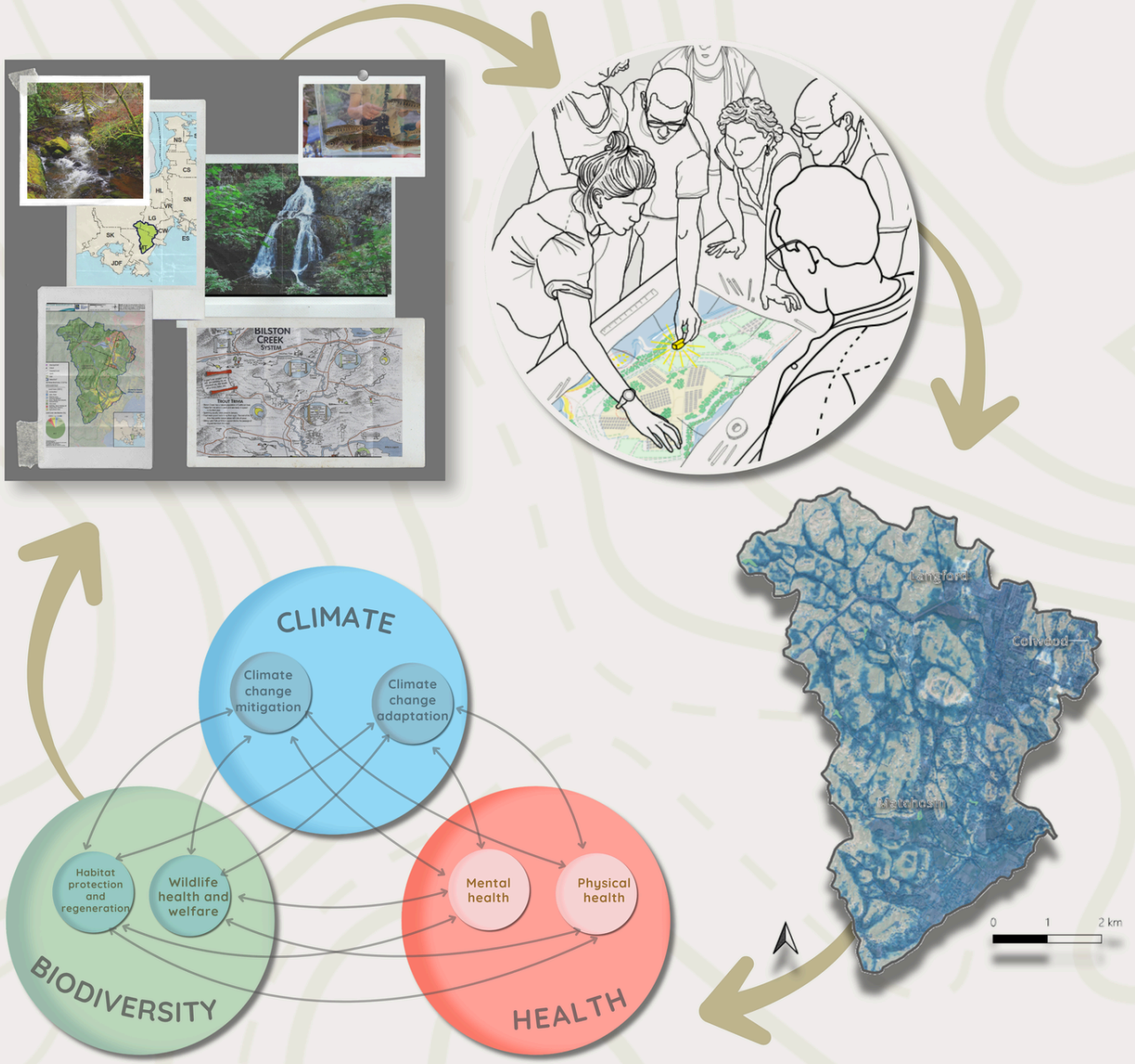


Integrating Flood Risk Models, Community Knowledge, and Systems Thinking for Watershed Planning and Management in the Bilston Creek Watershed

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TRIAS

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We respectfully acknowledge that the Bilston Creek Watershed lies within the traditional territories of the Lekwungen-speaking Peoples, the Songhees and Esquimalt (Xwsepsum) Nations, and the Sc'ianew (Beecher Bay) Nation. These communities have lived on, cared for, and held deep cultural, spiritual, and ancestral relationships with these Lands and waters, including the creeks, wetlands, and forests that constitute the watershed, since time immemorial.

We recognize that this research was conducted without the direct participation of First Nations or Indigenous rights holders, a limitation discussed further in this report, and we extend our gratitude for the opportunity to live, work, and learn on these Lands.

Hay'sxw'qa si'em (hy-sh-kwa sea-em)

1.Introduction

Watersheds are complex social–ecological systems shaped by interactions among hydrological processes, land-use patterns, governance arrangements, and community values. Healthy watersheds provide essential ecosystem services, including water purification, flood regulation, groundwater recharge, aquatic habitat, and resources that support human livelihoods and well-being (Issac & Newell, 2025). At the same time, watersheds are increasingly affected by interconnected pressures associated with climate change, urbanization, ecological degradation, and fragmented governance. These challenges often interact in ways that exceed the capacity of conventional sector-based management approaches, creating a need for integrated and participatory forms of watershed planning and management (Capital Regional District, 2011; Burdon et al., 2022).

Addressing complex watershed challenges requires approaches that recognize the interconnected nature of watershed systems while incorporating diverse forms of knowledge into decision-making processes. Systems thinking provides a useful lens for understanding watersheds as dynamic systems characterized by feedback loops, interdependencies, and leverage points (Arnold & Wade, 2015; Williams & Hummelbrunner, 2011). Participatory approaches are equally important, as they integrate technical information with local knowledge, lived experience, and stakeholder priorities to support collaborative learning and inclusive watershed governance (Creswell & Creswell, 2023; Issac & Newell, 2025).

This research applies systems thinking and participatory methods to explore watershed values, challenges, and management opportunities within the Bilston Creek Watershed. Specifically, the study integrates participatory modelling (i.e., collaborative systems mapping), participatory mapping (i.e., collaborative spatial mapping), and qualitative and spatial analysis techniques to examine how community knowledge can inform watershed planning and management. The climate–biodiversity–health (CBH) nexus framework (Newell, 2023) is used as an analytical lens to organize findings according to their contributions to climate resilience, biodiversity conservation, and community health and well-being.

The report is organized as follows. This section (i.e., Section 1) provides an introduction to the research context and purpose. Section 2 describes the research methods, including the study area, workshop design, and data analysis procedures. Section 3 presents a summary of the results, highlighting the key findings from the analyses. Section 4 discusses findings and presents recommendations organized according to the CBH framework. Section 5 summarizes the study's conclusions, limitations, and opportunities for future research. For readers interested in a more detailed examination of the analyses and findings, the complete Results and Analysis are provided in Appendix A, following the References section.

2. Methods

2.1. Research Design

This research applied a qualitative participatory case study design informed by a community-engaged research approach, systems thinking, and participatory methods. These complementary approaches support the integration of scientific, social, and ecological perspectives while facilitating stakeholder engagement in exploring complex watershed management challenges (Arnold & Wade, 2015; Creswell & Creswell, 2023). The methodological approach builds on recent applications of participatory research to support watershed management planning in the Capital Regional District (Newell et al., 2024; Issac & Newell, 2025).

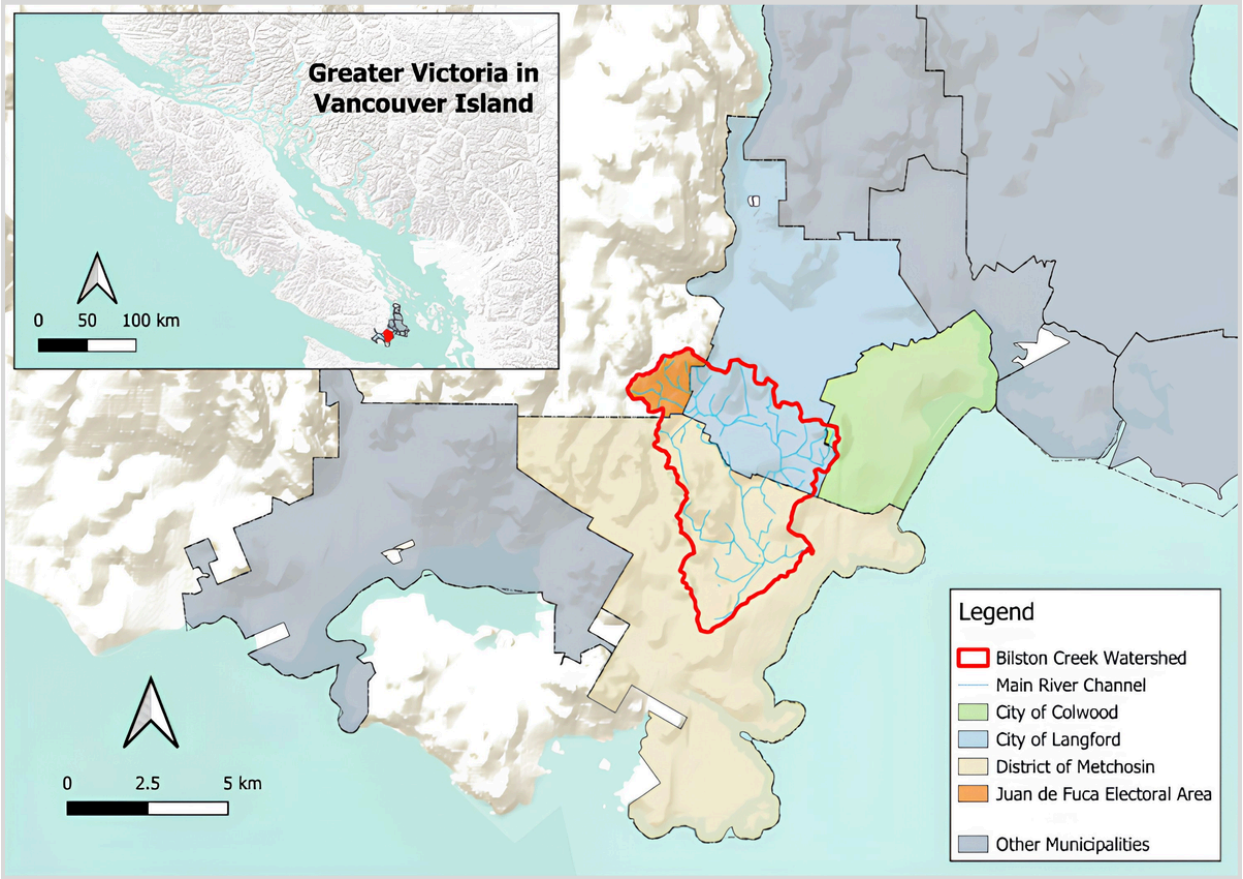
The study used a workshop format that involved participatory systems mapping and participatory spatial mapping activities. These activities involved participants identifying watershed values, challenges, and management strategies and then exploring relationships among these elements. The activities also involved participants identifying representative locations and the spatial distribution of values, challenges, and strategies across the watershed.

2.2. Study Area

The Bilston Creek Watershed is located on southern Vancouver Island, British Columbia, and encompasses approximately 3,174 hectares (Capital Regional District, 2019). The watershed extends into and across the City of Langford, the City of Colwood, the District of Metchosin, and the Juan de Fuca Electoral Area (See Figure 1). It contains a mix of forested lands, wetlands, riparian corridors, rural landscapes, agricultural lands, and urbanized areas that support important ecological, hydrological, and socio-cultural benefits and functions, including streamflow regulation, groundwater recharge, water quality maintenance, habitat provision, biodiversity conservation, recreation, and cultural values (Capital Regional District, n.d.). The majority of the watershed's land area lies within the District of Metchosin (54%) and the City of Langford (36%), with smaller portions extending into the Juan de Fuca Electoral Area (9%) and the City of Colwood (1%) (See Figure 2).

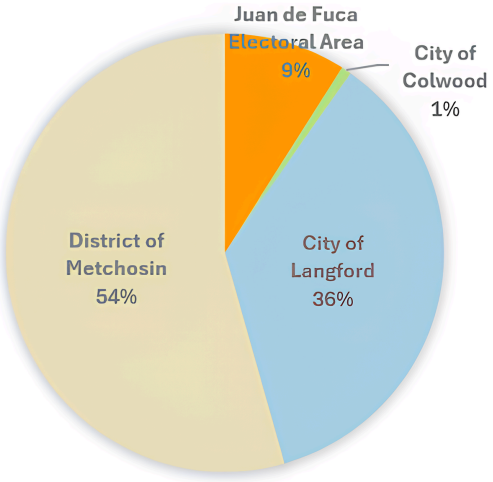
The watershed is in the rapidly developing Westshore region, where urban expansion increasingly influences land-use patterns and watershed management issues. The City of Langford has experienced nearly 60% population growth over the past two census periods, making it one of Canada's fastest-growing municipalities and prompting a transition from a predominantly suburban municipality to a more urbanized regional centre (City of Langford, 2025). The City of Colwood's Official Community Plan anticipates continued population growth and urban development, and it emphasizes the integration of environmental protection, infrastructure planning, and climate resilience into future land-use decisions (City of Colwood, 2025).

Figure 1. Map of the Bilston Creek Watershed Region



Note. Map developed using data from Esri, the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the Capital Regional District (CRD), and BC Data Catalogue. Data accessed June 2, 2026.

Figure 2. Bilston Creek Watershed Surface Area Distribution Across Municipal Jurisdictions



Note. The figure shows the proportion (%) of the Bilston Creek Watershed surface area located within each municipal jurisdiction. Basemap and reference layers were developed using GIS spatial analysis and municipal boundary data from the Province of British Columbia (BC Data Catalogue and DataBC Distribution Service). Data accessed June 2, 2026.

In contrast to Langford and Colwood, the neighbouring District of Metchosin maintains a deliberate low-growth planning strategy to preserve its rural character, agricultural lands, and ecological integrity. Its Official Community Plan recognizes that most future regional growth will occur within neighbouring Westshore municipalities, particularly Langford and Colwood, while Metchosin remains outside the region's primary urban containment area. Between 1996 and 2016, Metchosin's population remained essentially unchanged, whereas Langford and Colwood grew by approximately 102% and 22%, respectively (District of Metchosin, 2026).

The contrasting growth patterns among Metchosin and the rapidly-growing adjacent muncipalities of Langford and Colwood place the Bilston Creek Watershed at the interface between urbanizing environments and rural landscapes. Accordingly, the watershed exists in a complex planning context, where increasing development pressure, watershed protection, climate adaptation, and community stewardship must be balanced through integrated watershed management approaches.

2.3. Workshops

Two workshop offerings were co-organized with the Bilston Watershed Habitat Protection Association (BWHPA). The workshops were held on April 8 and 9, 2026, with each lasting about 2.5 hours. In total, 39 community members were invited, and 19 participated (i.e., 14 on Day 1 and 5 on Day 2). All participants were provided, reviewed, and signed letters of informed consent prior to engaging in workshop activities. The workshop sessions were audio-recorded with participants' knowledge and consent. All personal information was anonymized, and findings were reported in aggregated form, in accordance with research ethics protocols.

Participants were recruited through the BWHPA's established networks to ensure broad representation across backgrounds, roles, and levels of expertise. The resulting participant group included community volunteers, long-time residents, local government officials (including municipal councillors), technical consultants, and representatives from environmental non-governmental organizations and foundations. Participants were engaged in their capacity as community members, and the facilitator made it clear that technical expertise, lived experience, and place-based knowledge of the watershed were equally valued contributions to the process.

Each workshop session began with a brief presentation that situated the research in the Bilston Creek context. This was followed by two facilitated mental visualization exercises, designed to ground participants in place and to activate local knowledge. The first exercise invited participants to imagine a 'special place' in the watershed and reflect on what they value, what concerns them, and what a healthy watershed looks like to them.

Participants were then asked to imagine an extreme flood event in the watershed. This second mental visualization exercise was preceded by a presentation of photographs taken by the researcher during heavy rainfall in December 2025 and historical flood images shared by BWHPA members. These exercises served as experiential anchors for the analytical activities that followed (i.e., participatory modelling and participatory mapping).

Before the participatory exercises, participants received a contextual briefing to establish a shared understanding of the Bilston Creek Watershed and to support informed engagement in the workshop activities. The briefing consisted of historical and contemporary perspectives to ensure participants were grounded in the watershed's evolving conditions and management context.

Technical studies conducted in the early 1990s on flooding, fish habitat, and land stability were provided by the BWHPA for this research. The findings of these studies were summarized and presented to provide historical context and to highlight recurring concerns related to flood risk, habitat degradation, sedimentation, reduced riparian cover, streambank erosion, and localized slope instability. Participants were also introduced to ongoing municipal and regional initiatives and strategies, including stormwater management, climate adaptation, Development Permit Areas, and biodiversity conservation efforts.

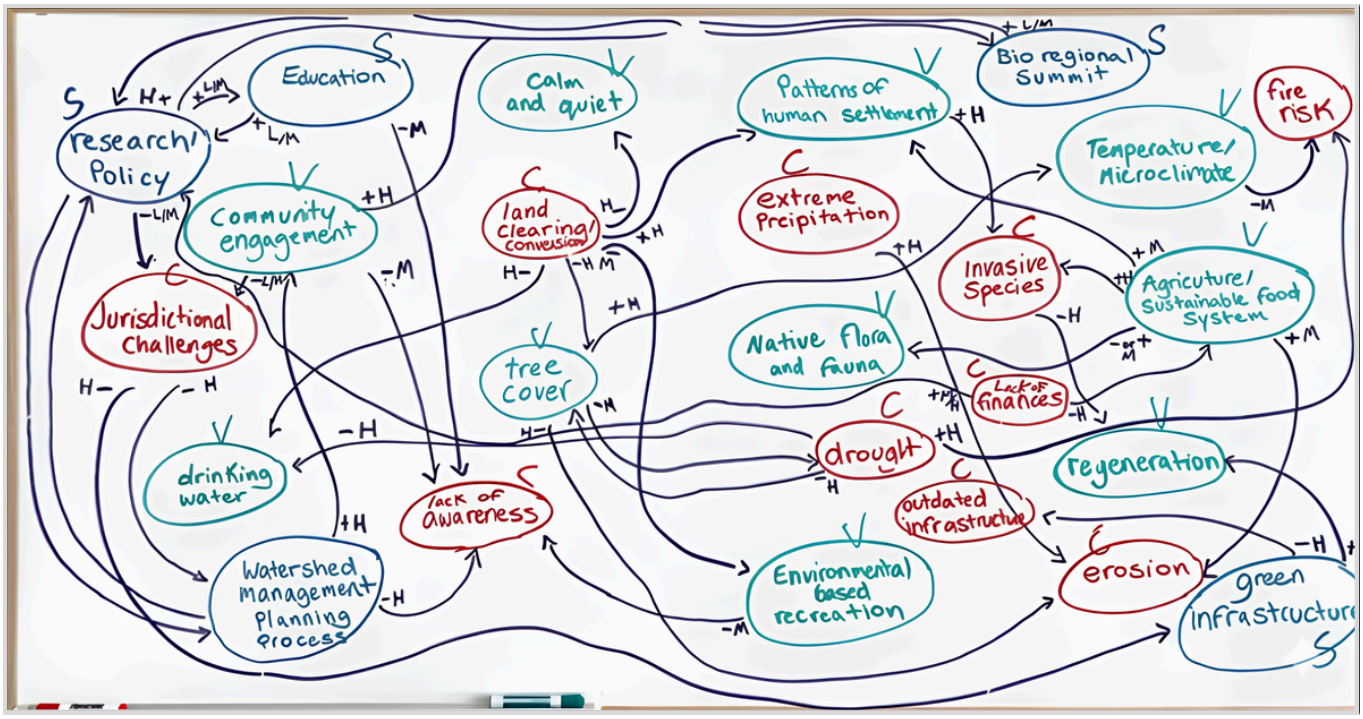
Participatory Modelling: Systems Mapping

Participatory modelling involves facilitated exercises in which stakeholders collaboratively create systems maps of the interactions and relationships surrounding a complex issue (Barbrook-Johnson & Penn, 2021; Issac & Newell, 2025).

On Day 1, 14 participants were organized into two groups of 7 to engage in a participatory modelling exercise; on Day 2, all 5 participants worked as a single group. Each group developed a systems map on a whiteboard using a structured, step-by-step facilitation process. Participants first identified watershed values (drawn in green), then challenges or threats to those values (red), and finally management strategies (blue).

After identifying watershed values, challenges, and strategies, participants drew lines and arrows to represent connections and relationships between elements, each labeled as positive (+, increasing or strengthening) or negative (-, decreasing or weakening), as well as given a strength rating of low, medium, or high. Connections were drawn between all types of elements (i.e., values, challenges, or strategies) capturing systems dynamics across the watershed system (See Figure 3). The process resulted in a total of three systems maps across the two sessions.

Figure 3. Example Participant-Generated Systems Map Outputs from the Participatory Modelling



Note. The systems map shown is one example of a group-generated output illustrating participants' identification of watershed values (green), challenges (red), and management strategies (blue), as well as their perceptions of the relationships among these elements.

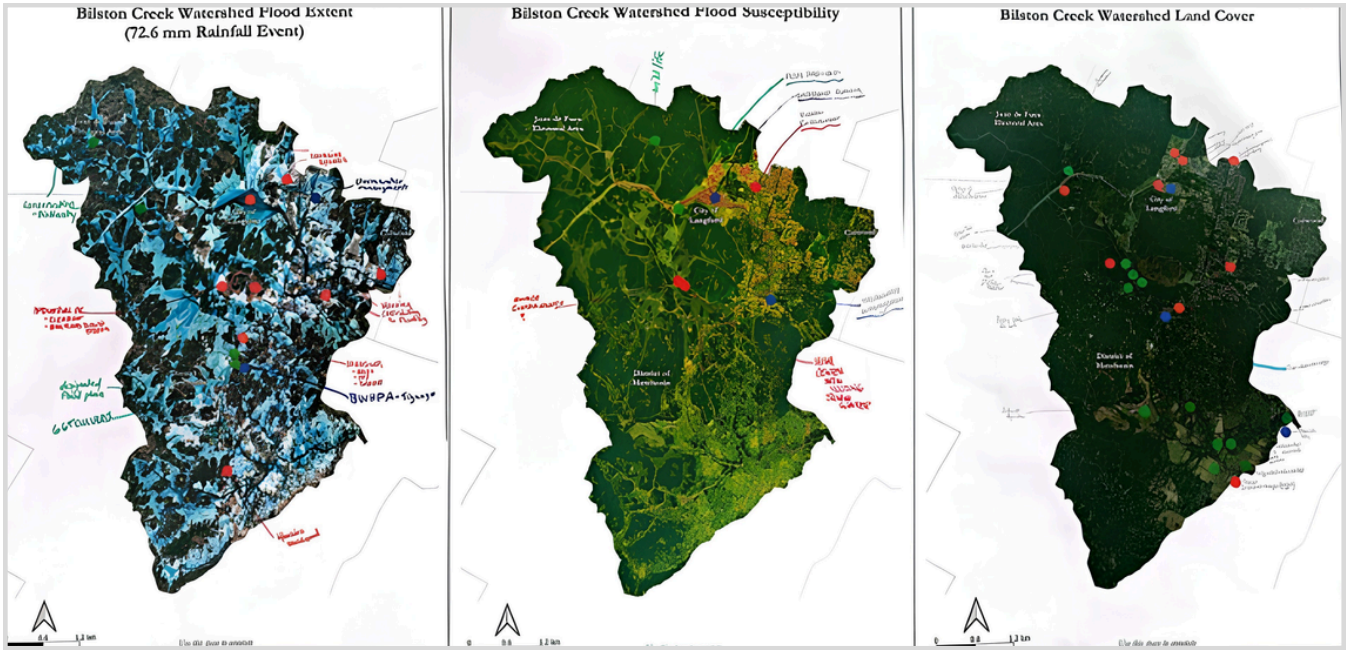
Participatory Mapping: Spatial Mapping

Participatory mapping is a technique for capturing and communicating local values and stakeholder knowledge in spatial form, and it serves to bridge community knowledge with technical spatial information to support collaborative decision-making (Cochrane & Corbett, 2020; Burdon et al., 2022). Following the participatory modelling exercise and working in the same groups, participants engaged in a participatory mapping activity.

Three spatial maps were developed as visual references for this exercise using QGIS and official, publicly available datasets, including the BC Freshwater Atlas, Digital Elevation Model, Capital Regional District land cover data, and BC Data Catalogue municipal boundaries. One map was a land cover map that illustrates surface characteristics at a 1-metre spatial resolution. Another map was a susceptibility map of areas with a topographic tendency to accumulate water. The final map was a flood extent map of a flood scenario based on the historical maximum daily rainfall of 72.6 mm recorded on November 15, 2021, at the Victoria Gonzales station (Environment and Climate Change Canada). The flood scenario map was developed by applying a runoff coefficient of 0.65 to approximate near-saturated conditions.

Each workshop was provided with a complete set of all three GIS-based maps, printed in large, full-color format and displayed as visual canvases during the exercise. Using coloured stickers and matching markers, participants annotated the locations of values (green stickers for 'special places'), challenges (red stickers for 'areas of concern'), and proposed management strategies (blue stickers) across the watershed. Groups were free to annotate across one or multiple maps, and they did so by selecting the spatial layer, or combination of layers, that best suited the elements they were locating (See Figure 4). Two sets of annotated spatial maps were produced across the two sessions.

Figure 4. Example Participant-Generated Spatial Mapping Outputs from the Participatory Mapping



Note. The annotated spatial maps shown represent an example of a group-generated output illustrating participants' identification of watershed values (green), challenges (red), and management strategies (blue) across the Bilston Creek Watershed.

2.4. Data Analysis

Data analysis involved four analytical methods, including network analysis, scenario modelling, qualitative thematic analysis, and spatial analysis, to generate a comprehensive understanding of the Bilston Creek Watershed as a coupled social–ecological system. Together, these methods enabled the integration of systems, qualitative, and spatial perspectives to examine watershed values, challenges, and management strategies from multiple analytical lenses. The analysis followed the work of Issac and Newell (2025), adapted to the present study's context and scope.

Systems Analysis

The three participant-generated systems maps were aggregated into a single systems map, which was developed and analyzed using semi-quantitative systems mapping techniques. This approach connects system elements (nodes) through directional, weighted relationships (edges) that represent participants' perceptions of causal influence within the watershed system (Issac & Newell, 2025). Consistent with this approach, each connection identified during the workshops was assigned a strength rating of Low, Medium, or High by participants, subsequently coded numerically (Low=1, Medium=2, High=3) to support the network and scenario analyses.

The aggregated systems map was digitized and analyzed using network analysis techniques in Gephi (v. 0.10.1), specifically examining six metrics:

- **In-degree centrality** measures the number of incoming connections a node receives and identifies components shaped by multiple converging influences.
- **Out-degree centrality** measures the number of outgoing connections a node generates and identifies components exerting influence across the system.
- **Betweenness centrality** measures the extent to which a node lies along the shortest paths connecting other nodes and identifies structural bridges and bottlenecks.
- **Authority score** identifies nodes that are strongly referenced by other influential nodes and represent focal points of convergence within the system.
- **Hub score** identifies nodes that connect to high-authority nodes and represent systemic amplifiers.
- **Modularity clustering** identifies subsets of nodes that are more densely connected internally than to the rest of the network and represent thematic subsystems.

These metrics provide insight into system structure, influence, connectivity, and emergent thematic patterns, supporting the identification of influential system components, feedback loops, leverage points, and structural bottlenecks within the Bilston Creek Watershed social–ecological system (Freeman, 1977, 1979; Kleinberg, 1999; Newman, 2006; Cordeiro et al., 2018).

Building on the network analysis, a scenario analysis was conducted in Mental Modeler (Gray et al., 2013), using the semi-quantitative systems modelling and simulation approach (Issac & Newell, 2025). Each of the 14 strategy nodes was individually activated by setting its value to 1 while holding all other nodes at 0. A value of 1 represents a strategy being implemented at its full strength, while a value of 0 represents a strategy that is not implemented.

Systems simulations were conducted to see the degree of effects that an activated strategy node has on each other node in the system, measured on a scale from -1 (a strong balancing or reducing effect) to +1 (a strong reinforcing or increasing effect). Individual strategy activations were followed by three grouped scenario runs, in which grouped strategies were activated simultaneously to examine synergistic and emergent system-wide effects.

Thematic Analysis

Qualitative data was collected through facilitated group discussions at the close of each workshop day, organized around two discussion questions:

1. What major concerns do the participatory exercises reveal about the watershed?
2. What strategies could help address the concerns and issues?

Workshop discussions were audio recorded, transcribed, aggregated across both workshop days, and analyzed in NVivo 15 using a three-layer coding framework. This consisted of a deductive coding layer that applied the CBH nexus framework (Newell, 2023) to categorize values, challenges, and strategies according to their relevance to climate action, biodiversity conservation, or community health. The second layer consisted of values, challenges, and strategies codes, as per the nodes identified through the participatory systems model. The final layer consisted of inductive codes that captured emergent themes (rather than predefined categories) identified from the data. Axial coding was done to examine relationships among codes across these three analytical layers.

Spatial Analysis

The two sets of annotated spatial maps were aggregated, digitized, and analyzed using QGIS (v. 3.40.15). Each point was assigned a default weight of 1. Five points that consist of four challenges (housing pressure, flooding, and two land-clearing points) and one strategy (watershed planning) were recorded as placed at the same location by different participants across the two workshop days. These points were assigned a weight of 2 to capture the fact that multiple participants identified the same location and shared community concerns and values.

Each point was given data attributes from other GIS layers. Administrative and jurisdictional attributes were derived through spatial intersection with municipal jurisdiction boundaries, a regional zoning framework, and protected-area boundaries, including BC Parks, ecological reserves, and Capital Regional District (CRD) regional parks. These layers were used to assign zoning or institutional contexts to each point (e.g., forest, park, residential, industrial).

Land-use and land-cover context was derived from the CRD urban land cover dataset at a 1-metre resolution. The land-use and land-cover data integrate LiDAR data across 24 distinct land-use and land-cover classes. Hydrological and transportation context was derived from the BC Freshwater Atlas stream network and the BC Data Catalogue road network, respectively.

A multi-scale buffer analysis was subsequently applied using three distances, 100 metres, 250 metres, and 400 metres, to normalize inconsistencies inherent in participatory point placement by treating each point as representing an area of spatial influence rather than a precise coordinate. The buffers were considered appropriate for representing the immediate locality surrounding participant-identified locations within the Bilston Creek corridor and for identifying statistically meaningful spatial clusters of values, challenges, and strategies across the watershed. The buffers were as follows:

- **A 100-metre buffer**, used to assess proximity to the BC Freshwater Atlas stream network, captured immediate riparian and ecological adjacency.
- **A 250-metre buffer** captured moderate site proximity.
- **A 400-metre buffer** captured the wider walkable locality surrounding each point, representing approximately a five-minute walking distance as per other walkability and accessibility research (Frank et al., 2006).

The watershed was divided into four zones using road corridors as spatial dividers: the Northern Watershed (north of Sooke Road), the Central Watershed (between Sooke Road and Happy Valley Road), the Eastern Watershed (south of Sooke Road and east of Happy Valley Road), and the Southern Watershed (south of the Lindholm Road corridor).

Kernel Density Estimation (KDE) was applied separately to the values, challenges, and strategies point layers using the same 400-metre search radius, incorporating participant weights to generate continuous density surfaces identifying spatial hotspots of community concern and value across the watershed. Hotspot and overlay analyses were then used to identify convergence zones where community priorities intersected with areas of environmental vulnerability.

3. Summary of Outcomes

This section presents a summary of the results, highlighting the key findings from the analysis. Readers interested in a more detailed examination of the analytical procedures and findings can refer to Appendix A, which provides the complete Results and Analysis.

3.1. Systems Components

The participatory modelling exercise produced an aggregated system map of 60 components, 24 values, 22 challenges, and 14 strategies, connected by 95 participant-identified relationships (see Table 1 and Figure 5). Flooding, biodiversity, and lack of awareness were identified as outcomes shaped by multiple interacting pressures rather than existing as singular, isolated problems. The aggregated systems map comprises three types of nodes:

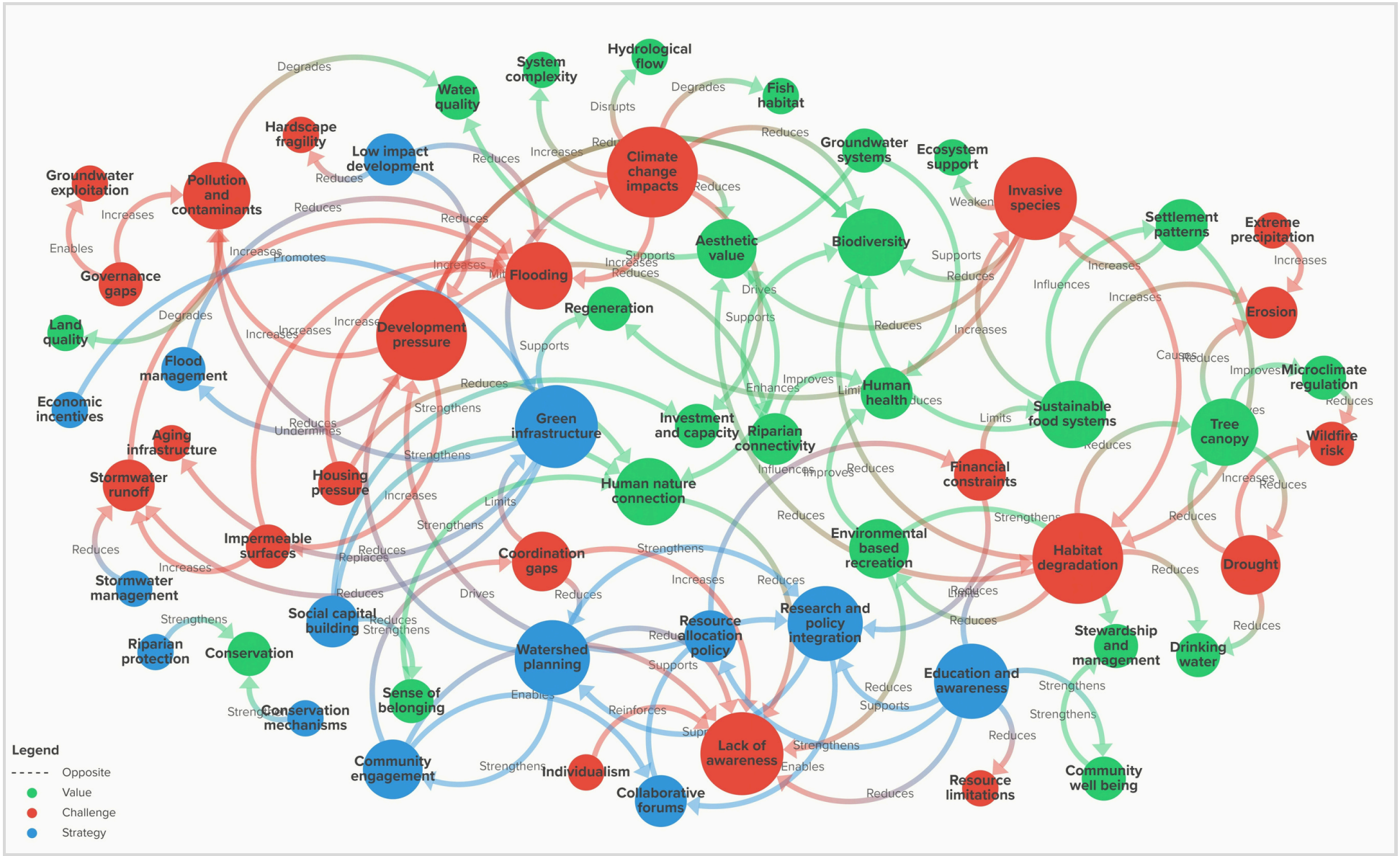
- **Values** represent components of the social–ecological system that contribute to, or are representative of, a healthy watershed and community. Collectively, they highlight the importance of ecosystem integrity, watershed functions, community well-being, and stewardship in supporting long-term watershed resilience.
- **Challenges** represent components of the social–ecological system that constrain, degrade, or threaten watershed and community health. Together, they illustrate how ecological degradation, development pressures, and institutional constraints interact to shape watershed conditions.
- **Strategies** represent actions or interventions proposed to protect, restore, or enhance watershed and community health. Collectively, they reflect participants' recognition that effective watershed management requires coordinated action across environmental, institutional, and social dimensions.

Table 1. Participant-Identified Values, Challenges, and Management Strategies

Values	Challenges	Strategies
• Aesthetic value	• Aging infrastructure	• Collaborative forums
• Biodiversity	• Climate change impacts	• Community engagement
• Community well-being	• Coordination gaps	• Conservation mechanisms
• Conservation	• Development pressure	• Economic incentives
• Drinking water	• Drought	• Education and awareness
• Ecosystem support	• Erosion	• Flood management
• Environmental-based recreation	• Extreme precipitation	• Green infrastructure
• Fish habitat	• Financial constraints	• Low impact development
• Groundwater systems	• Flooding	• Research and policy integration
• Human health	• Governance gaps	• Resource allocation policy
• Human–nature connection	• Groundwater exploitation	• Riparian protection
• Hydrological flow	• Habitat degradation	• Social capital building
• Investment and capacity	• Hardscape fragility	• Stormwater management
• Land quality	• Housing pressure	• Watershed planning
• Microclimate regulation	• Impermeable surfaces	
• Regeneration	• Individualism	
• Riparian connectivity	• Invasive species	
• Sense of belonging	• Lack of awareness	
• Settlement patterns	• Pollution and contaminants	
• Stewardship and management	• Resource limitations	
• Sustainable food systems	• Stormwater runoff	
• System complexity	• Wildfire risk	
• Tree canopy		
• Water quality		

Note. Values, challenges, and management strategies were identified by participants during the participatory modelling exercise and subsequently consolidated into the aggregated System´s Map. Values represent desired watershed conditions, challenges represent perceived pressures, barriers or threats, and management strategies represent actions proposed to address watershed challenges and enhance watershed resilience.

Figure 5. Aggregated System's Map of Watershed Values, Challenges, and Management Strategies



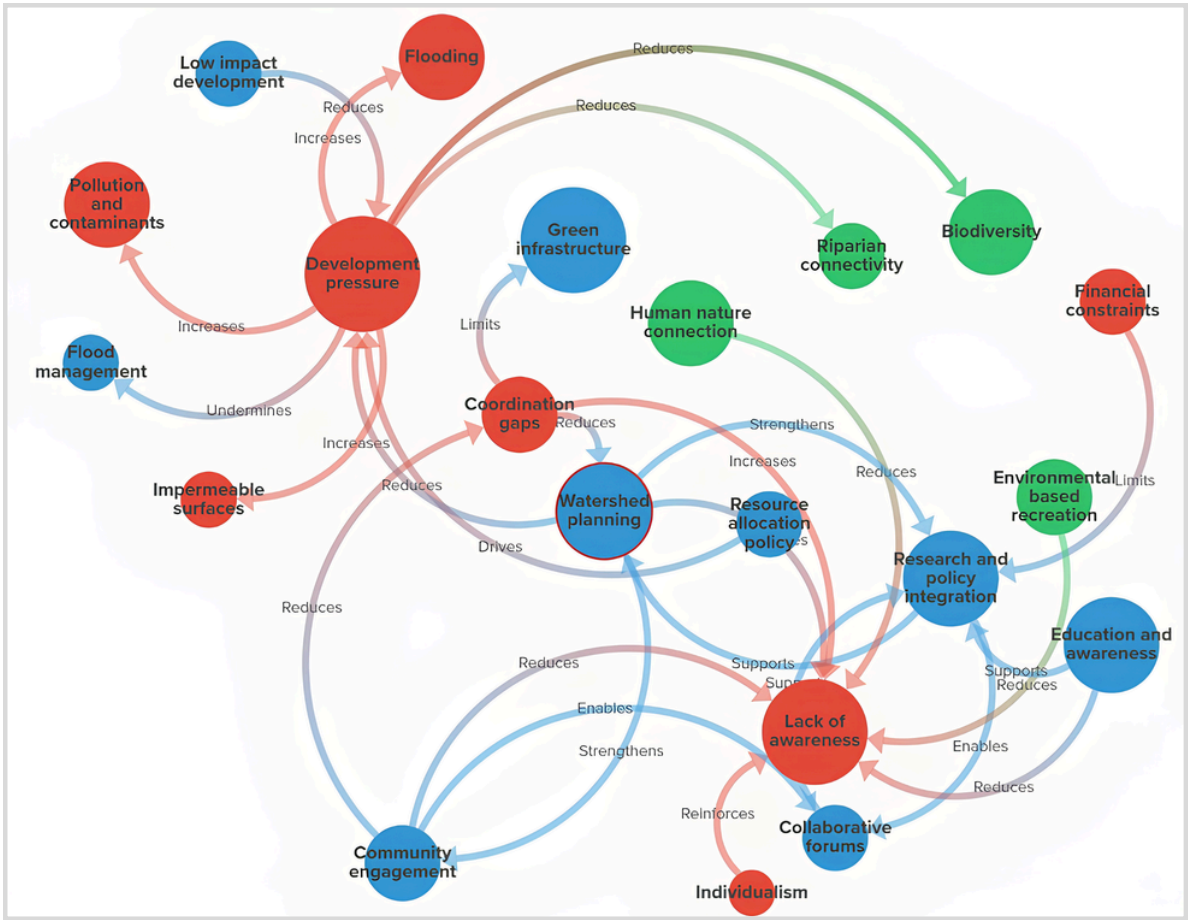
Note. Aggregation of participant-generated systems maps produced during the participatory modelling exercise. Nodes represent individual system components and arrows indicate participant-identified causal relationships. Green nodes indicate values, red nodes indicate challenges, and blue nodes indicate management strategies. This map formed the basis for the network and scenario analyses presented in subsequent sections.

3.2. Network Analysis

Watershed planning and green infrastructure emerged as the system's most structurally important strategies, exhibiting the highest and second-highest betweenness centrality scores, respectively, and functioning as the strongest bridges linking governance, ecological, and community subsystems. In contrast, development pressure and coordination gaps stood out as the two primary structural bottlenecks limiting the effectiveness of other interventions.

A lack of public awareness emerged as the system's principal vulnerable outcome, exhibiting the highest in-degree centrality (i.e., the greatest number of incoming connections) and being amplified by individualism, coordination gaps, limited community engagement, and insufficient education. The findings indicate that participants understood watershed vulnerability as occurring from multiple interacting social, institutional, and environmental pressures rather than isolated challenges (Figure 6).

Figure 6. Structural Network Characteristics of the Bilston Creek Watershed System



Note. Zoomed-in view of the aggregated systems map highlighting the extended network surrounding Watershed Planning, the system's principal bridging strategy, and the converging incoming connections associated with Lack of Awareness, the system's principal vulnerable outcome.

3.3. Scenario Analysis

System-wide benefits, defined as concurrent improvements across ecological, social, and governance outcomes, emerged only when related strategies were activated together as collections of strategies, particularly those associated with the Engagement and Partnership and Policy and Governance domains. No individual strategy produced effects of sufficient magnitude or breadth across the network to simultaneously influence outcomes across the ecological, social, and governance domains. This finding is consistent with systems thinking, which recognizes that meaningful change in complex social–ecological systems arises from the interaction and coordination of multiple interventions rather than from isolated actions (Arnold & Wade, 2015; Issac & Newell, 2025; Williams & Hummelbrunner, 2011).

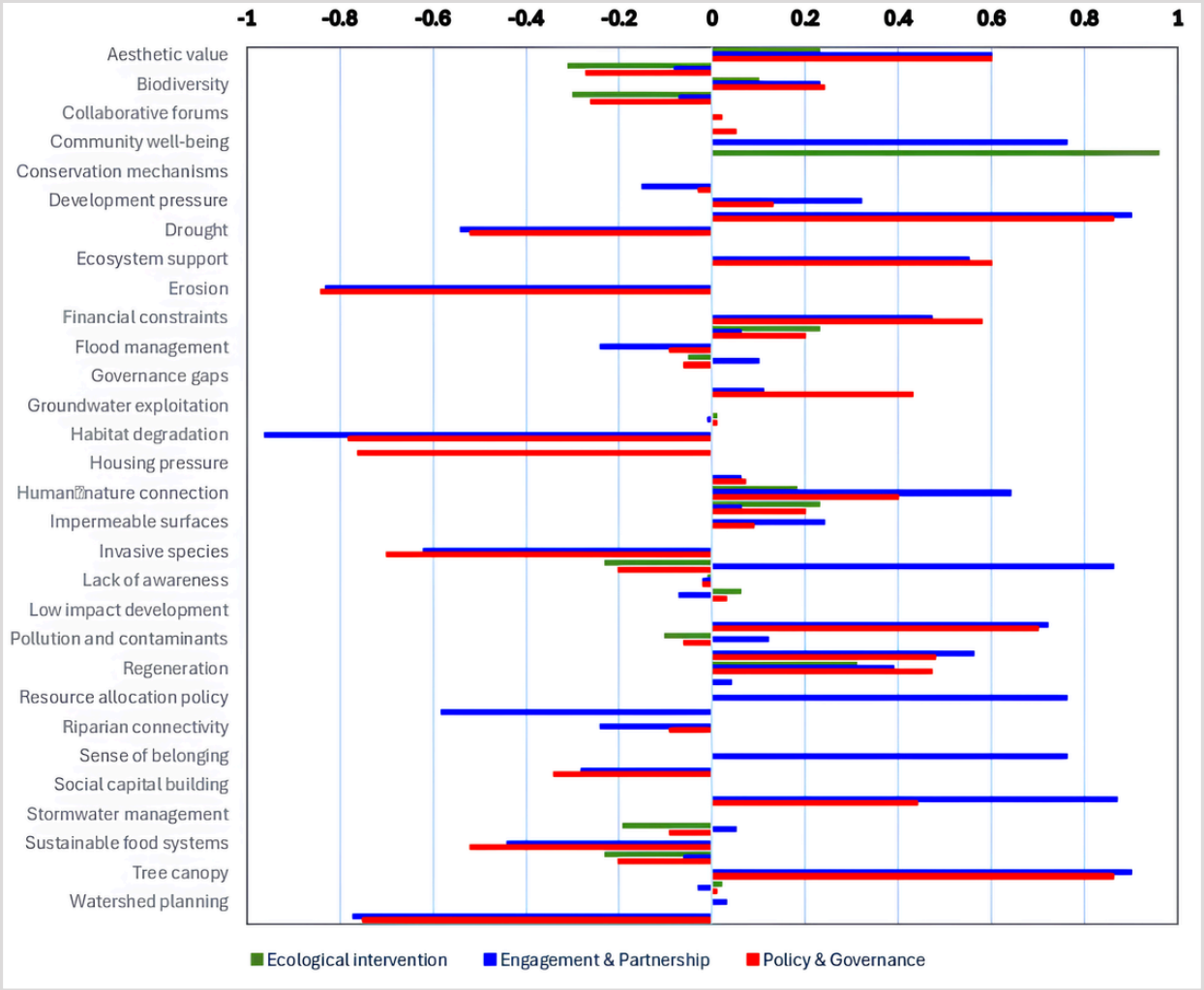
Additionally, every collection of strategies examined through model simulations exhibited trade-offs. No collection of strategies resulted in only beneficial outcomes without generating unintended effects elsewhere in the system. Table 2 summarizes the grouped strategy domains evaluated in the simulations. Figure 7 illustrates the resulting system-wide response when activated.

Table 2. Strategy Grouping for the Scenario Analysis

Strategy Group: Ecological Intervention	
Grouped Strategies: Conservation mechanisms, Flood management, Green infrastructure, Riparian protection, Stormwater management	This domain groups strategies aimed at modifying physical watershed conditions through habitat restoration, hydrological management, and nature-based infrastructure. These interventions primarily target ecological integrity, flood mitigation, water quality, and the functioning of natural systems, representing the biophysical dimension of watershed management.
Strategy Group: Engagement and Partnership	
Grouped Strategies: Collaborative forums, Community engagement, Education & awareness, Social capital building	This domain groups strategies that strengthen relationships among community members, organizations, and stakeholders through collaboration, learning, and capacity building. These interventions focus on increasing awareness, fostering stewardship, building social capital, and supporting collective action, representing the social dimension of watershed management.
Strategy Group: Policy and Governance	
Grouped Strategies: Economic incentives, Low impact development, Research & policy integration, Resource allocation policy, Watershed planning	This domain groups strategies that influence decision-making, resource allocation, planning processes, and regulatory frameworks. These interventions operate through institutional, policy, and planning mechanisms that shape watershed management outcomes and coordinate actions across ecological and social systems, representing the governance dimension of watershed management.

Note. Individual management strategies were thematically grouped into Ecological Intervention, Engagement and Partnership, and Policy and Governance domains to support the scenario analysis. Groupings reflect the primary function of each strategy within the watershed system.

Figure 7. System's Response to Grouped Strategies



Note. Simulated system response to the activation of grouped management strategies within the aggregated systems map. Strategies were activated according to the Ecological Intervention, Engagement and Partnership, and Policy and Governance domains using the hyperbolic tangent activation function in Mental Modeller. Values represent the resulting degree of effect (s) on system components, ranging from –1 (strong balancing effect) to +1 (strong reinforcing effect).

3.4. Qualitative Thematic Analysis

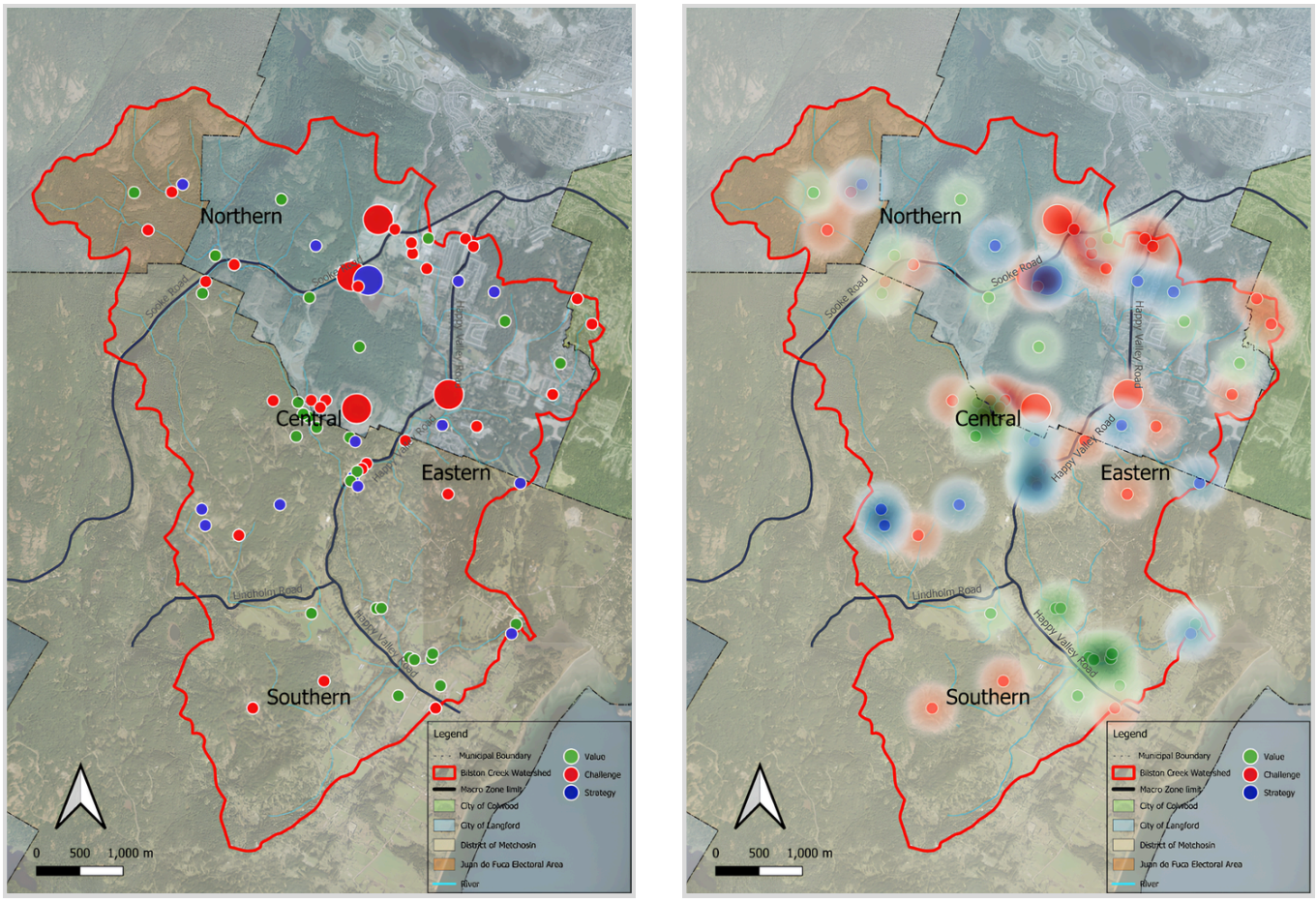
Across the climate, biodiversity, and health domains of the CBH nexus, participants consistently identified the absence of a cross-jurisdictional coordination mechanism as the foundational barrier constraining watershed action, compounded by volunteer burnout and a persistent communication gap that limits broader community engagement. With respect to strategies and opportunities, place-based engagement strategies and the potential revival of the Westshore Watershed Society as a coordinating body of watershed management efforts were identified as the most concrete and actionable opportunity across all three domains.

3.5. Spatial Mapping Analysis

The participatory spatial mapping exercise generated 72 spatial points. Each point represents a location within the Bilston Creek Watershed that relates to one of three categories: values (V,n=27), challenges (C,n=31), and strategies (S,n=14). The eastern watershed area contains the highest concentration of ecological and social values, and the central watershed area contains a concentration of environmental challenges. The Metchosin Creek corridor at the Langford–Metchosin boundary exhibited the highest overlap between values and challenges. No management strategy was mapped within this high-overlap zone, positioning it as the most significant unaddressed spatial planning gap identified through this research.

Figure 8a displays the distribution of participant-identified values, challenges, and management strategies across the watershed, while Figure 8b illustrates the corresponding Kernel Density Estimation (KDE) hotspot surfaces. The maps represent how participants' place-based knowledge distributes across the watershed, with respect to locations perceived as important for ecological values, management challenges, and future stewardship opportunities.

Figure 8. Participant-identified watershed attributes: (a) aggregated spatial map of values, challenges, and management strategies; and (b) Kernel Density Estimation (KDE) hotspots for these attributes.



Note: Participant-identified attributes across the Bilston Creek Watershed (N=72 points), categorized by attribute type (values: green; challenges: red; strategies: blue). (a) Shows individual point locations weighted by cross-group spatial convergence (enlarged symbols). (b) Shows KDE hotspot surfaces generated using a 400-metre search radius and weighted point inputs. Colour gradient indicates increasing point density. Basemap and reference layers were developed using data from Esri, the Capital Regional District (CRD), and the Province of British Columbia (BC Data Catalogue and DataBC Distribution Service). Data accessed June 2, 2020.

4. Discussion and Recommendations

4.1. Integrative Synthesis: Convergent Findings Across Analytical Streams

The research used four complementary analytical methods: network analysis (Gephi), scenario modelling (Mental Modeler), qualitative thematic analysis (NVivo), and spatial analysis (QGIS).

Two major themes emerged from the analyses:

1. Structurally critical systems nodes and locations function as the connective architecture of watershed governance; and
2. Social capital, community engagement, and sense of stewardship are foundations for watershed action.

Theme 1: Structurally critical systems nodes and locations function as the connective architecture of watershed governance

A small number of structurally critical strategies and locations function as the connective architecture of watershed governance, meaning that these strategies and locations bridge otherwise disconnected ecological, hydrological, governance, and community subsystems. The network analysis identified watershed planning and green infrastructure as the two most influential bridging strategies within the participatory systems model, linking governance, ecological, stormwater, and community subsystems together.

By contrast, strategies such as collaborative forums and research and policy integration exhibited narrow, dependent effects in the scenario analysis. Such findings reflect their role as enabling platforms, that is, their influence depends largely on activating these higher-leverage governance pathways, rather than acting as independent drivers.

Coordination gaps and development pressure emerged as the major structural bottlenecks limiting the effectiveness of many interventions. The scenario analysis reinforced these structural findings, as no individual strategy nor collection of strategies was sufficient to address all watershed challenges. For example, the Ecological Intervention collection of strategies produced strong ecological and hydrological recovery but left most social, governance, and community-oriented components of the system unchanged, indicating that ecological restoration alone is insufficient to build the social and institutional capacities that long-term watershed governance requires. Such findings illustrate how watershed resilience depends on a small number of these structurally critical nodes functioning together rather than in isolation.

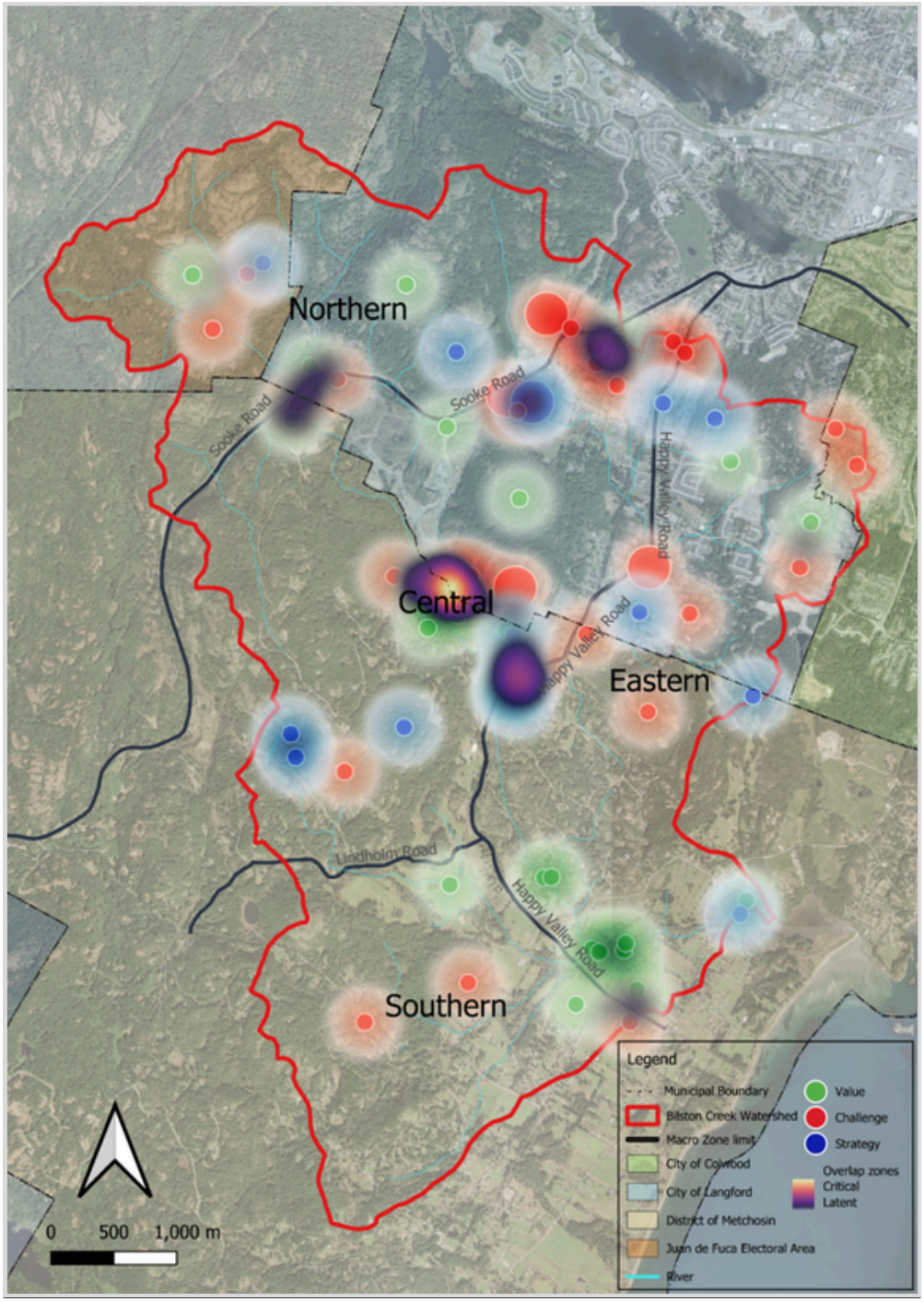
The qualitative thematic analysis provided institutional context for the findings. Participants repeatedly described the challenges of coordinating action across the municipalities of Colwood, Langford, and Metchosin, emphasizing the absence of formal mechanisms through which watershed priorities could be addressed collectively. Rather than reflecting a lack of willingness among organizations or governments, participants described a broader challenge of creating durable structures capable of supporting ongoing collaboration, information sharing, and joint decision-making. As one participant stated, "local governments need to connect," framing the bottleneck not as a failure of values nor intention but as the absence of operational architecture that makes cross-jurisdictional environmental governance a routine function rather than an exceptional effort.

The spatial analysis grounds these structural findings geographically. Riparian adjacency analysis showed that while participants located most ecological values close to watercourses, they positioned most proposed strategies at a slightly greater distance, in the transitional zone between the riparian corridor and the upland landscape. This spatial pattern is consistent with the network analysis findings that green infrastructure and watershed planning function as bridge nodes connecting ecological and governance subsystems. This suggests that participants intuitively located intervention points at the urban–natural interface, where those bridging functions are most needed. The land cover analysis reinforces this finding. The concentration of strategy points along the Galloping Goose Regional Trail corridor, spanning green infrastructure, riparian protection, and research and policy integration, points to this corridor as being a priority area for integrated watershed intervention.

The overlap analysis, combining the value and challenge density surfaces, identified the Metchosin Creek corridor spanning the Langford–Metchosin municipal boundary as the watershed's highest-overlap zone, where the density of participant-identified values and challenges converges most strongly (See Figure 9). Participants identified this corridor as important for ecological regeneration and community well-being on the Metchosin side, and for pollution and flooding concerns on the Langford side.

Notably, no participant-identified management strategy was mapped within the high-overlap zone at the Langford–Metchosin municipal boundary. By contrast, the Galloping Goose corridor, the watershed's moderate-overlap zone, is also the only location where community-proposed strategies (green infrastructure and riparian protection) fall within a zone of value–challenge convergence.

Figure 9. Spatial Overlap Zones Between Watershed Values and Challenges



Note. Spatial overlap analysis: overlay of value and challenge KDE surfaces identifying conflict zones (high-value, high-challenge convergence). Overlap areas indicate locations where valued watershed attributes and perceived pressures converge spatially, highlighting potential priority areas for management and intervention. Basemap and reference layers were developed using data from Esri, the Capital Regional District (CRD), and the Province of British Columbia (BC Data Catalogue and DataBC Distribution Service). Data accessed June 2, 2026.

Theme 2: Social capital, community engagement, and stewardship identity function as a foundational enabling condition for watershed action

The findings indicate that community participation functions not simply as an outcome of successful watershed governance but as one of its enabling conditions. In the network analysis, lack of awareness emerged as the node with the highest in-degree centrality, with incoming connections from individualism, coordination gaps, limited community engagement, and insufficient education and awareness. Such a finding indicates that participants perceived knowledge gaps, communication barriers, and limited public understanding as interconnected outcomes of broader watershed dynamics rather than a standalone communication problem.

The in-degree analysis suggests that participants understood watershed vulnerability through cumulative and relational processes, in which ecological degradation, governance challenges, and social disconnection are closely linked outcomes. The flooding node exhibited high in-degree values, even before flooding was discussed in the workshop, suggesting that this issue was already a relevant and deeply embedded concern within community perceptions of the watershed.

Education and awareness exhibited the second-highest out-degree centrality in the network analysis, positioning it as a foundational governance mechanism with broad system-wide reach. This finding was also reflected in the scenario analysis, where its activation produced the broadest and most socially anchored system response of any individual strategy. However, this response came with meaningful trade-offs, including increases in financial constraints and development pressure, underscoring the need for complementary planning and infrastructure measures.

In the scenario analysis, the Engagement and Partnership collection of strategies generated the strongest social and institutional activation effects of any grouped scenario, strengthening stewardship capacity, coordination, and human–nature connection. At the same time, the results suggest that engagement-based strategies, while highly effective at building stewardship capacity and collective action, are not substitutes for the technical, regulatory, and infrastructural measures needed to manage physical watershed pressures.

Community engagement functioned as a bridging strategy. Its activation in the scenario analysis generated a widespread (but overall mild effect) on the system, with positive effects on governance capacity, supporting ecological improvements, and reducing key watershed stressors. Social capital building, by contrast, functioned as a more narrowly social but still enabling intervention, concentrating its effects on relational nodes such as investment and capacity, sense of belonging, and human–nature connection. This suggests that social capital building requires integration with ecological, infrastructural, and governance interventions to generate broader system-wide outcomes.

Participants articulated the relationship between community participation, stewardship capacity, and durable watershed governance during the workshops. Even when discussing hypothetical scenarios involving unlimited funding, participants continued to identify broad community participation as one of the most difficult and important challenges facing watershed stewardship. The thematic analysis suggests that durable governance capacity may depend on the cultivation of locally rooted stewardship identities capable of supporting action across community, municipal, regional, and provincial scales. As one participant explained:

It has to trickle up…at the community level, at the stewardship level…at the local government level, and then the provincial level, and then the federal level…if you don't have buy-in at the bottom, you're not going to get buy-in at the top.

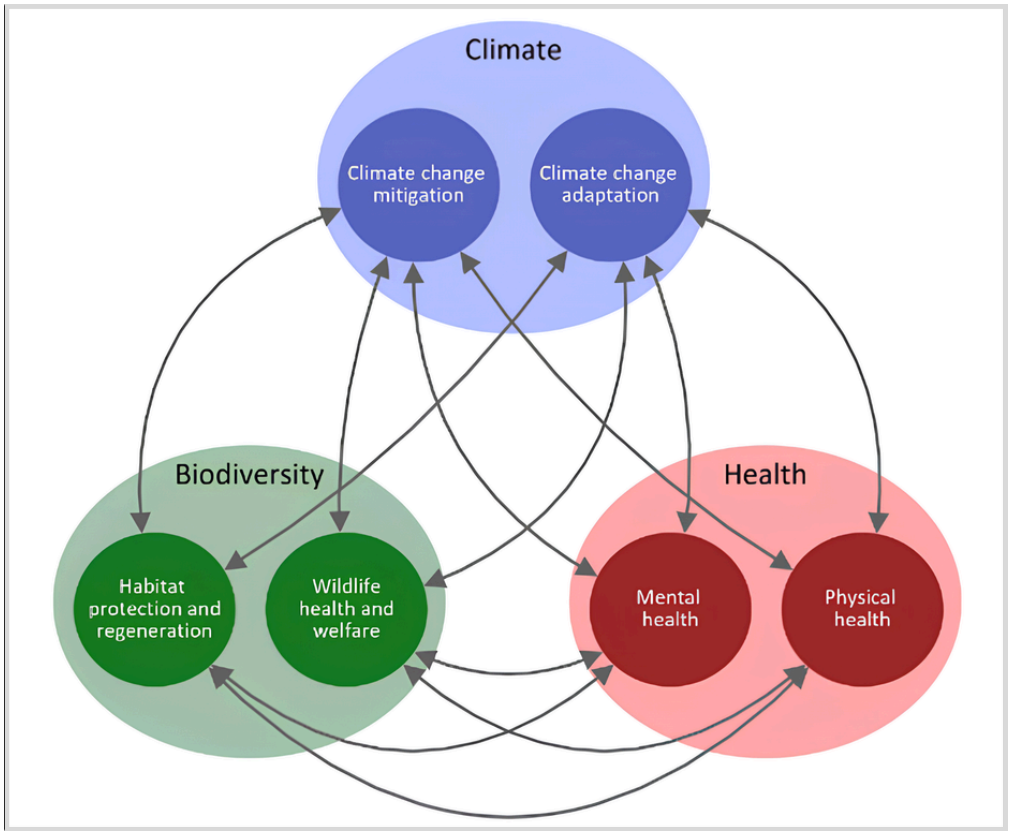
This comment refers to a bottom-up governance model in which community stewardship serves as the foundation for strengthening governance capacity across multiple institutional scales. It also aligns with the network analysis, which identified community engagement as one of the highest-betweenness nodes in the system, bridging social participation and institutional outcomes. The spatial analysis further supports this interpretation by identifying locations such as the Metchosin Creek corridor, where place-based engagement and stewardship-building may provide important foundations for future collaborative action.

4.2. Recommendations

The recommendations presented below are organized using the CBH framework (See Figure 10). Derived from participant-generated strategies identified through the systems mapping, spatial mapping, scenario modelling, and qualitative analyses, these recommendations are grouped according to their primary contributions to climate adaptation, biodiversity conservation, and community health.

The recommendations are based on the evidence across the four analytical methods conducted in this research. The intention of the recommendations is to inform future decision-making, implementation planning, and collaborative discussion among the Bilston Watershed Habitat Protection Association (BWHPA), municipal partners, and other watershed stakeholders.

Figure 10. Climate–Biodiversity–Health (CBH) Nexus Framework



Note. Taken from Newell (2023).

Climate

The climate domain encompasses strategies addressing flood risk, stormwater management, green infrastructure, and climate adaptation governance. Three recommendations emerge as follows:

Develop a coordinated, cross-jurisdictional watershed management plan as the overarching climate governance priority for the Bilston Creek Watershed.

The network analysis identified watershed planning as the single highest betweenness node, confirming its role as the primary structural bridge connecting governance, land-use, ecological, and community subsystems. The scenario analysis demonstrated that activating watershed planning generates simultaneous reductions in development pressure, coordination gaps, pollution, and stormwater runoff while strengthening community engagement, research and policy integration, and green infrastructure. The qualitative analysis identified the absence of such a plan as the most frequently cited structural barrier to climate adaptation. Participants pointed to the Koksilah Watershed planning process as an aspirational benchmark, being a multi-year, multi-government process that demonstrated what inclusive, well-resourced watershed planning looks like when all necessary parties are at the table. A cross-jurisdictional watershed management plan would directly address the horizontal governance silos between Colwood, Langford, and Metchosin that participants

identified as the primary institutional bottleneck constraining collective action. The value of such a plan would be most immediately demonstrated at the Metchosin Creek corridor, the watershed's highest-overlap zone and the clearest present-day illustration of what fragmented governance currently leaves unaddressed.

Scale green infrastructure investment comprehensively across municipal boundaries as the primary site-level climate strategy.

Green infrastructure exhibited the second-highest betweenness centrality value in the network analysis, functioning as a multifunctional bridge between stormwater management, pollution reduction, ecological regeneration, and climate adaptation domains. The scenario simulations for green infrastructure exhibited strong reductions in aging infrastructure, climate change impacts, system complexity, and stormwater runoff, while increasing regeneration, aesthetic value, fish habitat, and hydrological flow simultaneously. The spatial analysis identifies two priority geographic zones for green infrastructure investment, each playing a distinct role within an integrated approach. The Metchosin Creek corridor, the watershed's highest-overlap zone where flooding and pollution concerns on the Langford side directly overlap with community well-being and regeneration values on the Metchosin side, represents the highest-priority zone for new investment, precisely because no strategy is currently proposed there.

The Galloping Goose Regional Trail corridor in the Eastern Watershed is where green infrastructure and riparian protection strategies were identified by participants alongside concerns about hydrological flow, invasive species, and extreme precipitation. This area is a priority zone for expanding and strengthening an existing community-endorsed strategic direction.

The zones illustrate a useful distinction for green infrastructure investment planning, one where intervention needs to be initiated from a starting point of governance and community engagement (Metchosin Creek) and one where intervention can build directly on an existing participatory mandate (Galloping Goose). Participants proposed culvert removal, wildlife bridge construction across highway corridors, and rewilding of suitable parcels as nature-based climate adaptation interventions capable of generating co-benefits across hydrological, ecological, and community domains.

Engage proactively with the incoming provincial riparian regulations as an immediate policy window for climate-oriented watershed protection.

Participants identified new riparian regulations as a substantial near-term opportunity to compel municipalities toward more holistic watershed planning and to create structured openings for community and stewardship group participation in riparian governance. Proactive engagement by the BWHPA and partner organizations, including submission of community-informed priorities based on

the spatial and systems findings of this research, would position the participatory outputs of this study as directly actionable inputs to an emerging regulatory process.

Biodiversity

The biodiversity recommendations relate to strategies for habitat protection, ecological restoration, invasive species management, fish habitat connectivity, and conservation governance. Recommendations are as follows:

Integrate conservation mechanisms and riparian protection structurally into broader watershed planning and green infrastructure frameworks.

Strengthening the structural integration of conservation within watershed management would enable conservation-related actions to function more effectively across governance, social, and infrastructure subsystems. This can be achieved by explicitly incorporating conservation targets into watershed management plan objectives, embedding riparian protection standards within green infrastructure guidelines, and connecting stewardship restoration efforts to municipal development permit conditions. The thematic analysis captured how participants with decades of direct observational experience in the watershed have identified the disappearance of species once abundant and the ongoing loss of riparian habitat as being an outcomes of fragmented governance (rather than simply failures of stewardship effort).

Advance the revival of the Westshore Watershed Society as a strategically significant near-term biodiversity governance opportunity.

Participants identified this organization's existing charitable status as a ready-made institutional asset. This status, which confers eligibility for funding streams unavailable to non-profit societies, took significant time and effort to establish. It could immediately enable the BWHPA and other stewardship groups currently lacking a coordinated institutional mechanism to access resources, coordinate activities, and present a unified institutional face to government funders and regulatory bodies.

Develop a phased biodiversity restoration pipeline, anchored to the spatial priorities identified through the participatory mapping exercise.

The Habitat Conservation Trust Foundation funding application underway at the time of the workshops, targeting stream assessments, flow measurement, and fish habitat inventory, represents an immediate opportunity to build the evidentiary base needed to make the case for coordinated biodiversity investment to municipal councils. Such evidence could support the development of a biodiversity restoration pipeline that sequences invasive species removal, fish passage restoration, rewilding, and strategic land acquisition according to ecological need and spatial priorities.

The Metchosin Creek corridor is a valuable target for land acquisition efforts, which could be funded in part through a voluntary tax mechanism proposed by participants as a means of channeling philanthropic interest into land protection. The area was found to be the watershed's highest-overlap zone in terms of where biodiversity-relevant values converge with the most severe pollution and flooding pressures observed on the spatial map, as well as where no restoration or protection strategy were proposed.

Health

The health recommendations relate to social aspects of sustainability, such as well-being, community agency, sense of stewardship, and governance capacity. The qualitative thematic analysis established that participants across both workshop days converged on a shared understanding that the watershed health is not dependent on funding or policy alone but also the building of social capital, community awareness, and sense of stewardship. Without these community values and assets, neither governance investment nor ecological intervention can sustain itself over time.

Establish a jointly funded cross-municipal environmental coordination position, shared across Colwood, Langford, and Metchosin.

Participants described a cross-municipal environmental coordination position as being a "one-stop shop" that would triage community proposals, translate ecological priorities into governance language. The role would establish a consistent institutional contact that stewardship organizations currently lack when attempting to move priorities through three separate municipal decision-making systems. By strengthening cross-jurisdictional coordination, this role would help close the gap between stewardship capacity and governance-related action.

The network analysis supports this recommendation by revealing coordination gaps to be a key bottleneck for effective cross-jurisdictional watershed action. Addressing coordination gaps through a dedicated, cross-jurisdictional coordination mechanism would directly strengthen the effectiveness of watershed planning, community engagement, and research and policy integration, the highest-betweenness intervention nodes in the system.

The Metchosin Creek corridor provides a concrete example through which a coordinator role could demonstrate the value of improved cross-municipal coordination. The coordinator would help address the gap between stewardship capacity and governance action.

Implement place-based, lived-experience engagement strategies as the primary community health and stewardship-building mechanism.

Participants articulated a convergent set of health-domain engagement opportunities centred on making the watershed visible, relatable, and personally meaningful within everyday spatial experience. They suggested engagement approaches that ground watershed stewardship in participants' own sensory and recreational experience of place rather than in technical or statistical data.

Proposed approaches included placemaking initiatives such as murals on stormwater grates depicting fish downstream, community art installations, and watershed interpretation materials embedded in public spaces. Participants also emphasized framing watershed engagement through recreational, aesthetic, and sensory experiences already part of community life (e.g., children floating boats in seasonal creeks and families identifying wildlife) rather than through technical or urgency-based communication. Small, local, place-specific initiatives were also proposed, modelled on the Firehall Creek engagement effort, which succeeded because it was walkable, immediately relatable, and directly connected to participants' own spatial lives.

The spatial analysis offers two complementary geographic priorities for these engagement initiatives. The Galloping Goose Regional Trail corridor in the Eastern Watershed, where green infrastructure and riparian protection strategies already co-locate with recognized environmental vulnerabilities within an administratively protected park corridor, represents a zone where engagement can build on and celebrate an existing alignment between community vision and environmental need, consistent with participants' emphasis on celebrating visible ecological wins. The Metchosin Creek corridor represents a place where engagement is needed precisely because no shared vision yet exists and where place-based engagement would need to transcend municipal boundaries.

Design engagement strategies that lower the threshold for participation.

Participants identified communication and the “branding” of the watershed as a distinct and underappreciated barrier to public engagement. They emphasized that engagement strategies should explicitly lower the threshold for participation by addressing the structural barriers identified in the qualitative analysis, including economic precarity, cognitive overwhelm, and disconnection from the mechanisms through which individual actions contribute to collective watershed outcomes.

Participants suggested framing watershed engagement through tangible, emotional, and recreational experiences already embedded in community life. They also emphasized the value of celebrating visible ecological successes in nearby watersheds, such as salmon recovery on the Colquitz River (Bilston Creek itself does not support salmon runs due to the natural barrier posed by Sitting Lady Falls), as a proof-of-concept example that degraded ecosystems can be restored.

Participants suggested engaging incoming residents in emerging developments such as the Centre Mountain project before they arrive, when engagement initiatives may be most effective in shaping their relationship with the watershed. These participant-informed recommendations are further supported by the systems analysis, which identified lack of awareness as the highest in-degree node in the watershed system.

Summary

The following tables synthesize the study's recommendations and implementation considerations using the CBH framework. Table 3 presents the recommended strategies, together with example participant-identified actions and analytical evidence informing their prioritization. Table 4 identifies the key actors, implementation barriers, and opportunities associated with each CBH domain to support integrated watershed planning and implementation.

Actors include the individuals, organizations, or institutions identified by participants as influencing watershed outcomes, while barriers and opportunities represent the constraints and enabling conditions for advancing watershed resilience. Although organized by domain, many themes exhibited cross-domain linkages, reflecting the interconnected nature of climate, biodiversity, and human health within the Bilston Watershed system.

Table 3. CBH Strategy Classification and Prioritization Framework

CBH Domain: Climate		
Recommended Strategies	Example Actions Identified by Participants	Analytical Evidence
Cross-jurisdictional watershed planning	Development of a watershed-wide management plan involving Colwood, Langford, and Metchosin; use of the Koksilah Watershed planning process as a governance model; alignment of municipal planning and environmental objectives across jurisdictions.	Highest betweenness centrality (Watershed Planning, b=100.33); strong scenario performance; repeated emphasis in qualitative findings.
Green infrastructure and nature-based adaptation	Culvert removal and replacement; wildlife bridge construction across transportation corridors; rewilding of suitable parcels; stormwater retention features; riparian enhancement; expansion along the Galloping Goose corridor (moderate-overlap zone) and the Metchosin Creek corridor (highest-overlap zone).	Second-highest betweenness centrality (Green Infrastructure, b=90.0); strong scenario performance; spatial overlap analysis.
Proactive engagement with regulatory and policy windows	Proactive engagement with incoming provincial riparian regulations; incorporation of watershed priorities into municipal planning and development processes.	Qualitative findings; governance analysis; near-term policy window identified by participants.

CBH Domain: Biodiversity		
Recommended Strategies	**Example Actions Identified by Participants**	**Analytical Evidence**
Structural integration of conservation into governance	Embedding conservation targets within watershed management plan objectives; embedding riparian protection standards within green infrastructure guidelines; connecting stewardship restoration work to municipal development permit conditions.	Qualitative findings on fragmented governance and participant testimony describing cumulative species and habitat loss.
Stewardship coordination and conservation governance	Revival of the Westshore Watershed Society as an umbrella coordinating body; collaborative funding applications; coordination among stewardship organizations.	Qualitative findings; governance themes; alignment with Millstream Phase 1 recommendations.
Phased ecological restoration and land protection	Sequenced invasive species removal with native replanting; fish passage restoration through culvert replacement; rewilding in the Luxton area; strategic land acquisition in the Metchosin Creek corridor, supported by the HCTF funding application and a voluntary tax mechanism.	Spatial overlap analysis (Metchosin Creek highest-overlap zone); biodiversity themes; participant-generated strategies.
CBH Domain: Health		
Recommended Strategies	**Example Actions Identified by Participants**	**Analytical Evidence**
Cross-municipal environmental coordination	Jointly funded environmental coordination position serving Colwood, Langford, and Metchosin; consistent point of contact between stewardship groups and local governments.	Coordination gaps as a key structural bottleneck, near-equivalent in betweenness centrality to development pressure; network, thematic, and scenario analyses.
Place-based, lived-experience engagement	Murals on stormwater infrastructure; public art installations; interpretive signage; recreational and sensory engagement (e.g., children floating boats, wildlife observation); adaptation of the Firehall Creek initiative model.	Qualitative findings; place-based engagement themes; spatial priorities (Galloping Goose moderate-overlap zone; Metchosin Creek highest-overlap zone).
Lowered-threshold community engagement and sense of stewardship	Reframing watershed engagement through lived experience rather than technical communication; celebrating ecological successes in nearby watersheds (e.g., salmon recovery in Swan Lake and the Colquitz River); early engagement of incoming residents (e.g., Centre Mountain development).	Lack of awareness as the highest in-degree node (n=7); qualitative thematic findings; network analysis.

Note. The CBH strategy classification and prioritization framework integrates findings from the qualitative thematic analysis, network analysis, scenario analysis, and spatial mapping exercises. Priority strategies represent participant-identified actions organized according to the CBH nexus framework (Newell, 2023). Supporting analytical evidence identifies the primary findings informing strategy prioritization.

Table 4. Key Actors, Barriers, and Opportunities Identified Across the CBH Domains

CBH Domain	Key Actors	Key Barriers	Key Opportunities
Climate	BWHPA; municipal councillors; Provincial Government; Capital Regional District (CRD); private landowners; developers; community researchers	Funding constraints; cost-of-living pressures; inter-municipal governance silos; enforcement ambiguity; lack of political will; sacrifice-zone development mentality	Funding constraints; cost-of-living pressures; inter-municipal governance silos; enforcement ambiguity; lack of political will; sacrifice-zone development mentality
Biodiversity	Culvert removal and replacement; wildlife bridge construction across transportation corridors; rewilding of suitable parcels; stormwater retention features; riparian enhancement; expansion along the Galloping Goose corridor (moderate-overlap zone) and the Metchosin Creek corridor (highest-overlap zone).	Second-highest betweenness centrality (Green Infrastructure, b=90.0); strong scenario performance; spatial overlap analysis.	Funding constraints; cost-of-living pressures; inter-municipal governance silos; enforcement ambiguity; lack of political will; sacrifice-zone development mentality
Health	Proactive engagement with incoming provincial riparian regulations; incorporation of watershed priorities into municipal planning and development processes.	Qualitative findings; governance analysis; near-term policy window identified by participants.	Funding constraints; cost-of-living pressures; inter-municipal governance silos; enforcement ambiguity; lack of political will; sacrifice-zone development mentality

Note. Key actors, barriers, and opportunities were identified through qualitative thematic analysis of workshop discussions and organized according to the CBH nexus framework (Newell, 2023). Categories reflect participant perceptions regarding stakeholder roles, implementation constraints, and opportunities for integrated watershed management.

4.3. Cross-Cutting Structural Recommendations

Three recommendations cut across all three CBH domains.

Integrate urban growth management within watershed governance strategies.

The scenario analysis demonstrated that effective watershed governance strategies should integrate urban growth management alongside resource allocation and governance investments. Enabling strategies, including resource allocation policy and the Engagement and Partnership collection, inadvertently amplified development pressure when activated without accompanying regulatory growth management. The Policy and Governance collection of strategies produced similarly wide-ranging benefits but required substantial increases in financial constraints and carried its own trade-offs for food-producing landscapes and ecological connectivity, underscoring that governance-oriented reforms need to be paired with growth management measures.

Development pressure emerged as particularly resistant to intervention, increasing under nearly every individual and grouped strategy scenario tested. This finding aligns with the network analysis, which identified development pressure as one of the two primary structural bottlenecks within the watershed system. The Metchosin Creek corridor exemplifies this risk. The corridor is simultaneously the location of the highest density of participant-identified values and the site of its most severe flooding and pollution pressures, sitting at a municipal boundary where development decisions made separately by each municipality may seem reasonable when considered individually, yet overlook their implications for the shared watershed context.

Integrate participatory modelling and mapping into adaptive watershed governance

The participatory modelling (systems mapping) and participatory mapping (spatial mapping) approach applied in this study provides a replicable governance tool to support ongoing adaptive watershed management within the Bilston Creek Watershed. The spatial mapping identified of the Metchosin Creek corridor as the watershed's highest-overlap zone in terms of values and challenges, which is a finding that systems mapping alone could not have produced. Such findings highlight the value of the integrated two-part format for identifying place-specific governance gaps.

Additionally, the spatial mapping exercise engaged place-based knowledge that the systems mapping did not surface, including active land clearing along the industrial corridor and the Sooke Highway, reinforcing the value of the multi-activity format for revealing governance blind spots. Periodic repetition of this workshop process, perhaps on a three-to-five-year cycle aligned with municipal planning update processes, would enable adaptive tracking of how watershed conditions, community priorities, and governance responses evolve.

Support collaborative watershed governance through shared learning

The findings of this research provide a community-generated evidence base that can inform integrated watershed governance and collaborative dialogue among the municipal councils of Colwood, Langford, and Metchosin, the Capital Regional District, relevant provincial agencies, stewardship organizations, and community members. Consistent with the community-engaged research approach guiding this study, the dissemination of findings should also serve as an opportunity for collaborative reflection, stakeholder feedback, and co-validation of priorities before implementation pathways are pursued. Such engagement would enable community members, stewardship organizations, and government representatives to collectively review the findings, refine priorities where necessary, and identify practical opportunities for coordinated action.

5. Conclusions

This report synthesized community knowledge, systems thinking, and spatial analysis to support inclusive and adaptive watershed planning and management in the Bilston Creek Watershed. Working in collaboration with BWHPA, the research used participatory systems mapping, participatory spatial mapping, flood risk models, and complementary analytical approaches to examine how community knowledge can inform watershed governance. The findings demonstrate that watershed challenges are shaped not only by ecological and hydrological processes but also by the governance, social, and institutional conditions that influence how communities respond to them. Across all analytical components, participants consistently identified development pressure, climate change impacts, habitat degradation, flooding, and fragmented governance as interconnected challenges requiring coordinated rather than sector-specific responses.

The research demonstrates how participatory methods can operationalize systems thinking within watershed governance while applying the CBH framework as a practical means of organizing and prioritizing watershed management strategies. Beyond supporting the immediate needs of the Bilston Watershed, the study offers transferable lessons for other watersheds facing similar pressures associated with urbanization, climate change, and fragmented governance.

A central finding is that watershed resilience depends on the interaction of multiple strategies operating together. The network analysis identified watershed planning and green infrastructure as critical bridging mechanisms linking ecological, hydrological, governance, and community subsystems. At the same time, development pressure and coordination gaps emerged as major structural constraints that limit the effectiveness of other interventions. These findings suggest that the long-term health of the watershed depends not only on implementing individual interventions, but on strengthening the planning and governance structures that connect and coordinate them.

The scenario analysis showed that no individual strategy (nor any analyzed collection of strategies) was sufficient to address all watershed challenges. Several strategies exhibited benefits across multiple system components, yet some also produced unintended consequences when implemented without complementary planning and governance measures. These results highlight the importance of integrated implementation approaches in which community engagement, policy instruments, land-use planning, and environmental management operate together rather than independently.

The thematic analysis findings provided important context for understanding these structural dynamics. Participants consistently emphasized that while funding and policy support are necessary, meaningful watershed protection ultimately depends on public engagement, stewardship, and community participation. Participants noted that environmental issues often compete with more immediate day-to-day concerns, making awareness-building and relationship-building essential foundations for collective action. Strategies such as placemaking initiatives, visual educational tools, neighbourhood-scale stewardship projects, and locally relevant communication were viewed as important mechanisms for strengthening human–nature connections and fostering long-term stewardship.

Participants identified several barriers to the implementation of strategies, including jurisdictional fragmentation among local governments, limited coordination among organizations, volunteer burnout, political challenges, and funding constraints. Across discussions, a strong consensus emerged regarding the need for a coordinated watershed management framework capable of bringing together municipalities, stewardship organizations, technical experts, landowners, and community members around shared priorities. The potential revival or creation of an umbrella stewardship organization was frequently discussed as one mechanism for supporting this coordination and reducing duplication of effort.

The study demonstrates the practical value of integrating participatory systems mapping and participatory spatial mapping within a single engagement process. The combined approach generated complementary insights into system structure, stakeholder priorities, and spatial patterns of concern while creating opportunities for collaborative learning among participants. The research outcomes provide a community-informed evidence base that can support future watershed planning, stewardship initiatives, and policy discussions.

Ultimately, the findings suggest that the future resilience of the Bilston Creek Watershed will depend less on identifying new technical solutions than on strengthening the social, institutional, and governance capacities required to coordinate existing knowledge, priorities, and actions. Building community stewardship, supporting cross-jurisdictional collaboration, and advancing an integrated watershed management approach represent important opportunities for translating community knowledge into long-term watershed outcomes.

5.1. Research Limitations

Several limitations should be acknowledged. First, while participant recruitment sought to capture a diversity of perspectives, participation remained concentrated within networks associated with BWHPA and therefore may not fully represent all watershed interests. Although the study benefited from extensive local knowledge and stewardship expertise, future watershed planning efforts would benefit from broader engagement with additional stakeholder groups and governance partners, including First Nations communities, whose perspectives are essential to long-term watershed stewardship and management.

In addition, the study was conducted within a limited timeframe, restricting opportunities for iterative engagement, long-term monitoring, and repeated validation of findings over time. Moreover, the participatory and semi-quantitative nature of systems mapping involves a degree of subjectivity in the identification of system relationships and connection strengths. Although this subjectivity reflects the purpose of capturing stakeholder perceptions, it limits direct comparison with other watershed contexts.

A further limitation relates to the structural isolation of the conservation value and its associated strategies (conservation mechanisms and riparian protection) within the aggregated systems map. The network and modularity analyses identified these three components as forming a cluster that is entirely disconnected from the rest of the system. However, participants identified conservation-related concerns during the participatory spatial mapping exercise and elsewhere in the workshop discussions, recognizing connections between conservation, biodiversity, riparian buffers, water quality, and ongoing land-use change.

The structural isolation of the conservation-related nodes observed in the aggregated systems map likely reflects an oversight during the participatory systems mapping exercise than an accurate representation of participants' understanding of the watershed system. Because the workshops did not include a subsequent activity in which participants reviewed and revised the aggregated systems map, this kind of oversight could not be identified and corrected before the network and scenario analyses were conducted. Future applications of this participatory modelling approach would benefit from incorporating a post-workshop review step in which participants examine the aggregated systems map and confirm, revise, or supplement the relationships they identified, thereby strengthening the validity of subsequent structural analyses.

5.2. Future Research

Several opportunities for future research emerge from this study. Future work could integrate the participatory findings with additional environmental monitoring data, including water quality indicators, biodiversity assessments, streamflow measurements, groundwater monitoring, and climate-related datasets. Such integration would strengthen the ability to evaluate how community-identified priorities correspond with measurable ecological conditions and trends.

Additional research could examine governance mechanisms capable of supporting watershed-scale coordination across multiple jurisdictions and organizations. Comparative studies involving other urbanizing watersheds could help identify effective models for collaborative planning, stewardship coordination, and integrated watershed governance.

Expanding participation through hybrid and online engagement approaches may broaden representation and improve accessibility for residents, landowners, industry representatives, and other stakeholder groups who may not participate in traditional workshop formats. Future phases of work would also benefit from collaborative engagement processes that incorporate Indigenous knowledge systems and governance perspectives through relationship-based and co-developed approaches.

Finally, the participatory framework applied in this study offers opportunities for replication and refinement in other watershed contexts. Testing the combined use of participatory systems mapping, participatory spatial mapping, network analysis, scenario modelling, and CBH-based strategy classification across multiple case studies could contribute to the growing body of practice and research supporting participatory watershed governance.

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Appendix A. Results and Analysis

Note on Analytical Scope

During the network, modularity, and scenario analyses, the Conservation value node and the two strategies of Conservation Mechanisms and Riparian Protection formed an isolated cluster that was disconnected from the remainder of the watershed system map. This finding likely reflects a workshop-level limitation in the participatory modelling process, where participants did not explicitly identify relationships between conservation and closely related components, such as biodiversity and water quality, potentially due to time constraints and/or not seeing the lack of connections for these nodes within the visual complexity of the map. This finding likely does not reflect an accurate representation of the participants' understanding of the watershed system. Accordingly, this isolated cluster was excluded from the network, modularity, and scenario analyses presented in Appendix A. The main report presents the complete node list and aggregated systems map components, including the conservation-related nodes. The 5.1 Research Limitations section of the main report discusses this methodological limitation, together with recommendations for improving future participatory modelling exercises.

Participatory Systems Analysis

Systems Components

The participatory modelling exercise resulted in three systems maps. These maps were aggregated into a single systems map, representing participants' collective understanding of the Bilston Creek system. The aggregated map is comprised of 60 nodes (24 values, 22 challenges, and 14 strategies) (See Table 1 and Figure 5 in the main report) connected by 95 directed edges representing perceived relationships among system components. Edge weights reflect the strength of relationships as assessed by participants (Low=1, Medium=2, High=3). The complete node-edge list is presented in Table A1 at the end of Appendix A.

Values

Participants identified 24 values, and these values reflect a wide range of ecological, hydrological, social, and cultural priorities associated with the health and well-being of the Bilston Creek Watershed and its communities. Ecological values include biodiversity, ecosystem support, fish habitat, riparian connectivity, and hydrological flow. Groundwater systems, water quality, and drinking water reflect the watershed's role in sustaining community water resources. Land quality and microclimate regulation capture the productive and climate-buffering capacity of the landscape, with tree canopy and regeneration reflecting participants' recognition of the watershed's capacity for ecological renewal and resilience. Conservation was also identified as a value, reflecting participants' commitment to preserving natural areas and processes.

Social and cultural values include human health, community well-being, environmental-based recreation, human–nature connection, sense of belonging, and aesthetic value, reflecting the diverse ways in which participants relate to and derive meaning from the watershed. Investment and capacity values, referring jointly to the financial resources (investment) and human resources (capacity), and stewardship and management values capture participants' recognition that the active care of the watershed and the resources needed to sustain it are themselves worth protecting. Settlement patterns (described by participants as reflecting the form and character of community development within the watershed) and sustainable food systems were also identified as values, though participants also noted that in certain configurations, they can exert pressures on biodiversity, erosion, and ecological integrity. System complexity was also named as a value, acknowledging the intrinsic worth of a watershed shaped by diverse, interacting processes.

Challenges

The 22 challenges identified by participants span environmental, urban, and social dimensions. Climate change impacts emerged as the most active driver in the system, impacting biodiversity, aesthetic value, hydrological flow, flood resilience, and investment and capacity. Extreme precipitation and drought were identified as climate-linked challenges with cascading effects, including increased erosion, reduced drinking water availability, tree canopy loss, and elevated wildfire risk. Flooding was identified as a major challenge driven by multiple interacting pressures, including climate change impacts, development pressure, housing pressure, and inadequate stormwater management.

Development-related challenges include development pressure, housing pressure, and impermeable surfaces, which together drive increases in stormwater runoff, reduce riparian connectivity, and generate pollution and habitat degradation across the watershed. Stormwater runoff, hardscape fragility, and aging infrastructure reflect the physical vulnerabilities of the built environment under growing urban pressures. Habitat degradation, invasive species, pollution and contaminants are interconnected ecological challenges that adversely affect biodiversity, tree canopy, drinking water, aesthetic value, and environmental-based recreation. Groundwater exploitation and governance gaps were noted as linked challenges, with inadequate oversight enabling unsustainable extraction.

Governance and social challenges include coordination gaps, financial constraints, resource limitations, and individualism, which collectively limit the capacity for collective and institutional action. Lack of awareness (i.e., limited public understanding of watershed values, conditions, and management processes) emerged as the most highly targeted node in the system, and this issue was influenced/increased by housing pressure, individualism, coordination gaps, and human–nature connection.

Strategies

Participants identified 14 strategies for addressing the watershed challenges and protecting/enhancing the watershed values. Watershed planning reduces development pressure, strengthens community engagement, and supports research and policy integration, while collaborative forums and research and policy integration reinforce one another through bidirectional connections. Resource allocation policy was identified as an additional governance tool, influencing both financial constraints and development pressure.

Community engagement and education and awareness are closely connected strategies. Community engagement reduces lack of awareness and coordination gaps and enables collaborative forums, while education and awareness address habitat degradation, resource limitations, and lack of awareness, and strengthens resource allocation policy and community well-being. Social capital strengthens sense of belonging, human–nature connection, and investment and capacity. Green infrastructure is a central strategy in the system, reducing stormwater runoff, mitigating climate change impacts, supporting regeneration, and addressing aging infrastructure, with economic incentives identified as a catalyst for its uptake. Low impact development, stormwater management, and flood management strategies address flooding and stormwater runoff issues.

Network Analysis

Six network metrics were analyzed: betweenness centrality, in-degree centrality, out-degree centrality, authority scores, hub scores, and modularity clustering. These metrics support interpreting the watershed as an interconnected social–ecological system shaped by multiple interacting environmental, governance, infrastructural, and community-related dynamics. For the detailed full network metrics, see Table A3 at the end of Appendix A.

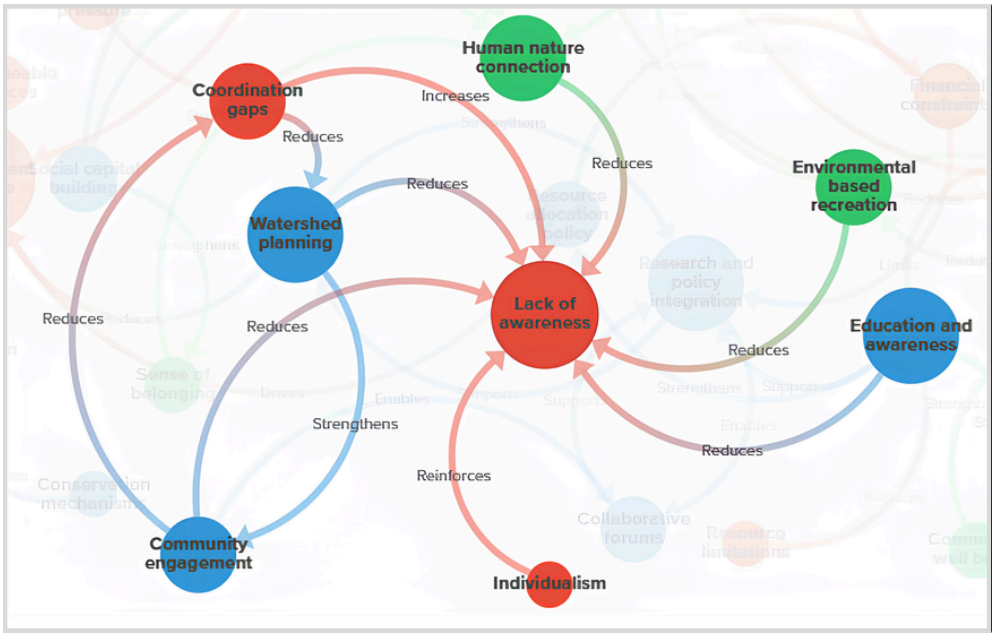
In-Degree Centrality: Vulnerability Outcomes and Cumulative Pressures

In-degree centrality measures the number of incoming connections received by a node and is commonly used to identify elements that are influenced by many other components within a network (Freeman, 1979; Cordeiro et al., 2018). Nodes with high in-degree centrality can be interpreted as outcomes or conditions that emerge from multiple interacting drivers, making them useful indicators of cumulative pressures and system vulnerability. Within the Bilston Watershed system, high in-degree scores identify values and challenges that participants perceived as being shaped by numerous interconnected influences.

Lack of awareness exhibited the highest in-degree value (n=7) among all the nodes, with it being influenced by individualism, coordination failures, limited community engagement, and insufficient education and awareness (See Figure A1).

Biodiversity and flooding followed as the second highest in-degree nodes (n=5 each), reflecting participant understandings of both as cumulative outcomes rather than isolated concerns. Biodiversity was identified as being affected simultaneously by climate change impacts, habitat degradation, invasive species, development pressure, and riparian connectivity. Flooding similarly emerged as a consequence of development and housing pressure, impermeable surfaces, stormwater runoff, and climate variability. Notably, flooding emerged as a prominent theme even though flood-related information was not introduced until the participatory mapping exercise. Research and policy integration and human–nature connection also demonstrated relatively high in-degree values (n=4 each).

Figure A1. Network Relationships Associated with Lack of Awareness as a Vulnerable Outcome



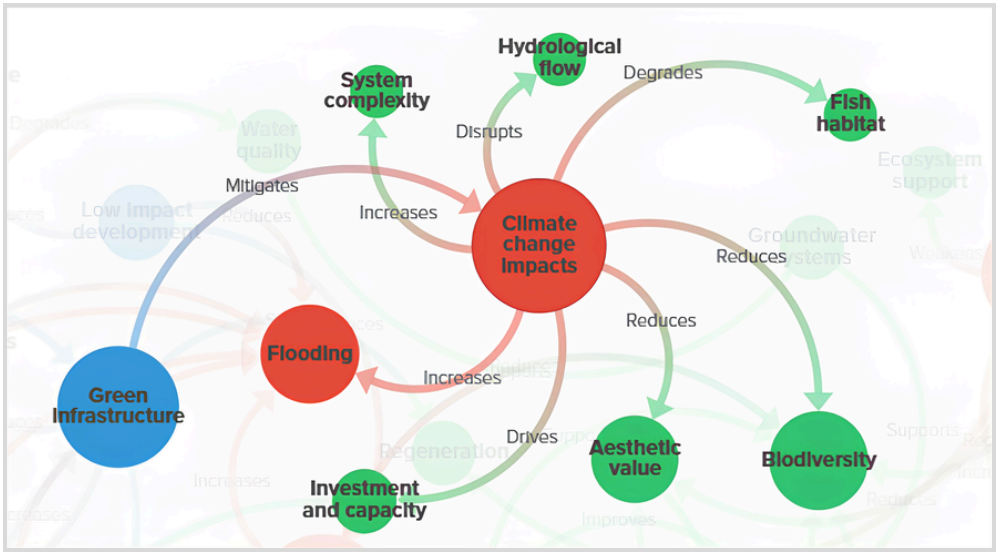
Note. Zoomed-in view of the aggregated systems map highlighting Lack of Awareness and its directly connected system components. This node exhibited the highest in-degree centrality score, indicating its role as a cumulative outcome shaped by multiple interacting influences.

Out-Degree Centrality: Upstream Drivers and Intervention Points

Out-degree centrality measures the number of outgoing connections originating from a node and is used to identify elements exerting influence across a network (Freeman, 1979; Cordeiro et al., 2018). Nodes with high out-degree centrality often represent drivers, intervention mechanisms, or causal factors capable of generating cascading effects throughout the system. Within the Bilston Watershed system, high out-degree scores highlight the challenges and strategies perceived by participants as having the capacity to influence multiple social, ecological, and governance outcomes simultaneously.

Climate change impacts emerged as the driver of the highest number of nodes (out-degree: n=7), linked to flooding, biodiversity and aesthetic value decline, hydrological flow disruption, fish habitat degradation, and increased system complexity (See Figure A2). Education and awareness demonstrated the second highest out-degree value (n=6), associated with reductions in habitat degradation, lack of awareness, and resource limitations, while strengthening community well-being, research and policy integration, and resource allocation policy. Invasive species, habitat degradation, green infrastructure, and development pressure each exhibited out-degree values of n=5.

Figure A2. Network Relationships Associated with Climate Change Impacts as an Upstream Driver



Note. Zoomed-in view of the aggregated systems map highlighting Climate Change Impacts and its directly connected system components. This node exhibited the highest out-degree centrality score, reflecting its influence across multiple ecological, hydrological, and social dimensions of the watershed system.

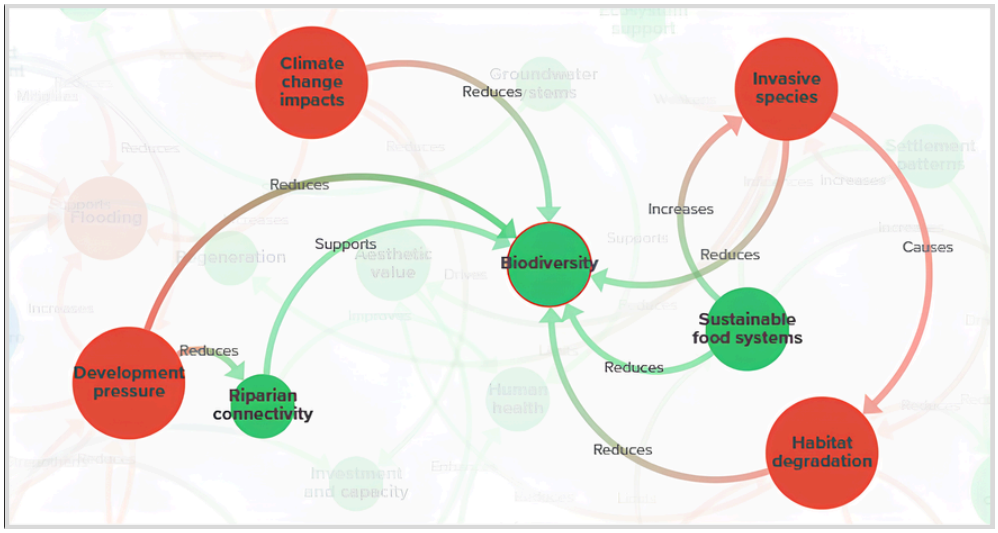
Authority Scores: Focal System Concerns

Authority scores identify nodes that are connected to influential nodes within a network by incoming connections, and high-authority nodes are interpreted as outcomes of interest, important conditions, and/or focal points of collective attention (Kleinberg, 1999; Cordeiro et al., 2018). Unlike in-degree measures, authority scores account for the relative influence of the nodes providing those connections in terms of how well those source nodes are themselves connected to other parts of the system, rather than simply counting them. Within the Bilston Watershed system, authority scores represent the values

and conditions around which multiple influential watershed dynamics converge.

Biodiversity emerged as the strongest authority node (a=0.537), indicating that participants consistently associated it with numerous influential watershed processes, among them climate change, invasive species, habitat degradation, development pressure, sustainable food systems, and riparian connectivity (See Figure A3). Its high authority confirms that ecological integrity is a central organizing concern of the participatory systems model. Aesthetic value demonstrated the second highest authority score (a=0.415), reflecting the importance participants placed on place-based and experiential relationships with the watershed landscape. Flooding also emerged as a significant authority node (a=0.318), with multiple drivers converging around flood-related concerns, reinforcing its centrality to community understandings of watershed risk.

Figure A3. Network Relationships Associated with Biodiversity as a Focal System Concern



Note. Zoomed-in view of the aggregated systems map highlighting Biodiversity and its directly connected system components. This node exhibited the highest authority score, reflecting the convergence of multiple influential watershed processes and its central role within participant understandings of watershed health.

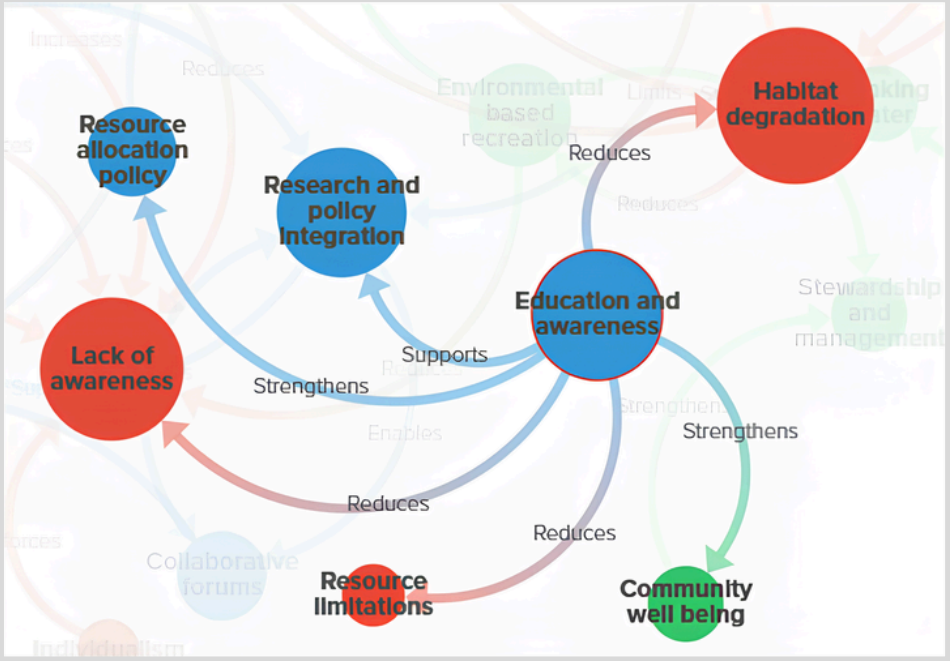
Hub Scores: Strategic Enablers and Systemic Amplifiers

Hub scores measure the extent to which a node connects to important authority nodes, and these metrics are used to identify influential connectors, enabling mechanisms, or strategic intervention points within a network (Kleinberg, 1999; Cordeiro et al., 2018). Nodes with high hub scores capture the extent to which a node functions as an amplifier or driver, capable of shaping multiple important conditions simultaneously. Within the Bilston Watershed system, hub scores highlight strategies and drivers that participants perceived as having broad capacity to influence critical

system outcomes.

Climate change impacts emerged as the strongest hub node (h=0.582), confirming its dual role as both a major out-degree driver and a systemic amplifier pointing toward multiple high-authority nodes. Invasive species (h=0.428) and habitat degradation (h=0.400) similarly demonstrated strong hub characteristics, reflecting their capacity to drive biodiversity decline, ecosystem degradation, and aesthetic value loss across multiple pathways. Education and awareness (h=0.242) emerged as an important intervention-oriented hub, influencing resource limitations, governance processes, and community well-being simultaneously (See Figure A4).

Figure A4. Network Relationships Associated with Education and Awareness as a Strategic Enabler



Note. Zoomed-in view of the aggregated systems map highlighting Education and Awareness and its directly connected system components. This strategy node demonstrated a high hub score, reflecting its capacity to influence multiple important watershed outcomes through governance, stewardship, and community engagement pathways.

Betweenness Centrality: Leverage Points and Structural Bottlenecks

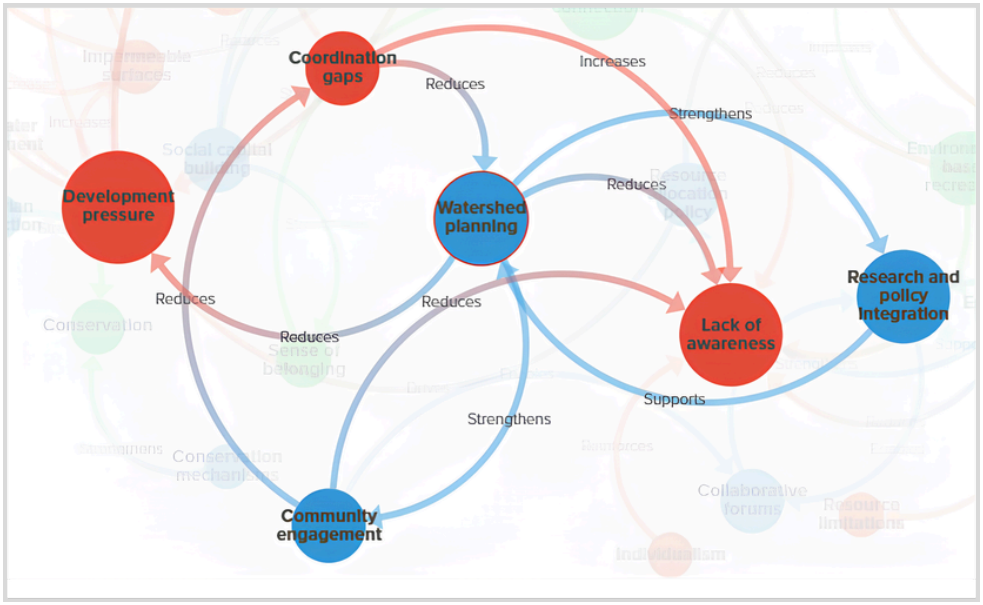
Betweenness centrality measures the extent to which a node lies along the shortest paths connecting other nodes within a network (Freeman, 1977, 1979; Cordeiro et al., 2018). Nodes with high betweenness centrality occupy intermediary positions that facilitate interactions among otherwise

disconnected parts of the system. Consequently, betweenness centrality is widely used to identify leverage points, bridging mechanisms, and structural bottlenecks whose removal or strengthening may substantially alter overall network functioning. Within the Bilston Watershed system, this metric provides an indication of nodes that connect distinct social, ecological, and governance subsystems.

Watershed planning exhibited the highest betweenness centrality value (b=100.33), indicating its strong bridging role across governance, land-use, ecological, and community-related subsystems (see Figure A5). Participants associated watershed planning with reductions in development pressure, lack of awareness, and coordination gaps, and with improvements in community engagement and research and policy integration, positioning it as the primary coordinating mechanism through which integrated watershed management could be advanced. Green infrastructure demonstrated the second highest betweenness value (b=90.0), bridging stormwater management, pollution and contaminants reduction, ecological regeneration, and climate adaptation, functioning as a multifunctional intervention connecting distinct environmental and infrastructural domains.

Development pressure (b=73.83) and coordination gaps (b=73.0) also exhibited high centrality values. Development pressure operates as an upstream structural driver propagating cascading degradation across ecological, hydrological, and governance pathways. Coordination gaps function as an institutional bottleneck constraining the effectiveness of strategies, including watershed planning itself, that depend on cross-jurisdictional collaboration. Research and policy integration (b=70.33) and climate change impacts (b=63) further reinforce the importance of knowledge systems and cross-cutting environmental pressures as critical connective components within the watershed. Community engagement (b=58) similarly acted as a bridge among awareness, governance coordination, collaborative forums, and stewardship-related dynamics, linking social participation to broader institutional outcomes.

Figure A5. Network Relationships Associated with Watershed Planning as a Leverage Point



Note. Zoomed-in view of the aggregated systems map highlighting Watershed Planning and its directly connected system components. This node exhibited the highest betweenness centrality score, indicating its critical role in connecting governance, ecological, land-use, and community-related subsystems within the watershed network.

Modularity Analysis: Thematic Subsystems

Modularity analysis identifies groups of nodes that act as clusters due to their interconnections (Newman, 2006; Cordeiro et al., 2018). In social–ecological systems, modularity can help identify distinct domains of interaction, governance, or concern that structure how participants understand complex relationships. Examining these clusters provides insight into how values, challenges, and strategies are cognitively organized within the system and helps identify opportunities for integration across domains.

Within the Bilston Watershed, modularity analysis identified five clusters (See Table A1) representing thematic subsystems that organize participant understandings of watershed dynamics into distinct but interconnected social–ecological domains. The results reveal how values, challenges, and strategies are arranged within participants' mental models of the watershed and provide an important structural foundation for the thematic interpretation.

Table A1. Identified Modularity Clusters

Cluster 0: Social–Ecological Relationships	
Values: Fish habitat; Human–nature connection; Hydrological flow; Investment and capacity; Sense of belonging; System complexity **Challenges:** Climate change impacts; Housing pressure **Strategies:** Social capital building	This cluster captures the relational interface between social conditions and biophysical dynamics, where housing growth, weakened community bonds, and climate variability converge to erode human–nature relationships and hydrological integrity.
Cluster 1: Governance and Community Engagement	
Values: Community well-being; Environmental-based recreation; Stewardship and management **Challenges:** Coordination gaps; Financial constraints; Individualism; Lack of awareness; Resource limitations **Strategies:** Collaborative forums; Community engagement; Education and awareness; Research and policy integration; Resource allocation policy; Watershed planning	This is the most strategy-rich cluster and contains both the major governance barriers and the corresponding intervention mechanisms, indicating that participants intuitively grouped institutional challenges alongside governance solutions, a finding with direct implications for prioritizing governance reform.
Cluster 2: Flood Risk and Land-Use Pressures	
Values: Groundwater systems; Human health; Land quality; Riparian connectivity; Water quality **Challenges:** Development pressure; Flooding; Governance gaps; Groundwater exploitation; Hardscape fragility; Pollution and contaminants **Strategies:** Flood management; Low impact development	This cluster captures the convergence of urbanization pressures, hydrological vulnerability, and water quality degradation as interconnected land-use challenges.
Cluster 3: Stormwater and Built Environment	
Values: Regeneration **Challenges:** Aging infrastructure; Impermeable surfaces; Stormwater runoff **Strategies:** Economic incentives; Green infrastructure; Stormwater management	Although functionally adjacent to Cluster 2, the algorithmic separation suggests that participants perceived stormwater infrastructure as a distinct domain from broader land-use and flooding governance, an important distinction for infrastructure planning.
Cluster 4: Ecological Degradation and Landscape Integrity	
Values: Aesthetic value; Biodiversity; Ecosystem support; Microclimate regulation; Settlement patterns; Sustainable food systems; Tree canopy **Challenges:** Drought; Erosion; Extreme precipitation; Habitat degradation; Invasive species; Wildfire risk **Strategies:** —	This cluster captures the interconnected processes of ecological stress, where invasive species, habitat loss, and settlement expansion compound to reduce biodiversity and landscape integrity.

Note. Clusters were identified using modularity analysis of the system map. Values, challenges, and strategies are grouped according to their tendency to form densely connected subnetworks. Cluster themes were interpreted and assigned based on the dominant patterns of relationships among nodes. The dash (—) indicates that no nodes from that category were present within the cluster.

Scenario Analysis

Building on the network analysis, a scenario analysis was conducted using Mental Modeler (Gray et al., 2013) following the semi-quantitative systems modelling and simulation approach described by Issac and Newell (2025). Each of the 14 identified strategy nodes was individually activated by assigning it a value of 1 (i.e., implemented at its full effect), while all other nodes were assigned a value of 0 (i.e., not activated at the beginning of the simulation). The resulting influence on the broader watershed system was calculated using the hyperbolic tangent activation function, producing a degree of effect for each system component on a scale from –1 (strong negative or reducing effect) to +1 (strong positive or increasing effect).

Individual strategy simulations were followed by three grouped-strategy scenario analyses, in which strategies were thematically grouped into the Ecological Intervention, Engagement and Partnership, and Policy and Governance domains (see Table 2 in the main report) and activated simultaneously to examine potential synergistic and emergent system-wide effects. Note that these groupings are distinct from the modularity clusters identified through the network analysis, and the groupings were done based on thematic similarities among the strategies. Together, the individual and grouped strategy simulations complement the structural findings of the network analysis by examining not only which nodes are most central, but also how the watershed system responds when different intervention strategies are activated.

Individual Strategy Activations.

Across the 14 individual activations, strategies varied substantially in both the extent of their system reach and the nature of their responses. Three broad patterns were observed: (1) some strategies had broad cross-system reach, (2) some strategies had targeted ecological or environmental impact, and (3) some strategies had narrow impact with a particular focus on only one or a few nodes.

Education and Awareness

Education and awareness produced the broadest and most socially-directed system response of any individual strategy. Activation generated substantial beneficial increases in drinking water (s=0.90), tree canopy (s=0.90), stewardship and management (s=0.87), community well-being (s=0.76), resource allocation policy (s=0.76), microclimate regulation (s=0.72), aesthetic value (s=0.59), environmental-based recreation (=0.56), ecosystem support (s=0.55), human–nature connection (s=0.39), regeneration (s=0.35), biodiversity (s=0.23), human health (s=0.05), research and policy integration (s=0.03), watershed planning (0.01), and water management-related governance pathways. The strategy also exhibited some of the strongest beneficial reductions observed in the entire analysis, including habitat degradation (s=-0.96), erosion (s=-0.83), wildfire risk (s=-0.77),

invasive species (s=-0.62), resource limitations (s=-0.58), drought (s=-0.54), settlement patterns (s=-0.28), and lack of awareness (s=-0.02).

Several important trade-offs emerged with this strategy. Financial constraints increased substantially (s=0.47), while development pressure (s=0.34), impermeable surfaces (s=0.26), pollution and contaminants (s=0.18), flooding (s=0.13), and stormwater runoff (s=0.11) also increased. Simultaneously, flood management capacity (s=-0.26), riparian connectivity (s=-0.26), sustainable food systems (s=-0.44), land quality (s=-0.11), water quality (s=-0.04), and groundwater systems (s=-0.02) declined.

Community Engagement

Community engagement exhibited system effects that link social mobilization with ecological and governance outcomes. Mild benefits from community engagement were seen with green infrastructure (s=0.11), regeneration (s=0.08), fish habitat (s=0.06), hydrological flow (s=0.06), aesthetic value (s=0.06), human–nature connection (s=0.05), collaborative forums (s=0.04), biodiversity (s=0.03), watershed planning (s=0.03), land quality (s=0.02), flood management (s=0.01), research and policy integration (s=0.01), riparian connectivity (s=0.01), and water quality (s=0.01). Mild beneficial reductions were observed for coordination gaps (s=-0.15), aging infrastructure (s=-0.08), climate change impacts (s=-0.07), system complexity (s=-0.06), stormwater runoff (s=-0.04), pollution and contaminants (s=-0.03), development pressure (s=-0.01), flooding (s=-0.01), impermeable surfaces (s=-0.01), and lack of awareness (s=-0.01). The strategy generated a trade-off, a small reduction in investment and capacity (s=-0.06). The strategy ultimately demonstrated to have a very widespread, but overall mild, effect on the system.

Watershed Planning

Watershed planning exhibited the most broadly distributed response profile among the individual strategies, with effects reaching components across governance, ecological, and community domains simultaneously, even though each individual effect magnitude was very mild. Beneficial increases occurred in community engagement (s=0.05), research and policy integration, riparian connectivity, and flood management (s=0.03), green infrastructure (s=0.02), biodiversity (s=0.02), and regeneration (s=0.02), and aesthetic value (s=0.01), collaborative forums (s=0.01), fish habitat (s=0.01), human health (s=0.01), human-nature connection (s=0.01), hydrological flow (s=0.01), and land quality (s=0.01).

The strategy also reduced several governance and land-use stressors, including development pressure (s=-0.05), coordination gaps (s=-0.03), pollution and contaminants (s=-0.03), and impermeable surfaces (s=-0.03), aging infrastructure (s=-0.02), climate change impacts (s=-0.02), and stormwater

runoff (s=-0.02), and flooding (s=-0.01), lack of awareness (s=-0.01), and system complexity (s=-0.01). Importantly, only a minor trade-off was observed, that is, a small decrease in investment and capacity (s=-0.01). The strategy's very mild but broadly distributed influence profile is consistent with its position as the highest-betweenness node in the network analysis, highlighting its role as a critical connector among ecological, hydrological, and governance subsystems.

Research and Policy Integration and Collaborative Forums

Research and policy integration produced a narrow but coherent governance response. Beneficial increases occurred in watershed planning (s=0.03), collaborative forums (s=0.02), community engagement (s=0.01), flood management (s=0.01), green infrastructure (s=0.01), and riparian connectivity (s=0.01). Beneficial reductions included development pressure (s=-0.01), coordination gaps (s=-0.01), impermeable surfaces (s=-0.01), and pollution and contaminants (s=-0.01). No trade-offs were observed. As with watershed planning, the magnitudes of the effects are very mild, indicating limited system-wide effects when this strategy is activated in isolation. Collaborative forums exhibited the most focused response of any governance strategy, influencing only research and policy integration (s=0.01), likewise at a very mild magnitude.

Resource Allocation Policy

Resource allocation policy produced one of the strongest system-wide responses, but also one of the most pronounced trade-off profiles. Beneficial increases included drinking water (s=0.86), tree canopy (s=0.86), microclimate regulation (s=0.70), ecosystem support (s=0.60), aesthetic value (s=0.58), environmental-based recreation (s=0.48), stewardship and management (s=0.44), human–nature connection (s=0.39), regeneration (s=0.37), biodiversity (s=0.22), and investment and capacity (s=0.01). Strong beneficial reductions occurred in erosion (s=-0.84), habitat degradation (s=-0.78), invasive species (s=-0.70), drought (s=-0.52), settlement patterns (s=-0.34), and lack of awareness (s=-0.02).

Trade-offs also emerged. Undesirable increases were observed in financial constraints (s=0.58), development pressure (s=0.56), impermeable surfaces (s=0.46), flooding (s=0.35), pollution and contaminants (s=0.34), stormwater runoff (s=0.25), coordination gaps (s=0.02), aging infrastructure (s=0.01), climate change impacts (s=0.01), and system complexity (s=0.01). At the same time, several beneficial system components declined, including sustainable food systems (s=-0.52), flood management (s=-0.46), riparian connectivity (s=-0.46), land quality (s=-0.24), research and policy integration (s=-0.23), collaborative forums (s=-0.05), groundwater systems (s=-0.05), community engagement (s=-0.03), green infrastructure (s=-0.02), fish habitat (s=-0.01), human health (s=-0.01), and hydrological flow (s=-0.01).

Green Infrastructure and Economic Incentives.

Green infrastructure produced the strongest ecological response among interventions directly targeting the physical environment. Beneficial increases included regeneration (s=0.31), aesthetic value (s=0.23), fish habitat (s=0.23), hydrological flow (s=0.23), human–nature connection (s=0.18), biodiversity (s=0.10), land quality (s=0.06), water quality (s=0.02), and groundwater systems (s=0.01). Beneficial reductions occurred in aging infrastructure (s=-0.31), climate change impacts (s=-0.30), system complexity (s=-0.23), stormwater runoff (s=-0.12), pollution and contaminants (s=-0.10), flooding (s=-0.03), and lack of awareness (s=-0.01). The primary trade-off associated with this strategy was a reduction in investment and capacity (s=-0.23), while most social and governance variables remained unchanged, indicating that green infrastructure is a powerful but a nature-based strategy with relative mild social outcomes.

Economic incentives produced similar results, with increases in green infrastructure (s=0.42), regeneration (s=0.27), fish habitat (s=0.20), aesthetic value (s=0.20), hydrological flow (s=0.20), human-nature connection (s=0.16), biodiversity (s=0.09), land quality (s=0.05), water quality (s=0.02), and groundwater systems (s=0.01). The simulations for economic incentives also produced reductions in aging infrastructure (s=-0.27), climate change impacts (s=-0.26), system complexity (s=-0.20), stormwater runoff (s=-0.11), pollution and contaminants (s=-0.09), flooding (s=-0.03), and lack of awareness (s=-0.01). The primary trade-off associated with economic incentives was a decline in investment and capacity (s=-0.20).

Low Impact Development

Low impact development produced a targeted multi-benefit response. Beneficial increases included flood management (s=0.08), riparian connectivity (s=0.08), biodiversity (s=0.03), land quality (s=0.03), human health (s=0.02), and water quality (s=0.01). Beneficial reductions included hardscape fragility (s=-0.76), development pressure (s=-0.13), impermeable surfaces (s=-0.08), flooding (s=-0.06), pollution and contaminants (s=-0.05), and stormwater runoff (s=-0.03). No notable trade-offs were observed.

Social Capital Building

Social capital building produced effects concentrated within the social and relational components of the system, rather than propagating into ecological or governance nodes. Beneficial increases occurred in investment and capacity (s=0.91), sense of belonging (s=0.76), and human–nature connection (s=0.62), whilst lack of awareness reduced (s=-0.02). No measurable reductions in stressors or trade-offs were observed.

Stormwater Management and Flood Management

The remaining strategies exhibited highly targeted and localized effects. Stormwater management reduced stormwater runoff (s=-0.17) with no additional system responses, while flood management reduced only flooding (s=-0.03).

Grouped Strategy Scenarios

Three grouped strategy domains (Ecological Intervention, Engagement and Partnership, and Policy and Governance) were defined thematically to support the scenario analysis and are distinct from the modularity clusters identified through the network analysis. System simulations on three grouped scenarios (i.e., activating all strategies within a group simultaneously) revealed systems effects substantially exceeding those of any individual strategy in breadth and magnitude, while also making clear trade-offs more analytically visible. Each strategy group demonstrated a distinctive system response profile, reflecting both the strengths and the limitations of its constituent strategies acting in combination.

Ecological Intervention Domain

The Ecological Intervention collection included flood management, green infrastructure, and stormwater management. The strategy group produced the strongest ecological and hydrological benefits of any scenario. Substantial gains were obtained in regeneration (s=0.31), fish habitat (s=0.23), hydrological flow (s=0.23), aesthetic value (s=0.23), and human–nature connection (s=0.18). Additional positive effects were observed for biodiversity (s=0.10), land quality (s=0.06), water quality (s=0.02), and groundwater systems (s=0.01), indicating broad improvements across ecosystem functions and watershed condition. The collection of strategies also generated meaningful reductions in several key stressors, including aging infrastructure (s=-0.31), climate change impacts (s=-0.30), investment and capacity (s=-0.23), system complexity (s=-0.23), stormwater runoff (s=-0.19), pollution and contaminants (s=-0.10), flooding (s=-0.05), and lack of awareness (s=-0.01).

The results suggest that ecological restoration and infrastructure-focused interventions can simultaneously improve watershed functions while alleviating multiple environmental pressures. However, the scenario produced little change across most social, governance, and community-oriented components, including community well-being, stewardship and management, community engagement, collaborative forums, governance gaps, coordination gaps, watershed planning, and resource allocation mechanisms.

Engagement and Partnership Domain

The Engagement and Partnership collection included collaborative forums, community engagement,

and awareness, and social capital building. The strategy group produced the strongest social and institutional effects among all the scenarios. Major increases were observed in drinking water (s=0.90), tree canopy (s=0.90), stewardship and management (s=0.87), investment and capacity (s=0.86), community well-being (s=0.76), sense of belonging (s=0.76), resource allocation policy (s=0.76), microclimate regulation (s=0.72), human–nature connection (s=0.64), aesthetic value (s=0.60), environmental-based recreation (s=0.56), ecosystem support (s=0.55), regeneration (s=0.39), biodiversity (s=0.23), green infrastructure (s=0.11), human health (s=0.06), fish habitat (s=0.06), hydrological flow (s=0.06), research and policy integration (s=0.04), and watershed planning (s=0.03). At the same time, the collection produced substantial beneficial reductions in habitat degradation (s=-0.96), erosion (s=-0.83), wildfire risk (s=-0.77), invasive species (s=-0.62), resource limitations (s=-0.58), drought (s=-0.54), settlement patterns (s=-0.28), coordination gaps (s=-0.15), aging infrastructure (s=-0.08), climate change impacts (s=-0.07), system complexity (s=-0.06), and lack of awareness (s=-0.02).

The findings demonstrate the capacity of social mobilization and partnership-building strategies to generate widespread ecological, institutional, and community benefits. However, important trade-offs emerged. Financial constraints increased substantially (s=0.47), while impermeable surfaces (s=0.24), development pressure (s=0.32), pollution and contaminants (s=0.12), flooding (s=0.10), and stormwater runoff (s=0.05) also rose. In addition, sustainable food systems (s=-0.44), flood management pressures (s=-0.24), riparian connectivity (s=-0.24), land quality (s=-0.07), water quality (s=-0.03), and groundwater systems (s=-0.01) experienced declines.

Policy and Governance Domain

The Policy and Governance collection, combining economic incentives, low impact development, research and policy integration, resource allocation policy, and watershed planning, produced the most structurally comprehensive response across all scenarios. Strong positive effects were observed for drinking water (s=0.86), tree canopy (s=0.86), microclimate regulation (s=0.70), aesthetic value (s=0.60), ecosystem support (s=0.60), environmental-based recreation (s=0.48), regeneration (s=0.47), stewardship and management (s=0.44), green infrastructure (s=0.43), human–nature connection (s=0.40), biodiversity (s=0.24), fish habitat (s=0.20), hydrological flow (s=0.20), human health (s=0.07), community engagement (s=0.05), land quality (s=0.03), collaborative forums (s=0.02), water quality (s=0.01), and groundwater systems (s=0.01). These responses indicate that policy and governance interventions can influence a broad range of ecological, social, and institutional outcomes simultaneously.

The strategy group also generated some of the strongest beneficial reductions observed across all analyses, including erosion (s=-0.84), habitat degradation (s=-0.78), hardscape fragility (s=-0.76), wildfire risk (s=-0.75), invasive species (s=-0.70), drought (s=-0.52), settlement patterns (s=-0.34),

Despite these broad benefits, several trade-offs were observed. Financial constraints increased substantially (s=0.58), and investment and capacity decreased (s=-0.20), representing the largest adverse response within this domain. Development pressure (s=0.13) and impermeable surfaces (s=0.09) also increased, while sustainable food systems declined (s=-0.52) and riparian connectivity and flood management pressures experienced a modest reduction (s=-0.09).

Thematic Analysis

The following analysis is organized around the three CBH domains, with actors, barriers, and opportunities examined within each. The detailed qualitative coding book is presented in Table A4 at the end of Appendix A.

Climate

Within the CBH nexus framework, the climate domain focuses on the ways climate-related drivers, risks, and adaptation responses shape both ecological systems and human well-being. Climate is understood not only as a source of environmental stress through flooding, drought, and extreme precipitation, but also as a governance challenge requiring coordinated action across institutions, communities, and landscapes (Newell, 2023). The following analysis examines how participants perceived the actors, barriers, and opportunities influencing climate adaptation and resilience within the Bilston Creek Watershed, as well as the broader implications of these dynamics for watershed management.

Actors

Climate-related concerns engaged the broadest cross-section of participants. Municipal councillors were present in each of the two workshops, and their contributions directly addressed institutional responsibility for climate adaptation, stormwater management, and development regulation. The BWHPA was consistently positioned as the primary actor mobilizing ground-level climate data and community concern upward through governance structures. The Provincial Government was identified as an important regulatory actor, with participants noting incoming provincial riparian regulations as a significant imminent development. The Capital Regional District (CRD) was identified as a potential funding source for watershed-scale climate initiatives. At the same time, private landowners and developers were characterized as actors whose decisions regarding land clearing and the expansion of impermeable surfaces directly shape flood risk.

Barriers

Participants identified funding as the most prevailing barrier to climate adaptation, with one participant observing that regardless of the sustainability issue (e.g. climate action, walkability, green space, food systems), funding appears to be a constraint. Beyond institutional funding, participants identified that most community members are more concerned about the increase in cost-of-living than about environmental priorities. One participant estimated that fewer than five to ten percent of the broader community would rank environmental issues highly if surveyed, not from indifference but from the structural weight of economic precarity. This finding is noteworthy because it positions cost-of-living pressures as a systemic constraint on the civic engagement that climate adaptation ultimately depends upon. The finding is reinforced by the network analysis outcome that exhibited lack of awareness functions as having the highest in-degree value, being affected by individualism, coordination failures, and governance fragmentation.

Silos among the three municipal jurisdictions sharing the watershed were identified as a structural governance barrier, with one participant commenting that the real bottleneck is not the vertical separation of grassroots and government but the horizontal disconnect among Colwood, Langford, and Metchosin, municipalities that do not operate through a common environmental governance framework despite sharing a watershed. Enforcement ambiguity, confusion about which level of government is responsible for implementing climate-relevant bylaws, was named as an impediment to translating community concern into management action.

An important barrier was the absence of political will, with participants framing political will as a systemic prerequisite. Unless there is willingness at the top of the governance pyramid, bottom-up efforts stall when they reach institutional levels. Participants also identified a sacrifice zone mentality around a potential industrial corridor along Sooke Highway, where ecologically significant lands may be written off for economic development purposes.

Opportunities

The upcoming provincial riparian regulations were identified as the most significant near-term policy window, offering a moment of regulatory change that, if engaged strategically, could compel municipalities toward more holistic watershed protection and create an opening for community involvement in riparian planning. Green infrastructure emerged as the most consistently named climate strategy across both days, with participants calling for a comprehensive, cross-boundary green infrastructure development plan as the highest-priority investment if funding constraints were removed. Participants proposed specific interventions including culvert removal, wildlife bridge construction across highway corridors, and rewilding of suitable parcels, which were framed as nature-based solutions capable of generating hydrological, ecological, and social co-benefits.

The Koksilah Watershed planning process was referenced as an aspirational governance model. The process is a multi-year, nation-to-nation, multi-government process that participants noted demonstrates what inclusive, well-resourced watershed planning looks like when everybody that needs to be at the table is at the table, establishing a benchmark against which current governance arrangements in the Bilston Creek context fall substaintially short. A participant explicitly named the outputs of the current research effort as a potential tool for presenting an up-to-date watershed snapshot directly to municipal councils, positioning the research process itself as a climate governance opportunity.

Biodiversity

Within the CBH nexus framework, biodiversity encompasses the ecological structures, functions, and processes that sustain watershed resilience and provide benefits to both ecosystems and communities. The biodiversity domain includes habitat connectivity, ecosystem integrity, and the capacity of natural systems to adapt to environmental change (Newell, 2023). The following analysis examines participant perspectives on the actors, barriers, and opportunities shaping biodiversity conservation and restoration within the Bilston Creek Watershed and their implications for long-term ecological resilience.

Actors

Biodiversity concerns were most actively articulated by BWHPA volunteers and long-term community stewards with direct observational experience of ecological change over decades. One participant described sixty years of living on the creek and witnessing the disappearance of species once abundant, exhibiting a form of place-based ecological knowledge that purely institutional actors rarely hold. Volunteers were consistently referred to as the operational core of biodiversity stewardship. The invasive species removal project in the area referred to by participants as the Buffer Lands in Metchosin (part of the land-swap area), drawing roughly twenty participants per session and targeting Scotch broom, was offered as evidence that ground-level ecological restoration is already underway and scalable. The Provincial Government was identified as a critical actor through its capacity to regulate riparian zones. Private landowners were named as a complex actor class, with some being active stewards and others being sources of significant degradation.

Peninsula Streams was presented as an organizational model for multi-watershed stewardship coordination but noted to be operating at capacity and unable to absorb the Bilston Watershed. Incoming residents from Centre Mountain development were identified as emerging actors and a potential new volunteer base, provided engagement frameworks are developed and put in place before they arrive. The aging population in Metchosin was acknowledged as a demographic constraint on labour-intensive restoration work.

Barriers

Volunteer burnout was identified as a threat to the continuity of biodiversity stewardship. Participants described a small group of keystone stewards running in circles, trying to secure funding simultaneously from multiple sources, including habitat conservation funds and provincial agencies. They noted a lack of dedicated coordination to consolidate funding efforts and advocate for watershed stewardship. Land-use and development trends constituted a second major barrier, with systematic land clearing driven by the imperative to increase the tax base through industrial zoning.

Institutional inertia was noted to stem from the absence of a single coordinating contact within or across municipal governments who could advocate for biodiversity interests. Institutional inertia was characterized as the decisive bottleneck for stewardship activities and the institutional decisions that determine land-use outcomes. This directly reinforces the network analysis finding that coordination gaps function as one of the two primary structural bottlenecks in the systems model.

Opportunities

Participants identified several concrete biodiversity restoration opportunities. These include comprehensive invasive species removal with native replanting, rewilding of suitable parcels in the Luxton area, culvert removal and replacement with aquatic-friendly structures to restore fish passage and ecological connectivity, and targeted land acquisition of parcels critical to watershed integrity. A participant proposed a voluntary tax for land acquisition as a mechanism for channeling philanthropic interest into permanent habitat protection. They suggested that land acquisition could provide a tangible, place-based goal that community members could easily visualize and support. In contrast, funding research, although recognized as essential for informing watershed management, was perceived as a less visible outcome and therefore less likely to inspire public financial support.

The Habitat Conservation Trust Foundation (HCTF) funding application underway at the time of the workshops, targeting stream assessments, flow measurement, and fish habitat inventory, was identified as a near-term opportunity to build the evidentiary base needed to make the case to councils for coordinated action. Celebrating visible ecological wins was proposed as a distinct mobilization strategy. The recovery of the salmon run on the Colquitz River was offered as a proof-of-concept example that degraded systems can be restored and that such tangible successes can activate broader public engagement more effectively than data or urgency-based communication.

The revival of the West Shore Watershed Society as an umbrella organization emerged as the most structurally significant governance opportunity identified across both workshop days. Its existing charitable status, which confers eligibility for funding sources unavailable to non-profit societies and took significant time to establish, positions it as a ready-made coordinating structure for the BWHPA and other West Shore stewardship groups. It was noted that this recommendation aligns directly with findings from the Millstream Watershed Visualization Project, which resulted in recommendations for the creation of a watershed coordinating and facilitating group to work alongside existing stewardship organizations rather than replace them (Newell et al., 2025).

Health

Within the CBH nexus framework, health extends beyond physical health outcomes to include social well-being, community agency, sense of stewardship, governance capacity, and the quality of relationships between people and place. Human health is understood as being closely interconnected with ecological conditions and governance processes, reflecting the broader social dimensions of watershed resilience (Newell, 2023). The following analysis examines participant perceptions of the actors, barriers, and opportunities that influence community well-being, engagement, and stewardship capacity.

Actors

Residents and citizens were consistently positioned as the foundational social infrastructure through which watershed health is sustained. The BWHPA was described as the motor and catalyst that keeps institutional and volunteer processes moving, though this role was simultaneously identified as a source of organizational fragility. Municipal councillors contributed directly to discussions of governance capacity, with one participant calling explicitly for a jointly funded environmental coordination position across Colwood, Langford, and Metchosin, a single point of contact between stewardship groups and elected decision-makers who could triage community proposals and translate ecological priorities into governance language. Children and youth were named as critical targets for stewardship identity formation, with school outreach cited as a priority. New residents arriving with the Centre Mountain development were framed as both opportunity and risk. These residents can be a potential new volunteer base if reached early, or a source of additional pressure on ecological resources if they are never provided with a contextual understanding of the watershed and the threats to watershed health.

Barriers

Participants identified individualism and passive interest as the default orientation of most community members, not from indifference but from a convergence of structural conditions, namely economic precarity, cognitive overwhelm, and disconnect from place.

One participant connected this to doom scrolling and the psychological weight of perceiving global environmental problems as being one's personal agency. The participant suggested the antidote to be local connection, small-scale visible impact, and the understanding that you can make a difference. These comments suggest that the barrier is not public apathy toward nature but public disconnection from the mechanisms through which individual action produces collective outcomes, a reframing that directly informs the engagement strategies participants proposed.

Communication and branding challenges were identified as distinct and underappreciated barrier to watershed management, that is, the word "watershed" itself was described as a term that goes over most people's heads and fails to activate engagement. Volunteer burnout also carries a direct health dimension beyond its biodiversity implications. The emotional and physical exhaustion of a small core of stewards who carry disproportionate organizational weight represents a social resilience gap, and the reliance on volunteers for continuity means that the system is perpetually one board-member illness or resignation away from significant capacity loss. Demographic constraints in Metchosin, an aging population with limited physical capacity for labour-intensive stewardship, intensify with each governance cycle.

Opportunities

Participants articulated a convergent set of health-domain opportunities centered on the idea that connections to place, to neighbours, to lived experiences in the watershed are simultaneously the goal and the mechanism of watershed health. Placemaking initiatives were identified as a high-leverage, accessible strategy. Such initiatives could include murals on stormwater grates depicting the fish downstream, free neighbourhood libraries housing watershed materials, and community art installations that make visible what is normally invisible were proposed as ways to ground abstract ecological concerns in everyday spatial experience.

Participants identified what they described as a "branding" challenge in watershed engagement, noting that most citizens do not naturally think in terms of watersheds and that technical terminology can limit public connection and participation. In this sense, "branding" referred to the need to translate watershed concepts into simple, relatable narratives grounded in people's everyday lived experiences and emotional relationships with place. Participants suggested that engagement would be more effective when framed through tangible and familiar experiences already present in daily life, such as children floating boats in seasonal creeks, couples enjoying wildflowers, or families observing wildlife. These kinds of place-based, experiential entry points were seen as more likely to resonate than abstract descriptions of watershed processes. Small, local, and place-specific initiatives were also viewed as more durable than large-scale campaigns, with the Firehall Creek initiative cited as an example of an engagement effort that succeeded because it was walkable, relatable, and directly connected to participants' lived experiences.

The findings demonstrate that climate adaptation, biodiversity conservation, and community well-being are not experienced as separate concerns by participants, but rather as interconnected dimensions of a broader watershed system. Across all three domains, recurring themes of governance coordination, stewardship capacity, community engagement, and ecological resilience emerged as critical determinants of watershed outcomes.

Spatial Mapping Analysis

The participatory spatial mapping exercise generated a dataset comprising 72 spatial points, each representing a location within the Bilston Creek Watershed identified by participants during the workshops and classified into one of three categories: values (V, n = 27), challenges (C, n = 31), and strategies (S, n = 14). Figure 8 in the main report presents the aggregated spatial map. The subsequent sections examine these spatial patterns from complementary perspectives, including their distribution across watershed zones, relationships with land cover and hydrological features, hotspot concentrations, and areas where community values and challenges spatially converge.

For zone-based reporting, the watershed was divided into four zones using prominent road corridors as spatial dividers: the Northern Watershed (north of Sooke Road), the Central Watershed (between Sooke Road and Happy Valley Road), the Eastern Watershed (south of Sooke Road and east of Happy Valley Road), and the Southern Watershed (south of the Lindholm Road corridor).

Industrial activity within the watershed emerged as a challenge during the spatial mapping exercise but had not been identified during the participatory modeling exercise. This finding suggests that the spatially-grounded nature of the mapping exercise activated place-based knowledge, particularly regarding ongoing land-use change and industrial development. It also confirms the value of the multi-exercise workshop format, as different participatory methods produced complementary insights, generating a broader watershed understanding.

Spatial Distribution Across Zones

The distribution of values, challenges, and strategies across the four zones aligns with the clear natural-to-urban gradient across the watershed. The Eastern Watershed Zone (south of Sooke Road and east of Happy Valley Road) contains the largest concentration of value points (n=12 of n=27), covering biodiversity, microclimate regulation, hydrological flow, environmental-based recreation (at Witty's Lagoon Regional Park), sustainable food systems, tree canopy, and human health. It also holds the highest concentration of strategy points (7 of 14), including research and policy integration (at Witty's Lagoon Regional Park), riparian protection and green infrastructure (along the Galloping Goose Regional Trail corridor), stormwater management, research and policy integration, and low impact development.

The Central Watershed Zone (between Sooke Road and Happy Valley Road) presents the most spatially complex profile of the four zones. It concentrates the largest number of challenge points in the dataset (14 of 31). These include the three highest-weighted signals of cross-group convergence: housing pressure (weight = 2) in the northern portion of this zone near Centre Mountain, flooding (weight = 2) along Bilston Creek, and land clearing (weight = 2) recorded at two separate locations in the Central Watershed Zone. Three of the four challenge points falling within industrial or commercial land-use contexts (based on the administrative and zoning GIS layers described in section 2.4. Data Analysis) also fall within this zone, including development pressure near Slegg Building Materials and land-clearing and invasive-species concerns in industrial-zoned areas. Despite this concentration of challenges, the Central Watershed Zone also contains 10 value points, the second highest count among all the zones, including biodiversity, regeneration, fish habitat, conservation, aesthetic value, drinking water, and community well-being. Watershed planning (weight=2) was mapped here alongside three green infrastructure points, providing the most direct spatial signal that participants perceive governance and nature-based solutions as the appropriate response to the challenges concentrated in this zone.

The Northern Watershed Zone (north of Sooke Road, encompassing the Sooke Hills Wilderness Regional Park and the upper reaches of the watershed) contains fewer points than the two zones discussed above (total of n=9). Conservation was mapped at Sooke Hills Wilderness Regional Park, and erosion was identified within the same park boundary, suggesting awareness of ecological pressures even within protected areas. Land clearing was recorded adjacent to Mount Wells Regional Park (one of the five weighted points), indicating participant recognition of encroaching pressures on the northern forested edge of the watershed. Notably, none of the nine Northern Watershed Zone points fall within 100 metres of a watercourse, reflecting the upper watershed's more dispersed hydrological network and the greater distances between land-use pressures and stream channels in this zone. Two green infrastructure strategy points were placed in the Northern Watershed Zone, one in the Juan de Fuca Electoral Area and one in the City of Langford.

The Southern Watershed Zone (south of Lindholm Road) contains five points: two sustainable food systems values (one at Parry Bay Sheep Farm), and challenges associated with coordination gaps, housing pressure (along the Galloping Goose Regional Trail), and erosion. No strategy points were mapped in the Southern Watershed, suggesting that participants understood this zone primarily as a landscape of ecological and agricultural value under moderate development pressure, rather than a priority zone for interventions.

Land Cover and Biophysical Context

The multi-scale land cover analysis reveals a consistent spatial logic underlying community

perceptions of the watershed across all three attribute categories. At the 400-metre scale (representing approximately a five-minute walking distance from each point), coniferous forest is the dominant land cover class surrounding value points (n=21 of n=27 points), challenge points (27 of 31), and strategy points (12 of 14), confirming that community spatial attention is predominantly oriented toward the watershed's forested landscape rather than its built environment or agricultural areas. Agricultural land cover appears as the second most common 400-metre buffer coverage for value points (5 of 27), reflecting the concentration of sustainable food systems values associated with the agricultural lands of the Southern Watershed Zone and upper Metchosin.

Land-use context analysis further differentiates the three attribute categories. Challenge points are the most diverse categorized in this context, falling across forest (n=14), park (n=9), residential (n=4), industrial (n=3), and commercial (n=1) contexts. Challenges formed the only category that had industrial points, and these were concentrated in the Central Watershed Zone. Value points fall predominantly within forest (n=16) and residential (n=5) contexts, with park (n=4) and meadow (n=1) contexts appearing in the Eastern and Southern Watershed Zones. Strategy points align closely with forest (n=7) and park (n=4) contexts, with the Galloping Goose Regional Trail targeted for strategy placement, appearing at three of the fourteen strategy points, including green infrastructure, riparian protection, and stormwater management, and the Witty´s Lagoon Regional Park targeted for research and policy integration.

Riparian Adjacency and Stream Proximity

Riparian adjacency analysis, using a 100-metre buffer threshold against the BC Freshwater Atlas stream network, reveals a strong and differentiated spatial orientation toward the watershed's hydrological network across all three attribute categories. Value points exhibit the highest riparian adjacency rate, with 56% (n=15 of a total n=27) falling within 100 metres of a watercourse. Of these points, n=10 of are adjacent to Bilston Creek, n=4 to Metchosin Creek, and n=1 to Cole Creek. These findings indicate that participants located ecological values, including biodiversity, hydrological flow, microclimate regulation, fish habitat, and environmental-based recreation, within or adjacent to the riparian corridor.

Challenge points show a lower percentages of riparian adjacency than observed with values, with of 32% (10 of 31) of the points being near watercourse. Of these points, n=6 are adjacent to Bilston Creek, n=3 to Firehall Creek, and n=1 to Metchosin Creek. The challenges closest to stream corridors include flooding (two riparian-adjacent points, one with weight=2), pollution and contaminants, invasive species, and extreme precipitation, a pattern indicating that participants understood these threats as directly impacting the riparian environment.

Strategy points exhibited a riparian adjacency percentage of 21% (n=3 of a total n=14), and all

three were adjacent to Bilston Creek, including stormwater management, green infrastructure, and riparian protection points in the Eastern Watershed. Such findings reveal how participants positioned most strategies somewhat away from riparian areas and in the transitional zone between the riparian corridor and the upland landscape, even though they located most ecological values close to watercourses.

Kernel Density Hotspot

KDE analysis of the value point layer identifies the Eastern Watershed Zone as a hotspot area for values, particularly the zone along the Bilston Creek and Metchosin Creek riparian corridors within the District of Metchosin (See Figure 8(b) in the main report). Points in this zone relate to biodiversity, microclimate regulation, hydrological flow, environmental-based recreation, and tree canopy values within a predominantly coniferous-forested landscape at the 100-metre scale. Another area of high value density is evident in the Central Watershed Zone, where biodiversity, regeneration, fish habitat, and conservation values are concentrated along the Bilston Creek corridor near its transition from forested to agricultural and residential land cover. Additionally, a more dispersed concentration of sustainable food systems values occurs in the Southern Watershed Zone within the agricultural landscape near Parry Bay.

KDE analysis of the challenge point layer identifies the Central Watershed Zone as the primary challenge hotspot of the watershed, particularly the area spanning the urbanizing interface between Sooke Road and Happy Valley Road within the City of Langford. This zone concentrates all four of the high-weighted (weight=2) challenge points recorded in the dataset, including housing pressure, flooding, and land clearing (recorded at two separate locations), alongside development pressure, pollution and contaminants, and invasive species. The land cover context shifts from coniferous forest at the 100-metre scale to a mixture of agricultural, residential, and industrial land cover at the 400-metre scale, reflecting the active land-use change underway in this zone.

Another challenge hotspot appeared in the Eastern Watershed Zone, concentrating flooding, extreme precipitation, invasive species, and housing pressure along the Galloping Goose Regional Trail corridor and the urban-rural fringe. The Northern Watershed Zone contains a smaller, distinct hotspot associated with land clearing near Mount Wells Regional Park and erosion within the Sooke Hills Wilderness Regional Park boundary.

Overlap Zones: Where Values and Challenges Converge

To identify where the watershed's values and challenges overlap, the value and challenge density surfaces were combined into a single overlap map (See Figure 9 in the main report). On the resulting map, these areas appear as rings of colour radiating outward, with a deep purple edge

marking the outer limits of overlap, shifting through orange-red, and in the most intense areas, brightening to a yellow core at the centre. Four overlap areas were identified across the watershed, varying in how strongly they stand out.

The highest-overlap zone sits along Metchosin Creek, in the Central Watershed, right where the District of Metchosin and the City of Langford meet. On the map, this is the only spot in the watershed where the full colour gradient appears, a complete dark purple ring with a bright yellow centre, fading outward through orange to purple. On the Metchosin side of the boundary, participants identified this stretch of the creek as important for community well-being and as a place with strong potential for ecological regeneration. On the Langford side, almost the same spot was flagged for pollution and contaminants and for flooding. A little further out, aesthetic value, biodiversity, and concerns about nearby industry add to the picture. None of the strategies that participants proposed were mapped here.

The moderate-overlap zone follows the Galloping Goose Regional Trail and Happy Valley Road in the Eastern Watershed, close to Bilston Creek on the Metchosin side, displaying a partial density gradient without the yellow core seen at the highest-overlap zone. Here, participants identified hydrological flow, invasive species, and concerns about extreme rainfall, alongside two proposed strategies (i.e., green infrastructure and riparian protection). This is the only one of the four overlap areas where community-proposed strategies fall within an overlap zone at all.

The two low-overlap zones are both located along the Sooke Road corridor toward the northern edge of the watershed, each displaying only faint purple tones with no progression toward orange or yellow. One is located within Langford, near where Sooke Road crosses close to the northern edge of the Bilston Creek riparian area, where a sense of ecological regeneration and concerns about pollution sit near one another. The other lies further west, close to where Langford, Metchosin, and the Juan de Fuca Electoral Area come together along Sooke Road, capturing a place where development pressure and conservation values are in proximity, overlapping border between Langford and Metchosin.

Table A2. Directed Edges: Participant-Identified Directed Relationships among Watershed Values, Challenges, and Management Strategies

#	Type	Source	Target	Weight	Label	Direction
1	Directed	Housing pressure	Human–nature connection	3	Reduces connection	Negative
2	Directed	Human–nature connection	Lack of awareness	3	Reduces lack of awareness	Negative
3	Directed	Sense of belonging	Human–nature connection	3	Strengthens connection	Positive
4	Directed	Aesthetic value	Human–nature connection	3	Enhances connection	Positive
5	Directed	Climate change impacts	Flooding	3	Increases flooding	Positive
6	Directed	Climate change impacts	Aesthetic value	3	Reduces value	Negative
7	Directed	Climate change impacts	Hydrological flow	3	Disrupts flow	Negative
8	Directed	Climate change impacts	Investment and capacity	3	Drives investment	Positive
9	Directed	Climate change impacts	System complexity	3	Increases complexity	Positive
10	Directed	Invasive species	Habitat degradation	3	Causes degradation	Positive
11	Directed	Invasive species	Aesthetic value	3	Reduces aesthetic value	Negative
12	Directed	Invasive species	Biodiversity	3	Reduces biodiversity	Negative
13	Directed	Invasive species	Ecosystem support	3	Weakens ecosystem support	Negative
14	Directed	Climate change impacts	Biodiversity	3	Reduces biodiversity	Negative
15	Directed	Habitat degradation	Biodiversity	3	Reduces biodiversity	Negative
16	Directed	Development pressure	Flood management	3	Undermines flood management	Negative
17	Directed	Development pressure	Flooding	3	Increases flooding	Positive
18	Directed	Development pressure	Pollution and contaminants	3	Increases pollution	Positive
19	Directed	Pollution and contaminants	Land quality	3	Degrades land quality	Negative
20	Directed	Pollution and contaminants	Water quality	3	Degrades water quality	Negative
21	Directed	Flood management	Flooding	3	Reduces flooding	Negative
22	Directed	Low impact development	Development pressure	1	Reduces development pressure	Negative
23	Directed	Low impact development	Hardscape fragility	3	Reduces fragility	Negative
24	Directed	Low impact development	Flooding	3	Reduces flooding	Negative
25	Directed	Housing pressure	Flooding	3	Increases flooding	Positive
26	Directed	Green infrastructure	Pollution and contaminants	2	Reduces pollution	Negative
27	Directed	Green infrastructure	Climate change impacts	2.5	Mitigates climate impacts	Negative
28	Directed	Education and awareness	Resource limitations	2	Reduces resources limitations	Negative
29	Directed	Education and awareness	Resource allocation policy	3	Strengthens policy	Positive
30	Directed	Education and awareness	Habitat degradation	3	Reduces habitat degradation	Negative
31	Directed	Education and awareness	Lack of awareness	2	Reduces lack of awareness	Negative
32	Directed	Resource allocation policy	Development pressure	2	Drives development	Positive
33	Directed	Resource allocation policy	Financial constraints	2	Influences finances	Positive
34	Directed	Social capital building	Sense of belonging	3	Strengthens belonging	Positive

35	Directed	Social capital building	Human–nature connection	3	Strengthens connection	Positive
36	Directed	Social capital building	Investment and capacity	3	Builds capacity	Positive
37	Directed	Groundwater systems	Human health	3	Supports health	Positive
38	Directed	Groundwater systems	Water quality	3	Improves water quality	Positive
39	Directed	Environmental-based recreation	Stewardship and management	3	Strengthens stewardship	Positive
40	Directed	Environmental-based recreation	Human health	3	Improves health	Positive
41	Directed	Groundwater systems	Water quality	3	Supports water quality	Positive
42	Directed	Community well-being	Stewardship and management	3	Strengthens stewardship	Positive
43	Directed	Riparian connectivity	Biodiversity	3	Supports biodiversity	Positive
44	Directed	Riparian connectivity	Human health	3	Improves health	Positive
45	Directed	Climate change impacts	Fish habitat	3	Degrades habitat	Negative
46	Directed	Governance gaps	Pollution and contaminants	3	Increases pollution	Positive
47	Directed	Governance gaps	Groundwater exploitation	3	Enables exploitation	Positive
48	Directed	Individualism	Lack of awareness	3	Reinforces lack of awareness	Positive
49	Directed	Coordination gaps	Lack of awareness	3	Increases knowledge gaps	Positive
50	Directed	Development pressure	Riparian connectivity	3	Reduces connectivity	Negative
51	Directed	Development pressure	Impermeable surfaces	3	Increases impermeability	Positive
52	Directed	Impermeable surfaces	Stormwater runoff	3	Increases runoff	Positive
53	Directed	Conservation mechanisms	Conservation	3	Strengthens conservation	Positive
54	Directed	Riparian protection	Conservation	3	Strengthens conservation	Positive
55	Directed	Stormwater management	Stormwater runoff	3	Reduces runoff	Negative
56	Directed	Economic incentives	Green infrastructure	3	Promotes green infrastructure	Positive
57	Directed	Green infrastructure	Stormwater runoff	3	Reduces runoff	Negative
58	Directed	Education and awareness	Community well-being	3	Strengthens community	Positive
59	Directed	Watershed planning	Development pressure	3	Reduces development	Negative
60	Directed	Community engagement	Coordination gaps	2.5	Reduces coordination gaps	Negative
61	Directed	Community engagement	Collaborative forums	3	Enables forums	Positive
62	Directed	Community engagement	Lack of awareness	2	Reduces lack of awareness	Negative
63	Directed	Tree canopy	Erosion	3	Reduces erosion	Negative
64	Directed	Tree canopy	Drought	2	Reduces drought impacts	Negative
65	Directed	Tree canopy	Microclimate regulation	3	Improves microclimate	Positive
66	Directed	Settlement patterns	Invasive species	3	Increases invasives	Positive
67	Directed	Environmental-based recreation	Lack of awareness	2	Reduces lack of awareness	Negative
68	Directed	Sustainable food systems	Settlement patterns	2	Influences settlement	Positive
69	Directed	Sustainable food systems	Invasive species	3	Increases invasives	Positive
70	Directed	Sustainable food systems	Biodiversity	2	Reduces biodiversity	Negative
71	Directed	Sustainable food systems	Erosion	2	Increases erosion	Positive

72	Directed	Microclimate regulation	Wildfire risk	2	Reduces fire risk	Negative
73	Directed	Coordination gaps	Watershed planning	3	Limits planning	Negative
74	Directed	Coordination gaps	Green infrastructure	3	Limits implementation	Negative
75	Directed	Habitat degradation	Drinking water	3	Reduces water quality	Negative
76	Directed	Habitat degradation	Tree canopy	3	Reduces tree cover	Negative
77	Directed	Habitat degradation	Environmental-based recreation	2	Reduces recreation	Negative
78	Directed	Settlement patterns	Habitat degradation	3	Drives degradation	Positive
79	Directed	Habitat degradation	Aesthetic value	3	Reduces aesthetic value	Negative
80	Directed	Extreme precipitation	Erosion	3	Increases erosion	Positive
81	Directed	Invasive species	Regeneration	3	Limits regeneration	Negative
82	Directed	Financial constraints	Research and policy integration	2.5	Limits research	Negative
83	Directed	Financial constraints	Sustainable food systems	3	Limits sustainability	Negative
84	Directed	Drought	Tree canopy	3	Reduces canopy	Negative
85	Directed	Drought	Drinking water	3	Reduces water availability	Negative
86	Directed	Drought	Wildfire risk	3	Increases fire risk	Positive
87	Directed	Education and awareness	Research and policy integration	1.5	Supports research	Positive
88	Directed	Research and policy integration	Watershed planning	3	Supports planning	Positive
89	Directed	Research and policy integration	Collaborative forums	3	Enables collaboration	Positive
90	Directed	Watershed planning	Research and policy integration	3	Strengthens research	Positive
91	Directed	Watershed planning	Lack of awareness	3	Reduces lack of awareness	Negative
92	Directed	Watershed planning	Community engagement	3	Strengthens engagement	Positive
93	Directed	Collaborative forums	Research and policy integration	1.5	Supports research	Positive
94	Directed	Green infrastructure	Regeneration	3	Supports regeneration	Positive
95	Directed	Green infrastructure	Aging infrastructure	3	Replaces outdated systems	Negative

Table A3. Full Network Analysis Metrics_Gephi

#	Id	VCS	In-Degree	Out-Degree	Degree	Closeness Centrality	Betweenness Centrality	Authority	Hub	Eigenvector Centrality	Modularity Class
1	Invasive species	Challenge	2	5	7	0.457142857	31	0.09551639	0.42849988	0.097899548	5
2	Habitat degradation	Challenge	3	5	8	0.590909091	55.33333333	0.22494002	0.39997792	0.15709612	5
3	Sustainable food systems	Value	1	4	5	0.367346939	36.16666667	0.01346512	0.23065454	0.035711089	5
4	Drought	Challenge	1	3	4	0.714285714	5	0.00876029	0.09440462	0.212261103	5
5	Settlement patterns	Value	1	2	3	0.414634146	13.16666667	0.06781518	0.094218	0.046253629	5
6	Tree canopy	Value	2	3	5	0.714285714	27	0.14535435	0.0297957	0.292351153	5
7	Extreme precipitation	Challenge	0	1	1	1	0	0	0.02464444	0	5
8	Aesthetic value	Value	3	1	4	0.666666667	18.83333333	0.41475236	0.02097297	0.324782441	5
9	Microclimate regulation	Value	1	1	2	1	4	0.00876029	0.0089328	0.212261103	5
10	Biodiversity	Value	5	0	5	0	0	0.53735465	0	0.523401665	5
11	Drinking water	Value	2	0	2	0	0	0.14535435	0	0.292351153	5
12	Ecosystem support	Value	1	0	1	0	0	0.12598407	0	0.098991968	5
13	Erosion	Challenge	3	0	3	0	0	0.08382123	0	0.264972965	5
14	Wildfire risk	Challenge	2	0	2	0	0	0.03038243	0	0.28630078	5
15	Conservation mechanisms	Strategy	0	1	1	1	0	0	0	0	4
16	Riparian protection	Strategy	0	1	1	1	0	0	0	0	4
17	Conservation	Value	2	0	2	0	0	0	0	0.012916466	4
18	Green infrastructure	Strategy	2	5	7	0.533333333	90	0.02874149	0.0966233	0.118043257	3
19	Impermeable surfaces	Challenge	1	1	2	1	8	0.04681189	0.01009826	0.230224199	3
20	Stormwater management	Strategy	0	1	1	1	0	0	0.01009826	0	3
21	Economic incentives	Strategy	0	1	1	0.361702128	0	0	0.00845034	0	3
22	Regeneration	Value	2	0	2	0	0	0.15439247	0	0.188939842	3
23	Stormwater runoff	Challenge	3	0	3	0	0	0.03434642	0	0.248771702	3
24	Aging infrastructure	Challenge	1	0	1	0	0	0.0284084	0	0.089947874	3
25	Riparian connectivity	Value	1	2	3	1	13.83333333	0.04681189	0.18634322	0.230224199	2
26	Development pressure	Challenge	3	5	8	0.666666667	73.83333333	0.0929679	0.15921767	0.35001791	2
27	Low impact development	Strategy	0	3	3	0.461538462	0	0	0.13226824	0	2
28	Flood management	Strategy	1	1	2	1	0	0.04681189	0.09350091	0.230224199	2
29	Groundwater systems	Value	0	2	2	1	0	0	0.03134752	0	2
30	Governance gaps	Challenge	0	2	2	0.666666667	0	0	0.02673835	0	2
31	Pollution and contaminants	Challenge	3	2	5	1	26	0.08308169	0.00327618	0.326630306	2
32	Flooding	Challenge	5	0	5	0	0	0.31801742	0	0.47209597	2
33	Human health	Value	3	0	3	0	0	0.09644014	0	0.28135849	2
34	Hardscape fragility	Challenge	1	0	1	0	0	0.03888844	0	0.006458233	2
35	Water quality	Value	2	0	2	0	0	0.01017978	0	0.243089145	2
36	Groundwater exploitation	Challenge	1	0	1	0	0	0.00786139	0	0.006458233	2

37	Land quality	Value	1	0	1	0	0	9.63E-04	0	0.236630912	2
38	Education and awareness	Strategy	0	6	6	0.303448276	0	0	0.24235322	0	1
39	Watershed planning	Strategy	2	4	6	0.329113924	100.3333333	0.03171817	0.15401624	0.547074371	1
40	Environmental-based recreation	Value	1	3	4	1	14.83333333	0.11759827	0.11032364	0.149200763	1
41	Coordination gaps	Challenge	1	3	4	0.393939394	73	0.02599733	0.08930586	0.186837502	1
42	Community engagement	Strategy	1	3	4	0.305882353	58	0.04528261	0.08842269	0.322967604	1
43	Individualism	Challenge	0	1	1	1	0	0	0.07153	0	1
44	Financial constraints	Challenge	1	2	3	0.248447205	34.5	0.00879685	0.04579786	0.020592073	1
45	Collaborative forums	Strategy	2	1	3	0.204724409	1	0.03145851	0.04183896	0.62232685	1
46	Resource allocation policy	Strategy	1	2	3	0.238372093	15	0.07125473	0.02992005	0.006458233	1
47	Research and policy integration	Strategy	4	2	6	0.254901961	70.33333333	0.14230362	0.01857469	0.72387552	1
48	Community well-being	Value	1	1	2	1	1	0.07125473	0.01043909	0.006458233	1
49	Lack of awareness	Challenge	7	0	7	0	0	0.24328946	0	1	1
50	Resource limitations	Challenge	1	0	1	0	0	0.07125473	0	0.006458233	1
51	Stewardship and management	Value	2	0	2	0	0	0.03550568	0	0.143126735	1
52	Climate change impacts	Challenge	1	7	8	0.75	63	0.0284084	0.58218735	0.089947874	0
53	Housing pressure	Challenge	0	2	2	0.75	0	0	0.11447388	0	0
54	Social capital building	Strategy	0	3	3	0.8	0	0	0.08620214	0	0
55	Human–nature connection	Value	4	1	5	1	7.833333333	0.07133374	0.07153	0.297999874	0
56	Sense of belonging	Value	1	1	2	0.666666667	0	0.02534446	0.02097297	0.006458233	0
57	Investment and capacity	Value	2	0	2	0	0	0.19651447	0	0.083047943	0
58	Hydrological flow	Value	1	0	1	0	0	0.17117003	0	0.07658971	0
59	System complexity	Value	1	0	1	0	0	0.17117003	0	0.07658971	0
60	Fish habitat	Value	1	0	1	0	0	0.17117003	0	0.07658971	0

Table A4. Qualitative Coding Book_Nvivo

Hierarchical Name	# of Coding References
Codes\\01_CBH_V2	**188**
Codes\\01_CBH_V2\Biodiversity	24
Codes\\01_CBH_V2\Biodiversity\Fish & Aquatic Habitat	4
Codes\\01_CBH_V2\Biodiversity\Habitat Protection	2
Codes\\01_CBH_V2\Biodiversity\Habitat Restoration & Regeneration	6
Codes\\01_CBH_V2\Biodiversity\Invasive Species Management	3
Codes\\01_CBH_V2\Biodiversity\Riparian Integrity	6
Codes\\01_CBH_V2\Biodiversity\Species & Ecological Value	3
Codes\\01_CBH_V2\Climate	11
Codes\\01_CBH_V2\Climate\Climate Adaptation & Resilience Capacity	3
Codes\\01_CBH_V2\Climate\Climate Impacts & Risk Perception	3
Codes\\01_CBH_V2\Climate\Flooding & Hydrological Variability	1
Codes\\01_CBH_V2\Climate\Green Infrastructure & Nature-Based Solutions (NbS)	3
Codes\\01_CBH_V2\Climate\Stormwater & Drainage Pressure	1
Codes\\01_CBH_V2\Health	153
Codes\\01_CBH_V2\Health\Awareness, Communication & Education	36
Codes\\01_CBH_V2\Health\Community Engagement & Agency	43
Codes\\01_CBH_V2\Health\Governance & Stewardship Capacity	40
Codes\\01_CBH_V2\Health\Human–Nature Connection	6
Codes\\01_CBH_V2\Health\Psychological Resilience & Well-being	17
Codes\\01_CBH_V2\Health\Recreation, Access & Well-being	1
Codes\\01_CBH_V2\Health\Sense of Belonging & Stewardship Identity	10
Codes\\02_VCS	**125**
Codes\\02_VCS\Challenges	46
Codes\\02_VCS\Challenges\Climate change impacts	1
Codes\\02_VCS\Challenges\Coordination gaps	3
Codes\\02_VCS\Challenges\Development pressure	2
Codes\\02_VCS\Challenges\Extreme precipitation_Flooding	1
Codes\\02_VCS\Challenges\Financial constraints_Resource limitations	7
Codes\\02_VCS\Challenges\Governance gaps	6
Codes\\02_VCS\Challenges\Habitat degradation	2
Codes\\02_VCS\Challenges\Individualism_Lack of awareness	17
Codes\\02_VCS\Challenges\System complexity	7
Codes\\02_VCS\Strategies	69
Codes\\02_VCS\Strategies\Collaborative Platforms	3
Codes\\02_VCS\Strategies\Community engagement	25
Codes\\02_VCS\Strategies\Conservation mechanisms	1
Codes\\02_VCS\Strategies\Education and awareness	12
Codes\\02_VCS\Strategies\Green Infraestructure	6
Codes\\02_VCS\Strategies\Research and policy integration	3
Codes\\02_VCS\Strategies\Resource allocation policy	2
Codes\\02_VCS\Strategies\Social capital building	4
Codes\\02_VCS\Strategies\Stormwater Management	2
Codes\\02_VCS\Strategies\Watershed planning	11
Codes\\02_VCS\Values	10
Codes\\02_VCS\Values\Conservation_Stewardship and management	2
Codes\\02_VCS\Values\Ecosystem Support & Regeneration	5

Codes\\02_VCS\Values\Sense of belonging	3
Codes\\03_Emergent	**239**
Codes\\03_Emergent\Actors	58
Codes\\03_Emergent\Actors\Community and Stewardship Groups	17
Codes\\03_Emergent\Actors\Community and Stewardship Groups\Bilston Habitat group	7
Codes\\03_Emergent\Actors\Community and Stewardship Groups\Children&Youth	1
Codes\\03_Emergent\Actors\Community and Stewardship Groups\Neighborhood Groups	2
Codes\\03_Emergent\Actors\Community and Stewardship Groups\Volunteers	7
Codes\\03_Emergent\Actors\First Nations	1
Codes\\03_Emergent\Actors\Funders and Grant Bodies	5
Codes\\03_Emergent\Actors\Government and Regulatory Bodies	27
Codes\\03_Emergent\Actors\Government and Regulatory Bodies\Federal Government	2
Codes\\03_Emergent\Actors\Government and Regulatory Bodies\Local Government	7
Codes\\03_Emergent\Actors\Government and Regulatory Bodies\Municipal Government	11
Codes\\03_Emergent\Actors\Government and Regulatory Bodies\Provincial Government	7
Codes\\03_Emergent\Actors\Industry_Developers	3
Codes\\03_Emergent\Actors\Residents and Citizens	5
Codes\\03_Emergent\Actors\Residents and Citizens\Aging Population	1
Codes\\03_Emergent\Actors\Residents and Citizens\New Citizens	1
Codes\\03_Emergent\Actors\Residents and Citizens\Private Landowners	3
Codes\\03_Emergent\Barriers	56
Codes\\03_Emergent\Barriers\Funding and resources	15
Codes\\03_Emergent\Barriers\Governance and coordination	7
Codes\\03_Emergent\Barriers\Horizontal Silos	7
Codes\\03_Emergent\Barriers\Institutional inertia	9
Codes\\03_Emergent\Barriers\Land use and development trend	6
Codes\\03_Emergent\Barriers\Libertarian Mindset	1
Codes\\03_Emergent\Barriers\Policy and regulation	4
Codes\\03_Emergent\Barriers\Sacrifice Zone Mentality	1
Codes\\03_Emergent\Barriers\Volunteer Burnout	6
Codes\\03_Emergent\Opportunities	125
Codes\\03_Emergent\Opportunities\Advocacy and Policy Windows	11
Codes\\03_Emergent\Opportunities\Capacity building	7
Codes\\03_Emergent\Opportunities\Collaboration and Partnership	6
Codes\\03_Emergent\Opportunities\Communication and branding	8
Codes\\03_Emergent\Opportunities\Community engagement and social capital	23
Codes\\03_Emergent\Opportunities\Cross-jurisdictional collaboration	12
Codes\\03_Emergent\Opportunities\Ecological restoration	3
Codes\\03_Emergent\Opportunities\Education and awareness	2
Codes\\03_Emergent\Opportunities\Lived Experience Branding	6
Codes\\03_Emergent\Opportunities\Monitoring and data collection	3
Codes\\03_Emergent\Opportunities\Placemaking and Identity	3
Codes\\03_Emergent\Opportunities\Policy and regulation alignment	5
Codes\\03_Emergent\Opportunities\Stewardship and volunteer capacity	11
Codes\\03_Emergent\Opportunities\Umbrella Organization	10
Codes\\03_Emergent\Opportunities\Watershed Framing	15