

How did the Geospatial Information Authority of Japan

Respond to the 2016 Kumamoto Earthquake?

-A Case Story-



October 2017



Geospatial Information Authority of Japan

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List of Acronyms

ALOS-2:	Advanced Land Observing Satellite
CORS:	Continuously Operating Reference Station
CDMC:	Central Disaster Management Council
DGO:	Designated Government Organization
DMHQ:	Disaster Management Headquarters
GEONET:	GNSS Earth Observation Network System
GSI:	Geospatial Information Authority of Japan
GSI-LB:	Geospatial Information Authority-Land Bird
MLIT:	Ministry of Land, Infrastructure, Transport and Tourism
NGIA:	National Geospatial Information Authority
ODMHQ:	On-site Disaster Management Headquarters
REGARD:	Real-time GEONET Analysis system for Rapid Deformation Monitoring
RSD:	(GSI) Regional Survey Department
SAR:	Synthetic Aperture Radar
SFDRR:	Sendai Framework for Disaster Risk Reduction 2015-2030
SGDAS:	Construction of Seismic Ground Disaster Assessment System
SI:	Seismic Intensity
UAV:	Unmanned Aerial Vehicle
UN-GGIM:	UN Committee of Experts on Global Geospatial Information Management
UN-GGIM-AP:	The Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific
VLBI:	Very Long Baseline Interferometry

Introduction

Role of Geospatial Information in Disaster Risk Reduction

Since natural disasters take away many lives and assets, and hinder sustainable development, disaster risk reduction has been an important international challenge. The United Nations, having recognized the importance of disaster risk reduction, convened in 1994 the first World Conference on Natural Disaster Reduction, and established the United Nations Office for Disaster Risk Reduction (UNISDR) in 1999 to facilitate the implementation of the International Strategy for Disaster Reduction. The outcomes of the subsequent efforts were consolidated at the 3rd United Nations World Conference on Disaster Risk Reduction in 2015 into the Sendai Framework for Disaster Risk Reduction 2015-2030¹ (SFDRR), which outlines the issues, policy framework and measures to be addressed on disaster risk management up to 2030. The resolution on SFDRR was subsequently adopted by the UN General Assembly in the same year. It is noteworthy that SFDRR recognizes the potential role of geospatial information in disaster risk reduction, and urges the geospatial information community to: develop location-based disaster risk information, including risk maps, by using, as applicable, geospatial information technology; make use of space and in situ information, including geographic information systems (GIS); and disseminate risk information with the best use of geospatial information technology, in its Priority 1 – Understanding disaster risk.

Activities of UN-GGIM on Disasters

Pursuant to the adoption of SFDRR, the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) established a Working Group on Geospatial Information and Services for Disasters (WG on Disasters) in 2015 to discuss the optimization of geospatial information applications and services at all levels of disaster risk management. The results of the WG on Disasters discussions were compiled into the Strategic Framework on Geospatial Information and Services for Disasters², which was adopted at the seventh session of UN-GGIM in 2017. The

¹ <http://www.unisdr.org/we/inform/publications/43291>

² [http://ggim.un.org/docs/UN-](http://ggim.un.org/docs/UN-GGIM%20Strategic%20Framework%20for%20Disasters%20(FINAL%20VERSION%20-%20UNGIM7%20dated%2003%20August%202017).pdf)

[GGIM%20Strategic%20Framework%20for%20Disasters%20\(FINAL%20VERSION%20-%20UNGIM7%20dated%2003%20August%202017\).pdf](http://ggim.un.org/docs/UN-GGIM%20Strategic%20Framework%20for%20Disasters%20(FINAL%20VERSION%20-%20UNGIM7%20dated%2003%20August%202017).pdf)

final goal of this Strategic Framework is that “quality geospatial information and services are available and accessible in a timely and coordinated way to support decision-making and operations within and across all sectors and phases of the emergency cycle.” The WG on Disasters is now drafting a resolution for the adoption of the Strategic Framework by the Economic Social Council of the United Nations, and is developing an assessment tool to assist Member States and UN-GGIM regional committees to evaluate and develop their respective implementation plans, and to monitor and report progress on the implementation of the Strategic Framework.

Activities of UN-GGIM-AP on Disasters

In parallel with this global attempt to implement the SFDRR, the Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific (UN-GGIM-AP) established a Working Group on Disaster Risk Management (WG on DRM) to discuss specific activities that National Geospatial Information Authorities (NGIAs) in the Asia-Pacific region, where the frequency and intensity of natural disasters are very high, and to contribute to disaster risk management in accordance with SFDRR. This Working Group has been closely cooperating with the WG on Disasters of UN-GGIM. The WG on DRM of UN-GGIM-AP so far has been concentrating its efforts to understand what the NGIAs and relevant disaster management agencies of the Member States in the region have been doing on disaster risk management, and to find out their best practices to share them in the region. One of the goals of the WG on DRM is to develop guidelines for the NGIAs in the region for the disaster risk management that will be consistent with the Strategic Framework, which was also welcomed at the Seventh Session of UN-GGIM in its decision. The guidelines are now in drafting phase and expected to be finally adopted at the UN-GGIM-AP at its Seventh Plenary Meeting in 2018.

Special Session at the Sixth Plenary Meeting of UN-GGIM-AP

In light of the need of thorough understanding on what NGIAs are actually doing specifically on disaster risk reduction and of sharing them among the NGIAs in the region, in order to develop the guidelines that are to include specific actions NGIAs could take to assist their respective governments in better managing disaster risk in accordance with the Strategic Framework, UN-GGIM-AP is organizing a special session on the applications of geospatial information for disaster risk reduction during its Sixth Plenary Meeting on 17 and 18 October 2017 in Kumamoto, Japan. Specifically, the special session will focus on a case study of disaster responses for

the 2016 Kumamoto Earthquake that occurred in April 2016. The Geospatial Information Authority of Japan (GSI), the host of the Sixth Plenary, will provide detailed information on the actions it took in response to the Earthquake, and will share its experiences. The participants will also be expected to join the case study and share their own experiences to find some common denominators on the role of NGIAs in disaster risk management as well as other relatively unique activities that may not be immediately applicable to some countries, but may be considered as important options as their potential roles for the future. GSI will share its activities and experiences for the Kumamoto Earthquake mainly on the types of geospatial information it prepared, the cooperation with relevant authorities and stakeholders, and how the information and data were disseminated in a timely manner. In addition, the GSI's activities will be shared for different phases of disaster, including, preparation phase, onset phase, early response phase, and recovery phase. The results of the special session discussions will be incorporated in the guidelines on the roles of NGIAs in disaster risk management, which are scheduled to be drafted by WG on DRM.

GSI prepared this case story document for the participants of the Special Session as the background information. The participants are expected to read this document in advance to get well prepared for sharing their own experiences and challenges during the session to facilitate the development of the guidelines.

Chapter 1

Background

1.1 Japanese Geography and Natural Disasters

Japan consists of several island arcs that form a part of the circum-Pacific orogenic zone off the eastern edge of the Eurasian Continent. It consists of five relatively large islands – Hokkaido, Honshu, Shikoku, Kyushu and Okinawa from the north, and nearly 7,000 islands around them. Geologically, the country is situated at the eastern end of the Eurasian Plate and the end of the North American Plate. The major parts of archipelago are thought to have been detached from the continent and formed due to the subduction movements of two oceanic plates (i.e. the Pacific Plate and the Philippine Sea Plate) under the two continental plates. Since it is situated at the convergence zone of the continental and oceanic plates, active crustal movements cause approximately 20 % of the world's earthquakes of magnitude 6 or higher in and around Japan. With 110 active volcanoes, constituting nearly 7% of the global total, Japan is also one of the most volcanically active countries in the world.

The Japanese archipelago except Hokkaido is in temperate wet monsoon climate zone, with significant temperature variation in the year and four distinct seasons. The annual average precipitation is approximately 1,700 to 1,800 mm. The weather is hot and humid between June and August due to the southeast monsoon which, in combination with typhoons, causes a large amount of rainfall. In winter between November and March, the northwest monsoon prevails. The continental side of the mountainous backbone of the Japanese archipelago has heavy snow that becomes more than several meters deep in some places, while the Pacific side has a dry climate in winter. Due to the steep and complex landform, temperature and precipitation variations by regions and seasons are significant.

Due to its location on the earth, topographical features, weather and other natural environmental conditions, Japan suffers many natural disasters, such as earthquakes, tsunamis, volcanic eruptions, typhoons, local downpours and heavy snow. Between 2001 and 2010, the annual average number of earthquakes with noticeable tremors

was approximately 1,700³. It means, using a simple average, tremors large enough to be felt by people take place approximately five times every day somewhere in the country. Of the 1,036 earthquakes of 6.0 or greater in magnitude that occurred on the globe in the first ten years of the 2000s (2000 – 2009), 212 (20.5%) occurred in Japan⁴. On average, every year 2.6 typhoons that are born above the Pacific Ocean hit the Japanese archipelago.

Economic loss due to such natural disasters is enormous and many precious human lives have been lost. Since 1945, for example, the death tolls were 2,306 in the Mikawa Earthquake and 3,756 in the Makurazaki typhoon in 1945, 3,769 in the Fukui Earthquake in 1948, 5,098, in the floods caused by the Ise Bay typhoon, or Typhoon Vera in 1959, 6,437 in the Great Hanshin-Awaji Earthquake in 1995 and 18,880 in the Great East Japan Earthquake in 2011, and 84, in the landslides caused by the torrential rain in western Japan in 2014.

1.2 Policy and Legal Frameworks on Disaster Risk Reduction

1.2.1 Legal Framework

What kinds of measures have been taken in Japan against such disasters? The Basic Act on Disaster Control Measures was enacted in 1961 as the most fundamental law for disaster management, after the Ise Bay typhoon tragedy in Nagoya region in 1959. It provides the fundamentals of disaster prevention schemes and plans required for the national and local governments, as well as of disaster management and responses⁵. The Act also clearly states that it is the responsibility not only of government agencies, but also of the entire nation to commit to the implementation of disaster management plans, mutual cooperation and other measures. After experiencing the Great East Japan Earthquake in 2011, the Act was amended to take advantage of geospatial information in 2012. It is also noteworthy that the Act mandates municipalities to prepare hazard maps for floods, landslides and tsunamis in their jurisdiction.

The national and local governments have established organizational structures and disaster prevention plans in accordance with the Act. Specifically, the national

³ Source: Seismic intensity database search on the Japan Meteorological Agency website

⁴ Excerpt from the Cabinet Office White Paper on Disaster Management 2010

⁵ The definition of disasters by the Basic Act on Disaster Control Measures includes not only disasters caused by earthquakes, local downpours and other abnormal natural phenomena, but also accidents such as large-scale fires, explosions and release of radioactive substances.

government has the Central Disaster Management Council (CDMC) led by the Prime Minister with the participation by the Minister for Disaster Management and all other ministers. The Cabinet Office serves as the Council's secretariat where the development and implementation of Japan's Basic Disaster Management Plan are managed. The twenty four Designated Government Organizations (DGO), including GSI, have developed their respective Disaster Management Operation Plans, which are used in conjunction with the Basic Disaster Management Plan to respond appropriately to disasters. All prefectural (forty-seven) and municipal (more than 1,700) governments have their respective Disaster Management Councils and develop and implement their local Disaster Management Plans.

1.2.2 Policy Development and Enforcement at the Time of Disaster

The response at the time of a disaster in accordance with these disaster management plans at national level is as follows. When a large-scale natural disaster⁶ is first reported to the CDMC, the Disaster Management Office will be established in the Prime Minister's Office, and the members of the emergency team, consisting of staff members of the Cabinet Secretariat and relevant ministries, and individual ministries will be contacted immediately to begin the collection of information on the damage and response status. Photos and videos acquired with helicopters and other platforms, and general damage information provided from relevant ministries and public agencies will be compiled by the emergency team at the Office of the Prime Minister.

If large scale damage is reported, Disaster Management Office will be replaced by Disaster Management Headquarters (DMHQ). When DMHQ is established, all cabinet members will be summoned by using all available means. The duties of the DMHQ are: the collection of disaster information from DGOs; the prioritization of the government's policies based on the understanding of the overall situations; and the enforcement of the policies on emergency disaster countermeasures and other matters through the DGOs. When necessary, a government investigation team headed by the Minister for Disaster Management or an initial emergency survey team will be deployed to the stricken areas. DGOs will engage in their respective duties in

⁶ A call for an emergency team is issued when an earthquake with a seismic intensity (on the Japanese scale) of 5 or higher in the 23 special wards of Tokyo and 6 or higher occur in other areas, or when a warning of a tsunami or Tokai Earthquake Advisory Information is announced by the Meteorological Agency.

Seismic intensity (seismic coefficient) (SI) is a scale to indicate the strength of earthquake vibrations. In Japan, SI means the seismic intensity scale of the Japan Meteorological Agency.

accordance with the policies adopted at DMHQ. At the same time, individual ministries and organization establish their disaster management headquarters to take necessary countermeasures in a timely and coordinated manner. These initial and emergency responses will be made within two or three hours from the outset of the disaster.

Meanwhile, disaster management headquarters will also be established by the local governments of the stricken areas to collect detailed information on the damage, and conduct rescue and first aid measures for the victims. If the national government deems it necessary to enhance the coordination between the local governments in the stricken areas, an On-site Disaster Management Headquarters (ODMHQ) will be established, with the deployment of a Minister of the Cabinet Office and his or her staff members.

1.2.3 Role of Local Communities

While emergency measures taken by the national and local governments mentioned above including the rescue of victims, the securing of evacuation routes and means, the prevention of secondary disasters, the establishment of shelters, and the supply of everyday commodities are all crucial to save people's lives and their properties, it is often emphasized in Japan that a balanced approach is important on the combination of Self-help, Mutual-help and Public-help. Self-help means protection of people's own lives through improved preparedness and appropriate responses for disasters by the people themselves. Mutual-help means the protection of local community and people living there through enhanced preparedness and appropriate responses for disasters by helping each other with family members, local communities, companies and others in the vicinity. Public-help means emergency rescue and support, and restoration and recovery measures conducted by public agencies, including the police and fire departments. Public-help is limited at the time of a large-scale disaster. While Self-help is the basis of disaster responses, not all people can protect their own lives by themselves. Thus, Mutual-help is reevaluated and promoted to enhance the capacity of disaster responses in local communities, particularly helping vulnerable people, including small children, senior citizens, and disabled people.

After experiencing the Great East Japan Earthquake in 2011 and following disasters occurring frequently throughout Japan, people have been reminded of the importance

of disaster management. Disaster drills at community, school and company levels, and inventory of emergency goods such as portable flashlights and food stocks have become very common in local communities because of the elevated awareness of people on the importance of Mutual-help to minimize disaster damage. Furthermore, 2,200 “disaster prevention corps” have been organized in Japanese local communities. Along with the official fire fighters belonging to fire departments, a total of 860,000 disaster prevention corps members now engage in fire-fighting and rescue activities at the community level, ensuring Mutual-help aspects for disaster response.

1.3 GSI's Role in the Government

GSI, which is one of the expert organizations in the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), conducts survey administration in accordance with the Act for Establishment of MLIT and the Survey Act. With 650 staff members and 86 million US dollars of budget (for fiscal year 2016), GSI itself conducts survey that provides the basis of all survey works (basic survey), and give guidance and advice on public survey conducted by other national government agencies and local governments. As a DGO, it also acquires image data of stricken areas using airplanes, UAV and satellites, analyzes crustal movement by GNSS surveying, and provides acquired geospatial information to relevant government organizations and the general public, at times of natural disasters.

1.3.1 Core Responsibilities of GSI

The three fundamental missions GSI is engaged are “Surveying,” “Portraying” and “Safeguarding” the national land. In “Surveying,” GSI maintains the horizontal and vertical datum in Japan using VLBI and other space surveying technologies. It runs the GNSS Earth Observation Network System (GEONET)⁷ as an infrastructure for surveying and real-time positioning. In “Portraying,” it has developed the Digital Japan Basic Map as the basis of all maps and provides it in a variety of media. A web-based online map called “the GSI Map” is one of the most popular media GSI uses to disseminate its products. The GSI Map provides aerial photo images, thematic maps and the latest disaster information and archives (e.g., damage situation maps) in addition to the Digital Japan Basic Map. GSI puts high priority in updating the

⁷ GEONET (GNSS Earth Observation Network System) is a continuous observation system consisting of Continuously Operating Reference Station (CORS) at 1,300 locations throughout Japan and the Data Analysis and Management Center at GSI Headquarters in Tsukuba. GEONET is used for the establishment of a high-density and high-precision surveying network and monitoring of crustal movements.

Digital Japan Basic Map, particularly the transportation networks as soon as they are made available to the public, to ensure that the Map is always ready even for those who are deployed on an emergency mission to unfamiliar areas in case of disasters.

1.3.2 GSI's Activities on Disaster Management

GSI developed the GSI Disaster Management Operation Plan in 1996 as a DGO and as one of its missions of "Safeguarding." It stipulates the following operations during normal time, or preparation phase of disaster:

- Development of guidelines and organizational arrangements for disaster management;
- Good management of observation facilities;
- Cooperation and communications with relevant disaster management organizations;
- Strengthening office buildings for disaster resiliency; and
- Improvement of disaster response capacity of employees.

Specifically, GSI provides the following geospatial information and services to improve the disaster preparedness for government organizations and individuals:

- Basic topographical maps as backdrop for creating disaster situation maps;
- Aerial photos which record pre-disaster landscape;
- GEONET data necessary for crustal deformation analysis;
- Thematic maps (e.g. active fault maps, land condition maps, volcanic land condition maps) that serve as basic data for preparing hazard maps and for evaluating disaster risks;
- Provision of virtually all geospatial information on web maps; and
- Management of the National Hazard Map Portal Site in cooperation with the MLIT.

The Disaster Management Operation Plan also specifies the following emergency measures GSI should take once a disaster takes place:

- Establishment of GSI Disaster Management Headquarters;
- Confirmation of the safety of all staff members and their facilities;
- Establishment of a liaison relationship with DMHQ and relevant government offices including MLIT;
- Preparation of geospatial information products including situation maps and their provision to relevant government offices and to the general public; and
- Technical assistance with geospatial information to the Technical Emergency

Control Force (TEC-FORCE) of MLIT that is deployed to stricken areas for the recovery of damaged infrastructure.

More specifically, the following geospatial information and services are provided once a disaster takes place:

- GEONET data for 24 hours a day;
- Spatial distribution of crustal deformation detected by interferometric analysis of data acquired by the L-band Synthetic Aperture Radar (SAR) aboard the Advanced Land Observing Satellite-2 (ALOS-2) launched by JAXA;
- Aerial photos taken before and after the disaster;
- Provision of basic topographical maps;
- Five-meter grid digital elevation models (DEM) developed by airborne laser surveying; and
- Production and distribution of situation maps (e.g., Tsunami inundation maps).

1.3.3 Meeting Surge of Demand for Geospatial Information

GSI has a light airplane for aerial photography, which is deployed to take aerial photographs of the stricken areas when a disaster takes place. Then GSI prepares ortho-rectified photos and situation maps prepared by interpreting the photos, and provides them to relevant organizations and the general public.

However, it is sometimes beyond the capacity of the single airplane to take emergency photographs in case of a disaster that affects large areas. GSI overcomes this difficulty by cooperating with the private sector. Since there are many aerial survey companies in Japan, GSI has established an agreement with the association of these companies on the emergency photography at times of disasters. Such government-private cooperation in photographing enables the prompt acquisition of damage information.

Chapter 2

Outset of the 2016 Kumamoto Earthquake

2.1 Geography of Kumamoto Prefecture

Kumamoto Prefecture is located at the center of Kyushu, which is one of the five main islands constituting the Japanese Archipelago. It is 900 km west-southwest of Japan's capital Tokyo, and 120 km south of Fukuoka City (population: 1.56 million), which is the largest city in the Kyushu Island. The prefecture has a population of more than 1.76 million, of which approximately 740,000 live in its capital city Kumamoto. The main industry is agriculture, and its total agricultural products rank seventh out of 47 prefectures.

A distinctive characteristic of the region's tectonics is the presence of a tectonic zone called the Beppu-Shimabara Graben. Extending 200 km in length and 20 to 30 km in width, it divides the Kyushu Island into southern and northern parts. The GSI's GEONET observation has revealed that the northern and southern parts of the island are moving in opposite directions with each other at this graben. Since this graben is lined with several active faults, consisting mainly of normal faults such as the Futagawa fault, the potential of seismic activities is thought to be high. The Government estimated that the probability of an earthquake whose magnitude is larger than or equal to 6.8 is 18-27% in 30 years. However, the last number of years had seen little seismic activities in this region, which caused the local people and the local governments to become less concerned with the potential risk of earthquakes and to use it as the sales talk to invite investment in the region.

2.2 The First Shock

Since the fiscal and academic years begin in April in Japan, April sees many students who just start their schools, and many people who are newly employed or transferred to new workplaces. Therefore, it is a season when many people are working or studying with a fresh mind, trying to get used to the new environment. Consequently, most schools and workplaces are not usually ready for disaster drills in April.

The people in Kumamoto Prefecture who had little anticipation of earthquakes and

little preparation for disasters were shaken by a strong earthquake that took place at 9:26 pm on 14 April in 2016. Its focal depth was 11 km and magnitude (Mj) was 6.5. The SI 7, which is the highest in the intensity scale, was observed in Mashiki Town, 10 km east of downtown Kumamoto. It was an inland earthquake caused by the activity of the Hinagu fault that runs across the western part of the Prefecture from southwest to northeast. The shock was so strong that people could not stay on their feet, and refrigerators and copy machines fell down in Kumamoto City. This earthquake was reinterpreted later as the “foreshock” of the second earthquake of Mj 7.3 that took place on 16 April in less than two days after the first one.

The Earthquake Early Warning⁸ terribly sounded from TVs, smartphones and mobile phones, and alarmed people all over Japan who were ready for going to bed. The first report of the earthquake in Kumamoto immediately reached the senior officials and disaster response staff at GSI.

2.3 Initial Response of GSI after the First Shock

Immediately after the foreshock, GSI began its disaster responses consisting mainly of the following:

- Emergency teleconference of senior officials;
- Assessment of damage caused by the earthquake;
- Analysis of GEONET data to detect crustal movements;
- Establishment of communication channels with relevant agencies; and
- Establishment of information management team.

2.3.1 Starting Initial Response

The senior officials and responsible staff members of GSI first set up the Disaster Management Headquarters (Headquarters) consisting of relevant employees of GSI to take special emergency actions collectively to respond to the disaster in a timely manner. Since SI of 7, the highest on scale, was observed and serious damage was expected, the establishment of the Headquarters was informed to Headquarters members' cell phones via email immediately after the outset of the earthquake. At the same time, this message was used to confirm the availability of the senior officials by

⁸ The Earthquake Early Warning (EEW) system is a system to issue a warning several to several tens of seconds before the arrival of a large shock after the occurrence of an earthquake. It is a forecast/warning provided mainly by the Meteorological Agency of Japan. Its partial trial operation began in 2004, and the full-fledge operation for most of the country, except for some remote islands, was commenced on 1 October 2007. It is the first system of its kind in the world.

asking them to acknowledge the receipt within 10 minutes, a method known as the “10-minute rule.”⁹

In parallel with the establishment of the Headquarters, the safety of all employees and their family members was confirmed with a safety confirmation system via mobile phones or on the internet. This system is activated in case of an earthquake of a SI of 6- or higher (SI of 5+ or higher in the 23 special wards of central Tokyo). At the time of the Kumamoto Earthquake, the safety of the employees of the Kyushu Regional Survey Department 100 km north of the epicenter was also confirmed with this system.

Then at 9:35 pm, nine minutes after the outset of the earthquake, the impact of the earthquake on the ground including land slide, liquefaction and other land deformation was estimated with SGDAS¹⁰ and shared within GSI, to have common understanding on the magnitude of potential damage caused by the earthquake.

At 10:15 pm (49 minutes after the occurrence of the earthquake), a teleconference was convened with the members of the Headquarters and chaired by the Director General. Director-General of GIS reminded the members of the need to respond to the disaster with a sense of alertness, and requested them to take necessary measures to find out the impact of the damage, including photo shooting with the GSI’s airplane, analysis of crustal movements using GEONET data and interferometric analyses of SAR data, operation of DiMAPS¹¹ and cooperation with relevant ministries and organizations and ODMHQ. Approximately three hours after the earthquake, at 0:30 am on 15 April, the Headquarters convened the second meeting to get the reports on the progress of the activities and make necessary adjustments. Then the third and fourth meetings

⁹ The 10-minute rule requires that, when the person in charge of disaster management sends an e-mail to notify the occurrence of a serious disaster to the official mobile phones and workplace PCs of the GSI’s senior officials and persons in charge of disaster management, those who received the mail must send a blank mail back within 10 minutes to acknowledge the receipt.

¹⁰ The Seismic Ground Disaster Assessment System (SGDAS) estimates the probability of ground liquefaction, slope failure and other types of deformation based on the seismic intensity distribution of an earthquake and by using preset topographical and geological data, and shows the results on maps. At present, information is shared only within the GSI.

¹¹ The Integrated Disaster Information Mapping System (DiMAPS) has been used by the Water and Disaster Management Bureau of the MLIT, and GSI since September 2015. At times of earthquake, wind, flood and other natural disasters, it can quickly collect disaster and damage information and indicate on the GSI’s web map in an easy to understand and integrated manner. The system has been used for collection of information from the sites of disasters, sharing of information with disaster management-related agencies, provision of information to the general public and various other purposes.

were held at 7:30 am and 5:00 pm, respectively, on the same day. RSDs of Kyushu and other regions also participated in these meetings via a web conference system. Since the circumstances of the stricken areas kept changing after the earthquake including the frequent aftershocks, it was important to frequently update the Headquarters members on the progress of the activities within GSI and make necessary adjustments. Therefore, the Headquarters meetings were held twice a day, in the morning and early evening, and whenever else necessary during the first few days after the onset of the earthquake.

2.3.2 Taking Aerial Photographs

When the first shock hit Kumamoto, the GSI's airplane was stationed at Miyako Airport in Okinawa, 1,040 km southwest of Kumamoto City in direct distance, for a planned mission of taking aerial photos of the area. In light of the difficulty of deploying the airplane immediately to Kumamoto area, GSI, in accordance with the agreement on emergency photography at times of disaster, contacted the association of private aerial survey companies at 10:30 pm immediately after the first teleconference of the Headquarters to identify companies that will be able to deploy their airplanes to the stricken areas to take aerial photos. Simultaneously, GSI fixed the extent of photographing and shared that information with aerial survey companies at 1:40 am on the next day.

After the daybreak, two affiliated companies began to take oblique photos around the epicenter in Mashiki Town at 7:00 am. Subsequently, oblique and vertical photos of areas assigned to each company were taken. Acquired aerial photo data were sent to GSI, and the oblique photos were posted on the GSI map, GSI's web based online map, at 2:30 pm of the same day. The poor weather in Okinawa prevented the GSI's airplane from taking off immediately after the daybreak. However, by late morning the weather became moderate and it was able to leave there at 11:30 am, and started taking oblique photos around Kumamoto City starting at 3:40 pm.

In addition, the GSI Land Bird team, which was formed to use UAVs for both normal operations and disaster responses, was deployed from the Headquarters to Kumamoto at 10:00 am on 15 April.

2.3.3 Crustal Movement Analysis

Crustal movements that accompanied the earthquake were also analyzed with

GEONET data. The check-up of each of the GEONET stations was completed in 83 minutes after the earthquake at 10:49 pm, and the Q3 analysis¹² result of the observation data of the stricken areas was released at 7:30 am and 5:00 pm on the next day. A model of the earthquake fault was also analyzed and released on the GSI website at 1:15 pm. This fault model revealed that a crustal movement of approximately 60 cm in the horizontal direction took place along the fault at the time of the first shock.

2.3.4 Cooperation with Relevant Disaster Management Organizations

In parallel with these activities at the Headquarters of GSI, the Kyushu RSD contacted local authorities of the stricken areas to find out their needs of geospatial information, and provided available existing geospatial information. At 10:00 pm, 34 minutes after the first shock, the Department provided GSI's topographical maps of different scales to the Kyushu Regional Development Bureau of MLIT, which manages infrastructure development in the region, including road and river networks in the Kyushu Region. The Government established the ODMHQ at the Kumamoto Prefectural Government office at 10:40 am in the next morning following the earthquake, and coordinated the efforts made by different government organizations for their efficient operations through sharing the latest needs and ongoing activities of relevant organizations to rescue victims and assess the impact.

For better sharing of geospatial information prepared before and after the disaster within MLIT, GSI also began to provide available geospatial information on DiMAPS at 10:45 pm, 79 minutes after the earthquake. Active fault maps of the Kumamoto region and acquired aerial photos were also posted on the GSI map, which was announced through social networks (e.g., Twitter) at 11:48 pm on 14 April.

2.4 The Second Earthquake: the Mainshock

The disaster response to the earthquake that occurred at 9:26 pm on 14 April seemed to have been set on the right path and making progress thanks to the activities on 15

¹² Q3 analysis is a type of GEONET analysis conducted routinely using observation data of CORSs for six hours and the IGS ultra-rapid products. It is also known as the quick solution. Q3 analysis is conducted every three hours in GEONET.

April. However, a second earthquake with bigger magnitude at midnight did not allow the GSI staff members to have a sound sleep that night.

The new earthquake occurred at 1:25 am on 16 April, 28 hours after the first shock. Due to the larger magnitude of Mj 7.3 than the first shock, the new one exceeded the first one both in the intensity and the extent of damage. While the SI of 7 was observed only in Mashiki Town at the first shock, the same intensity was also observed in Nishihara Village, in addition to Mashiki Town at the second shock. This latter earthquake was also an inland earthquake and was caused by the movement of the Futagawa fault and the northern part of Hinagu fault that triggered the first shock. Since the second shock was greater in both magnitude and intensity than the earlier earthquake, it was later interpreted as the mainshock of the 2016 Kumamoto Earthquake. Accordingly the first shock was called foreshock.

2.5 Reconsideration of Disaster Management after the Mainshock

Immediately after the main shock, SGDAS automatically assessed the potential damage to the ground in Kumamoto region and shared the result of its analysis within GSI at 1:34 am, nine minutes after the earthquake. The fifth Headquarters meeting was held over telephone 54 minutes after the earthquake, at 2:19 am on 16 April. The meeting decided to repeat the emergency procedures as those that were done for the foreshock, including survey of the safety of employees, examination of the functioning of facilities, and renewed arrangements for the aerial photographing by private companies. It was found that nine CORSSs in the region had lost the power due to the power outage at that time, though they were able to continue its observation with the battery installed in each station, which has the capacity to support the operation for about 72 hours.

At 6:00 am on 16 April, the sixth Headquarters meeting was convened to share the latest situation after the mainshock within GSI. Due to far greater damage caused by the mainshock, the Director-General of GSI ordered a complete renewal of the response strategy¹³ and work plan, and the development of renewed measures as shown below.

< Renewed measures taken after the Mainshock >

¹³ As the renewed strategy was presented in the early morning, it was nicknamed “Dawn Policy”

- 1) Assignment of personnel
 - Full mobilization of available employees and their timely assignment to additional tasks to support the sustainable response operations, including the deployment of the personnel to RSDs in Tokyo and Kyushu to keep close contact with relevant disaster management organizations in Tokyo and Kumamoto.
- 2) Information sharing
 - Understanding of the latest situations in the stricken areas and the needs of relevant disaster management organizations.
- 3) Aerial photography
 - Taking aerial photographs of Kumamoto, Aso, Kikuchi and Oita areas early in the morning of 16 April by mobilizing airplane of GSI and private companies based on the prior agreement.
- 4) Interpretation of aerial photographs
 - Discontinuation of photo interpretation of those aerial photographs taken after the foreshock.
 - Reassignment of photo interpreters to focus on the new aerial photographs taken after the mainshock
 - Analysis of the amount of collapsed sediment caused by the earthquake.
- 5) CORS data analysis
 - Analysis of crustal deformation with the REGARD system¹⁴, including baseline length analysis, S3 analysis¹⁵, Q3 analysis, and vector diagrams.
- 6) Interferometric SAR data analysis
 - Analyses of a series of SAR data observed from different satellite paths of ALOS-2 to detect the spatial distribution of crustal deformation and to decompose the deformation into the horizontal and vertical directions.
- 7) Shooting videos with drones
 - Land slide areas and ruptures that have appeared on the ground surface were videoed with drones.
- 8) Provision of geospatial information
 - Timely preparation of maps, aerial photos, and thematic maps of the stricken

¹⁴ The REGARD system stands for the Real-Time GEONET Analysis system for Rapid Deformation monitoring. It is a system to detect crustal movements instantaneously using real-time data (one-second interval) of CORSSs.

¹⁵ S3 analysis is a type of GEONET analysis using hourly observation data of a random duration and IGS ultra-rapid products and conducted mainly in emergencies. It is also known as a very quick solution and is conducted mainly with data for three hours from the viewpoint of stability and accuracy of analysis.

areas, and their distribution to relevant disaster management organizations.

Chapter 3

Emergency Disaster Response Activities

3.1 Disaster Responses after the Mainshock

Analysis of GEONET data with the REGARD system conducted immediately after the mainshock revealed that it caused subsidence up to more than one meter deep on the north side of the Futagawa fault and upheaval up to more than 30 cm high on the south side of the fault. Interferometric analysis of SAR data acquired by the ALOS-2 radar satellite also revealed that, in the horizontal direction, there were lateral dislocations of up to more than one meter long toward the east on the north side and up to more than 50 cm long toward the west on the south side.

The area damaged by the foreshock was struck by an even greater earthquake, which caused destruction and collapse of many houses and slopes over extensive areas and death of 40 people. In the Tateno area of Minamiaso Village, the Aso Ohashi Bridge, which is an arched bridge longer than 200 m in length, collapsed due to a large landslide caused by the mainshock and cut off the main traffic route between Kumamoto City and the Aso Caldera area. Being fully alert to this alarming situation in Kumamoto area, GSI began its disaster response activities in accordance with the renewed strategy. It held the 7th to 10th Headquarters meetings twice a day on the weekend holidays of 16 (Sat.) and 17 (Sun.) April to confirm the damage caused by the mainshock, and check and adjust their operations to the changing situations.

3.1.1 Assistance to Other Organizations

Since requests for damage-related geospatial information from relevant authorities were increasing after the mainshock, GSI provided assistance to ODMHQ and relevant organizations with geospatial information by deploying staff members of RSD-Kyushu there. In order to make this assistance sustainable, staff members of surrounding RSDs were also deployed to RSD-Kyushu as well as ODMHQ.

3.1.2 Aerial Photography and Interpretation

The flight plan of aerial photography after the foreshock was revised to cover the larger extent of the areas possibly damaged by the mainshock. In the afternoon of 16

April, aerial photographs taken from GSI's airplane for making vertical photograph were transmitted from the airport in Kyushu to the GSI Head Office in Tsukuba via the internet. Aerial photographs were also taken by affiliated companies. Aerial photography of all scheduled areas was nearly completed by 20 April. Ortho-rectified aerial photos were consequently made public through the GSI Map website.

Concurrently, GSI aerial photo interpretation team began its work at 11:10 pm on 16 April to prepare a map of landslides caused by the earthquake, and ended at 3:25 am on the following day. Approximately 12 hours later, at 3:00 pm on 17 April, the first edition of the landslide distribution map was referred to the Sabo (Erosion and Sediment Control) Department of MLIT, which is in charge of landslide disaster management, in order to keep the integrity of government information for the public. The final version of landslide distribution map was then released on the GSI website late in the night of 18 April after incorporating the comments from MLIT.

3.1.3 UAV Imagery

Despite poor traffic conditions due to many unpassable roads immediately after the earthquake, GSI-LB conducted UAV photography on 16 April at the landslide site of the Aso Ohashi Bridge and in the other areas where faults emerged on the ground surface. The acquired UAV videos were released on the GSI website. They were quoted in many newspapers, including the New York Times in the US. Additional videos of cracks on the ground surface were acquired by UAV on 18 and 20 April to provide evidence of the extent of the earthquake faults that are longer than those that had been known before. The result was also incorporated into the compilation of a crack distribution map around the Futagawa Fault, which was also released on the GSI website in the early evening of 20 April.

3.1.4 Geodetic Infrastructure Management

In order to make detailed analysis on crustal movement using GEONET data, the operation status of CORS in the stricken areas had to be checked. The check-up was completed by 9:30am on 16 April, eight hours after the mainshock. Although all CORS were working, nine stations near the Futagawa Faults were initially running with the internal auxiliary battery, which is supposed to last 72 hours only, due to grid-power outages. While six out of nine stations regained the power very soon, the remaining three were likely to stay powerless beyond their battery capacity. In order to keep them operational, solar panels were installed in these three CORSs on 18 April.

Due to the large crustal deformation in the stricken areas and their surroundings caused by the earthquake, the existing survey results including the coordinates of triangulation points, benchmarks and CORSs had to be suspended in order to avoid errors in the surveys. The suspension was announced to government agencies and survey companies throughout Japan at 6:00 pm on 16 April.

3.1.5 Information Provided through the GSI Map

Most geospatial information acquired and created by data analyses in the disaster response activities, including the epicenter of the mainshock, S3 analysis results of GEONET data and aerial photos of the stricken areas before and after the earthquake were provided through the GSI map. When new information is uploaded on the GSI map, it was announced through GSI website with a special banner as well as social network services such as Twitter.

3.2 Applications of Geospatial Information to Address Secondary Disaster Risks

3.2.1 Concerns of Larger Landslides

While the areas around Kumamoto City were still frequently hit by aftershocks even after the mainshock, they also had to endure heavy rainfall of approximately 20 mm between the evening of 16 April and the morning of 17 April, and subsequently more than 75 mm on 21 April. Because the ground had already been loosened by the severe earthquakes and the subsequent aftershocks, it was seriously concerned that the rain water that was seeping into the ground would cause much larger landslides as secondary disasters. The areas stricken by the Kumamoto Earthquake are known to be prone to landslides since it is covered extensively with a thick layer of pyroclastic flows and volcanic ash, which has been accumulated over the years from the past eruptions of Mt. Aso and other volcanoes, and tends to easily collapse with heavy rainfall.

3.2.2 GSI Responses Addressing to Secondary Disaster Risks

Given that the earlier aerial photograph interpretation identified many landslides caused by the earthquakes, the 14th Headquarters meeting on 21 April decided to engage in the third mission of aerial photography of larger areas to cover the potential land slide areas. Specifically, flight plans were developed for 23 areas by using the GSI's airplane and eleven airplanes of the affiliated companies, and a total of

approximately 10,000 aerial photographs were taken on 19 and 20 April.

Fortunately, no secondary disasters (e.g., large-scale landslides) were identified with the third aerial photography mission. Meanwhile, these aerial photographs were then used by municipalities (local governments) of the stricken areas for the fast track issuance of disaster victim certificates¹⁶ that prove the status of victims' damaged houses.

In the course of aerial photograph interpretation for landslides, GSI discovered some cracks at the top of a slope in Aso City that were unknown to the rescue teams on the ground and could potentially cause landslide. Therefore, in order to avoid the risk of potential landslide of the slope, which could cause much damage to the community below, GSI immediately transmitted emergency warning information to the ODMHQ at 11:50 am on 21 April. As a result, the Aso City municipality advised the residents of the slope area to evacuate at 2:00 pm.

3.3 Preparation of Shelter Distribution Map

Due to the two large earthquakes, 8,198 houses were destroyed completely, 29,761 were half-destroyed and 138,102 were partially destroyed (Cabinet Office, as of September 14, 2016). Evacuees were compelled to live in shelters prepared by local governments or in their cars. Approximately 180,000 residents were in the shelters immediately after the mainshock. However, the national government's ODMHQ did not initially have adequate information on the distribution, locations and capacities of all shelters, or their needs for supplies, and had extreme difficulty in providing necessary relief supplies to the shelters that needed them in a timely manner, all because it did not even know "where" the shelters were.

The Chief of the ODMHQ, Vice-Minister of the Cabinet Office at that time, took this situation seriously, and requested GSI through its liaison official on 18 April to prepare a shelter distribution map. In response to the request, GSI prepared a shelter database and prepared a shelter distribution map and provided the first edition on 20

¹⁶ Disaster victim certificate: If a building is damaged by a natural disaster, the municipal government issues a disaster victim certificate to its resident after conducting a damage certification investigation of the building based on the request from the resident. The types of certification vary by the degree of damage to the building (e.g., totally destroyed, mostly destroyed, half-destroyed, partially destroyed). The certificate serves as official proof when victims receive housing-related support or claim for earthquake or other damage insurance money.

April. This map greatly contributed to the improvement of the ODMHQ's access to shelters and of the efficiency in supporting evacuees. Although some of the shelters have been rearranged or abolished since then with the progress of reconstruction of the stricken areas, GSI continued to contribute to the updating of the map based on the latest information on shelters provided via GSI staff members deployed to ODMHQ, until early August 2016.

3.4 Meeting the Needs of Stakeholders

NGIAs are mandated to create, manage and provide geospatial information of the respective countries. In the course of fulfilling this important mission, it is crucial to pay much attention to the needs of users on the products. The same thing is true in disaster responses, and it is more challenging for NGIAs to meet user needs because the situations of the stricken areas change rapidly over time. In the case of the Kumamoto Earthquake, the requests for geospatial information from the ODMHQ and other government offices actually changed much over time. In this connection, it is important to deploy staff members to key disaster management organizations to find out the latest user needs and respond to them in a timely manner. In addition, in order for NGIA's geospatial information to contribute to disaster response activities to protect people's lives, safety and assets, it is important to always confirm what kind of information is transmitted to who and how, and if it is transmitted accurately and at the best timing.

3.4.1 Provision of Geospatial Information to Public Organizations

Established in the Kumamoto prefectural government building, ODMHQ consisted of personnel gathered from various ministries and agencies, working in the same room. GSI deployed two staff members to ODMHQ to liaise with the other ministries and agencies and find out and respond to their needs. They immediately recognized the need of printers to print out maps for the rescue and recovery operations. Based on their suggestion, GSI sent large-format printers to ODMHQ and provided map printing services there. Also, GSI liaisons listened to the needs of the ODMHQ and made necessary modifications to the GSI data before printing maps.

As a DGO, GSI puts the highest priority in meeting the need of the other government offices. Whenever emergency aerial photographs and other geospatial information were newly acquired through its disaster response operations, push-type e-mails containing the URL of the download site were sent simultaneously to relevant

government offices, including local governments, police, and self-defense force that have been actively engaged in their operations in the stricken areas. A total of 49 e-mail messages were sent out until 15 July. In addition, GSI responded to 40 requests for geospatial information from public organizations. For example, GSI was asked by the police and the Kumamoto prefectural government to calculate the volume of debris caused by landslides by analyzing aerial photographs to estimate the amount of work to remove the debris in the search of persons who went missing in landslides. GSI also provided topographical maps of Kumamoto with coordinate grids through its RSDs to the counterpart Regional Development Bureaus of MLIT that deployed their staff members to the stricken areas in Kumamoto in order to support their recovery operations on the damaged infrastructure.

3.4.2 Provision of Geospatial Information to Mass Media and the Public

Mass media is one of the most effective channels to disseminate information to people in different sectors and communities in a timely manner, particularly in the case of disasters. At the same time, the journalists working in mass media need to understand the significance of the information before releasing it through their media to make sure that the information will be well understood by the recipients. Since some of the geospatial information GSI provides during its disaster response activities is often technical and may not be easily understood by the recipients, GSI sometimes invites journalists at a press conference to explain to them about the technical details in an easy-to-understand manner, in addition to normal press releases.

It is also important to have other channels to reach out to the general public. Because of the recent infiltration of social network services into the society, it is particularly effective to provide timely information to the general public through social network services including Twitter and YouTube. For example, GSI-LB's UAV videos have received significantly increased access of more than 250,000 times, once it was tweeted in the Twitter.

3.4.3 Functional Teams for Provision of Geospatial Information

When a large disaster hits the country, the GSI's guidelines for disaster management stipulates the immediate establishment of specific functional teams, including recording, public relations, information provision support, and emergency map production as to fulfill cross-cutting tasks during the disaster. These designated teams process the requests from relevant stakeholders by providing the geospatial

information prepared by GSI in such a way to meet their needs.

Chapter 4

Activities for Recovery and Reconstruction

4.1 Development of a Disaster Response Plan for the Recovery Phase

In the stricken areas, major transportation services were gradually resumed and recovered with the reopening of all Kyushu Shinkansen (Bullet train) lines on 27 April, less than two weeks after the earthquake, and the restoration of expressways for automobile in Kumamoto Prefecture was also on the right track for the reopening by mid-May. Living conditions of residents in the stricken areas were beginning to return to normal, with the power supply completely regained by 20 April, and 90% of water supply recovered by 21 April. While approximately 38,000 people were still evacuated to shelters at the end of April, the disaster operations were moving towards recovery phase from initial emergency phase.

Emergency disaster responses were nearly completed by the end of April. Since efforts by local governments and other organizations were expected to start in full fledge starting from early May, GSI began to plan the preparation and provision of geospatial information that would be useful in the recovery and reconstruction phase. Specifically, it developed plans on the resurveying of triangulation points and benchmarks, and the preparation and provision of maps for recovery and reconstruction measures and elevation data.

4.2 Geospatial Information Necessary for Recovery and Reconstruction

GSI commenced the following processes in early May to prepare and provide geospatial information necessary for the recovery and reconstruction phase in a timely manner:

- Resurveying of triangulation points and benchmarks;
- Preparation and provision of aerial laser surveys and digital elevation models as measures against the rainy season for the areas that underwent subsidence after the earthquake;
- Preparation and provision of basic maps necessary for reconstruction planning;
and
- Revision of the active fault maps.

4.2.1 Resurvey of Control Points

The first task that needs to be done before major reconstruction activities is the resurvey of control points, including triangulation points and benchmarks that have been moved by the co-seismic activities of the earthquake. However, there are two questions that have to be answered before actually starting the resurveying project: i) what will be the extent of the areas for resurveying or more specifically, which control points will have to be resurveyed?; and ii) when will be the earliest time to start the resurveying, since the ground was still moving, though slowing down, even after the earthquake due to the post-seismic activities around the faults?

When the CORS system was not available in the past, GSI had to spend many months to resurvey all ground control points that may have been influenced by crustal movement. Thanks to the GEONET, however, GSI is now able to accurately monitor the extent and amount of crustal movement in a few hours. This capability enabled GSI to find the control points that needed to be resurveyed and anticipate when the post-seismic activities would wane.

Based on the amount and extent of crustal movement detected by GEONET, 38 CORSs, 4,169 triangulation points and 296 benchmarks in Kumamoto and four surrounding prefectures had been already announced to be suspended for use at 6:00 pm on 16 April. By monitoring the GEONET data, GSI decided to revise the coordinates of 38 suspended CORSs on 16 June, two months from the mainshock, and identified the control points that needed to be resurveyed. While all 4,169 triangulation points were found to be resurveyed, due to the inaccessibility to the monuments, 116 points were not resurveyed and kept suspended. As for the benchmarks, it turned out only 156 points were found to be resurveyed while the rest did not need resurveying due to the negligible impact of the earthquake. Resurveying works on the ground were outsourced to private survey companies, and new survey results of almost all reference points were provided by 12 September. For those control points that had been placed by local governments, GSI provided transformation parameters to calculate the new coordinates from the original coordinates.

4.2.2 Post-earthquake Aerial Laser Survey

There emerged a concern about the danger of further landslides and floods caused by

heavy rain during monsoon season in June and July prevailing Kyushu region. Since ground subsidence caused by the crustal movements of normal fault activities at the earthquake was found in some low elevation areas of the stricken areas, some local governments requested post-earthquake elevation data for measures against potential floods caused by the heavy rain and typhoons. Aerial laser surveying was conducted with a private company and completed on 8 May. A digital elevation model (DEM) was created from the laser data. Then, the newly acquired DEM data was subtracted from the DEM data that was developed by aerial laser surveying in 2005 to prepare height difference data.

The height difference map that shows the height difference between before and after the earthquake was prepared from the height difference data and presented to the mayor of Mashiki Town, who requested the map. On 31 May, the map was also provided and explained to the mayor of Nishihara Village, east of Mashiki town, and other parties concerned. The map was made available on the GSI's web map, for a variety of applications including flood and inundation forecasts.

4.2.3 Basic Maps for Recovery and Reconstruction

Basic maps are one of the most fundamental information we need to have before starting the reconstruction of damaged infrastructures and the communities in the stricken areas. The maps will be used to develop a reconstruction plan, which requires basic “backdrop map” reflecting the post-earthquake geography in the stricken areas. Therefore, the GSI prepared 1:2,500-scale basic and photo maps to be used by the national and local governments as their standard basic maps. These maps were prepared using aerial photographs taken after the earthquake that show the landslides, collapsed buildings and other damage on the ground accurately. The same type of map was also prepared for the tsunami stricken areas after the Great East Japan Earthquake in 2011. The final versions of ortho-photo maps and the basic maps were completed by the end of September 2016 and the end of December 2016, respectively, after simplified preliminary version of both types of maps were provided in June.

4.2.4 Revision of Active Fault Maps

Since new cracks that appeared on the ground after the earthquake suggested that the existing active faults that had been mapped before actually have longer and complex structures, it became necessary to provide the latest active fault information for future urban planning and people's consideration on the places to live in, GSI is currently

updating active fault maps in the stricken areas, where the original version of active fault maps was published in 2001, based on the knowledge and geomorphological evidence of related active faults at that time.

4.3 Other Relevant Activities

The Kumamoto Earthquake severely damaged the Kumamoto Castle, one of the most prominent symbols of Kumamoto area, of which the original premise was built around 1470. In its attempt to repair the Castle, the Kumamoto City government requested GSI to develop a detailed 3D model of the Castle with UAVs to record the conditions of collapsed stone walls and other damaged parts. GSI also employed a terrestrial laser system to develop a detailed 3D model of stone walls to identify and record each stone piece which will have to be removed from the stone walls first before the walls are to be reconstructed. The UAV videos were made available on the GSI website and YouTube on 19 May.

During preparation of such geospatial information necessary for recovery and reconstruction, heavy rain exceeding a total of 500 mm that continued in the Kumamoto region between 20 and 30 June caused many landslides as secondary disasters. The rain also caused power outages at electronic reference points and the situation seemed to be back to the emergency response period from the recovery period. GSI took aerial photographs of the area where landslides occurred in cooperation with an affiliated company in early July, and submitted the results of extracting landslide sites in the form of a landslide distribution map to the Sabo Department of MLIT. The map was also made available for the general public on the GSI website with the final update on 27 July.

Chapter 5

Lessons Learned from the Kumamoto Earthquake Response

5.1 Managing Disaster Responses

The Disaster Management Headquarters meetings at GSI were held every day, up to three times a day, since the first meeting held immediately after the foreshock of the Kumamoto Earthquake on 14 April, to keep all staff members on the same page on the situations on the disaster, and to discuss the policies and actions to be taken by GSI to appropriately respond to the disaster, while flexibly updating them in accordance with the changing circumstances of the stricken areas under the leadership of the top management. Replacement of the Director General of the GSI, who is also the Chief of the Disaster Management Headquarters, on 21 June did not make any gap in the leadership on the policies or activities, because the new Director General had been working closely with the former Director General as his Deputy.

As mentioned above, in the case of large disasters, such as the Kumamoto Earthquake, the GSI's disaster responses have been managed by the Disaster Management Headquarters led by the Director General. At the outset of a disaster, the latest situations are shared, and the initial, emergency and recovery/reconstruction policies are discussed and revised at the headquarters meetings. Disaster response activities are conducted in accordance with the policies, and geospatial information that shows the impact of the disaster on the ground is prepared and provided to the national and local governments and other stakeholders for their use in disaster responses in the stricken areas. While GSI usually starts with preparing geospatial information that it considers necessary from the viewpoint of the provider, it is important to find out the needs of recipients/users of the information, and when it finds it necessary, to tailor the original geospatial information to make it meet their needs by establishing a good communication channel with them to keep up with their changing needs.

In managing the disaster response activities, it is also important to improve the way the disaster responses are conducted by reviewing them through the cyclic steps of Plan, Do, Check and Action in each disaster phase and when each cycle of disaster response is completed, by following the PDCA cycle, which is a leading management

method for quality control in business activities. It is also useful to find out how the GSI's products have been used in different government offices for the future improvements of disaster responses.

Most GSI's disaster responses for the Kumamoto Earthquake, which started with the foreshock on 14 April, were found to be completed at the 42nd Headquarters meeting on 25 July. In order to find out the potential areas of improvement in the disaster response activities and policies while the memory of the staff members are still fresh, a meeting to review the emergency responses was held on 8 July in advance of the 42nd meeting, in which staff members involved in the disaster responses presented issues and areas for improvements in disaster response operations and procedures. These specific points are to be reflected on future improvement in disaster responses.

When a large-scale natural disaster occurs, it becomes a concern not only of the victims but also of the entire nation, and its progress is covered extensively by TV and other mass media. Under such circumstances, there are high expectations for timely provision of appropriate geospatial information to respond to the needs of the stricken areas and relevant authorities. It is the responsibility of NGIAs to provide the latest situations of the land promptly and present it to the society, while continuously improving its operations in their timeliness and accuracies.

5.2 Conclusion

The above mentioned activities are just one example of disaster responses conducted by GSI. Just after the end of major responses to the Kumamoto Earthquake, three typhoons hit the Japanese archipelago in August caused river flooding and landslides that required another disaster responses.

Although it is impossible to prevent all natural disasters, there are still many things that NGIAs can do to minimize the damage at times of disaster, through preparation and provision of geospatial information. GSI will continue to take thoroughgoing measures based on its experience and lessons learned in past disaster responses while learning best practices of the other countries.