College of ENGINEERING, COMPUTING AND APPLIED SCIENCES

Watershed Scale Resilience Assessment of Community Water Supply

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Introduction

With the rising threat of climate change and cascading impacts from infrastructure failure, there is a growing need to strengthen community resilience. This research aims to evaluate the resilience of water treatment infrastructure to identify vulnerabilities and strengths though the development of resilience metrics. This poster summarizes a case study assessing the resilience of the water supply within Anderson County, South Carolina. The case study provides important insight into the weaknesses and strengths of water suppliers related to their capacity to respond to the cascading impacts from infrastructure failure and diverse disruptions that threaten their communities.

Resilience Assessment Framework

The Resilience Matrix (RM) [1] defines the phases of resilience as prepare, absorb, recover, and adapt. This element emphasizes the importance of evaluating a system's entire performance over time. The intersections in the matrix incorporate four domains that address all the phases of resilience: physical, informational, cognitive, and social. Figure 1 below provides further definitions of the cross sections in the RM. The advantage of the RM lies in its scalability to different spatial scales and diverse organizations, especially pertinent to critical infrastructure systems.

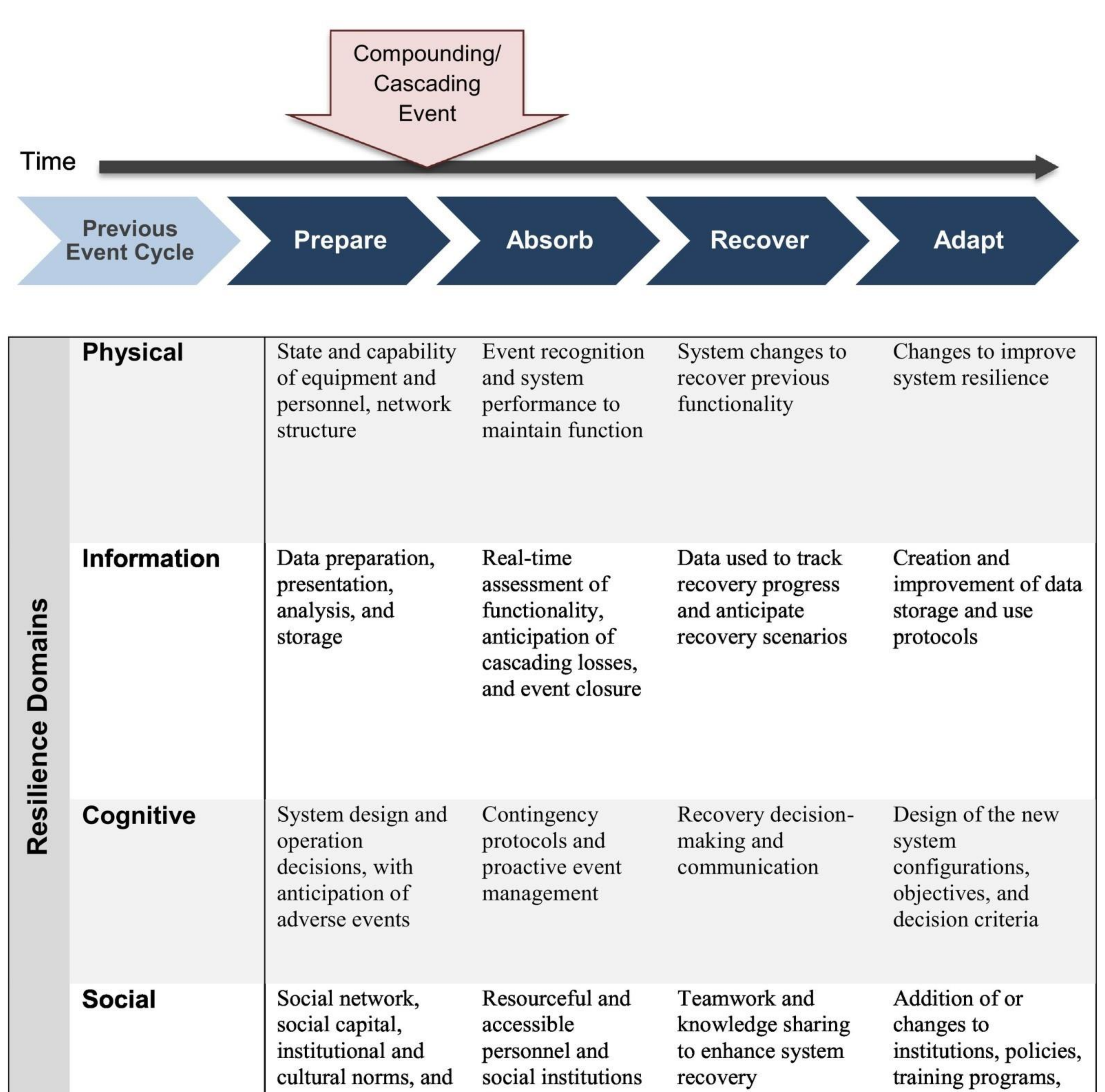

Figure 1. Definitions of phases and domains of the resilience matrix. [1]

Creating Resilience Metrics

We created metrics to quantify characteristics of a resilient system using the resilience domains in the RM. The metrics focus on evaluating a community or organization's capability and capacity to be resilient.

Table 1. Resilience metrics for drinking water treatment plant owners and operators

Resilience Matrix Categorization	Metric Category	Metric	Quantifying Question	Unit
Prepare, Physical	System Performance	1) Sludge Accumulation	Sludge capacity?	Years
		2) Treatment Capacity Utilization	Percentage of water treatment plant (WTP) capacity used at 24-hour peak demand?	Percentage
		3) Raw Water Storage	Volume of on-site raw water storage?	MG
		4) Finished Water Storage	Volume of on-site finished water storage?	MG
	System Vulnerability	5) Infrastructure Location Awareness	Percent of infrastructure with known location?	Percentage
		6) Water Storage Condition	-Condition of water storage structures?	Likert scale (1-10)
		7) Pipe Age Average	Average age of water distribution pipes?	Years
		8) Distribution System Condition	Overall condition of water mains and distribution?	Likert scale (1-10)
	Emergency Funding	9) Repair Fund Size	Size of emergency repair fund compared to annual budget.	Percentage
	System Reliability	10) Water Outages	Unplanned water outages from source in past 5 years?	Count

Metric 1 has the resilience matrix categorization of "Prepare, Physical", a metric categorization "System Performance", a metric name "Sludge accumulation" and a quantifying question "average daily volume sludge storage". This metric, and all others, asks for a comfortability rating on a Likert scale from 1-10. The Likert Scale is used to compare to other scores for metrics in and outside its RM category. The quantifying questions were used to interview the system managers and operators when collecting data.

Resilience Assessment: Comparison of

The interview responses from the system managers varied and the differences help illuminate our understanding of how they perceive resilience and what variability exists among water treatment systems. For 46% of metrics the systems answered similarly but Table 2 summarizes three metrics that have high variability in scores. Metric 22 highlights this well; Systems A & B are limited to treating their only water source, but system C has a backup water source. However, System C is reliant on other providers as their water source. This makes them dependent on another system's resilience to maintain function.

Table 2. System manager responses to resilience metrics

Metric	Unit	System A Value	System A Comment	System B Value	System B Comment	System C Value	System C Comment
15) Drought Response Planning	Yes/No & Likert scale (1-10)	Yes, 3	Drought plan exists; low confidence; relies on system managers for usage reduction	No, 9	Never an issue	Yes, 8	Drought plan under revision
22) Water Source Diversity	Percentage	0	One source	0	Saluda River only source	100%	Mainly Greenville 95%, some from Anderson 5%, option from Easley
33) Critical Mission Water Needs	Percentage & Likert scale (1-10)	0%, 1	---	0%, 1	--Weekly and monthly checks	100%, 10	Can go to medical clinics

Resilience Assessment: Data Trends

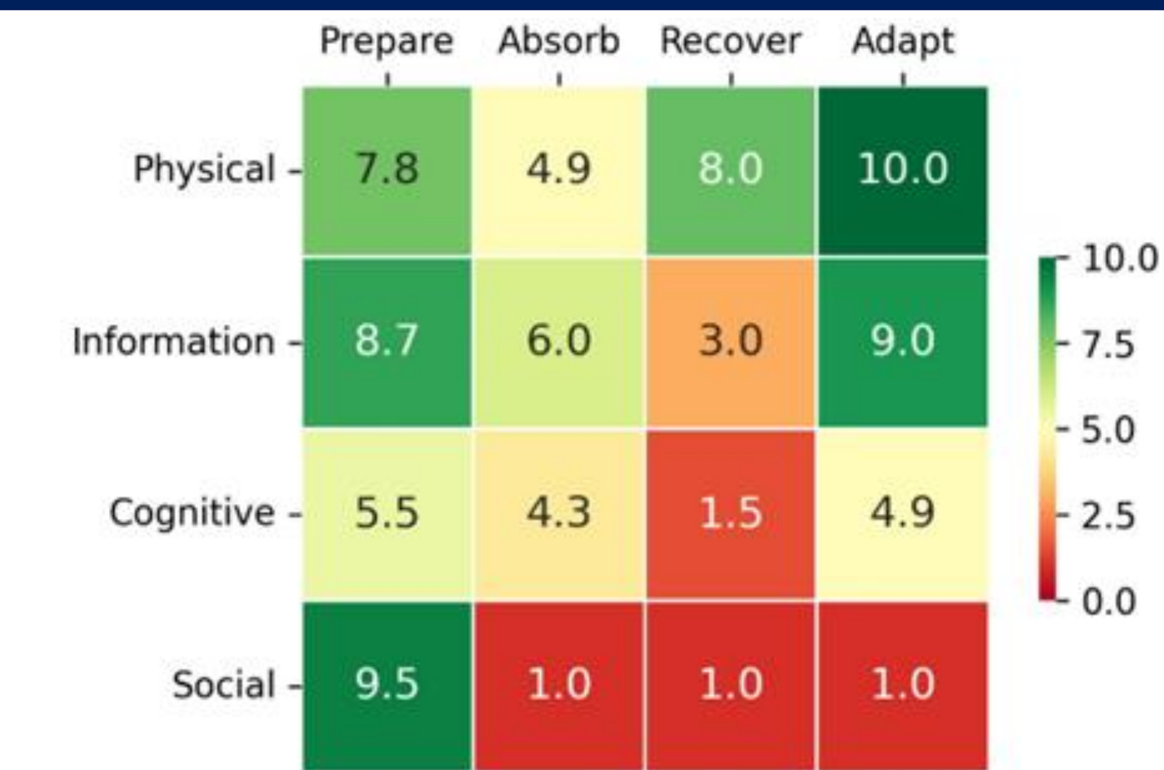

Figure 2. Matrix of systems' average scores

The results of the case study reflected general trends that are often seen in resilience analysis. Because the traditional focus of infrastructure systems has been to minimize risk, they tend focus primarily on preparing for these risks which is reflected in the relatively higher scores in the "Prepare" column. Because the resilience-based emphasis on recovery is relatively new, infrastructure systems tend to be less prepared for recovery, reflected in the relatively lower scores in the "Recover" column. Similarly, hazard mitigation is most often achieved through changes to the physical structure of an infrastructure system, resulting in higher relative scores in the "Physical" domain row. While decision-making and decision-makers are also critical for resilience, they tend to receive less focus in the planning process, which is mirrored in lower relative scores in the "Cognitive" and "Social" domains.

Conclusion

Continued application of the resilience metrics for drinking water systems will strengthen the knowledge of our communities' capacity to respond to the cascading impacts of infrastructure failure. With this knowledge, communities can develop steps to address weaknesses by applying for available federal funding for projects to increase community resilience. By documenting our process, this case study will be replicable across the country and to other infrastructure types.

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US Army Corps of Engineers

References

[1] Wells, E. M., Boden, M., Tseytlin, I., & Linkov, I. (2022). Modeling critical infrastructure resilience under compounding threats: A systematic literature review. Progress in Disaster Science, 15, 100244.