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A Smart River for a Better Community

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Water resources are fundamental to our well-being and the sustainable growth of our communities (Olatunde et al. 2024; Scanlon et al. 2023). They affect many things, including how we live together as a society, generate income, and protect our environment (WWAP 2015). Hence, understanding the basic elements of our water resources (i.e., what they are made of, how clean they are, and how they impact us) is important. (fig. 1).

To aid in this effort for improved understanding of our water resources, scientists and community leaders have partnered to develop "smart rivers" (Cortes Arevalo 2018; Verbrugge 2020; WildFish 2024). Innovative technology fosters advanced design principles for industry, enhances the environment, and supports community economies (PIANC USA 2024).

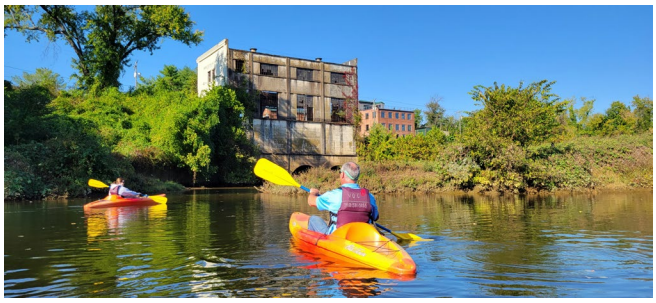


Figure 1. Kayakers on the Rappahannock River view the Embrey Power Station in Fredericksburg, Virginia. (Photo courtesy of RIVERE.)

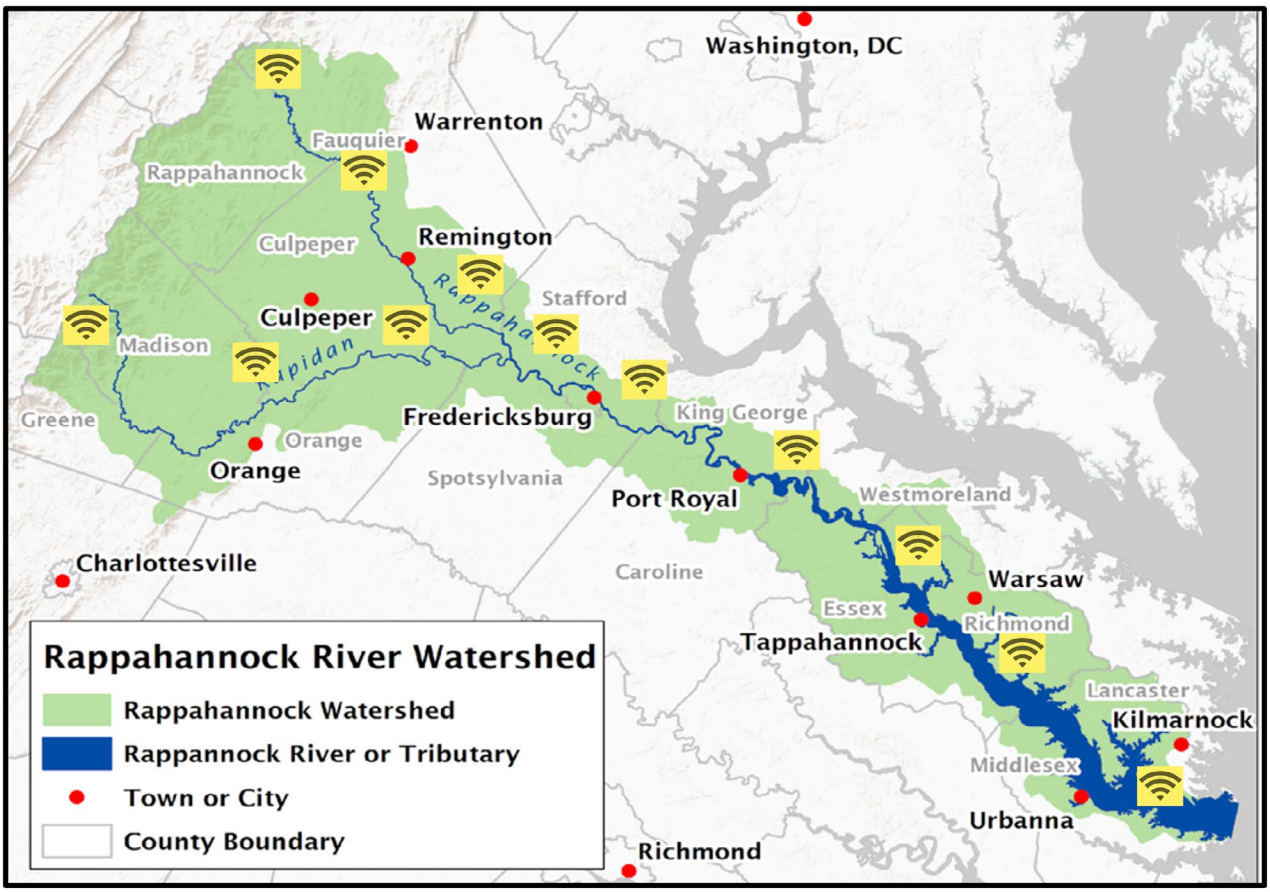
What Is a Smart River?

Smart River is the designation given to a flowing body of water that offers enhanced access to data on the health of the river, typically through advanced technology (Cabanga et al. 2021; U.S. Geological Survey 2012). Technological devices like sensors are deployed in rivers, with the primary goal of monitoring and managing water resources effectively (Bernardo et al. 2022). The use of information systems and technology in the water industry is growing, and river management can greatly benefit from new advancements in the information technology sector in the future (Gourbesville and Ma 2022). These technologies can be used for a variety of purposes, including constant monitoring of temperature, flow rate, and water quality (Onojake et al. 2023). Its uses also include the identification of possible risks, like rising water levels and flooding (Zainudin et al. 2023). In addition, societal and economic development have caused rivers to be polluted with complex pollutants that have adverse effects on human health and economic growth (Tajudin et al. 2020), but those pollutants can be monitored with innovative technologies (fig. 2), allowing farmers and other stakeholders to determine the appropriate timing of interactions with the river (Onojake et al. 2023).

Figure 2. Equipment for transmitting data from water monitoring sensors. (Photo courtesy of RIVERE.)

One example of using technology for river management is the Rappahannock SmartRiver Initiative, established by RIVERE, a nonprofit organization in Fredericksburg, Virginia. As population and industrial growth put pressure on river systems, tracking pollutants such as phosphorus, nitrogen, and sediments in waterways is vital for predicting environmental effects and guiding policymakers' decisions. To gather real-time data on the river's chemical, biological, and physical characteristics, the Rappahannock SmartRiver Initiative works to combine an automated wireless sensor network with applied machine learning (RIVERE 2023). The data can be transmitted through a centralized server for processing, storage, and online availability.

The primary objectives of the initiative are to establish the Rappahannock River as a test bed for implementing and assessing emerging Smart River sensor technologies, to optimize the advanced technologies of a Smart River system for possible community gain through community-based participatory research, and to locate and deploy sensors (fig. 3). Community-based participatory research is "a collaborative process between community-based organizations and academic investigators" (Weiner and McDonald 2013, 1). The Rappahannock SmartRiver Initiative is designed to engage experts from Virginia Cooperative Extension, Virginia Tech, Virginia Military Institute, Chesapeake Bay Foundation, U. S. Geological Survey Next Generation Water Observing System, Friends of the Rappahannock, Rappahannock River Basin Commission, University of Mary Washington, and Virginia Innovation Partnership Corporation.



** Sensors shown here do not reflect actual sensor locations*

Base Map Credit: Friends of the Rappahannock

Figure 3. Anticipated Smart River sensors along the Rappahannock River. (Photo courtesy of RIVERE.)

Why Is It Needed?

Sustainable river management requires stakeholder communication of water quality data, which is the central idea of Smart River management (Adu-Manu et al. 2020). In a focus group conducted as a part of the Rappahannock SmartRiver Initiative, participants identified two significant benefits of smart technology solutions: enhanced data security and cost reduction.

First, focus group participants emphasized the importance of utilizing technology solutions to reduce risks and increase resilience. They discussed that because rivers can be prone to fluctuations in water levels, floods, and accidents resulting from recreational activities, the use of technology could help improve awareness of the physical, chemical, and biological state of the river at any given time. The technology could notify stakeholders about possible dangers to and inform their decision-making.

Second, participants identified the significant economic benefits of using the available technologies (e.g., time and cost savings from the reduced need for on-site visits by using remote-sensing technologies instead). The discussion called for an inclusive and participatory approach to Smart River management that ultimately promotes healthy river systems that directly impact the overall watershed and coastal systems. Community participation and engagement were identified as the cornerstone for the success of the SmartRiver Initiative. The importance of communicating the individual and collective benefits of the project to community members was highlighted. One focus group participant explained:

> You cannot just do these things detached from the community, then you come later [and say], "This is what we found, and this is what must be done." I think early community engagement [is important] so that the community [will] feel part and parcel of the whole process. (January 2024)

Community-Based Participatory Research

The widespread use of technology in the water sector makes the collection, storage, and use of data more accessible and convenient. However, it also exposes associated individuals, communities, and organizations to the risk of attacks on the data. When technologies such as cameras or sensors are introduced in a river, a wide range of individuals and communities that have direct or indirect interactions with the river are likely to be impacted (e.g., the communities residing along the watershed area, farmers, fishermen, tribal communities, local government, industries, hydropower companies, water treatment plants, and so on). Thus, it is possible for stakeholders to have privacy concerns, and they could be reluctant to accept the introduction of a new technology. This could affect the functionality of the technologies and data integrity.

Stakeholder engagement holds specific significance in the water sector due to its fragmented nature, with multiple actors involved and varying needs that must be met; this helps to determine what solutions can be used and what technology may be needed (Gourbesville and Ma 2022). Also, to encourage a sense of individual accountability and involvement, it is beneficial to implement the activities of the SmartRiver Initiative with community norms and values that were evident from stakeholders' responses in the focus group. This implies that those likely impacted by the project should be actively involved in its design and implementation, and the individuals and communities should have a say in the processes and decisions that directly impact their lives.

Through the application of the community-based-participatory-research approach, communities are actively involved in influencing the planning and implementation of the Smart River system. This connects project activities with the needs and concerns of the community. In the SmartRiver Initiative, a combination of formal research methods and informal approaches is used both to encourage participation and to advance understanding of the context and unique challenges in the targeted area, considering the complex nature of the water sector. Hassenforder et al. (2019) claim that formal research combined with more informal methods, such as focus groups, can be helpful in creating a meaningful and participatory process. To encourage people to attend and engage in educational initiatives, it is important the community understands the significance of awareness. They should be able to personally relate to the initiative for this to happen (Huntinghawk et al. 2020). To ensure this, it is important for stakeholders to feel connected to the river (fig. 4). This could be achieved through effective communication about the economic, environmental, and cultural importance of the river by increasing access to the river. Visual tools such as pamphlets, imagery, and digital interfaces can be particularly useful in educating the public and motivating greater community involvement.

Figure 4. People kayak in the Rappahannock River. (Photo courtesy of RIVERE.)

Acknowledgments

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