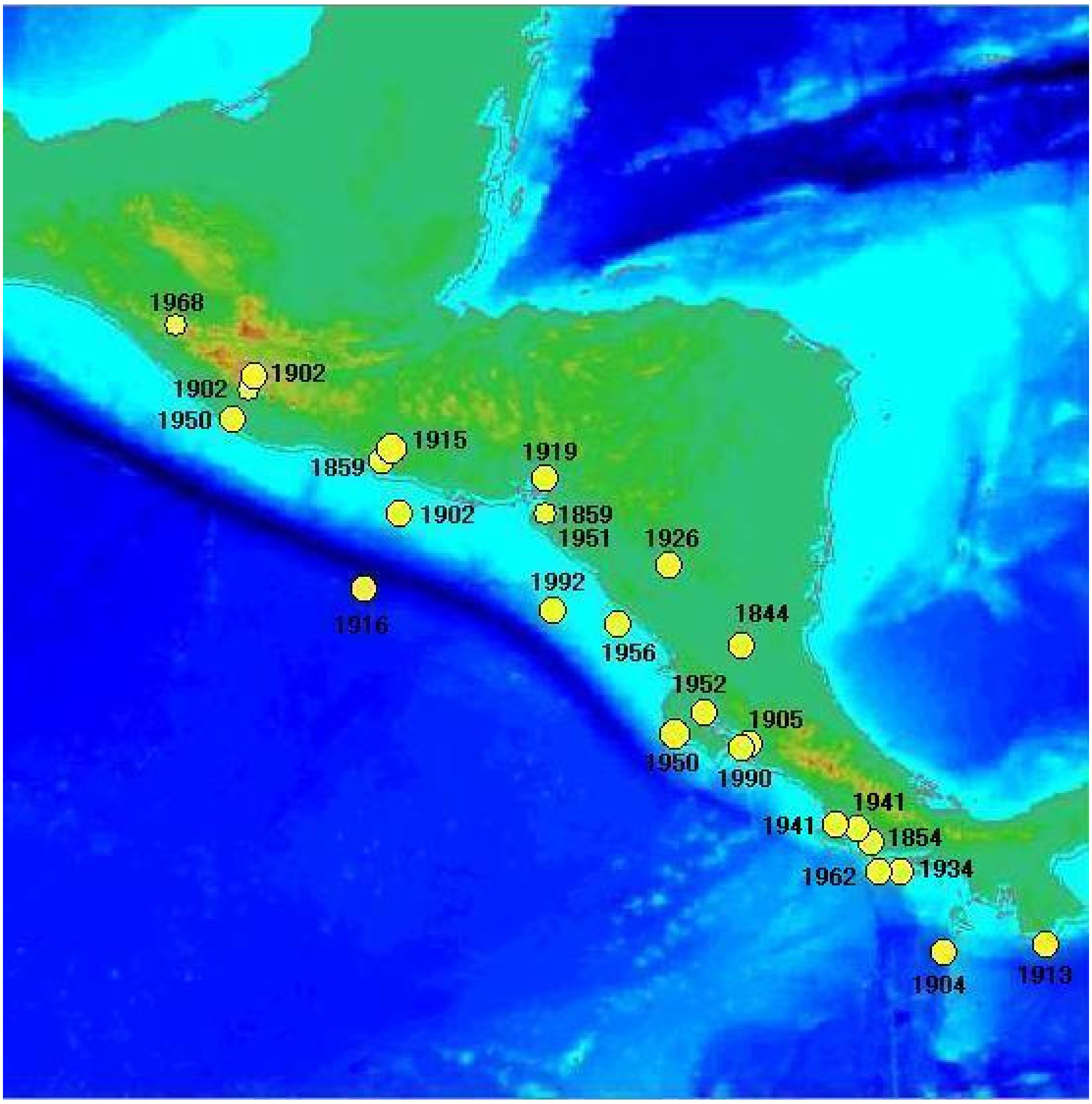


Figure 8-65 Location of Historical Tsunami. (Fernandez et al., (2000))

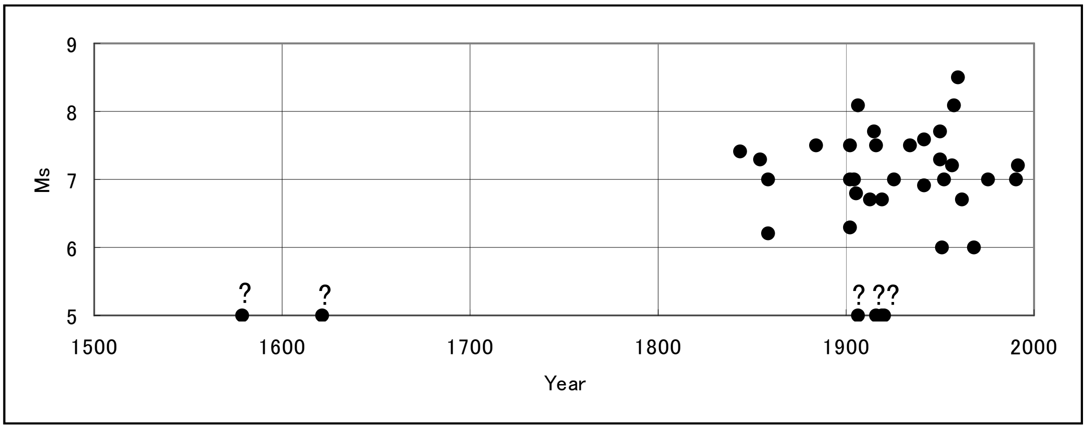


Figure 8-66 Histogram of Tsunami along Pacific Coast in Central America (Fernandez et al., (2000))

Table 8-17 Historical Tsunami Effect in Nicaragua

Date	Lon	Lat	Depth (km)	Ms	Tsunami Effect
1844/05	84.8	11.2	130	7.4	Two rivers were reopened and Lake Nicaragua cascaded through the rapids causing damage. Seiches (standing waves) in Lake Nicaragua. Water discharged from Lake Nicaragua.
1919/6/29	87.5	13.5	> 40	6.7	Flooded areas in Golfo de Fonseca and Corinto.
1919/12/12					Flooded areas in Ostial Village.
1926/11/5	85.8	12.3	135	7	The earthquake was reported as destructive in Nicaragua. The shock was felt at sea on two ships.
1950/10/5	85.7	10	< 60	7.7	Small oscillations of the sea level were recorded at San Juan del Sur, Nicaragua and at La Union, El Salvador. The tide gauge at Puerto Armuelles was destroyed and those at Puntarenas (Costa Rica), La Union (Salvador), San Juan del Sur (Nicaragua) and Hilo (Hawaii), recorded a sea wave of 10 cm.
1956/10/24	86.5	11.5	S	7.2	Reliable earthquake information but no reliable Tsunami information.
1992/9/2	87.4	11.7	S	7.2	A sea wave 9.5 m high. Wave run-up to 1km was reported at Masachapa. The horizontal extent of the inundation was of the order of few hundred meters. About 170 casualties. The largest run-up occurred in the central part of Nicaragua coast. Sea wave of 2-4m high in Costa Rica. Damage to small harbors and boats.

Source: Fernandez et al., (2000)

(4) Source parameter

There have been several simulation studies for the 1992 Nicaragua Tsunami. The tsunami source model by Imamura & Shuto (1993) is shown in Table 8-18.

Table 8-18 Source Parameters for the 1992 Nicaragua Tsunami

Date	September 2, 1992	Strike	302 degrees
Origin time	00:15:57.5 GMT	Dip	16 degrees
Latitude	11.76 N	Slip	87 degrees
Longitude	87.42 W	Fault length (km)	200 km
Depth	Less than 10 km	Fault width (km)	100 km
Duration time	100 seconds	Dislocation	0.375 m
Seismic moment	$3x10^{27}$ dyne*cm		

As shown in Table 8-19, Satake (1995) proposed a tsunami fault model, which is different from the seismic model, to better understand tsunami.

Table 8-19 Fault Parameters by Satake (1995)

Parameter	Seismic model	Tsunami model
Fault length	200 km	250 km
Fault width	100 km	40 km
Displacement	0.5 m	3 m
Rigidity	$3x\ 10^{10}\ N/m^2$	$1x\ 10^{10}\ N/m^2$
Seismic Moment	$3x\ 10^{20}$ Nm	$3x\ 10^{20}$ Nm
Strike angle		315 degrees
Dip angle		15 degrees
Slip angle		90 degrees

Ihmle (1995) used an empirical Green's function analysis of the 1992 Nicaragua Tsunami to show that the center of low frequency radiation was located about 40 km from the epicenter towards the trench. The study also revealed that the relative source time function was an average of about 120 seconds, and the rupture was unilateral toward the southeast along the trench axis with a rupture velocity of less than 1 km per second. He suggested that subducted sediment at the plate interface might be responsible for the slow and smooth nature of the 1992 Nicaragua Tsunami.

(5) Inundation data during Tsunami

The post tsunami survey data gives important information for the calibration of a simulation. There are two post tsunami surveys. At 18 days after the tsunami Abe et al. (1993) conducted a survey of 35 areas for 5 days. Murfy et al. (1993) conducted a survey of 12 areas two months after the tsunami.

8-4-2 Bathymetry Survey in Masachapa

(1) Equipments for Sounding

An outline of the equipment and software for the survey, which our counter part prepared, is shown in the Table 8-20. The launch, which is owned by EPN, has been made for bathymetry surveying and is frequently used in Nicaragua for surveying near the coast (Refer Photo 8-7).

The HydroTrack sounding device is the most popular type used worldwide and has a built-in function to export digital data such as the GPS coordinates of the ship and the depth to the sea-bottom. These data are imported into the HypackMax software, which is installed in the Personal Computer (PC) used in conjunction with the HydroTrack described above. With this configuration, the measured data are saved on the PC to assist the navigation of the survey ship. HypackMax is able to plot the survey line, to filter (Refer Photo 8-8) and correct the measured depth with the predicted or actual tidal data measured at a particular site. However, HypackMax is not capable of analyzing and plotting the iso-depth lines. Therefore, the collected data need to be transferred to an appropriate shareware/software program for this analysis.

Table 8-20　Outline of Equipment and System of Bathymetry Survey

ITEM	Special Features	Owner
Sounding Ship		
Nolan Ponce	Length 12.71m, Sleeve 3.45m, Prop 1.7m, Draught 1.6m, Max. Speed 15km/hr, made from Hard Steel, equipped with a Rolan system	Empresa Portuaria Nacional, Managua
Sounder		
HydroTrack	Echo pulse frequency 1Hz, equipped with GPS and Radio Beacon	INETER Hydrografia
Navigation Recording and analysis system		
HypackMax	Connecting with HydroTrack, assists navigation, records, analyzes and outputs the data and corrects the depth data combining with external tidal data	INETER Hydrografia
Tide Measurement	Measured by eye sight at the pier in Montelimar located about 2 km Northwest of Masachapa using a temporal tide scale of 4m, the elevation of which is fixed by on-site leveling by the Geodesia Team of INETER	INETER Hydrografia

Photo 8-7　Survey ship Nolan Ponce

Photo 8-8　HydroTrack connected to PC

During the survey, the tide height (as elevation) was measured by eyesight every 30 minutes on the hour and between using the temporarily installed tide scale, with a maximum height of 4m, attached to a column beside the pier in Montelimar around 2 km Northwest from Masachapa village (Refer Photo 8-9). The reading of tidal height was corrected in elevation in relation to the elevation of a temporary benchmark installed at a corner of the surface of the pier. The level of the temporary benchmark (Refer Photo 8-10) was previously measured by the leveling team from Geodesia of INETER based on the known benchmark installed in Pochomil Park located in the Southwest of Masachapa.

The predicted tide tables for the four ports in Nicaragua are published quarterly by INETER, from data provided by the USGS. The measured tide record at Masachapa is confirmed by comparing it with the predicted tide table of the nearby Port Puerto Sandino. As a result, the corrected depths of the sea-bottom are given in elevation derived from the ground elevation.

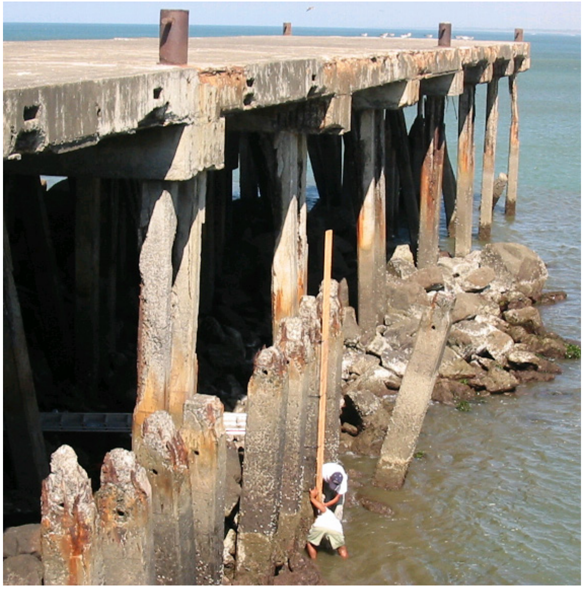


Photo 8-9 Installation of Tide Scale

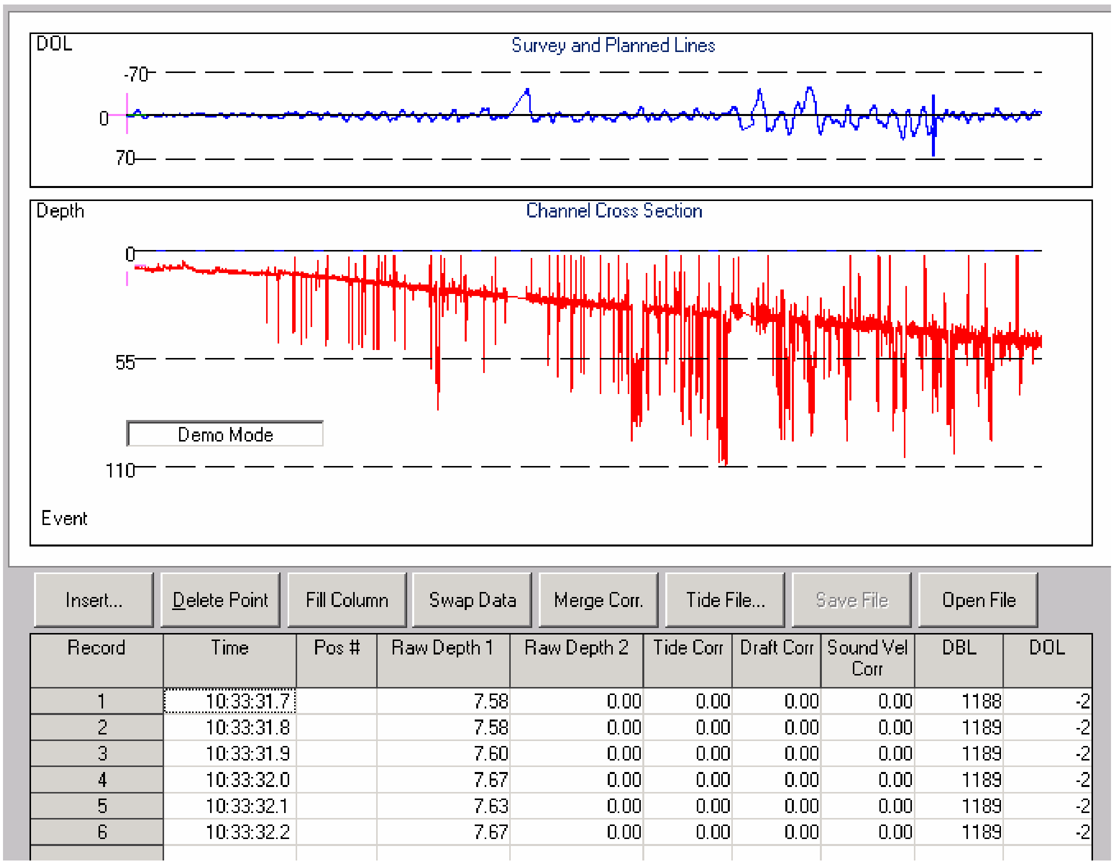
Photo 8-10 Bench mark of the Pier(EL.7.548m)

(2) Preliminary on-site sounding survey

On finishing the installation of the temporary tide scale, we started the sounding survey at 10:33 on February 9 with a speed of around 10 km/hr on the northernmost sounding line in the initial survey plan. The aim of this trial sounding was to confirm that our equipment was capable of measuring the sea depth at 60 to 65 km offshore under the climatic conditions at that time.

The result was that we could navigate the launch Nolan Ponce for only 2 hours until 12:30 offshore up to a depth of 20 m where the launch was continuously and strongly pitched and rolled making it impossible to receive the echo pulse signal. Moreover the equipment on the ship almost toppled onto the floor. Judging that no more data would be available even if we navigated further offshore risking the crew, the supervisor ordered the captain to turn the launch and leave the area.

The measured data (in the form of the digital value of measured depth) of the day were plotted on the display using HypackMax. The next day, February 10, we attempted a similar sounding navigation on a trial line set north from the previous one. The wider the displayed width of the black lines the larger the deflection from the designated course of navigation. The results of the second day were recorded up to a depth of 65 m at a point about 35 km from the shore. We decided from the trial navigation over two days that these points offshore would be the reachable limit of the sounding lines in our bathymetrical survey planned in that season.



Record	Time	Pos #	Raw Depth 1	Raw Depth 2	Tide Corr	Draft Corr	Sound Vel Corr	DBL	DOL
1	10:33:31.7		7.58	0.00	0.00	0.00	0.00	1188	-2
2	10:33:31.8		7.58	0.00	0.00	0.00	0.00	1189	-2
3	10:33:31.9		7.60	0.00	0.00	0.00	0.00	1189	-2
4	10:33:32.0		7.67	0.00	0.00	0.00	0.00	1189	-2
5	10:33:32.1		7.63	0.00	0.00	0.00	0.00	1189	-2
6	10:33:32.2		7.67	0.00	0.00	0.00	0.00	1189	-2

Figure 8-67 Navigation line (Upper) and Records (The rest) of the 1st day of Preliminary Sounding

(3) The Revision of Survey Plan and Final Survey Plan

In light of what was obtained at the preliminary sounding described above, the Initial Survey Plan was modified to become the Final Survey Plan as follow:

i) The practical sounding area with our sounding equipment could not extend more than up to 10 to 30 km offshore under the sea conditions in the area during the survey period. Therefore, the length of the survey line to be sounded should be, in place of the initially targeted length of up to the depth of 100m, decided as what was possible under the sea conditions on the day of survey.

ii) Following the above, the number of lines per day that could be sounded by the cycle that repeats, a start from the coast to the offshore turning point and back to the coast, within a maximum of 12 hours from sunrise until sunset might be increased compared with the initial plan. As a result, it could be expected that the required time period for surveying the near coast area would be shortened. Considering this time saving, we would try to extend the survey with additional sounding lines outside of the lines at 300 m intervals centered on Masachapa village. The survey should be carried out within a design time period of 25 days with 5 days allowance for unfavorable sea conditions. By this revision of the survey plan, even if we were unable to obtain the expected lens-shaped shallow sea-bottom profile, we would be able to acquire a sea-bottom profile in detail for a wider area along the coast, which will assist future numerical Tsunami analysis.

iii) By comparing the profile suggested by the NOAA data and the data to be obtained in this survey, the suggested shallow lens-shaped sea-bottom profile should hopefully be confirmed, with some correction, and used in combination with the near coast sounding data with high accuracy.

iv) The Final Sounding Survey was programmed to start February 11th and completed on March 7th.

(4) Result of Tide measurement

The measured tide height in elevation is compared with the predicted tide height at Puerto Sandino after correction, the original data of which has been given based on the Lower Low Water Level at Puntarenas in Costa Rica (e.g., -1.168m). Figure 8-68 shows the comparison with the data obtained on February 11th. The tide height at Masachapa is very similar to that of Puerto Sandino: however, the minimum and maximum tide occurs a little earlier than at Pt. Sandino by 10 to 15 minutes. The minimum and maximum tide height at San Juan del Sur is predicted as earlier than that of Pt. Sandino by about 1hour and 20 minutes; therefore the tide measurement at Masachapa is considered as sufficiently reliable.

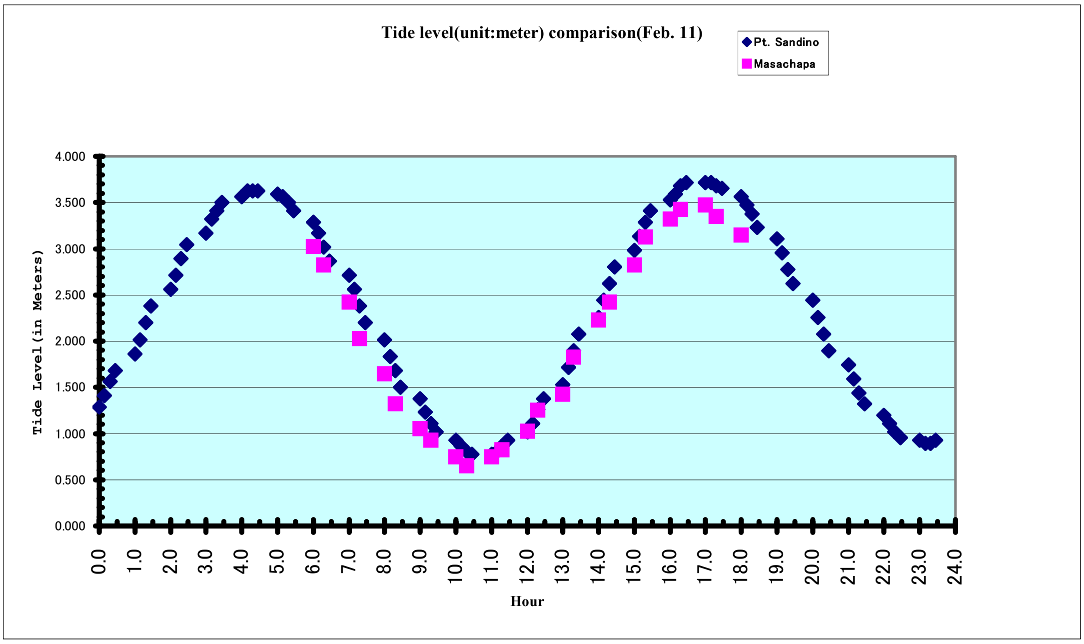


Figure 8-68 The comparison of Tide height in Masachapa with the predicted one at Pt. Sandino

(5) The area, which could be sounded by March 6th 2005 with in the order of 50 sounding lines, is as shown in Figure 8-69.

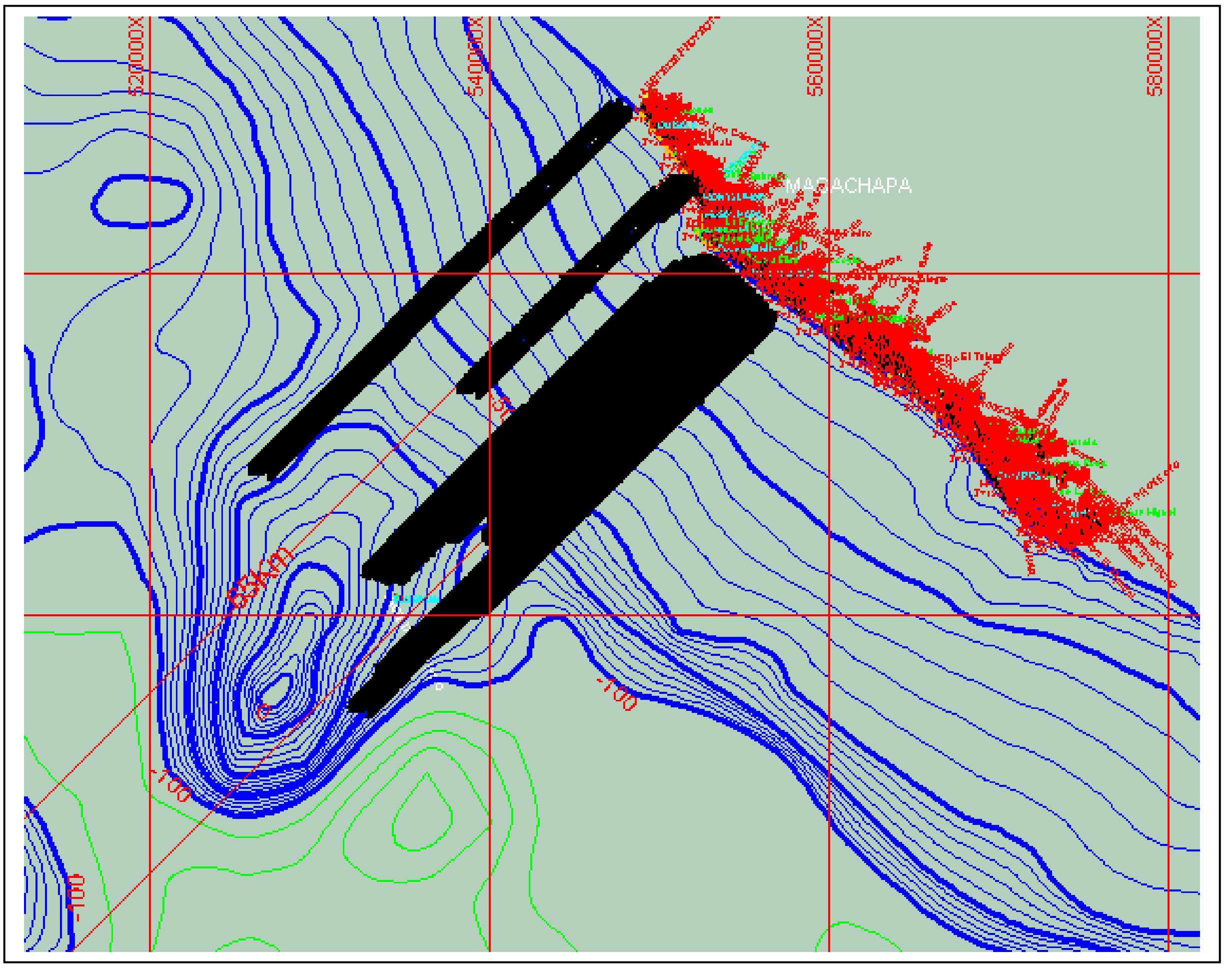


Figure 8-69 The Area which the sounding was completed by March 6th, 2005

(6) Final form of surveyed data

The data to be provided by the Counterpart, Hydrografia INETER, is the digital data in the same format of XYZ03 (Latitude, Longitude, Depth and Elevation) corrected with the tide elevation data based on the temporal tide measurement at Masachapa.

8-4-3 Simulation Method

(1) Definition of Scenario Tsunami

Historical data on tsunami disasters along the Pacific coast in Nicaragua are limited. Most of them are recorded after mid-19th century, when population of coastal area began. Among them, the 1992 Nicaragua Tsunami is the worst event, in terms of magnitude as well as the location of the source area with respect to the most of the Nicaraguan coast.

For this reason, the 1992 Nicaragua Tsunami was basically considered as the worst case for the Pacific Coast of Nicaragua.

In this study, attempts were made firstly to reproduce the 1992 Tsunami to verify the methodology. The source parameters were primarily based on existing studies, but were adjusted to obtain a good fit with observed records, such as tide gauge records or inundation heights obtained by post-Tsunami field surveys.

Once the parameters to reproduce the 1992 Tsunami were defined, a fault with the same dimension but a different location was tested to estimate the possible “worst case” for each study area.

(2) Parameter Setting

Based on existing studies, two models were tested to reproduce the 1992 Nicaragua Tsunami. Parameters used for each base model are as shown in Table 8-21.

The basic parameters for the scenario tsunami are based on each paper, respectively. The displacements and strike angles were modified to fit the observed data by trial and error.

It should be noted that the water level of the ocean is set as the maximum water level (1 m above mean sea level) in the simulation. This is because the 1992 Nicaragua Tsunami occurred at the time of maximum water level, which is also considered the worst case.

Table 8-21 Parameters used for the simulation to reproduce the 1992 Tsunami

	Imamura based model	Source	Satake based Model	Source
Length	200 km	Imamura & Shuto (1993)	250 km	Satake (1995)
Width	100 km		40 km	
Dip	16 degrees		15 degrees	
Slip	87 degrees		90 degrees	
Strike	302-322 degrees	Within the range in Imamura & Shuto (1993)	315 degrees	
Displacement	6 km		6 km-12 km	Within the range in Imamura & Shuto (1993)
Rise time	300 seconds		300 seconds	

(3) Topography Model Development

The simulation program solves the equation of motion using the finite difference method. For this method, the topography of the seabed and the land is expressed as a grid model. The grid size of the area near the shore was made small to define the shape of coastline or gulf. However, it does not make sense for the huge overall analysis area including the tsunami wave source area to be defined with a small size grid. Therefore, several sizes of grid were applied for the analysis. The calculation was conducted using smaller grids, one by one, towards the land from offshore.

The grid size is defined by following considerations herein. A 2700 m square grid system was applied to the open sea area including the wave source area. Then 900 m, 300 m and 100 m square grid systems were applied towards the land from the offshore. Since there are various sources of topography data, the data with better precision were preferred when two sets of data overlapped in the same area.

The grid size is defined in following conditions:

1) The velocity of the wave in simulation should exceed the velocity of a real tsunami wave.

The wave velocity of a tsunami in deep water is approximated as equation (1), where g is acceleration of gravity (= 9.8 m/sec2) and hmax is the maximum depth of water in the region of calculation.

$$V_{Physical} = (2gh_{max})^{1/2} \qquad (1)$$

Examples of velocity with respect to water depth are shown in Table 8-22.

Table 8-22 Water depth and wave velocity of Tsunami

H_{max} (m)	$V_{Physical}$ (m/sec)		H_{max} (m)	$V_{Physical}$ (m/sec)
5000	313.0		100	44.3
2000	198.0		50	31.3
1000	140.0		20	19.8
500	99.0		10	14.0
200	62.6		5	9.9

On the other hand, the wave velocity in simulation Vnumerical is expressed as equation (2), where Δs is the size of the grid in meters and Δt is the time step of calculation in seconds.

$$V_{numerical} = \Delta s / \Delta t \qquad (2)$$

The wave velocity in simulation varies according to the time step of calculation and grid size, as shown in Table 8-23. In this study, time step is set as two seconds through the evaluation as shown in Table 8-24.

Table 8-23 Grid size, time step, and numerical velocity

$V_{numerical}$		Δt(sec)				
		1	2	3	5	10
Δs (m)	2700	2700	1350	900	540	270
	900	900	450	300	180	90
	300	300	150	100	60	30
	100	100	50	33.3	20	10
	50	50	25	16.7	10	5

Table 8-24 Estimation of Time step for this study

Δs	h_{max}	$V_{Physical}$	$\Delta t<$
2700	6000	342.9	7.9
900	200	62.6	14.4
300	100	44.3	6.8
100	70	37.0	2.7

2) To avoid the numerical viscosity factor and the numerical dissipation factor, the grid size should satisfy equation (3) as a minimum requisite, or satisfy equation (4) if possible.

$CT/20 >= \Delta S$ (3)
$CT/30 >= \Delta S$ (4)

Where

$C=(gh)^{1/2}$
$T=L/(gh_s)^{1/2}$
C : wave velocity (m/sec)
h : average water level in simulation area (m)
T : apparent period of Tsunami (sec) (=524.9 sec)
h_s : average water depth in Tsunami source area (m) (=3000m)
L : length of minor axis for Tsunami source area (m) (=90000m)

Table 8-25 Estimation of Grid size for this Study

Δs	h	CT/20	CT/30
2700	2200	3853.6	2569.0
900	80	734.8	489.9
300	60	636.4	424.3
100	30	450.0	300.0

As a result, the four level nested grid systems as shown in Figure 8-70 were developed. The entire area is divided into a square grid of 2700 m. Each study area is divided into 900 m, 300 m and 100 m sized grids. Each grid has an identification number and its details are described in 2-4 Tsunami in Manual2, Hazard Mapping.

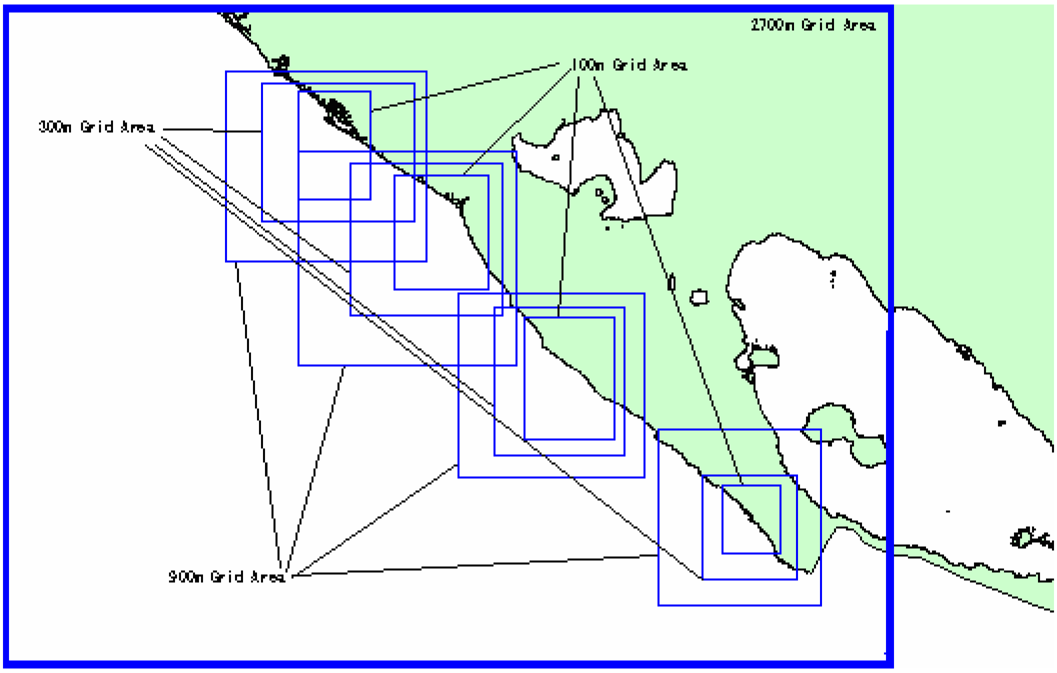


Figure 8-70 Grid systems developed for analysis.

(4) Program Development

The source code of the simulation program was developed by Prof. Imamura in Japan, and published by UNESCO. In the original program, the simulation of linear calculation for wave propagation and inundation are separate. For this study, the two programs are combined to enable simultaneous calculation. The flow chart for the developed program is shown in Figure 8-71. The details of the routines, variables and strings are documented in 2-4 Tsunami, Manual 2 Hazard Mapping. The necessary modifications to apply to other areas are also documented in the Manual.

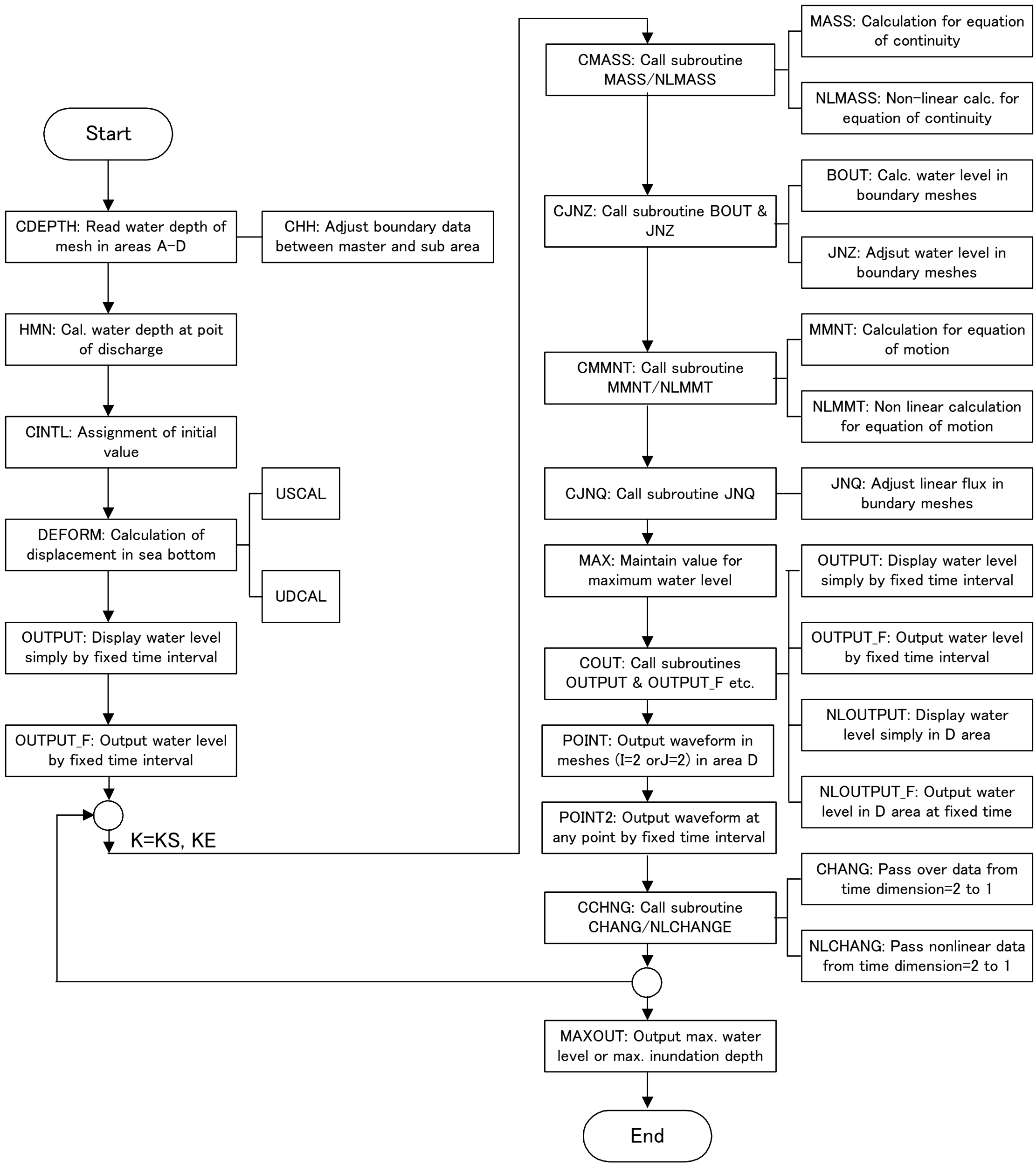


Figure 8-71 Flowchart of the Developed Program

(5) Visualization

The following outputs are obtained from simulation. The details can be found in Tsunami, Tsunami Manual 2 Hazard Mapping.

1) Quick check of wave field

Changes of water level in the calculation area are output to a file in character format to allow a quick check of the wave field, as shown in Figure 8-73.

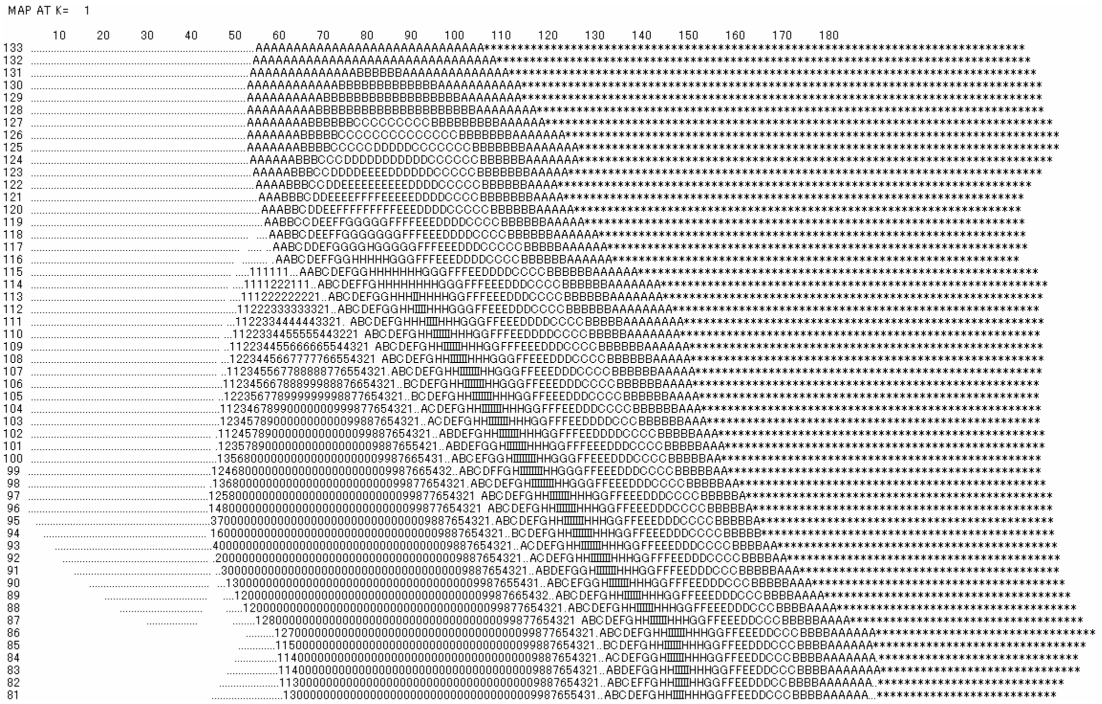


Figure 8-72 An Example of Quick Check of Wave Field

2) Waveform

Changes in water level over time at any specified point are written to an output file. The tsunami water level is illustrated as shown in Figure 8-73. The waveform output is displayed as shown in Figure 8-74.

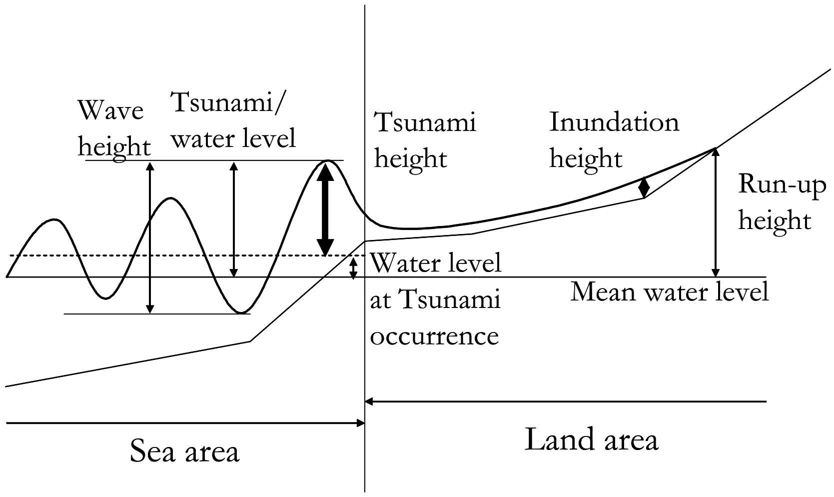


Figure 8-73 Illustration of Tsunami Water Level

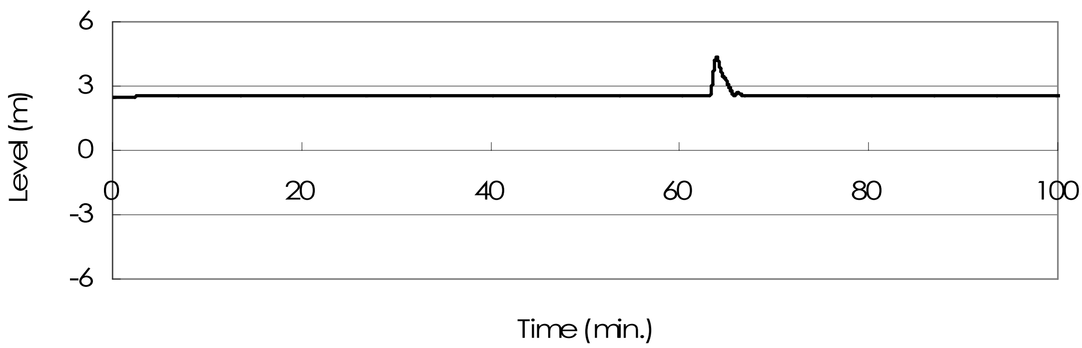


Figure 8-74 Examples of Water Level Changes (above) and Inundation Height (below) at its Adjacent Grid

3) Wave field

Changes of water level at fixed time intervals in each calculated area (A to D) are output to a series of files. These files can be combined using a utility program. The combined file should be converted to GIS format and be geo-coded via the grid identification number of the grid. The results can be displayed graphically using the GIS function, as shown in Figure 8-75.

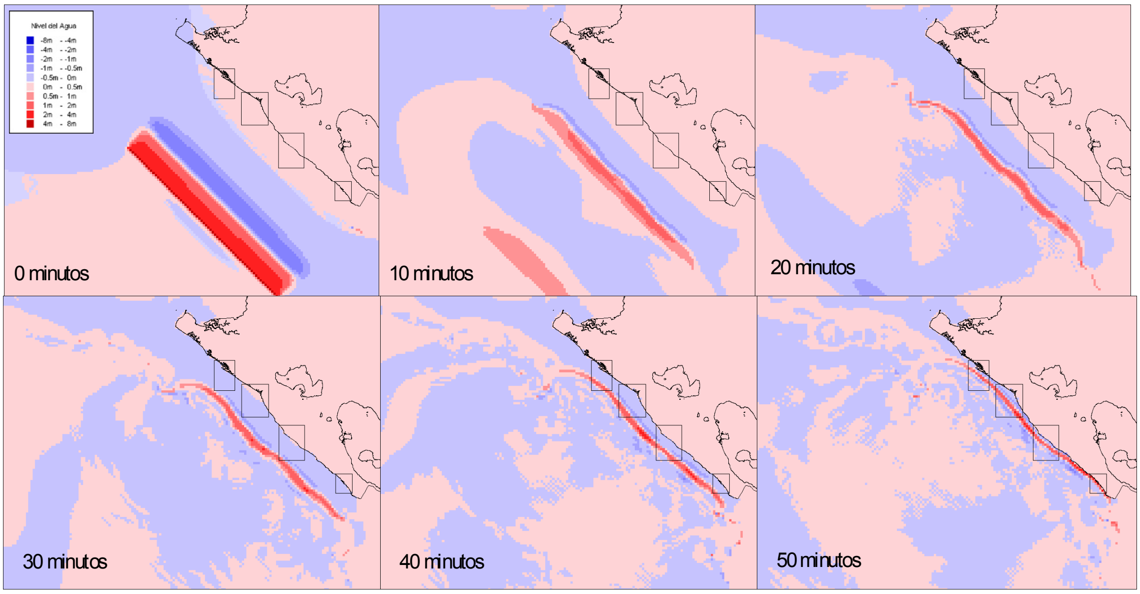


Figure 8-75 A series of images showing changes in water level over time

4)　　Maximum inundation depth

The maximum inundation depths in area D (100m grid) are output to a file.　The file should be converted to GIS format and be geo-coded via the grid identification number of the grid.　The results can be displayed graphically using the GIS function, as shown in Figure 8-76.

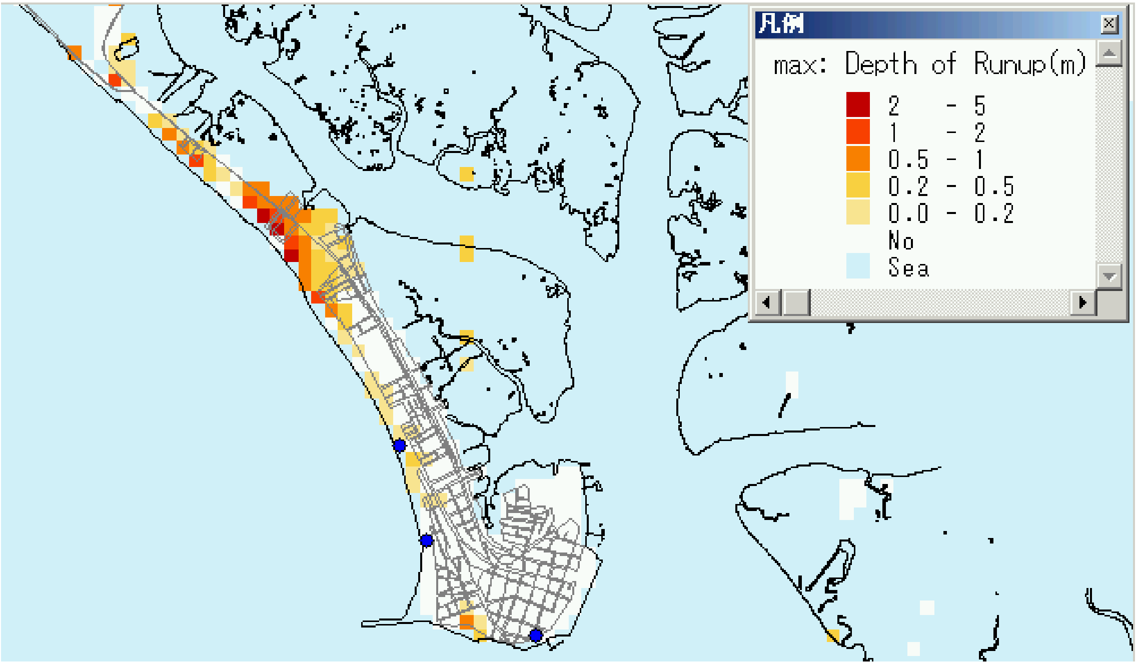


Figure 8-76 Example of maximum inundation depth map

8-4-4 Results of simulation

(1) Reproduction of the 1992 Nicaragua Tsunami

1) Imamura based model

Firstly, fault models based on Imamura (1993) were tested with different locations, displacements and strike angles as shown in Table 8-35 and Figure 8-77. The results were not successful in reproducing the run-up for the four study areas, as the 200 km long fault length is not long enough with respect to the coastal length of Nicaragua.

Table 8-26 Parameters for the Imamura-based fault models

		Model				
		1	2	3	4	5
Length (km)		200	200	200	200	200
Width (km)		100	100	100	100	100
Displacement (m)		8	6	6	6	6
Rise Time (seconds)		300	300	300	300	300
Strike (degree)		302	312	312	312	312
Dip (degree)		16	16	16	16	16
Slip Angle (degree)		87	87	87	87	87
Depth of Upper Edge (km)		1	1	1	1	1
Origin of Fault	Latitude	10.6510	10.3592	10.2138	9.5765	10.5049
	Longitude	87.05797	87.0617	86.9119	86.7004	87.2072

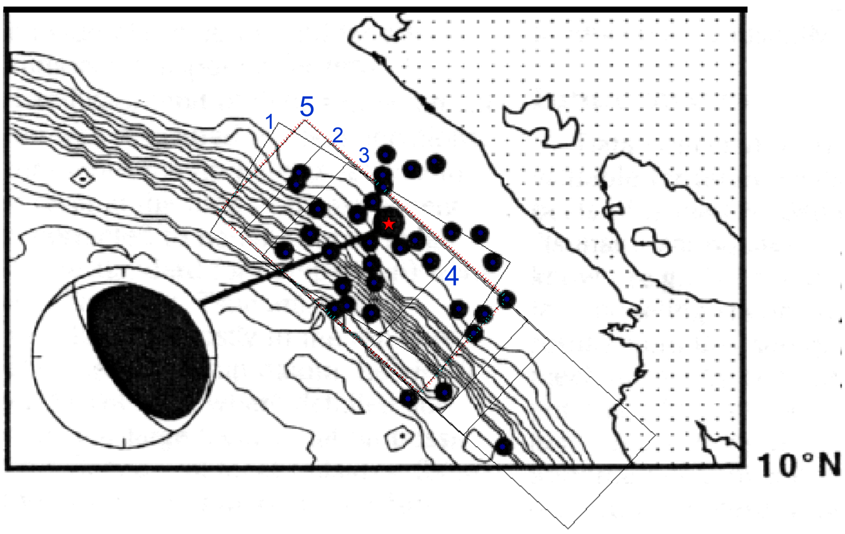


Figure 8-77 Location of Imamura-based fault Models

2) Satake based model

Fault models based on Satake (1995) were tested as shown in Table 8-36 and Figure 8-78. The initial location (Model S5, S6) was taken as it appeared in the paper, but it was moved northward (Model S7-S9), and displacement was also adjusted to obtain a better fit with observed data. As a result, model S8 gave a best fit with observed data.

Table 8-27 Parameter for the Satake-based Models

		Model				
		S5	S6	S7	S8	S9
Length (km)		250	250	250	250	250
Width (km)		40	40	40	40	40
Displacement (m)		6	8	8	10	12
Rise Time (seconds)		300	300	300	300	300
Strike (degree)		315	315	315	315	315
Dip (degree)		15	15	15	15	15
Slip Angle (degree)		90	90	90	90	90
Depth of Upper Edge (km)		1	1	1	1	1
Origin of Fault	Latitude	10.0626	10.0626	10.2880	10.2880	10.2880
	Longitude	86.5712	86.5712	86.8073	86.8073	86.8073

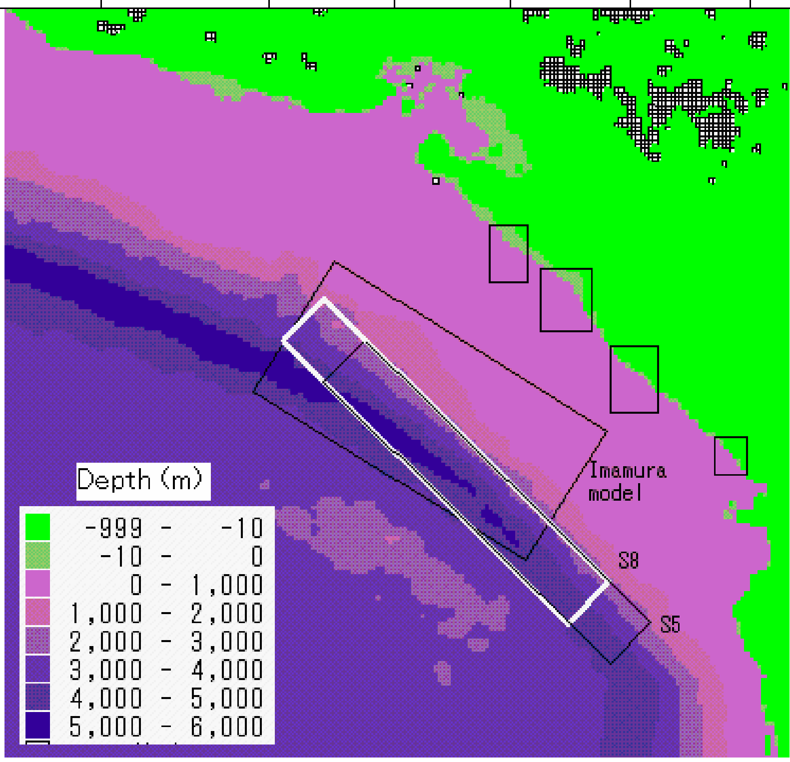


Figure 8-78 Location of Satake-based fault models

2)-1 Waveform of tide record Arrival time

Figure 8-79 shows a comparison of the waveform between the observed tide gauge record during the 1992 Nicaragua Tsunami and the calculated time history waveform. The calculated arrival time of the first wave at Puerto Sandino agrees with the observed record (64 minutes). The arrival time of the first wave at Corinto was 52 minutes by observation, while the calculation shows 54 minutes.

It would be necessary to increment the strike angle to reduce the calculated arrival at Corinto but the direction of trench off Corinto shows a smaller value than used for simulation. Therefore, the difference in arrival time at Corinto between simulation and observation could not be reduced further in this simulation.

The simulated waveform record at Cotinto closely agrees with the observed record. The observed record at Puerto Sandino was saturated, but the simulated record shows agreement until the saturation by the first wave.

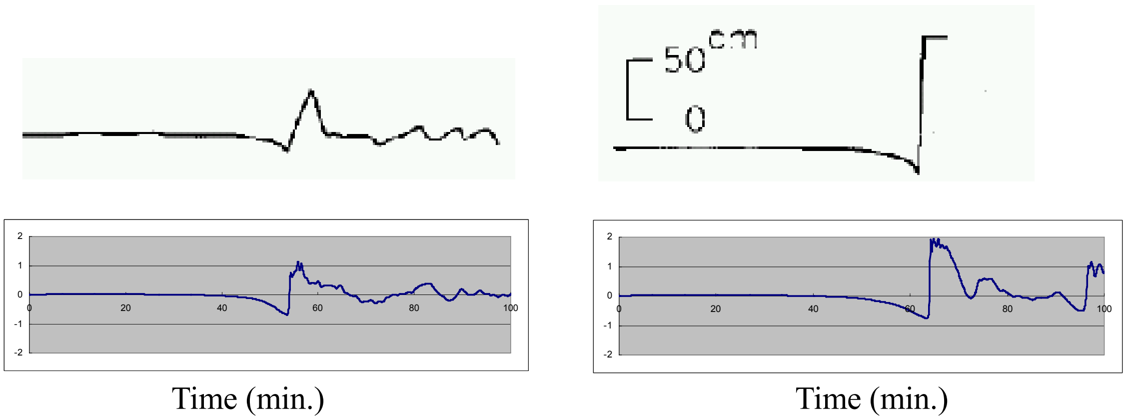


Figure 8-79 Comparison of observed tide gauge record (top) and simulated waveform (bottom) for 100 minutes. (Left Corinto, right: Puerto Sandino)

2)-2Inundation along coast

Table 8-28 shows run-up data from the field survey by Abe et al. (1993) within the 100 m grid area in the study areas. In some cases, there are several observed values within the same mesh. In such cases, the observed run-up height was averaged for the mesh. It should be noted that the reliability of the observed run up data differs from point to point.

Table 8-28 Observed Run up during the 1992 Nicaragua Tsunami

Area	Point (page in the report)	Tsunami Height above MSL(m)	Grid (I,J)		Situation
			Point	Nearest Sea	
Corinto	Corinto-C (p.43)	2.7	113,278	113,277	Inundation depth0.3m
	Corinto-B (p.43)	3.9	105,285	104,285	Inundation over dike
	Corinto-A (p.43)	3.5	103,292	102,292	Inundation over dune, Inundation depth of 0.7m
Puerto Sandino	Salinas Grandes (p.44)	4.5 – 4.9	130,343	130,342	Water reached to frontage
		3.3	131,344	130,342	
	Puerto Sandino (p.45)	3.5	232,276	231,276	Dock, inundation depth0.6m
		3.7	232,279	231,279	Dead plant by sea water
	Miramar (p.47)	5.2 – 5.9	234,246	233,246	Heights
	El Velero (p.48)	5.0 – 5.4	250,215	249,214	Park
	Playa Hermosa (p.48)	3.6	254,202	253,201	Inundation trace
	El Transito (p.49)	6.4	293,120	292,119	Village on dune, the largest disaster area
		7.5	295,118	294,117	
		9.9	296,116	296,115	
		6.4	297,115	296,115	
Masachapa	Julio (p.53)	7.6	47,368	47,367	Inundation depth 5.13m
	Montelimar (p.53)	4.5	60,350	59,350	Trace on building
	Masachapa (p.53)	4.9 – 6.2	65,330	63,330	Trace on building & tree
		3.4 – 4.4	65,329	63,329	Trace on road, sand on slope, and tree
		4.1	64,328	63,328	Trace on building
		3.3	65,328	63,328	Trace on building
	Pochomil (p.56)	4.5 – 6.0	78,310	77,309	Trace on building
	La Boquita (p.57)	2.5	209,212	208,212	Trace on building
		2.7 – 5.8	209,210	208,210	Trace on building
	Casares (P.58)	6.8	249,160	249,159	Trace on building
		4.7 – 5.5	245,163	244,162	Trace on building & tree
	Huehuete (p.60)	5.4	271,144	270,144	Inundation depth 1.1m
San Juan del Sur	Marsella (p.62)	8.1	66,167	66,166	Dune along the coast in front of bay
		5.0	69,162	68,162	
	San Juan del Sur (p.64)	4.0 – 4.8	100,125	100,126	Port area, inundation depth of 0.6 – 1.5m
		3.6	102,130	101,130	Inundation depth of about 2m.
		2.9	103,130	101,130	Inundation depth of 0.7m
		2.0	105,131	101,130	Limit of run-up
	Playa El Coco (p.67)	2.7	179.24	178,24	Inundation trace

The observed records are compared with the results of simulation and are plotted as shown in Figure 8-80. In the graph, the distance on the horizontal axis is measured southward from the northern end of Nicaraguan Coast (Cosiguina Peninsula). The calculated values for model S8 are distributed in the middle of observed values and the overall shape of the distribution corresponds to the observed data as well.

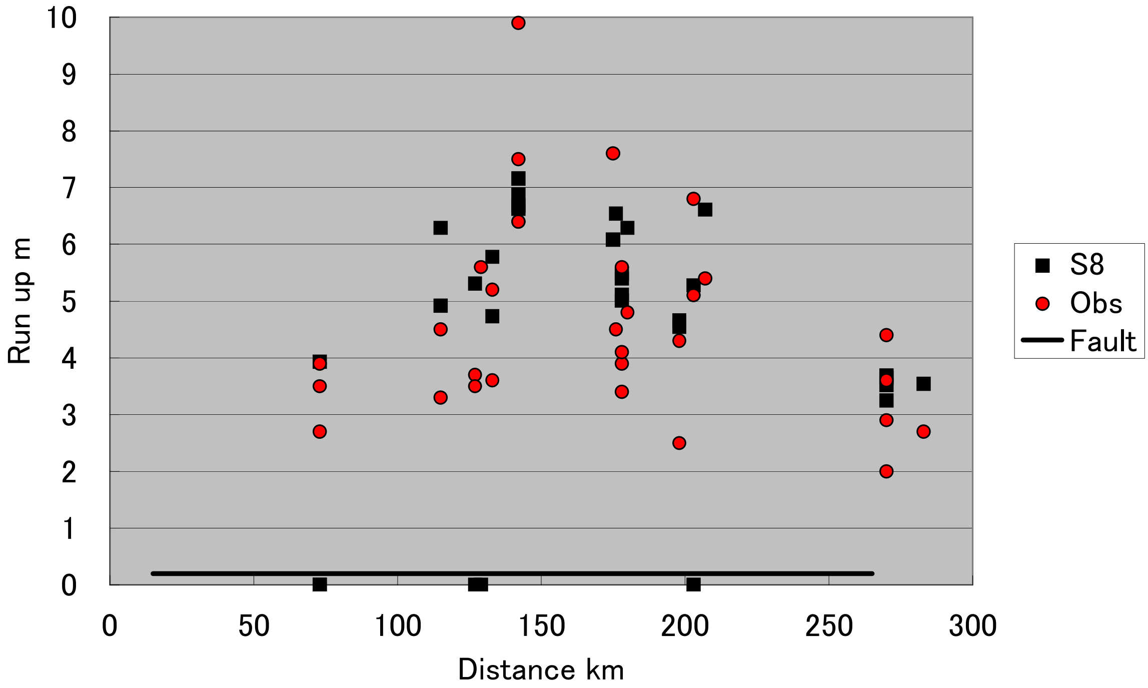


Figure 8-80 Comparison of Observed Data and Simulation Results

Table 8-29 Maximum Inundation by Tested Models

Area	Name	Data Quality	Distance (km)	Observed inundation (m)	Model S7	Model S8	Model S9
Corinto	Corinto_A	A	73	3.5	0.0	3.9	4.2
	Corinto_B	B	73	3.9	0.0	0.0	0.0
	Corinto_C	A	73	2.7	0.0	0.0	0.0
Puerto Sandino	Salinas_Grandes_ACD	A	115	4.5	5.3	6.3	7.0
	Salinas_Grandes_B	A	115	3.3	4.3	4.9	5.4
	Puerto_Sandino_A	B	127	3.7	0.0	0.0	0.0
	Puerto_Sandino_B	C	127	3.5	4.6	5.3	5.8
	Miramar_ABC	A	129	5.6	0.0	0.0	0.0
	El_Velero_AB	A	133	5.2	5.0	5.8	6.4
	Playa_Hermosa	C	133	3.6	4.2	4.7	5.5
	El_Transito_A	A	142	6.4	5.8	6.9	8.1
	El_Transito_B	A	142	7.5	6.1	7.2	8.3
	El_Transito_C	A	142	9.9	5.7	6.7	7.7
	El_Transito_D	B	142	6.4	5.8	6.6	7.5
Masachapa	Julio	A	175	7.6	5.3	6.1	6.7
	Montelimar	A	176	4.5	5.8	6.5	7.1
	Masachapa_ABC	CBB	178	5.6	5.0	5.5	6.0
	Masachapa_DEF	ABA	178	3.9	4.8	5.4	5.9
	Masachapa_G	A	178	4.1	4.6	5.1	5.5
	Masachapa_H	A	178	3.4	4.4	5.0	5.6
	Pochomil_AHD	B	180	4.8	5.5	6.3	7.0
	La_Boquita_AB	A	198	4.3	4.1	4.6	5.1
	La_Boquita_F	B	198	2.5	4.1	4.7	5.1
	Casares_BD1D2	AB	203	5.1	0.0	0.0	5.5
	Casares_I	A	203	6.8	4.5	5.3	6.0
	Huehuete	A	207	5.4	5.7	6.6	7.2
San Juan del Sur	SJS_AF	A	270	4.4	0.0	3.7	4.2
	SJS_J	A	270	3.6	3.2	3.7	4.1
	SJS_K	A	270	2.9	3.0	3.5	4.0
	SJS_L	A	270	2	2.8	3.3	3.8
	Playa_El_Coco	A	283	2.7	3.0	3.5	4.0

2)-3 Statistical evaluation

Aida (1977) proposed two indices, geometrical average and geometrical standard deviation, to statistically evaluate the simulation result. Accordingly, the simulated result was evaluated using these indices.

- Geometrical average K is defined as

$$\log K = 1/N^* \Sigma (\log Ki)$$

where N: number of data

Ki=Ri/Hi

Ri: Observed run-up at i-th point

Hi: Calculated run-up at i-th point

It is noted that desirable range for the value of K is $0.95 < K < 1.05$.

- Geometrical standard deviation **κ** is defined as

$$\log\kappa = Sqrt(1/n^*\Sigma((\log Ki)^2)-n^*(\log K)^2)$$

where N: number of data

Ki=Ri/Hi

Ri: Observed run-up at i-th point

Hi: Calculated run-up at i-th point

It is noted that desirable range for the value of κ is $\kappa < 1.45$.

Although the total number of data available for this study was rather limited for a statistical evaluation, the results are in a reasonable range as shown in Table 8-30.

Table 8-30 Results of statistical evaluation

Model	S7	S8	S9	Desirable value
Displacement	8m	10m	12m	--
Number of data	24	26	27	--
K (Geometrical average)	0.97	0.86	0.77	0.95<K<1.05
κ(Geometrical standard deviation)	1.28	1.27	1.26	**κ**<1.45

(2) Simulation for the “worst case”

1) Definition of the “worst case” scenario

The historical record of tsunami disasters in Nicaragua is mostly limited to the last 150 years when the coastal area was populated. Of those disasters, the 1992 Nicaragua Tsunami was the worst one so far. Here the worst case for each area was studied using a model with the same dimension of fault as observed for the 1992 Nicaragua Tsunami.

In general, areas close to the center of the fault length can expect larger inundation. For this reason, the aim was to locate the fault so that the center of fault length was close to the center of each study area.

2) Definition of fault location

The location of the north-end and south-end of the fault has some limitation due to the following observation.

Seismological observation at INETER indicates that seismic activities change in the north and south of the Pacific coast of Nicaragua. Geomar (2004) proposed that the northern end of the fault segment is located in front of Fonseca gulf. Therefore, the northern limitation of possible fault location was defined as being in the middle of the Fonseca gulf.

For the southern end, Geomar (2004) proposes that the southern end of the fault segment is located off the Nicoya peninsula in Costa Rica. In addition, the deep part (deeper than -4000 m) of the trench bends in the northern coast of Nicoya peninsula, so the extent of the segment to the south was limited to the bending of the trench in the Nicoya peninsula.

As a result, the possible range of locations for the fault for “worst case” is shown in Figure 8-81, and the locations of the possible “worst case” faults for each area are shown in Table 8-31. For Corinto and Puerto Sandino, the fault for the possible “worst case” could not be located in front of each area, due to the north end limitation of the segment. For Masachapa, it is possible to locate the fault in front of the area. For San Juan del Sur, it was not possible to locate the fault in front of the area, because of the southern end limitation of the segment location.

Table 8-31 Location of worst case for each study area

Area	Lon	Lat	Distance
Corinto	-86.8073	10.2880	11km-261km
Puerto Sandino	-86.8073	10.2880	11km-261km
Masachapa	-86.5878	10.0748	53km-303km
San Juan del Sur	-86.3732	9.8681	93km-343km

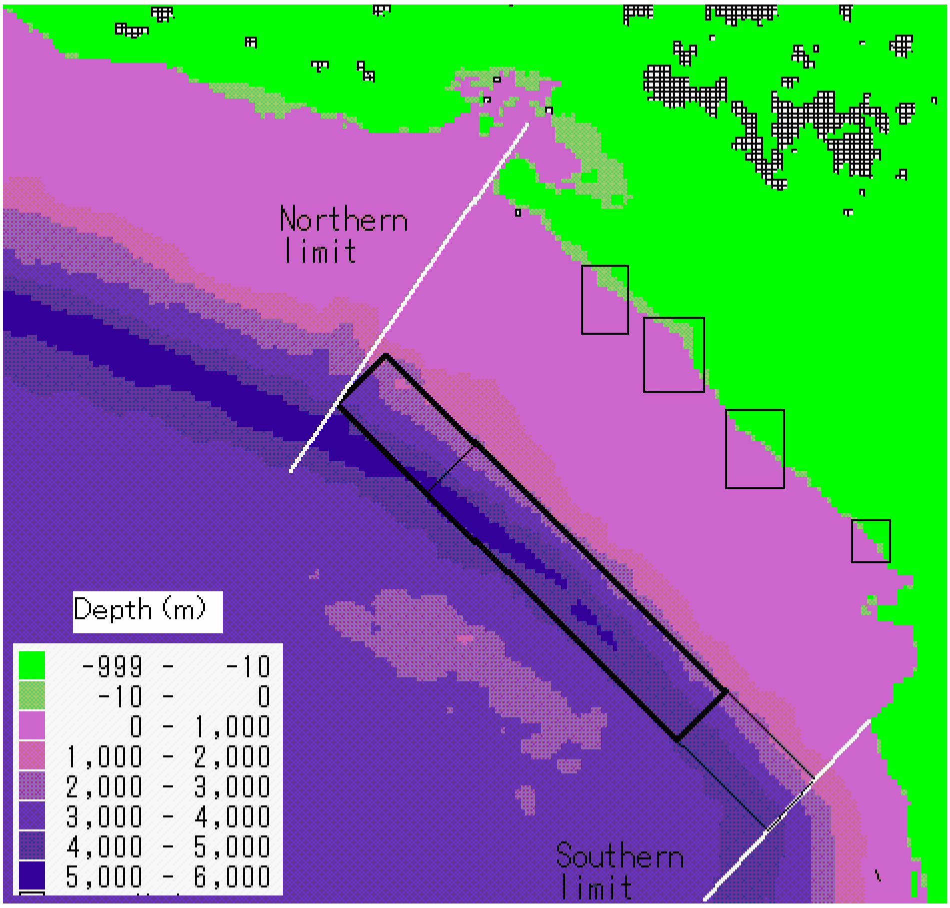


Figure 8-81 Range of fault location for the possible "worst case"

3) Result of simulation

Table 8-32 shows a comparison of the maximum inundation along coast by the reproduction of the 1992 Tsunami and by the possible “worst case” for each area. Except for the San Juan del Sur area, the difference between the two calculations is only 0.1 m, if any. Further comparison by mapping also showed that there is practically no difference between the two calculations except for San Juan del Sur. This is because the 250 km fault length is so long that slight differences in the location do not affect the resulting run-up along coast except for the San Juan del Sur, which is located at the southern end of the fault. As a result, the 1992 Nicaragua Tsunami can be regarded as a worst case for the Nicaraguan Coast, except for the San Juan del Sur area.

Table 8-32 Maximum inundation by the 1992 Tsunami and by the “worst case”

Area	Name	Distance (km)	Maximum inundation (m)		
			The 1992 Tsunami		Worst case
			Observed	Simulated	
Corinto	Corinto_A	73	3.5	3.9	3.9
	Corinto_B	73	3.9	0.0	0.0
	Corinto_C	73	2.7	0.0	0.0
Puerto Sandino	Salinas_Grandes_ACD	115	4.5	6.3	6.2
	Salinas_Grandes_B	115	3.3	4.9	4.9
	Puerto_Sandino_A	127	3.7	0.0	0.0
	Puerto_Sandino_B	127	3.5	5.3	5.3
	Miramar_ABC	129	5.6	0.0	0.0
	El_Velero_AB	133	5.2	5.8	5.8
	Playa_Hermosa	133	3.6	4.7	4.7
	El_Transito_A	142	6.4	6.9	6.8
	El_Transito_B	142	7.5	7.2	7.1
	El_Transito_C	142	9.9	6.7	6.7
	El_Transito_D	142	6.4	6.6	6.6
Masachapa	Julio	175	7.6	6.1	6.2
	Montelimar	176	4.5	6.5	6.6
	Masachapa_ABC	178	5.6	5.5	5.5
	Masachapa_DEF	178	3.9	5.4	5.4
	Masachapa_G	178	4.1	5.1	5.1
	Masachapa_H	178	3.4	5.0	5.1
	Pochomil_AHD	180	4.8	6.3	6.3
	La_Boquita_AB	198	4.3	4.6	4.5
	La_Boquita_F	198	2.5	4.7	4.6
	Casares_BD1D2	203	5.1	0.0	0.0
	Casares_I	203	6.8	5.3	5.3
	Huehuete	207	5.4	6.6	6.6
San Juan del Sur	SJS_AF	270	4.4	3.7	6.2
	SJS_J	270	3.6	3.7	6.2
	SJS_K	270	2.9	3.5	6.2
	SJS_L	270	2	3.3	6.5
	Playa_El_Coco	283	2.7	3.5	6.2

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9 RECOMMENDATIONS

9-1 Recommendations to INETER

9-1-1 Uses of Basic Topographic and Geographic Information

Maintaining the Geographic Base Data with Same Specification

The 1:50,000 Topographic base data prepared by the Study has the spheroid WGS84 as reference. Therefore, all the new geographic data to be produced in the future should use the same reference to facilitate their overlying with greater accuracy. Along these lines, the old 1:50,000 Topographic maps prepared during the 60's, which have the spheroid NAD27 as reference, should be converted to Spheroid WGS84 to ensure compatibility.

Extending the Geographic Basic Data to the rest of the Country

Since the Study covers only the Pacific Coast of Nicaragua, in an area of less than 20% of the Nicaraguan territory, it is necessary to continue these studies to produce geographic data for the rest of the country. This will facilitate the performance of GIS analyses for greater areas of the country or even for the whole territory by the Nicaraguan institutions.

Installation of Original Bench Marks

Original bench marks do not exist in Nicaragua and need to be installed. Benchmarks are crucial to monitor height changes. When they are not available, heights from the geoid model derived from GPS observation might be sufficient for survey purposes. However, for seismic activity monitoring, original bench marks are indispensable and need to be prepared.

Updating Interpretation Keys

Updating the interpretation keys is important for consistent field identification among surveyors. About forty-two keys were prepared during the Study; they need to be refined and standardized for future use.

Preparation of Gazetteer

An annotated database should be prepared utilizing the data prepared during the field identification process carried out by the project. This database can become a good source for a gazetteer. It has to be noted that, during the field identification, all the annotation data were extracted from existing topographic maps. The results of that work should be systematically organized for future use.

Development of New Products and Services and Their Marketing Strategies

With the introduction of GIS technology in this project and the utilization of new software such as Adobe Illustrator, which was being used for the first time at INETER, it is now comparatively easy to edit the maps and to produce them in easy-to-distribute formats such as eps, bitmap, gif, and jpg graphic formats. Therefore, besides producing paper maps, INETER now can provide digital maps, which can be very useful and have numerous uses and applications by the Nicaraguan institutions in both the public and private sectors. New distribution, administration, and marketing mechanisms need to be developed to make the digital maps easily accessible to the society.

Establishment of Crustal Movement Observing System

As the GPS technologies are becoming affordable recently, a crustal movement observing system should be establish to setup permanent GPS stations in the hazard target area. The information and data generated by these stations should be accessed easily and downloaded by the users through the internet. This information could be useful in, for example, monitoring earthquake and volcanic activities as well as the early detection of slope stability problems.

Human Resource Allocation

Until knowledge and skills become the resource of an organization, moving the experienced trainees shall be limited as much as possible. The trained staffs need to document the acquired skills and technologies as much as possible in Spanish so that newly placed individuals will be able to learn skill from the experienced staff.

Knowledge Sharing among the Staff

The skills and knowledge shall be shared in the department as much as possible. Those who have skills and technology shall be compensated or awarded for their contribution to the dissemination of technology or for their leadership.

9-1-2 Hazard Mapping

These recommendations are based on the material included in questionnaires filled by the Japanese experts in charge of the preparation of the hazard maps produced by this project. Four hazards are considered: 1) Seismic hazard, 2) Volcanic hazard, 3) Flood hazard, and 4) Tsunami hazard.

(1) Earthquake Hazard

Recommendations a the institutional level

The activities carried out in collaboration with INETER staff showed that they understand the calculation procedure well and that, theoretically, they are in the capacity of performing similar studies for other cities in Nicaragua. However, the main and most difficult problem they face is the lack of basic information and the system to realize a reliable simulation of future earthquake hazard. In this context, the following actions can be recommended:

- Acquisition of improved earthquake location data with better location control of earthquakes ranging from very shallow to deep focal depth. This shall be achieved through the deployment of seismological observation network sites with high-sensitivity seismometers especially on the far Caribbean side of Nicaragua.
- Establishment of a larger number of continuing (24 hours/day) strong motion stations in the strong motion observation system. A standard processing format for recorded motions and periodic publication of the results of the analyses are also recommended.
- Collection of reliable data on the characteristics of past disastrous earthquakes and the associated damage and loss observations. The data should be analyzed quantitatively in order to formulate empirical relations that can be used to forecast future damage and losses.
- Collection of geophysical and geotechnical data of surface soil layers and underlying engineering bed rock. For this purpose, a suitable number of boring machines and undisturbed soil samplers, as well as physical and mechanical testing apparatus, should be distributed among domestic institutions working on geotechnical engineering.
- Establishment of a national program for the acquisition of the necessary data to perform simulations similar to the one performed in this project in other areas of Nicaragua.
- Careful extension of these studies to the rest of the country taking into account that the information available for other areas is even less complete than the one available for Managua.
- Better allocation of resources on human resources development to improve the rather uneven levels of education, knowledge and ability of the staff within INETER. Cur-

rently, the knowledge and technologies brought by international projects are limited to the individuals that were in charge (as counterparts) of these projects.

Recommendations to improve the earthquake hazard map for Managua City

The quality and quantity of currently available data is not enough for and accurate earthquake hazard evaluation using a 500 m grid system in Managua City. The situation of other cities and areas of Nicaragua may be even worse. Therefore, a national program to generate basic earthquake-hazard-related information should be designed and implemented immediately that will allow the future preparation of earthquake hazard maps for other areas of the country.

- Development of a database of site-response characteristics derived from strong motion records obtained in the past.
- Development of a reliable database of seismic intensities observed for historical disastrous earthquakes
- Integration and analysis of micro-tremor data to investigate the characteristics of site response in the Managua City area
- Collection and evaluation of all available geologic data on active faults
- Collection and evaluation of available geologic and geophysical data on the geological profile, classification, and physical and dynamic properties of subsurface soil layers and the underlying engineering bedrock.

Consideration of other areas outside Managua

Since the level of information available for other areas outside Managua is lower than the one available for the Nicaraguan capital, extreme care should be taken if the earthquake hazard simulation method applied in this project were to be applied to other areas of the country. Quality and quantity of the existing data should be analyzed carefully to understand the limitations and applicability of the simulation process.

Better allocation of resources on human resource development

The levels of education, knowledge and ability of the staff are rather uneven within INETER. This is true even within the Sections of the institution. In the case of the Department of of Geophysics, the members of the Seismology Section are fairly better prepared than the members of other sections. In general, and especially after Hurricane Mitch, the Department of of Geophysics has received numerous foreign-assisted projects and contributions because this department deals with the most common natural hazard affecting Nicaragua, such as earthquakes, landslides, and volcanic eruptions. As a result of this active interaction with international projects, the Department of Geophysics has been able to incorporate significant amounts of new technology, equipment and software. However, these technologies are limited to the individuals that were in charge (as counterparts) of these foreign projects. In order to continue and improve the Department's capability to provide the services they are expected to provide, an internal educational scheme that spreads the knowledge and reaches all the persons.

(2) Volcanic Hazard

Volcanic hazard mapping in Nicaragua, which is carried out mainly by INETER, faces various challenges in the different stages of the process. Some of those challenges and recommendations on how to overcome them are presented below.

Interpretation of aerial photography

INETER volcanological staff has had very few opportunities to work with aerial photographs and, as a result, they hardly know about the interpretation techniques. Even when they have some knowledge, the technical level is considerably low. This situation could change if the usefulness of aerial photography were recognized and this very valuable information were frequently adopted in the studies. At present, however, there are only exits only about 6 stereoscopes in all INETER in spite of the fact that these instruments are needed for the interpretation of aerial photography. Moreover, these stereoscopes are not well calibrated and the acquisition of new instruments is recommended.

Hazard Mapping Procedures

So far, there have not been enough discussions on the basic idea and the logic of volcanic hazard mapping at INETER's General Direction of Geophysics. As a result, the counterpart and other researchers of the Section wrongly think that this work can be completed on the computer using just some related software. It is necessary to go deeper in the discussions on the basic concepts and philosophies of hazard mapping necessary to elaborate maps that reflect the local realities. To make these discussions possible, it is indispensable to continue with the training and capacity building programs at INETER.

Geologic research on volcanoes

The interaction with INETER staff seemed to show that that, while they have the basic knowledge acquired at the university on this aspect, they lack the necessary knowledge ad experience to do field work in volcanic areas. It is particularly notable the gap that exists between the knowledge they have of volcanic structures and their capacity to identify them on the field. Also, there is a clear lack of basic knowledge on volcanic processes and volcanic geology. To solve this problem, it is necessary for them to develop systematic training programs with emphasis in the practical aspects of volcanic geology.

Human resources

The first priority should be to develop the human resources with the capacity of executing field investigations on the Nicaraguan volcanoes, since this is a very volcanically active country. For that purpose, a experienced vulcanologist will have to train INETER staff on both the theory and practice of volcanoes.

Basic data collection and organization

Systematic programs for data acquisition, validation, synthesis and analysis must be implemented. A specialist with deep knowledge of GIS techniques and volcanic geology should guide the Geophysics researchers on the proper generation and handling of data. Also, INETER has not enough basic books on volcanic geology and has difficulty in subscribing to international academic magazines, which limits its staff's opportunities to increase their knowledge.

Short-term capacity building aspects

In the short-term, the Section of Vulcanology could strengthen its technical capacity by focusing in the following aspects:

- Acquisition of basic knowledge of volcanic geology including field practice programs in a regular basis
- Definition of the basic philosophies of volcanic hazard mapping in order to develop a logical framework for the representation of the results of the calculations.
- Increase coordination with the seismic observation section to benefit from each other's interaction
- Proper identification and analysis of the volcanic seismicity
- Development of regular training and educational programs to raise the staff's technical capacity.

(3) Flood Hazard

Human resource development

In order to continue the learning process on flood hazard mapping initiated by this project, the following activities are recommended to be taken immediately:

- Translate into Spanish and complete the operation manual that was prepared and distributed during the training sessions on flood hazard mapping. This should be the basis for the development of their own manual.
- Apply to other river the methodology utilized and taught in this project. The INETER staff should get familiar with each step of the procedure and prepare the necessary supporting manuals and guidelines.
- The staff of the Hydrological Resources Section should master hydraulic analysis, especially the two-dimensional analysis of unsteady flow.
- Every effort should be made to increase the Fortran programming and numeric simulation capabilities of the staff so that they can prepare computer programs that match their specific needs and reduce the dependency on pre-prepared, unnecessarily complex, and usually expensive computer programs.

Accumulation of data

Accumulate hydrological data and establish a comprehensive, well-organized database. Nicaragua's main problem is the lack of basic information. Every effort should be made to generate, collect, validate, and organize new data in a systematic way.

Flood catalogue

A "flood catalogue" should be established to collect and organize the valuable information from past disasters.

Master plan development

A master plan should be developed with the long-term goal of preparing hazard maps for all the rivers in Nicaragua. The master plan should define priorities, funding sources, and a time line that realistically reflects the local resources and capabilities.

Project team

Establish, train, and develop a "project team" specialized in the estimation and mapping of flood hazard.

Strategy development

Develop a strategy that would allow the actual implementation of the master plan for hazard mapping of all the rivers in Nicaragua. This strategy should include the active collaboration with other institutions, local authorities, and the communities.

Research program

A research program should be established on the particular characteristics of flood hazard in Nicaragua. The results of these investigations would allow the customization of Nicaragua's hazard maps to better reflect the local conditions and needs. This customization could include, among other things, the definitions of suitable methods of hydrological analysis, adequate mesh sizes for the analysis, simulations programs, necessary criteria for parameter selection, contents of studies and maps, users and applications.

Improvement of flood forecasting procedures

The flood forecasting procedures should be improved and combined with hazard mapping methodologies in order to prevent flood disasters in a more effective way.

(4) Tsunami Hazard

Collaboration between the Department of Geophysics and Hydrology Department

For the future improvement of tsunami hazard map, closer collaboration between the Departments of Geophysics and Hydrological Resource is indispensable.

New data collection for better simulation

New and better data are needed, especially bathymetry data in the near coast area, which is a key factor for the improvement of the models used in the simulation. In order to generate the appropriate information, good understanding of the simulation methodology is a must in both the mentioned Departments.

Topography model improvement

In this Study, best available topography data to date is used to develop topography model. However, it is found that density of data is still limited, especially in near coast where data with sufficient distribution density is required to develop a 100 m sized grid. It is strongly recommended to conduct bathymetry survey in the near future, at least in areas where population is concentrated along the coast. For this, good collaboration between geophysical department and hydrological resource department is required.

Field survey

For a reliable simulation basic data gained from disaster survey is very important. Though the field survey for the 1992 Tsunami was done by mainly foreign researchers, such studies should be done by Nicaraguan by themselves in the next event. For this, training of field survey should be done. Additionally, hearing from residents is recommended to document disaster memory among local residents for educational purpose, as well as to record scientific data.

Application to disaster prevention

As INETER is a scientific research institution, its interest in hazard map is rather limited to do simulations. The purpose of developing hazard map should be discussed within INETER and with related institutions. Territorial planning department in INETER and SINAPRED can be important elements for land use planning. Besides, cooperation with related institutions such as INTUR, EPN, MTI, MARENA, and MIFIC etc are important. It is recommended to form a working group including these institutions and to incorporate preventive measures in main activities in each sector.

Trainings to other staff

There is no staff currently assigned uniquely to the tsunami study, and the number of trainees was rather limited this time. It is expected that contents provided in training should be transferred to other staffs within INETER to promote basic understandings.

Learning from international experiences

As major tsunami is rare phenomenon, experiences in other countries and access to the advance in the tsunami study in international level provide good opportunities to its better understandings. For this, joining International Tsunami society (www.sthjournal.org), or studying experiences in other countries, such as Japan, US, Hawaii, Chile, Indonesia etc is recommended.

9-1-3 Uses and Development of GIS Technology

Sharing of Geographic Basic Data

Since the preparation of geographic basic data requires the investment of a significant amount of resources, sharing of such data among the largest possible number of agencies will significantly increase work's efficiency and, consequently, reduce the initial investment cost. Moreover, circulation of reliable map data as social infrastructure by the government will result in the promotion of public-private partnership and encourage the growth of private investment.

Effective Data Distribution and Support for Users

The geographic basic data so prepared by this study shall be circulated through various feasible channels, such as internet, CD-ROM, DVD, and printed maps, to ensure its widespread use as an instrument for decision-making or as a tool for information analysis. However, since it is impossible to expect all the users to have the necessary capabilities for data management and customizing, appropriate support programs for the users should be designed and implemented.

Providing Data for SINAPRED

The following types of data shall be provided to SIPNPRED:

basic information for the before/during/ and after stages of the disaster,
assistance for emergency response activities, and
maps tailored to the specific needs and conditions of any location within the country.

Training on system's structural design

An in-depth GIS training program should be implemented on the proper design of the system's structure and its systematic implementation. The system should be designed with an institutional vision and structured in such a way that all the Sections of INETER benefit from its existence. In a more practical sense, manuals and adequate documentation should be prepared on the systems' design so that the system expansion will be performed methodically and all the staff members have easy ways to understand the system's structure. Standardized procedures should be developed to ensure the integrity of the system's original design when adding new obtained or generated information.

Promotion of the interaction among the various INETER sections

The GIS training program implemented in this project could be utilized as a model for the implementation of larger-scale programs that include all the sections of INETER. The formation of multi-section classes and the rotation of the training places among the various sections should promote interaction among the INETER sections and would facilitate the formation of inter-sectional working groups and the exposure of people of a given section to the work done by the other sections. Additionally, this inter-sections work would certainly reduce the wide variation of GIS capabilities among the various INETER sections and would facilitate the sharing of experiences, knowledge, and working techniques.

Development of marketing and distribution strategies for INETER's products

Marketing techniques should be implemented to identify all the current and potential users of INETER's products as well and their needs and preferences. That should help INETER dedicate its efforts to the production of outputs that respond to the market demand and, therefore, are looked after by INETER's clients and beneficiaries of its work. Finally, appropriate announcement and distribution methods should be developed to ensure a smooth and user-friendly access to INETER's products by the current and potential users.

Proper utilization of the GIS packages

Due to its visibility and tangibility, GIS systems have become a popular tool for international assistance. Many computers and software licenses have been donated to Nicaraguan institutions. However, donations of hardware and software are not enough and every effort should be made to ensure that the necessary steps are also taken to strengthen the institutions, provide adequate training, and create formal structures for the efficient use and exchange of information among institutions. This will ensure proper understanding of GIS technology and its applications and will not let this useful tool to remain underutilized.

9-1-4 Georiesgos GIS

The Geographic Information System (GIS) of Georiesgos (Georisks), developed by the Geophysics Division in cooperation with INETER's other divisions and several local and international organizations, is a technically sound system, the most advanced of its type in Central America, which already includes a significant amount of information on hazards, vulnerability and risk in Nicaragua. Through INETER's LAN, all the computers of the institution have access to this GIS, which also publishes electronic information through the Internet, including interactive maps. The interdisciplinary fashion in which this system has been developed should be promoted and enhanced in the future. The Georiesgos GIS has also been given a regional scope through the collaboration with institutions in neighboring countries. The utilization of this existing system is recommended for the following activities:

Integration of hazard data in the GIS

Integration of all the results of this project in the Georiesgos GIS and follow up on the development and update of the produced databases and maps. Publication of maps and covertures in the Georiesgos GIS' map server.

Integration of geographical information in the GIS

Integration into the Georiesgos GIS of all the geographic information, aerial photography, and DEM produced by the project so that they can readily and efficiently be usable for the development of new hazard, vulnerability, and risk maps and for emergency response activities.

Integration of at-risk elements information in the GIS

Integration in the Georiesgos GIS of a database of the at-risk elements and publication of this information in the way of an interactive map on INETER website so that it can reach a wide audience and be utilized, especially, in case of emergencies. Continuous update of this information.

Utilization of Georiesgos GIS by all INETER Divisions

Utilization, on a regular base, of the Georiesgos GIS by all the INETER divisions, which should have access to all the databases although each division could have its own GIS applications. Training of staff in other divisions on the use of the Georiesgos GIS. Closer collaboration between the Divisions of Geophysics and Cartography/Geodesy is especially recommended to take advantage of the work done in both divisions by the project.

Utilization of Georiesgos GIS by SINAPRED and other institutions

Utilization of the Georiesgos by SINAPRED and other institutions to optimize resources and save funds and time in the development of disaster prevention programs.

9-2 Recommendations to other institutions and the National System

9-2-1 Uses of Hazard Maps

A comprehensive program of activities was developed and implemented to collect the relevant information and promote the necessary discussions to produce recommendations on the Uses of the Hazard Maps to be prepared by the project and on the Strengthening of Disaster Prevention in Nicaragua. Questionnaires were prepared to collect the necessary information. The recommendations presented here are the result of the analysis of more than 350 questionnaires completed by representatives of more than 50 organizations from the public, private and civil society sectors of Nicaragua. After discussing the results among the Study Team members, the Study Team has concluded to recommend the uses of hazard maps in two major aspects: 1) Application of the results for risk reduction activities; and 2) Information dissemination measures.

(1) Application of the results for risk reduction activities

Incorporation of Census Data to Hazard Maps

As a first step, the combination was suggested of this information with the results of the census underway to determine the population under risk This information can be utilized to implement emergency response drills, design early warning systems, and determine safe and evacuation areas.

Development Disaster Prevention Management Plans

It is crucial to incorporate the community in risk reduction activities. User-friendly versions of these maps can be utilized to educate and raise awareness about the existing risk among the community and its leaders. These results should be utilized in the preparation of appropriate contingency plans for cities and organizations and for the revision of the existing ones. This work can be carried out by the local disaster preparedness committees. Working with the communities, these maps can be utilized to prepare specific maps for small towns, villages or municipalities for them to get familiar with their particular risk.

Development of Regional Plans

SINAPRED, local authorities, and organizations in charge of infrastructure should coordinate the incorporation of these results in the corresponding regulatory and legislation instruments for disaster risk control. Land use and urban planning regulations should be revised utilizing the new information produced by the project.

Regional Disaster Prevention Policy Formulation

SINAPRED should utilize these results to update existing and create new disaster reduction policies and regulations. Similarly, INETER should utilize this experience to prepare maps of the areas that have not been considered in the Study and disseminate the learned technology through educational programs both within INETER and in other related institutions.

(2) Information Dissemination Measures

Local authorities

Local authorities and local emergency committees should disseminate these results working in collaboration with community leaders.

Collaboration with the media

Training programs should be prepared for the mass media so that professional communicators can effectively transmit accurate information to the community. Mass media such as radio, TV, and newspapers could greatly help to disseminate the project findings. A TV presentation, for example, was suggested as an effective way to take this information to the community.

Brochure Preparation for General Public

It is important to ensure access by the general public to all the important information and results produced by these studies. To facilitate this, easy-to-understand material should be prepared that properly explains to the community the project findings and results. Educational programs should be prepared especially for vital facilities such as schools, hospitals and public buildings. In general, it is necessary to identify the different groups of users and edit the products and develop distribution mechanisms for each of them.

Making Hazard Maps Available

Copies of the resulting maps can be made available at public places such as community centers, libraries, schools, churches, hospitals, public buildings. Also, regular seminars and workshops for the communities can be implemented that would not only educate the public but would also collect the citizen's feedback and clarify any doubts that might exist

Information Dissemination through Institutions and Professionals

One of the best ways to disseminate these studies is through their utilization in the education of new professionals in the Universities. This new information should be incorporated in the education of new professionals. Also, professional associations (engineers, architects, urban planners), universities, chamber of construction should be involved in disseminating these results among the Nicaraguan professionals and practitioners.

The dissemination work of all related institutions needs to be coordinated. A regular program of seminars could be established in which all the related institutions have an opportunity not only to learn about the studies but also to give their input and recommendations. Risk reduction related organizations could then utilize these results to prepare training programs for community's capacity building.

Comprehensive Coordination of Publicity and Promotion Activities

It is crucial that INETER updates its distribution mechanisms and makes it known to potential users to facilitate the access of these results by all related organizations. It was suggested, for example, to make all these results available on the web utilizing software that facilitates handling of this information.

9-2-2 Strengthening Disaster Prevention

The Study Team conducted series of discussions and interview sessions with local authorities and stakeholders regarding disaster prevention. The major themes of the research were on: 1) Institutionalization of risk reduction on: 2) Future activities to be undertaken; and 3) Community involvement and participation. With these themes, the Study Team came up with the following recommendations.

(1) Institutionalization of risk reduction

- Revise the legal framework in order to decentralize risk reduction activities and reduce the current strong dependency on centralized decisions. The decentralization of the system and the empowering of the local sectors will increase the effectiveness and efficiency of the risk reduction programs and activities.
- Improve the coordination of the projects and activities implemented through foreign assistance to increase their impact and efficiency and optimize the use of the resources made available by the international community. Synergies should be promoted among the cooperation agencies and their projects to increase the effectiveness of these efforts and avoid repetition of efforts.
- Improve the communication and collaborative work between SINAPRED and the technical institutions such as INETER, universities and research centers. In the same way, interaction and collaboration with end users such as local authorities and community leaders should be increased and improved to promote a better coordination of activities.
- Create a disaster reduction information center that compiles, organizes and makes all the existing and newly produced information available to all the potential users. The proposed information center should collect all the existing documentation and information that is now spread among different institutions without any systematic organization.

- Put local capacity building at the center of any new program on disaster risk reduction. The institutions of the SINAPRED system should be provided with the sufficient knowledge on risk management to allow them focus their activities in risk reduction and recovery planning rather than in emergency response only. Similarly, local governments should have the capability to introduce risk management in their development and investment plans. The empowerment of local governments will facilitate the decentralization process.
- Secure financial stability of risk reduction initiatives. The existing legal framework of the SINAPRED should be revised to allow and facilitate the active incorporation of the private sector and its valuable financial and technological resources. Also, a municipal fund for disaster risk reduction purposes could be established to guarantee long-term continuity of risk reduction efforts. Finally, the role of the insurance sector in sharing risk and providing necessary funds for reconstruction should be recognized and incorporated in risk management initiatives at all levels.
- Enhance the local authorities' role in informing the communities about existing risk and means to reduce it. This cannot be done only by SINAPRED and/or the Civil Defense. The strengthening of local capacities should take maximum advantage of the existing local social structures and work in collaboration with community leaders.
- Coordinate the individual efforts already made by organizations in both the public and private sectors. Uncoordinated, independently developed contingency and risk reduction plans may interfere with each other reducing their effectiveness and impact.
- Develop programs and mechanisms to incorporate the active participation of all the sectors (public, private, civil society) of the community in risk reduction activities. These efforts should include the revision and strengthening of the university system to improve the preparation of new professionals and incorporate risk management in their education.
- Perform a systematic evaluation of the current state of risk management in Nicaragua to identify what has been achieved and what is lacking. Based on that evaluation, consensus should be built on the actions to be taken to construct on what has already been achieved, the implementation strategies to be adopted, and the optimal utilization of resources.
- Secure operational continuity. Financial and technical programs should be developed to guarantee maintenance and operation of the equipment donated by international-assistance projects after the conclusion of those projects. If this is not done, as it currently happens, the donated equipment will become a burden rather than a solution.

(2) Future actions to be undertaken

- Improve the quality of available data by implementing programs to systematically collect new information and perform the required analyses to validate their quality and usefulness.
- Prepare appropriate disaster risk reduction and contingency plans for cities and organizations and revise the existing ones. Similarly, efforts should be made to prepare recovery plans to ensure that risk is not re-created after a disaster.
- Develop tools and mechanisms to monitor and evaluate progress of the risk management activities in order to perform periodic evaluations of the process and make the necessary corrections. A program of regular evaluations should be developed for both the national risk reduction system as a whole and for individual initiatives to objectively measure their actual impact.
- Implement special programs in collaboration with construction companies, professional associations, and Chamber of Construction to train the professionals on effective risk reduction techniques and proper construction practices.
- Establish training programs for local authorities, who are the end users of these results and information produced by risk reduction studies. Through the implementation of training programs targeted for decision makers, local authorities should be

able to utilize this information and incorporate risk management considerations in development planning and investment programs.

- Utilize the experience and technology learned from projects like this one to continue the work covering all the national territory. In the specific case of this project, for example, the studies cover just about 40% of Nicaragua's territory. There is almost no work done for the central region and the Atlantic Coast of the country. It is necessary to use the experience of this and other similar projects to develop similar studies for other areas of Nicaragua.
- Coordinate with other similar institutions in the region that are doing similar studies in neighboring countries to increase the completeness and impact of these studies. Since the geographical, social, economic, and cultural conditions are very similar among the region's countries, regional initiatives should be promoted rather than national and local ones.

(3) Community incorporation in risk reduction activities

- Incorporate all the sectors of the society as active actors in the implementation of risk reduction activities. Since disasters are complex processes, they have to be dealt with adopting multidisciplinary approaches and having the participation of all the community sectors.
- Utilize the results of this and other similar studies to implement systematic programs of regular disaster drills with the communities. The general public needs to get familiar with the characteristics, causes, and effects of the natural hazards to avoid the paralysis caused by irrational fear or the chaos resulting from misinformation or the existence of myths.
- Incorporate risk reduction in the school programs through the Ministry of Education. So far, there have been several efforts to educate the community through informal, short lived educational programs. The introduction of disaster risk reduction in formal education will help create a well-established culture of prevention.
- Raise community awareness of the existing risk and of feasible measures to reduce it. The general public's attitude should change from a fatalistic or reactive attitude to a proactive one in which the level of acceptable risk is recognized, understood, and decided. This can be done through the implementation of regular, well-coordinated educational programs for the community. These efforts should include awareness raising and capacity building campaigns for decision makers so that they can include risk management in their planning and investment decisions.
- Incorporate risk reduction in mainstream community life. For these purposes, the establishment of special dates to remember the importance of disaster preparation should be considered. In Corinto, for example, the establishment of the "Tsunami Day" on September 1st, anniversary of the 1992 Tsunami, was suggested to raise community awareness on the existing risk and the importance of reducing it.