3.4.2. Alert system

From August 30, 2013, JMA begun operating an emergency warning system that calls for the highest level of caution (JMA, 2013). JMA announces emergency warnings when heavy rains and tsunamis that far exceed the warning announcement standards are predicted and when the risk of serious disasters is significant. Some examples of past phenomena targeted by this special warning system are the great tsunami triggered by the Great East Japan earthquake, which resulted in more than 18,000 casualties. Another incident is the Isewan typhoon, which resulted in more than 5,000 casualties and recorded the highest tide level in Japan's observation history. During the heavy rains of July 2018, eleven prefectures (Gifu, Kyoto, Hyogo, Okayama, Tottori, Hiroshima, Ehime, Kochi, Fukuoka, Saga, and Nagasaki) announced an emergency warning at 17:00 on July 6, calling for the maximum caution. The number of municipalities subject to emergency warnings peaked at 157-the highest since the system started in 2013.

3.4.3. Disaster damage

Cabinet Office Japan (2019) reported the following:

> The heavy rain event of July 2018 caused river flooding, inundation, sediment, and other disasters, which rendered 237 people dead, 8 persons missing, and 466 people injured. Damage to houses included complete destruction, partial destruction, and flooding of 6,767, 15,447, and 28,510 houses (information from the Fire and Disaster Management Agency, as of January 9, 2019. Reference: https://www.fdma.go.jp/disaster/info/items/h30-7_59.pdf).
>
> Debris flows occurred concurrently at several locations. A massive flooding disaster occurred because of the breach of levees that occurred because of a "backwater phenomenon," wherein the water level remains high over a long period at the point where the tributary meets the main stream. River flooding occurred owing to heavy rainfall exceeding the capacity of the river control facilities. Nationally, heavy rainfall caused damage to 346 points. Inland inundation occurred at 88 municipalities in 19 prefectures. Furthermore, 2,581 sediment disasters—791 debris flows, 56 landslides, and 1,734 cliff failures—occurred in 32 prefectures (information from the Ministry of Land, Infrastructure, Transport, and Tourism, as of January 9, 2019. Reference: http://www.bousai.go.jp/updates/h30typhoon7/index.html).
>
> Damage to utilities included power outages, affecting a maximum of approximately 80,000 households. The power supply for residential areas was restored on July 13, 2018. Gas supply was also disrupted, affecting approximately 290 households; this was restored on July 8, 2018 (information from the Ministry of Economy, Trade, and Industry as of January 9, 2019. Reference: http://www.bousai.go.jp/updates/h30typhoon7/index.html). Water outages occurred at 80 municipalities in 18 prefectures, affecting a maximum of approximately 260,000 households; it was subsequently restored in all areas by August 13, 2018 (information from the Ministry of Health, Labor, and Welfare, as of January 9, 2019. Reference: http://www.bousai.go.jp/updates/h30typhoon7/index.html).
>
> A total of 3,779 shelters were built in all the prefectures. The maximum number of evacuees was approximately 28,000. All the general shelters were closed by December of the same year (some welfare shelters remained open until March 2019).

The agriculture sector suffered the following damages: 30 billion JP¥ for crop production, 56.5 billion JP¥ for damage to farmland at 26,000 locations, and 85.4 billion JP¥ for damage to agricultural facilities including 32 collapsed irrigation ponds. The total damage amounted to 340.9 billion JP¥ (MAFF, 2019).

3.4.4. Disaster response

Cabinet Office Japan (2019) reported the following:

> From July 2, 2018, the government held a series of inter-agency disaster alert meetings to prepare for emergencies. The government established the Major Disaster Management Headquarters, headed by the Minister of State for Disaster Management at 8:00 a.m. on July 8. The headquarters held 23 meetings until September 6. The prime minister attended most of the meetings and led activities to grasp the extent of the damage, the overall coordination of response measures, and the prevention of secondary disasters.
>
> The government immediately began rescue operations in early July. Organizations, such as the local police, Fire and Disaster Management Agency, Self-Defense Force, and Ministry of Land, Infrastructure, Transport and Tourism, dispatched rescue units from across Japan to the affected areas to conduct rescue and search operations as well as secondary damage prevention activities and life support activities.

The government established the Heavy Rain Event of July 2018 Initial Response Review Team to analyze and review the initial response measures taken by government officials and utilize the lessons learned from this disaster for future disaster response initiatives. In the aftermath of the disaster, many government officials carried out various support activities at the affected local governments. The review team held discussions based on reports on measures taken by individual ministries and agencies as well as reports submitted by 79 government officials, including senior officials from the cabinet office, who were in charge of on-site coordination (Deputy Director-Generals and Directors) and other senior officials from ministries and agencies (Director-General/Director-level officials) dispatched to the affected areas. The Review Team outlined items that should be appreciated and those that require some improvement with respect to the following five areas, where the most initial response efforts were focused: (1) ascertainment of the shelter situation, (2) debris disposal and sediment removal, (3) water supply support and restoration of water service, (4) securing of housing, and (5) support for local governments.

Since personal and social damage was tremendously huge, several local governments, such as Hiroshima, Okayama, Ehime, and Gifu Prefectures, have verified and reported on the disaster emergency response. In addition, Okayama Prefecture and Hiroshima City published disaster records to make citizens and local residents aware of the scale of the disaster. Many universities and research institutes, such as Ehime University, Okayama University, and the Disaster Prevention Research Institute of Kyoto University, have also published disaster investigation reports.

4. Past-Future Countermeasure

4.1. Basin flood countermeasures

In order to prepare for the increase in flood risk due to climate change, it is necessary to build a system with the collaboration of all concerned parties (central government office, local government, municipalities, companies, residents, etc.). This system is called "basin flood countermeasures," which aims to ensure that all parties voluntarily and initiatively tackle the flood with embankments, protection facilities, appropriate operation of drainage gates and pumps, land-use plans, evacuation plans etc.
For example, the following two flood countermeasures are being considered in rural areas. The first one is dam reservoir operation for flood control. Most dam reservoirs for irrigation equip the spillway at the top, and water flows over the spillway during floods to avoid holding excess water. Thus, most dam reservoirs contribute little to flood control. However, we now consider that the reservoirs can drain stored water in advance of flood and hence maintain their high storage capacity (Fig. 12, MLIT, 2020).

Fig. 12. Flood control operation of an irrigation dam reservoir (left: water drained to increase vacant storage in advance of a typhoon, right: typhoon runoff water was held in the dam, MLIT, 2020)

The other flood countermeasure involves improving the drainage facilities, such as repairing and replacing aging facilities (especially those close to city areas) such as pumps, gates, and waterways. This is because the transformation of paddy fields into residential areas reduces the rain storing capacity, increases flood risk and human and economic damage during inundation.

4.2. Efforts to reduce the number of victims further

As mentioned earlier, the death toll from flooding has decreased significantly in Japan due to the construction of river and coastal defenses. Such structures are usually designed to withstand a maximum of once-in-100-years rainfall; hence, the defenses function sufficiently for rainfall less than this scale, indicating that damage is unlikely. However, due to the effects of climate change, rainfall events exceeding the scale of once in 100 years are becoming more likely. Therefore, minimizing the number of victims in the event of rainfall exceeding assumed levels is an important issue in Japan. In addition to improving existing flood defenses and weather forecasting, individuals evacuating on their own initiative in the event of a disaster is a suggested solution.

It has been observed that a certain number of residents do not evacuate in the event of a disaster. According to psychological analysis, this is believed to be due to normalcy bias and conformity bias. Normalcy bias is a psychological bias referring to the mental state where "when humans confront an unexpected abnormality, they believe that a certain degree of abnormality is within the normal range," which is essential for humans to survive. However, in the event of a disaster, excessive normalcy bias makes people unable to recognize the danger accurately. Conformity bias is a psychological bias referring to the mental state where humans "do not want to stand out by acting differently from other people," which causes them to prioritize behaving the same as others around them over their own free will.

In a survey of people affected by the heavy rain of July 2018, the most common reason given by people who did not evacuate was "I did not think I would be harmed." Several people also responded: "because the area in which I live has never been damaged in the past" and "because my neighbors did not evacuate." All these responses involve normalcy bias and conformity bias (Taniyama, 2019). Therefore, to reduce the number of victims, each individual should understand that "disasters that exceed expectations will occur, and if that happens, I will need to make the decision myself to evacuate to save my own life" and evacuate as appropriate.

4.3. Introduction of research results: System to predict water levels in real time during flooding, to support decisions about the operation of drainage pumps

Two programs were developed to predict the water levels of drainage pumping stations and drainage channels in low-lying areas in real time, based on weather information, etc (KIMURA et al. 2019 and AZECHI et al. 2021). Both these programs can predict water levels several hours ahead in real time, based on the most up-to-date measurements and weather forecast data.

The program to predict the water levels of drainage pumping stations is a long short-term memory (LSTM) program, which is an improved version of a recurrent neural network (RNN) that identifies the characteristics of a temporal sequence of data. By learning sufficient past rainfall and water level information, this program can perform prediction calculations with a high accuracy at high speed (Fig. 13). This program can be applied to any location where there are sufficient past observation data; hence, it can predict water levels at water level observation points, not just at drainage pumping stations.

The program to predict the water levels of drainage channels is a one-dimensional unsteady flow analysis. It can make stable prediction calculations by applying an implicit method to the rainfall runoff and a non-equidistant third-order finite difference method (quickest method) to reproduce the water level (Fig. 14). It can calculate the water level of a network of drainage channels and examine the process of water overflowing around these channels. Prediction results for an entire area can be output at arbitrary time intervals. To perform these calculations, local information such as the cross-section of channels must be established and entered in advance.

These two programs form the main elements of the local wastewater management and disaster mitigation information system that we have developed (Fig. 15). This system can present users with prediction results from the two programs to support the efficient operation of drainage pumps, or to help users make decisions about the appropriate operation of facilities, such as sluice gates.

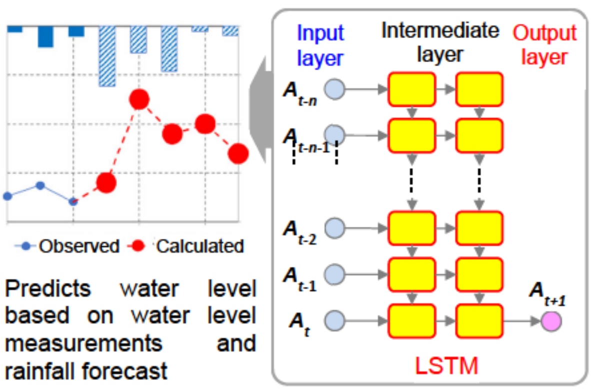

Fig. 13. Image of water level prediction at pumping station (LSTM program)

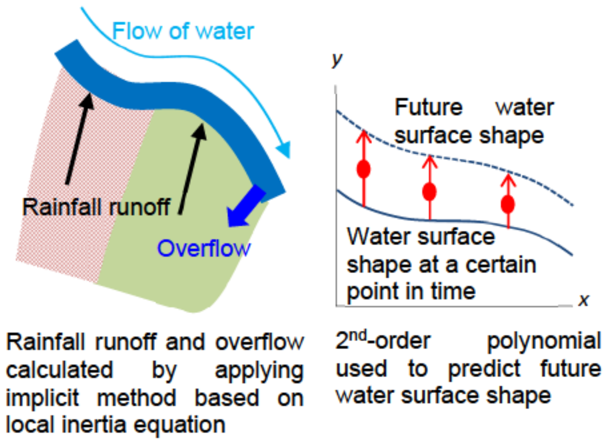

Fig. 14. Image of rainfall runoff and overflow calculation (Hydraulic program)

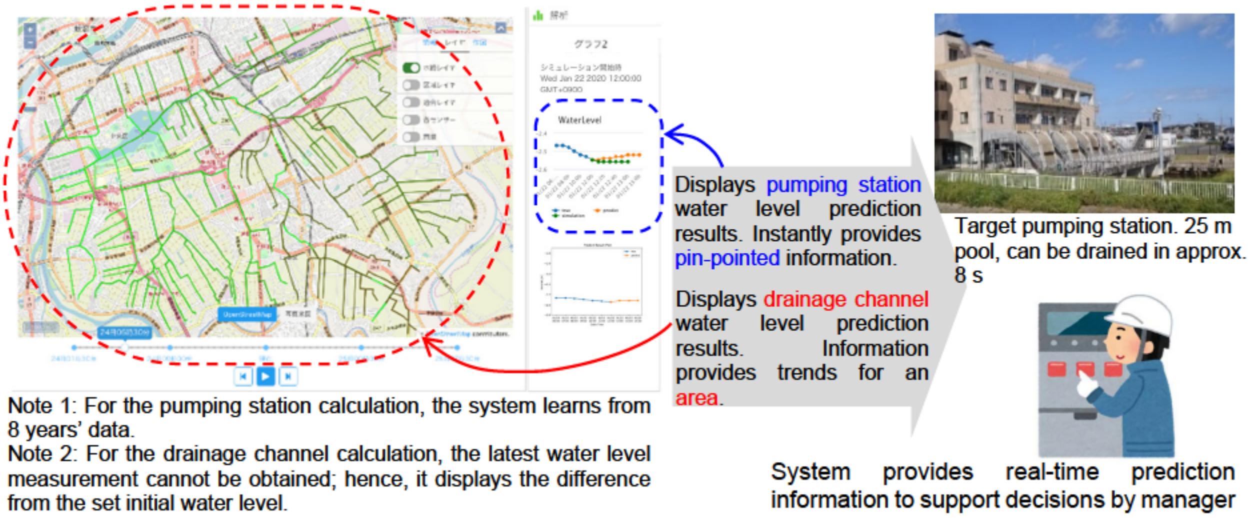

Fig. 15. Display results and usage of the two programs in the local wastewater management and disaster mitigation information system

5. Conclusion

In Japan, damage from flooding is on the decline, owing to the construction of flood defenses. However, due to the effects of climate change, rainfall exceeding expected levels is becoming more likely; hence, there is an increasing risk of severe rainfall events. This indicates that there is a possibility that existing flood defenses may not function. Thus, it is necessary for all organizations, people, and institutions related to the river basin to work together to minimize damage from flooding in the event of a disaster. In particular, to reduce human casualties, it is important for individuals to make their own decisions to evacuate; hence, it is necessary to take action to raise awareness in this regard.

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