

tsunami disasters and landslides. Consequently very big damages were caused among people in Flores Island.

This is entirely different from similar earthquake damages in Japan where is artificially changed, urbanized with enough knowledge of the countermeasures against earthquake damages.

And it seems that there are not enough system for monitoring danger of disasters caused landslides, earthquake, heavy rainfall and tsunami. For example, observation system of earthquake, and slope steak.

- (3) There are not enough maps for showing and clarifying characteristics of the land. Especially, it is inconvenient to use medium scale maps. It is necessary to establish a system for users to be able to use new maps without much limit for administrative purposes.
- (4) Flores Island consists of Tertiary and Quaternary geology which are remarkably weathered. The combination with volcanic areas and volcanic fans can easily cause geomorphological changes which are erosion and accumulation. It is necessary to prepare various types of thematic maps for the countermeasure against natural disasters as one the most fundamental information to clarify characteristics of the island : geologic maps, geomorphological maps, soil maps, vegetation maps, natural disaster maps and land use maps.
- (5) For the construction of roads, it seems not to have considered geologic and geomorphological conditions whether or not the locations are safe as road routes. These physical conditions — land condition, geomorphological condition — can be available to use for the decrease of natural disasters.
- (6) People live in natural landscapes. Then, usually, knowledge of earthquake damages is not necessary for their daily life. Education of earthquake knowledge is necessary to decrease damages caused by the earthquake.

6.6 Recommendation

- (1) The characteristics of geology should be clarified when road plans are made whether the rocks are weathered or enough hard to decide the gradient of side slope.
- (2) 'Slope stake' is available to monitor the behavior of landslides. This is a very simple method.
- (3) Aerial photo interpretation should be used more to compile various kinds of thematic maps for clarifying characteristics of the land and to catch natural disasters damages.
- (4) When the researcher can not reach damaged area such as this time, oblique photographs can be available to interpret actual conditions of hazards based on geomorphological classification. Especially, geomorphology and geology of the objective area can be roughly interpreted using oblique aerial photographs. And it is possible to clarify characteristics of hazards using the relationships between geomorphological and geologic conditions and slope failures. The result is available to make a fundamental countermeasures against slope failures (landslides).

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Photo 6.1 Soil Liquefaction Maumere Urban
The photo area includes damaged area by soil liquefaction along the coast line of the port.



Photo 6.2 Soil Liquefaction Suburbs, Maumere
Area between maumere and mountainous area is undulating hilly area. The area is used as dry fields and palm forests.



Photo 6.3 Soil Liquefaction Port Maumere
Wharf area was damaged by the tsunami and soil liquefaction
Photo shows damaged and tilted house (warehouse so on) is seen.
Wharf is also damaged.



Photo 6.4 Soil Liquefaction Port Maumere
The coastal zone subsided by soil liquefaction. Damaged port facility drowned about one meter in water. The part was changed from paved wharf into drowned part.



Photo 6.5 Soil Liquefaction Maumere Port
Port facility (fish market) was tilted and partly drowned vertical and horizontal displacement of soil layer (soil liquefaction).



Photo 6.6 Soil Liquefaction Maumere Port
Road was drowned by land subsidence caused by soil liquefaction.



Photo 6.7 Soil Liquefaction Maumere Port
Port facility. Paved area was damaged. Cracks were caused in many sites.



Photo 6.8 Soil Liquefaction Maumere Port
Port facility. Paved area was damaged. In this case, sand boils came out from cracks by soil liquefaction.



Photo 6.9 Soil Liquefaction Maumere Port
Beside an office, sand boil spouted out from cracks. Cracks are linear and straight. This site inundated by tsunami.

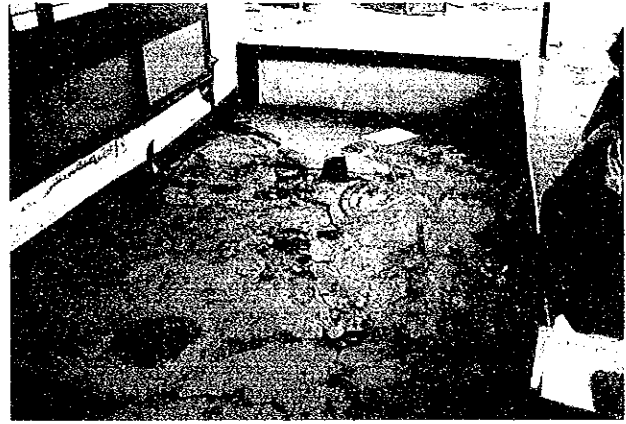


Photo 6.10 Soil Liquefaction Maumere City
In the residence area of Maumere, many houses were damaged by soil liquefaction. In the inside of the houses much sand with water spouted out from the floor. The house can not be used for daily life. Cracks were formed through the inside and outside.



Photo 6.11 Cracks Maumere City
There are many long and wide cracks in Maumere City.

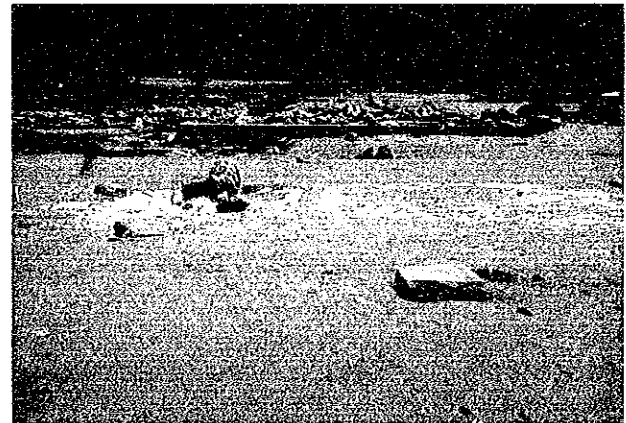


Photo 6.12 Soil Liquefaction Babi Island
Whitish part is the trace of sand boil. Sand was washed away by tsunami wave. In this case, sand boil was caused in the inside of the house. This type of traces can be seen in many sites of the Babi Island and in the coastal line of the main island of Flores.



Photo 6.13 Soil Liquefaction Babi Island
 Example of traces of sand boils which was caused in the inside of the house. The house was washed away and only the part of the foundation and stone wall remained.



Photo 6.14 Soil Liquefaction Babi Island
 Long cracks were formed in many sites here. And sand boils spouted out from the cracks during and after tsunami wave. Most of spouted sand boils were washed away. Initial forms were pretty changed.

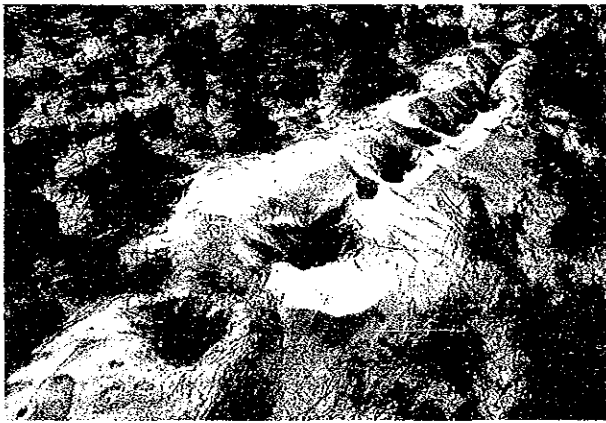


Photo 6.15 Soil Liquefaction Babi Island
 Some of sand boils were formed after tsunami wave. For the reason, initial forms of sand boils could be kept. Linear sand boils were formed on the linear cracks. But single one was formed in the inside of the houses.



Photo 6.16 Soil Liquefaction Babi Island
 Here, sand boils consist of various kinds of sand bar material which are very small snails, coralltips and coral sand.



Photo 6.17 Road Side Slope Failure, Flores Island
 The site consists of weathered limestone. One side is a part of hill and another side is valley slope with a river floor. Probably this site was repeatedly collapsed. Cut and banked site was collapses.



Photo 6.18 Road Side Slope Failure, Flores Island
 This site consists of Tertiary pyroclastic flow material. Cut site was damaged.



Photo 6.19 Road Side Slope Failure, Flores Island
 This site consists of volcanic material. Cut and bank site was damaged. Valley side road bed was collapsed. Relative height of crack was about 70 cm. Road was paved temporarily.



Photo 6.20 Road Damages, Maumere – Nebe
 There are many bridges in the route from Maumere to the east. Many bridges were damaged as shown in the Photo. Most of them were temporarily repaired.

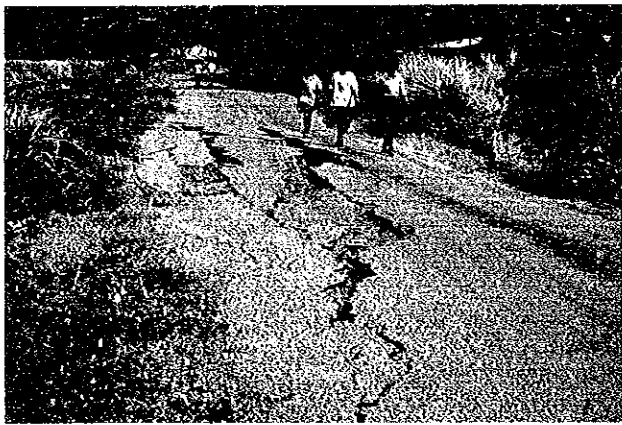


Photo 6.21 Road Damages
 In the route from Maumere to the east, there are many cracks on the road. Most of them are fine and long. Photo shows an example which is about 10 m long and 123 cm deep.



Photo 6.22 Landslides, Road Side Slope Failure, Maumere – Ende
 Hill slope was failed at the hillside and valley side. Soil covered the road.



Photo 6.23 Landslides, Road Side Slope Failure, Maumere – Ende
 In hilly area, road side was collapsed. Only mountain side was collapsed.

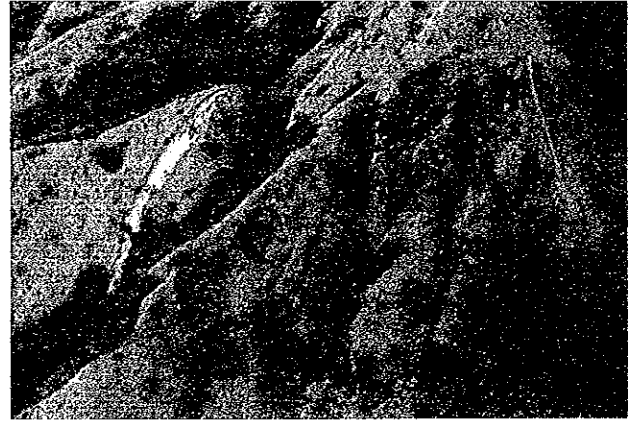


Photo 6.24 Landslides, Surface Side Slope Failure, Maumere – Ende
 Single collapse was caused in a dendritic drainage system area. The surface consists of weathered soil and deep layer consists of rock.

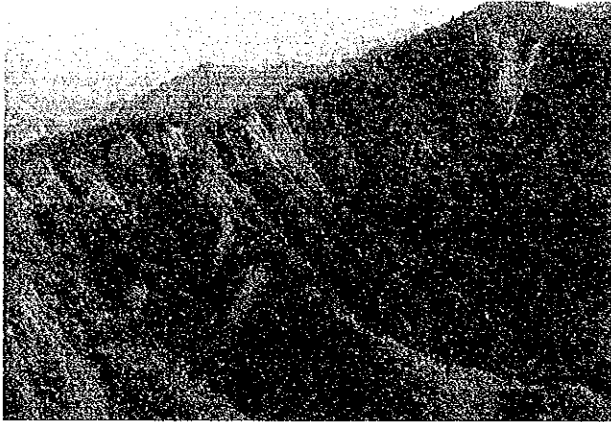


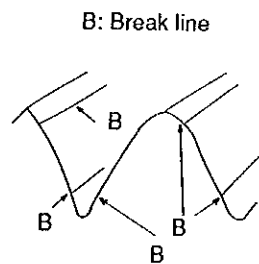
Photo 6.25 Top Landslides, Maumere – Ende Surface Collapses



Photo 6.26 Middle Landslides, Maumere – Ende Surface Collapses



Photo 6.27 Bottom Landslides, Maumere – Ende Surface Collapses



In the mountainous area, surface landslides were caused in many places. Top is a group of surface collapses. Middle is complex collapses. 6.25, 6.26 and 6.27 were caused just under break lines of ridges in steep slopes. Break line means a line which steep slopes change their gradients. Break lines can be interpreted using aerial photographs based on geomorphological method.



Photo 6.28 Active Volcano (top)



Photo 6.29 Active Volcano (middle)



Photo 6.30 Active Volcano (bottom)

This active volcano has three crater lakes, Keli Bara, Radiation type of drainage system. Left bottom of the top photo, there is a deep collapse. And parallel valleys flow down in the volcano slope. Middle and bottom photos are the same deep and large collapse from ridge to valley floor. It has large and deep head and very long tail deposit. (transportation and depositional area).

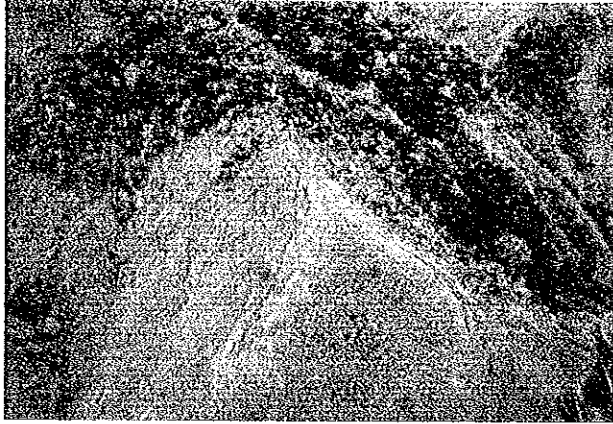


Photo 6.31 Landslide
 This landslide is surface land creep. There are cracks on the ridges. It is not clear whether it moved or not by this earthquake shock. Slope streak can be used available to monitor the behavior of landslide.

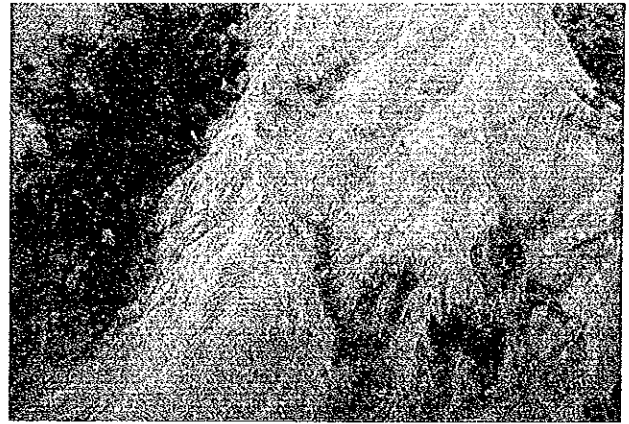


Photo 6.32 Landslide, Surface Collapses
 Slopes are controlled based on contour farming. Right bottom of the photo shows a group of collapses in the slopes and at the valley floors. This influences land use by farmers.



Photo 6.33 Landslide, Rock Wall Failures Mountainous Area
 This route was damaged by the rock wall failures and supplementary deposits. The site is one very bad geomorphological condition.

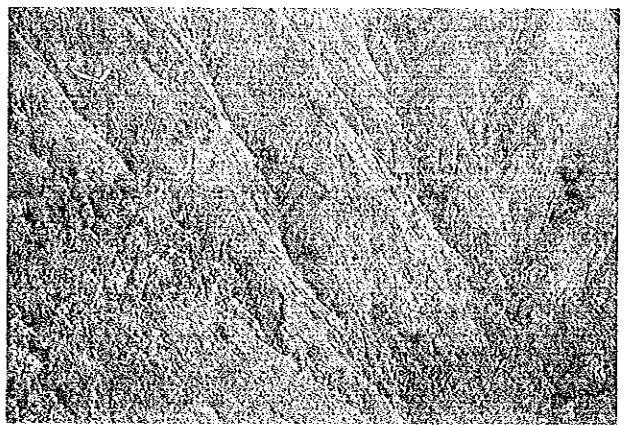


Photo 6.34 Landslide
 1) Road construction caused road side failures.
 2) Surface collapses were also caused in mountainous slopes.
 3) Geomorphologically landslides and collapses can be easily caused at the sites. And roads cross the sites and consequently roadbeds were damaged.



Photo 6.35 Landslide, Geomorphological Condition and Damages
 Geomorphologically, landslides were caused in specified sites and the tails cross the road.

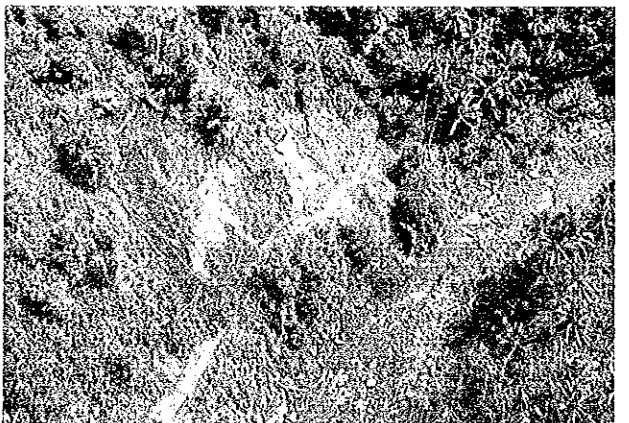


Photo 6.36 Landslide, Road Side Slope Failure, Near End
 Side slope was failed through the roadbed. But it was a kind of surface failure.

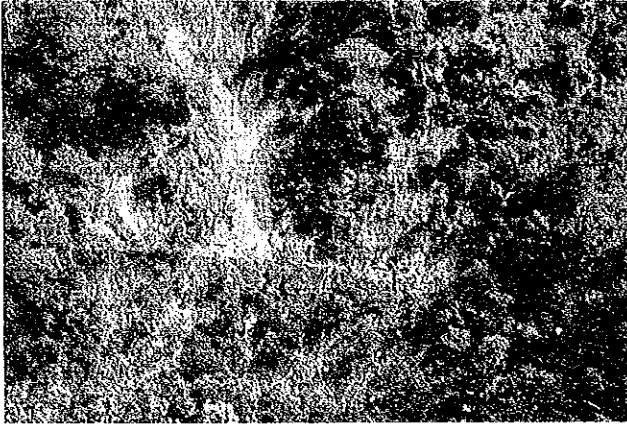


Photo 6.37 Landslide, Rock Boulder Flow
 Previously there is a 0-order valley. Earthquake shock supplied many rock boulders from mountain slopes to the downward through the 0-order valley and deposited on the road. A case that road is loated at very bad geomorphological conditions.

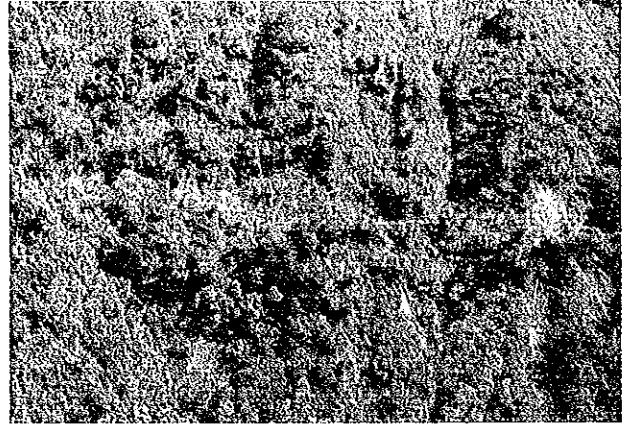


Photo 6.38 Landslide
 Photo shows the road through bad geomorphological condition area. On the road, there are a few buses.



Photo 6.39 Same as above

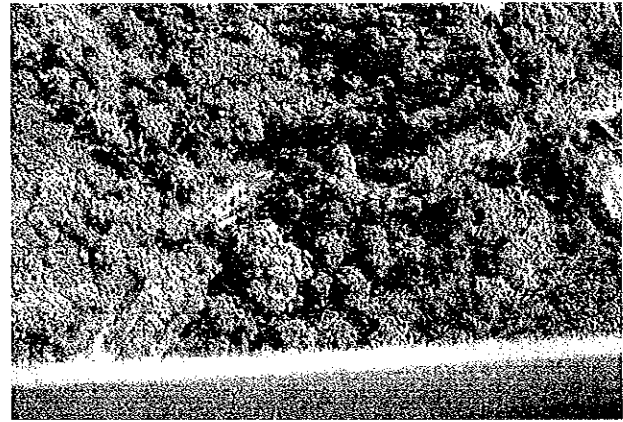


Photo 6.40 Landslide
 The site where the road recovery construction is in work from Ende side.



Photo 6.41 Landslide
 Side slope was collapsed.

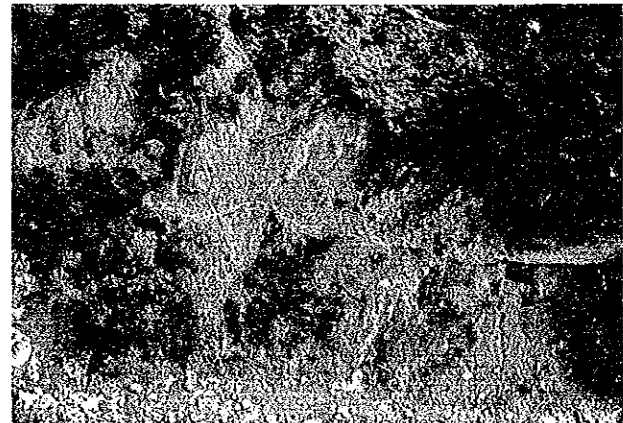


Photo 6.42
 Side slope was collapsed.

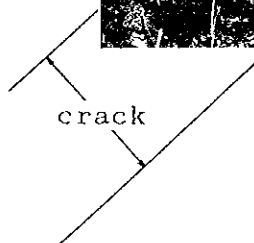


Photo 6.43 Geomorphological Change at Babi
Soil was washed away about one meter deep by tsunami wave. Before tsunami, the surroundings of roots of palm trees was covered by sand bar.



Boundary of tsunami

Photo 6.44 Cracks
Cracks were caused at the upper part of backshore of coastline 100 m long, 1 m wide, 1 m deep. From the man to the corner, a clear crack was caused.
Top of the photo is covered by green. Green part was not drowned by tsunami wave.



7. Emergency Countermeasures Against Disaster

7.1 General Description of Emergency Activities

(1) The System for Emergency Activities

- 1) When the larger-scale disasters break out, the emergency operation system, which is consisted from the central government to the local government, will be established according to the declaration of President "Decree of the President of the Republic of Indonesia, Number 43, Year 1990, on the National Coordinating Board for Disaster Management."

In this case, also, according to this decree emergency activities are being executed under the cooperation of the central government, province, regency, sub-regency and armed forces of Republic of Indonesia (ABRI). The total organization is as shown in Fig. 7.1.

- 2) Because of the serious damage of the regency office, the chief of regency is taking command of the Headquarters for Disaster Countermeasures in the Governor's official residence. (Photo 7.1)
- 3) Brigadier General Sulatin in the Udayana District (Head Office: Denpasar) was dispatched to Maumere and is taking command of his own headquarters in Waioti Airport.

(2) Collection and Transmission of the Information

The government information seems to flow from sub-regency to upper organization.

Regency seizes detail information such as human damage, building damage, the amount and distribution of supplies and name of contributors.

The countermeasures conducted by Provincial government has been unknown.

It seems, that information were not communicated well to the central government, probably due to the lack of the communication measures.

The ways to communication at emergency is shown in Fig. 7.2 (Photo 7.2)

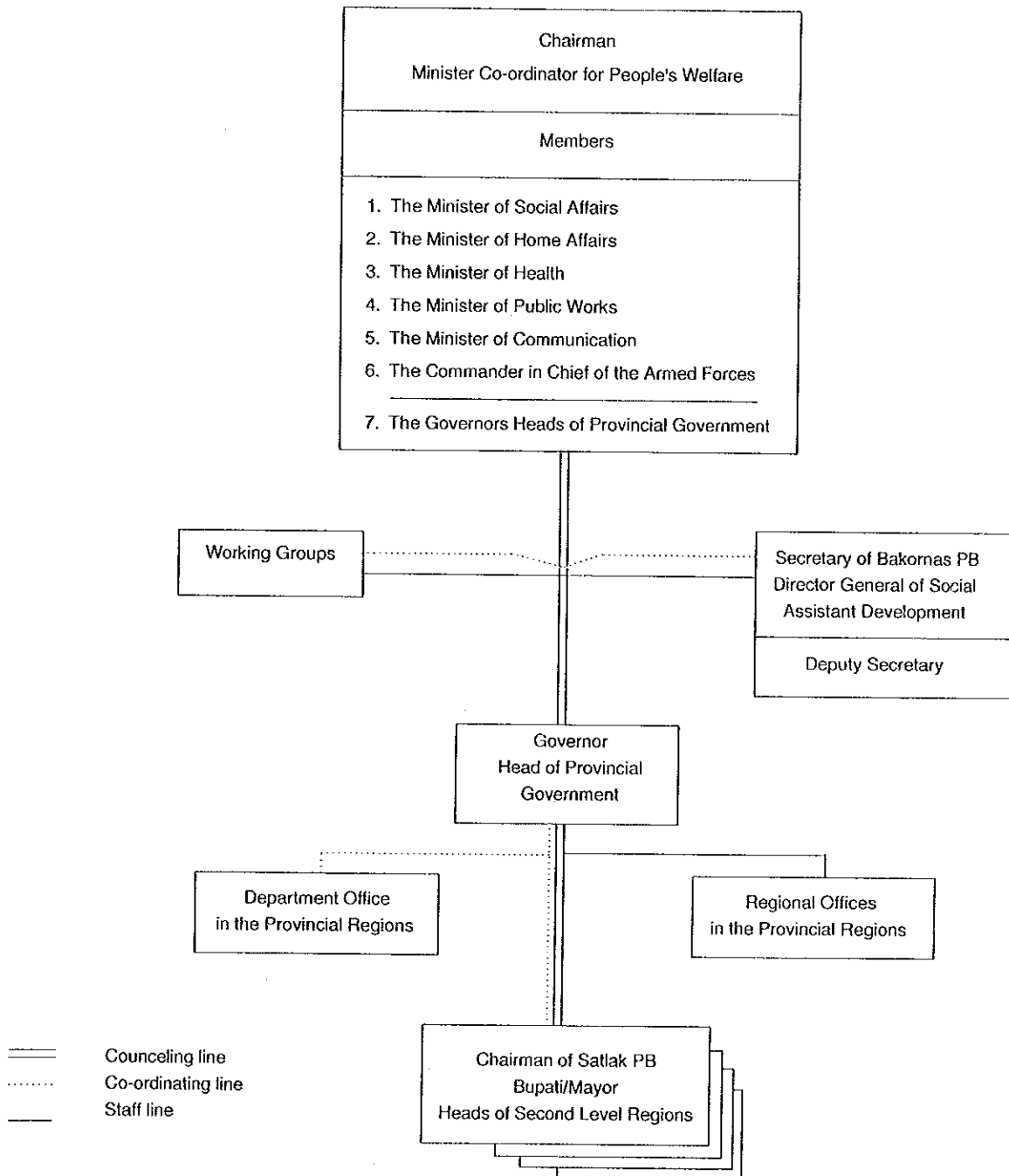
(3) Medical Activity

- 1) The first-aid stations were placed in Maumere to give the first-aid treatment. Hospitals are still functional after the earthquake and the number of the patients coming to hospitals after December 12th is shown in Table 7.1.
- 2) There are good enough medical and pharmaceutical products supplied in Maumere Regency, which must be distributed to districts.
- 3) The relief supplies seems not to be received enough in Ende Regency because the road between Maumere and Ende was interrupted.

(4) Daily Living

- 1) Maumere (as of December 24th)

- a. There has been no trouble in daily life since business services resumed and the relief supplies were arrived. (Photo 7.3 to 7.6)



**Fig. 7.1 Structure Diagram of Bakornas PB Organization
Chairman of Bakornas PB**

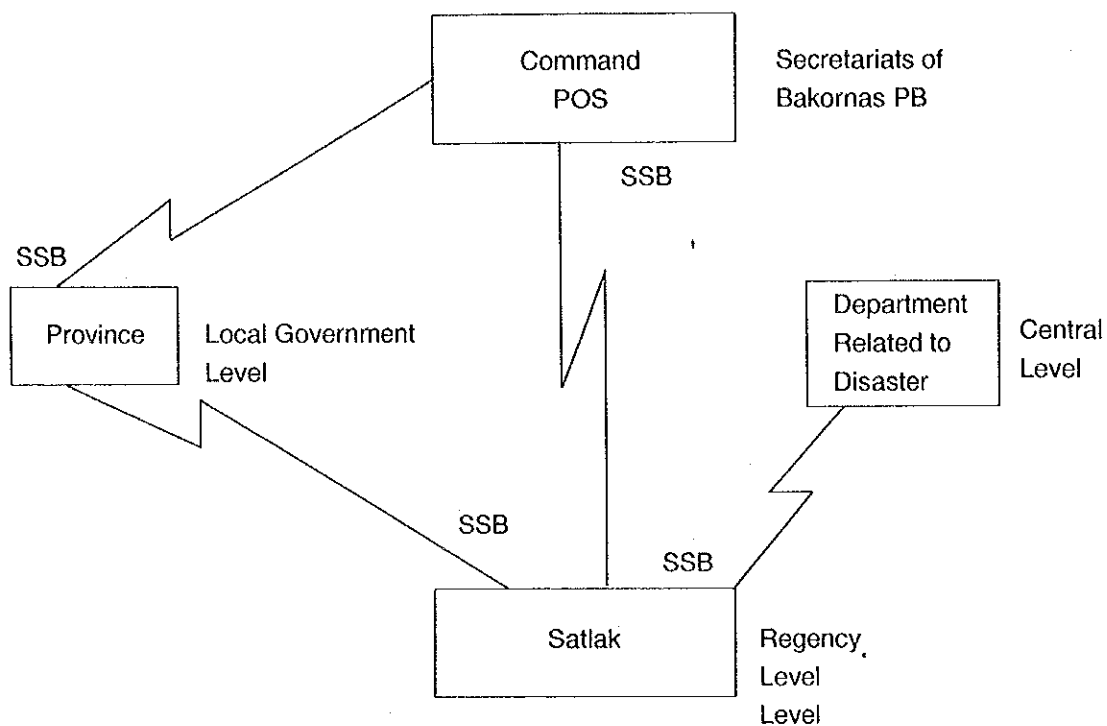


Fig. 7.2 Disaster Communication Network

Table 7.1 Patient Condition

(Prs)

Date	Visiting a hospital	Entering a hospital	Attending a hospital	Dead	Return home
12 Dec. '92	128	82	10	36	-
13	68	46	20	2	15
14	39	23	16	-	30
15	287	27	260	-	21
16	222	25	197	-	28
17	205	6	199	-	3
18	229	5	224	-	3
19	322	3	319	-	4
20	154	5	149	-	-
21	225	6	219	-	-
Total	1,879	228	1,613	38	104

Source: Army's Headquarters for Emergency Activities in WAIOTI Airport in Maumere.

- b. The waterworks were stopped for three days. Afterward, some main wells were broken and the capability of water supply was less than half compared with before. Now water supply is implemented with tank trucks. (Photo 7.7 to 7.10)
 - c. Electricity and telephone services have been already recovered.
 - d. LPG and fire woods used as fuel seems to make the daily living little trouble.
- 2) Ende (as of December 23rd)
- a. Though business services were resumed, the relief supplies from Maumere are not enough to be accepted in Ende because of the road between Maumere and Ende despite the operation of the helicopters. Helicopter operation is conducted to distribute the supplies in mountain areas but the amount of distribution is limited.
 - b. Electricity, telephone and water supply services have been already recovered.
 - c. 5,000 units of tent accommodate 7,500 people.
- (5) Tentative Accommodation
- 1) Most of the people, who lost their houses, are living in tents as tentative residence. (Photo 7.11 to 7.13)
 - 2) The lack of tents makes some people accommodated in open space like the style of camp. Approximately 100 tents are pitched in the field in front of official residence. Big tents of them are accommodated as many as 10 families (each family consists of 3 to 4 persons). (Photo 7.14)

7.2 General of Restoration and Rehabilitation

- (1) The emergency works (recovering minimum function) are being planned on completing up to the beginning of January and the rehabilitation works (recovering full function) being planned up to the end of March.
- (2) Some heavy construction machines such as bulldozer were offered by ABRI and rehabilitation works is about to be carried out practically. (Photo 7.15 to 7.18)
- (3) The rehabilitation of local public organizations and schools will be hoped to be conducted as soon as possible.
- (4) It takes a long time to rebuild schools but big tents will make school function possible. The target date of resuming schools is the beginning of January.
- (5) The emergency works (recovering minimum function) for rehabilitation of public facilities like roads have been earnestly implemented to be completed by the beginning of January. The first priority is pointed to rehabilitation works for road between Maumere and Ende, which is now under process.
- (6) Indigenous people start their own rehabilitation works by themselves.

7.3 Future Countermeasures

- (1) It is really important for the government to offer urgent supports and actions such as accurate and rapid communication, medical activity, seize of transportation facilities and the provision of relief supplies when urgent works are required at disaster occurrence. Especially as for the information, the common forms, which the Ministries and Agencies related to disaster countermeasures posses, is indispensable to be prepared in parallel with strengthening communication network.
- (2) It is urgently required to prepare the comparatively big tents for the tentative residence and those as wide as possible to accommodate about 40 pupils for school reopening.
- (3) There are many people staying in their tents pitched in their houses' courts in fear of earthquake reoccurrence. It is necessary to investigate the damage of houses as well as to explain inhabitants the characteristics of this earthquake and several aftershocks in case so that they can restart their own usual lives as same as before.
- (4) It might be required to make a system which loans them to rebuild their lives and makes up the interest of the loan. There are some problems coming out of disasters to support the victims losing their jobs with job training and to aid the victims' lives.
The victims have led their evacuated lives for as long as more than one year and a half due to Mt. Unzen volcanic eruption in Japan. There are several examples to resolve the problems, which cannot be handled by existing law system, with the interest of the newly established fund. The donation must be considered to be made a good use.
- (5) The area damaged by tsunami this time is easy to be attacked again topographically. It should be necessary to make up the restoration plan for the damaged area in order not to be damaged again before the victims rebuild their houses disorderly.
- (6) It was said that the number of residences living on low area along the sea has been increased gradually as there has been no huge tsunami at least for seventy years. Besides almost all people do not have the idea, earthquake-tsunami-evacuation. As a result, the damage was more serious as expected.
It is essential to acquire proper knowledge and accurate information when earthquake and tsunami occur. The public instruction on the behavior at earthquake and the comprehension on earthquake and tsunami in childhood can reduce their damages compared with no recognition.

7.4 Recommendations

- (1) The restoration plan, which includes disaster prevention, early rehabilitation and restart of the victims' lives, should be made especially in Wuring area urgently.
- (2) The housing plan should be made urgently as not to force the damaged people into prolonging their temporal evacuation lives.
- (3) The public instruction on disasters, diffusion of knowledge on disaster prevention should be promoted strongly in order to make a people's proper action not only at earthquake but tsunami with appropriate scientific understanding on earthquake and tsunami.



Photo 7.1 Headquarters of Ende Regency

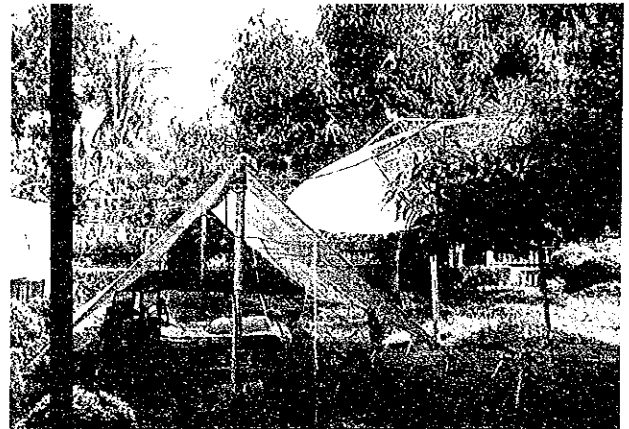


Photo 7.2 Parabola Antenna in the Headquarters of Ende Regency



Photo 7.3 Relief Supplies at Maumere Airport



Photo 7.4 Helicopters to Distribute the Supplies



Photo 7.5 Transport of the Relief Supplies or Heavy Construction Machines by ABRI



Photo 7.6 Transport of the Relief Supplies or Heavy Construction Machines by ABRI



Photo 7.7 Water Supply with Tank Trucks

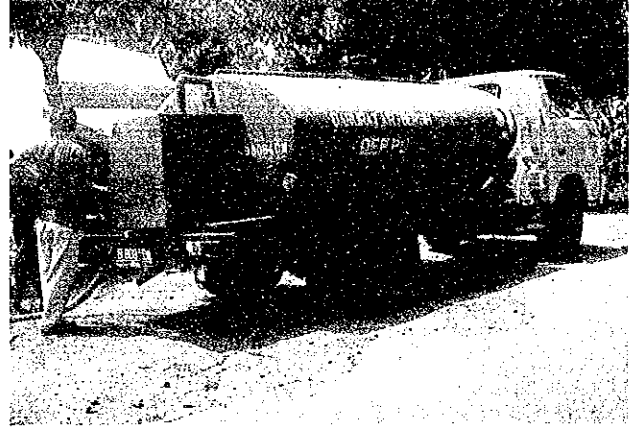


Photo 7.8 Water Supply with Tank Trucks

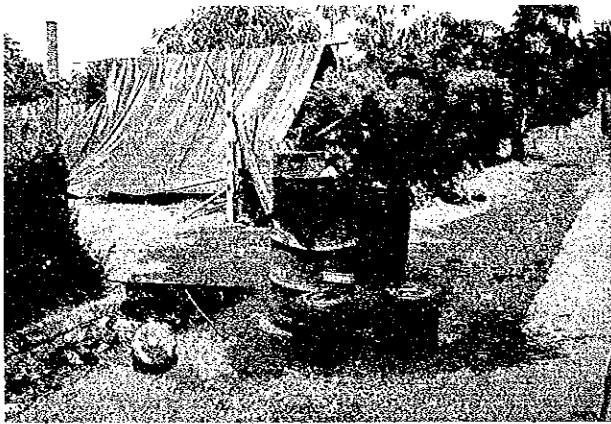


Photo 7.9 Water Supply with Tank Trucks

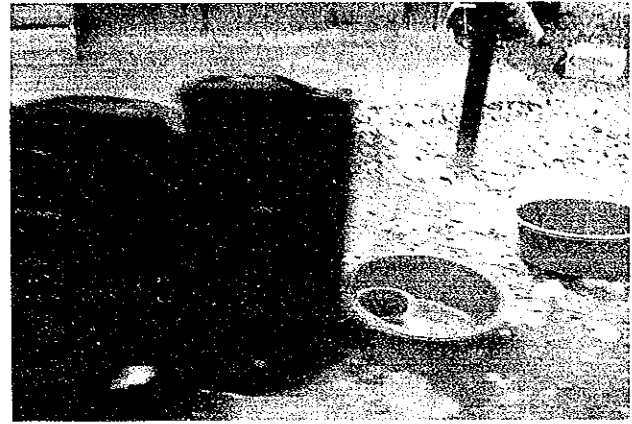


Photo 7.10 Water Supply with Tank Trucks



Photo 7.11 Tentative Residence with Tents



Photo 7.12 Tentative Residence with Tents



Photo 7.13 Tentative Residence with Tents

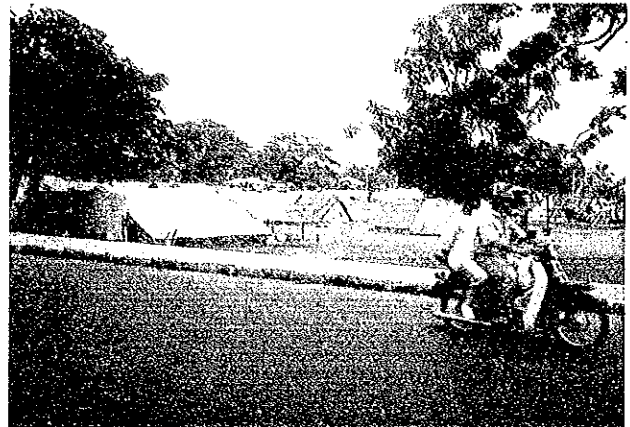


Photo 7.14 Tentative Residence with Tents



Photo 7.15 Bulldozer Offered by ABRI



Photo 7.16 Bulldozer for General Use

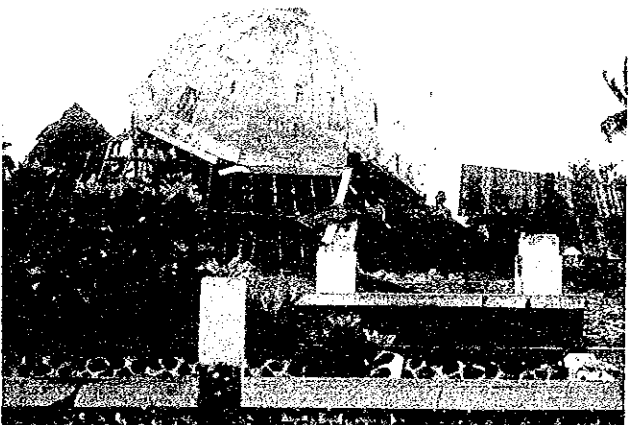


Photo 7.17 Rehabilitation Work by ABRI

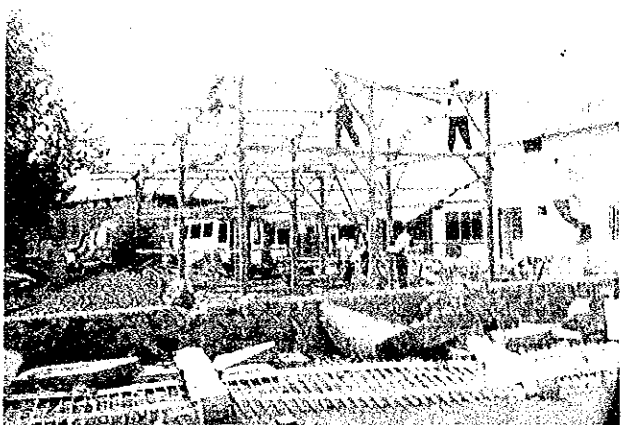


Photo 7.18 Rehabilitation Work by People

IV. SUMMARY OF RECOMMENDATION

IV. SUMMARY OF RECOMMENDATION

Recommendation on emergency countermeasures, further earthquake preparedness and earthquake study is described in Chapter III. The following are its summary.

- 1) Denser seismic observation networks are required to locate the hypocenters with good accuracy. They should consist of three-component sets of seismometers equipped with telemetry systems for quick data processing. Broad-band seismic stations are also important to understand the earthquake mechanism.
- 2) It is recommended to install strong motion accelerographs on the ground and on structures for evaluating strong ground motion and structural response.
- 3) Must evacuate from potentially dangerous area for tsunami as rapidly as possible after the earthquake. It must be strictly prohibited to approach to the shoreline to see the tsunami or the movement of boats.
- 4) The village in Babi Island was protected against the wind waves because of its location in the sheltered area of the island itself. However, it does not necessarily mean for the safety against tsunami. In Indonesia there are many island having the same natural conditions as Babi Island. It is advisable to check the safety of these islands against tsunami.
- 5) The forests formed by palm trees or other trees must be protected because they are useful for reducing tsunami energy.
- 6) In the locations where high tsunami run-up was observed such as in Maumere Port, some signs showing the inundation height (usually recorded on the outside wall of the houses) should be noticed to open public in order to inform people of the danger of the tsunami and not to forget the tsunami disaster.
- 7) When people must live in the potentially dangerous area for tsunami as in the case of Babi Island, it is recommended to build shore protection facilities such as the coastal dike along the shoreline.
- 8) It is urgently required to prepare the comparatively big tents for the tentative residence and those as wide as possible to accommodate about 40 pupils for school reopening.
- 9) As long as masonry structure is low rise building, in-plane shear strength of masonry wall may be enough to such level of earthquake as occurred as this time. However the out-of-plane bending resistance is very small. It is required some reinforcement or prestressing using reinforcing bars, wires and bamboos, should be installed in masonry walls with enough encourage to concrete foundation systems.
- 10) If we use bamboo as reinforcement, which is available in Sikka Prefecture, its Young's modulus and tensile strength are $1.25 - 1.55 \times 10^5 \text{ kg/cm}^2$ and $1700 - 2400 \text{ kg/cm}^2$ respectively. So, bamboo can be much effective for strengthening wall system by intelligent device of construction.
- 11) The detailed construction manual for local people should be based on the test results which shall be planned and conducted in Research Institute of Human Settlements, Ministry of Public Works, Bandung.
- 12) It is recommended to carefully inspect the bridges in Flores Island with the major attention to the damage of substructures. For those bridges which suffered damage to the abutments in such a manner that the foundations slid to the deck side direction with the top of the abutment being tilted to the back fill side, it is recommended to fully replace the abutment to avoid the possible falling down of the girder. Because those bridges are very old with only one lane, evaluation needs to be made whether they should be repaired or replaced with new structures.

- 13) Because there are a number of bridges in Indonesia which were constructed at the age when the seismic effects were either disregarded or insufficient, it is recommended to develop a simple seismic evaluation method of existing bridge structures. The evaluation method has to be as simple as possible so that the inspection be made at the sites without complex calculation. The evaluation of the seismic stability of substructures is the key item to be considered. A master plan for seismic evaluation and possible strengthening of existing bridges may be important as a future plan.
- 14) It is difficult to prevent the failure of cut and natural slope along the road in mountainous area. It is recommended to investigate the possible measures against slope failure from cost and effective point of view. It is advised at this point to widen the road so that at least full two lanes of traffic be guaranteed. This may be effective to provide a space to store the falling soils and rocks from the above of the road during an earthquake. Covering the slope above the road by concrete mortar may be effective to prevent the weathering.
- 15) Because road network in Flores Island is poor, it is recommended to established a master plan of future road network so that the major cities be prevented from isolation from other areas by an interruption at one location. Such a master plan may be very important for developing the Flores Island.
- 16) For restoring the Maumere port, it is recommended to consider the soil liquefaction effects in design. Some treatment for preventing the failure of the retaining wall may be effective to reduce the damage of wall and apron. It is also recommended to consider the soil liquefaction effect for reconstruction of important buildings in the port.
- 17) It is recommended to establish a system to systematically conduct the strong motion observation including the maintenance system. This may be very important to evaluate seismic design force and to evaluate soil and structural response during an earthquake.
- 18) The characteristics of geology should be clarified when road plans are made wheather the rocks are weathered or enoughly hard to decide the gradient of side slope.
- 19) A 'slope stake' method is available to monitor the behaviour of landslides. This is very siple method.
- 20) Aerial photo intepretation should be used more to compile various kinds of thematic maps for clarifying characteristics of the land and to catch natural disasters damages.
- 21) The restoration plan, which includes disaster prevention, early rehabilitation and restart of the victims' lives, should be made especially in Wuring area urgently.
- 22) The housing plan should be made urgently as not to force the damaged people into prolonging their temporal evacuation lives.
- 23) The public instruction on disasters, diffusion of the knowledge on disaster prevention should be promoted strongly in order to make people's proper action not only at earthquake but tsunami with appropriate scientific understanding on earthquake and tsunami.

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