

Challenges and Opportunities in Operationalizing Coupled Human and Natural Systems Research in the Chesapeake Bay Watershed



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Executive Summary

Brief Overview

In coupled human and natural systems (CHANS) thinking, the complex relationship between human behavior and environmental change is considered through the various and dynamic mechanisms both affect the other. These interactions are continuous cycles or feedbacks that can cause a variety of dynamic outcomes over time. CHANS scholars study and categorize those dynamic outcomes, or emergent properties, in order to explain why coupled human and natural systems do not always work the way we might expect based solely on examining separate interactions between humans and their environment. This disconnect occurs because human actions alter the environment without providing immediate or obvious feedback to those responsible.

Nutrient pollution in the Chesapeake Bay Watershed arises from a complex array of feedbacks with embedded disconnects and bottlenecks. Temporal lags and spatial disconnects separate the actions that release nutrients from their downstream effects, such as harmful algal blooms (HABs) and eutrophication in the Bay itself, and nutrient flows are shaped by path-dependent processes in land use, sanitation, and transportation infrastructure. Technologies, economic constraints, and social norms further shape how people perceive nutrient pollution and whether they act to reduce it. Understanding these feedbacks is challenging, but critical to the partnership's success.

The report serves two purposes. The first is substantive, presenting the recommendations the groups produced. The second, and primary, is methodological. It argues that the structured, facilitated, cross-actor approach demonstrated during the workshop should become a standing practice of planning and decision-making rather than a single event.

Major Findings

Social and institutional dynamics matter. The biophysical science and strategic watershed planning the partnership has built over four decades remain the foundation of its work and coupled-systems thinking adds to that base. The workshop identified a set of social and institutional dynamics that may be limiting factors on the implementation of protection, restoration, and stewardship activities in the watershed. When groups mapped their focal systems and when they imagined the Chesapeake of 2050, they consistently wrote about people, institutions, and politics, and less often about nutrient loads or best management practice (BMP) efficiencies.

Independent groups converged on the same diagnosis. Through their CHANS analysis, six breakout groups identified a small set of structural elements that strongly influence Chesapeake water quality governance (trust, engagement, and institutional fragility). This convergence is notable because the groups started in very different places, diagramming coupled human and natural systems across a variety of issues (e.g., poultry litter, coastal water quality, urban stormwater, crop agriculture) and regions (e.g., the Susquehanna River Watershed and the Delmarva Peninsula).

Trust was the most pervasive factor. Trust appeared as the controlling feedback for practice adoption and as the variable that determined whether actors cooperated or assigned blame under stress. Lack of trust was the most frequently named barrier to effective human responses to environmental change. Current monitoring and modeling treat trust as external to the system, if they account for it at all.

Institutional fragility exceeded ecological fragility. When groups traced shocks, such as major HABs or price changes through their system maps, the primary disconnects occurred at governance nodes, and recovery depended more on the institutional and funding response rather than the triggering event. The same pattern held when groups diagnosed what keeps the system on its current path: the dominant obstacles were structural barriers and institutional rigidity, not technical limitations.

Because feedbacks route through institutions, the partnership is both a connector and a potential bottleneck. Few watershed residents directly experience the environmental costs of their nutrient-related decisions, so those signals reach people through organizations like the CBP. This makes the partnership a critical mediator of the system's response, as well as a point at which that response can stall.

A post-workshop survey corroborated the workshop motivation and exposed a gap between commitment and capacity. Respondents to a post-workshop survey rated all of the CHANS concepts we introduced as highly relevant to restoration but rated their current use in CBP work much lower, with institutionalization the lowest-rated dimension. A large majority (81%) were uncertain or not confident that the 2025 Watershed Agreement's commitment to integrate social science would translate into substantive change. At the same time, 77% of respondents indicated they intended to incorporate coupled-systems thinking into their own work.

The workshop was a successful demonstration of the engagement method. Participants rated the workshop's cross-disciplinary composition as its single greatest strength and identified systems mapping as a concrete and transferable tool. The most consequential limitation was the composition of the participant pool, which skewed toward academic and natural scientists and under-represented practitioners and local stakeholders. That limitation is itself a finding, and the recommendations are written to address it in a second iteration.

Key Recommendations

The workshop demonstrated that a structured, facilitated convening of an intentionally heterogeneous group of researchers, managers, and practitioners could map, stress-test, and diagnose the coupled system. In two days, the method produced a coherent and convergent set of findings that the partnership's conventional analysis is less likely to produce on its own. Accordingly, STAC and the CBP should convert this approach into a recurring capability:

1. Establish recurring CHANS-based facilitation as a standing partnership practice (MR1), timed to the partnership's decision cycle so that each convening informs a live decision.
2. Build facilitator and convener capacity deliberately (MR2), through training, reusable materials, and a standing pool of skilled conveners maintained by the partnership.
3. Design heterogeneous, practitioner-inclusive representation into the process (MR3), setting composition targets and removing the barriers that limit participation from non-academics.
4. Route substantive recommendations through a defined partnership-level intake mechanism (MR4), so that outputs are formally received, acted on, and tracked.
5. Document and steward the format as a repeatable STAC method (MR5), retaining cross-group review as a standard element.
6. Feed structured products back into the modeling, monitoring, and indicator systems (MR6), so that findings reach the tools through which the partnership makes decisions.

Six groups, working largely independently on different focal systems and composed of different participants with different initial framings, converged on a common and limited set of targets, and those targets are the substantive recommendations. They stand on their own while also demonstrating that the method yields useful, actionable output. In brief, the groups recommended that the partnership:

1. Build trust and relationship infrastructure for BMP adoption (SR1).
2. Pre-position science and project libraries so that short windows of funding or crisis can be acted on within months (SR2).
3. Pair locally-led capacity with flexible frameworks matched to sub-watershed heterogeneity (SR3).
4. Undertake a multi-year science-and-indicator program that instruments the social and behavioral system components to understand and address key system disconnects (SR4).
5. Institutionalize CHANS competency inside existing CBP structures, so that recommendations are produced and received where decisions are made (SR5).

Most of these steps can begin within a single planning cycle, and none requires a new mandate or significant new funding. Together, they would help convert a single, well-received workshop into the standing capability the commitment in the 2025 Watershed Agreement will require.

1. Introduction

1.1. Purpose

The Chesapeake Bay and its watershed are among the most extensively studied and actively managed estuarine systems in the United States, and an exemplary case of a coupled human and natural system (CHANS). Restoration efforts spanning several decades have been guided by the Chesapeake Bay Watershed Agreement (Chesapeake Executive Council 2014), which first established 10 goals and 31 measurable outcomes organized around five major themes, and was recently updated (Chesapeake Executive Council 2025). The Chesapeake Bay Program (CBP) partnership, which includes federal and state agencies, academic institutions, and nongovernmental organizations, has made substantial progress in reducing pollutant loads and advancing water quality. Despite this progress, significant challenges persist: implementation gaps in nonpoint source pollution control, gaps between management actions and observed water quality responses (particularly in shallow waters), and deep uncertainties about how interacting ecological, social, and institutional conditions will evolve under continued environmental change (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023).

CHANS research, also described as social-ecological systems or nature-society systems research (Liu, Dietz, Carpenter, Alberti, et al. 2007; Liu, Dietz, Carpenter, Folke, et al. 2007; Schlüter et al. 2023), offers a framework for understanding these challenges in a more integrated manner. The Chesapeake Bay Watershed (CBW) exhibits the hallmarks of complex adaptive systems, including the six examined in this workshop: heterogeneity, feedback loops, nonlinearity, adaptation, learning, and memory (Preiser et al. 2018). Much of the CBP's restoration enterprise has focused on how human activities affect environmental conditions, such as how land use drives nutrient loading, how agricultural practices influence sediment, and how development expands impervious surfaces. Less attention has been given to the reverse relationship: how environmental conditions affect human behavior, quality of life, decision-making, and governance, or the dynamics created by repeated interactions between humans and the environment. These feedbacks are central to understanding why some management actions succeed, why others fall short, and where restoration strategies may need to be adapted.

The CBP's monitoring, modeling, and management systems provide a strong foundation for science-based decision-making. At the same time, existing tools and institutional processes do not fully capture relevant connections between environmental change and human response. The CBP's modeling framework effectively models many human impacts on the environment but does not capture feedback loops that occur as humans experience environmental impacts and change their behavior accordingly (Bitterman and Webster 2024; Lim et al. 2023; Webster 2022). This asymmetry is especially consequential for issues such as nonpoint source pollution, climate resilience, land-use change, and adaptive management, where restoration outcomes depend as much on social and institutional dynamics as they do on ecological ones.

Recent CBP planning documents and scientific assessments have called for directly addressing this gap. The CESR report (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023) emphasized the need for improved adaptive management approaches, including sandboxing and experimentation, the development of outcome-oriented incentives, and the integration of monitoring networks and feedback mechanisms into watershed modeling. The "Beyond 2025" report (Beyond 2025 Steering Committee 2024) similarly identified the need to integrate social science into a systems-based understanding of decision-making across multiple spatial and temporal scales. In their letter of support for this workshop, the co-chairs of the Enhance Partnering, Leadership and Management and Water Quality Goal Implementation Teams noted that while the CBP has long studied how humans affect the environment, the partnership has "limited knowledge on how the environment impacts human quality of life, behavior, and decision-making", an acknowledgment that the coupling runs in both directions and that the current state of knowledge is incomplete.

More recently, the revised Chesapeake Bay Watershed Agreement has carried this recognition into formal commitment, pledging the partnership to "integrate social science holistically throughout the partnership" in support of adaptive management and community engagement (Chesapeake Executive Council 2025). This commitment builds on a standing STAC-led Social Science Standing Workgroup established in 2024 to define the role of social science within the CBP and to advise on its integration (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2024). Together, these developments form part (though not all) of the institutional context motivating this workshop, and mark increasing momentum toward

integrating social science across the partnership. A substantial gap remains between this commitment in principle and the routine, operational practice of coupled-systems thinking in the partnership's modeling, monitoring, and decision-making processes. This is the asymmetry described above and closing that gap cannot be accomplished by any single agreement or lone workgroup. Rather, it is precisely the work this workshop was convened to advance; to ask not whether coupled-systems science is relevant to the Bay and its watershed, but how it might be operationalized and institutionalized.

This report serves two purposes. The first is substantive – to present the [recommendations](#) developed by expert breakout groups for integrating coupled-systems thinking into Bay restoration. The second, which carries the report's primary weight, is more methodological. The workshop differed substantially from STAC's customary State-of-the-Science convenings in that the method it employed was itself part of the contribution. Specifically, the workshop was a structured, facilitated convening of an intentionally heterogeneous group of researchers, managers, and practitioners. Participants worked collectively to map, stress-test, and diagnose the coupled human and natural system. Accordingly, STAC and CBP should treat this practice not as a single "one-off" event, but as a recurring capability. These parallel purposes are connected. The substantive recommendations are valuable and stand on their own, and they also serve as evidence that the practice can yield useful, actionable output.

The intended audience is first STAC and the CBP partnership, and secondarily researchers and practitioners engaged in comparable work in other watersheds. Recommendations are offered as guidance for institutional practice (i.e., how the partnership might build capacity and structure over time) and not as determinations about any single management or policy decision. As a single workshop, it constitutes a demonstration of a method rather than a comprehensive evaluation of it; the scope and limits of its claims are discussed below.

This STAC workshop was convened on March 26-27th, 2026, at the Philip Merrill Center of the Chesapeake Bay Foundation in Annapolis, Maryland, with the goal of exploring how CHANS research can be brought to bear on the practical challenges of Bay restoration. The workshop emphasized application over theory, bringing together federal, state, local, and academic partners, alongside practitioners and community representatives whose expertise is essential for

designing solutions that work on the ground, to assess the state of applied CHANS science, identify key socio-ecological feedbacks and gaps, and develop recommendations for the CBP.

The workshop focused on four primary objectives:

1. Synthesize the current state of applied CHANS science and its relevance to persistent challenges in the CBW, drawing on experience from the Bay watershed and comparable systems elsewhere, with attention to how CHANS frameworks can address implementation and response gaps and identify opportunities to improve system resilience.
2. Map critical feedbacks and identify gaps between how the Chesapeake Bay system functions and how it is currently managed, with particular emphasis on nonpoint source pollution, adaptive management limitations, and the disconnects between policy objectives and ecological realities.
3. Assess CHANS applications and identify strategies for improving policy and management, examining barriers to adoption and exploring solutions through CHANS-informed approaches, with findings aimed at practical, solutions-oriented applications aligned with CBP goals and the Chesapeake Bay Watershed Agreement.
4. Develop actionable recommendations for incorporating CHANS insights into the CBP's adaptive management framework, including proposed strategies, pilot projects, and decision-support tools that better account for human-environment feedbacks and improve the partnership's capacity to respond to changing conditions.

This workshop represents a timely step toward operationalizing CHANS science within the Bay's restoration strategy. The findings and recommendations presented in this report are intended to inform future research priorities, improvements to the CBP modeling system, and governance strategies within the broader CBP partnership.

1.2 Workshop Design and Participants

The workshop design followed a two-day progression (workshop agenda can be found in the appendices). Day 1 centered on characterizing the coupled system, including synthesizing the current state of applied CHANS science and mapping the CBW's principal social-ecological

elements, feedbacks, and gaps. Day 2 activities focused on developing recommendations for the partnership. Collaborative co-development was the organizing principle across both days.

Day 1 opened with a welcome and short primer on coupled-systems vocabulary and frameworks, intended to establish a common vocabulary and conceptual baseline among participants of varied expertise. A five-speaker panel, *Shared Challenges and Opportunities in Coupled Systems*, followed. The invited panelists were selected to provide perspectives from other U.S. watersheds (Puget Sound, Bay-Delta, and the Gulf) interwoven with insights from two panelists from within the Chesapeake. The panelists were asked to discuss their experiences in working in coupled systems, including (1) surfacing which couplings matter, (2) which are hardest to observe or represent, and (3) what typically hinders translation of coupled-systems insights into models and policy. The remainder of Day 1 was spent in small-group breakouts, each followed by a full-group report-out that allowed groups to learn from one another.

Day 2's planned sequence was adjusted to accommodate Representative Sarah Elfreth's schedule. Accordingly, the day opened with a panel discussion, followed by a visioning exercise and breakout groups. The second panel, *Policy and Implementation Challenges* (Hilary Harp Falk, Chesapeake Bay Foundation; Maggie Woodward, Chesapeake Bay Commission; Representative Sarah Elfreth, U.S. House of Representatives, MD-3), grounded the day's activities in real-world decision contexts. Participants then completed the plenary "Headlines from 2050" exercise, where each group drafted two short newspaper headlines for the Bay's future (one desirable, one undesirable) based on Day 1 themes. Two further breakout activities followed, and the workshop closed with final group presentations and a facilitated synthesis of cross-cutting themes.

Participants worked in six breakout groups (five in-person, one virtual). Each group was led by a trained facilitator from the workshop Steering Committee and worked from a common set of instructions that included: (1) a systems-mapping template, (2) shock briefs for the propagation exercise, (3) an importance-vs-representation grid, (4) a paired barrier-opportunity worksheet, and (5) a recommendation rubric. Groups also engaged in and recorded cross-group peer review of their final recommendations, in which each group's recommendation was critiqued by another participant group rather than by outside disciplinary referees.

The workshop drew approximately 65 participants (full participation list can be found in the appendices), including academic researchers, federal and state agency staff, and non-governmental and policy organizations. Although the design sought a broader mix of participants, (e.g., community leaders, practitioners, extension specialists, planners, industry professionals) alongside scientists, the realized participant pool was skewed towards natural-science researchers and managers. As the post-workshop survey documents, approximately 62% of respondents identified their background as natural or physical science, and roughly 48% worked in academic or research institutions. The report discusses the implications of the participant pool and the importance of broadening participation in [Section 6.2](#).

1.3 Scope and Limitations

This report synthesizes the workshop's activities and findings rather than directly transcribing them. Within the scope of this report are the cross-group synthesis of each activity, triangulation against a post-workshop survey, the substantive recommendations developed by the breakout groups, and the methodological recommendations that form the report's primary contribution. Elements outside of the scope of this report include verbatim panel transcripts, detailed individual contributions, specific policy or technical determinations, and any comparative evaluation of CHANS against alternative conceptual frameworks or analytic traditions.

The most consequential limitation is the composition of the participant pool. As noted above, the workshop underrepresented practitioners and, especially, local and community stakeholders relative to the steering committee's intent, and the post-workshop survey samples skew similarly toward academic and natural scientists. This limitation is most relevant for recommendations that depend on practitioner and place-based knowledge and is itself a finding. More homogeneous groups tend to fill analytical gaps without recognizing their own blind spots, and this limitation is translated into an explicit design recommendation. A second limitation is the scope of inference regarding the method. Activities over two days with approximately 65 attendees constitute a demonstration of the method rather than a comprehensive evaluation of its effectiveness.

However, the workshop's strengths should also be noted. By the measures available, it was a single but effective workshop. Participants rated its cross-disciplinary composition as its greatest strength, identified the systems-mapping exercise as a concrete and transferable tool, and a large majority (77%) reported they intend to incorporate coupled-systems thinking into their own work. This report treats the workshop as a demonstration of an effective method and a point of departure from traditional structures. Its limits describe what a second iteration should address. They do not diminish what this first workshop has demonstrated. The recommendations in [Section 8](#) are written to make the next iteration better composed, better resourced, and better embedded in STAC's standing portfolio.

2. Systems thinking for the Chesapeake Bay Watershed

This section provides the theoretical foundations for this report. It defines the coupled systems vocabulary used throughout the report and how those terms are applied. It then lays out why operationalizing this work is timely for the partnership, describes what the CBP's current analytical apparatus does well and where it might be strengthened through the application of CHANS thinking, and identifies the building blocks of the cross-actor systems demonstrated during the workshop.

2.1 CHANS, SES, CAS: Working Definitions for this Report

The relationships between people and nature in the CBW are best understood as a single connected system, and Coupled Human and Natural Systems (CHANS), is the operative term used in this report. CHANS are a particular kind of Complex Adaptive System (CAS) – a system in which many autonomous agents (e.g., farmers, watermen, agencies, households, and firms) each follow their own logic, and in which the interactions among them produce system-scale outcomes (Holland 1992; Liu, Dietz, Carpenter, Folke, et al. 2007; Liu, Dietz, Carpenter, Alberti, et al. 2007). This framing is useful because it emphasizes a specific set of system properties, each with consequences for restoration (see Figure 1). While there are many properties of CAS and CHANS, six recur throughout the workshop's analyses, and each is visible within the CBW.

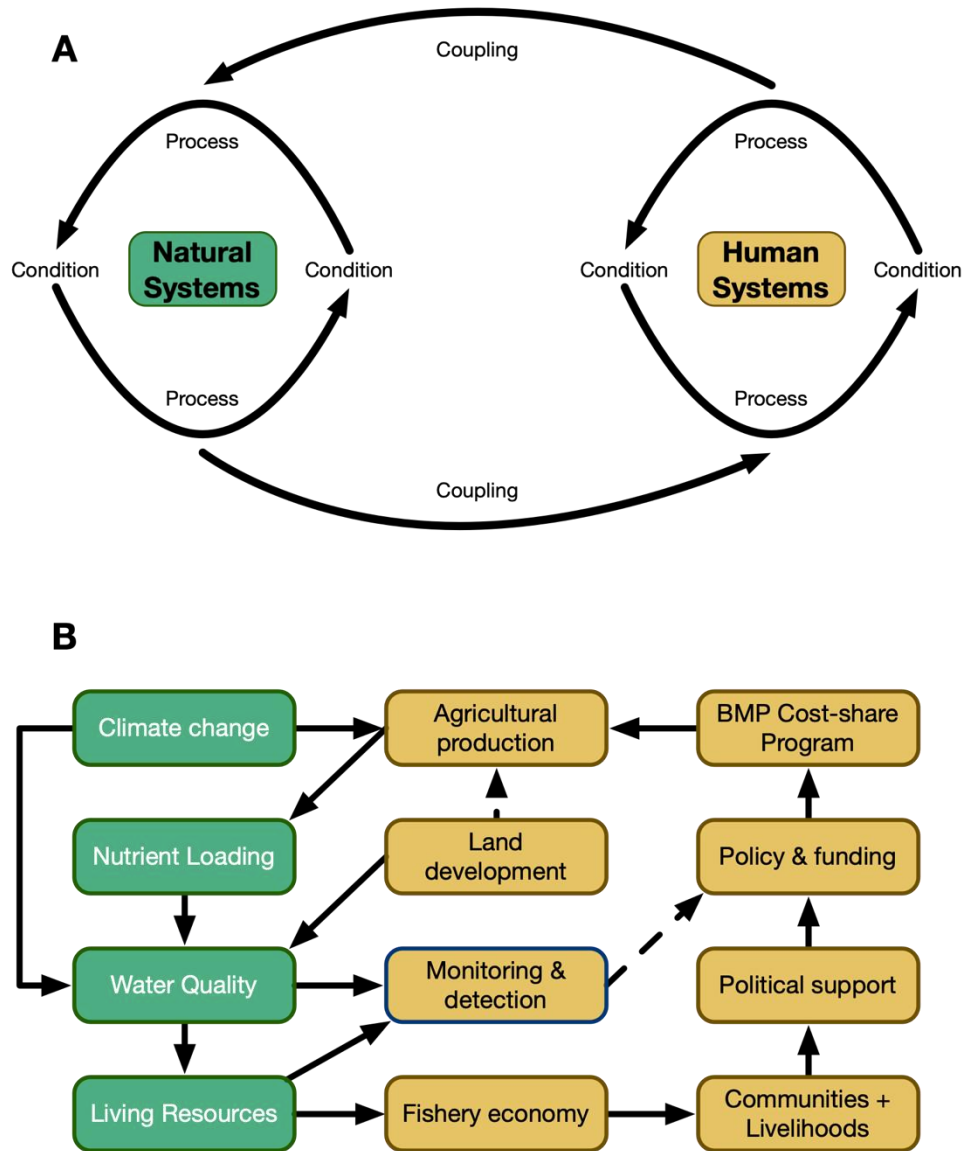


Figure 1: Panel A details a traditional conceptualization of a coupled human and natural system, where each of the natural and human sub-systems have conditions and processes. These sub-systems are connected by mechanisms that coupled the two sub-systems. In Panel B, a more detailed conceptual diagram describes elements of the coupled system within the CBW. As with all representations, it is a simplification of reality but captures systems dynamics across domains and spatial and temporal scales.

CHANS Property 1: Feedback. In CHANS, the outcomes of a process often "loop back" to reshape the conditions that produced them. Some feedback loops reinforce the process, while others dampen or attenuate it. A reinforcing (or positive feedback) loop appears in the CBW when early adopters of a conservation practice see visible improvements, which build trust and draw additional participation. As the number of adopters increases, the rate at which new adopters join also increases. A balancing (or negative feedback) loop prevents change. For instance, BMPs may reduce nutrient inputs into the watershed, but these reductions can be cancelled out by related releases of legacy nutrients back into the water column.

Feedbacks can compound each other as well. According to the CESR report, monitoring data show limited water quality response despite sustained implementation effort (likely due to a negative feedback). This could potentially erode political support for continued investment (a positive feedback with negative consequences), and thereby produce a pattern that might undercut the very actions intended to drive recovery (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023).

CHANS Property 2: Non-linearity. Relationships between cause and effect are rarely proportional. Small changes in a driver can produce disproportionately large effects when positive feedbacks are at work, and large efforts can yield little visible change until a threshold is crossed, potentially shifting the system into an alternative stable state. The CBW offers textbook cases. Nutrient-load reductions have not produced proportional improvement in dissolved oxygen (DO) in deep-channel habitats, and submerged aquatic vegetation (SAV) can recover quickly once water quality passes a threshold (Lefcheck et al. 2018). Gradual progress short of a threshold can therefore appear as failure, even when the system nears a tipping point.

CHANS Property 3: Heterogeneity. Actors, ecosystems, and institutions all differ across space, time, and context. The CBW spans roughly 64,000 square miles and seven jurisdictions, ranging from intensive agriculture on the Eastern Shore, across rural forested headwaters, and to the rapidly urbanizing corridors around Baltimore and the District. A uniform policy applied across this variation produces uneven results, which is part of the motivation for the 2025 Agreement's emphasis on place-based approaches (Chesapeake Executive Council 2025).

CHANS Property 4: Adaptation. The coupled system changes over time. Actors learn from experience and adjust their behavior, and institutional rules evolve in response to novel conditions (Folke 2006; L. Gunderson et al. 2017; L. H. Gunderson et al. 2006). The partnership's own practice of adaptive management is an institutional expression of the property, in that it commits the partnership to revising its actions as monitoring results and experience accumulate. Adaptation is the property that allows a coupled system to respond to change and is also what makes the system a moving target for analysis, since the rules and behaviors a model represents at one moment may not hold at the next.

CHANS Property 5: Memory. Past decisions constrain the options available in the present, so the system effectively carries its history forward. This property, or path dependence, is especially consequential across the watershed and in the estuary. Legacy nutrients stored in soils and groundwater, established infrastructure, and long-standing institutional norms all carry forward. The Total Maximum Daily Load (TMDL) reduction targets, for example, have organized monitoring design, model structure, and political accountability around specific goals for more than fifteen years, shaping what the management system is equipped to see and do (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023; US EPA 2010).

CHANS Property 6: Emergence. System-level patterns arise from the interactions among components in ways that cannot be anticipated from observing any one component alone, so the whole behaves differently from the sum of its parts. The persistent gap between practices implemented and water quality outcomes achieved is, in this sense, an emergent property of the CBW. No single actor or program designed it. It arises from the interactions of individually reasonable decisions – farmers weighing costs against uncertain benefits, conservation districts prioritizing enrollments they can count, modeling systems that treat BMP adoption as external input, and accountability frameworks that track practices installed rather than outcomes achieved. Because no one designed the gap, optimizing any single part will not close it; doing so requires changing the interactions among the components. This last point is central to the design of the workshop's activities and this report's recommendations.

CHANS and CAS frameworks themselves have evolved over time, and their emphasis on feedbacks and system dynamics has been strengthened by other perspectives. For example, social-ecological systems (SES) research foregrounds institutions and governance, and in particular how groups of people organize to manage common-pool resources (Ostrom 2009; Preiser et al. 2018). This perspective is especially relevant to the CBW. Restoration is a large collective action problem. Nutrient reduction depends on the coordinated behavior of many independent actors across multiple jurisdictional levels, none of whom can achieve the shared goal by themselves. SES draws attention to the rules, norms, and institutional arrangements (the TMDL accountability framework, the partnership's goal-team structure, state-level implementation authority) through which that coordination is attempted, and to questions of resilience, adaptation, and regime shifts in both the ecological and the governance subsystems. The CHANS, CAS, and SES traditions overlap and have co-evolved with several decades of empirical and applied development behind them and a growing record of use in environmental management (An et al. 2025; Schlüter et al. 2023). Throughout this report, these frameworks are treated as complementary. CHANS serves as the operative term, CAS is referenced where the analysis turns on non-linearity, threshold, and emergence, and SES framings are used when discussing institutions and governance. The question addressed throughout this report is: ***how can their insights be leveraged in the specific institutional setting of the Chesapeake Bay Program?***

2.2 The 2025 Agreement and the Social Science Turn – Why Now?

The case for taking up this work at this moment rests on a specific institutional development. The revised Chesapeake Bay Watershed Agreement commits the partnership to integrate social science "holistically throughout the partnership," in support of adaptive management, community engagement, and the individual and collective behaviors on which partnership goals depend (Chesapeake Executive Council 2025). This commitment sits alongside an interconnectedness principle, which holds that all parts of the ecosystem, including its human components, are connected. Together, these establish coupled-systems thinking as a partnership-wide expectation.

A holistic commitment is broad by design. It implies that social science has a role in every goal area and decision process, not only in a single workshop or a discrete set of outreach activities. In practice, this functions as a directive, tasking the partnership, STAC included, with building social science and coupled systems capacity into the routine business of protection, restoration, and stewardship. However, that breadth is also a source of difficulty. A holistic commitment runs well ahead of current practice across most of the partnership, as social science integration is real but still nascent. The standing Social Science Workgroup was established only in 2024 (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2024), and the apparatus that drives day-to-day decisions (e.g., the watershed model, the monitoring network, and the indicator and accountability frameworks) remains, for understandable historical reasons, oriented toward the biophysical components of the system. The gap between this integrated commitment and a structure built largely around feed-forward processes is the practical problem this workshop was convened to address.

Accordingly, this workshop was particularly well-timed. The partnership now has, for the first time, a formal and broad mandate to operationalize coupled-systems thinking, though it has not yet settled the mechanism for doing so.

2.3 Strengths and Motivating Opportunities in Current CBP Analysis

By the standards of large environmental programs, the CBP's analytical infrastructure is exceptional, with a linked watershed model covering a large basin, one of the longest water quality monitoring records in existence, multi-jurisdictional coordination across six states and the District of Columbia, and a shared accountability framework. The five areas described below build on that foundation and follow from prior analyses of the partnership's modeling and governance (Bitterman and Webster 2024; Lim et al. 2023; Webster 2022).

Three of these areas are gaps in representation, or features of the coupled system that current tools largely do not capture. First and most consequential is behavioral feedback. The watershed model represents how human activities affect environmental conditions in great detail but treats the adoption of best management practices (BMPs) as largely external input, with little

representation of producer decision-making as a function of incentives, information, trust, and observed conditions. This is the directional asymmetry introduced above, in which the forward path from human action to environmental outcome is modeled well, while the return pathway is largely absent. The second is trust – agency-producer and community-jurisdiction trust dynamics shape how readily practices are adopted and how durable adoption proves to be, yet neither is an endogenous variable, and monitoring instruments are not designed to detect them. The third area of attention is cross-scale governance. While the partnership works extensively across spatial scales, the governance dynamics across those scales are unrepresented as part of the system. For example, how regional targets translate (or fail to translate) into the authority, capacity, trust, and political will that local actors need to act on them. These frictions, such as jurisdictional inertia and lags between regional decisions and local action, are treated as the context of analysis rather than the focus of it, despite their direct influence on restoration outcomes.

The remaining two areas are better described as partial integration – those capabilities the partnership already exercises that are not yet embedded in the mechanisms that drive decisions. The first of these is anticipatory analysis. The CESR report is one example of a forward-looking evaluation of system response (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023), and the watershed model routinely runs management scenarios, but anticipatory reasoning about how shocks might propagate through coupled human and institutional pathways is less common. The final focal area is the range of evidence formally admitted into analysis. The Goal Implementation Teams (GITs), advisory committees, and workgroups regularly draw upon qualitative and stakeholder knowledge through deliberation, but that knowledge irregularly enters the formal modeling, monitoring, and indicator systems that anchor accountability. These two elements can be strengthened by building on existing tools. For example, this might include a standard practice of tracing potential shocks as they cascade through social and institutional components, or protocols that admit qualitative and place-based knowledge (including Indigenous and local ecological knowledge) into the modeling and monitoring frameworks.

These five areas of opportunity share a common structural origin: *the operational structure of the CBP does not fully represent or consider human agency and the reflexive feedback it generates, even in cases where the partnership openly deliberates about these dynamics.*

3. Workshop Framing: Presentations and Panels

Workshop activities were preceded by framing presentations organized into two panels. An opening talk set the conceptual and motivational frame, followed by a Day 1 panel that offered perspectives from other watersheds and from within the Chesapeake region. A Day 2 panel focused on policy and implementation. Their shared purpose was to present participants with a common vocabulary, an understanding of the state of the field, and a set of real-world constraints to consider as they began their own group analysis.

3.1 Opening Framing, Patrick Bitterman (Kent State University): CHANS for the CBW

The workshop opened with a presentation that set the motivating problem, surveyed the state of the field, and established what would be expected of participants. It introduced the coupled-systems vocabulary developed in Section 2 above and grounded the workshop in the directional asymmetry described there – that the partnership understands the path from human action to environmental condition far better than the return pathway.

Much of the talk concerned the state of CHANS research, which has matured over the past two decades, though unevenly. Recent assessments have found that empirical and modeling approaches remain poorly integrated, with most studies relying on one or the other (Schlüter et al. 2023), and that applications of complex-systems science to sustainability problems are still largely conceptual or small in scope, with limited extension to the management-relevant systems where decisions are made (An et al. 2025). While the frameworks are well developed, their translation into operational, decision-relevant tools remains unfinished.

A second line of research bears directly on the asymmetry the workshop addressed. A typology of human-environment studies distinguishes: (1) parallel work, which examines human and environmental systems side by side without interaction, (2) one-way work, which traces effects in a single direction, and (3) bidirectional work, which represents human-environment feedback loops explicitly (Shin et al. 2022). Bidirectional coupling (feedback loops) work, which is argued here as the type the CBW most needs, is the least common of the three. However, bidirectional

couplings are more likely to appear in research when social scientists are part of the research team and when the work uses simulation models or conceptual frameworks. This framing helped motivate the workshop's emphasis on bringing together participants with diverse expertise.

The introductory talk also drew on a consensus account of why socio-environmental modeling is difficult, which sets out eight grand challenges, among them bridging epistemologies across disciplines, handling spatial and temporal scales, combining qualitative and quantitative methods, capturing structural change over time, and representing human dimensions (Elsawah et al. 2020). To these challenges, the opening presentation added the role of technology and infrastructure as components of the coupled system in their own right. Examples include the monitoring networks, modeling platforms, and decision-support tools that determine which signals reach decision-makers and which are filtered out. This connects to a finding of the CESR report, that monitoring in the partnership is oriented more toward accountability, asking whether criteria have been met, than toward learning, asking why outcomes have or have not appeared (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023).

Finally, the presentation closed by setting an expectation about the workshop itself. The maps, gap analyses, and recommendations would be produced by the participants, with the presentations and panels supplying vocabulary, examples, and provocation. It then handed off to the first panel.

3.2 Panel: Shared Challenges and Opportunities in Coupled Systems

The panel consisted of five speakers, three representing other watersheds or systems and two representing the Chesapeake Bay watershed. Each panelist delivered an 8-10 minute presentation followed by a moderated question-and-answer session facilitated by Theo Lim using Mentimeter. The panel included both in-person and virtual speakers.

Each panelist was asked to address the following questions:

- what are the most important couplings between people, institutions, and environmental conditions in their system; and are how those interactions are currently tracked or managed,
- which dynamics are hardest to observe, represent, or act on,
- where typical model, policy, or management design falls short for real-world watershed problems,
- what feels distinctive about their case, and which lessons are transferable.

Mindy Roberts (Executive Director, Puget Sound Partnership). Mindy discussed the evolution of recovery efforts in the Puget Sound region. She noted that while early management strategies were developed through traditional expert elicitation of scientific subject matter experts, current efforts are shifting toward more inclusive co-design processes. This transition is guided by Washington's [Healthy Environments for All \(HEAL\) Act](#), which mandates that environmental justice be central to identifying what a "healthy" ecosystem looks like and for whom it is being restored. Roberts highlighted the importance of recognizing the deep history of human-natural coupling in the region, specifically citing indigenous "clam gardens" as a form of ancient aquaculture that tribal nations are now reinvigorating to manage nearshore tidal resources. A major takeaway from her presentation was the strategy of engaging marginalized communities through "hub organizations" that serve as trusted intermediaries with existing community relationships, and the necessity of providing compensation for participant time to ensure equitable engagement rather than extractive research. Ultimately, Roberts argued that recovery solutions must reflect broader community values rather than just the perspectives of the experts who originally built the management systems.

Jeff Lerner (EPA Office of Water). Jeff presented on the 2014 Chesapeake Bay Watershed Agreement, utilizing a "puzzle piece" metaphor to illustrate that the Agreement's 21 outcomes are fundamentally interconnected. He introduced the conceptual framework of "headwinds" and "tailwinds," explaining that human behavior can either facilitate restoration (tailwinds) or make it significantly harder through intensifying development and agricultural practices (headwinds). These headwinds require increased resources and fuel to achieve the same amount of restoration progress. Lerner underscored the value of spatial conservation planning, arguing that watershed

plans should transition from just tracking pollution load limits alone to identifying exactly where on the landscape actions should be taken. This spatial alignment allows watershed goals to intersect more effectively with local land-use decisions and non-point source pollution mitigation. He also introduced the term "strategic opportunism," suggesting that successful management requires a balance between rigid long-term planning and the flexibility to pursue immediate conservation opportunities as they arise. Lerner concluded that while the Chesapeake Bay is a uniquely complex system with seven jurisdictions, it can learn from smaller watershed partnerships that excel in building relationships and capacity among partners to secure tangible watershed health in specific catchments.

Lew Linker (EPA Modeling Coordinator, Chesapeake Bay Program). Lew focused on the air-water nexus, demonstrating how atmospheric nitrogen deposition is a major driver of nutrient loads in the estuary. He presented findings from the [Global Change Analysis Model \(GCAM\)](#), which simulates the co-evolution of climate, energy, agriculture, and land use over time to provide managers with an "advantage of insight" into future environmental conditions. Linker's data revealed that the [Clean Air Act](#) and subsequent state-level energy targets have already driven dramatic reductions in nitrogen deposition from 1985 levels, but further gains are possible through "net zero" energy scenarios. He detailed the high sensitivity of the coupled system to economic feedbacks. For example, high global energy prices increase the cost of fertilizer, which can incentivize farmers to plant more nitrogen-fixing soybeans, thereby fundamentally altering the nutrient profile of the watershed. By capturing these interconnected feedbacks between energy policy and agricultural behavior in simulation systems, Linker argued that managers can identify more cost-effective and efficient ways to reduce nutrients compared to siloed water-only strategies. His presentation emphasized that regional water quality is inextricably linked to national and global shifts in energy generation and agricultural markets.

Alyssa Dausman (Chief Scientist, The Water Institute). Alyssa presented the importance of "nexus thinking" that recognizes natural systems are a complex weave of energy, food, health, and the economy. She explained that traditional geographic watershed approaches are often insufficient because critical drivers like groundwater flow and virtual water supply chains cross political and hydrologic lines. Dausman identified a common failure in scientific modeling:

many tools are developed as specialized academic exercises rather than being co-developed with end-users for real-world decision-making. She highlighted that in complex political environments like the Gulf Coast, decision-makers often make choices based on their trust in the individual scientist rather than the raw data itself. To bridge this gap, her organization utilizes Structured Decision-Making (SDM) to build transparent, durable frameworks that can survive political turnovers and administration changes, as seen with the Louisiana Climate Action Plan (Climate Initiatives Task Force 2022). Dausman cited the case of the Mid-Barataria sediment diversion, a multibillion-dollar project that was stalled largely because a subset of stakeholders felt they were never fully engaged as partners in the decision-making process. She concluded that building long-term, non-extractive relationships with communities is as vital as the technical science itself.

Brett Milligan (University of California at Davis, Professor of Landscape Architecture).

Brett examined the California Bay-Delta, describing it as a massive "switching yard" for the state's elaborate water infrastructure. He pointed out that while the Delta is managed under "co-equal goals" of water supply and ecological recovery, these mandates often neglect a "third leg of the stool" which is the place-based values and well-being of the people who actually reside in the Delta. Milligan presented survey data showing that 83% of stakeholders perceive current water management as inequitable, indicating a profound crisis of trust. To combat this, he uses transdisciplinary design and participatory scenario planning to create a shared vision of the future. A primary goal of his work is to "open the black box" of complex engineering models, such as the [CalSim](#) water allocation program, which were previously accessible only to technical experts. By making model results publicly available through interactive websites, Milligan's team allows stakeholders to "pull the levers" of different policy scenarios to see who benefits and who is harmed. He observed that this transparency has uniquely held disparate interest groups in the same room, fostering a co-learning environment where people are actually curious about how others are impacted by climate adaptation decisions.

Common Themes from the Panel

Together, these case studies reveal that the primary obstacles to restoring large-scale ecosystems are not solely technical, but also reside at the intersection of human values, trust, governance,

and institutional transparency. Across the Puget Sound, Chesapeake Bay, Gulf Coast, and California Bay-Delta, panelists identified several convergent themes essential for operationalizing CHANS research and thinking.

1. The Centrality of Trust and Relational Science. A key theme was that scientific data is only as effective as the trust established between scientists and stakeholders. In CHANS terms, a lack of trust creates a disconnect that can delay effective response, while misplaced trust can also divert efforts into ineffective paths. Alyssa Dausman explicitly stated that decision-makers often prioritize their trust in a specific scientist over the science itself, a sentiment echoed by Brett Milligan and Mindy Roberts. To build this trust, the panelists argued for a move away from "extractive" research, in which scientists enter a community solely to collect data, and toward long-term, non-transactional relationships. This includes strategies such as working through "hub organizations," reporting findings back to the community to show how their input was used, and providing compensation for the time of community participants who are not environmental professionals.

2. Shifting from Expert-Led Elicitation to Community Co-Design. Panelists discussed the need for a fundamental shift in how restoration goals are set. Historically, these were determined by "scientific expert elicitations," but the current trend is toward inclusive co-design and participatory planning. Mindy Roberts highlighted how this approach ensures that "healthy" ecosystem outcomes reflect the quality of life and cultural values of marginalized communities rather than just technical metrics. Similarly, Brett Milligan demonstrated that participatory scenario planning can build "social capital" by allowing stakeholders to co-learn and explore the trade-offs of different future adaptations together. This inclusive process expands feedback pathways in CHANS and may also address inequity perceived by the public in systems like the California Bay-Delta.

3. Nexus Thinking and Trans-Geographic Connectivity. Panelists highlighted that traditional watershed boundaries are often too narrow to capture modern coupled systems. "Nexus thinking" was described as a framework for understanding the interdependencies between air, water, energy, food, and the economy. Lew Linker's work showed that water quality in the Chesapeake

is tied to global energy prices and national energy policy, which in turn influence agricultural behavior. Alyssa Dausman added that virtual water supply chains and groundwater movement make geographic watersheds insufficient for addressing the deep uncertainties of climate change and economic shifts. Operationalizing CHANS requires models that simulate these co-evolutionary feedbacks.

4. Transparency and Democratizing Models. To overcome institutional silos and public skepticism, the panelists emphasized the need for transparency and the democratization of scientific data. Brett Milligan's focus on "opening the black box" of engineering models through public-facing, interactive tools is a prime example of this. By making the "levers" of water allocation and policy trade-offs visible, these tools help stakeholders understand the spatial impacts of decisions and who ultimately benefits or is burdened by them. In addition to strengthening trust and accountability, this transparency was cited as a prerequisite for creating durable decision-making frameworks that can survive the rapid turnover of political leadership and administrations.

5. Strategic Opportunism and Spatial Alignment Finally, the panel highlighted the need for management to be both strategic and spatial. Jeff Lerner argued that watershed planning must move toward spatial conservation mapping to align restoration goals with local land-use and development patterns. Furthermore, the concept of "strategic opportunism" was proposed as a way to balance long-term objectives with the flexibility to take advantage of immediate partnerships or funding as they arise. This requires a common lexicon between different types of managers – such as foresters, water quality engineers, and local planners – to ensure that diverse goals like "forest protection" and "nutrient reduction" are realized through the same on-the-ground actions.

3.3 Panel: Policy and Science for Chesapeake Bay Restoration

The panel consisted of three speakers representing federal policymaking, nonprofit leadership, and interstate governance. Each panelist delivered opening remarks followed by a moderated discussion and audience question-and-answer session facilitated by D.G. Webster. The

discussion focused on the institutional, political, and implementation challenges associated with Chesapeake Bay restoration.

Representative Sarah Elfreth (US House of Representatives, Maryland District 3)

Representative Sarah Elfreth emphasized the necessity of moving beyond "random acts of restoration" which she described as politically popular ribbon-cutting events that often lack a meaningful impact on water quality. Her legislative centerpiece, the Maryland Whole Watershed Act (SB 969/HB 1165), represents a shift toward a "bigger, bolder, faster" model informed by scientific reports like the CESR report (Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) 2023). The legislation aims to reduce administrative barriers by bundling funding from multiple sources and ensuring that local zoning and permitting processes are integrated from project inception to prevent inflated costs and years of delays. Elfreth acknowledged that while politicians rarely admit to getting things wrong, the 43-year history of the restoration movement requires a healthy acknowledgment of past failures to refine future strategies. She stressed that the most formative partnership for a lawmaker is with scientists who can translate complex data into actionable policy goals.

Questions and Answers for Representative Elfreth

During the Q&A, Representative Sarah Elfreth addressed the current federal landscape, noting that despite a hyper-partisan environment, the Chesapeake Bay remains a bipartisan success story, recently securing a budget increase from \$92 million to \$93 million. On the "human side" of restoration, she noted that the movement's focus on TMDL metrics, such as nitrogen and phosphorus, can cause it to lose the human connection. She argued that maintaining public support requires emphasizing "living resources" and visible improvements, such as swimmable and fishable water, and public access. When questioned about competing land-use priorities like solar fields and data centers, Elfreth advised that advocates must recognize that not all land is "equally ecologically valuable." She suggested prioritizing the preservation of old-growth forests while balancing the national needs for housing and energy. Finally, she expressed an intent to take the whole-watershed concept national after proving its "theory of the case" through the [Whole Watershed Program](#) (WWP), a five-year pilot program targeting five watersheds through a varied approach of environmental actions for the purposes of improving overall watershed

health. The WWP was legislatively established through the Whole Water Act and funded through existing administrations administered by the MD Department of Natural Resources, MD Department of the Environment, and MD Department of Agriculture.

Hillary Harp Falk (President and CEO, Chesapeake Bay Foundation)

Hillary Harp Falk, President and CEO of the Chesapeake Bay Foundation, highlighted the critical role of STAC and the scientific community, noting that Bay science has been "under attack" and requires dedicated advocacy to protect its funding. She pointed to a significant gap between "what we know and what we do," asserting that world-class science cannot implement itself without the buy-in of local communities and thousands of individual daily decisions. Falk encouraged scientists not to avoid the complexity of the Bay's coupled systems but to "sell it to the public elegantly" by aligning data with the passion people feel for their heritage and identity. A primary focus of her leadership is providing the public with a "winning path to success" by celebrating visible wins, such as the return of seagrasses, to combat the discouragement that can arise when progress remains invisible or falls short of major milestones, such as the 2025 TMDL goals.

Maggie Woodward (Maryland Director, Chesapeake Bay Commission)

Maggie Woodward detailed the immense heterogeneity across the watershed states, where differences in geography, population density, and government structure dictate policy feasibility. For example, while Maryland is almost entirely within the watershed, Pennsylvania's portion is largely rural and agricultural, leading to a focus on local stream health and abandoned mine drainage (AMD) rather than tidal issues. Woodward emphasized that because legislative sessions in Maryland and Virginia are extremely short, ranging from 45 to 90 days, policy ideas must be fully vetted, and opposition managed during the legislative "off-season" to be successful. She highlighted the Chesapeake Bay Commission as a bipartisan forum where legislators from different states can share and adapt successful ideas, citing the recent coordinated cross-state legislation to prevent PFAS-contaminated biosolids from being diverted across state lines, including Maryland Senate Bill 719 (Chapter 329, 2026).

Questions and Answers for Falk and Woodward

The combined Q&A session focused on regional resilience and the psychological impact of restoration grading. When asked whether "yellow" or "orange" report cards could mislead the public during wet years, Falk argued that while transparency is vital, these grades must be paired with a vision of the actions needed to move a specific watershed toward a "light green" status. Woodward addressed concerns about "infrastructure grief" following federal regulatory rollbacks, positioning state legislatures as a critical "firewall" that can quickly reinstate environmental protections (such as those lost following the *Sackett v. EPA* decision [2023]) at the state level. Woodward also warned that policymakers must keep their "eye on the ball" regarding "un-shiny" wastewater infrastructure, noting that the Bay Restoration Fund (SB 320 (Bay Watershed Restoration Fund) 2004) is scheduled to sunset in 2030. Both panelists concluded that visible infrastructure failures, while tragic, have the potential to make otherwise "invisible problems" salient, allowing advocates to strengthen public support for restoration investments.

Commonalities and Key Points: Real-World Barriers and Opportunities

Real-World Barriers:

- **Competing Land Uses:** Policymakers must balance restoration with urgent, competing needs for affordable housing, large-scale energy generation (e.g., solar development), data centers, and food production.
- **Science-to-Implementation Gap:** High-level science often lacks the necessary community "implementers" or the local zoning and permitting alignment required to move from data to on-the-ground action.
- **Narrative Fatigue and Invisible Feedback:** The public can become discouraged by persistent "C" and "D" report card grades over more than four decades of restoration, particularly when feedback loops are slow and major milestones, such as the TMDL 2025 goals, are not achieved.
- **Infrastructure and Funding Sustainability:** Critical funding for wastewater and other basic infrastructure may expire or become vulnerable while public attention remains focused on newer initiatives.

Real-World Opportunities:

- **The State-Level Policy Backstop:** State legislatures can respond proactively when federal environmental protections are weakened or rolled back, preserving or strengthening protections within their own jurisdictions.
- **Whole-Watershed Approach:** Opportunities exist to coordinate funding for the purpose of streamlining implementation and reducing administrative barriers, by focusing on holistic watershed restoration rather than isolated projects.
- **Living Resource Narratives:** Moving toward a "heart-led" narrative that prioritizes swimmable waters, fishable streams, and visible restoration successes, such as recovering seagrasses, can bolster public engagement and sustain long-term taxpayer support for restoration.
- **Inters-jurisdictional Collaboration:** Bipartisan organizations and commissions, such as the Chesapeake Bay Commission, facilitate the exchange of successful policy approaches across jurisdictions, as demonstrated by coordinated PFAS legislation in Maryland and Virginia.

3.4 Cross-cutting themes

The opening presentation and two panels provided participants with a shared vocabulary with which to reason about coupled systems, a set of case study examples from other watersheds and within the Chesapeake, and a candid account of the policy and implementation constraints the restoration effort faces. Several common themes emerged: (1) trust between scientists and people who must act on their findings, (2) the gap between what is known and what is done, (3) the heterogeneity of conditions across a large watershed, and (4) the political and human dimensions that determine whether and which technical solutions are adopted. These are the same dynamics the workshop's activities were designed to examine, and the panels clearly established the dynamics as shared points of reference for the subsequent work in breakout groups.

4. Workshop Activities: Design and Rationale

The workshop addressed the limitations identified in [Section 2](#) through a set of structured activities, guided by facilitators from the workshop steering committee. Five themes were central:

1. Heterogeneous actor participation considers the composition of each group and its facilitation as methodological instruments in their own right. By assembling researchers, managers, and practitioners around common analytical tasks, this approach elicits connections and dependencies less likely to be identified by a single discipline or domain.
2. Systems mapping asks each group to construct a shared diagram of its focal subsystem. Here, the analytical value lies in the generative process, which requires participants to reconcile competing assumptions into a common representation.
3. Anticipatory shocks, or probes, introduce a hypothetical disturbance and trace its propagation through the group's map. The points at which a system fails under stress indicate the dependencies on which its functioning relies, making shocks an efficient means of identifying fragilities in the system, particularly in the governance and social pathways that conventional scenario analysis irregularly examines.
4. The barrier-opportunity diagnostic pairs each identified obstacle with a corresponding opportunity, distinguishing structural obstacles from contingent ones, and aligning each opportunity with an appropriate time horizon to assess when and where intervention is feasible.
5. Cross-group review subjects groups' outputs to critique by others. Where well-informed groups reach divergent conclusions, the dialogue can itself be considered an analytical result warranting further examination.

This section describes the structure and purpose of each activity, along with the materials provided to support it. The results these activities produced are reported in [Section 5](#).

4.1 Systems Mapping and Feedback Typology

Systems mapping is a structured method for representing a system as a diagram of its components and the relationships among them. As a practice, it draws on multiple established traditions, including: 1) causal-loop diagramming of systems dynamics, which represents feedback structure explicitly and treats system behavior as a product of that structure (Sterman 2001; Forrester 1994; Carpenter and Gunderson 2001); and 2) participatory and stakeholder modeling, in which the people holding knowledge of a system jointly construct its representation (Voinov and Bousquet 2010; Peterson et al. 2003). In a participatory systems map, nodes denote elements and edges correspond to the causal or feedback relationships between them. In addition to the knowledge embedded in the system maps, the value of the process also lies in the act of their construction, which requires participants to externalize their mental models and reconcile them into a shared representation.

Working group activities began with systems mapping in order to address the participant and program knowledge gaps diagnosed in Section 2. The return-path feedbacks that are least-represented (i.e., behavioral response, trust, cross-scale governance) are those relationships that verbal discussion most often leaves implicit. Requiring groups to draw social, institutional, and biophysical components in one diagram forces the connection among them to be explicitly specified, including the direction of influence and the mechanism by which one element acts on another. The map is also the artifact built upon by all subsequent activities, so the shared representation it produces is the foundation for the rest of the workshop.

Each group's mapping efforts began with a focused sub-system in which its members had direct experience, selected from a menu of "seed" sub-systems (e.g., agricultural runoff in the Susquehanna, urban stormwater in the Baltimore-Washington corridor, living-resource management on the Eastern Shore) or defined by the group, with instructions to initially favor depth over breadth. Groups first mapped how human decisions shape environmental conditions, using color-coded cards for social, ecological, and technical elements and drawing links annotated according to direction, expected time lag, and strength of evidence. For example, a

solid line denoted a well-supported link, whereas dashed line indicated one that is plausible or contested. The group's facilitator directed participants to add the return pathways from environmental conditions back to human behavior, including the mechanism underlying each pathway. For instance, a pathway running from monitoring data through regulatory reporting to budget allocation would be distinguished from a pathway connecting observed hypoxia to a waterman's harvest decision. A further overlay on the system maps separated those feedbacks mediated by technical systems from those mediated by governance processes. Finally, groups classified each feedback using a typology based on how well they are represented in the CBP modeling, monitoring, and management systems compared to how well the problem is understood. The four classes in this typology were:

1. Known but poorly observed (KO): a monitoring problem
2. Observed but poorly represented (OR): a modeling problem
3. Represented but not actionable (RA): a decision-support problem
4. Constrained by norms and politics (NP): a governance problem

Each group's output was an annotated map of its subsystem, followed by a closing reflection comparing the return pathways it had drawn with the forward pathways.

4.2 Shock-propagation and Gap Analysis

Session 2 comprised two linked activities – a shock-propagation exercise followed by a gap analysis. Shock-propagation is a form of scenario-based stress testing. Scenario planning utilizes a small number of contrasting, plausible futures to examine how a system might behave under conditions that cannot be predicted with confidence (Peterson et al. 2003). Applied to the groups' system maps, it becomes a perturbation analysis, where a disturbance is introduced and followed through the network of components and feedback loops, in the spirit of resilience research on how systems absorb (or fail to absorb) disturbance (e.g., (Walker et al. 2004)).

This exercise addresses the anticipatory-analysis limitation identified in [Section 2](#). The partnership conducts scenario analyses on biophysical loadings, but reasoning about how shocks

propagate through coupled human and institutional pathways is less routine. Tracing a disturbance through a system map brings those pathways more clearly into view and identifies where detection fails, where response does not follow, and where the chain of causation breaks.

Each group stress-tested its Session 1 map against one of three classes of disturbance scenarios (i.e., ecological, policy, and socio-economic), which were supplied as a one-page brief and anchored to historical analogs (e.g., the 1997 Pfiesteria outbreak, Pennsylvania's longstanding AMD legacy, the January 2026 Potomac Interceptor breach) to ensure the scenarios were viewed as plausible. The disturbance briefs are included in the report appendices. The tripartite division directed attention to governance and economic disturbances, not just ecological ones. Groups traced the shock from its point of entry, marking each link as either: (1) intact, (2) weak or delayed, (3) broken, or (4) absent. They then recorded, at each affected node, who would detect the change, by what mechanism, and how long after it occurred.

The gap analysis is a prioritization method adapted from importance-performance analysis, which places attributes on a grid according to their importance and their current performance in order to direct attention where it is most warranted (Martilla and James 1977). In this adaptation of the method, the second axis replaces "performance" with "representation" – each system interaction is positioned by its *importance to restoration outcomes* and by *how well current tools represent the interaction*. This activity was designed to address the admissible evidence and behavioral feedback limitations of Section 2. The use of a grid compels groups to rank their concerns, and positions the high-importance/low-representation quadrant as the primary target, as it is where the behavioral, trust, and governance gaps are expected to fall.

Working from the gaps and breakdowns the shocks exposed, each group selected up to three interactions that matter most for system behavior but are weakly represented, first recording for each its importance and the nature of the representation problem, then asking why the interaction is difficult to formalize (e.g., limitations in data, institutional incentives, nature of the interaction). Groups placed their selections on a single shared matrix at the back of the room, aggregating their contributions into a workshop-wide map of priority gaps.

4.3 Headlines from 2050

Following the rescheduled Day 2 panel, participants engaged in a "Headlines from 2050" futures exercise. Groups were asked to develop concrete news headlines describing the watershed at a chosen future date, treating them as imagined newspaper accounts. Each group wrote its headlines on color-coded newspaper templates, with instructions to be specific and concrete rather than vague or aspirational. For example, a headline naming a measurable outcome (e.g., a first summer with zero hypoxic days, the closure of the last crab-processing plant) was preferred to a general statement that the Chesapeake Bay had recovered or declined. Groups could add a short sub-headline to provide additional context and posted their headlines to a shared wall, where the full set served as the starting point for the session that followed.

This method belongs to the tradition of normative scenario analysis and backcasting, in which a group articulates desirable and undesirable end states, and then reasons backward to the decisions that would produce them. Backcasting provides a mechanism for social learning about which futures are possible and which are worth pursuing (Robinson 2003). By writing a contrasting pair of headlines, one desirable and one undesirable, groups followed the scenario-planning principle that a small number of divergent, plausible futures can illuminate the uncertainty surrounding a decision (Peterson et al. 2003).

The Headlines activity serves two purposes. First, it elicits and makes explicit the values and assumptions participants hold about what restoration is for, which the more technical activities leave implicit. and in doing so admits narrative and normative reasoning as legitimate analytical inputs. As noted in Section 2, this mode of knowledge is seldom formalized in the partnership's tools. Second, it generates the raw material for the following session, as placing desirable and undesirable futures side-by-side allows groups to identify the critical thresholds where the system can tip into alternative states.

4.4 Barrier-Opportunity Diagnostic

The barrier-opportunity diagnostic is a structured method for identifying the factors that hold a CHANS on its current trajectory and what internal or external forces might shift it to a new regime. The method's analytical basis includes barriers to adaptation, which treats obstacles to change as a diagnosable set with distinct types and sources (Moser and Ekstrom 2010). Pairing each barrier with an opportunity, and then distinguishing among opportunity types, draws upon the policy-process and transitions literature, including the notion of a policy window – a transient opening in which change that is normally blocked becomes possible (Kingdon 1984).

This activity was designed to address the cross-scale governance and behavioral limitations identified in Section 2 by making explicit the institutional and political obstacles to change. It also provides a structured transition from diagnosis to action. By requiring an opportunity for every pairing, it prevents the exercise from devolving into one simply producing a catalog of complaints. Further, by classifying each barrier as structural or contingent, it separates obstacles that require deliberate reform from those that current conditions could potentially shift.

Each group returned to its headlines to complete the barrier-opportunity activity. Comparing the desirable and undesirable versions of the future, groups identified the critical points at which the system could tip toward either outcome, and marked them on their Day 1 map. For approximately three of those critical points, they identified the barrier holding the system on its current path and a concrete opportunity to shift it, essentially working both sides simultaneously. Each *barrier* was characterized by type (i.e., institutional, political, technical, economic, social), by whether it was structural or contingent, and by the actor (s) who maintained it. Next, each *opportunity* was characterized by its mode – reform, work-around, or exploitation of a window – along with its time horizon, the actors who would need to act, and its feasibility.

4.5 Recommendations and Cross-Group Peer Review

The final activity built on all previous efforts by developing the barrier-opportunity pairs into specific recommendations and subjecting them to cross-group peer review, in which each group's

recommendation is critiqued by another group of workshop participants. Note, we distinguish within-workshop peer review as distinct from the anonymous disciplinary refereeing the term ordinarily denotes. This activity reflects the premise of knowledge co-production – that knowledge intended to inform action is more useful when those who will use it are involved in its production (Norström et al. 2020). The standard established by the activity for a recommendation, and the criteria used in its review, parallel what the literature identifies as the conditions for actionable knowledge. Namely, that it should be scientifically credible, salient to decision-makers' needs, and legitimate in how it was produced (Cash et al. 2002).

This final activity was where the workshop's many diffuse analyses and artifacts coalesced into a set of actionable proposals. The activity's design enforced specificity to ensure a reader who did not attend the workshop could act on the recommendations. Specifically, each recommendation must state: (1) what should be done, (2) by whom, (3) at what spatial scale, and (4) why it would work. Review by an adjacent group evaluated each recommendation against these criteria before it was finalized, and treats disagreement among groups as information about a recommendation's robustness.

Working from their strongest barrier-opportunity pairs, groups developed them into a full recommendation structured around five elements:

1. A problem statement linked to the Day 1 map and Session 3 analysis.
2. A concrete proposed action.
3. An implementation pathway with near-term, medium-term, and long-term steps, as well as a candidate home among CBP structures.
4. Risks and dependencies.
5. Indicators of success.

Each group then passed its top recommendation to another group, which reviewed it for credibility, feasibility, and consequentiality. The reviewing group then returned written feedback. Given time limitations at the end of Day 2, peer review was unfortunately cut short, and a planned second round of iteration and review was omitted. Groups closed by preparing a short

verbal summary of their strongest recommendations, and a nominated group member presented them to the full workshop.

Together, the five activities form a deliberate, structured sequence. First, groups produced a shared map of the system. They then stress-tested the map to identify and prioritize gaps. Next, they imagined a pair of futures, explored the barriers between them, and finally developed a set of recommendations to address them. Each activity supplied the working materials for the subsequent task. Group facilitators provided summaries of the two days' activities, which contributed to this report. All participant materials are included in the appendices.

5. Workshop in Practice: Activities and Outcomes

This section reports the outputs of the workshop's activities. Each subsection details the outputs of the six breakout groups for a single activity, then synthesizes the patterns and themes that emerged across groups. Groups worked on deliberately varied focal systems, including poultry litter on the Eastern Shore (Group 1), coastal climate and water quality (Group 2), Delmarva agriculture (Group 3, and Group 5 with an emphasis on chicken litter and crop-poultry integration), Pennsylvania urban stormwater (Group 4), and agricultural runoff in the Susquehanna (virtual group, Group 6).

5.1 Systems Mapping

The systems maps produced by the six groups differed as much as their focal systems, yet converged on a common perspective. As noted above, the groups began their work by focusing on agriculture, urban stormwater, and the coast, addressing problems as disparate as poultry litter, coastal water quality, and AMD. However, across all groups, the system maps centered on structural elements within the social "side" of the coupled system: the importance of multi-scale policy and regulatory agencies and concomitant processes, trust among producers and policymakers (e.g., group 6), the importance of relationship building (e.g., group 2), and connections between regional decisions and local action. In most cases, biological pathways were drawn quickly and the group annotations indicated greater confidence in their understanding. In contrast, the contested and under-developed parts of the maps were social, institutional, and governance-related.

Several groups made the centrality of social systems explicit in the architecture of their maps. For example, Group 3 placed "People" at the literal center of its Delmarva agricultural map, with governance, markets, technology, and cropland arrayed around it, and the most consequential links annotated as bi-directional connections. Group 2 first placed trust between communities and institutions at the center of its coastal map, pulling in policy, social inequity, and vulnerability as the diagram emerged, until hazard vulnerability, inequity, and trust formed a closed loop running through both human and natural subsystems.

Even groups that did not start with humans at the center of their analysis still converged on similar conclusions regarding the importance of social systems. Group 4, working on Pennsylvania urban stormwater, mapped a causal chain from development and climate through runoff to flooding and water quality, and then found that the binding constraints lay elsewhere in the system. In this instance, the constraints were in a permitting process that handles applications in order of submission rather than priority, in a documented loss of the specialized modeling and GIS capacity the work requires, and in the long temporal lag between the installation of stormwater infrastructure and its eventual improvements on quality of life – so delayed that in the opinion of the group, it barely registers as a feedback at all. Group 1, mapping poultry litter, traced the nitrogen that pollutes water and the ammonia that pollutes air and burdens neighboring communities, then concluded that the driving forces in the system were regulation, demand, and political will. It also captured a feature of the partnership's monitoring and modeling framework, which the group described as, "we monitor the things we model." The data and the model each constrain the other.

When the groups annotated feedbacks on their maps using the provided typology, governance and behavioral linkages were overwhelmingly classified as "constrained by norms and politics" (NP) or "known but poorly observed" (KO), whereas the biophysical links were judged as adequately managed. Group 3 went further and created a fifth label, "KORA" (known, observed, represented, and actionable). They applied the KORA label to just two links, both of which were purely technical (i.e., agricultural efficiency and technical systems acting on cropland outcomes). Every link to the socio-economic/governance components of Group 3's map was labeled as NP. Further, the human relationships that Group 3 identified as most central, links between people and both technical systems and economic disparity, were classified as KO (known but poorly observed) or OR (observed but poorly represented). Group 1 independently reached the same classification, placing its governance processes in the NP category (constrained by norms and politics), and noting that these processes turn on trust, transparency, and social networks that current CBP tools do not capture.

The system maps repeatedly identified trust and the complex, context-dependent nature of

human decision-making is an under-represented layer in Chesapeake Bay CHANS. The virtual group (Group 6) mapped agricultural runoff in the Susquehanna region, and filled its social quadrant with the realities that Pennsylvania's county conservation districts confront: farmers' trust in advisors, a stigma labeling the acceptance of government grants as "taking a handout", and producer behavior that CAST represents only through generalized assumptions. Group 5 built its Delmarva map around the structural separation of crop and poultry operations established over decades.

Two groups also found that their starting frame had hidden or omitted consequential elements. For example, Group 2 had left exposure out of its hazard-vulnerability exploration, an omission that surfaced after its 2050 Headlines exercise (see 5.3) focused on housing and businesses. This illustrates how an initial framing choice or stakeholder inclusion can create blind spots that propagate through subsequent analyses. Group 1's facilitator observed that a group composed almost entirely of natural scientists had treated stakeholder engagement as a remedy without fully engaging with it – a reminder, in the facilitator's words, that coupled-systems methods "may help participants fill in gaps and recognize a wider range of system interactions without actually challenging their preconceptions." What a group leaves off its map, and who is in the room to notice, shapes the scope of the analysis.

Overall, the mapping exercise emphasized (often to participants new to coupled-systems work) that the least-developed part of the Bay's analytical structure is the representation of human agency, trust, and governance – the return feedback pathways discussed in Section 2. Notably, groups did not require new ecological data to reach this conclusion, but rather they needed a method that required them to draw the social and institutional causal links and to mark how well current tools handle each. The diagrams capture each group's perspective of the system, but the larger benefit to the activity was the shared understanding produced by their creation.

5.2 Shock Propagation and Gap Analysis

In the second breakout session, groups traced ecological, economic, or policy disturbances as they propagated through the systems maps they had built. Across the groups, these shocks

exposed institutional and governance fragility more readily than ecological fragility. In other words, when the system failed to adapt to a shock, it was typically because of disconnects in the social component of the CHANS diagram. Also, the pathway(s) that determined whether the system was able to recover were almost always related to policy and funding responses, rather than the initial triggering event.

As an illustrative example, Group 3's scenario shock provided the cleanest case. As the group traced the adoption of a pay-for-performance nutrient regulation through its map, it found that the connections in the system most likely to be weakened or broken were social feedbacks among governance structures, technical systems, and economic disparity. In contrast, the agronomic chain from inputs to cropland results remained intact. In tracing the shock, the group also identified a connection from climate change to irrigation that the group's original map had omitted. In refining their analysis, the group concluded the perturbation caused the system to fail through its institutional connections, while the biophysical machinery remained intact and functioning.

Group 1 examined one shock for each of three scenario types, drawing the same general lessons from all: (1) lack of trust in government obstructed response, (2) financial resources strongly influenced the system's ability to absorb the shocks, and (3) the government often acted as a bottleneck, except for relatively "easy", politically expedient fixes such as bailing out troubled industries. In the ecological scenario, for example, a wet spring produced hypoxia and harmful algal bloom events that killed crabs and other species, harmed watermen and the seafood industry, and activated environmentalists who pushed for stronger nutrient reductions. Backlash from poultry farmers offset pressure from environmentalists, while there was no opposition to a bailout for the watermen and limited terrestrial agricultural reform. The group treated this dynamic as a rapid cycle with limited long-term impact, distinguished between "easier" options and the "harder" choice of increasing BMP implementation, and added a new feedback link from farmers to regulators.

Continuing with Group 1's policy and funding scenario, a 40% cut to CBP funding reduced monitoring, enforcement, engagement, and support for popular programs. The group concluded

that the response would depend on whether environmentalists, farmers, and other stakeholders worked together to restore funding or instead became "stuck in the blame game." Finally, the group's socioeconomic scenario (a sudden rise in crop-farmers' production costs that cut demand for poultry litter and reduced the profitability of chicken farming) again resulted in farmers demanding relief and the provision of short-term government subsidies. Across all three scenarios, the group identified political influence as an important moderator of feedbacks from the environment to affected individuals to decision-makers and, ultimately, back to the environment.

Group 4's treatment of the funding-reduction shock lengthened every project timeline and, flipping the scenario around, exposed the opposite problem: the partnership cannot absorb sudden funding injection efficiently, as these often arrive on short timelines with pressure to spend the funds before the planning and permitting are in place. The group named the costs of perpetuity waiting for windfalls that may never materialize as "hope fatigue."

Group 2, for its part, could not trace its funding shock until it resolved an ambiguity in its own node labels, discovering that "hazard" and "water quality" had opposite meanings to different members depending on the direction of interaction. All of the groups experienced similar instances of continued learning and discovery during this stage, though most were not so thoroughly diverted.

The gap analysis that followed transformed the specific failures due to the simulated shocks into a more general picture. Each group placed the interactions it judged most important and least well represented onto a shared matrix, defined by importance to restoration outcomes versus representation in current tools. Aggregating the contributions from all groups produced a workshop-wide map of priority gaps. The high-importance/poorly-represented quadrant was aligned with the highest priority gaps. Groups filled this quadrant with social, behavioral, and governance items – social and psychological response, trust and relationship building, the navigation of public outreach, incentives for nutrient management plan adoption, regulatory bottlenecks, and the temporal lag between funding allocation and action. The well-represented quadrant held the biophysical and technical apparatus of the CBP, largely corresponding to water

quality monitoring and modeling. A single unqualified "BMPs" entry was the only item placed in the low-importance, poorly-represented quadrant.

Together, the shock-propagation and gap activities allowed participants to both individually and collectively produce the diagnosis found in Section 2. When asked where the system was fragile, groups pointed to governance and social pathways. When considering which interactions matter and which tools fail to represent them, participants collectively developed a map of priority gaps that was almost entirely social, behavioral, and institutional. The aggregated matrix was the workshop's evidence of the directional asymmetry in our understanding of the coupled system. The partnership effectively represents the forward, biophysical pathways, whereas the return paths of behavior, trust, and governance remain the least of represented.

5.3 Headlines from 2050

Asked to imagine the Chesapeake of 2050 in a pair of newspaper headlines, one desirable and one undesirable, the groups wrote almost exclusively about people, institutions, and politics. The positive and negative futures alike turned on whether the partnership held together, whether communities were displaced, and whether restoration maintained public support. Nutrient loads and BMP efficiencies appeared, if at all, only as the implied backdrop behind human outcomes. The full set of twelve headlines is reproduced below, and the source worksheets are included in the report appendices.

Table 1: Headlines from 2050, as produced by breakout groups. Each group created headlines representing desirable and undesirable futures.

Group	Desirable Headline	Undesirable Headline
1. Eastern Shore Poultry	<i>Chickens Power the Watershed & Heal the Bay!</i>	<i>60 Years, Billions Spent. Chesapeake Still a 'D' – Is it time to retire the CBP?</i>
2. Coastal community, water quality	<i>Record Investment in Community Resilience Act Bolsters Shorelines and Affordable Housing!</i>	<i>Thousands Displaced in Annapolis, Last Business Closing Its Doors – Critical Stormwater Funding Cancelled</i>
3. Delmarva agriculture	<i>25 Year after performance-based nutrient regulations, bay recovery remains stagnant</i>	<i>Drinking water Nitrate Levels Continue to Decline in Delmarva</i>
4. Urban stormwater	<i>Chesapeake Bay Wetland Comeback Cuts Baltimore Flood Damage by Half, Saving Neighborhoods millions in Annual Repair Costs</i>	<i>Baltimore's 100th Hundred-Year Flood in a Decade Overwhelms Aging Infrastructure, Displacing Thousands of Residents</i>
5. Delmarva agriculture; chicken litter	<i>Have another Crab Cake Chesapeake Bay is Great Again!</i>	<i>Chicken shit and bullshit, Policymakers struggle to find a path forward</i>
6. (Online) Susquehanna agriculture	<i>All CB states met 2045 goals and the watershed is thriving</i>	<i>Environmental rollbacks lead to fishery collapse in the Chesapeake Watershed and stormwater continues to be a problem!</i>

Several groups made the CBP itself the subject of their headlines. Group 1's undesirable future asked, after "60 Years, Billions Spent, Chesapeake Still a 'D'," whether it was "Time to Retire the CBP?" Group 3's undesirable headline reported that "25 Years After Performance-Based Nutrient Regulation, Bay Recovery Remains Stagnant." The virtual Group 6 juxtaposed a positive future of "All CB states met 2045 goals and the watershed is thriving" against an undesirable possibility, "Environmental rollbacks lead to fishery collapse in the Chesapeake Watershed." In both futures (positive and negative), the unit of analysis was the institution and

its credibility, and the gap between the two was driven primarily by political will rather than any biophysical threshold.

Within a single focal system, headlines commonly diverged in tone. For example, both Groups 1 and 5 worked on Eastern Shore agriculture. Group 1's hopeful "Chickens Power the Watershed & Heal the Bay!", premised on a manure-to-bioenergy technology the group admitted it "did not really expect" to occur, stands in contrast to Group 5's bleak "Chicken shit and bullshit, Policymakers struggle to find a path forward." The comparison captures the swing between technological optimism and governance cynicism that emerged during the workshop. Group 5's desirable future, "Have another Crab Cake – Chesapeake Bay is Great Again!," framed recovery from the perspective of restored seafood and public enjoyment, rather than any single intervention. Group 1 noted that the causal pathway behind its hopeful headline lay almost entirely outside its system map, in exogenous forces it could not control.

The coastal and urban groups wrote the most explicitly about people in the coupled system. Group 2 paired "Record Investment in Community Resilience Act Bolsters Shorelines and Affordable Housing" with "Thousands Displaced in Annapolis, Last Business Closing Its Doors – Critical Stormwater Funding Cancelled," and Group 4 set a wetland comeback that "Cuts Baltimore Flood Damage by Half, Saving Neighborhoods Millions in Annual Repair Costs" against "Baltimore's 100th Hundred-Year Flood in a Decade Overwhelms Aging Infrastructure, Displacing Thousands of Residents." In both cases, the headlines turned on funding, displacement, and who bears the costs, highlighting the social-equity dimension of restoration that is unrepresented in technical tools.

Because the exercise asked groups to reason backward from each headline to the decisions, feedbacks, and tipping points that would have produced it, the activity produced more than simply a set of imagined futures. The backcasting step transformed each narrative into an explicit account of the causal pathways, institutional failures, and research gaps separating the desirable and undesirable futures. Group 3's worksheet provides evidence of the backcasting process and outcomes. Its desirable headline, "Drinking Water Nitrate Levels Continue to Decline in Delmarva," placed success in a tangible, household-level outcome, the quality of communities'

drinking water. Working back from its undesirable headline, in which Bay recovery "Remains Stagnant," the group listed the causes as: (1) government "fails to get industry and farmer buy in," (2) "farmers don't follow nutrient management plans," and (3) "cost share programs discontinue in exchange for regulation." When prompted to identify what the group would most want to have started studying in 2026, it answered with "a way to measure performance," an "ag mass balance," and "behavioral science."

The headlines approached the admissible-evidence points of Section 2 from a different direction. When groups were asked to imagine the future using narratives instead of numbers, participants immediately focused on people, institutions, and politics, or the parts of the system that formal tools currently hold at arm's length. The exercise suggests that participants already recognize where the consequential dynamics lie. However, what remains limited is a routine mechanism for integrating that knowledge into formal analysis.

5.4 Challenges and Opportunities

Across groups, the identified barriers holding the system on its current trajectory were predominantly institutional, political, and social. Trust recurred most often as agency-producer trust for the agricultural groups, or community-jurisdiction trust for the coastal-focused breakout groups. Institutional rigidity was also a common barrier, in Group 3's "regulations resisted", Group 4's "overly rigid state agencies," and Group 5's structural barrier that "...poultry and crop farms have been established over decades." A third cluster of barriers was related to capacity. Group 1 found that engagement professionals are stretched thin, while Group 4 reported losses in GIS and specialized modeling expertise.

Group 2's trust barrier was perhaps the clearest example. The group argued that trust erodes through an information-relevance disconnect, where there is a "gap between what [information] scientists believe stakeholders need and what stakeholders actually use." The group repeatedly returned to an illustrative example: a chicken farmer "needs information about boosting productivity to feed their family, not abstract water quality metrics for the Bay." The corresponding opportunity identified by the group was to tailor information to decisions that

stakeholders actually face, using reporting protocols and communication channels already in use by those stakeholders.

Pairing each barrier with an opportunity guided the analysis toward action, while sorting opportunities by mode (i.e., reform, work-around, exploiting a window) separated actions that could move quickly from those that would require structural change. Group 3 matched its contingent barrier of "resisted regulation" to a window of opportunity. If funding to help farmers comply "materialized," the state legislature could act within two to three years. Group 4 drew an opposite lesson from its windfall problem and proposed preparing in advance so that a funding window could be met with a "library of shovel-ready projects" rather than an empty pipeline. Group 5 judged its crop-poultry barrier to be structural, an example of path dependency in which the separate establishment of poultry and crop operations over decades has locked the system in a configuration that resists change, and is therefore a matter of longer-term structural reform (Pierson 2000; Allison and Hobbs 2004).

The barrier-opportunity activity required groups to distinguish between actions that could be taken immediately from those that would take a generation. For each barrier, participants were asked to identify who maintains it, and whose interests the current arrangement benefits. It was also the most loosely completed of the day's activities. With time short on Day 2, several groups completed the worksheets only in part, and the record from this session is therefore thinner than for other activities. However, the groups' outputs still identified a distinction among system barriers. The structural barriers reflect a lock-in mechanism based on the system's history, while the contingent ones mark windows of opportunity where a well-timed intervention might redirect it (Kingdon 1984). By naming the "holder" of the barrier (e.g., a farm lobby, permitting queue, election cycle), participants translated the issue or complaint into a target of action. Once again, this finding illustrates the need to treat system governance not merely as background context, but as its own subject of analysis.

5.5 Recommendations and Cross-Group Peer Review

In the workshop's final activity, each group converted its earlier diagnoses into a single recommendation and reviewed the recommendations developed by a neighboring group. These proposals represent the participant's clearest statement of what the partnership should do differently. Nearly every recommendation targets the "return path" of the system from environmental conditions back to human behavior. The mapping and shock activities demonstrated that the partnership represents the forward, biophysical pathways well, but the return path of behavior, trust, and governance less effectively, and the groups proposed methods to strengthen the latter. This convergence is a finding in itself. Six groups, working largely independently on different focal systems and composed of different participants with different initial framings, arrived at a common and limited set of targets:

1. trust and relationship infrastructure
2. locally-led and flexible implementation
3. readiness for funding and crisis
4. indicators for the social signals omitted by current models
5. an institutional home for the competency to pursue the preceding priorities

In a coupled, complex adaptive system, convergence of this form from heterogeneous initial conditions strongly suggests that a small number of structural elements govern much of the system's behavior. [Section 7](#) presents the developed recommendations and the rationale for each.

The peer review conducted between adjacent groups produced disagreements that are themselves worth recognizing as a finding, although the record is partially incomplete, as time was short at the close of Day 2, and a planned second round of reviews was accordingly omitted. The exchanges reveal important differences among groups while also highlighting the value of collaborative review. For example, Group 1's reviewers maintained that "lack of trust was not the only barrier," and that economic incentives were absent on both the price and cost sides of farmers' decisions. Here, the groups framed the same evidence differently, with one leading with trust and the other with incentives. Group 2's reviewers questioned whether trust could be

established at the necessary scale through only "a few projects," and whether CBP possesses the structure and resources to support such an effort. Group 4's reviewers raised the practical question that its optimization proposal had left unanswered in "who will do the community engagement, and how will funding be channeled?" Beneath these specific disagreements, however, there was a shared conclusion. Most groups affirmed the methodological gap within the CBP, noting that the partnerships' current analytical structure does not produce the modes of outputs required to act on the priority-gap items identified during the workshop.

The candor of the review process speaks to the open communication channels within the partnership. Group 1's facilitator recorded that the group's recommendations felt "fuzzy" and that the group had often treated stakeholder engagement as a "panacea." The facilitator attributed this tendency to a group composed almost entirely of natural scientists, who regarded the principal drivers of pollution as largely beyond their control and had few practitioners present to challenge that perspective. Disagreements represented in the review process, arising among well-informed groups reasoning from the same evidence, constitute legitimate scientific findings for a cross-actor workshop. Current CBP practice provides no standing mechanism to elicit or act on these differences in perspectives, a gap directly addressed in the methodological recommendations in [Section 8](#).

6. Synthesis

Running multiple activities with several groups allows the workshop findings to be triangulated, with each method and data source serving as a check on the others. Three conclusions follow. First, a single diagnosis recurs across activities that approach the system from different perspectives and analytical methods. Second, a post-workshop survey of attendees independently corroborates that diagnosis. Third, the coupled-systems framing altered some aspects of the analysis while leaving others untouched.

6.1 Cross-cutting Findings Across Activities and Groups

The clearest signal in the workshop outputs is the centrality of social systems. When participants mapped their systems and when they imagined the Chesapeake of 2050, they wrote about people, institutions, and politics, and rarely about nitrogen loads, BMP efficiencies, or atmospheric deposition. The system maps encoded this structurally, while the headlines did so narratively. By locating the consequential dynamics in the social layers, the groups arrived independently at the central premise of coupled human and natural systems research: that the social subsystem is endogenous, and linked to the biophysical components by bidirectional feedbacks (Liu, Dietz, Carpenter, Folke, et al. 2007; Ostrom 2009; Folke et al. 2021).

Three activities reached the same conclusion regarding where the CBW system is most fragile. The systems maps placed governance and regulatory nodes at the core of their causal structure (see [Section 5.1](#)); the shock-propagation chains broke at those same nodes, where the institutional response (and not the triggering event) determined whether the system recovered ([Section 5.2](#)); and the barrier-opportunity diagnostic identified institutional rigidity and trust as the controlling constraints ([Section 5.4](#)). The aggregated gap-analysis matrix made this convergence explicit, as the high-importance, poorly-represented quadrant was almost entirely filled by social, behavioral, and governance items.

Trust was the most pervasive factor throughout. It appeared in the maps as a producer-adoption feedback (Group 1) and at the center of Group 2's analysis. In the shock responses, trust was the

variable that determined whether actors cooperated or assigned blame (Group 1, Group 6). It was the most commonly cited barrier during that activity and is also present in the substantive proposals below. The workshop treated trust as endogenous to the system (shaped by the system *and* shaping it in turn), whereas current monitoring and modeling frameworks treat it as exogenous, if they consider it at all. That treatment aligns with the literature on conservation behavior, in which trust between producers and agencies is among the most reliable predictors of practice adoption (Stern and Coleman 2015; Prokopy et al. 2019; Lu et al. 2022). Recent work in the CBW reaches the same conclusion, finding that engagement efforts that build practitioner-farmer trust directly influence adoption (Read et al. 2024).

Institutional rigidity took three forms across the workshop. The first was jurisdictional inertia (identified by Group 3), realized here as the lag between a regional decision-making and local action, representing a scale mismatch and fit problem (Cash et al. 2006; Folke et al. 2007; Bodin et al. 2020). The second was the lock-in of performance-based programs (Group 3, Group 5), which has the structure of a rigidity trap in which the controls directed at short-term gains erode longer-term adaptive capacity (Carpenter and Brock 2008; Goldstein et al. 2023). The third was the absence of CHANS competency from the partnership's formal structures (identified across all groups).

In cross-actor workshops of this kind, groups routinely disagree and hold differing perspectives, and those disagreements can themselves be treated as findings. For example, cross-group review distinguished trust-first from incentive-first explanations of farmer behavior, as well as technical-predictive from community-engagement approaches to implementation. These are differences in how well-informed participants framed the same evidence, and they are the kinds of disagreement that post-normal science treats as legitimate analytical content rather than noise (Turnhout et al. 2020; Funtowicz and Ravetz 1998). A partnership that intends to use cross-actor analysis will require a formal mechanism to capture differing perspectives and treat them as evidence.

6.2 Triangulation with Post-workshop Survey

To assess whether the workshop's themes resonated across participants, and to capture individual reactions that may have been less apparent in a group setting, an anonymous Qualtrics survey was administered in the weeks following the workshop. The instrument received 20 completed responses and covered five areas: (1) respondents' background and experience, (2) the importance of integrating social science into the partnership's work, (3) the relevance and current use of CHANS concepts, (4) an evaluation of the workshop itself, and (5) interest in a follow-up interview. Most questions used simple Likert scales, with open-text fields for elaboration. The breakout groups reasoned together in the open, while the survey reached participants individually and in private. Accordingly, the survey serves as an independent verification on the workshop outputs. The full instrument and results are included in the appendices. This section summarizes the key findings from both the survey and the breakout activities.

The survey's central finding aligned with those from the workshop. Respondents rated all six CHANS concepts as relevant to Chesapeake restoration, with averages between 3.29 and 3.55 on a four-point scale, with feedback loops and path dependence receiving the highest ratings. They then rated the current state of CHANS thinking in the CBW work much lower, with all six dimensions between 1.9 and 2.32, corresponding to "minimally reflected." Institutionalization, defined here as embedding CHANS thinking in formal processes, was the lowest rating at an average of 1.90. Accordingly, the gap between high relevance and low institutionalization is the survey's central result (Figure 2). This pattern of relevance without uptake is known as a knowledge-action gap (Cash et al. 2003; Kirchhoff et al. 2013; Chambers et al. 2021), and mirrors the conclusion reached by the breakout groups, which recommended housing CHANS competency within the partnership's formal structures (see [Section 7](#)).

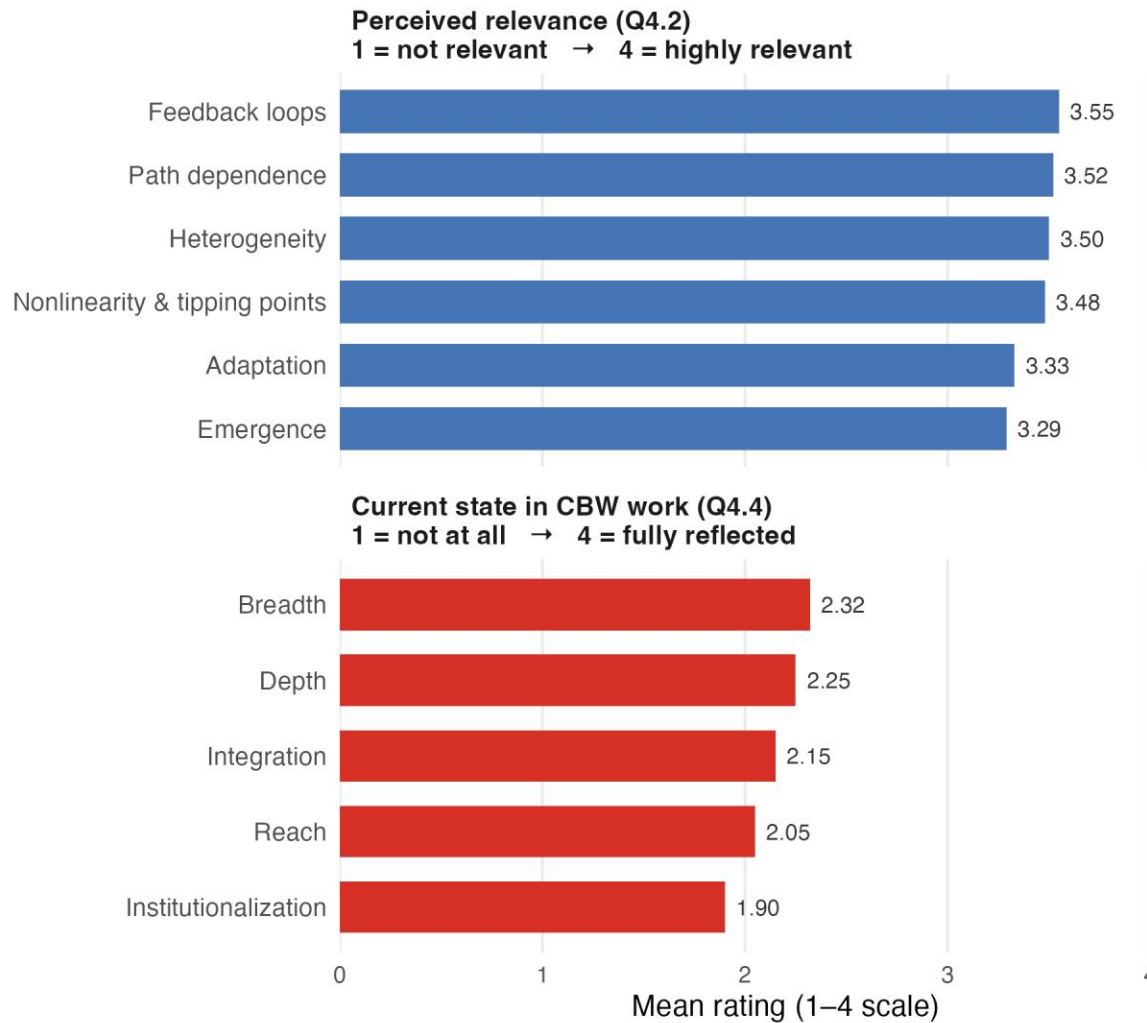


Figure 2: Perceived relevance and current state of CHANS-thinking in and to the CBP partnership. Elements were scored by respondents on a 1-4 scale.

The survey's barrier question corroborates the in-workshop barrier-opportunity diagnostic activity. When asked for the single most significant obstacle to integrating social science, respondents named the institutional structures that do not create space for it (29%) and skepticism about its relevance or rigor (19%), together accounting for nearly half of all responses (Figure 3). Both are organizational and cultural issues, which matches the institutional rigidity and political-cultural ambivalence groups identified, and neither is a question of technical capacity. While respondents communicated doubt about social science's relevance or rigor as a barrier to integration, the inverse also holds. Social science proposals do not consistently contain defined entry points into the system, specified deliverables, or measurable constructs, which can

make them difficult for the partnership to act on, despite their intellectual merit. Recognizing the reciprocal nature of this skepticism suggests there is value in structured venues in which specific proposals are presented, critiqued, and aligned with partnership decisions points.

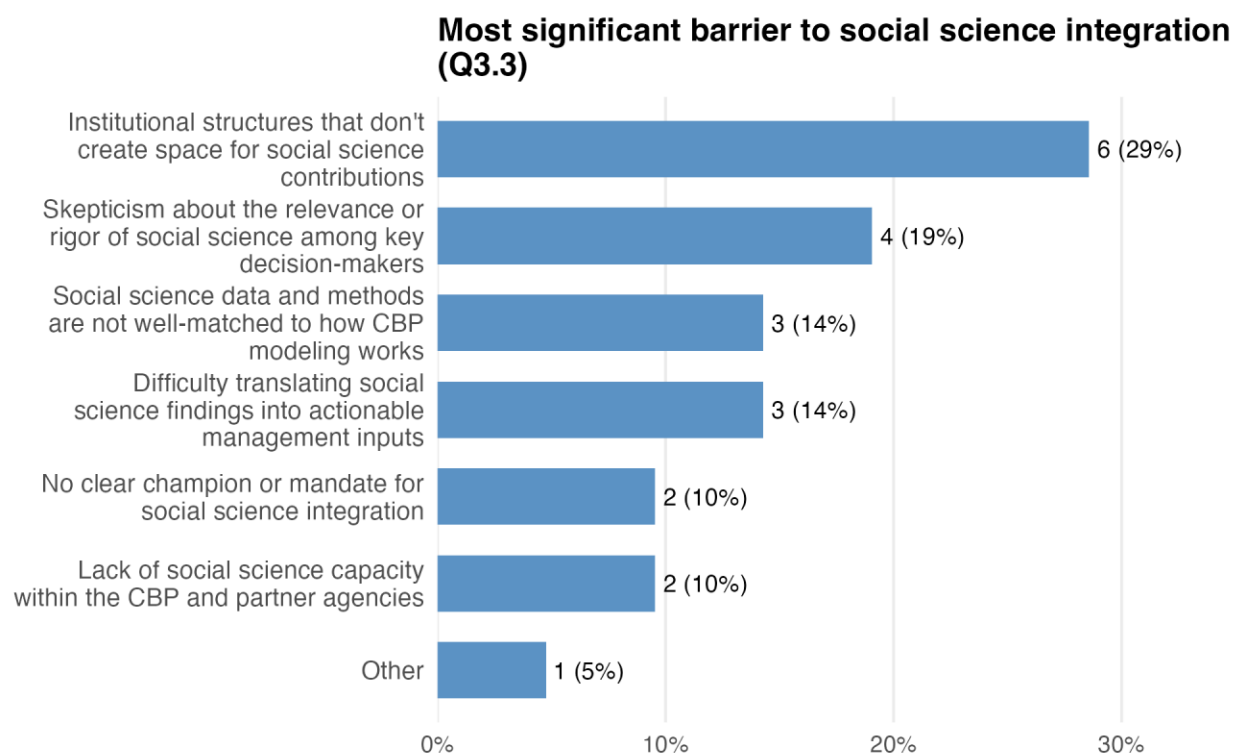


Figure 3: Perceived barriers to integrating social science, as reported by survey respondents. Note, as the total number of participants and respondents is relatively few, statistical inference should not be derived from these results.

The open-text responses further identify the systems mapping exercise as the most valuable element of the workshop, consistent with the depth and convergence of the maps themselves. One respondent described it as a "lexicon or framework to better describe the social/human aspects of complex systems."

The survey's most pointed finding has direct bearing on this report's methodological argument. Asked to rate their confidence that the 2025 Agreement's commitment to "integrate social science holistically" would translate to substantive change, 81% of respondents were uncertain or not confident, and none selected "very confident" (Figure 4). This distribution strongly suggests a credibility gap between the partnership's stated commitment and its structural reality, and it

aligns with the outcomes of the breakout groups. Section 8 presents methodological recommendations intended to help address this gap.

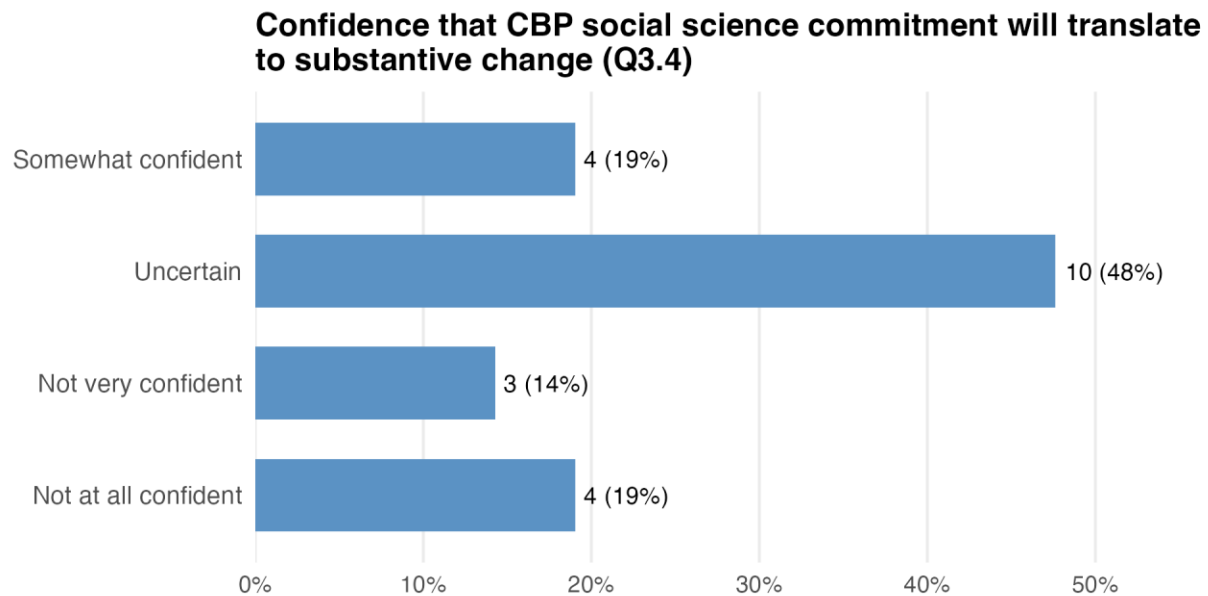


Figure 4: Reported confidence that the social science commitment made by the CBP and partners will translate to substantive change. The results suggest uncertainty and a general lack of confidence among workshop participants.

These survey findings are subject to several limitations related to the respondent pool. The sample skews toward natural and physical scientists (62%) at academic and research institutions (48%). Several respondents identified the under-representation of practitioners and local implementers, with one writing "...these events need a better ratio of practitioners (more) to scientists (fewer)." The workshop's composition reflected the same imbalance. And yet demand for the systems-thinking in practice appears to be real and substantial. After a single two-day workshop, 77% of respondents reported they are somewhat or extremely likely to incorporate CHANS-thinking into their own work, and 14 of 21 volunteered their time for a follow-up interview. The institutional vehicle for translating demand into action is nascent.

6.3 The Reach and Limits of CHANS Framing

A single two-day workshop cannot prove that any framework or perspective definitively "works". However, it provides a meaningful comparison between a conventional feed-forward

analysis and the coupled-systems approach used in this workshop, with an emphasis on its strengths and shortcomings.

Against that baseline, the coupled-systems framing contributed four things the partnership's standard tools do not. First, it treated governance and trust dynamics as endogenous feedbacks, where current tools leave them as background conditions. The maps and gap analyses further identified those elements as the primary constraints in the system. Second, it legitimized qualitative and narrative evidence. The headlines and story-based reasoning of the shock exercise produced diagnoses that a more traditional "loads-and-models" framing would likely not have surfaced, and this is the kind of qualitative reasoning supported by participatory scenario methods (Peterson et al. 2003; Pereira et al. 2020). Third, it made anticipatory thinking concrete, replacing generic scenario language with specific shocks and corresponding response architectures. Finally, it made cross-group peer review a method of knowledge production, rather than leaving disagreements implicit (Norström et al. 2020).

However, this workshop's CHANS framing also has limits. It did not produce, nor was it intended to produce, quantitative model inputs. Methods for representing human decisions endogenously in coupled-systems models are well developed – for example, agent-based modeling and socio-hydrology (An 2012; Di Baldassarre et al. 2013), though their use across the partnership is currently minimal (but see Lin et al. 2023; Thapa Chhetri et al. 2025). The framing did not, on its own, challenge participants' preconceptions in cases where a group was compositionally homogeneous. As noted earlier, Group 1's predominately natural-science group used the provided methods to fill in gaps within its map but treated stakeholder engagement as a "panacea" without critical engagement. A further limitation follows from the workshop's premise. Participants were asked to reason about coupled systems, and the attention they gave to social and institutional dynamics reflects that framing to some degree. The convergence across groups is therefore evidence about which social dynamics the participants judged to be most consequential, and it is not a measure of how those dynamics rank against biophysical ones. Finally, in two days the framing did not change the degree of coupled-systems thinking institutionalization, which is the central challenge addressed in this report and the motivation for [Section 8](#).

7. Substantive Recommendations from the Breakout Groups

The following five substantive recommendations (SR) consolidate the breakout groups' proposals into the report's substantive advice for the partnership. They are the groups' own outputs, synthesized across focal systems and organized by recommendation rather than by group. The activity design that produced the recommendations and the cross-group peer review process that evaluated them are described in [Section 5.5](#). Per-group materials are provided in the appendices. These recommendations address what the workshop participants identified as priorities for what the partnership should study or implement. The broader methodological recommendations, addressing how STAC and the CBP should institutionalize this kind of coupled-systems work, follow in Section 8.

SR1: Trust and relationship infrastructure for BMP adoption (Group 1, Group 2)

Sustained adoption of BMPs depends on durable trust, both between agencies and producers, and between communities and the jurisdictions that regulate them. CHANS-thinking explains why the partnership has a particular stake in building, maintaining, and studying trust. Few CBW residents directly experience the environmental costs of their nutrient-related decisions, so those feedbacks are routed through organizations like the CBP, which serves as a feedback moderator between actions and their consequences. Trust is a precondition for the technical work of restoration and the foundation on which it succeeds or fails, making it worthy of investment in its own right.

The two groups that built their analyses around trust supplied the corresponding support for these assertions. Group 1 (poultry litter, Delmarva) named producer trust as the controlling adoption feedback and, concluding that the group risked "reinventing the wheel," proposed beginning by consulting those who already work with farmers and "ask[ing] them what they need to build trust." Group 2 (coastal, water quality) placed trust at the center of its systems map and traced its erosion to an information-relevance disconnect, juxtaposing scientists offering "abstract water quality metrics" for the Bay while a chicken farmer "needs information about boosting

productivity to feed their family." *The following substantive recommendations follow from that understanding:*

1. fund, hire, and train the engagement professionals who hold these relationships, from extension agents to local coordinators to grant writers.
2. compensate producers for their engagement time and include them in research from the start.
3. pair engagement with reasonable economic incentives for BMP uptake.
4. tailor information to the decisions stakeholders actually face.

The results from Group 1 provide an initial way forward. For example, having concluded that they risked “reinventing the wheel,” the group proposed beginning with those who already work with farmers. The partnership maintains an extensive engagement infrastructure, including the Local Government Advisory Committee, the Stakeholder Advisory Committee, state agency and conservation district networks, and Extension programs across the jurisdictions. Mapping the existing networks and identifying relationships and gaps would be a necessary first step.

More broadly, SR1 asks the partnership to shift from outreach-as-information to outreach-as-relationship, a transition that recent work in the CBW finds central to making conservation programs work (Read et al. 2026), and that the broader conservation-behavior literature ties to trust in agencies and advisors (Ranjan et al. 2019). Group 2 also identified a structural condition: implementation authority "must rest with entities that have the power to act," with the CBP "serving as coordinating partner rather than the lead implementer."

It is worth noting that peer review challenged this recommendation in part. Group 1's reviewers pressed that "lack of trust was not the only barrier," and that economic incentives were missing on both the price and cost sides of producers' decisions, reinforcing the need to pair trust infrastructure with incentive design. Implementation of this recommendation aligns most closely with the Agricultural Workgroup, LGAC, and the CBP Communications team. Its binding constraint, sufficiently skilled and adequately resourced engagement leaders, is the capacity question addressed in [MR2 below](#).

SR2: Pre-positioned science and project libraries to exploit windows (Group 4)

Windows of opportunity in restoration are short, whether opened following a flood, a funding decision, or a change in policy, and they tend to close before the partnership can design, vet, and permit a response. A flood, in particular, is a focusing event that can open a brief window of public attention before closing (Birkland 1998). In the vocabulary of complex adaptive systems, the system delivers both crises and resources as emergent surprises. Substantive recommendation 2 calls for matching that tempo with readiness, and developing a pre-vetted portfolio of projects (e.g., designs, sites, partnerships) that can be activated within months, with permitting aligned to priorities rather than order of submission.

Group 4 (urban stormwater) reached this conclusion from a shock analysis showing the partnership can absorb neither sudden cuts nor sudden windfalls. A funding cut lengthened every project timeline. Conversely, a windfall arrived with pressure to spend before the planning and permitting needed to do so responsibly and effectively exist. Further, the permitting queue handles applications on a first-come, first-served basis regardless of priority, so money may be spent without being optimized. The group's answer was a "library of shovel-ready projects" pre-designed and pre-permitted, and prioritized by a socio-economic optimization tool to be "co-developed by managers and researchers." The co-development was an intentional step to avoid creating "yet another tool" no one uses.

Group 4 was candid about the potential cost of the proposal, including the "hope fatigue" of doing "a lot of proactive work for funds that may never arrive." At the same time, the group's measure of success was equally as concrete, trying to avoid, for example, that "the next 100-year flood doesn't take out Ellicott City." The group's peer reviewers pressed the question left open by the optimization framing, asking "who will do the community engagement, and how will funding be channeled?" This feedback connects the proposed project library to the trust infrastructure of SR1. Implementation of this recommendation aligns most closely with the SSWG, the modeling team, and state implementation agencies, and the proposed optimization tool should be co-developed with its end users.

SR3: Locally-led capacity and flexible BMP frameworks (Group 3)

Conditions, advisors, and access to resources are heterogeneous and unevenly distributed across the watershed, so a uniform prescription necessarily fits unevenly. Substantive Recommendation 3 (SR3) pairs flexible frameworks with locally-led capacity (technical assistance and monitoring partnerships) at the sub-watershed scale. This is the kind of nested, locally-tailored arrangement the polycentric governance literature favors for heterogeneous resource systems (Ostrom 2010), and that recent assessments of the Bay's own multi-jurisdictional governance reinforce (Batiuk et al. 2025).

Group 3 (Delmarva agriculture) arrived at this recommendation by tracing how performance-based regulation stagnates when farmers lack buy-in, do not follow their nutrient management plans, and see cost-share funding traded away for enforcement. The group's answer was a set of realistic, flexible nutrient management plans, adjustable for weather and supported by automated feedback. These would be developed with "all the trusted advisors" (e.g., certified crop advisors, fertilizer representatives, NMP planners, fellow farmers) and delivered through sub-watershed pilots, with compliance independently tracked toward a target of 95%.

The peer-review record for this pairing is limited. The underlying concern that a framework flexible enough to fit local conditions must also credibly demonstrate load reductions is familiar, however, which is why independent verification is built into the recommendation.

Implementation of this recommendation aligns most closely with the Agricultural Workgroup and conservation districts, through a sub-watershed pilot program supported by blended state, federal, and philanthropic funding, and would connect that work to the modeling-and-monitoring design in MR6 below.

SR 4: High-priority science gaps and indicator development (Groups 5 & 6, cross-group)

As participants constructed their system diagrams, they repeatedly encountered questions those diagrams could not resolve – what information moves between actors, and how that information

shapes individual behavior or the effectiveness of organizations such as the CBP. These questions identify science gaps. The partnership monitors what it models, so the dynamics its models omit (e.g., producer behavior, trust, capacity) go unmeasured and largely unmanaged. Closing these gaps requires admitting heterogeneous sources of information and treating qualitative, local, and relational evidence as legitimate. Accordingly, substantive recommendation 4 (SR4) recommends that the partnership should undertake a multi-year program of science and indicator development that instruments the social and behavioral system identified by the workshop participants. Six gaps define this effort:

1. Behavioral-response modules in the modeling suite, drawing on established methods for embedding behavioral theory in social-ecological models (Schlüter et al. 2017; Bourceret et al. 2022), and representing BMP adoption as an endogenous function of incentives, information access, and observed conditions.
2. Indicators of trust, capacity, and civic participation, incorporated into milestones, and building on frameworks that operationalize such social measures for ecosystem assessment (Breslow et al. 2016).
3. Integration of Indigenous and local ecological knowledge into monitoring, an issue Group 6 raised most explicitly, through a multiple-evidence-based approach (Tengö et al. 2014; Berkes 2009).
4. Governance-event detection and representation of jurisdictional lag, to capture the cross-scale inertia between regional decisions and local action; the CBP modeling team has itself called for finer-resolution modeling to serve local and jurisdictional management, while its models continue to treat management decisions as exogenous inputs (Hood et al. 2021).
5. Climate-resilience indicators constructed as explicit cascades and feedbacks rather than as standalone climate variables, with each cascade terminating in a social receiver, and identifying an actor or institution positioned to detect the signal and act on it. This operationalizes the "who detects?" question that recurred in the [shock exercise](#).
6. An institutional protocol establishing what qualifies as legitimate evidence, under which qualitative and narrative findings may be admitted as primary evidence rather than treated as supplementary.

Some of this work is already underway. For example, members of this workshop's Steering Committee are part of an NSF-funded team developing behavioral modules, providing an opportunity for the partnership to build upon that work.

As one illustrative example, Group 5's worksheet develops one of these gaps into a full proposal. Its problem statement identified, "a lack of understanding of the real-world voluntary behavior change in Ag." Its proposed actions include a systematic, state-level evaluation of conservation programs, pilot locations with existing monitoring such as the Choptank, and capacity-building for stakeholder communication. The implementation pathway progressed from a near-term scan of existing programs and their performance, through the identification of a monitoring-ready watershed, through behavior-change research, and ultimately toward better-designed programs that make "the invisible progress visible." For its institutional home, the group looked to STAC and the Agricultural Advisory Committee to help start the work and throughout, instructed the partnership to "partner with a social scientist." The program as a whole would belong to STAC, the SSWG, and the modeling team, with explicit per-year deliverables. While this example is but one suggestion emerging from the workshop, it indicates the promise of integrative, systems-focused work.

SR5: Institutionalizing CHANS thinking inside CBP structures (cross-groups)

The preceding recommendations include specific interventions and an agenda of science gaps to address. The fifth substantive recommendation (SR5) concerns the institutional capacity to generate such interventions, and where that capacity should reside. The justification for SR5 lies in how the other recommendations arose. Each emerged from applying a CHANS concept to the watershed: trust infrastructure (SR1) from treating adoption as a behavioral feedback the partnership motivates; pre-positioned project libraries (SR2) from treating funding and crises as emergent, short-lived windows; locally-led flexible frameworks (SR3) due to sub-watershed heterogeneity; and the science-and-indicator agenda (SR4) from the recognition that the partnership focuses its monitoring on modeled elements. These recommendations do not follow from conventional, already-institutionalized analysis procedures. Rather, they result from an

explicit consideration of the coupled nature of the systems that comprise the CBW. A partnership that seeks recommendations of this kind on a recurring basis – rather than once from a single workshop – must embed that perspective within its own structures.

SR5, therefore, is to embed CHANS competency inside existing CBP structures (e.g., the GITs, Social Science Workgroup, LGAC, STAC, the modeling team), so that recommendations are produced and received where decisions are made, rather than housing them in a standalone unit whose outputs dissipate at the partnership interface. This perspective is supported by the literature on embedding social science in environmental management. Capacity that is mainstreamed within institutions tends to gain more traction than capacity appended to them (Bennett et al. 2017), and established bodies such as the GITs and STAC can function as the boundary organizations that connect knowledge to decisions (Guston 2001). The virtual Group 6 articulated this governance overlay explicitly, and the other groups converged on the same structures. The post-workshop survey lends independent support to this recommendation, with institutionalization receiving the lowest current-state rating of any item (1.90).

Ultimately, where competency is housed is a matter of institutional design and political will, and the approach carries a corresponding risk. Distributing competency across many bodies can diffuse accountability, which makes a defined intake process at the partnership level (see Section 8) a necessary, parallel component. This work should belong to the STAC and CBP partnership leadership, with CHANS-competency expectations in workgroup composition norms as a longer-term objective. However, two qualifications apply. First, elements of coupled-systems practice are already present in the partnership’s work, though they are often described using different terms. As noted in Section 2.3, the GITs, advisory committees, and workgroups regularly draw upon qualitative and stakeholder knowledge through deliberation, which this report characterizes as partial integration. SR5 asks the partnership to make that reasoning more explicit and consistent, and to connect it to relevant analytical structures and processes. Second, the readiness of existing structures to absorb this work has not been assessed. Accordingly, a reasonable and phased approach would be to first assess the CHANS-consistent practice already underway across the partnership, then follow with a limited number of pilots in workgroups suited to host them, with any broader expectation following from those outcomes.

One potential pathway for SR5's proposed embedding is the use of programmatic logic models. As GITs and workgroups develop management strategies and work plans for their outcomes, the logic models supporting that work could identify social and behavioral factors *alongside* ecological ones, when considering limiting factors to be overcome. This would bring social dimensions into the same planning the budgeting process that governs ecological strategies and would clarify what resources – including people – their resolution requires. A sub-watershed nutrient-reduction strategy may, for example, pair its load-reduction target with a farmer-to-farmer program to broaden BMP adoption and with farm-scale planning support. Groups engaged in versions of this reasoning during the workshop, and the approach could be further developed as strategies and work plans are revised.

8. Methodological Recommendations: Institutionalizing CHANS-based Facilitation in CBP/STAC

The substantive recommendations presented above in Section 7 are a highly-visible product of the workshop. The report's primary contribution, however, is methodological in nature. The method demonstrated by this workshop was a structured, facilitated convening of an intentionally heterogeneous group of researchers, managers, and practitioners, who collectively mapped, stress-tested, and diagnosed the coupled system together. Over the course of two days, this method produced a coherent and convergent set of findings that the partnership's conventional analysis is less likely to produce on its own. The methodological recommendations (MRs) in this section accordingly focus on how STAC and the CBP might convert this single demonstration into recurring institutional capabilities.

These methodological recommendations differ from the substantive recommendations of Section 7 in their source and intended audience. The SRs are the breakout groups' own proposals and describe what the participants believe the partnership might study or undertake. The MRs that follow represent the Steering Committee's perspectives. They are addressed to STAC and to the partnership leadership, and are concerned with how coupled-systems work of this form should be resourced, compounded, governed, and connected to the existing analytical apparatus. As with

the SRs, they are offered as guidance for institutional practice, and not as determinations regarding any particular management or policy decision.

Each methodological recommendation describes a function as well as a candidate home for it. The assignment assumes that candidate is resourced to carry the function. Where it is not, the recommendation identifies what the partnership would need to resource rather than describing capacity already in place.

MR1: Establish recurring CHANS-based facilitation as a standing partnership practice

The workshop was a single event, and while it was based on best practices and academic literature, a single event does not, on its own, establish an institutional practice. The method produced a convergent diagnosis and a set of actionable recommendations within two days, but the capacity that produced them, including trained facilitators, the prepared materials, and the assembled mix of participants, does not persist after the workshop concludes. For the partnership to benefit from this arrangement of working on a continuing basis, the practice itself must be made recurrent. This accords with substantial literature on knowledge co-production, which treats the production of usable knowledge as a sustained, governed relationship rather than a discrete event (Lemos et al. 2018; Djenontin and Meadow 2018; Wyborn et al. 2019).

The first methodological recommendation (MR1) is that *the partnership should establish structured, facilitated, cross-actor CHANS analysis as a recurring element of its science program, with STAC advising on when a convening is warranted and on the scientific framing of its focal question*. The convening, recruitment, and resourcing of each event should sit with the partnership bodies that hold the relevant decision, including the Social Science Workgroup and the Goal Implementation Teams. The timing should be synchronized to the partnership's decision cycle, such that each convening informs a live decision rather than producing abstract recommendations. The quarterly progress meetings of the Strategy Review System, at which Goal Implementation Teams and workgroups report to the Management Board, offer frequent and decision-relevant occasions. The two-year milestones, the updating of jurisdictional Watershed Implementation Plans, and the revision of the Watershed Agreement provide less

frequent ones, suited to larger convenings. Regular recurrence allows the method to be refined between iterations, builds a community of participants and experienced facilitators, and gives the 2025 Agreement's commitment to “integrate social science holistically” a mechanism to be actualized.

A standing practice should accordingly be resourced and evaluated. Partnership leadership should secure dedicated and predictable funding for the convenings. Each event should also be assessed against explicit criteria, including the quality and uptake of its recommendations, the breadth of participation, and the degree to which its outputs reach partnership decisions. Evaluation will help the practice to iteratively improve and demonstrate its value over longer periods.

MR2: Build facilitator and convener capacity deliberately

The quality of the workshop and its activities depended substantially on its facilitators. Drawn from science experts on the Steering Committee, facilitators guided each group through systems mapping, shock-propagation, and the barrier-opportunity diagnostic. They managed interactions within a heterogeneous group and kept the work progressing towards a usable product. This is a specialized skill set that combines facilitation, working knowledge of the coupled system, and familiarity with the specific activities – and facilitation competence of this kind is widely identified as a key determinant of the quality of participatory modeling (Voinov et al. 2016; Vennix 1999). For this workshop, that capacity was assembled informally. Facilitators were chosen for their knowledge of the CBW system rather than for prior training in facilitation, and most took on the role for the occasion. That the workshop succeeded on this basis speaks to the robustness of the structured design, but also shows that facilitation capacity cannot be assumed, and that a recurring practice would require that capacity to be deliberately developed rather than improvised.

The partnership should, therefore, develop and maintain a standing pool of facilitators and conveners skilled in coupled-systems methods, with STAC defining the competencies the role requires and advising on curriculum. Maintaining the pool is a continuing operational

commitment, and that commitment should sit with a body resourced to carry it. Building this pool would involve training new facilitators, providing reusable materials and guidance, and pairing less-experienced facilitators with experienced ones across successive events. The artifacts developed for this workshop, including the systems-mapping template, shock briefs, importance-versus-representation grid, barrier-opportunity worksheet, and recommendation rubric (all included in the Appendices), provide an initial basis for such a training and can be refined as the practice matures.

This capacity constraint is related to the one identified at the level of producer engagement in SR1. In both cases, the limiting factor is less related to the method, and more connected to the availability of skilled and adequately-resourced individuals able to lead relationship-centered, facilitated work. Investment in facilitation capacity and in producer-engagement capacity are clearly complementary, and the partnership should treat the development of skilled conveners as a long-term commitment. The boundary-spanning skills involved are increasingly recognized as a distinct capability that operations must cultivate and resource deliberately (Bednarek et al. 2018).

MR3: Design heterogeneous, practitioner-inclusive representation into the process

The composition of each group functions as its own methodological instrument, not simply as a logistical detail. Assembling researchers, managers, and practitioners around a common analytical task elicits connections and dependencies that a single discipline or perspective cannot reliably generate. The corollary is that compositionally homogenous groups tend to identify and fill analytical gaps without recognizing their own blind spots, producing analyses that appear complete by reflecting a narrow range of assumptions. The stakeholder-participation literature consistently finds that who participates, and how that participation is structured, shapes both the quality of the process and validity of its outcomes (Reed 2008; Reed et al. 2018).

This workshop illustrated the impacts of falling short of that standard. Its participant pool skewed toward academic and natural scientists, and under-represented practitioners and, in particular, local and community stakeholders, relative to the Steering Committee's intent. The

one group composed almost entirely of natural scientists treated stakeholder engagement as a remedy without critically examining it, an outcome the group's facilitator attributed to the group's homogeneity. This under-representation is both a limitation of the present workshop and a self-evaluative finding about the method – the validity of the analysis depends on who is present to produce it.

Adequate representation rarely results from open invitation alone and should instead be an intentional component of the design. *Convening teams should set composition targets for each convening, recruit deliberately through practitioner, agency, and community networks, and address the practical barriers that limit participation from non-academics, with STAC advising on the composition the method requires.* These barriers commonly include uncompensated time, travel and lodging costs, and scheduling that conflicts with working calendars. Removing these barriers requires budgeting for compensation and logistical support from the outset. Because the recommendations that depend most on place-based and practitioner knowledge are the same as those a researcher-heavy group is least equipped to evaluate, designed representation is a precondition for the validity of the method, and not simply a matter of inclusiveness.

MR4: Route substantive recommendations through defined partnership-level intake mechanism

Recommendations provided by a CHANS convening are of limited value to the partnership if there is not a defined path for them to be received and acted upon. The gap between knowledge that is produced and that which is used is well documented in environmental management (Knight et al. 2008). Narrowing the gap depends on deliberate mechanisms for knowledge exchange and uptake, and not only on the quality of knowledge alone (Cvitanovic et al. 2015). The workshop's own cross-group peer review identified a methodological gap on the partnership's side, namely that its current analytical structure is not configured to produce, receive, or process the types of outputs this work generates. The post-workshop survey affirms this point, finding institutionalization to be the dimension of CHANS thinking least reflected in current practice, with the lowest current-state rating of any item assessed.

Methodological recommendation 4 (MR4) states that *the partnership should establish a defined intake process for the outputs of CHANS-based work*. This process would be a designated point of receipt, situated with sufficient authority and standing to triage the recommendations it receives, route them to the appropriate goal implementation team(s) or workgroup(s), and report on their disposition. This process serves two main functions. First, it ensures recommendations are formally considered and not allowed to dissipate at the partnership interface. Second, it produces a record of which recommendations were adopted, deferred, or declined, and on what grounds.

This intake process is a necessary counterpart to embedding CHANS competency within existing structures, as recommended in SR5. Distributing capacity to generate recommendations across multiple bodies, but without a corresponding mechanism for receiving and adjudicating them, would risk diffusing accountability. Accordingly, the two recommendations should be pursued together. SR5 distributes the capacity to produce coupled-systems analysis, and MR4 ensures analysis products converge at a point at which the partnership can act upon them.

MR5: Steward systems-thinking-with-heterogeneous-actors as a documented STAC method

STAC convenes many workshops, and the format demonstrated here should be retained and reused rather than rebuilt each time. This workshop's format can be described as a structured systems analysis with a heterogeneous group of actors. Retaining it as a repeatable option will require documenting the process (e.g., sequence of activities, standard set of materials, clear expectations of outcomes), which will further facilitate facilitator training, consistency in how convenings are run, and continuous, iterative improvement. The activity sequence is general, and the focal question of a convening is what adapts it to a particular application. This workshop let groups select their own focal subsystems from a menu of seed examples, which suited its broad state-of-the-science charge. A convening organized around a specific decision (e.g., a milestone revision, a WIP update, a living-resources target) would instead fix a single focal question for all groups and recruit participants accordingly. Scoping that question should therefore be the documented protocol's first step. Other participatory-modeling methods follow a similar

approach with respect to maintenance. Companion modeling, for example, is an established method with documented procedures and shared materials (Étienne 2014; Voinov et al. 2018).

Particular attention should be given to the cross-group peer review process. This workshop treated disagreement among well-informed groups as a legitimate piece of analytical content, consistent with literature on knowledge co-production (Norström et al. 2020; Turnhout et al. 2020). A STAC-stewarded method should preserve peer review as a standard element, and ensure the process includes a broader range of stakeholders than this workshop was able to engage.

STAC is well positioned to hold this stewardship role. As the partnership's scientific and technical advisory body, it works across goal areas, maintains institutional memory between events, and is able to evaluate the method's performance over successive convenings. *Placing the responsibility with STAC also allows the method to be refined on the basis of accumulated experience and expertise and mitigates dependency on any individual organizer.*

Stewardship in this sense is an advisory and documentary function. It asks STAC to maintain the protocol, to carry what is learned from one convening into the next, and to evaluate the method's performance over time. It does not ask STAC to convene, staff, or fund the events themselves, which MR1 assigns to the partnership. This distinction is important when considering resources. Stewardship is episodic work that draws on STAC's standing scientific expertise, while convening is a continuing operational commitment, and the two functions should not be assumed to sit within the same body.

MR6: Feed structured CHANS products back into the modeling, monitoring, and indicator systems

If CHANS-thinking is institutionalized as suggested above, then the outputs of those processes – including systems maps, priority-gap matrices, and the science-and-indicator agenda set out in SR4 – should not remain standalone documents. The value of these products to the partnership depends on them reaching the partnership's decision-making apparatus. In particular, the

modeling suite, monitoring network, and indicator and milestone frameworks. The partnership's monitoring is closely tied to its modeling capacity (see Section 6.1). Any analyses that never enter the modeling and monitoring systems are therefore unlikely to change what the partnership measures or manages.

The final methodological recommendation (MR6) is that *STAC, the Social Science Workgroup, and the modeling team should jointly define a structured handoff process between the outputs of convenings and the modeling and monitoring systems*. The handoff process would specify a standard format and mechanism by which a convening's findings inform model development (e.g., the behavioral-response modules described in SR4), monitoring design (e.g., indicators of trust, capacity, civic participation), and the indicators written into partnership milestones. Established methods for co-developing indicators with stakeholders (Reed et al. 2006), and for translating participatory systems maps into semi-quantitative models (Gray et al. 2015), provide examples for such a process. If MR6 is not followed, it is likely that well-formed outputs would accumulate as lightly-read reports and not as instruments to help improve decisions.

While the above handoff is relevant to the partnership's technical structures and processes, a parallel handoff is required for the practitioners, local implementers, and community representatives whom MR3 asks the partnership to bring into the room. Analyses that do not reach those groups and individuals positioned to act on them are unlikely to change the situation "on the ground." Accordingly, each convening should produce differentiated framings of the same underlying findings, prepared for defined audiences. The practice of the Intergovernmental Panel on Climate Change (IPCC), which derives both a Technical Summary and a Summary for Policymakers from a single assessment report, is one established model. For a CHANS convening, a corresponding set might include: (1) a technical product for the modeling and monitoring teams, specifying proposed model structures and candidate indicators; (2) a decision summary for the goal implementation teams and the Management Board, stating what is recommended and on what evidence; and (3) a plain-language summary for practitioner and community participants, reporting what the convening concluded and how their contributions informed it. Products of this kind can function as boundary objects, sharing an analytical core while also being interpretable within different communities of practice (Star and Griesemer

1989). The case for the third product extends beyond communication. Day 1 panelists described reporting findings back to participating communities as a condition of non-extractive engagement (Section 3.2). Convenings that draw on practitioner and community knowledge should return information and credit to those who supplied it, which will further develop the trust on which subsequent convenings will depend.

The process recommended here would be tightly connected to the longer-term science-and-indicator program recommended in SR4, and the two should be planned jointly. Together, they close the loop that the workshop identified in nearly every activity. Without this, the social and behavioral dynamics currently under-represented in the CBP's toolset will remain unmeasured – and will therefore remain largely unmanaged until the work that identifies them is connected to the tools that act on them.

9. Conclusion

Over two days in March 2026, approximately sixty-five researchers, managers, and practitioners convened to test what coupled human and natural systems analysis can contribute to Chesapeake Bay restoration. Working in facilitated breakout groups, participants mapped their focal systems, stress-tested those maps against plausible shocks, diagnosed the gaps between what matters most and what current tools represent, imagined the watershed's possible futures, and developed recommendations for the partnership. By the available measures, the workshop was unusually successful. Participants rated cross-disciplinary composition as the single greatest strength of the event, singled out the systems-mapping exercise as a concrete and transferable tool, and most reported they would carry coupled-systems thinking into their own work. The workshop was not without limitations, and this report has been candid describing where a second iteration should improve. These limitations, however, should not detract from the considerable work accomplished by the Steering Committee and workshop participants.

This report set out to accomplish two tasks. The first was to present the recommendations produced by the breakout groups, organized as substantive advice to the partnership (Section 7). The second, and the report's primary contribution, is to argue that the method that produced those recommendations (structured, facilitated, cross-actor systems analysis) should become a standing

practice as opposed to a single event. The workshop produced a coherent account of the CBW's coupled dynamics in two days, and the partnership has already committed, via the 2025 Watershed Agreement, to integration of just this kind. What remains is to turn that commitment into practice.

9.1 The 2025 Agreement as a Test Case

The 2025 Watershed Agreement committed the partnership to integrate social science holistically, the most explicit such commitment in its history. The workshop was, in part, an early test of that commitment, and an attempt to establish what coupled-systems analysis can contribute to Bay restoration and what sustaining the practice would require. Its central result is a convergent one. Working from different focal systems, and through several independent activities, the breakout groups arrived at the same diagnosis of the system. The parts of the CBW system least well represented in current tools are social and institutional, including trust, governance, and the couplings between regional decisions and local action. These comprise the "return" feedback paths in the coupled system and are where the partnership's analytical apparatus is weakest.

The workshop also clarified the partnership's readiness for work. The demand for more integrated thinking and science is clear. Participants took coupled-systems thinking readily, rated aspects of it highly valuable, and most reported they would carry the approach into their own work. The supporting infrastructure for such a transition, however, is not yet in place. In the post-workshop survey, respondents rated the current institutionalization of CHANS thinking the lowest of any dimension assessed, and a large majority were uncertain or not confident the Agreement's commitment would translate into substantive change. The demand for the work currently runs well ahead of the supporting structures.

The Agreement is, in this sense, a test case. It asks whether the partnership can move a broad commitment from principle into the routine business of restoration, across modeling, monitoring, and decision-making. The gap is a matter of capacity and structure, and it is the size of this gap this report has specified. We do not conclude that closing the gap requires a new mandate. It

instead requires the partnership to build the practice, the people, and the channels through which coupled-systems work can inform decisions across scale and scope.

9.2 Suggested Next Steps for STAC

As the partnership's scientific and technical advisory body, STAC works across goal areas, is a repository for institutional memory, and advises the partnership on where science is most needed. It is therefore the natural steward of the method this report describes. Section 8 assigns the convening and resourcing of the work itself to the partnership, and the steps below reflect that division. Most can begin within a single planning cycle and without waiting on a larger reform.

In the near term, STAC can:

1. document the workshop method as a repeatable protocol, drawing on the materials in the Appendices, so that a second convening does not begin from scratch (MR5).
2. advise partnership leadership on the timing and focal question of a second convening, so that it informs an upcoming decision point such as a quarterly progress meeting or milestone review, and on the practitioner and local-stakeholder representation that this first workshop lacked (MR1, MR3).
3. define the competencies this work requires of a facilitator, and seed a pool by pairing experienced facilitators with new recruits at that convening, treating facilitation as a skill to be deliberately developed (MR2).
4. open a discussion with partnership leadership about where the outputs of this work should be received and acted on, and how they should feed the modeling, monitoring, and indicator systems (MR4, MR6).

None of the above initial steps requires a new mandate or significant new funding to begin, and each builds on the previous. A documented engagement method makes the next convening easier to run; a more representative group yields more credible recommendations; a larger pool of trained facilitators makes a recurring practice feasible; and a defined intake process helps

translate the results into decisions across the partnership. The practice these steps lead toward will require sustained resourcing, and Section 8 is explicit that the convening and the facilitator pool should be assigned to the bodies equipped to carry them. What STAC can do now is establish the method and make the case for the rest. Together, the recommendations in this report will help convert a single, well-received workshop into the standing capability the 2025 commitment will require.

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Appendix A: Workshop Agenda



Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop
**Challenges and Opportunities in Operationalizing
Coupled Human and Natural Systems Research (CHANS)
in the Chesapeake Bay Watershed**
March 26-27, 2026
Chesapeake Bay Foundation [Philip Merrill Environmental
Center](#)

Workshop Objective: Explore how Coupled Human and Natural Systems (CHANS) research can be more effectively applied to Chesapeake Bay restoration by connecting social and ecological feedbacks, identifying gaps in current modeling and management frameworks, and developing actionable recommendations to strengthen adaptive management.

- **Day 1 Objective:** Synthesize the current state of applied CHANS science and map key socio-ecological feedbacks and gaps affecting Bay restoration outcomes.
- **Day 2 Objective:** Co-develop strategies and recommendations for integrating CHANS approaches into Chesapeake Bay Program decision-making and policy

Thursday, March 26, 2026

8:45 am **Coffee & Light Breakfast (Provided)**

9:00 am **Welcome and Introduction to CHANS Theory/Frameworks – Steering Committee members**
Steering Committee members/co-chairs will kick off the workshop with a welcome and introductions and outline the objectives of the workshop.

An introduction and/or refresher regarding basics of CHANS/SES theories, frameworks, and components. Objective is to introduce key vocabulary and concepts and lay foundation for future talks and group work.

9:30 am **Panel: Shared Challenges and Opportunities in Coupled Systems**

A structured set of 8–10 minute talks (interspersing 3 perspectives from other U.S. watersheds with 2 perspectives from within the Chesapeake Bay watershed) to surface the most important socio-ecological couplings/feedbacks, what is hard to observe/represent/act on, and what typically gets in the way of translating coupled-systems insights into models, policy, and management. Participants will submit questions during the talks (e.g., via Mentimeter).

- Mindy Roberts, Puget Sound Partnership
- Jeff Lerner, EPA
- Lew Linker, EPA, including contributions from Gopal Bhatt, PSU
- Alyssa Dausman, The Water Institute
- Brett Milligan, University of California, Davis

10:45 am **15-minute Break**

11:00 am	Breakout Session 1: Systems Mapping Using a series of prompts as well as CHANS concepts as a guide, participants will work in small groups to create visual diagrams that identify critical reinforcing and balancing feedbacks (e.g., land use, water quality, policy incentives, social behavior). An artifact will be provided to guide discussion and systems mapping, but considerable flexibility will be given such that group creativity/perspectives come through. Objective is to generate a shared understanding of how human and environmental systems interact in the Bay, and to identify points where those interactions may be poorly understood, underrepresented in models, or misaligned with policy. System maps will form the foundation for later sessions on policy and institutional innovation, ensuring a common conceptual baseline across the workshop.
12:15 pm	Lunch (provided)
1:15 pm	Group Synthesis Groups will report out their activities from session 1 to the full workshop. We will provide instructions for session 2.
2:00 pm	Breakout Session 2: Addressing Feedbacks and Identifying Gaps Using earlier systems maps, participants will explore how feedbacks between environmental conditions and human behavior (e.g., agricultural practices, stormwater management, institutional responses) are currently incorporated (or not) in modeling, monitoring, and policy processes. Objective is to identify critical gaps in the representation and use of environment-to-human feedbacks, with special attention to nonpoint source pollution, climate resilience, and adaptive decision-making. Outcomes from this session will directly inform day 2 activities.
3:15 pm	15-minute Break
3:30 pm	Group Synthesis: Report Out from Session 2, Discussion, Setup Day 2 Activities
4:30 pm	Adjourn
4:30 pm	Optional Poster Session (participants, speakers)
6:00 pm	Optional Dinner (offsite) STAC staff will coordinate a reservation for an informal group dinner at a nearby restaurant and share a few additional nearby options for those who prefer to make other dinner plans.

Friday, March 27, 2026

- 8:45 am** **Coffee & Light Breakfast (Provided)**
- 9:00 am** **Welcome and 2050 Headlines Exercise**
Participants will draft two short newspaper headlines for the Chesapeake Bay watershed in 2050 (one desirable and one undesirable) based on themes from Day 1. Headlines will be posted before the panel and used to frame the discussion and Session 3.
- 9:20 am** **Panel: Policy and Implementation Challenges**
A moderated conversation with policymakers, practitioners, and researchers on the real-world barriers that shape Chesapeake Bay restoration—what slows progress, where response gaps persist, and why. Panelists will use a CHANS/SES lens to surface the institutional and stakeholder dynamics (and key feedbacks) that matter most, helping ground the workshop in on-the-ground decision contexts and tee up practical constraints and opportunities for CHANS-informed management.
- Hilary Harp Falk, Chesapeake Bay Foundation
 - Maggie Woodward, Chesapeake Bay Commission
 - Representative Sarah Elfreth, U.S. House of Representatives (MD-3)
- 10:30 am** **Breakout Session 3: Challenges and opportunities**
Building on outputs from Sessions 1 and 2, groups will examine the practical, institutional, and political challenges that create disconnects and prevent alignment among system dynamics and management strategies. Groups will then identify opportunities to mitigate, eliminate, or work around these challenges, focusing on CHANS-informed strategies (e.g., improved feedback integration, cross-sector collaboration, adaptive governance). Objective is to identify actionable insights about where and how systemic barriers can be reduced, laying the groundwork for informed, practical recommendations in the final workshop synthesis.
- 11:45 am** **Lunch (provided)**
- 12:30 pm** **Breakout Session 4: Developing Recommendations**
Groups will identify specific strategies, pilot projects, or institutional reforms aimed at improving how feedbacks (focusing on human-environment ones) are represented in modeling, monitoring, and adaptive decision-making. Emphasis will be on proposals that addressing implementation and response gaps, aligning model capabilities with policy needs, and supporting other experimental approaches to institutional innovation. Objective is to identify recommendations that will form the basis of the workshop report and support ongoing efforts to operationalize CHANS science in the Bay’s restoration strategy.
- 1:30 pm** **Final Group Presentations and Discussions**
Each breakout group will share key takeaways and recommendations from their sessions, followed by a facilitated full-group discussion to identify cross-cutting themes, areas of consensus, and opportunities for continued collaboration.
- 2:00 pm** **Closing Remarks and Workshop Conclusion – led by Workshop Steering Committee**
- 2:15 pm** **Workshop Adjourn**

Appendix B: Workshop Participants

Name	Affiliation
Allison Colden (v)	CBF
Allyson Gibson (v)	Lancaster Clean Water Partners
Alyssa Dausman (v)	The Water Institute of the Gulf
Amy Handen *	EPA-CBPO
Bill Dennison ^ (v)	UMCES
Breck Sullivan	USGS-CBPO
Brent Murry ^ (v)	WVU
Brett Milligan (v)	UC Davis
Callie C. Sams (v)	WVDEP
Caroline Kleis (v)	CRC
Cassandra Davis (v)	NYSDEC
Christine Kirchhoff *(v)	Penn State
Craig Bettenhausen	Chemical & Engineering News
Denice Wardrop *(v)	CRC (retired)
DG Webster *	Dartmouth College
Emilie Litsinger (v)	Puget Sound Partnership
Erik Michelsen	Anne Arundel County
Erin Letavic^ (v)	HRG
Ethan Yang *	Lehigh University
George E. Onyullo (v)	DC-DOEE
Greg Noe ^	USGS
Hilary Harp Falk	CBF
HL Campbell (v)	CBF
James Martin	Virginia DCR
Jason Yoo	Kent State University
Jeff Lerner	EPA Office of Water
Jeni Keisman ^	USGS
Jeremy Hanson	CRC-CBPO
Jim Pizzuto	University Delaware (emeritus)
Joe Wood ^ (v)	CBF
Jun Suk Byun	UMCES
Kate Beats	PA DEP

Name	Affiliation
Kathy Bunting-Howarth ^ (v)	NY Sea Grant-Cornell University
Kayle Krieg	UMD Sea Grant Extension
KC Filippino ^ (v)	HRPDC
Kelly Williams (v)	Clearfield County Conservation District
Kevin Orner ^	West Virginia University
Larry Sanford ^ (v)	UMCES and STAC
Leah Palm-Forster ^ (v)	University of Delaware
Lewis Linker	EPA-CBPO
Lisa Wainger (v)	UMCES-CBL
Lora Harris	UMCES
Mark Monaco ^	NOAA
Matthew Houser	TNC/UMCES
Mindy Roberts (v)	Puget Sound Partnership
Olivia Martin	Devereux Consulting
Patrick Bitterman *	Kent State University
Peter Claggett	USGS
Raleigh Hood *	UMCES
Robert Sabo	EPA
Sarah Elfreth (v)	US House of Representatives
Scott Knoche ^ (v)	Morgan State, PEARL
Sevgi Erdogan (v)	Syracuse University
Shannay Rawal	WVU
Sophie Waterman	USGS-CBPO
Suzanne Etgen	Watershed Stewards Academy
Suzanne Trevena	EPA Water Division
Taylor Woods	USGS
Theo Lim *(v)	University of British Columbia
Uzma Jabeen	Kent State University
Victoria Coles *	UMCES
Xin Zhang *	UMCES
Yanyu Wang	UMCES

* Steering Committee member

^ STAC member

(v) virtual participation

Appendix C: List of Figures and Tables

- Figure 1. A traditional conceptualization of a coupled human and natural system along with a more detailed conceptual diagram describing elements of the coupled system within the CBW
– section 2.1
- Table 1. Desirable and undesirable headlines from 2050, produced by workshop groups
– section 5.3
- Figure 2. Post-workshop survey results showing perceived relevance and current state of CHANS-thinking in and to the CBP partnership
– section 6.2
- Figure 3. Post-workshop survey results showing perceived barriers to integrating social science
– section 6.2
- Figure 4. Post-workshop survey results showing reported confidence that that the social science commitment made by the CBP and partners will translate to substantive change
– section 6.2

Appendix D: Breakout Session Prompts and Facilitation Materials

Session 1: Mapping the CBW Coupled System

Your group will build a shared visual map of how the Chesapeake Bay Watershed (CBW) system functions. The primary focus of this session is the connections that run from environmental conditions back to the people and institutions that manage them: how changes in water quality, habitat, or living resources alter what managers observe, what communities experience, and what decision-makers do. To build toward that, you will first map how human decisions shape environmental conditions, then add the return pathways that close the loop.

No single group can map the entire CBW system in 75 minutes, nor should they try!!!

Instead, you will start with a focused sub-system where your group has direct knowledge and experience. The “seed” sub-system menu at the end of this worksheet offers several starting points, or your group can define its own. Your goal is depth over breadth: a well-developed partial map with honest annotations about uncertainty and gaps is more useful than a sprawling one that papers over them.

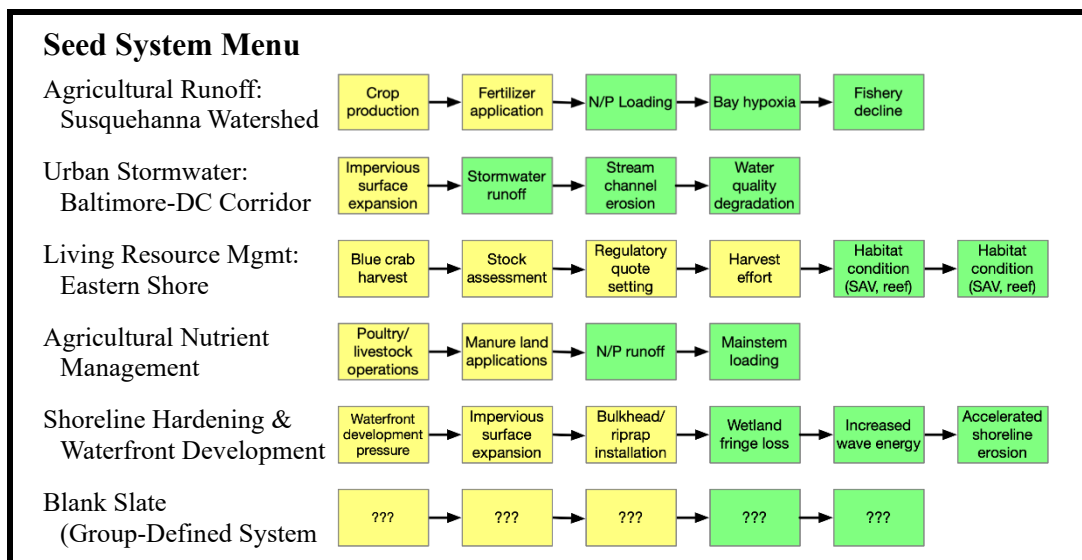
Step 1: Confirm your focal system ~5 min; facilitator-led

Every systems map needs a place to start. *Before* your group can begin placing cards and drawing connections, you need to agree on which piece of the CBW system you are starting with. This does not need to be a perfect or permanent decision, but it does need to be specific enough to ensure everyone at the table is talking about the same thing.

There are several ways to anchor your starting point. For example, you might organize around:

- a geographic area (the tidal Potomac, the upper Susquehanna, the Eastern Shore),
- a management problem (nutrient loading from agriculture, stormwater in urbanizing watersheds, declining blue crab harvests),
- a particular set of actors and institutions (farmers and extension agents, municipal stormwater managers, watermen and fisheries regulators),
- or a specific scale of decision-making (farm-level BMP adoption, state-level TMDL compliance, federal policy design).

Any of these can work as an anchor. What matters is that your group shares a rough sense of who is in the system, what environmental conditions they are responding to, and at what scale decisions are being made. In the Seed System Menu below are example diagrams where your group may choose to start. Take two or three minutes to discuss and agree on your own focal system before moving on.



Step 2: Map human impacts on the environment ~20 min; hands-on mapping on poster board

Using color-coded cards, place key system elements on the poster board. Then draw causal connections showing how human decisions and actions lead to environmental change. If appropriate, you may also want to map interactions entirely within the social system or entirely within the environmental system. Aim for at least 8-12 cards on your initial map. Use your card colors consistently:

- Yellow: social / economic / governance elements
- Green: ecological / environmental elements
- Blue: technical elements

As you draw the connections, use a:

- *Solid line* if the direction and existence of this link is well-supported by evidence or direct experience
- *Dashed line* if the link is plausible or theoretically expected, but is poorly documented, highly context-dependent, or contested among your group

Next, for each causal link you draw, annotate two things directly on the poster:

1. *Direction of influence*: draw an arrow showing which way causation runs
2. *Expected time lag*:
 - a. write "short" along the connection if the interaction results in a change in a small time frame
 - b. write "medium" along the connection if the interaction results in a change in a moderate time frame
 - c. write "long" along the connection if the interaction results in a change over a long time frame.

Step 3: Draw connections from the environmental system to the human system

~20 min; your facilitator will pause the group before this step

Your facilitator will prompt you with the following question. Take a moment to individually reflect, then discuss with your group.

Facilitator Prompt

Where do environmental conditions feed back to the people making decisions? Or to those impacted by environmental change? How does that signal actually travel?

Now add those environment-to-human connections to your poster map. For each feedback pathway you add, go beyond just drawing the arrow as you did before. Here, you should discuss the actual mechanism connecting the elements.

Example: An arrow from "water quality monitoring data" to "TMDL reporting" to "agency budget allocation" is a different mechanism than an arrow from "hypoxia extent" to "watermen's harvest decision."

Step 4: Overlay technical and governance mediation

~15 min; highlighters on posterboard + annotation

Return to your poster. Using highlighters, trace over the feedback pathways you drew in Step 3:

- *Blue highlighter*: trace feedbacks mediated by technical systems (e.g., monitoring programs, models, decision-support tools, remote sensing products)
- *Green highlighter*: trace feedbacks mediated by governance processes (e.g., regulations, cost-share programs, permit requirements, reporting mandates, collaborative forums)

For each highlighted feedback, write directly on the poster:

1. What does this connection carry or represent (e.g., information, a material change, a direct experience)
2. What mechanism (e.g., a regulation, a program, a norm, a contract) either turns that signal into action, or prevents it from doing so?

Appendix D: Breakout Session Prompts and Facilitation Materials

Step 5: Synthesize ~10 min; group discussion using below materials

As a group, classify each feedback loop on your map using the typology below. Write the code *on the poster next to each feedback connection*. Then record your classifications and discussion notes in the log that follows.

Typology reference

Category	What this means	Mark on map as
Known but poorly observed	The connection exists and is theoretically understood, but empirical measurement is sparse, infrequent, or spatially mismatched.	KO
Observed but poorly represented	Data exist, but the connection is absent or distorted in models or decision frameworks.	OR
Represented but not actionable	The connection appears in models or reports, but outputs do not reach or change management decisions.	RA
Constrained by norms or politics	The connection is understood and observed, but institutional, cultural, or political factors block response.	NP

Classification Log

For each feedback pathway identified, assign a typology code and briefly note the group's reasoning.

Feedback pathway	Code	Group notes / reasoning

Step 6: Reflection ~5 min; discussion and preparation for report outs

The following questions will be the basis of our report out session. Review and discuss as a group. Record any important points you would like to share.

- When you added the feedback pathways (from the environment to human systems), how did they compare to the pathways running in the other direction? Were there fewer of them, were they less direct, or were you less confident in how they work?
- Which feedback loops in your map feel most consequential, but also least reliably represented in models or decision-support tools?
- Did your group disagree about the direction or strength of a link? If so, is that disagreement rooted in a gap in evidence, a difference in scale or context among your group members, or something more political?

Session 2: Shock Propagation and Gap Analysis

In Session 1, your group constructed a map of how your sub-system works under normal conditions. ***In this session, you will stress test it.*** Your group will be assigned one of three disturbance scenarios and will trace how it propagates through your map.

Your objective is to find where the map breaks down: where signals do not get detected, where responses do not follow, and where the chain of cause and effect is missing, blocked, or significantly delayed. The goal is not to solve those problems here! Rather, your goal this session is to characterize them precisely enough that they can be addressed in future session.

Step 1: Read your scenario brief ~10 min; facilitator-led

See Appendix E for Shock Scenario Briefs.

Your facilitator will provide a one-page description of your assigned shock scenario. Read it individually first, then take a few minutes as a group to discuss the questions below before moving to the map.

- Does this scenario feel plausible given what you know about the CBW? What makes it realistic or not?
- Has anyone in your group experienced something similar, or observed a partial version of this scenario?

Step 2: Trace your shock through the systems map ~20 min

Starting from where the shock enters your system, follow its propagation step by step using your Session 1 map. At each link or node in the chain, mark its functional status using the legend below. *Using a RED marker, write directly on the poster using the symbols provided.*

Functional Status Legend

Mark	Status	What it means
———	Intact	The link functions as expected. Signals propagate and responses follow.
- - -	Weak/Delayed	The link exists but operates slowly, unreliably, or with significant attenuation.
X	Broken	The link should function but does not. Signals are lost, responses do not follow.
?	Absent	No link exists at this point. The propagation chain stops here.

- Where does the shock first encounter a broken or absent link? Describe what stops or attenuates the propagation.

Step 3: Annotate the chain of propagation ~15 min; annotate and discuss

At each major node where change occurs, place a sticky note on your poster answering three questions below.

Detection Annotation Log

Node where change occurs	Who detects it?	What is the detection mechanism?	How long after change is it detected?

Step 4: Identify points of interest and complete the gap analysis

~15 min; discussion and issue selection

Step back from the specific shock and look for patterns in your map and annotations. Here, the goal is to move from thinking about *this particular scenario* to a more general characterization of where and why your system struggles to represent or respond to important interactions.

Prompt 1: Under-representation

Which types of interactions among system components on your map matter for system behavior but tend to be *weakly represented, simplified, or handled indirectly in models or decision-support tools*?

Select up to three key interactions. For each, write on a sticky note the following information:

- Interaction label (e.g. name, purpose, what it connects)
- Interaction importance (High, medium, low)
- Representation issue

Prompt 2: Why

For each interaction you selected, explain why it is difficult to formalize or represent consistently. Consider whether the difficulty is primarily about data, about institutional incentives, about the nature of the interaction itself, or about something else.

Annotate the reasoning for the representation difficulty on the sticky note as well.

2x2 Matrix: Importance vs. Representation

Find the large poster that looks like the figure below. Place your sticky notes in the appropriate quadrant(s).

	Poorly represented	Well represented
High importance	Priority gap <i>High priority</i>	Functioning well <i>Note for confirmation</i>
Low importance	Noted but low priority <i>May not need action</i>	Well represented, low stakes <i>Low priority</i>

Step 5: Reflection ~5 min; discussion and preparation for report outs

The following questions will be the basis of our report out session. Review and discuss as a group. Record any important points you would like to share.

- Which shock propagation pathways surprised you most?
- What does detection actually look like in your system? Who notices a change, through what mechanism, and how long after the change occurs? Is that lag fast enough to matter?

Session 3: Challenges and Opportunities

See Appendix G for 2050 Headlines Activity.

Your group will receive a cluster of 2050 Headlines from the morning wall. You will use them as a diagnostic lens to identify the barriers that determine which trajectory the CBW system follows, and then pair each barrier with a concrete opportunity to address it. These barrier–opportunity pairs are the direct input to Session 4, where you’ll develop them into formal recommendations.

Step 1: Headlines as a diagnostic lens ~25 min

As a group, review the headlines you were given by your facilitator. Next, discuss the 4 questions below the headlines and answer them briefly. Use bullet points, write directly on the newspaper sheets.

Now compare the two headlines. Look at the critical decision points or tipping points you identified in Box 2 for each. Where do the same decision points or tipping points appear in both? In other words, where are the places where the system could have tipped toward either outcome? Those are the *critical junctures*. Mark them on your Day 1 system map.

Critical junctures shared across both headlines (note and mark on your Day 1 map):

Step 2: Barrier-opportunity pairs ~30 min

For each critical juncture you identified (aim for 3), identify the barrier that holds the system on its current trajectory and a concrete opportunity to shift it. ***Work on both sides simultaneously!*** Thinking about the barrier and the opportunity *together* produces sharper analysis than treating them sequentially.

After filling out the three Pair Tables, mark each barrier’s location on your Day 1 map with an orange marker

Reference guide

BARRIER TYPES	OPPORTUNITY MODES
• Institutional / organizational (mandate constraints, jurisdictional fragmentation, organizational routines) • Political / accountability (electoral cycles, blame avoidance, distributional conflicts) • Technical / epistemic (data gaps, modeling limitations, scale mismatches) • Economic / resource (funding structures, cost allocation, market failures) • Social / behavioral (trust deficits, coordination costs, cultural norms, information asymmetries)	• Reform: change the structure (high impact, long timeline) • Work-around: alternative pathway (moderate impact, shorter) • Exploit a window: leverage emerging conditions (variable, timing-dependent)
<i>Is it structural or contingent?</i> <u>Structural barriers</u> are embedded in institutional design, legal frameworks, or physical system properties and require deliberate reform. <u>Contingent barriers</u> arise from current political conditions, leadership, or funding levels and could shift.	
<i>Who maintains this barrier?</i> Whose interests, routines, or mandates are served by the current arrangement?	

Pair Table

THE BARRIER	THE OPPORTUNITY
What feedback or interaction does this barrier affect?	What would weaken or circumvent this barrier?
Barrier type: <i>institutional / political / technical / economic / social</i>	Opportunity mode: <i>reform / work-around / exploit a window</i>
Is the barrier structural or contingent?	Who would need to act? How feasible is it?
How is this barrier maintained?	Time horizon and dependencies for implementing the opportunity?

Session 4: Developing Recommendations

The work your group has accomplished across three sessions comes together here. Using the barrier-opportunity pairs from Session 3, you'll develop specific, actionable recommendations for the workshop report. An adjacent group will review your top recommendation. Then you'll prepare a short verbal summary to share with the full workshop.

Step 1: Complete recommendation worksheets ~35 min

See Appendix H for Recommendation Worksheet.

Starting with your top 2-3 barrier-opportunity pairs from Session 3, develop each into a full recommendation. Aim for at least one that is thoroughly developed; the others can be more concise. Each worksheet has four sections: 1) problem statement, 2) proposed action, 3) implementation pathway, and 4) risks/success criteria.

Step 2: Peer review/exchange ~15 min

Pass your **top recommendation worksheet** to an adjacent group. Read theirs and provide brief written feedback on three dimensions:

- **Credibility:** Is the problem statement grounded in the workshop's analysis? Is the approach logically coherent?
- **Feasibility:** Is the implementation pathway realistic given CBP's institutional structure, resources, and political dynamics?
- **Consequentiality:** If implemented, would this meaningfully change the system dynamics the workshop identified as problematic?

Step 3: Prepare Your 5-Minute Summary ~10 min

Choose your group's two strongest recommendations. Structure your summary as:

"The problem is X. We propose Y. It would work because Z. The first step is W."

Appendix E: Shock Scenario Briefs

ECOLOGICAL SHOCK A

Sustained Hypoxia Following a Record Wet Spring

What happens: Following an unusually wet winter and spring (consistent with increasing precipitation trends across the mid-Atlantic) the Bay and several major tributaries experience the most severe and spatially extensive hypoxic event in the modern monitoring record. Dissolved oxygen falls below 1 mg/L across broad areas of the mainstem and extends into shallow-water habitats that are normally well-oxygenated. The hypoxic zone persists from late May through mid-October, roughly six weeks longer than the recent average.

Consequences: The extended hypoxia produces visible fish kills in several tributaries, covered by regional media. Blue crab harvests decline as crabs crowd into shallower refuge habitat. SAV beds that had been recovering suffer dieback from light limitation and anoxic sediment conditions, losing an estimated five years of recovery progress in a single season. Benthic communities are severely depleted, with recovery expected to take two to four years.

Context: This is not unprecedented, but it is at the extreme end of observed variability. The CESR documented that higher water temperatures already offset a portion of the WQ benefit from nitrogen reductions. This scenario compounds that with a high-flow year delivering a large pulse of nutrients and sediment, including legacy nutrients stored in soils and floodplains.

Before moving to the map, discuss:

- Does this scenario feel plausible? What makes it realistic or not?
- Has anyone observed a partial version? Maybe a year where conditions were notably worse than predicted?
- How would the actors in your Session 1 map become aware of this event? Who notices first?

ECOLOGICAL SHOCK B

Rapid Spread of an Emerging Pathogen in Oyster Populations

What happens: A novel or mutated strain of an oyster pathogen (e.g., *Perkinsus*) emerges across multiple tributaries during a period of above-average water temperatures and salinity. Unlike previous outbreaks that were localized and gradual, this strain spreads rapidly – facilitated by warming waters and aquaculture activity that creates transmission pathways between wild and farmed populations. Within a single growing season, oyster mortality increases 40–60% above baseline.

Consequences: The outbreak threatens both the wild fishery and the expanding aquaculture industry. Restoration reefs representing years of investment are affected in several tributaries. Ecosystem services from oyster reefs (e.g., filtration, habitat, shoreline stabilization) diminish in affected areas. Watermen and aquaculture operators face immediate economic losses, and uncertainty about the pathogen's trajectory makes next-season planning extremely difficult.

Context: Oyster disease is a persistent Bay challenge, and the management system has experience with Dermo and MSX. But this scenario tests whether monitoring, research, and management can respond to a novel pathogen at a pace matching its spread — particularly when the outbreak crosses jurisdictional boundaries. Climate change is expected to continue shifting the conditions governing pathogen dynamics.

Before moving to the map, discuss:

- Does this feel plausible given current temperature, salinity, and oyster management trends?
- Has anyone experienced something similar with a different species or pathogen?
- Where does this shock enter your Session 1 map? Maybe at a node you included, or from a direction you didn't map?

POLICY/FUNDING SHOCK A

Major Federal Funding Reduction for Bay Restoration

What happens: Federal budget austerity and shifting political priorities result in a 40% reduction in federal funding for Bay restoration over two years. The cuts affect multiple streams: EPA's Bay Program office, USDA conservation cost-share programs (EQIP, CRP, RCPP), NOAA restoration grants, and Army Corps projects. The one-time boost from Bipartisan Infrastructure Law and Inflation Reduction Act conservation funding (already winding down, subject to rescission) provides no buffer.

Consequences: State agencies relying on federal cost-share freeze new BMP enrollments. CBP monitoring networks and Phase 7 modeling development face staff reductions. Nonprofits dependent on federal pass-through funding experience layoffs. Innovative pilot programs (e.g., pay-for-performance, targeted outreach to underserved communities) are among the first cut because they lack established constituencies. Existing contracts are honored, but the pipeline of new implementation stalls.

Context: This doesn't require dramatic legislative action. Rather, it reflects cumulative budget pressures, competing priorities, and the difficulty of sustaining funding for a multi-decade effort that hasn't yet met its stated goals. The 2025 Watershed Agreement is voluntary and carries no appropriation. The TMDL provides legal framework, but enforcement depends on EPA capacity and political will. Similar dynamics have played out in other large-scale environmental programs.

Before moving to the map, discuss:

- Does this feel plausible in the current fiscal environment?
- Has anyone experienced a significant funding disruption? What happened to implementation momentum?
- Which connections in your map depend (directly or indirectly) on federal funding?

POLICY/FUNDING SHOCK B

Shift to Performance-Based Agricultural Nutrient Regulation

What happens: In response to persistent implementation and response gaps, one or more Bay states adopt legislation requiring measurable nutrient loss reductions from agricultural operations above a size threshold. The framework moves from voluntary cost-share toward performance-based accountability: covered operations must demonstrate nutrient losses don't exceed specified benchmarks, tightened on a five-year cycle. Operations meeting benchmarks retain cost-share access; those that don't face escalating consequences (e.g., mandatory plan updates, loss of eligibility, and eventually civil penalties).

Consequences: Larger operations with existing nutrient management infrastructure adapt relatively quickly. Smaller farms with tighter margins push back through commodity organizations and legislative allies. Conservation districts and extension services face a fundamental role shift: from voluntary facilitation to regulatory implementation. This strains relationships built over decades. Some environmental groups celebrate; others worry the backlash could undermine broader conservation support.

Context: The CESR report noted that additional funding for existing voluntary programs alone is unlikely to produce needed reductions and that new requirements "in case-specific circumstances may be necessary." But the politics of moving from voluntary to mandatory frameworks are fraught, particularly where agricultural communities have deep roots and significant political influence. This scenario tests how the coupled system responds when a core institutional assumption changes.

Before moving to the map, discuss:

- Does this feel plausible? Has anything like it been proposed in jurisdictions you know?
- How would different actors respond (e.g., farmers, extension agents, conservation districts, commodity groups, elected officials)?
- Where in your map would trust between institutions and landowners matter most?

SOCIO-ECONOMIC SHOCK A

Accelerated Farmland Conversion in Peri-Urban Watersheds

What happens: High housing demand in the Baltimore-Washington corridor, rising farmland values, and declining agricultural profitability trigger a wave of farmland-to-residential conversion. Over five years, the conversion rate doubles relative to the 2015–2025 baseline, concentrated in counties at the rural-urban interface where zoning allows development.

Consequences: Effects on the nutrient budget are mixed: conversion removes some agricultural sources, but construction generates sediment and completed development replaces pervious land with impervious surfaces producing different pollutant profiles. Remaining farms face pressure from suburban neighbors complaining about odors, noise, and spray drift. Agricultural support infrastructure (e.g., feed mills, equipment dealers, extension offices) thins as the customer base shrinks. Farmland preservation programs struggle to compete with development offers.

Context: Land use change is the watershed's slow-burning structural challenge. The 2025 Agreement includes conservation targets (2 million additional acres by 2040), but the forces driving conversion are largely exogenous to the Bay management system. The feedback from water quality to land use decisions is weak to nonexistent: no one sells a farm because Bay DO is low, and no one keeps farming because SAV is recovering.

Before moving to the map, discuss:

- Is the rate of conversion accelerating in areas you're familiar with?
- How does land use change interact with other elements in your map? At one point or many?
- Who would detect this change first? Monitoring data, permit applications, satellite imagery, or community experience?

SOCIO-ECONOMIC SHOCK B

Collapse of a Major Regional Seafood Market

What happens: A combination of pressures – multi-year decline in blue crab abundance, competition from imported seafood, rising fuel and equipment costs, and an aging workforce with few new entrants – pushes the commercial crab fishery into economic crisis. Several of the largest processing plants on the Eastern Shore close or dramatically reduce operations within two years. There isn't a single catastrophic event, but the system reaches a tipping point following a slow accumulation of pressures.

Consequences: The impact falls on working waterfront communities, including watermen, processing workers (many on seasonal H-2B visas), marinas, fuel docks, restaurants, and tourism businesses. Some watermen shift to oyster aquaculture, but skills and capital requirements differ. The cultural identity of these communities faces an existential challenge. State fishery managers face pressure to relax harvest restrictions even when population data suggest caution.

Context: The crab fishery is one of the most visible connections between Bay health and human well-being. And it is a case where the feedback loop is mediated by global markets, labor policy, demographic change, and cultural identity, none of which appear in the current watershed modeling system. The 2025 Agreement includes blue crab outcomes focused on population sustainability, not community economic resilience. This tests whether the system can respond to a shock that is simultaneously ecological, economic, and social.

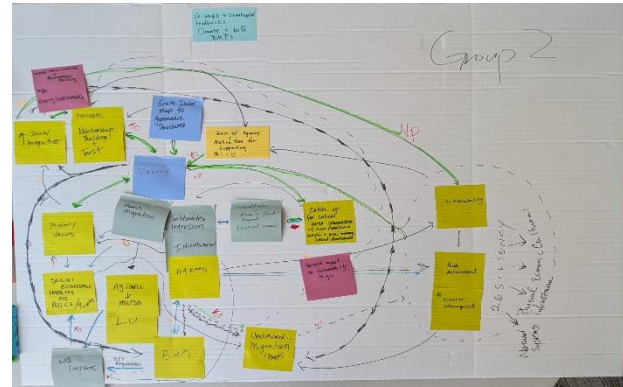
Before moving to the map, discuss:

- Has anyone observed these pressures playing out in specific communities?
- Does this shock enter your map through the ecological system, the economic system, or the social system?
- What feedback loops connect the decline of the fishery back to environmental management? Are they in your map?

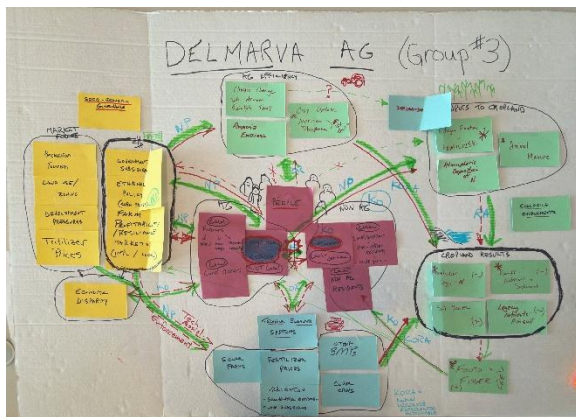
Appendix F: System Maps and Gap Matrix



System map created by Group 1.



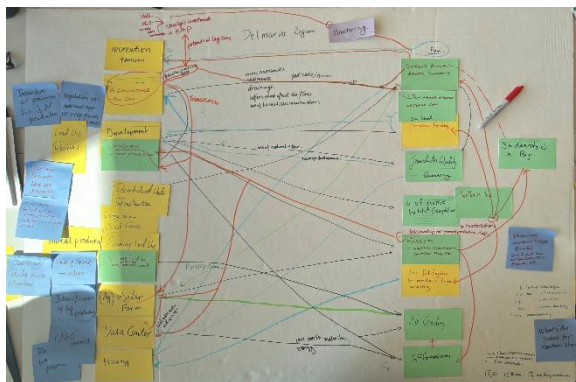
System map created by Group 2.



System map created by Group 3.

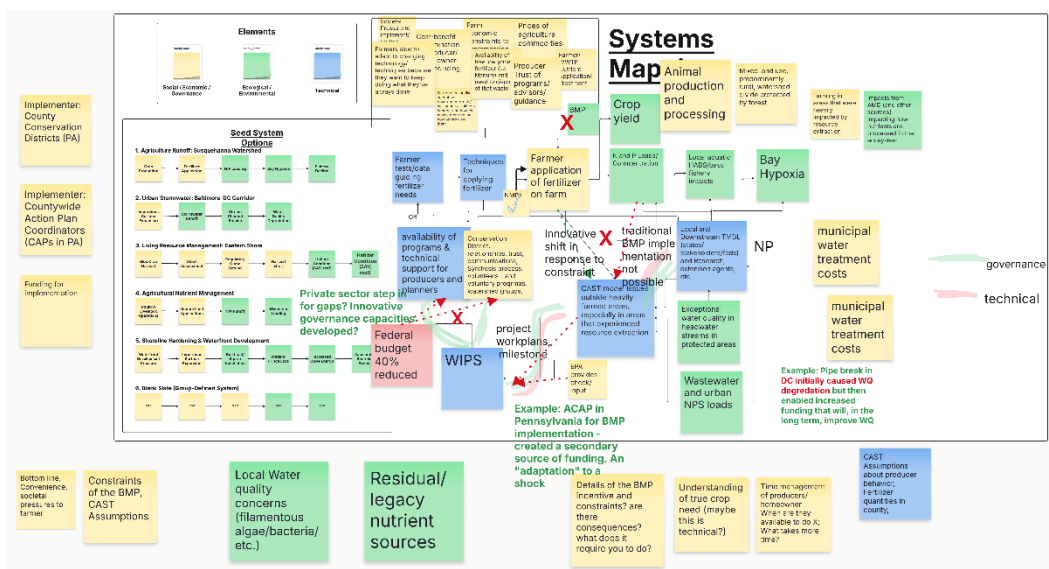


System map created by Group 4.

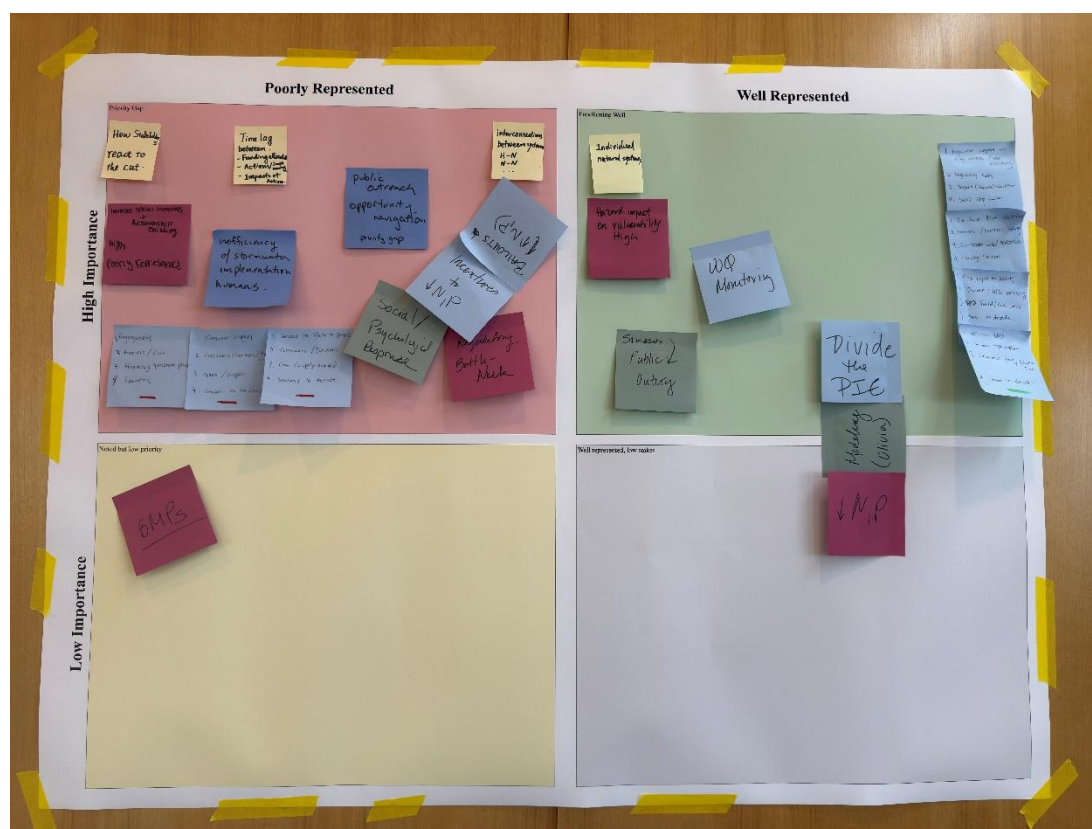


System map created by Group 5.

Appendix F: System Maps and Gap Matrix



System map created by the online group.



Gap matrix that Groups 1-5 contributed to.

Appendix G: 2050 Headlines

Activity: Headlines from 2050

See next page for the newspaper sheet.

Before the morning panel begins, your group will write two newspaper headlines imagining the Chesapeake Bay in 2050 – one desirable outcome, one undesirable. This is a quick generative exercise, not a prediction. Be specific and concrete rather than vague and aspirational.

The headlines you write will be displayed on the wall during the panel and used as the starting point for Session 3. Leave Boxes 1-4 blank for now – we'll return to them in Session 3.

Task 1: Write a desirable headline on the green sheet

Describe a specific, concrete outcome. What would a genuinely good 2050 trajectory look like for the Chesapeake Bay Watershed, given what you know from your work on Day 1?

Good headlines are specific.

"Chesapeake Bay Restored" - too vague

"First Summer with Zero Hypoxic Days Recorded in Mainstem Bay; SAV Acreage Hits Pre-Colonial Estimates" - specific, testable

Task 2: Write an undesirable headline on the salmon sheet

Same standards: specific, concrete, grounded in the dynamics you've been analyzing. What would a bad trajectory actually look like?

"Things Got Worse" - too vague

"Last Commercial Crab Processing Plant on Eastern Shore Closes; Watermen's Association Dissolves After 140 Years" - tells a story

Task 3 (optional): Add a sub-headline or lead sentence to each paper

Write a sentence or two below your headline that makes it feel like it's reporting on something real. This adds context and will help other groups when they work with your headline in Session 3.

Task 4: Post both sheets on the headline wall

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THE CHESAPEAKE CAPITAL SUN-STAR BAY JOURNAL

PILOT-PRESS DEMOCRAT

You sole surviving consolidated news source for the watershed
Today: mostly sunny 81/58, Tomorrow: snow flurries 34/22

Printed on 100% recycled oyster shell paper
Now with 23% fewer hallucinations than the AI edition
March 27, 2050

\$20

Write your headline here

1. What decisions, feedbacks, and events led to this headline becoming reality? Think about the causal chain.

2. Where could the system have gone a different direction? What were the critical decision points or tipping points?

3. What new risks or unintended consequences emerged? What did people not see coming?

4. Looking back from 2050: what would you most want to go back to 2020 and start studying or monitoring?

Blue Crab Population Develops Own Form of Governance; Demands Seat on GLT6

Bay Bridge Tunnel Completes Fourth Bore; Toll Now \$847

Old Bay Shortage Enters Third Month, MD Governor Activates National Guard in response

Annapolis Tourist Asks "What's a Watershed?" for 4 millionth time; Gift Shop Adds FAQ Kiosk

(Write your own funny ones below)

Appendix H: Recommendation Worksheet

Problem statement	
3-4 sentences: what specific feedback, gap, or barrier does this address? Link to your Day 1 map and Session 3 analysis.	
Proposed action	
What, specifically, should be done? By whom? At what scale? Be concrete. <i>Test: "Integrate social data into the modeling system" is not a recommendation. "Develop a behavioral response module for the CBP watershed model that represents farmer BMP adoption as a function of economic incentives, information access, and observed environmental conditions, piloted in 2-3 sub-watersheds" is.</i>	
Implementation pathway	
Near-term (within 6 months): what could start now?	
Medium-term (1-3 years): development and piloting	
Long-term target state: what does success look like?	
Which CBP structures could house this? (GITs, workgroups, STAC, modeling team)	
Risks & dependencies	How would you know it's working?
What could prevent this from working? Political feasibility? Resources? Risk of co-option?	Success indicators? What evidence would trigger revision or abandonment?

Appendix I: Post-Workshop Survey

Following the workshop, this survey was distributed to all participants to help assess how useful Coupled Human and Natural Systems (CHANS), Social-Ecological Systems (SES), and/or Complex Adaptive Systems (CAS) frameworks are for the Chesapeake Bay watershed community and inform future research and engagement efforts.

Participant Background

- What is your primary disciplinary background?
 - Natural/physical science (e.g., ecology, hydrology, biology, chemistry)
 - Social/behavioral science (e.g., economics, sociology, political science, psychology)
 - Modeling, data science, or quantitative analysis
 - Law, policy, or planning
 - Communications, education, or outreach
 - Other: _____
- What type of organization do you primarily work for?
 - Federal agency
 - State or local government agency
 - Tribal government
 - Academic or research institution
 - Non-profit or NGO
 - Private sector / consulting
 - Legislative or regulatory body
 - Other: _____
- How familiar were you with CHANS (Coupled Human and Natural Systems) frameworks **before** this workshop?
 - Not familiar at all
 - Slightly familiar
 - Moderately familiar
 - Very familiar
 - Extremely familiar

Integrating Social Science in the Chesapeake Bay Watershed

A recurring theme at the workshop was the need to better integrate social science in modeling, monitoring, adaptive management, and institutional design. This section asks about opportunities and pathways for that integration.

- How important do you think it is to more deeply integrate social science into each of the following areas of the partnership?

	Not at all	Slightly important	Moderately important	Very important	Extremely important	N/A
Watershed modeling (e.g., representing human behavioral responses, not just land use inputs)	☐	☐	☐	☐	☐	☐
Monitoring indicator development (e.g., tracking social conditions, institutional capacity, behavioral change)	☐	☐	☐	☐	☐	☐
Adaptive management processes (e.g., learning loops that incorporate social feedbacks)	☐	☐	☐	☐	☐	☐
Policy design and evaluation (e.g., understanding why certain interventions succeed or fail across different contexts)	☐	☐	☐	☐	☐	☐
Stakeholder engagement and communication strategies	☐	☐	☐	☐	☐	☐
Funding and program prioritization decisions	☐	☐	☐	☐	☐	☐

- In your view, what is the most significant barrier to integrating social science more deeply into the CBP and related watershed programs?
 - Lack of social science capacity within the CBP and partner agencies
 - Institutional structures that don't create space for social science contributions
 - Difficulty translating social science findings into actionable management inputs
 - Skepticism about the relevance or rigor of social science among key decision-makers
 - Social science data and methods are not well-matched to how CBP modeling works
 - No clear champion or mandate for social science integration
 - Other: _____
- The 2025 Chesapeake Watershed Agreement includes a commitment to “integrate social science holistically to support adaptive management.” How confident are you that this commitment will translate into substantive change?
 - Very confident
 - Somewhat confident
 - Uncertain
 - Not very confident
 - Not at all confident
 - Unsure / unfamiliar with the commitment

Relevance of CHANS thinking

This section focuses on the core frameworks introduced at the workshop. In particular, the five properties of coupled systems presented during the workshop (nonlinearity, feedback loops, heterogeneity, adaption/memory, and emergence), and how applicable you find them to Bay restoration challenges.

- How relevant do you find each of the following CHANS/SES/CAS concepts to understanding Chesapeake Bay restoration challenges?

	Not relevant	Slightly relevant	Moderately relevant	Highly relevant	I am not familiar with this concept
Nonlinearity and tipping points (e.g., disproportionate responses to nutrient load reductions)	☐	☐	☐	☐	☐
Feedback loops between environmental conditions and human activities	☐	☐	☐	☐	☐
Heterogeneity (e.g., across actors, places, and scales)	☐	☐	☐	☐	☐
Adaptation	☐	☐	☐	☐	☐
Path dependence (e.g., legacy nutrients, entrenched institutional frameworks)	☐	☐	☐	☐	☐
Emergence (e.g., how system-level patterns emerge from individual outcomes)	☐	☐	☐	☐	☐

- Which of the above concepts do you find **most** compelling or useful for your own work, and why?

Appendix I: Post-Workshop Survey

- In your view, to what extent is CHANS/SES/CAS thinking currently reflected across the following dimensions of Chesapeake Bay watershed work?

	Not at all	Minimally reflected	Somewhat reflected	Substantially reflected	N/A
Depth: when CHANS concepts are used, they are applied rigorously and with nuance (not just as buzzwords)	☐	☐	☐	☐	☐
Breadth: CHANS thinking is present across multiple organizations, programs, and jurisdictions in the watershed	☐	☐	☐	☐	☐
Reach: These frameworks influence actual decisions, not just research publications or planning documents	☐	☐	☐	☐	☐
Integration: Social and ecological dimensions are genuinely coupled in models, monitoring, and management tool	☐	☐	☐	☐	☐
Institutionalization: CHANS approaches are embedded in formal processes, not just individual champion efforts	☐	☐	☐	☐	☐

- Where do you see the biggest gap between where CHANS/SES thinking *is* and where it *needs to be* in the CBW?

- The workshop emphasized a key gap: models and monitoring systems in the CBP tend to represent **human** → **environment** feedbacks (e.g., land use → water quality) much better than **environment** → **human** feedbacks (e.g., water quality conditions → farmer behavior, political support, investment). *How significant do you think this gap is?*
 - ☐ Not significant – current frameworks are sufficient
 - ☐ Somewhat significant – it is a known gap, but manageable
 - ☐ Very significant – it undermines the ability to understand system dynamics
 - ☐ Critical – this asymmetry is a root cause of implementation and/or response gaps
 - ☐ Unsure
- What do you see as the **single most important** place where CHANS thinking could change how the Chesapeake Bay watershed community approaches restoration?

Overall workshop reflections

- Please rate your level of agreement with each of the following statements

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
The workshop gave me new ways of thinking about Chesapeake Bay restoration challenges	☐	☐	☐	☐	☐
The CHANS framework is relevant to the work my organization performs	☐	☐	☐	☐	☐
The mix of participants (scientists, managers, policymakers) strengthened the discussions	☐	☐	☐	☐	☐
The workshop produced outputs (maps, recommendations) that could be useful to the CBP	☐	☐	☐	☐	☐
I learned something valuable from the perspectives of participants outside my discipline	☐	☐	☐	☐	☐
I would recommend this kind of workshop to colleagues working on Bay restoration	☐	☐	☐	☐	☐

- What was the single most valuable thing you took away from the workshop?

- As a result of this workshop, how likely are you to incorporate CHANS/SES/CAS thinking into your own work?
 - ☐ Extremely unlikely
 - ☐ Somewhat unlikely
 - ☐ Neither likely nor unlikely
 - ☐ Somewhat likely
 - ☐ Extremely likely