After plotting the planimetric feature data, accuracy control of the following items per model was conducted to correct any errors:

- Number of faulty entries and omissions of codes (faulty entries include faulty attributes and inaccurate shapes.)
- Number of edge mismatching points

After compilation of the planimetric feature data, accuracy control of the following items per map sheet was conducted to correct any errors:

- Faulty entries and omissions of codes (including marginal information data)
- Number of points of plane-type planimetric features and contour lines unmatched with those in orthophotos
- Number of edge mismatching points

(9) Horizontal/Vertical Sectioning of Rivers

For analyzing river floods, the horizontal/vertical section map of a river selected in “Discussions about hazard map production plan” was prepared through navigational measurement. The horizontal section survey lines were generated at a pitch of 2km from the vertex of the fan-shaped land and a width of 500m (250m on one side). The vertical section map was made at a scale of 1/10,000 on the horizontal axis (distance) and 1/100 on the vertical axis (height), while the horizontal section map was made at a scale of 1/1,000 on the horizontal axis (distance) and 1/100 on the vertical axis (height).

After making the horizontal and vertical section maps of the river, accuracy control of the following items per index map sheet was conducted to correct any errors:

- Faulty entries and omissions of survey lines (faulty entries include faulty attributes and inaccurate shapes.)
- Output positions
- Errors in output items

(10) Automatic Creation of Orthophotos

The orthophotos were produced by automatic processing using the created DEMs and the digitized aerial photo data. This process defined which photo of a stereo pair, left or right, was used, and the tie line was roughly drawn. The original images of the generated orthophotos were stored on the hard disk in the internal format of the digital plotter.

After generation of the orthophotos, accuracy control of the following items (per photo) was conducted to confirm that there would be no problem in subsequent work:

- Resolution
- Brightness
- Contrast
- Noise (flaws and folds)
- Image drift
- Positional accuracy
- Maximum positional error (Digital plotting data is displayed in overlay and the maximum value is entered.)

(11) Mosaic Processing

The Study Team selected the joining line of the created orthophoto with the adjacent photo within the overlap range to set a tie line manually and create a mosaic image. The mosaic image was then subjected to cut-out processing for each 1/10,000 map sheet.

The specifications of the neat line files were as follows:

Resolution : 600 dpi
Gradation : 256 monochrome gradation levels
Format : TIFF

After completion of mosaic processing, accuracy control of the following items per index map sheet was conducted to correct any errors:

- Number of tie lines (positions) requiring correction
- Number of tie-line image points requiring correction
- Quality of image correction (if a tie-line image is no good)
- Resolution
- Brightness
- Contrast
- File size
- Format (TIFF, uncompressed, 256 monochrome gradation levels)
- File name (whether data and file names coincide or not)

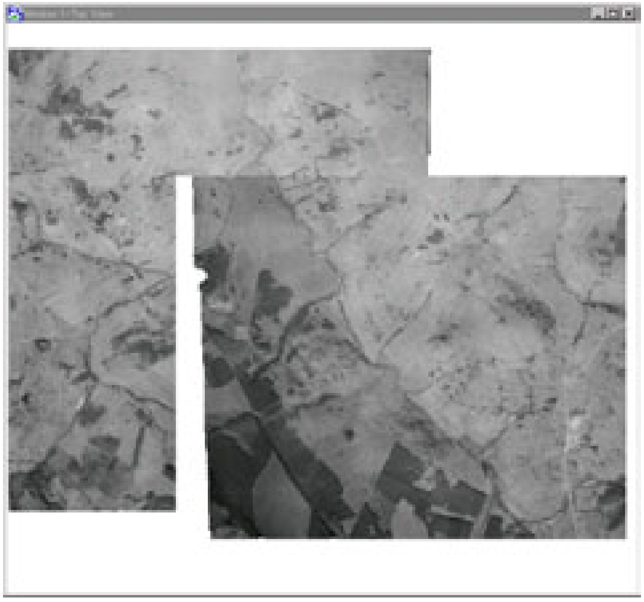

Figure 2.2-4 Mosaic Processing

(12) Outline of public facility/administrative boundary/administrative name survey

A study was made on the ground of the accurate locations of public facilities (schools, churches, police and military facilities) and medical facilities (hospitals and clinics) and annotations of town and village names, to gather the socioeconomic information to be used in hazard maps. This survey was mainly carried out by 16 counterparts divided into 8 groups. The annotations were prepared on the basis of annotations at the 1:50,000 level, and these were adapted for use in the 1:10,000-scale orthophotos.

The results of the field survey were organized and displayed on the orthophotos, together with the information received from the Guatemalan side, after which they were revised and input in a cooperative effort by the Study Team and the counterparts, using the digital editing equipment procured as equipment for the study.

Because this work was seen as the final field survey on orthophotos, it was carried out while the Study Team was in Guatemala, then the data was output again and a final inspection done as part of the technical cooperation by IGN.

As a result, the work of updating, modifying and inputting the data of 401 orthophoto map sheets was completed as planned in the original schedule.

The progress and problems of this work are described in detail below.

(13) Preparation for the field survey

Based on the administrative boundary data and 1:50,000-scale annotations acquired or created under “Investigation of administrative boundaries/names and terrain/planimetric features”, the orthophotos for the field survey were prepared in the second work in Japan.

The maps prepared for the Study are as follows.

- Annotation material maps (blue block, black block and existing topographic maps): Products from last year
- Road attributes material maps: Products from last year
- 1:50,000-scale database output maps (with 1:10,000 neat lines)
- 1:250,000-scale administrative boundary / name data output maps
- 1:10,000-scale orthophoto output maps (image + line data: for field survey)
- 1:10,000-scale orthophoto output maps (image + line data: for organization)
- 1:10,000-scale orthophoto output maps (line data)

(14) Checking of administrative boundaries and names

As they were prepared based on the 1:50,000-scale annotations, not all of the 1:10,000-scale maps have the administrative names entered in them. Thus, it was necessary to rearrange each 1:10,000-scale orthophoto map so that the administrative names would be entered. It was decided through consultation with IGN that where a map showed no administrative boundary, one administrative name would be positioned at the centre of the map. Where a map did show administrative boundaries, one administrative name would be arranged at the centre of each administrative district.

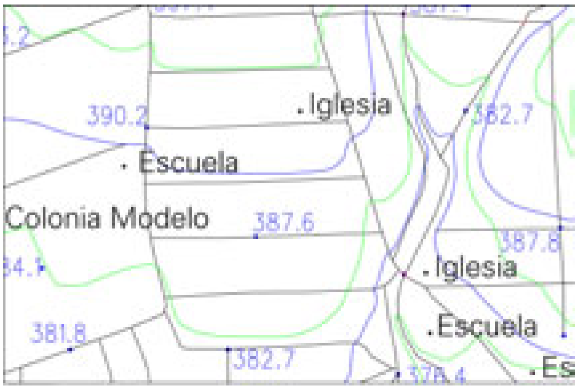

Figure 2.2-5 Compilation of annotation data by MicroStation

Figure 2.2-6 Merger of annotation data and orthophoto

To check administrative boundaries and names, the annotation material maps (blue block, black block and existing topographic maps), 1:50,000-scale database output maps and 1:250,000-scale administrative boundary and name data output maps were used.

(15) Preliminary observation work for supplementary survey in the field

The positional accuracy and arrangement density of the 1:50,000-scale annotations are on the 1:50,000 scale. This means that for 1:10,000-scale maps, it is possible that the number of annotations is fewer and the positional accuracy is poorer.

1) Checking of annotation positions

Of the annotations to be moved, those of which the new positions were clear were rearranged on the organizational maps as part of the indoor work. Annotations of which the new positions were not clear were reconfirmed in the supplementary field survey and marked on the 1:10,000-scale orthophoto output maps (image + line data: for field survey).

2) Rectification of arrangement density

For areas with a low annotation arrangement density, the villages were marked and the names of the villages added to the maps on the ground.

3) Checking of necessary public and medical facilities

From the viewpoint of a disaster prevention GIS, the locations of public offices, places of refuge and hospitals are essential. As the information on facilities designated as places of refuge could not be obtained from CONRED, the position of every symbol for a school, church, hospital, police station, military base and public office on the existing 1:50,000-scale topographic maps was marked on the 1:10,000-scale orthophoto output maps (image + line data: for field survey) and used in the supplementary field survey.

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4) Annotations to be deleted

Annotations other than those whose positions can be identified are unnecessary. Abstract annotations such as “Lava” (lava), “Piscina” (pool), “Cem” (cemetery) and “Vado” (river-crossing road) that are the names of ordinary features were deleted.

(16) Supplementary field survey

Even though the area was relatively safe, the field survey was conducted under thorough safety control. Specific safety controls included the formation of a separate group to monitor security conditions, regular inter-group communications and regular communications between IGN and the groups. The main work done in the supplementary field survey is described below.

Photo 2.2-1 Field survey and OJT

1) Checking of annotation positions

The positions of annotations that were unclear and picked out in the preliminary observation work were checked.

2) Rectification of arrangement density

The names of new villages picked out in the preliminary observation work were investigated directly in the field. The input annotations were stored separately in an Excel file by IGN in order to prevent spelling errors. The file contained the same items and codes as in the study conducted last year.

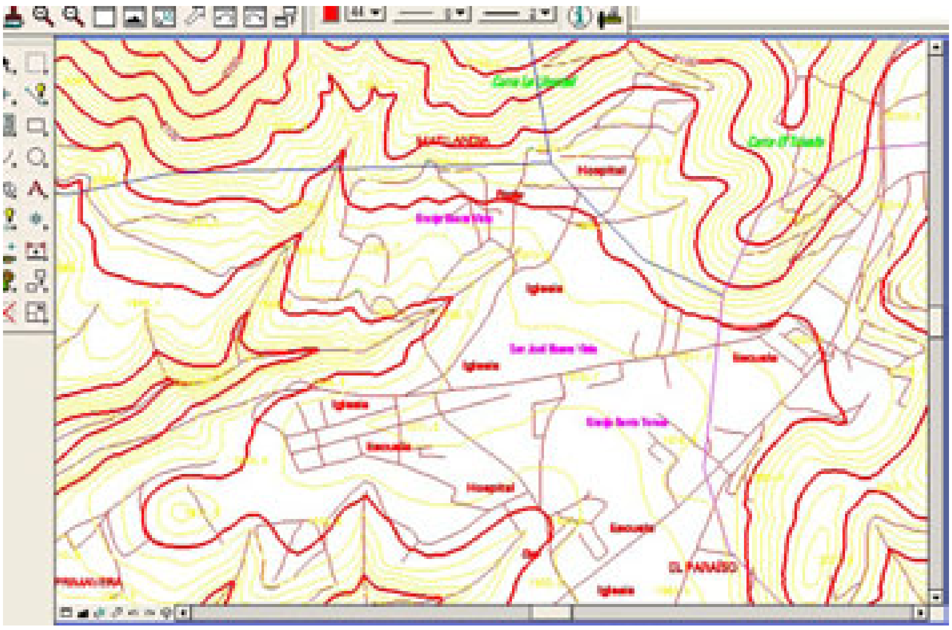


Figure 2.2-7 Results of revising/compiling annotation data by MicroStation

3) Checking of necessary public and other facilities

The positions of schools, churches, hospitals, police stations, military bases and public offices were checked accurately in the field. These facilities are public and medical institutions that at time of disaster would be designated as rescue and relief facilities and places of refuge.

These facilities were not entered as symbols, but as annotations such as “Escuela”, “Iglesia”, “Hospital”, “Policia”, “Militar” and “Municipalidad”, and the buildings were marked.

(17) Organization, updating and input of supplementary field survey data

The information verified in the field was arranged on the 1:10,000-scale orthophoto output maps (image + line data: for arrangement), and on the basis of these, the updating and input of the information was done as a cooperative effort by the Study Team and the counterparts, using Microstation and the digital editing system that was procured as study equipment.

After input of the revised data, the dgn file data was output using the study equipment plotter and a final inspection (spellings of annotations and revision errors) that was carried out as a cooperative effort with the IGN counterparts.

(18) Data entry of annotations/administrative boundaries

As a rule for the annotations on orthophoto maps the data created in preparing the 1:50,000-scale national base maps were input at reduced size. This means that some objects indicated by the annotations were unclear, but their positions were rectified on the basis of survey results. Not only these annotations but also the orthophotos and the data on planimetric features and annotations will be utilized in the hazard maps to be prepared in following work. In particular, because of the importance of information on the position of schools and churches, which it is expected will be used as places of refuge in time of disaster, their positions were identified, entered as points and annotated (see Figure 2.2-8.). After completion of the work to input the annotations, all 401 map sheets were plotted out using the study equipment, and an inspection of all the sheets was

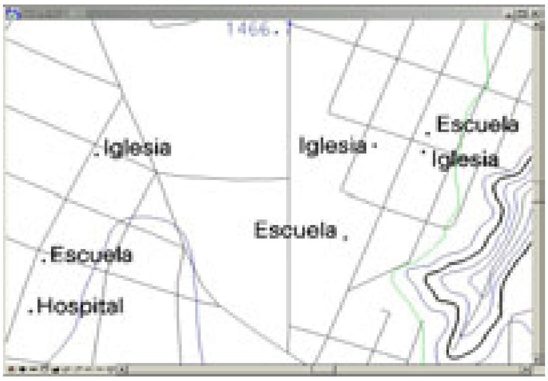


Figure 2.2-8 Input of schools and churches

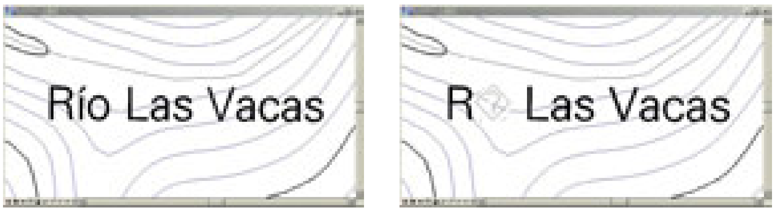


Figure 2.2-9 Normal and garbled character lines

carried out by the counterparts, with particular stress placed on spelling checks. The results of the inspection were reflected on the data immediately.

Something that caused problems during the work of annotation input was notations unique to the Spanish language. When Spanish words are input into MicroStation, if the operating system and MicroStation are non-English versions, characters become garbled and do not show up correctly.

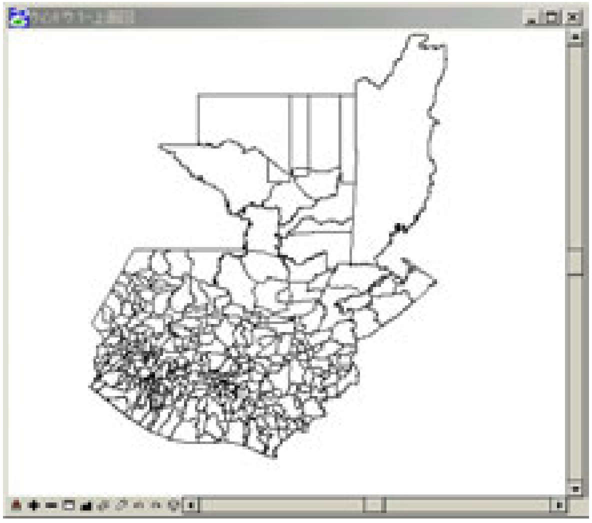


Figure 2.2-10 Administrative boundary data

Although the study equipment provided to Guatemala had English-language versions of both the operating system and the software, on the equipment that the Study Team used both were Japanese-language versions. Therefore, as a temporary measure the Study Team substituted accents and other marks with other characters when editing the annotations. When all the work was completed, the Study Team carried out a batch conversion of the annotations in Microstation on the study equipment, to replace substitutes with the correct accents and symbols.

The administrative boundary data for national, provincial, state and municipal boundaries was provided by the counterparts (see Figure 2.2-10). The data was converted into a MicroStation design file to be reflected on each map sheet file. The administrative boundary data is an essential element that could not be moved at the discretion of the Study Team. Even so, the Study Team’s review of the administrative boundary data discovered many instances of boundaries deviating from the central lines of ridge lines and rivers, and some places that were obviously not consistent with the topographic (planimetric) features. As it was thought these discrepancies would affect the work of producing the 1:50,000-scale national base maps that is under way, it was finally decided to check them with the counterparts during the fourth field survey (2002) when the national base map supplementary survey was carried out.

(19) Digital compilation/structuralization

The data on topographic and planimetric features, annotations and administrative boundaries for which digital compilation was completed were subjected to structuralizing compilation in order to promote the effective use of GIS in the future. Specifically, the centre-line elements of roads, railways, rivers, etc., that form a network were inspected for data directivity and continuity, and corrected. In particular, the line elements between map margins where continuity is easily lost (see Figure 2.2-11) were inspected and corrected carefully.

For double-line rivers, the same processing was done after centre lines had been generated separately. (See Figure 2.2-12)

It was confirmed that the shorelines of lakes and swamps were represented as closed figures. (See Figure 2.2-13)

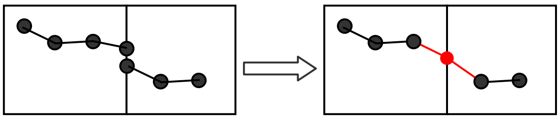


Figure 2.2-11 Connection between map margins

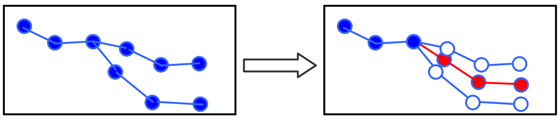


Figure 2.2-12 Generation of river centre line

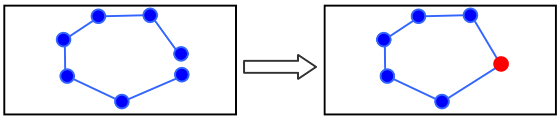


Figure 2.2-13 Closed figure for lake or swamp

All the planimetric feature data was 2-dimensional in consideration of the convenience of data use. For data on height, topographic data such as contour lines and elevation points were acquired, as well as DEM data.

The necessary marginal information such as map name, the coordinate values at 4 corners of the map margins, compass points and names of adjacent map sheets, were indicated and stored on one layer.

These planimetric feature data, topographic feature data and marginal information were all classified into layers and stored in one design file, for the priority being the convenience of data management. (See Figure 2.2-14)

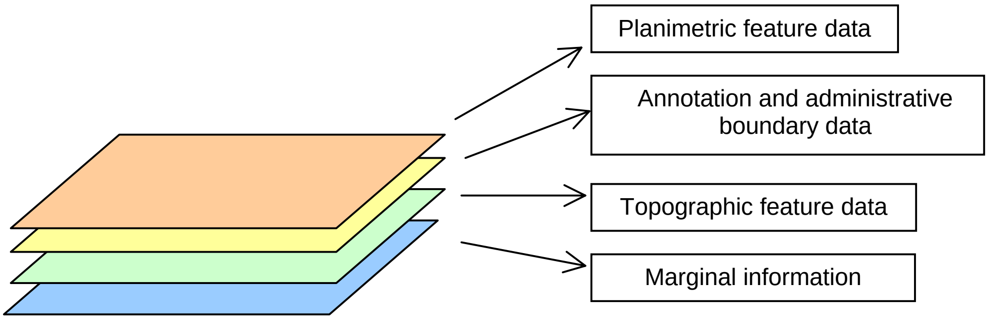


Figure 2.2-14 Layer architecture of design file

(20) Accuracy control

The Study Team carried out an inspection on rough discrepancies for each neat line and on the height of the entire study area, continuity of data and layer architecture, and prepared an accuracy control table on the inspection results. Where necessary, they then repeated the compilation and structuralizing processes.

(21) Orthophoto Maps - Production of output maps and CD-ROMs

The orthophoto maps were produced by overlaying various types of hazard information on the orthophotos produced using the digital photogrammetry system.

The total number of 1:10,000 scale orthophoto maps produced was 401 sheets, and it is expected that their handling and data management will be complicated. Considering the original purpose of the hazard maps, the Study Team and the counterparts decided that there was no need to output the 1:10,000 scale orthophoto maps. Thus, it was decided to divide the area for the production of hazard maps into 6 blocks and to output them at a scale of 1/25,000.

As the orthophoto data is set by latitude and longitude, the map margin lines were warped. On the orthophoto images the pixels of the oblique parts touching the map margins were set to white, so that if things were left in this state there would be gaps between adjacent orthophoto images. This problem was solved by using graphic software to remove the white color.

Each type of hazard map was overlaid on this image data, then all the map sheets were given marginal information and output. Separately from the output maps, the ortho image data and graphic data for all the map sheets were stored on CD-ROMs.

2.3 Hazard mapping

2.3.1 Outline of hazard mapping study

(1) Purpose of hazard mapping

The Republic of Guatemala suffered severe damage from Hurricane Mitch in 1998. Since the country is essentially prone to natural disasters such as earthquakes and volcanoes, the definition of hazard areas and promotion of evacuation measures and safe use of land through the creation of hazard maps is extremely important in order to minimize losses arising from disasters.

The hazard mapping project was carried out through the cooperation of the JICA Study Team and Guatemalan government agencies, particularly INSIVUMEH, had as its aims the creation of the hazard maps that are indispensable for improving Guatemala's ability to withstand natural disasters, the transfer of the technology for creating hazard maps, and proposals on how the maps should be best used.

(2) Overall flow of hazard mapping study

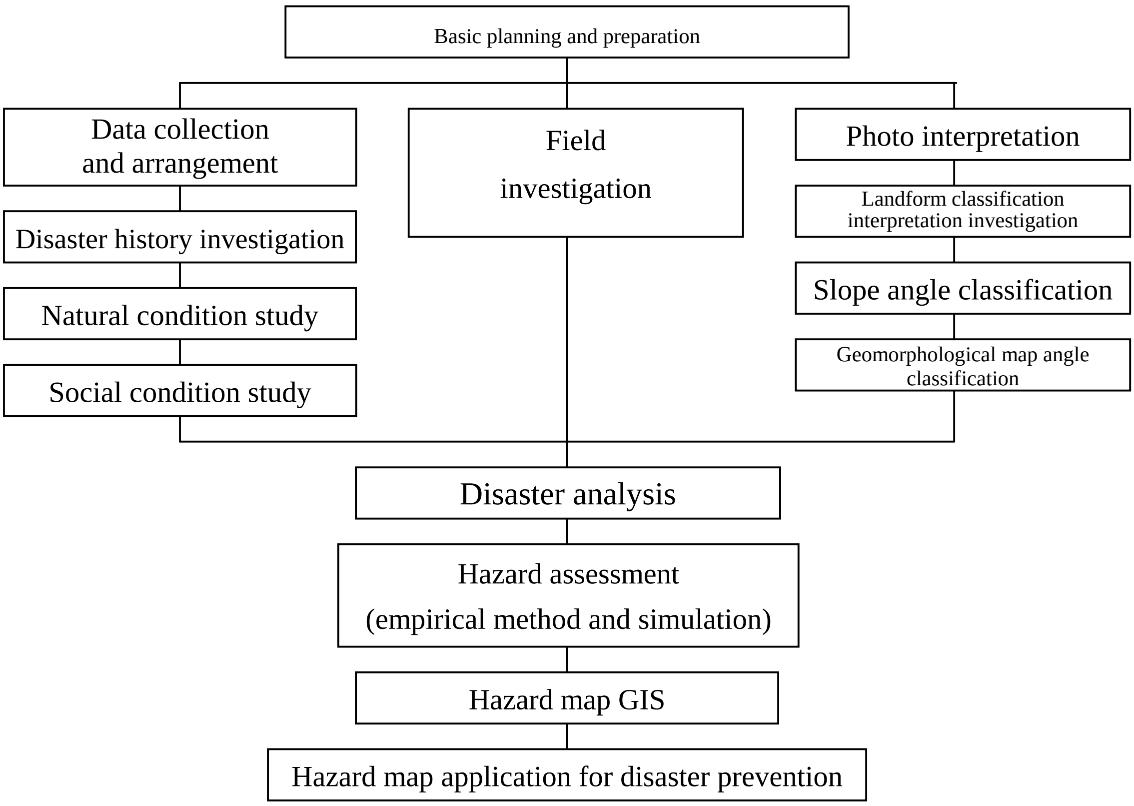


Figure 2.3.1-1 Overall flow of hazard mapping study

(3) Study team and counterpart

A hazard map team was formed with the following 6 members: Satoru Tsukamoto (assistant study team leader), Hitoshi Takeuchi (in charge of volcanology), Hiroyoshi Ishikawa (in charge of floods), Valerio Gutierrez (in charge of landslides), James Wilkinson and Toshiyuki Matsumoto (in charge of seismology). The counterpart staff assigned from INSIVUMEH are as shown in Table 2.3.1-1.

Table 2.3.1-1 List of counterparts

Items	JICA(KOKUSAI)	INSIVUMEH
General affairs	Satoru Tsukamoto	Dir. Eddy Sanchez Sub Dir. Sergio Hernandez
Earthquake	James Wilkinson Toshiyuki Matsumoto	Eng. Enrique Molina
Volcanic eruptions	Hitoshi Takeuchi	Eng. Ottoniel Matias Eng. Gustavo Chigna
Landslides	Valerio Gutierrez	Eng. Manuel Mota
Floods	Hiroyoshi Ishikawa	Eng. Pedro Tax Eng.Victor Perez Eng. Luis Santos Tecn. Jorge Izaguirre Eng. Claudio Castañón
GIS	James Wilkinson Hitoshi Takeuchi Hiroyoshi Ishikawa	Eng. Oscar Porras Eng. Claudio Castañón
Climatology	Hitoshi Takeuchi	Eng. Fulgencio Garavito Tecn. Letty Tellez Tecn. Albert Hernandez
Meteorology	Hitoshi Takeuchi	Tecn. Cesar August George Eng. Mario Bautista

(4) Definitions of hazard map and risk map

Problems in the definition of terms or in the Spanish translation were identified during the implementation of this study. Accordingly the following terms were identified to avoid conflicts or problems that may arise due to misunderstanding during the implementation of the work.

1) Opinions about the preliminary study report

The hazard map is defined as a map that forecasts/classifies how a natural phenomenon is easily triggered or the intensity of the natural phenomenon that significantly impacts human conditions. A risk map forecasts disasters based on forecasts of natural phenomenon and the distribution of the protected population, properties and the facilities to mitigate damages.

2) Interpretation by CONRED

◎ Definition of hazard and risk

(from “MANUAL PARA LA ORGANIZACION DE LOS COODINADORAS DEPARTAMENTALES, MUNICIPALES Y LOCALES PARA LA REDUCCION DE DISASTERES”)

Hazard：

External factor of risk, represented by the potential occurrence of an event of natural or human origin; with a determinate intensity and duration. Immediate risk of occurrence of a disaster. Hazard event or possibility of occurrence of potentially damaging phenomenon into an area or period of time.

Risk：

Contingency, possibility, proximity of damage, danger. Possibility of an event exceeding: specific, social, environmental, and economical damages of a defined place and during a determinate time. Established factors involve a significant probability of an accident or disaster occurrence. Mathematical formulae are used to calculate losses (lives, victims, damaged property, stopped economical activity) during a period of reference in a given region to a particular danger. Risk is the product of a hazard and vulnerability to this hazard.

◎ Definition of risk

(from “Experiencias y contribuciones para la preparación ante los desastres naturales en América Central”)

Risk is defined as the combination of natural hazard that can take place in the future in association with vulnerability to the hazard. Vulnerability is influenced by a series of social conditions or factors that make a society inclined to disasters.

Conceptually, risk, hazard and the degrees of vulnerability can be associated as:

Risk= Hazard x Vulnerability

Hazard is associated with natural events or phenomena, such as earthquakes and floods, while vulnerability is associated with the infrastructure and similar factors of a social nature.

Risk management is the collective activities (prevention, mitigation, prediction) before a catastrophic natural event, having as a goal to reduce the impacts, in essence to reduce the hazard and the vulnerability.

Some authors define disaster mitigation as these collective activities, having a goal to reduce vulnerability. For example, the use of construction codes in the construction of a house is a measure of mitigation. The goal is to reinforce the housing to resist an earthquake.

3) Interpretation by UNESCO (1972)

Risk:

Risk is the possibility of a loss of life, property and productive capacity, etc. within an area very likely subjected to hazards. The factors entering into the assessment or quantitative estimation of risk may be defined by the following relation (Fournier d’Albe,1979):

Risk = Value * Vulnerability * Hazard

Hazard:

Hazard is a complex function of the probability of the natural phenomena that poses a potential threat to persons or property in the given area within a given period of time. If sufficient data of the past episodes are given, a probability should be assigned to a potential hazard.

4) Definition for this Study

The report for this study only refers to the production of a hazard map. With the following definition, hazard map will be identified as “Mapa de Amenaza” in Spanish.

Hazard maps:

Hazard maps are defined as distribution maps of areas of natural phenomena that have an impact on the area where people conduct various activities. Hazard maps represent the degrees (grades) of impact of the natural phenomena. Sometimes, the degrees (grades) are analyzed by quantitative methods using numerical simulations, in these cases degrees (grades) are based upon physical elements like time, volume, depth, thickness, velocity, etc. However, some phenomena such as landslides are difficult to analyze by numerical simulations, in this case we analyze by empirical methods, for example evaluations of geological conditions, geomorphological conditions and records of past disasters.

Risk maps:

Risk maps are defined as distribution maps of expected damages or influences for economic activities in case of the future disasters. For creating the risk maps, it is not only to have hazard information but also social information.

Risk = f (hazard, value, vulnerability)

Value means number of population, amount of properties, for example houses, buildings, farmland, factories, roads, etc.

Vulnerability involves difficult evaluation, like structured resistance against earthquakes, social level for disaster prevention, etc.

2.3.2 Results of data collection for hazard map production

(1) Topographic maps

The topographic maps of Guatemala are available at scales of 1:50,000, 1:250,000, 1:500,000, and 1:1,000,000. Only the 1:50,000 topographic map can be used for hazard map production in this study. Most of the areas shown in the 1:50,000 topographic maps are 20 years old and may not have been fully revised according to the changes (road, rivers and structures) that may had taken place after the maps were produced. However, since these maps are essential to the preliminary study for hazard map production, 85 map sheets that cover the entire study area were collected prior to the study.

(2) Geological information

Several series of geologic maps at different scales are available from IGN for Guatemala, however, coverage is incomplete nationwide. These maps contain basic geologic and structural (faults) information. Geologic maps for several of the selected hazard mapping areas were available at scale 1:50,000. Almost all geological maps of scale 1:50,000 were made from late 1960's to middle of 1970's in conjunction with several universities of U.S.A. Geologic maps for Guatemala City and Quezaltenango areas were available at scale 1:250,000 and cover most of the project area. Map scale 1:50,000 is acceptable but the 1:250,000 scale maps are generalized and difficult to extract details. As for the Puerto Barrios area, there are no detail geologic maps available, only the regional 1:500,000 and 1:1,000,000 scale map which is highly generalized and not acceptable for detailed work.

INSIVUMEH has created special map sets, one each for Guatemala City and Quezaltenango. These map sets contain more detailed maps at scale 1:50,000 (Guatemala) and 1/100,000 (Quetzaltenango) showing many different themes, including geology, groundwater, structure, precipitation and others.

Many geologic reports and research papers, some with maps or diagrams, were obtained. These reports and papers were created primarily from assistance agencies, academic research, and private researchers. These are usually very subject-specific and limited in scope, ranging from a study of volcanoes to a site assessment for a town. The maps are usually page-size and either very general (regional) or very specific. Some of these reports and papers are closely related to the project and helpful to provide limited information and details. There is some limited information for the Puerto Barrios area related to the 1976 earthquake, but there are no details for this area.

Additionally, there are a few maps or map reports that are either unpublished or not yet published. The sources of these map data include IGN, INSIVUMEH, CONRED, academic research, and foreign assistance programs. Some of these data are available and others are not yet available. Areas covered are various but no data were found for the Puerto Barrios area.

We acquired five columnar sections of wells in 5 earthquake study areas. 88 columnar section in Guatemala city area, 25 in Quetzaltenango area, 5 in Mazatenango area, 10 in Escuintla area and 6 in Puerto Barrios were collected and used for making soil maps.

(3) Meteorological information

1) Meteorological observation

Aside from INSIVUMEH, a private firm also carries out meteorological observations, i.e. rainfall measurements. At present the climatic variables are monitored in the country by 93 meteorological stations (Figure 2.3.2-1). Most of them belong to INSIVUMEH, however there is the cooperation of voluntary private meteorological stations.

Meteorological observations focus on precipitation, temperature (maximum and minimum temperature), temperature of dry and wet bulb, ground temperature, evaporation, relative humidity, atmospheric pressure, solar radiation, wind direction, velocity, cloudiness, visibility and insolation. Precipitation is measured at every climatological stations.

On the other hand, at present, the observation of radiosounding are not carrid out as they were done 10 years ago. However, the meteorological section of INSIVUMEH in the Aurora Airport has access to NOAA satellite images that enables the analysis of the upper level wind using these images. Among the neighboring countries, Belize, Honduras and Nicaragua have aerological observatories. The upper level wind data detected at these observatories was available for this study.

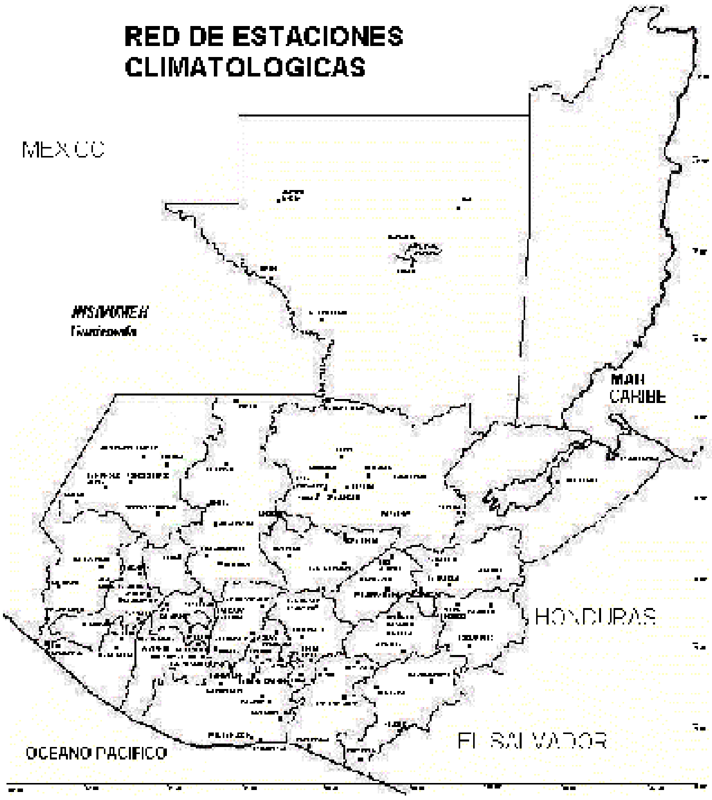


Figure 2.3.2-1 Meteorological observation station of INSIVUMEH(2003)

Figure 2.3.2-2 Flow of meteorological data of INSIVUMEH(2003)

2) Meteorological data

The meteorological and climatological data shown in Table 2.3.2-1 will be used for hazard map production.

Table 2.3.2-1 Necessary Data for meteorological and climatological analysis

Disaster Factor	Items	Usage
Volcanic Eruption	Upper level winds (wind direction and velocity of each altitude)	Basic data for the simulation of Airfall ash Wind direction and velocity on several altitude is necessary.
	Precipitation (hourly precipitation, daily precipitation)	Basic data for the simulation of debris flow Hydrographs are created by hourly precipitation data (rainfall intensity)
Flood	Precipitation (hourly precipitation, daily precipitation)	Basic data for the simulation of floods Hydrographs are created by hourly precipitation data (rainfall intensity)

The above data for Guatemala were collected as follows.

○Upper winds

Winds in the upper level were measured up until 12 years ago, however, at present are not registered. To obtain such data for simulation work, investigations should be carried out for the use of meteorological satellite images in Guatemala, method of estimating upper level winds based on the satellite images, the measurements carried out by other neighbor countries of the region, and obtaining of wind data at the upper level at the atmosphere.

○Precipitation

Around Quetzaltenango periphery at the upstream section of Samala River where a flood simulation is planned, many meteorological observation stations have precipitation data. To measure the probable rainfall amount, data produced from long term observations will be collected and analyzed.

(4) Hydrological information

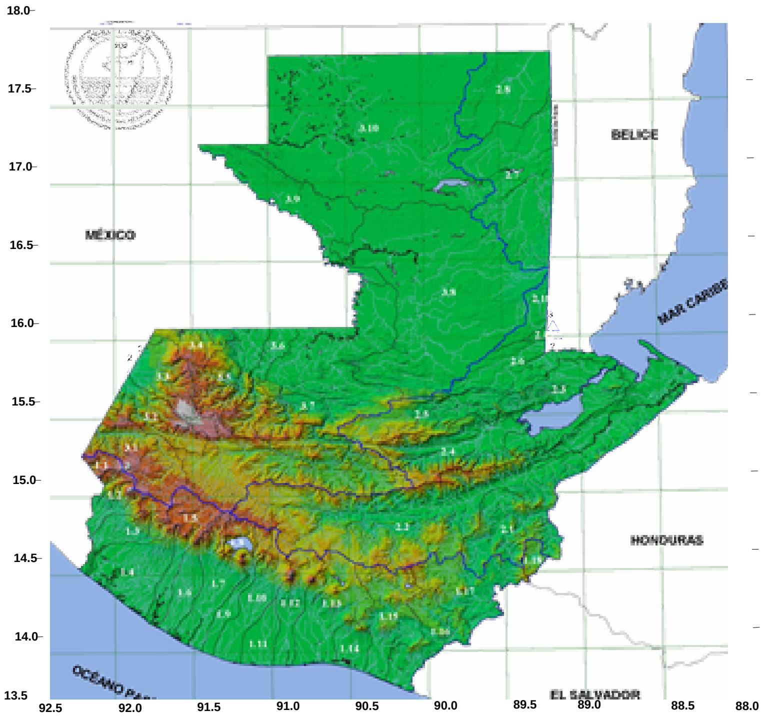
1) Hydrological observation

Hydrological and meteorological observations in Guatemala commenced in the 1910's. Observation stations were constructed and despite interruptions in the activities, such observations are still being carried out to this day. To date, there are 54 hydrological observation stations nationwide (Figure 2.3.2-3). Each station records for water level measurements; 4 stations simultaneously observe precipitation and 1 observes both precipitation and the temperature.

Water level measurements are carried out by manual observation as well as by a self-recording instrument and a sensor. Residents near the station are contracted to observe and record measurements by manual observation. These people then record the water level twice a day, once in the morning and once in the afternoon, and send a report to INSIVUMEH once per month. Further, a radio telecommunications system is installed in their residence for them to be able to directly contact INSIVUMEH, through the relay station established at Pacaya Volcano, in case of emergency. The self-recording instrument is supplied with a new roll of paper once per month.

On the other hand, observation stations directly send their water level observation data and precipitation data to the Caribbean District of USGS through satellites. These observation data can be accessed in real time through the USGS and INSIVUMEH home pages on internet.

INSIVUMEH has an early warning system for flood conditions (Figure 2.3.2-3). The person in charge of the observation reports normal observation information to INSIMUVEH, and INSIMUVEH notifies CONRED of these reports. The person in charge, however, directly notifies INSIMUVEH and CONRED using the radio telecommunications system when observation information indicates flood conditions.



No	Estación	No	Estación
1	Cunlaj	28	La Laguna
2	Malacatán	29	San Agustín Chixoy
3	Pajapita	30	El Porvenir
4	Meléndrez II	31	San Pedro Mactún
5	Coatepeque	32	Chachaclún
6	Caballo Blanco	33	Bethel
7	Cantel	34	Tikal
8	Candelaria	35	La Franja
9	La Máquina	36	Río Blanco
10	Monte Cristo	37	Puente Chocox
11	San Miguel moca	38	Xococ
12	Puente Coyolate	39	San Pedro Cadenas
13	Puente de Itzapa	40	Sto.Tomas de Castilla
14	San Luis Las Carretas	41	Vado Hondo
15	Alotenango	42	Las Lechuzas
16	El Pino	43	Las Cruces
17	El Portezuelo	44	Pto. Quetzal
18	Petapilla	45	Amatillo
19	Camotán	46	Cenizas
20	Morales	47	Guacalate
21	Chiché	48	Guacamayas
22	Puente Orellana	49	Telemán
23	Panajax	50	Matucuy
24	Modesto Méndez	51	San Juan Gascon
25	Cuilco	52	Gualán
26	Chojil	53	Corral Grande
27	Xemal	54	El Jobo

Figure 2.3.2-3 Hydrological observation stations（2003）

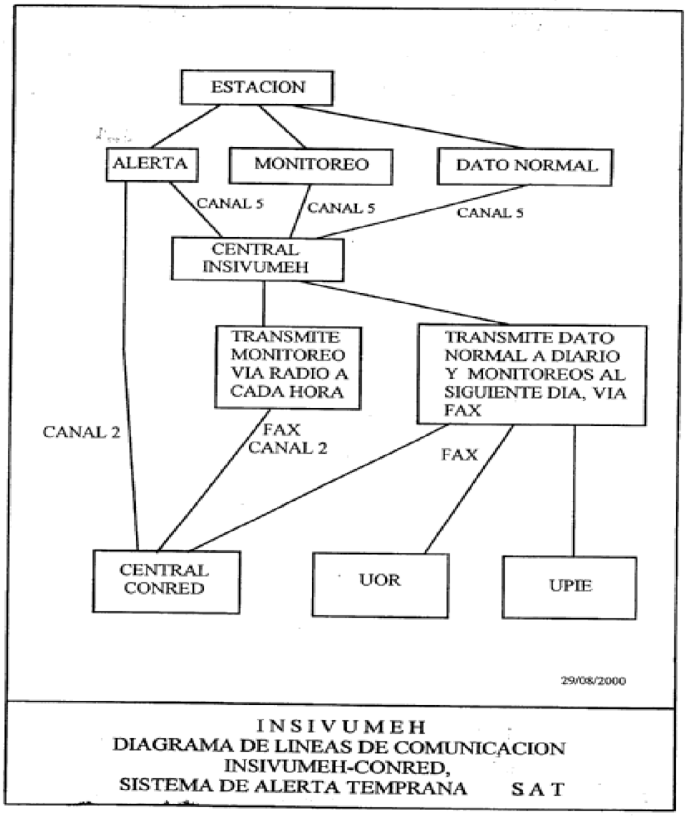


Figure 2.3.2-4 Diagram of alert information communication

2) Hydrological data

The following are the hydrological data stored at INSIVUMEH.

Annual observation data reports have been compiled from 1966 to 1986. The reports contain data of daily runoff, maximum and minimum monthly runoff, monthly average runoff, and monthly total runoff observed at each station. These reports were terminated after 1986.

At present, the hydrological data observed is limited to water level which is measured manually by the person in charge, a self-recording instrument, and the satellite system.

- Data according to the person in charge:

  Water level measurement is carried out twice per day (morning and afternoon) and reported once per month. Available data dates from 1986 to the present.

- Data collected from the self-recording instrument:

  Data observed from 1962 are still available in the paper form that they were recorded.

- Data from the Satellite System:

  This observation system was launched in June 2000. The observed data is updated every 15 minutes and is available through the USGS Caribbean District home page (http//pr.water.usgs.gov/) (Figure 2.3.2-5).

These data are only regular water level measurement data. There is no hydrograph based on consecutive observations of water level and runoff in times of flooding. The output (paper) of the self-recording instrument that contains the water level measurement is not compiled as a report.

It has been confirmed that there is a shortage of data on runoff during heavy rain. These data are considered important to carry out flood simulations.

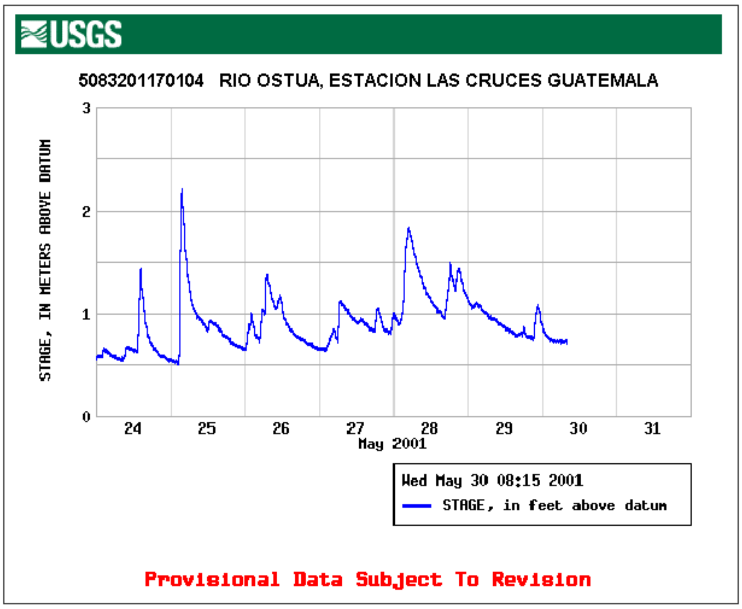


Figure 2.3.2-5 Water level data by USGS

Damage to the hydrological stations destroyed all the observation data of Hurricane Mitch. However, the INSIVUMEH report shows the highest water level and maximum runoff estimates of 7 observation stations (see Table 2.3.2-2).

Meteorological data contains daily precipitation at every station, fluctuations in precipitation and a distribution map of the precipitation due to the Hurricane Mitch.

Table 2.3.2-2 Runoff and return period of historical events and the case of hurricane Mitch.

No.	Station	Runoff for MITCH m^3/s	Historical Runoff m^3/s	Estimated Return Period
1	San Luis Las Carretas	35.76	8.63	>20years
2	Camotán	1880.06	664.10	>30years
3	Malacatán	508.00	812.70	>30years
4	Alotenango	146.41	28.24	>30years
5	Morales	2214.27	1945.13	>30years
6	Puente Orellana	1742.93	1507.00	>30years
7	Panajax	1003.00	833.41	>30years