The unprecedented heavy rainfall that occurred in western Japan in 2018 caused flooding, inundation, and sediment disasters extending over a wide area, resulting in various types of damage to lifelines, transport systems, diverse structures and so on, and exposing problems that extend across many sectors. One of the major roles of the Japan Society of Civil Engineers is to compile disaster survey data regarding the frequent occurrence of increasingly severe disasters in recent years and then share this information widely with the public. In order to contribute to the development of disaster prevention technologies and academic fields, this special issue is devoted to a collection of reports and preliminary research papers regarding the 2018 heavy rain event in western Japan. Some of the Japanese papers have been translated into English and posted on the Journal of JSCE.

Key Words: 2018 Japan floods, Typhoon Prapiroon, Baiu front, sediment disaster, lifeline, traffic network

1. INTRODUCTION

From June 28 through July 8, 2018, concentrated heavy rainfall occurred over a wide area, principally in western Japan and also in Hokkaido and the Chubu region. Typhoon Prapiroon and the rain front stimulated and intensified by the typhoon produced total rainfall exceeding 1,800 mm in the Shikoku region, 1,200 mm in the Chubu region, 900 mm in the Kyushu region, 600 mm in the Kinki region, and 500 mm in the Chugoku region, setting records for 48-hour and 72-hour rainfall in each region. This resulted in major landslides, river flooding and burst levees, primarily in Hiroshima Prefecture and Okayama Prefecture. Casualties nationwide came to 271 people dead or missing, and there was extensive damage to homes: 6,783 completely destroyed, 11,346 partially destroyed, 6,982 flooded above the floor level and 21,637 flooded below the floor level. In October of the following year (2019), Typhoon Hagibis produced heavy rains across a wide area that included the Kanto-Koshin’etsu region and the Tohoku region. In July 2020 a seasonal rain front that was stationary for a long period produced record-breaking heavy rainfall primarily in the Kyushu region, resulting in enormous damage.
The extensive flood damage occurring over a wide area caused diverse and multifaceted damage to transport systems and lifeline elements that included waterworks and communications systems, thereby exposing civil engineering issues that extend across multiple sectors. In the face of the frequent occurrence of increasingly severe flood damage in recent years, it is important to compile valuable data from disaster surveys conducted from a variety of perspectives in various fields. Making this information public and sharing it widely is an effective means of learning lessons from the disaster and indicating the disaster prevention measures that will be needed, as well as bringing to light technical issues that must be resolved to that end. Needless to say, this is a crucial mission of the Japan Society of Civil Engineers, which embraces various technologies and a variety of research fields.

For these reasons, this special issue is devoted to reports and preliminary research papers on the heavy rain event that occurred in western Japan in 2018, with the aim of contributing to the development of disaster prevention technologies and academic fields. This editorial presents an overview of all of the papers contained in the Japanese edition of the special issue. Some of the Japanese papers have been translated into English and posted on the Journal of JSCE. The damage from the heavy rain event is examined from a weather standpoint and a disaster standpoint, and many research findings are presented. We hope this special issue will be of some help in future studies of disaster prevention and disaster mitigation.

2. PAPERS CONTAINED IN THE SPECIAL ISSUE

(1) Weather, rainfall, and hydrology

In the heavy rain event that occurred in July 2018, the impact of the seasonal rain front and Typhoon Prapiroon caused warm, extremely moist air to flow into the area near Japan over a long period. This resulted in the generation and stagnation of training (linear precipitation bands) in many regions, primarily in western Japan, which produced heavy rains. This special issue contains preliminary research papers on the cause of the heavy rains and the effect of global warming, as well as reports and papers on the three-dimensional structure of the training, the correlation between inundation damage and building location, and special disaster prevention operations for dams. These research findings will be valuable references that will aid in our understanding of the phenomenon and the study of future preventive measures.

Osakada and Nakakita used large-scale ensemble experiment data (d4PDF) on the current and future climate to identify atmospheric fields that were similar to the one that produced the July 2018 heavy rain event, and then assessed the impact of global warming. The paper examines the changes that may occur in the future in the frequency and characteristics of heavy rains caused by seasonal rain fronts that are stagnant for a long period and produce heavy total rainfall. This knowledge will be extremely valuable in the consideration of adaptive measures with respect to global warming.

Yokoe et al. used the Meso-Scale Model (MSM) of the Japan Meteorological Agency to report on the characteristics of the meteorological field at the time that the heavy rain event occurred in July 2018. They also verified the accuracy of the rainfall observations made by the eXtended RAdar Information Network (XRAIN) in Hiroshima Prefecture and analyzed the three-dimensional structure of the training observed by that radar system. They found a clear correlation between the characteristics of the rainfall system and the meteorological field, making this a very valuable preliminary report.

Ito et al. focused on the damage from the July 2018 heavy rain in Mabi-cho, Okayama Prefecture and Ozu, Ehime Prefecture and used independently created time series building point data for three periods in the 1970s and thereafter to identify the relationship between flood damage and the historical changes in land use and building location, based on the relationship between building location and inundation height. The study reveals the fragility within the flood plain at the two disaster sites and contains a great deal of valuable information.

Umeda and Hiyaoka examined the progress of special disaster prevention operations conducted for Hattabara Dam, where the highest inflow was recorded since management began, as well as future issues to be resolved, based on experiments conducted at the site. This study, reporting the special dam operation conducted after confirming that flooding in the next period would not occur based on weather forecasts and so on, as well as judging from the status of reservoirs and downstream rivers, provided important knowledge that needs to be shared with many engineers, making this a very valuable preliminary report.

(2) Debris flows, sediment-flood disasters

The heavy rain event that occurred in July 2018 caused sediment disasters in various regions, primarily in Hiroshima Prefecture and Ehime Prefecture, and extending over a wide area that encompasses 31 prefectures. In Hiroshima Prefecture, which experienced many instances of debris flows, there were 87 casualties, approximately 80% of the total nationwide...
from this heavy rain event. In Hiroshima Prefecture, debris flows caused large quantities of sediment to flow into rivers, resulting in sediment-flood disasters, and studies of ways to prevent similar occurrences in the future have begun. The papers on the 2018 Japan floods collected in this special issue will serve as valuable resources for these future studies.

Nakajima et al.\textsuperscript{9)} conducted a topographical interpretation and site survey of slopes in Kochi Prefecture where zero-order basins were distributed, and described the topographical and geographical features of the zero-order basins where debris flows occurred. Although at present, further study is needed with regard to usefulness and universality, these findings are expected to be developed into knowledge that can be applied to other regions, by increasing the examples of debris flows occurring at zero-order basins and studying the slope of the stream bed, the ratio of the width between contour lines, and the length in the depth direction.

Kobashi et al.\textsuperscript{9)} examined the rainfall data from the XRAIN network that has excellent spatial resolution, showing the features of each slope in mountainous areas where slope failure occurred during the heavy rain event of July 2018, in which rain fell over a wide area for an extended period, producing numerous debris flows. In contrast to past debris flow disasters in Hiroshima Prefecture in which intense short-term rainfall was predominant, this rain event was characterized by intense long-term rainfall. The applicability of the rainfall index $R'$ is discussed from the standpoint of the debris flow occurrence rate using the features of the watershed and the rainfall half-life. This report will prove valuable for the development of a more sophisticated method for assessing the debris flow risk level.

Amano et al.\textsuperscript{10)} discuss and report on the impact of sediment and driftwood outflow on river flooding at the Norogawa Dam and downstream areas in the Norogawa River Basin in Hiroshima Prefecture. Using observational data and numerical models, they shed light on the characteristics of the damage in the river basin, which could be called a classic example of a compound heavy rain disaster comprising a sediment disaster and a river disaster. In addition, they provide knowledge that can be applied to future analysis of the factors that cause flood damage, making this a very valuable report.

Moriwaki et al.\textsuperscript{11)} compare the occurrence of sediment disasters, rainfall characteristics, geological features etc., in the heavy rain disasters that occurred in Hiroshima Prefecture on June 26, 1999; on August 20, 2014; and in July 2018, in order to discuss the characteristics of the July 2018 heavy rain disaster. They also verify the usefulness of their proposed rainfall index. This is a valuable paper that incorporates valuable data concerning the sediment disasters that occurred due to the heavy rain event of July 2018.

Onaka et al.\textsuperscript{12)} conducted a site survey and performed an analysis of debris flows, outflow, flooding, and inundation in order to get a clear picture of the compound disaster caused by the heavy rain event in July 2018, which involved debris flows and river flooding in the Osogoe area of Iwakuni City through which the Higashi River (part of the Shimata River System) in Yamaguchi Prefecture flows. They found that river flooding in the Osogoe area occurred when debris flows caused large quantities of sediment and driftwood to flow into the river; and at the same time the accumulation of driftwood at bridges blocked the flow of water. This type of investigation of the damage status and public release of the results of analysis, and the explanation of the cause of sediment and river flooding, will be extremely valuable in future disaster prevention and mitigation efforts.

Hasegawa et al.\textsuperscript{13)} conducted a site survey and numerical simulation of the sediment disaster that occurred in the Tenno area of Kure City in July 2018. The study is highly regarded in that it constituted an investigation of a phenomenon that is important in both engineering and social terms, and the site survey also yielded very intriguing findings.

Takebayashi and Fujita\textsuperscript{14)} studied the relationship between the Sediment Disaster Caution Zone and the characteristics of inundation at a house lot in Kawanumicho, Aki-gun in Hiroshima Prefecture that was subjected to debris flow, based on the results of a site survey and numerical simulations. The study provided valuable knowledge, such as the fact that there were many areas within the Sediment Disaster Caution Zone where there was no sediment inflow; thus, using the areas where sediment does not flow in as evacuation areas can be expected to increase the probability of survival.

Nakatani et al.\textsuperscript{15)} compiled the disaster status for debris flow disasters that occurred in Kobe and Hiroshima during the heavy rain event of July 2018, based on site surveys and numerical simulations, and studied safe land use in residential areas. Sediment disasters and flooding and inundation increased due to clogging of the covered culvert at the valley outlet, and as a result of road gradients in the residential areas and the large content of fine-grained sediment in areas with granite. Land use proposals based on these findings are expected to be useful in planning future disaster measures.

(3) Flooding and Inundation

In the heavy rains that occurred in July 2018, record-breaking rainfall was observed particularly in the Chugoku and Shikoku regions, and flood discharges that exceeded the capacities of rivers caused
flooded and inundated damage in various locations. The water level in the main river remained high for a long period, and it was noted that levee failures caused by the backwater phenomenon, as well as inundation from tributaries, resulted in even more extensive damage. For this special issue, papers elucidating the facts of the flooding and inundation, based on observational data, site surveys, numerical analysis, and so on, were submitted. These studies are expected to become basic references for devising future flood damage mitigation measures.

Yoshida et al.\textsuperscript{16} performed a statistical analysis of the rainfall characteristics throughout Okayama Prefecture at the time of the heavy rain event in July 2018. They also conducted a site survey and a flood flow analysis to determine the river damage that occurred in the Asahi River system in the prefecture and study the characteristics of flood flow in the downstream portion of the Asahi River. This is a very valuable paper that presents helpful knowledge pertaining to river management issues and the value of river maintenance work, such as pointing out the possibility that improvement work in the branch section of the river may have prevented inundation damage.

Nakano et al.\textsuperscript{17} studied the status of damage in the Renotani River in the Ota River system and the effectiveness of past maintenance projects. River maintenance conducted for the damage from the heavy rain disaster in August 2014, which led to a revision of the maintenance plan, was confirmed to have been effective with respect to the heavy rain event in July 2018, making this an extremely valuable report.

Shimizu et al.\textsuperscript{18} conducted site observations and investigated the behavior of inundation water during flooding in the Funaki area of the Nuta River, which sustained flooding damage due to overflow, overspill, and levee failures on tributaries. Next, based on observed water-level data and the results of an outflow analysis, they investigated the characteristics of the flood flow and the effect of the Fukutomi Dam and Mukunashi Dam upstream. In addition, they used horizontal two-dimensional analysis to consider the impact of vegetation on the flood flow. The result is a very valuable paper.

Akoh and Maeno\textsuperscript{19} focused on the middle reaches of the Takahashi River, which sustained enormous damage due to levee failure and inundation. They investigated the disaster status through a site survey and used numerical analysis to study the flooding and inundation mechanism. This is a very valuable paper that provides important information from a survey of the disaster and performs careful numerical analysis to clarify the actual state of inundation damage to a considerable degree, and even touches on the effect of land locks.

Maeno et al.\textsuperscript{20} used an analysis of references from the Ministry of Land, Infrastructure, Transport and Tourism and Okayama Prefecture, as well as site measurements, interviews, and a comprehensive inundation analysis model to study the status of damage in the Mabi area of Kurashiki City due to the heavy rain event that occurred in 2018. In particular, the paper has been praised for the fact that the authors used a very versatile numerical analysis model to recreate with high accuracy the process of inundation that was confirmed by the site survey, helping to explain the phenomenon. These findings will be extremely valuable for the study of future measures to deal with flooding and inundation.

Tsuda et al.\textsuperscript{21} focused on the Ashida River, which sustained unprecedented major flooding damage in the heavy rain event that occurred in western Japan. They used an unmanned aerial vehicle (UAV) to study and report on the shape of the riverbed before and after the heavy rains and changes in the distribution of vegetation. The report is a useful one that contains valuable data that should be shared widely.

(4) Damage to river structures

The heavy rain event of July 2018 caused numerous instances of damage, including levee failure and breakage, revetment failure and damage, and damage to bridge piers and bridges. These produced and increased inundation damage, as well as severed transportation networks and the like, which exacerbated the damage synergistically. River structures are constructed with a planned high water level with respect to the external force of the floodwater, but when this level is exceeded, the degree of safety is decreased significantly. Considering the maintenance level of small- and medium-size rivers and the increased rainfall intensity that will be caused by climate change, this is an issue that will be very important in the future, and the following papers submitted for this special issue include useful information for its study.

Takeshita et al.\textsuperscript{22} measured the seepage behavior at a river levee over the course of two years and, based on four flood records that included the heavy rain event of July 2018, they considered the fluctuations in water level within the levee and the amount of moisture retained in the soil. This report contains a detailed depiction of the changes in the water level in the river and the internal retention status, and it provides valuable data for considering future disaster prevention and mitigation measures for river levees.

Sako et al.\textsuperscript{23} conducted a careful study of the causes of the levee damage in the Gonokawa River, based on a site survey of sand boiling and water leakage resulting from piping of the foundation ground and levee subsidence and slope collapse, as well as a seepage analysis. In addition, they investigated the applicability of a method using satellite Synthetic...
Aperture Radar (SAR) to determine changes in the surface at ground level resulting from levee deformation. In the case of an analysis with a narrow scope, levee deformation locations and disaster locations are sometimes identical, but at present it is difficult to detect levee deformation from wide-area observations; thus, there are high hopes for further progress in research in this area.

Yamamura and Nihei\textsuperscript{24} focused on the Misasa River in the Ota River system where bridges sustained enormous damage, and studied the longitudinal distribution characteristics of bridge damage based on a survey of the damage status for a total of 94 bridges. They studied indicators for assessing the weak points of bridges based on the hydrological characteristics of the river and structural factors. Their proposed dimensionless cross-sectional area is useful from the river engineering point of view terms and has received high praise.

(5) Evacuation and disaster information, damage to transportation networks and infrastructure, self-help, and mutual assistance

Even if the wild forces of nature cannot be controlled completely by civil engineering structures, the extent of the human casualties and economic damage that result will differ enormously depending on the approach taken by society. This special issue includes discussions that focus on action by society at the time of the heavy rain event of July 2018, particularly transportation and resident evacuation behavior, and the like. The discussions include the confirmation of phenomena and knowledge that had been pointed out in the past, newly confirmed matters, aspects of this disaster that were unique, studies aimed at the establishment of a universal observation methodology, policy recommendations, and so on.

Kawasaki et al.\textsuperscript{25} proposed a method for detecting vehicles taking detours during a disaster using a one-class support vector machine (OCSVM), and applied it to the detection of detours taken by commercial vehicles due to the damage sustained in the heavy rain event in western Japan. They also analyzed the cause of the detours. Up to now, detection of vehicles taking detours was done by visually confirming the trajectory of probe vehicles, which was very labor-intensive. Automating the process using the proposed system described in this paper is expected to be useful in providing a speedy response in the event of a disaster.

Matsumura et al.\textsuperscript{26} determined the actual status of disaster volunteer activities by students at Ehime University in the heavy rain event of July 2018, and used an opinion survey to study the correlation between disaster volunteer activities by the students and their sense of self-efficacy. They concluded that the regular curricular activities of the students at the university (attending lectures, doing exercises etc.), as well as the club and other extracurricular activities increased their intention to pursue volunteer activities. This finding is thought to be an extremely valuable one for university personnel.

Kubo et al.\textsuperscript{27} focused on the Monobe River, which experienced record flooding during the July 2018 heavy rain event. They presented an overview of the flooding and flood forecasting, and so on, and analyzed the causes based on an opinion survey of the effectiveness of the backward displacement of the levee that had been conducted in recent years and the problematic low level of people evacuated. The paper also touched on the importance of integrated infrastructure-related and systems-related measures.

Chikaraishi et al.\textsuperscript{28} used three types of observational data (ETC 2.0 probe data, vehicle sensor data, and cell phone base station data) to perform a detailed analysis of transport fluctuations and their causes at the time of the heavy rain event in western Japan. Basic or existing methods were used for the analysis, but the multifaceted analysis of trip generation, trip attraction, intrazonal trips, and travel time before and after the heavy rains was generally successful in determining the changes in transport status due to the heavy rain disaster. This knowledge is expected to be useful for the emergency response following a disaster, restoration activities, ensuring transport during non-emergency times, and so on. The paper was also highly praised for providing useful knowledge for future policies, such as the location of disaster centers and the establishment of a structure for using data during the disaster.

Kanda et al.\textsuperscript{29} compiled information on the policy for planning and implementing an “Emergency BRT” system to provide an alternate means of transport for the public transport service between Hiroshima and Kure that sustained tremendous damage in the heavy rain event of July 2018. This paper is considered to have great value for future studies of ways to secure public transport service in the event of a disaster.

Yoshida et al.\textsuperscript{30} analyzed the temporal correlation between the announcement of disaster prevention climate data (Japan Meteorological Agency) and evacuation data (municipalities) based on observational data of the actual situation during the heavy rain event of July 2018. The study contains valuable hints for the effective use of disaster-related information in the future.

Kamiya et al.\textsuperscript{31} compiled information on the planning and implementation of an Emergency BRT system to provide an alternative means of transport for the public transport service between Hiroshima and Kure, which sustained tremendous damage in the heavy rain event of July 2018. The paper has been
praised for providing valuable records and knowledge that can be applied to other disasters and regions in the study of management policies that can help to maintain and secure public transport services in the event of a disaster.

Nakano et al. analyzed the relationship over time of newspaper reports, the number of evacuees, and the number of volunteers at the time of the heavy rain event in western Japan. The paper presents intriguing knowledge with regard to a variety of issues, and it is timely in the sense that heavy rain disasters have been occurring frequently and human casualties have been increasing. It is extremely important to build an informational infrastructure that can respond to disasters that change suddenly and affect a wide area.

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