Unzen-Fugendake Eruption Executive Summary

1990－1995

November 2007

1. Status of Misunashi River area before the disaster (Spring 1981) (Photo: Kokusai Kogyo Holdings Co.)

Note: Mt. Fugendake is upper outside section. Mizunashi River indicates a serpentine line in the center. The horizontal line in the lower section is National Highway #251. The line above the National Highway #251 is agricultural road. The line slightly tilted to the right direction above the agricultural road is the National Highway #57. The pyroclastic flow occurred on July 19, 18: 21 reached 100m downstream of the National Highway #57.

2. Complete view of Unzen-Fugen and the disaster-affected area (September 27, 2003)

(Photo: Unzen Restoration Project Office, Ministry of Land, Infrastructure and Transport)

3. Eruption after the interval of 198 years (November 17, 1990) (Photo: Kazuya Ota)

Note: The volcanic smoke on the left indicates the Jigokuato crater. The elevated section on the right front is Byobuiwa. The volcanic smoke in the right is from Kujukushima crater.

4. Fire in Akamatsu Valley caused by pyroclastic flow (December 23, 1991) (Photo: Shinichi Sugimoto)

5. Growing lava dome (November 27, 1992)
(Photo: Kazuya Ota)
Note: Lobe No. 8, Lobe No. 6, Lobe No. 4 from left. Pyroclastic lava cones is seen in the center right.

6. Lava dome of Unzen-Fugendake and pyroclastic sediments filling the valley (November 9, 2001)
(Photo: Kazuaki Ito)

7. Pyroclastic flow approaching houses (September 27, 1992)
(Photo: Shinichi Sugimoto)

8. Ruin of Kita-Kamikoba Farming Training Center damaged by pyroclastic flow on June 3, 1991, when many people lost their life. (November 6, 1991)
(Photo: Shinichi Sugimoto)

9. Ono-Koba Elementary School in Fukae Town was burned down by pyroclastic flow in September 15, 1991 (November, 1991)
(Photo: Shinichi Sugimoto)

Note: The ruin of the school has been preserved as a historic object of pyroclastic disaster.

10. A house aggraded by debris flow (April 30, 1993)
(Photo: Shinichi Sugimoto)

11. Water sprinkle vehicle (March 10, 1993) (Photo: Tokinao Iwanaga)

12. Coverage of the disaster at the fixed point where many journalists lost their life by pyroclastic flow on June 3, 1991 (May 1991)
(Photo: KTN TV Nagasaki)

13. JSDF heading for search of victims in the severe pyroclastic flow (June 4, 1991) (Photo: Tokinato Iwanaga)

14. Sign board of "Access Prohibited" (March 9, 1993) (Photo: Shinichi Sugimoto)

15. Emergency evacuation place (school gymnasium) (May 1991, Photo: Shimabara City)

16. Passenger ship "Utopia" chartered for provisional accommodation of disaster refugees in collective evaluation (June 1991) (Photo: Shimabara City)

17. Temporary house (July 28, 1992) (Photo: Shimabara City)

18. Distribution of clothes as rescue supplies (August 4, 1991)
(Photo: Shinichi Sugimoto)

19. Wireless receiver for disaster prevention rented to local citizens without charge (December 2006)
(Photo: Shinichi Sugimoto)

20. Biwa fruits covered by volcanic ash (May 1992)
(Photo: Tokinao Iwanaga)

21. Explanation meeting for local citizens (March 10, 1993) (Photo: Shinichi Sugimoto)

22. Nita tract-house development Buildings where disaster refugees were collectively moved into (Photo: Shimabara City)

23. Sediment removal inside hazard area using unmanned technique (April 11, 1994)
(Photo: Munehiro Matsui)

24. Remote controlling for unmanned construction work (April 11, 1994)
(Photo: Munehiro Matsui)

25. Training dike in Mizunashi River, sabo dam and Mt. Fugen (August 23, 2006) (Photo: Munehiro Matsui)

26. Reforestation approach using indigenous plants (May 2001) (Photo: Shinichi Sugimoto)

27. Mt. Unzen Disaster Memorial Center (June 2002) (Photo: Mt. Unzen Disaster Memorial Center)

Introduction

The Heisei Eruption of Mt. Unzen-Fuzen which started in November 1990 continued until February 1995. After May 1991, frequent incidence of debris flow and pyroclastic flow caused disasters. Once a pyroclastic flow occurs, evacuation is no more possible. While evacuation warning was issued to secure human safety against the pyroclastic flow, 43 peoples were killed or lost. Accordingly, the designation of hazard area based on the Article 63 of the disaster countermeasures basic law was applied for the first time to the urban districts densely populated by houses and commercial facilities. Although the human safety was secured by this designation of hazard area, problematic situation was observed for prolonged period due to issues such as the inability of operating agricultural and commercial activities because of long-term evacuation, the disturbance to workplace / school commuting, the difficulty of maintaining personal assets including private houses, agricultural land, traffic facilities and lifelines as well as the inability to start disaster prevention countermeasure including the counteraction against the debris flow. The disaster impacted not only the directly damaged area but also the whole Shimabara Peninsula due to indirect damages on commercial activities caused by decrease of tourists and shoppers who visited Shimabara. Flow-out of population was also a part of such impacts. Because current laws including the disaster relief act are not sufficient to address these damages, measures to support disaster refugees were implemented within the framework of elastic operations and special measures of the current laws and regulations. Restoration of the life of disaster refugees was supported not only by national-level approaches but also by multiple funds such as Unzen Disaster Countermeasure Fund established by Nagasaki Prefecture and local funds established by Shimabara City and Fukae Town based on donations.

Because the erosion control program including the construction of sabo dams in Mizunashi River was formulated based on the assumption that the eruption would end soon, only permanent countermeasures were formulated. With the prolongation of the volcanic disaster, damage through debris flow was escalated in the hazard area due to inability of starting disaster prevention work, resulting in increased number of damage on houses and disconnection of transportation caused by damage of roads and railroads. Construction of temporary training dike and unmanned work based on the first-aid / urgent measures were introduced for the first time.

Throughout the whole process of risk management, Institute of Seismology and Volcanology (Faculty of Science, Kyushu University) involved in monitoring of volcanic activities on a local site played a significant role. Regarding the monitoring of volcano, specifically about the monitoring of pyroclastic flow, the monitoring system and

monitoring device by Japanese Ground Self-Defense Force were very useful.

In case of devastating damages on social infrastructures through volcanic disaster such as loss of villages as well as road and railroad damages, a restoration program is necessary instead of rehabilitation program. Based on the program focusing on three key policies, i.e. “reconstruction of citizen life”, “creation of city prepared for disaster prevention” and “activation of local community", Shimabara City and Fukae Town complemented the vacancy not covered by existing systems through mutual coordination of national and prefectural restoration projects from the standpoint of reconstruction of citizen life and activation of local community. The restoration programs of the local level were reflected in the national and prefectural restoration program, contributing to the area-based improvement and clarification of role splitting.

Besides, the involvement in the restoration works encouraged the development of leaders and volunteers in the local community. Thereafter, they played important roles as key persons in domestic and international supports for initial stage of disaster relief as well as disaster refugee support networks including those for Great Hanshin-Awaji Earthquake and Mt. Usu eruption.

In the current outline report, the above-mentioned Unzen-Fugendake volcanic disaster is summarized.

Unzen-Fugendake Eruption Disaster Study Group

Chapter 1: History of Unzen-Fugendake eruption and the eruptions between 1990 and 1995

1. Eruption disasters since the dawn of history

Being a composite compound volcano comprising multiple groups of lava dome, Mt. Unzen is an active volcano occupying the major part of Shimabara Peninsula. The volcano has a history of three eruptions since the beginning of the historic age, namely, in 1663, 1792 and 1990－1995, all of which are the eruption of Fugendake, the main crest. In the eruption in 1663, the eruption started at the Kujukushima crater and lava flowed out from the north-east hillside (Furuyake lava ; lava extrusion of approx. 5 million ㎥). In the next year, more than 30 people were killed by debris flow on the east hillside. In the eruption of 1792, eruption started at the Jigokuato crater followed by lava extrusion from the north-east hillside (shinyake lava ; lava extrusion of approx. 20 million ㎥). One month after the termination of eruption, an earthquake occurred resulting in large-scale collapse of Mt. Masu and debris of 0.34㎦ flowed into Ariake Sea. This caused a large Tsunami with maximum wave height of 10m which killed more than 15000 people, making it the most serious volcanic disaster in Japan. The damage was serious also in Higo (current Kumamoto Prefecture) on the opposite shore. The story of this calamity was handed down among local people as “disaster in Shimabara causing great panic in Higo afterwards”.

2. Progress of eruption and monitoring in 1990-1995

The volcanic eruption in 1990－1995 started on November 17, 1990 as an aqueous vapor explosion after a precursor earthquake activities for about one yea **(Front picture 3)**. The eruption sites were at the Jigokuato crater and the Kujukushima crater. Then, after magma-aqueous vapor explosions, lava extrusion started on May 20, 1991 at the Jigokuato crater and a growth of lava dome began.

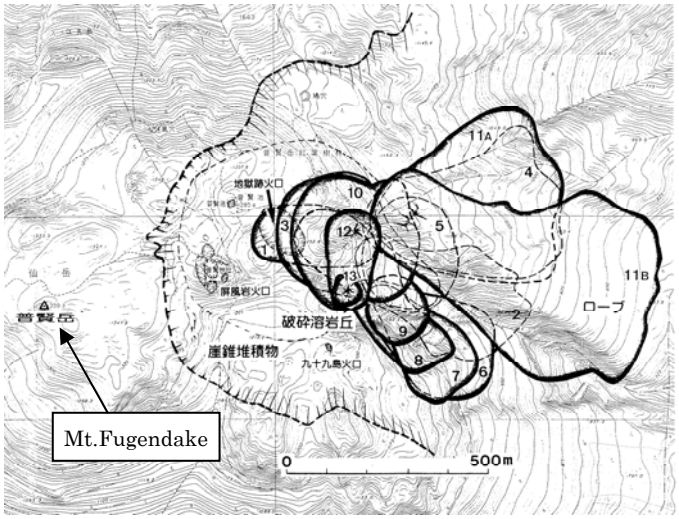

Figure 1　Figure showing accumulation of lobes

Note: 1. Volcano basic chart by Geographical Survey Institute with 1/5,000 scale is used.
2. The numbers indicate lobe numbers and the contours shows the lobe contour at its maximum level of growth. These lobes do not preserve previous forms due to partial / total collapse or aggradation. (Kazuya Ota, 1996)

With the collapse of lava block from the lava dome on May 24, a pyroclastic flow occurred at the east hillside of Mt. Fugendake. Thereafter, frequent pyroclastic flows were observed with the growth of the lava dome **(Front picture 4)**. While total incidence of the pyroclastic flow reached about 6,000 times, low distance exceeded 4km in some of them. The lava extrusion reached 0.3～0.4 million㎥ / day during the peak period, resulting in formation of multiple lava lobes **(Figure 1)**. While lava extrusion almost stopped temporarily in the end of 1992 **(Front picture 5)**, it resumed in February 1993. Since then, formation of lobes and pyroclastic lava cones occurred with fluctuating volume of extrusion, following which a single gigantic lava dome was formed finally. When the eruption terminated in February 1995, total lava extrusion amounted to 200 million ㎥, the half of which remained as lava dome and the other half became pyroclastic flow sediments as a result of collapse during the process of growth **(Figure 2) (Front picture 6)**.

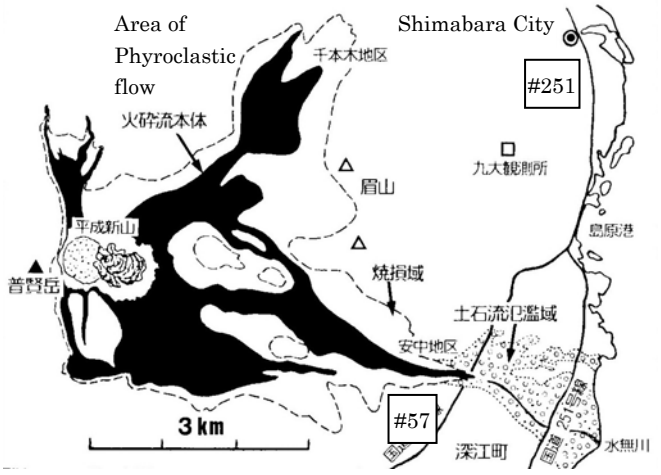

Figure 2 Area of phyroclastic flow reach across the whole disaster period

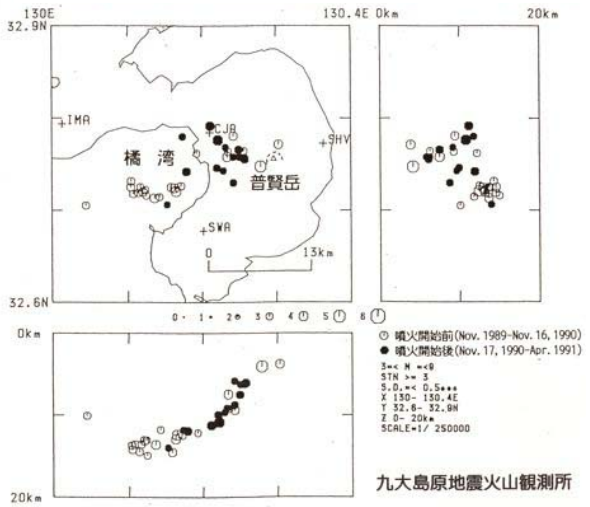

Figure 3 Distribution of focus regarding the activities larger than Magnitude 3 during the period from generation of precursor earthquake to lava extrusion (Ota, 1997)

Note: Before starting eruption (November 1989 - November 16, 1990)
: After starting eruption (November 17, 1990 - May 1991)

Because constant monitoring of the Volcano Unzen had been implemented by Japanese Meteorological Agency and Kyushu University since before 1990－1995, precursor phenomena of the eruption such as volcanic earthquake swarm and volcanic tremor could be documented **(Figure 3)**. However, the timing of eruption start could not be predicted. After the eruption started in November 1990,

monitoring by Japanese Meteorological Agency and national research institutes was reinforced in parallel with various research observations by joint monitoring teams organized by nation-wide universities. These research observations including the daily observation from the sky using a helicopter were carried out under the supports of Japanese Self Defense Force. The observation results by each organization were reported to Coordinating Committee for the Prediction of Volcanic Eruptions of Japan, which served as a basis for examining the status of volcanic activities. Three days before generation of lava dome in May 1991, the chairman of the Coordinating Committee for the Prediction of Volcanic Eruptions of Japan made an announcement that "there is a high possibility of lava extrusion", demonstrating successful prediction of lava extrusion. However, after the start of lave extrusion, the Committee made a prediction on the possible development into lava flow on the basis of previous two historic eruptions and failed to predict formation of lava dome and frequent incidence of pyroclastic flow. The extrusion of lava continued for about four years since then, it was not easy to predict progress of eruptive activities including the timing of eruption termination. The problems related to excessive dependency on the previous cases were recognized and the importance of establishing physical / chemical models for quantitative eruption prediction was perceived as one of the main emphasis. Accordingly, to establish a quantitative models, "Volcano Unzen : International Joint Study for Clarification of Eruption Mechanism and Magma Activities by Scientific Excavation" was implemented in fiscal 1999-2004 subsidized by incentive coordination program of Ministry of Education, Culture, Sports, Science and Technology and the budget of ICDP （International Continental Scientific Drilling Program）, which lead to success of volcanic conduit excavation and acquisition the first core samples immediately after the eruption.

3. Progress of disaster and countermeasures

Immediately after confirming the eruption on November 17, 1990, Obama district started "Coordinating Committee for Warning against Mt. Fugendake Volcanic Activities" and Nagasaki Prefecture set up "Headquarters for Disaster Readiness". Since the spring 1991, debris flows occurred due to ash fall and rain fall **(Front picture 14)**, and Shimabara City issued the first evacuation warning on May 15 to the local inhabitants who lived upstream of Mizunashi River. On May 24, Nagasaki Prefecture switched its Headquarters for Disaster Readiness into Headquarters for Disaster Countermeasures （the HQs were arranged in Shimabara City on May 18 and in Fukae Town on May 26）.

Further, on May 24, the first pyroclastic flow occurred and one citizen was insured on May 26. Considering the fact, Shimabara Headquarters for Disaster Countermeasures issued the first evacuation warning to avoid risks related to pyroclastic flow on the same day. One citizen was injured by this pyroclastic flow. On June 3, the pyroclastic flow flowed about 4.3 km along the Mizunashi River eastward of the crater, giving serious impacts in Kitakamikoba Town in Shimabara City, where 43 people were killed or lost and about 170 buildings were damaged **(Front picture 13, 8)**. On June 4, the Government established "Emergency Headquarters for Disaster Countermeasures for Heisei 3 Eruption of Mt. Unzen ". The hazard areas based on disaster countermeasures basic law were designated by Mayor of Shimabara City on June 7 and by Mayor of Fukae Town on June 8, respectively, upon receiving the persistent advice by Governor of Nagasaki Prefecture. Through this action, access to the areas were limited. Then, a larger pyroclastic flow occurred on June 8 that exceeded the magnitude of pyroclastic flow on June 3. The flow along the Mizunashi River reached about 5.5 km. However, because all inhabitants had been evacuated from the pyroclastic flow range based on the designation of the hazard areas, human damage could be prevented. Even thereafter, the cinders on June 11, the debris flow on June 30 and the pyroclastic flow on September 15 caused serious damages on the houses. Specifically during the pyroclastic flow on September 15, Ono-Kiba Elementary School was burned down. The prolonged period of hazard area designation due to repetitive disasters gave enormous impacts on every aspect of the local citizens.

In 1992, most of the pyroclastic flows flowed towards southeast direction, gradually filling Akamatsu Valley **(Front picture 7)**. In 1993, pyroclastic flow was frequently bound for Northeast hillside heading for Oshiga Valley or Nakao River. On June 23, 1993, during the pyroclastic flow in Nakao River direction, many houses in Senbongi district of Shimabara City were burned and a male citizen who accessed the hazard area to check his house was killed due to systemic burn. Further, repeated debris flows from April to July gave serious damages on many houses and disconnection of national highways and Shimabara Railroad at multiple locations caused temporary isolation of urban districts in Shimabara City.

In 1994, the pyroclastic flow flowed down northwards to the directions of Yue River and Mie River for the first time. The lava extrusion terminated in February, 1995, and no pyroclastic flow was observed after the last one on May 1, 1996. Giving consideration to this fact, Headquarters for Disaster Countermeasures operated by Nagasaki prefecture,

Shimabara City and Fukae Town were adjourned on June 3, 1996 while Government's Emergency Headquarters for Disaster Countermeasures was adjourned on June 4. Nevertheless, the lava dome still remains unstable, where risk of collapse through earthquake or sever rain fall cannot be eliminated. Based on this fact, the designation of hazard areas still continues to date (2007) with reduced scale.

4. Summary of damages

Most parts of the human damage were attributable to pyroclastic flow with the details of the victims as follows: 12 disaster prevention staffs, 16 journalists, 4 taxi drivers transporting journalists, 3 foreign volcanologists and 7 local inhabitants. 2 policemen were also killed in the disaster who tried to report the occurrence of the pyroclastic flow immediately after the incidence.

Meanwhile, 2,511 houses were destroyed, most of which were attributable to the debris flow and the remaining parts were due to fire caused by the pyroclastic flow **(Front picture 10)**. Because education facilities were included in the building damage, there was an severe impact on the school education activities.

Regarding the commercial damages, the evaluation of the amount of direct damage was difficult because it was impossible to perform site inspection due to designation of hazard areas etc. Accordingly, survey of indirect damages was carried out to all cities and town in Shimabara Peninsula with the purpose to collect basic data for designation of severe natural disaster. According to its results, the total amount of damages for 5 years from June 1991 is estimated to be 148016560000 Yen **(Front picture 11)**.

Besides, the details of the total accumulated agricultural and forestry damages during 1991-1995 were as follows: damages on livestock industry were 21,591,399,000 Yen, damages on farmlands were 18,143,000,000 Yen and damages on forestry industry were 26,374,998,000 Yen, which added up to 66,109,397,000 Yen in total. The repeated debris flows and ash falls gave damage on the marine product industries too, centered on coastal fishery. The fishery production from Ariake Sea reduced by 58% in quantity and by 44% in value versus 1995 **(Front picture 20)**.

Besides, flora of the district was seriously affected. The forestry area damaged by fire, ash fall and fallen trees reached 2,640ha, where the total amount requiring for rehabilitation was approximately 80 billion Yen.

Chapter 2　Countermeasures against sediment related disasters

Sediment related disaster countermeasures were implemented from immediately after the eruption to March 1993 by Nagasaki Prefecture. The countermeasures implemented by the Prefecture were removal of sedimentats from river route of Mizunashi River and construction of sand pockets etc. These measures were effective to mitigate disaster caused by debris flow. However, the frequent incidence of pyroclastic flow increased unstable sediments, expanding the scale of debris flow related disasters. Having such a situation as background, Nagasaki Prefecture requested the Government to implement appropriate measures. Address this request, the Government newly established Unzen Restoration Work Office in April, 1993 with the purpose to implement sediment related disaster countermeasures within the framework of government-operated volcanic erosion control project. Key aspects of the sediment related disaster countermeasures implemented in government-operated project are described in the following section.

1. Emergency restoration measures inside hazard areas

Because the rain season in 1993 had higher level of precipitation, debris flow occurred frequently. Downstream area of Mizunashi River suffered devastating damage because the area was totally aggraded with sediments from the debris flow. The sand pockets constructed by Prefecture were also aggraded with sediments. While local inhabitants had shown negative attitude to the Basic plan for erosion control programs, they changed their opinions to support the Basic plan, requesting prompt implementation of the emergency restoration measures. As a part of the emergency restoration measures, removal of debris from the sand pockets, expansion of sand pocket capacity and construction of temporary training dike were planned. However, these works should be done within the hazard areas where there was a risk of being attached by pyroclastic flow.

It meant an enormous danger for workers who were to be involved in the program, since the temperature of the pyroclastic flow exceeded several hundred ℃. On top of it, the pyroclastic flow moves with high speed of approximately 18m/s on average (approx.65km/hour) as it took only 5 minutes to reach the National Highway #57 which is about 5.5 km downstream from the point of the lava dome (horizontal distance). Meanwhile, because the sand pocket in the location most effective for capturing the debris flow is situated close to National Highway #57, pyroclastic flow could reach the jobsite within 5 minutes. The first priority in implementing the manned construction was the establishment of the system to ensure safety of workers.

Due to this reason, construction safety system was established. In this framework,

vehicles dedicated for evacuation and drivers were arranged in the area adjacent to the jobsite. In the event of pyroclastic flow, the evacuation to the safe area should be completed via predetermined evacuation route before the flow reached the jobsite. This system was supported by a wireless communication network. The occurrence of the pyroclastic flow should be immediately reported through this network by Japanese Self Defense Force, who monitored the event on 24-hour basis. Being supported by this construction safety system, the temporary training dike construction was started from April, 1994.

Besides, shelters to secure safety against hot blast from the pyroclastic flow were arranged at 50～100m interval along the evaluation route based on the assumption that some unexpected trouble occurred during the process of evacuation. **【Photo-1】**. However, because the pyroclastic flow could reach the jobsite within a few minutes, there was a limitation in the emergency restoration measures based on the manned system, even if they were supported by such a construction safety system.

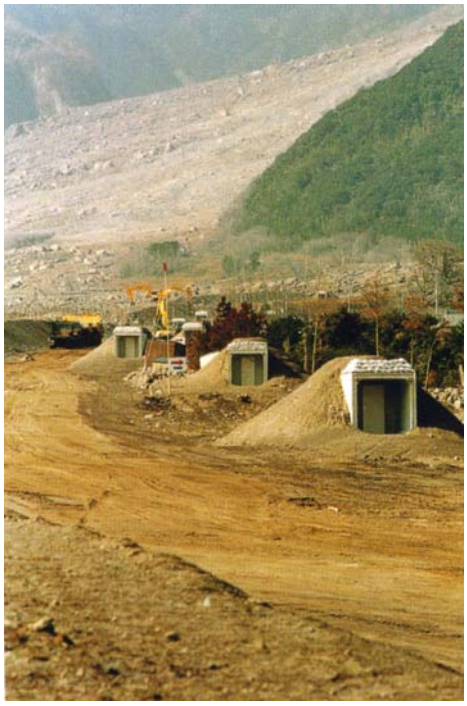

Photo 1　Evacuation shelters
(May 12, 1994, Photo by Munehiro Matsui)

2. Unmanned construction

In July 1993, based on active use of the new system, Ministry of Construction invited participation of several private companies to offer unmanned construction technology suitable for removing sediment. On-site pilot construction was conducted for the technologies that satisfied the public invitation criteria and demonstrated immediate availability. Details of the technologies offered were all based on the wireless remote control of a series of sediment removal processes, including soil gathering by bulldozer, excavation and loading by back-hoe and soil transportation by dump tracks. Followings were found as a result of on-site pilot construction: ①Construction could be carried out much smoother than initial estimation, ②It took no longer than one week for operators to be familiarized with the machine operation. ③During the machine operation by operators, they needed to watch only 1 or 2 screens in each phase while multiple images were displayed.

After the pilot construction, full scale sediment removal construction was carried out from 1994 to 1995 on the unmanned bases **(Front picture 23, 24)**. In the process of this

construction, various issues were improved. As the world-first case, this unmanned construction technology was adopted also in the Sabo dam construction started in September 1995. Sabo dam was a key element of the debris flow countermeasures.【Photo −2】.

The unmanned construction technology played a significant role in the volcanic erosion control countermeasure implemented for the disasters caused by Mt.Usu eruption and Miyake Island Eruption in 2000. Further, full-scale utilization of this technology has been started not only in the volcanic erosion control countermeasures but also in the restoration work for many other disaster scenes of the general types.

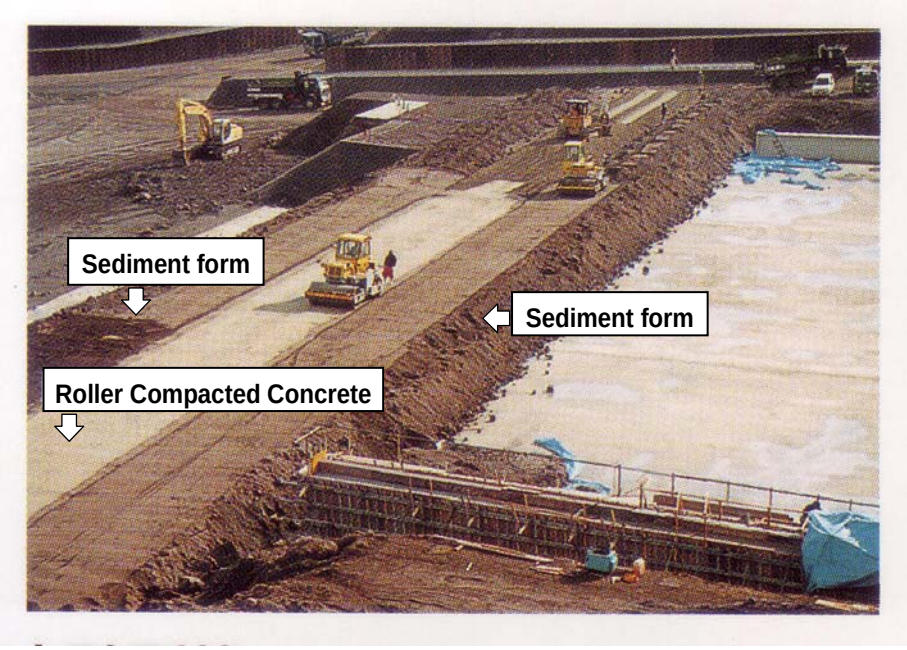

Photo 2 Construction of main section using the sediment form (Source: Unzen Restoration Project Office- Project outline)

Chapter 3 Risk management, information transfer and press

When the eruption occurred, Unzen Station of Japanese Meteorological Agency and Shimabara Station of Institute of Seismology and Volcanology (Kyushu University) were operating as volcano monitoring organizations. Because Japanese Meteorological Agency and Coordinating Committee for the Prediction of Volcanic Eruptions of Japan were responsible for supplying information about volcanic activities and had no involvement in risk management by local governments, the local governments should depend on the Shimabara Station of Kyushu University.

In July 1990, volcanic earthquake swarm and volcanic tremor were detected in the Mt. Fugendake area. Shimabara Station of Kyushu University reported possibility of eruption to Ministry of Education, Culture, Sports, Science and Technology on November 9.

The eruption began on November 17. One city and 16 towns in Shimabara Peninsula established their Headquarters for Disaster Countermeasures or Headquarters for Disaster Readiness. Specifically, Being highly vigilant against the possible collapse of Mt. Mayu, Shimabara City started to develop an evacuation program. Lava flow was assumed as one of the eruption modes initially, where local people were concerned about the risks of debris flow cause by ash fall and the collapse of Mt. Mayu through earthquake. On May 15 in the next year, upon occurrence of debris flow, evacuation warnings were issued in succession. Unlike adjacent Fukae Town where public wireless network for disaster prevention was already available, the only way to instruct evacuation was public relation vehicles and fire engines in Shimabara City. Occurrence of debris flow occurred repeatedly thereafter. After the breakage of wire sensor on May 26, no workforce could access the site due to pyroclastic flow and fire brigade members conducted monitoring at an upstream location.

No researcher witnessed the pyroclastic flow on May 24. The images shot by a TV station was brought in on the next day, which caused an argument on whether or not the event of pyroclastic flow should be publicly announced. Giving consideration to the possible panic among citizens, the fact was announced as “a pyroclastic flow of a small scale”. On May 26, after human injury due to pyroclastic flow was reported, Shimabara City issued an evacuation warning to inhabitants of Kamikoba district, responding the recommendation by Shimabara Station of Kyushu University. This was the first evacuation warning due to pyroclastic flow, while the evaluation warning was issued previously to avoid risks related to debris flow. However, this area was constantly accessed by people including the local citizens who tried to carry out their household goods and those who were engaged in farming during daytime, fire brigade members, journalists, disaster prevention staff and researchers. Among others, coverage of mass media in this area was escalated day by day. In the midst of the heated competition for scoop, many appealing images were shot such as the dynamic debris flow shot by unmanned camera, the lava dome first appeared on May 20, the first pyroclastic flow on May 24 and a night view of glowing lava. Press people started to shoot images from the position directly faced to Mt. Fugendake (so called “fixed point”) and, at the peak period, more than 100 press people were reported to be working in Kamikoba district **(Front picture 12)**. On May 29 and 31, Shimabara City requested press organizations to evacuate from the evacuation area. While the fire brigade followed the evacuation request, the press organizations did not follow the request. Further, unauthorized use of electricity and telephone by press people in the evacuated houses was reported. Due to this reason, the fire brigade returned its station to Kamikoba in the morning, June 2. On

4:08, June 3, a devastating disaster by pyroclastic flow occurred, resulting in 43 victims including the death and the missing. The details of the victims are fire brigade members, policemen, local inhabitants, journalists and taxi drivers transporting journalists. In the morning of the same day, officers from Shimabara City visited the evacuation area to survey opinions of refugees. This tragedy could have been prevented if the significance of issuing the evacuation warning by trading off daily life of local inhabitants could have been correctly understood by legislators, citizens and mass media.

While the governor officially requested actions by Japanese Self Defense Force (JSDF) at night on June 3, the JSDF (16th Infantry Regiment) had already opened its information stations in Shimabara city hall on May 19 and in the prefectural Headquarters for Disaster Countermeasures on June 1 to initiate activities with arranging resident relays team. The JSDF who entered the area on June 3 arranged the relays team in Kyushu University Station, where activities related to pyroclastic flow were monitored by using a seismic wave monitor. On the next day, a monitor station performing 24-hour monitoring was opened, where information collection equipments for battle application such as terrestrial radar were installed. While its initial purpose was the search for the missing people and the rear-area support to the body recovery activities, JSDF's warning and monitoring networks based on positive use of high-tech equipments for scouting and communication applications were fully utilized by each disaster prevention organization, who intercepted the information sent on real-time basis. Specifically between JSDF and Kyushu University, close relationship for developing a system to monitor volcanic activities was established. Offering helicopter service by JSDF for volcano observation, reciprocal information exchange and the recommendation by Kyushu University Station to allow decision making based on the information gathered by JSDF were a part of this tie-up. The joint establishment of the risk management support system by JSDF and

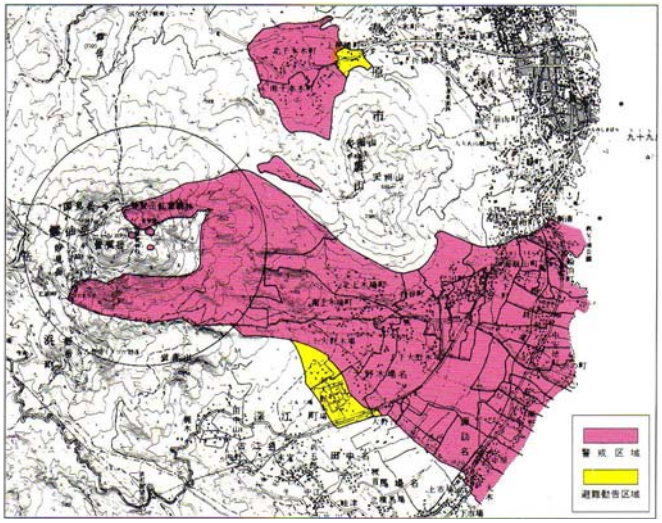

Figure 4 Range of hazard area
Hazard area was expanded because the pyroclastic flow occurred frequently since August 26, 1991 at northeast hillside of Jigoku Crater
(September 10, 1991) (Shimabara City)

Hazard area Evacuation warning area

Kyushu University Station for local authorities was the first approach in our country, which was proved as extremely useful.

After June 3, the risk management system was implemented under the positive initiative of the governor. From June 7, access to the areas at high risk was strictly controlled with the designation of hazard area. Although the designation of the hazard area was proposed to the mayor of Shimabara City by the governor on June 5, the mayor rejected this proposal with citing its serious impact on the daily life of local citizens. The mayor rejected this proposal again in the morning on June 6 when the governor made the second request, the mayor finally agreed to follow the proposal during the head-to-head meeting in the afternoon. He accepted the request on the premise of closing a written form of agreement to promises that "the national government and the prefectural government shall jointly provide supports for rehabilitation from the damages and loss of local citizens". This meeting lasted for more than 3 hours. The evacuation area and the hazard area were appropriately expanded or reduced depending on the occurrence of pyroclastic flow **(Figure 4)**. While the authorized party for designating these area based on the disaster countermeasures basic law was the mayor of Shimabara City and the mayor of Fukae Town, the preliminary coordination was conducted under the initiative of the governor and with the participation of the Chief of Kyushu University Station. Then, approval was obtained in the meeting attended by security-related organizations such as JSDF, police, fire station and the Maritime Safety Agency, followed by consent by municipal / town Headquarters for Disaster Countermeasures for final determination. As an emergency public relation system for the local citizens, Shimabara City actively promoted the improvement of public wireless network for disaster prevention. Within this program, receiver was introduced to each household in addition to outdoor loudspeakers **(Front picture 19)**. When the local citizens in the evacuation area accessed the area temporarily when the status of pyroclastic flow is stable, each citizen carried around this individual receiver to complement monitor system operated by disaster prevention organizations. Further, the images delivering the status of pyroclastic flow / debris flow were shot by volcanic monitor cameras installed by the prefecture and these images were sent also to the Headquarters for Disaster Countermeasures in Shimabara City and Fukae Town. Further, the images from helicopters and the 24-hour monitor cameras by JSDF were broadcasted constantly on the disaster prevention channel of the private cable TV. Afterwards, images from terrestrial cameras were replaced by the images shot by Unzen Restoration Work Station of Ministry of Construction to date.

Attitude of press organizations was more reserved after June 3, when they had victims from their own community and the death of the fire brigade members was attributable to

them. Meanwhile, some criticism arose among free journalists against the fact that the mass media totally gave up the coverage inside the hazard area and their dependency on the JSDF for collecting images of the affected area. Having such a situation as back ground, “Unzen Meeting”, a new initiative to establish a relationship with local citizens in the disaster area, was started by mass media as a whole. This initiative was operated by an executive committee organized by The Mainichi Newspapers Union and other unions in the press organizations in Nagasaki area. Dialog has been held between press people and the local citizens in Shimabara every year around June 3 for 10 year.

Chapter 4 disaster refugees measures and life reconstruction

Since occurrence of debris flow on May 15, 1991, evacuation warning was issued frequently and shelters without legal basis were arranged including Kita-kamikoba Farming Training Center and Minami-kamikoba Town Public Hall. Since the application of the disaster relief law on May 29, 16 shelters including municipal sports center were opened during the peak period in accordance with the expansion of the disaster and 166,718 people were accommodated in total **(Front picture 15)**. In each shelter, 3～5 staffs including the support staffs from neighboring local authorities were engaged in administration service with taking a shift under the unified shelter operation manual. Besides, considering the preservation of local community as a basic rule also in the shelters, grouping was based on the unit of town neighborhood association.

With the prolongation of the life in shelter, measures were taken to charter passenger ships, hotels and pensions to accommodate refugee families to improve quality of life, which was at risk due to compromised privacy **(Front picture 16)**. This measure had a positive impact also on the local hotel industry, which suffered from drastic decrease of tourists though not directly affected by the disaster.

Based on the regulatory criteria, only “person without financial capacity” who cannot secure the place of living by himself / herself can enter the temporary house. The number of households that satisfied this criteria was considered very limited in the current eruption disaster. Nevertheless, Nagasaki Prefecture requested the national government to operate the concerned regulations elastically and started preparation of construction. While the ordinary process requires prior determination of people qualified for entering temporary houses, the local authority started the construction promptly before survey. As a result, 26 apartments for 988 households in Shimabara City and 10 apartments for 467 households in Fukae Town were constructed, respectively. During the peak period, 5,669 people (1,444 households) were accommodated in these facilities. Due to prolongation of the disaster, the installation period of these facilities was extended repeatedly. They were used for 4.5 years

until December 25, 1995, when the last household vacated from the temporary house **(Front picture 17)**.

With the prolongation of the period of using the temporary houses, requests for recreation room of elderly people, study rooms for children and students and meeting room were submitted by the refugees accommodated in the temporary houses. To address these needs, vacant rooms were used for these purposes. In addition to the construction of temporary houses, the council houses and the houses for employment promotion in the neighboring towns and villages were used to satisfy increased housing demands. The households entering these facilities were exempt from the payment of rent and deposit. Because the house rent for council houses was exempted along with the free temporary houses, financial supports were extended to the households who rented private houses by themselves due to inevitable reasons such as commuting convenience and nursing for young children / patients to achieve balance.

Concerning the mental health during the prolonged period of evacuation, many people complained problems such as sleep disturbance, muscle pain on shoulders and constipation caused by unfamiliar collective life and fear for pyroclastic flow / debris flow during the initial period of evacuation. With the prolongation of the evacuation, countermeasures to ensure mental health became necessary, for instance, to mitigate stress. Under the tie-up with psychiatrists and nursing staff in health center, various measures were taken such as installation of telephone help line and information collection on mental / physical health of people in the temporary houses by support staff who visited individual houses.

As a life support, 100 items in 21 areas were covered by national government who approved these items one by one depending on the necessity to relieve disaster refugees with the prolongation of the disaster period. As a consequence they constituted an extensive compilation of disaster countermeasures and relief actions for this eruption disaster instead of just being a mean of life support. However, because the current disaster was the unprecedented disaster without any forecast of closure, there was a movement to request special legislation to relieve disaster refugees. Instead of such a legislation, “fund for restoration from Mt. Unzen disaster” was established. The fund was financed by reserving and operating the interests of subsidies from prefectural government, loans and a part of the private donations. The characteristics of the fund was its positioning as “a mean to complement various disaster countermeasures implemented by administration” and its emphasis on the subsidized projects with the purpose to encourage local citizens to recover from the disaster. Because of this, the projects to be implemented through direct involvement or subsidizing of national and local authorities were out of the scope. Besides, donation-based funds were established in Shimabara City and Fukae Town to support disaster refugees.

Enormous amount of sympathy, encouragement, financial donation and relief supplies were delivered to the area affected by this disaster **(Front picture 18)**. The total amount of donations reached more than 23. 3 billion Yen. To perform fair allocation of the donations, a committee for donation allocation was established by the organizations concerned. One of the characteristic actions in this disaster was the fact that a part of the donation was reserved as funds. This action was taken to maximize the significance of the support from numerous people instead of just sharing them among the parties concerned.

In the current disaster, the reconstruction of the buildings was difficult because many houses were swept away / burned and their original premises were designated as hazard area. Because of this, securing houses were the main emphasis for reconstruction of the life of local citizens. As an action to promote permanent moving, Nagasaki Prefecture developed a collective apartment buildings. The flat sales price was decreased to the affordable level for the disaster refugees by utilizing the Unzen Disaster Countermeasure Fund **(Front picture 22)**. Further, financing for house reconstruction was a hard challenge for disaster refugees since there was no regulatory support system to provide cash to the people who wanted to rebuild their houses. To overcome this challenge, a part of the reconstruction cost was subsidized from the donations, Unzen Disaster Countermeasure Fund of Nagasaki Prefecture and the donation-based funds of Shimabara City and Fukae Town, extending a great support for house reconstruction.

While activities of disaster support volunteers had become widely acknowledged since the eruption disaster of Unzen-Fugendake, the volunteer activities such as cleaning of public toilet and categorizing / dispatching rescue supplies were conducted by local groups for area promotion at the initial stage. These groups played a significant role of contact / accepting points for external volunteers after a flood of volunteers visiting the affected area from all over the country caused a panic among the local administrative staffs and citizens. Since the termination of eruption activities and the reduction of the scale of direct disaster relief activities, focus of the volunteer activities are moving to the handing-down of the experiences in Shimabara along with the project to reinforce nation-wide volunteer network.

Chapter 5 Restoration promotion program and rehabilitation of urban facilities

It was difficult to discuss restoration openly while many disaster refugees were still living the prolonged evacuation life. However, when the disaster-affected local authorities tried to submit requests on disaster refugee measures to Nagasaki Prefecture and national government, the requests should be accompanied by a restoration program that indicates future policy for restoration to be persuading. Due to this reason, Shimabara

City and Fukae Town developed restoration programs as local authorities that held the closest position to the local citizens.

Based on the lessons and the challenges in the current disaster, “reconstruction of citizen life”, “creation of city prepared for disaster prevention” and “activation of local community" were designated as the three key policies for the area activation. Restoration program formulated by Shimabara City complemented the vacancy not covered by existing restoration programs by national government and Nagasaki Prefecture through systematic mutual coordination from the standpoint of reconstruction of citizen life and vitalization of local community to achieve well-balanced restoration for the community. This allows subtle management of the various initiatives such as area improvement including preparation of land use programs, review of city development plan, and formulation of new residential areas, effective use of disaster prevention facilities, improvement of tourism facilities around the disaster prevention facilities, formulation of evacuation programs and nurturing of volunteer disaster prevention organizations.

Because the Shimabara’ s restoration programs delivered preference of local communities not only to the general public but also to the national government and Nagasaki Prefecture, its importance was well acknowledged, leading to relatively smooth process of adoption. Also, it showed a relatively high level of perfection. Nevertheless the promotion under close cooperation of the local community and administration as well as tie-up with national government and Nagasaki Prefecture were indispensable to achieve large scale products such as increase of elevation of whole Annaka triangle district and development of residential areas.

In 1995, when the eruption terminated, the initial movement to promote vitalization of whole Shimabara Peninsula was observed. Increase of Unzen Disaster Countermeasure Fund by 100 billion Yen and its extension of further 5 years made it possible to implement these restoration measures.

This volcanic disaster had a serious impact not only on the directly affected Shimabara City and Fukae Town but also on the whole Shimabara Peninsula. Specifically, reduction of local population and tourists who stayed in the hotels in this area was noticeable. Giving consideration to these facts, Nagasaki Prefecture determined 1996 to be the first year of full-scale restoration. With the joint efforts of local communities, citizens and affiliated organizations of national and prefectural agencies, “Shimabara Area Regeneration Action Plan (Gamadasu Plan)” was formulated. “Gamadasu” means “To make best efforts” in Shimabara dialect. Based on this Unzen restoration programs,

many initiatives were achieved such as reconstruction of houses and farmland through increase of elevation of whole Annaka triangle district that had been totally aggraded with sediments from the debris flow, active use of designated area for erosion control including restoration of the Waren River, spring of water and recovery of greens through reforestation, and the utilization of ruins of the volcanic disaster for tourism resources including preservation of previous Ono-Kiba Elementary School in Fukae Town that were severely damaged by pyroclastic flow **(Front picture 9)**.

The main characteristics of the restoration from this volcanic disaster was the increase of elevation of whole Annaka triangle district **(Figure 5)**. This district had a total area of about 93.4ha lived by 324 households (1,183 poeple). The Annaka triangle district was damaged by intermittent debris flow occurred in August 1992 as well as from April to July in 1993. The debris flow aggraded 70% of the houses in this district. Rehabilitation by individual efforts was extremely difficult in this situation. The inhabitants considered that it would be difficult to find a replacement land within Shimabara City with limited area. On the other hand, rehabilitation of their living seemed to be much easier for them if the could reuse their own houses and farmland in their home town. On top of it, they could thus maintain their traditional local community. Among the local inhabitants who were highly concerned about disappearance of Annaka District when facing the growing damage, request for "increase of elevation of whole Annaka triangle district" was proposed.

As a consequence, they concluded that the Project to increase the elevation of whole Annaka triangle district was indispensable.

To achieve this project, demolition of the remaining houses within Annaka Triangle and construction of various facility for erosion control as well as channels for drainage of rain water were necessary. The project costs necessary for these works was 9.07 billion Yen. To generate financial resources for this project, introduction of the soil dumping

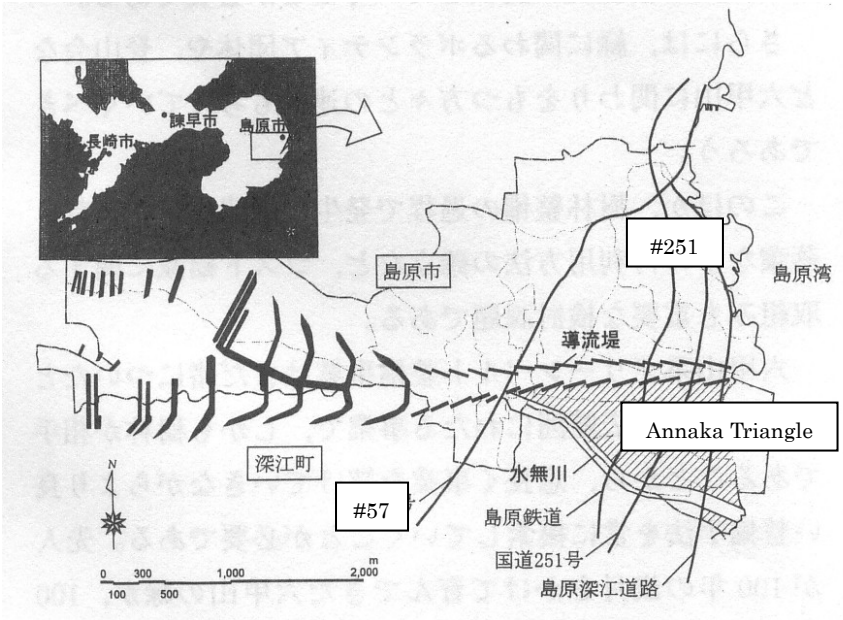

Figure 5 Location of Annaka Triangle District in Shimabara City
(Prepared by Takuro Kimura)

project in Annaka Triangle was determined in April 1994 with the support of Ministry of Construction and Nagasaki Prefecture. In this project, Ministry of Construction was designated as a provisional soil dumping yard. To be specific, sediments generated through debris flow in the training dike and Mizunashi River as well as the remained soils from disaster prevention works were brought into the Annaka Triangle and the soil damping fees collected were allocated to the budget for the elevation increase project. **(Figure 6)**. The average level increase was about 6m (maximum: approx. 8m, minimum: approx. 3m) and the soils necessary for the elevation increase was approx. 3.26 million m^3.

The main characteristics of this project were i) it was started based on the idea of the inhabitants, ii) soils necessary for elevation increase could be obtained by designating the Annaka Triangle as a soil damping yard with keeping the area as private assets of the inhabitants, iii) Shimabara City collected the soil damping fees to allocate the profit to this project.

About the supply of the soils necessary for the elevation increase, prediction was made based on the performance between 1991 and 1994 that soil supply of 0.8 million m^3 is

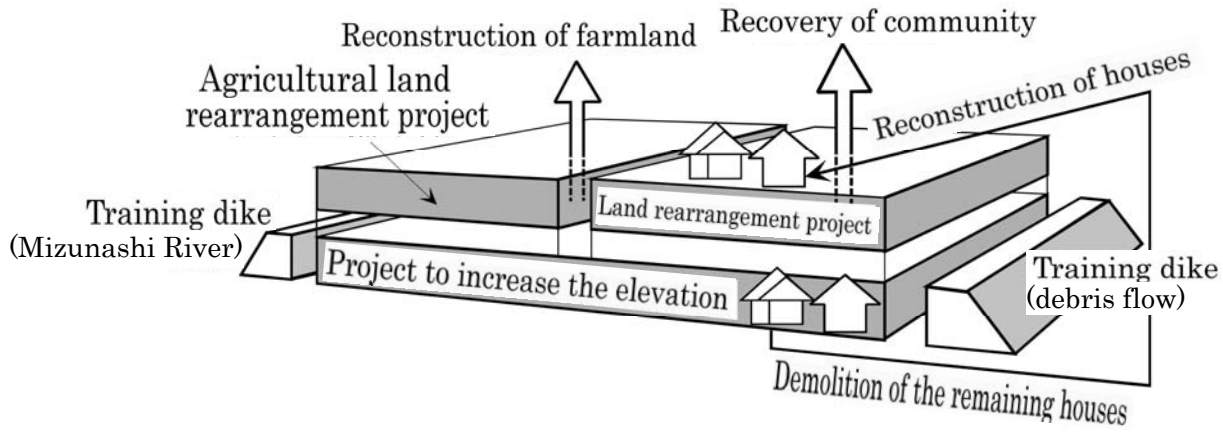

Figure 6 Restoration Concept of Annaka Triangle District (Prepared by Takuro Kimura)

secured annually, making it possible to secure total quantity necessary for the project in 4 .5 years. Based on this estimation, Shimabara City considered that the length necessary for the elevation increase would be 5 years at maximum. In total, about 8 years was spent to complete this project since 1992, when an idea of the elevation increase was proposed by the inhabitants.

Regarding the status of house construction in Annaka Triangle, reconstruction of 130

houses was projected in total, where construction of 128 houses were completed and 2 houses were still under work as of December end, 2005. Because total household number of Annaka Triangle was 245, reconstruction of approx. 53% has been achieved so far.

The experience of the volcanic disaster of Unzen-Fugendake indicated that the areas lived by citizens were severely affected by ash fall, pyroclastic flow, debris flow and cinders. Having leant lessons from this volcanic disaster, Shimabara City has introduced several countermeasures to protect its urban facilities and lifelines including: i) prevention of isolation by employment of block configuration, networking and multi-route configuration, ii) reinforcement of base section of cable tower as well as burying of communication cables to prevent damage through debris flow, iii) moving the cable tower for power supply to the place with lower risk of pyroclastic flow or increase of the heights of the tower.

Chapter 6 Lessons

1. Countermeasures against sediment related disaster

The lessons obtained through implementation of volcanic erosion measures are i) new technology can be developed by challenging difficulties with creative spirit, ii) sophistication of emergency measures are essential, iii) both hardware and software-related measures are necessary prior to eruption. These lessons are effectively utilized in the volcano-related projects for the other volcanoes in Japan.

Reviewing the area restoration under the light of the process of sediment related disaster measures, however, the most significant lesson was “the cooperation of pubic and private sectors”. Without mutual trust and cooperation among the national government, prefecture, city, town and local citizens, the restoration of Shimabara Area to the current status could not have been achieved in such a short period. This fact leaves us a significant lesson that can be applicable to any disaster case.

2. Risk management

“The widely accepted belief that the flood of heterogeneous information would cause confusion in the society was proved to be invalid in the community that suffered from long-term disaster and desperately seeking for information” （from ”Anniversary Publication Commemorating Retirement of Professor Kazuya Ota”）. The disaster caused by eruption of Mt. Fugendake gave a motivation for discussion on the information transfer, where efforts were made to find out how the relationship among researchers,

administrators, mass media and local citizens should be. The results of the exploration could be effectively utilized in the Mt. Usu eruption in 2000. At the initial stage of Mt. Fugendake eruption, not all researchers and administrators showed positive attitude to information publication. On the other hand, before the eruption of Mt. Usu, volcanic information reporting the urgency of eruption was announced without hesitation. In order to cause actual evacuation of local citizens, however, the constant relationship and trust established between the researchers / administrators and local inhabitants were essential. If resident opinion leaders present recommendation to head of local authorities and provide detailed explanation to local citizens to promote their understanding, administrators can make appropriate decision. Professor Kazuya Ota who monitored Unzen-Fugendake and Professor Hiroshi Okada (Hokkaido University) involved in Mt. Usu case have demonstrated this fact. Meanwhile, a tendency to reverse this trend raises concern in recent years, where centralization and rationalization of monitoring and communication technologies as well as the privatization of universities may lead to abolishment of “home doctor” for each volcano.

3. Disaster refugee measures

Flexible actions were seen in various aspects of disaster refugee measures including charter of passenger ships, hotels and pensions to address prolonged stay in shelters, relaxation of eligibility criteria for applicants for entering temporary houses and arrangement of meeting facilities to respond to requests from refugees. Such flexibility had a tremendous power to promote the process of disaster prevention and restoration projects through national government, prefecture and city / town. These actions were effective to obtain feeling of trust from the people in the shelter, making it easier to elicit cooperation from them in the later stage.

In the case of Unzen-Fugendake eruption disaster, sophisticated supports to disaster refugees could be achieved by ”Disaster Countermeasure Fund”, which was a significant fruits of this project. Since this success, establishment of a fund has been widely adopted including the earthquake in south-west coast in Hokkaido and Great Hanshin-Awaji Earthquake though method is different depending on each case. On the other hand, no fund has been established so far for Mt. Usu case and Miyake Island case while its necessity has been pointed out. The largest factor is the issue related to interest of financial organization and not because the necessity of fund is decreased. So as to ensure sophisticated and flexible disaster refugee measures and supports, it is essential to review the optimal method of establishing a fund in future.

4. Restoration program

Shimabara City formulated its restoration program stepwise in the order of basic policy, basic concept and basic program with employing opinions from disaster refugees and local communities. A method was used to formulate feasible plans with performing coordination with national government and Nagasaki Prefecture, while forming agreement among local communities. In addition, disaster prevention program and restoration program were further reviewed with prolongation of the disaster so that the programs to enable "creation of city prepared for disaster prevention" and "reconstruction of citizen life" could be formulated based on the assumption of prolonged disaster period. Thus, this program was a specific summary of the basic policies based on the adequate level of basic survey. During the preparation process, agreement formulation among local communities as well as tie-up and coordination with disaster prevention / restoration-related organizations were carried out. While the period of preparing the program was short, its level of perfection deserves high evaluation because the programs delivered preference of local communities to the national government and Nagasaki Prefecture **(Front picture 27)**. While formulation of municipal-level / town-level restoration program has its limitation in the availability of technology, financial resources and project operator, such a restoration program is judged as essential to deliver preference of local community.

During this disaster numerous houses and farmlands were aggraded with repeated debris flow and enormous acre of land was lost. The level of damage exceeded the range that could be restored by individual efforts. Because of this, reconstruction of houses were extremely difficult for disaster refugees **(Front picture 21)**. The loss of land is one of the biggest characteristics of the eruption disaster. Accordingly, the nature of life reconstruction supports to disaster refugees should be reviewed based on the assumption of land loss in future.

While it was successfully accomplished, the elevation increase project in Annaka Triangle in this case was a very risky project, because it was forced to depend upon the sediments generated during the rain for its soil supply. After the earthquake in south-west coast in Hokkaido in July 1993, the method of land regeneration was implemented in Okujiri Town with taking the elevation increase project in Annaka Triangl as its model. There will be a need for this type of project also in future. Giving consideration to this fact, further review of this project method by public sector is considered necessary.

This executive summary was compiled by Unzen-Fugendake Eruption Disaster Study Group including Chairman, Unzen-Fugendake Eruption Disaster Study Group, Kazuo Takahashi (Professor), Department of Civil Engineering, Nagasaki University and produced by Unzen Restoration Project Office, Kyushu Regional Construction Bureau, Ministry of Land, Infrastructure and Transport to provide useful data for erosion control measures in future.

The Study Group is comprised of the volunteered members from the Working Group who authored “Unzen-Fugendake Eruption Report 1990-1995”.

The Working Group belongs to the “Special Study Board for Succession of Lessons from Disaster Experience in the Central Disaster Prevention Committee” in the Cabinet.

We express our deep feeling of appreciation for the volunteered members of the Working Group and Authorities concerned.

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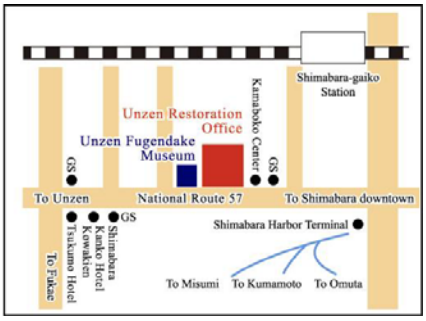

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