Development and application of Virtual Flood Experience System (VFES)

a) Background of the development of VFES

With climate change driving an increase in water-related disasters, delays in evacuation during floods have become a serious concern. Because major floods are relatively rare events, the general public often cannot easily imagine the conditions or dangers they would face during such disasters. This lack of intuitive understanding is considered one of the factors contributing to delayed evacuation.

Communicating the risks of water-related disasters before they occur is therefore essential for effective disaster-risk communication. Local governments and river management organizations have been actively promoting such communication by providing hazard maps and encouraging the creation of "My Timeline," a personalized timeline outlining the actions to be taken during an emergency. To convey these efforts in a clearer and more accessible way, initiatives that visualize flood hazards in relation to residents' everyday living environments can play an important role.

Recent advances in ICT research and technology have made it increasingly feasible to visualize flood risks. One example is virtual reality (VR), which can be used to let people virtually experience the potential dangers posed by floods, relatively rare events that are therefore difficult for the general public to imagine. However, VR imagery created in past studies and projects often lacks a solid scientific basis, resulting in imagery that is more conceptual than evidence-based.

To address this issue, ICHARM introduced the RRI model and other scientific approaches to reproduce and forecast flood hazards more realistically. These technologies give ICHARM strong potential to overcome the limitations of conventional VR-based flood simulations.

Previous studies and projects have not fully taken advantage of the potential of VR. In addition to its visualization and simulation capabilities, VR also incorporates metaverse-like functions. For example, through avatars (i.e., virtual representations of users), it can enable people to experience others' physical abilities or interact within simulated social environments.

Leveraging these technologies, ICHARM developed and implemented VFES by integrating scientifically grounded flood-hazard reproduction and forecasting methods with the virtual-experience and metaverse capabilities of VR. The following sections present research projects using VFES over the past several years.

b) Development of prototype VFES: Research in Aga Town, Niigata Prefecture, Japan, and Flood-Risk Communication

Typhoon Hagibis (Typhoon No. 19) in 2019 caused severe damage across eastern Japan, particularly in the Kanto region. Significant damage also occurred in Aga Town, Higashikanbara District, Niigata Prefecture, which had been one of ICHARM's research sites. Focusing on the Sanegawajima area of Aga Town, which has repeatedly suffered flood damage throughout its history, ICHARM developed and applied a prototype of VFES and confirmed that the system successfully reproduced flood conditions and contributed to effective flood-risk communication.

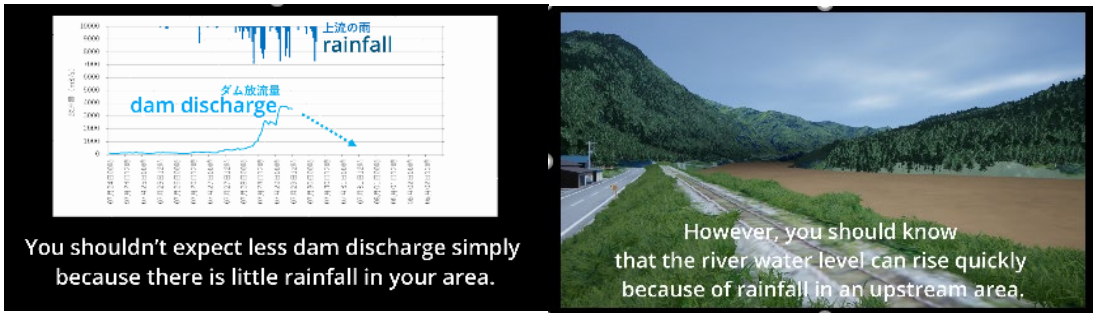


Figure 1　A VR lesson created in Aga Town (Left: Relying on lessons is dangerous, Right: Don't go back to retrieve forgotten items)

c) Demonstration of VFES's educational potential at the 9th International Conference on Flood Management (ICFM9)

From February 19 to 22, 2023, ICHARM hosted ICFM9 at the Tsukuba International Congress Center. As part of the conference, the public symposium "Can You Survive an Unexpected Flood?: esports@KasenBousai" was held, inviting junior-high, high-school, university, and graduate students from Tsukuba City. They first virtually experienced evacuation during a flood using VFES and then participated in an evacuation competition also using VFES. The students showed strong engagement and enthusiasm throughout the competition. This event clearly demonstrated that VFES can serve as an effective tool for flood-risk education.

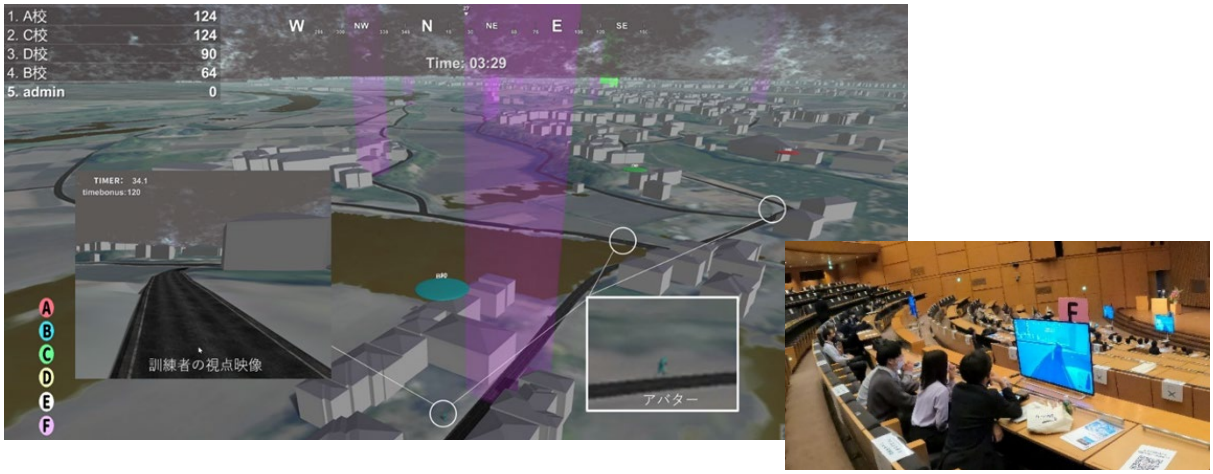


Figure 2　Screenshots and images of the venue from the evacuation competition.

d) Development of educational VFES for wider dissemination

After the public symposium at ICFM9, Namiki Secondary School in Tsukuba City, whose students had participated in the event, requested to continue flood-risk education using VFES. In response, ICHARM proposed a joint development effort to improve VFES, and the school agreed.

Because the prototype VFES requires highly complex programming for its software and high-performance devices that are costly, ICHARM ported VFES functions into Minecraft Education, educational game software. Within this environment, ICHARM led students to recreate urban spaces in flood-prone areas around Tsukuba City and improve the accuracy of spatial information. Through activities such as refining spatial data themselves,

students demonstrated that VFES can effectively support sustained, self-directed learning about flood risks among younger generations.

e) Participation in SIP

By FY2024, ICHARM had completed the development of two versions of VFES: one using a game engine and the other using educational software. Starting in FY2024, ICHARM joined the Cabinet Office's SIP program and was assigned to a sub-project, "Development of a Resilient Smart Network System against Natural Disasters." SIP requires participating groups to engage not only in research and development but also in the social implementation of the outcomes. ICHARM therefore advanced the social implementation of VFES.

The game-engine version has been applied in many municipalities – Sapporo, Asahikawa, Obihiro, and Memuro in Hokkaido; Jōsō City in Ibaraki Prefecture; Nagano City and Matsumoto City in Nagano Prefecture; Kurashiki City in Okayama Prefecture; and Kurume City in Fukuoka Prefecture – achieving substantial progress in both technological development and dissemination.



Figure 3 Recreation of the Kurashiki Bikan Historical district using VFES
(Left: Actual scene, Center: Recreation using VFES, Right: Scene of flooding)

The educational-software version has been further developed with new learning content, and it has been applied to inquiry-based learning on water-related disasters in municipalities, such as Jōsō City in Ibaraki Prefecture and Nagano City and Matsumoto City in Nagano Prefecture. Recognizing the novelty of the educational version, the Cabinet Office invited ICHARM to participate in a side event at the 2025 Osaka Expo. In response, ICHARM developed an Osaka version of the VFES educational software, which was also highly praised.



Figure 4 A recreation of Osaka city by VFES (Left: Flooding in progress, Center: Recreation of Osaka Castle, Right: Scene from an experience event at the Expo side event)

f) Future prospects for flood risk communication using VFES

Having reached a certain level of technical maturity, VFES now shows the potential to analyze the decision-making processes that lead to "delayed evacuation," one of the most critical challenges in flood

management. In psychological research, analytical methods are generally classified into experimental and observational types, and VFES has the flexibility to support both approaches.

Experimentally, the system can reproduce signs of an impending flood and conditions during a flood in a virtual environment, and record the evacuation behavior of participants. Subsequently, observational approaches, such as questionnaire surveys, can be conducted to analyze evacuation behavior and the decision-making processes behind those behavioral choices.

These two approaches enabled by VFES are applicable not only to understanding people's evacuation behavior but also to analyzing how companies make investment decisions for flood risk reduction. When analyzing individual behavioral choices or corporate investment decisions for flood management measures, it is necessary to develop highly customized versions of VFES that reflect the characteristics of the local community or the specific company.

However, creating such highly tailored versions entirely within research projects would require substantial funding. If local residents themselves could create customized systems for their own communities, flood risk communication using VFES would advance significantly. To achieve this, it is essential to establish a dissemination framework that enables VFES construction by local residents with a certain level of technical skill. Moving forward, promoting social implementation in collaboration with local communities will be crucial.