Research Initiatives for Disaster Prevention in River Basins and Coastal Areas in Preparation for Climate Change

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1. Introduction

In August 2021, the Summary for Policymakers of the Report of Working Group I on the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) was released. This Summary for Policymakers indicates that the magnitude of external forces causing water-related disasters in basins and coastal areas will increase in the future, including that (i) the certainty is high that "On a global scale, extreme precipitation in terms of daily precipitation will increase by about 7% per 1°C of global warming", and (ii) it is almost certain that "Global average sea level will continue to rise during the 21st century".

In Japan, we have suffered disasters described as "never experienced before" every year due to fronts, typhoons, etc. and it is expected that we will suffer disasters of even higher intensity and frequency in the future.

As disasters are expected to intensify in the future, the Council for Infrastructures has reported a shift to "River Basin Disaster Resilience and Sustainability by All (basin flood control)" in terms of water-related disaster countermeasures in light of climate change. Basin flood control is a multilayered approach that considers not only the catchment area and river area but also the flooded area as one basin area, and all parties involved in the basin work together on measures to (i) prevent or reduce floods as much as possible, (ii) reduce the damage target, and (iii) mitigate damage, and accelerate recovery / reconstruction.

The River Department is responsible for research on rivers and coasts, and each division publishes one article in this report. The **Figure** shows the relationship between the articles and basin flood control, and the following describes the aims, overview, and direction of the research.

2. Quantitative assessment of climate change impacts

If we do not accelerate the improvement of infrastructure such as river management facilities and coastal conservation facilities that achieve the target level of safety as soon as possible, the level of safety will relatively decrease due to the increase in external forces caused by climate change. Quantitative evaluation is needed to reflect climate change impacts in the planning of improvement.

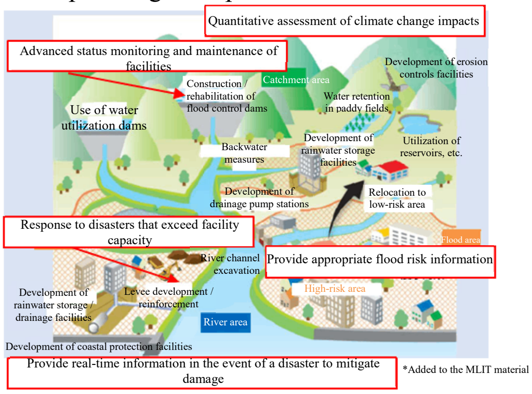

Figure: Relationship between articles and basin flood control

Therefore, the Water Cycle Division is studying future changes in rainfall to revise flood control plans that take climate change into account[1]. For example, future rainfall change ratios are calculated for each temperature / sea surface temperature scenario according to each regional category with similar rainfall characteristics in Japan. Although results vary according to regional classification, the average rainfall change ratio for a 2°C rise in average temperature was 1.15 times in Hokkaido and 1.1 times in other regions. Other results show that average rainfall change ratios for a 4°C rise are 1.4 times in Hokkaido and northwestern Kyushu, and 1.2 times in other regions. The average rainfall change ratio for a 2°C rise is now being used in the review of river improvement basic policies. Please note that the above is based on average external forces for flood control planning. For basin flood control, it is necessary to continue to study future changes in precipitation and the spatiotemporal distribution of rainfall that exceed the average external forces.

3. Response to disasters that exceed the capacity of facilities

In the 2019 East Japan Typhoon, river levees broke in 142 locations across the country, more than 80% of which were broken due to "overtopping" factors. In addition, Typhoon No. 21 in 2018 and other typhoons caused storm surges and high waves that recorded the highest tidal levels, etc. ever before. Such phenomena are likely to occur more frequently in the future, and levees need to have a "resilient structure" that demonstrates disaster mitigation effects, such as a levee that is less prone to breaking, and allows as much time as possible before breaking, even when water or waves overtopped the crown.

For this reason, the River Division has been studying river levee structures that are resilient and resistant to breaking even in the event of overflow due to flood [2]. River levees are generally made of earth, and breaks occur due to a back erosion process where the back slope of the levee (the slope or bottom of the levee on the opposite side of the river) is eroded, followed by a crown failure process where the crown collapses after the entire levee back slope is eroded. By confirming these mechanisms through full-scale hydraulic model experiments, we will propose structures, such as covering the levee with anti-absorption sheets, blocks, and vegetation, as countermeasure works.

4. Advanced status monitoring and maintenance of facilities

As global warming increases the risk of flooding, it is necessary to properly manage river management facilities and coastal conservation facilities at all times so that they can perform as planned in the event of a disaster. This represents the viewpoints of status monitoring and maintenance for facilities.

In the field of dam management, dams are monitored for abnormalities in status through patrols and measurements, but depending on the data acquired, it may be difficult to determine whether or not action should be taken. For this reason, the Large-scale Hydraulic Structure Division has begun to develop dam management support technologies to improve the quality of dam maintenance through the use of AI [3]. Specifically, we are doing research to (i) forecast changes in measurement data, such as the amount of deformation in the dam body that is periodically acquired on-site, using deep learning with a Recurrent Neural Network that detects abnormalities based on deviations from actual measurements, and (ii) detect possible structural damage to the dam body by unsupervised machine learning of features calculated from earthquake motion data observed in the dam body during an earthquake. Technologies related to DX, including AI, are expected to improve in the future, and we are conducting research in the field of maintenance as well.

5. Provision of appropriate flood risk information

Enhancing flood risk information, such as hazard maps, is important from the viewpoints of both information in the event of flood evacuation and prerequisites for community development. While progress has been made in providing flood risk information such as inundation maps for large rivers, provision of such information for small and medium-sized rivers has lagged behind. In fact, during the East Japan Typhoon in 2019, human casualties occurred in areas where flood risk information was lacking. It is also important to provide flood hazard information in a multi-phased manner, including not only large-scale rainfall, but also assumption of floods with the scale of medium and high frequency external forces, and assumption of floods in the phase of advancement in river development, such as after completion of river development.

Therefore, the Flood Disaster Prevention Division is working with the Prefectural and Regional Development Bureaus to solve technical problems and provide technical support in order to eliminate the risk information blank areas for small and medium-sized rivers, which is an urgent issue [4]. We will also study specific methods for examining damage mitigation measures for each area in the event of flood inundation [5].

6. Provision of real-time information upon occurrence of a disaster to minimize damage

When a flood, storm surge, or high waves are forecast to occur, it is important to improve the information on river levels, tide levels and waves, which are prerequisites for starting flood prevention and evacuation activities, as well as to organize such information. Accordingly, the Coastal Division is developing a "Storm Surge / High Waves Mitigation Support System" that forecasts in real-time the risk of flooding due to storm surge / high waves with the aim of supporting flood prevention activities during such events [6]. This system forecasts the height of wave runup at 500 points nationwide and evaluates the inundation risk of coastal areas throughout the country in three levels, which are then colored and displayed on the map. This system's accuracy has been confirmed to a certain degree and results of forecasts are being provided to municipalities upon request on a trial basis. Based on what we learned from this trial, we are improving the forecast information to make it easier to understand and to trigger residents to take evacuation action.

☞See the following for details.

1) Research on future changes in rainfall for flood control planning considering climate change, p. 52, this report

2) Development of resilient levees that are more effective than crisis management-type structural countermeasures, P. 50, this report

3) Utilization of AI in safety management of dams - Development of dam management support technology to enhance the quality of maintenance, p. 145, this report

4) Eliminating flood hazard information blank areas - Trial flood hazard mapping in small rivers, p. 54, this report

5) For avoiding the worst-case flood scenario - Study on damage reduction measures in case floods overwhelm flood control structures, p. 56, this report

6) Development of a system to forecast flood damage from storm surge and high waves in advance - Aiming

to provide easy-to-understand information that leads to
evacuation actions, P.137, this report