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RESEARCH

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## Exploring social processes in transformation: the case of a collaborative water partnership in South Africa

Catherine B. Pringle<sup>a</sup>, Richard Meissner<sup>b</sup>, ReINETTE Biggs <sup>a,c</sup>, Claudia Pahl-Wostl<sup>d</sup>, Sabine Stuart-Hill<sup>e</sup> and Nadia Sitas<sup>a</sup>

<sup>a</sup>Centre for Sustainability Transitions, Stellenbosch University, Stellenbosch, South Africa; <sup>b</sup>Department of Political Sciences, University of South Africa, Pretoria, South Africa; <sup>c</sup>Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden; <sup>d</sup>Institute of Geography and Institute of Environmental Systems Research, University of Osnabrück, Osnabrück, Germany; <sup>e</sup>Centre for Water Resources Research, University of KwaZulu-Natal, Pietermaritzburg, South Africa

### ABSTRACT

We explore the social processes supporting transformation towards collaborative water governance in the uMngeni catchment, South Africa. Using Holling's adaptive cycle as a heuristic of phases (conservation, release, reorganisation and exploitation) present during transformation of social-ecological systems, we consider the role of learning, power, agency and structure during each phase of the evolution of the uMngeni Ecological Infrastructure Partnership (UEIP). The UEIP is a partnership between government, research institutions, and civil society groups that facilitates broader and more collaborative participation in water management. During the conservation phase, strong control power and institutional structure (denoted by a hierarchical governance mode embodying control and regulation by the State) limited the introduction of new ideas and reinforced single-loop learning. The release phase was triggered by a shock which weakened control power and permitted the introduction of new ideas thereby enabling double-loop learning. The changing conditions gave rise to protean power (defined as results of practices of agile actors coping with uncertainty) which enhanced the agency of key actors who began to mobilise others in a rapid phase of re-organisation. Triple-loop learning was evident in the exploitation phase as new collaborative institutions, that were better able to accommodate innovative ideas, began to emerge. We found the adaptive cycle helpful for delineating phases of change, while the four multifaceted processes of learning, power, agency and structure proved useful in illuminating dynamics of change. This understanding may help to inform actions to steer transformations towards more sustainable and collaborative water governance in South Africa and elsewhere.

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## Introduction

The depth of the social and environmental challenges that we face calls for profound changes in the governance of interlinked social and ecological systems. How transformation to more equitable and sustainable futures can be realised, is increasingly discussed and debated (Future Earth 2014; Patterson et al. 2017; Leach et al. 2018). Transformation requires radical and systemic changes in multiple aspects of social-ecological systems such as changes in values and beliefs, patterns of social behaviour, and multilevel governance and management regimes (Olsson et al. 2014; Sievers-Glotzbach and Tschersich 2019; Herrfahrtd-Pähle et al. 2020). Such processes typically involve interactions of multiple factors, acting at different scales (Olsson et al. 2006, 2014). Central to transformative change is triple-loop learning, which progresses from changes in established paradigms (single-loop learning), to challenging underlying assumptions (double-loop learning), and finally towards structural change and new ways of

knowing and meaning (Johannessen et al. 2018). Triple-loop learning is only possible though when more intricate political (power relations) and social (structure-agency-learning) aspects are addressed (Flood and Room 2018). However, these processes and their dynamics are not well-understood, and there is limited guidance available to governments or other actors about how to foster or support transformative change.

Although there is consensus that transformation requires fundamental change, diverse world views have fostered different understandings and applications of the concept. The term 'transformation' is used both strategically to offer a potential solution to issues that are practical and socially desirable as well as analytically to study and explain past and present developments (Brand 2016). The strategic use of the concept does not engage with structural barriers to transformation. However, its analytical application takes into account the hierarchical aspects of societies and the ways in which individuals and groups are situated in relation to social structures and

**CONTACT** Catherine B. Pringle  [catherine.kate.pringle@gmail.com](mailto:catherine.kate.pringle@gmail.com)

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systems of power (social and power positions). These positions are established according to relations of class, gender, and race and are reflected in economic, political, and cultural interactions (Brand 2016). In this paper, we use an analytical approach to explore existing structures and narratives to better understand transformation.

Several analytical and conceptual frameworks have emerged for analysing transformations. These include the multi-level perspective framework (MLP) (Geels 2011; El Bilali 2019), transitions management (Kemp et al. 2007; El Bilali 2019), innovation systems (Lachman 2013) and social-ecological transformations (and broader resilience theory) (Olsson et al. 2004, 2006). Despite extensive application of these frameworks, various shortcomings have been identified. The MLP has been criticized for amongst others, underplaying the role of agency (Smith et al. 2005; Geels 2011), omitting institutions and ideologies (Geels 2011; Meadowcroft 2011), and failing to adequately address power and politics (Geels 2011; Kern 2011; Meadowcroft 2011). Transitions management has tended to simplify the scope of the transition and neglected the influence of internal and external factors such as belief systems, political interests, and culture (Lachman 2013), while social-ecological transformations (and broader resilience theory) have been criticised for not considering the role of power and politics in transformation processes (Pelling and Manuel-Navarrete 2011; Fabinyi et al. 2014; Moore et al. 2014; Olsson et al. 2014). Although scholars in some fields have sought to address these concerns, they have tended to analyse pieces of the transformation puzzle, such as the role of learning (e.g. Armitage et al. 2008; Pahl-Wostl et al. 2013; Johannessen et al. 2018), power (e.g. Pelling and Manuel-Navarrete 2011; Avelino and Wittmayer 2016) and agency (e.g. Westley et al. 2013; Sannino 2015) but have rarely captured the dynamic and inter-dependent relationships between social processes that occur during transformations.

We address this gap and investigate the role of four interdependent social processes, namely, learning, power, agency, and structure, in transformation towards collaborative water governance. Using a case study of a collaborative water partnership in South Africa, we aim to explore the role of these processes in different stages of transformation, as defined by the adaptive cycle (Gunderson and Holling 2002). Our objective is to strengthen analytical understanding of transformation, and thereby inform strategic actions to support transformative change.

## Conceptual framework

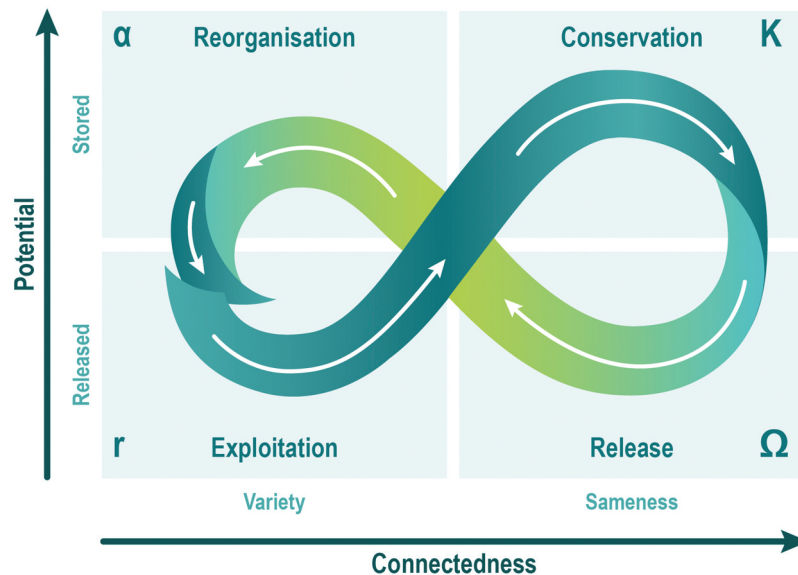
To achieve our aim, we first map the evolution of a collaborative water partnership onto the adaptive cycle, and then explore how different facets of

learning, power, agency and structure, shift during different phases of change. Below we describe the adaptive cycle and how we interpret these four social processes in the context of our study.

### Adaptive cycle

The adaptive cycle is a heuristic framework that has been widely used to describe phases of change in social-ecological systems (Gunderson and Holling 2002). It has also proved useful for illuminating dynamics in social systems, including governance systems (Gunderson and Holling 2002; Bohensky 2008; Daedlow et al. 2011; Herrfahrtdt-Pähle and Pahl-Wostl 2012; Westley et al. 2013; Salvia and Quaranta 2015). The adaptive cycle is based on two dimensions, the range of potential in the system and the degree of connectedness (Gunderson and Holling 2002) (Figure 1). Potential (represented on the Y-axis) describes the wealth of ecological, social or economic resources available to a system for change (Holling 2001; Bohensky 2008; Westley et al. 2013; Sundstrom and Allen 2019). These resources may be accumulated or released and set the limits of possible options (Holling 2001; Gunderson and Holling 2002). Connectedness (represented on the X-axis) reflects the strength of internal relationships and processes that mediate and regulate external influences (Holling 2001; Bohensky 2008). Low connectedness implies a set of diffuse components loosely connected to one another, whose behaviour is dominated by outside variability. High connectedness is associated with aggregated components that mediate the influence of external variability (Gunderson and Holling 2002). Connectedness also provides a measure of the degree of flexibility or rigidity of a system (Holling 2001; Gunderson and Holling 2002). A highly internally connected system is often rigid and vulnerable to a shock or disturbance because of reduced diversity and an inability to self-organise (Fath et al. 2015; Sundstrom and Allen 2019).

Together, potential and connectedness shape four interlinked phases of change: growth or exploitation (r), conservation (K), collapse or release ( $\Omega$ ) and reorganization ( $\alpha$ ) (Gunderson and Holling 2002) (Figure 1). It is assumed that complex systems move from exploitation to a mature phase of conservation on the front loop of the cycle. As potential and connectedness increase, the system becomes rigid and vulnerable, and a new phase of release may be triggered by a disturbance. The system then shifts to the back loop of the cycle where the release of accumulated resources is quickly followed by a period of reorganization. At the end of the reorganization phase, the system may enter a second iteration of an alternatively configured system (Holling 1986). Adaptive cycles can be connected in a nested



**Figure 1.** The adaptive cycle showing the four phases of change (exploitation, conservation, release and reorganization) along the dimensions of connectedness (x-axis) and potential (y-axis) (adapted from Gunderson and Holling (2002) and Westley et al. (2013)).

hierarchy at multiple scales of space and time. This interacting set of hierarchical scales is known as panarchy.

### Learning, power, agency and structure

We focus our analysis on four social processes, namely, learning, power, agency and structure, as several scholars recognize them as essential components of transformation in social-ecological systems. For instance, Pahl-Wostl (2009), Pahl-Wostl et al. (2013) and others consistently highlight the importance of multi-loop learning in transformative processes (see also Armitage et al. 2008; Johannessen et al. 2018) while Pelling and Manuel-Navarrete (2011) draw attention to the crucial role of power in determining when and how transformations occur. Similarly, there has been much discussion on how agency influences system dynamics (see for example Emirbayer and Mische 1998; Garud and Karnoe 2005; Westley et al. 2013) and the interaction between agency and structure has been the subject of a long-running debate (Bourdieu 1977; Giddens 1984; Archer 2003; Unger 2004). In a new conceptual framework proposed by Lotz-Sisitka et al. (Forthcoming), these four social processes are also recognized as useful start-up lenses for analyzing larger transformative processes, particularly in nexus settings.

Learning, power, agency, and structure are multifaceted and can be understood in different ways. Below we outline how we understand and apply these concepts within our study.

- **Learning:** We focus on transformative learning and consider three types of learning loops: single, double and triple-loop learning. Single loop

learning entails making improvements within established paradigms; double-loop learning occurs when reframing challenges established beliefs, while triple-loop learning involves structural change and new ways of knowing and meaning (Argyris 1999; Pahl-Wostl et al. 2013; Johannessen et al. 2018).

- **Power:** We draw on the concept of social power ‘the capacity of persons to bring about certain states of affairs by influencing the actions of others by giving them a reason to act’ (Stahl 2011, p. 351). We differentiate four types of power: control power, agential power, protean power and ideational power. Control power is usually understood in behavioural, institutional, and structural terms (Katzenstein and Seybert 2018) and refers to the consequences of actions in contexts of risk that are experienced as such by actors (Katzenstein and Seybert 2018). In contrast to relatively passive control power, agents may acquire power through intentional actions or through inaction or failure to act (Hayward and Lukes 2008). This type of power is underpinned by structuration theory and is captured in the concept of reflexive agential power defined as the ability ‘... to enhance their power by working “through” or “with”, rather than “against”, social forces at the domestic, regional and global levels’ (Hobson and Ramesh 2002, p. 9–10). Although Hobson and Ramesh’s (2002) definition is commonly used in political sciences, we acknowledge that agential power is a contested concept (Gilbert 2018). The power of agents may also emerge in relation to uncertain contexts and is captured in the

notion of protean power. Katzenstein and Seybert (2018) define protean power as the results of practices of agile actors coping with uncertainty. Finally, we consider ideational power, the capacity of actors (whether individual or collective) to influence other actors' normative and cognitive beliefs through the use of ideational elements (Carstensen and Schmidt 2016; Meissner and Warner 2021).

- **Agency:** We rely on theories of transformative agency, and its dynamics as it relates to individuals and groups. Individual agency refers to the capacity of an individual to influence their functioning and the course of events by their actions (Bandura 2001), whereas strategic agency is produced through the actions of several actors rather than those of just one individual (Garud and Karnoe 2005; Westley et al. 2013).
- **Structure:** Our evaluation of social structure considers both institutional and relational structure. Institutional structure encompasses the formal and informal norms that shape individual action, while relational structure includes the relations between actors in the network (López and Scott 2000).

These processes are emergent and interdependent and can be iteratively related to one another. They are also strongly influenced by context as well as spatial and temporal scales (Lotz-Sisitka et al. *Forthcoming*).

### Case study: the uMngeni ecological infrastructure partnership

This study focuses on the evolution of the uMngeni Ecological Infrastructure Partnership (UEIP) within the broader water governance system of the uMngeni catchment. This evolution entailed a process by which the prevalent water governance system shifted into a new configuration of collaboration, which we assume represents a transformation.

The UEIP is a collaborative partnership that includes representatives from provincial and local government, research institutions, and business and civil society groups working in the uMngeni catchment (see [Appendix A](#) for a description of key participants). The UEIP has been hailed as a flagship structure that can be applied in other catchments. The Partnership is centred around the concept of ecological infrastructure, which refers to 'naturally functioning ecosystems that deliver valuable services to people, such as fresh water, climate regulation, soil formation and disaster risk reduction' (SANBI 2013: 1). The UEIP aims to harness the potential of these intact, functioning ecosystems to complement built infrastructure in order to improve water security. To achieve this, the Partnership promotes

strategic investment in ecological infrastructure by enabling coordination, collaboration and joint learning.

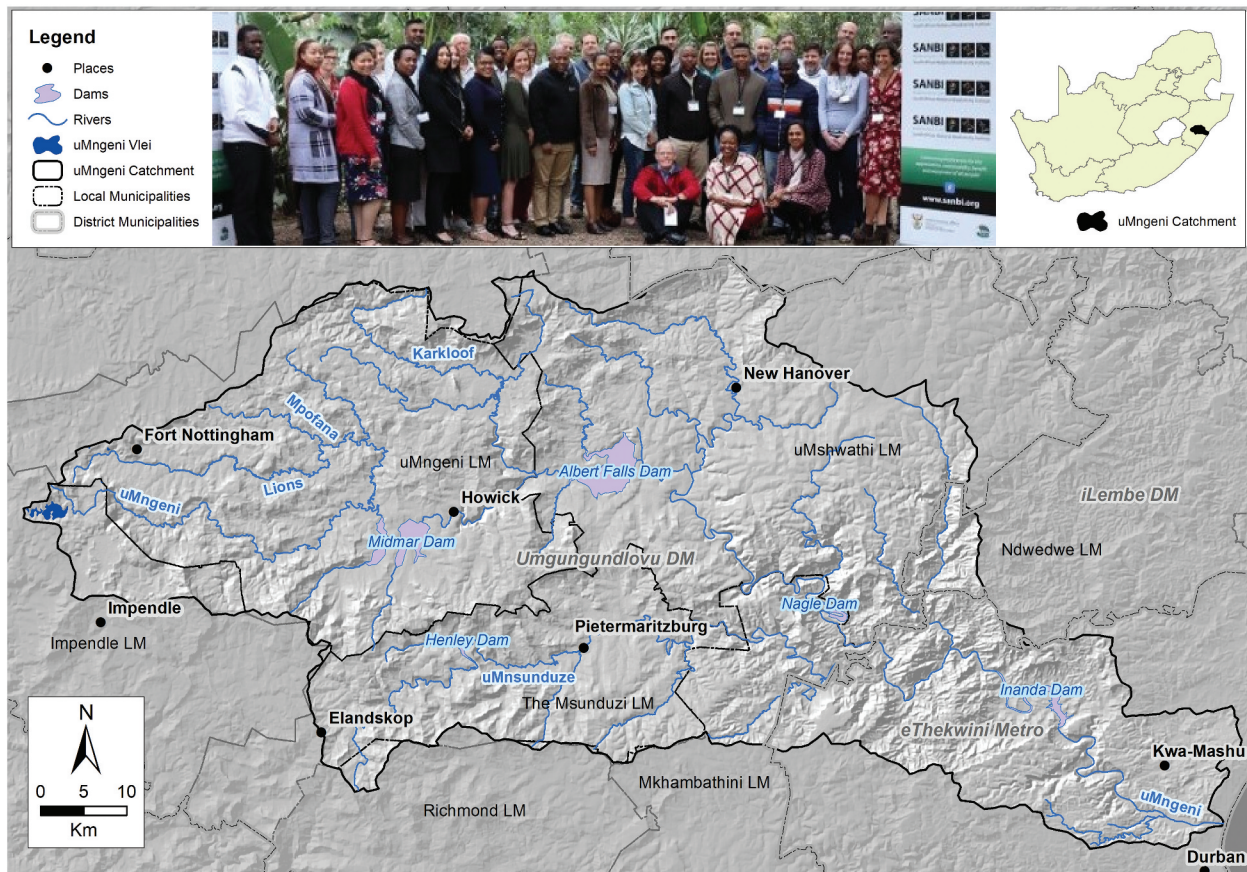
The UEIP was formally established in November 2013 upon the signing of a Memorandum of Understanding (MoU) by 16 founding partner organisations (UEIP 2013). The launch of the UEIP followed a turbulent period of service delivery protests and water shortages, which prompted key actors to rethink water management strategies. This turbulent period formed part of the crisis narrative from which the UEIP emerged. Since its launch, the Partnership has become institutionalized with its activities managed by a fulltime co-ordinator, a coordinating committee, and a research sub-committee.

The UEIP operates within the uMngeni catchment located in the province of KwaZulu-Natal (KZN), South Africa ([Figure 2](#)). The catchment covers less than 5% of the province but provides water to 42% of KZN's population, including the economic hub of Durban governed by the eThekweni Metropolitan Municipality (Pringle et al. 2016; UEIP 2016; Meissner 2021). The catchment includes the 225 km-long uMngeni River which rises in the uMngeni Vlei in the west and flows through uMgungundlovu District Municipality and the eThekweni Metropolitan Municipality before entering the Indian Ocean just north of Durban.

The catchment is primarily used for commercial agricultural activities including cattle, dairy, poultry, sugar cane and timber production. These activities, coupled with rapidly expanding urban and peri-urban areas, have significantly impacted water quality while the spread of invasive alien plants has adversely affected water availability (Jewitt et al. 2015). Demand for water from the catchment also exceeds its ability to supply a burgeoning population and increased economic activity. Consequently, the catchment is 'closed', meaning that all available water has been allocated and the catchment is in water deficit (DWA 2013).

As with other catchments in South Africa, the uMngeni is managed by the Department of Water and Sanitation (DWS), who is the designated legal custodian of the country's water resources. In accordance with the National Water Act and Water Services Act, the DWS is supported by several official entities that are constituted by law (such as Catchment Management Agencies, Water User Associations, Water Services Authorities, Water Service Providers, and Water Boards). There are also some voluntary platforms that stakeholders can participate in to discuss water resource issues, including Catchment Management Forums and the UEIP. Although the UEIP itself does not have any decision-making authority, it is regarded as flagship structure that can strongly influence water resource management decisions.





**Figure 2.** Map indicating the location of the uMngeni catchment. Inset photo shows some of the UEIP participants (Photo credit: South African National Biodiversity Institute).

## Materials and methods

### Data collection and analysis

We applied an instrumental case study approach (Stake 2005; Yin 2009) to explore social processes in the different phases of transformation of the UEIP within the broader water governance system of the uMngeni catchment. Case study research draws on multiple sources of evidence (Stake 2005; Yin 2009). Documents may be used as a source of contextual information about events that cannot be directly observed and are often coupled with personal observations and experience of researchers involved in the case (Stake 1995).

For this study, we used data from two key sources:

- (1) A group of researchers who have an in-depth understanding of the UEIP as they have been working in the catchment for more than a decade. During a Water-Energy-Food (WEF) nexus workshop held in Grahamstown, South Africa in November 2019, a group of five researchers working in the uMngeni catchment (four of whom are authors in this paper) reflected on the four social processes during the evolution of the UEIP. These reflections were captured on a flipchart with supporting notes

and later refined using written records and personal observations.

- (2) Various documents reporting on the UEIP, including minutes from UEIP meetings, workshops and annual progress reports, as well as books, reports, journal articles and graduate student theses. Following the workshop, documents were gathered from key stakeholders involved (either currently or formerly) in the Partnership and from a literature search conducted on Google Scholar using the term ‘uMngeni Ecological Infrastructure Partnership’. The latter yielded a total of 52 documents, which were reviewed. Documents which only briefly mentioned the uMngeni Ecological Infrastructure Partnership were discarded leaving a total of 17 documents, which were included in the analysis (see Appendix B).

To analyse the documents, we followed a deductive approach to identify information for (i) mapping the evolution of the UEIP in terms of the adaptive cycle, and (ii) understanding the social processes within each phase leading to change. Deductive approaches are useful when researchers have a clear understanding of the concepts that they are interested in (MacQueen et al. 1998). To identify the different

phases of the adaptive cycle, we developed pre-defined codes for selected dimensions of potential and connectedness (namely trust and commitment, diversity of actors; diversity and strength of relationships; and water governance approaches coded as either systems or reductionist). This information was later combined with other numerically based indicators to reflect on the phases of the adaptive cycle. To explore the social processes within each phase leading to change we developed pre-defined codes for the different dimensions of learning, power, agency and structure (namely, single-, double- and triple-loop learning; control, protean, ideational and agential power; individual and strategic agency; institutional structure coded as either hierarchical, network or hybrid governance styles, and relational structure coded as diversity of actors and level of interaction). The documents were reviewed and coded using these pre-defined codes to identify relevant statements and examples of each dimension. The emerging data were coupled with notes from the WEF workshop to adjust or expand on our initial interpretations. Further detail on each of these dimensions is included in the following section.

### *Mapping the evolution of the UEIP onto the adaptive cycle*

We determined phases of change aligned to the adaptive cycle. Our goal was to define different phases in the transformation process rather than to test the usefulness of the adaptive cycle concept.

The identification of different stages of change was first carried out by the research group at the WEF workshop based on local knowledge and experience. Three initial stages were defined for the uMngeni water governance system namely 1) start-up, 2) take-off, and 3) stagnation. Following the workshop, these were refined based on an approximate analysis of system potential and connectedness. This analysis relied on a combination of documentary evidence, data, and local knowledge and followed an iterative process. Although our analysis was underpinned by a considerable amount of data, it still retained a certain degree of subjectivity, particularly in determining the diversity of actors and their level of interaction, which impacted both the identification of the phases and the assessment of structure. To minimise the impact of subjectivity, we used peer debriefing, in which the results were reviewed for potential errors and biases by other team members not involved in the analysis but who have an understanding of the catchment and the UEIP.

To assess potential, we followed other scholars in exploring the accumulation or release of different types of capitals (see for example Abel et al. 2006; Daedlow et al. 2011; Salvia and Quaranta 2015). We

focused on three types of capital which we define as follows:

- Social capital: ‘networks together with shared norms, values and understandings that facilitate cooperation within or among groups’ (OECD 2001, p. 41);
- Natural capital: the stock of natural resources or assets from which ecosystem services flow (Costanza and Daly 1992; Costanza et al. 1997);
- Economic capital (or specifically financial capital): the financial resources which underpin economic activity (Goodwin 2003).

System potential was gauged from the levels of social, natural, and economic capital inferred from levels of trust and commitment (Fu 2004; Nkhata et al. 2008; Myeong and Seo 2016), ecosystem condition (Grizzetti et al. 2019) and the amount of stored financial capital, respectively (Table 1 and Appendix C). These criteria were plotted and/or described to identify trends and breakpoints in time. For each time period, we then captured the overall accumulation (high level) or release (low level) of each capital to determine system potential. High levels of capitals signalled high system potential.

Within the time periods (identified from trends in capital), we then assessed connectedness. Similar to Nkhata et al. (2008), we conceptualised connectedness as the degree to which actors in water governance in the uMngeni catchment are linked and the strength of those links that mediate change. Using document analysis and our collective experience in water resource management in the catchment, we inferred the degree to which actors are linked based on the diversity and strength of relationships between them. This was partly informed by the water resource management approach reported in the literature, with a reductionist approach reflecting a lower diversity of actors involved in water resource management. We then used the levels of system potential and connectedness expressed during different time periods to map the evolution of the UEIP onto the adaptive cycle (Holling 2001; Gunderson and Holling 2002).

### *Analysis of learning, power, agency and structure*

To analyse learning, power, agency and structure within each phase of the adaptive cycle, we developed a set of qualitative indicators that capture different facets of each of these four processes.

In respect of learning, and similar to Johannessen et al. (2018), we identified examples linked to the three types of learning loops. For single-loop learning, we identified where past patterns of behaviours were re-enacted, such as where strategies or actions, underpinned by accepted values and norms, remained unchanged. For double-loop learning, we highlight

**Table 1.** Criteria, linked to capitals, used to determine system potential.

Capital	Criterion	Justification	Application in our study
Social capital	Trust and commitment	Trust and commitment regarded as two key attributes of relational capital and suggested as a proxy for potential by other scholars (Nkhata et al. 2008; Tadesse and Kassie 2017).	Assessed at catchment & organisational level. <ul style="list-style-type: none"> <li>• Catchment: trust in local government used as proxy of trust in other tiers of government.</li> <li>• Organisational: inferred level of 'trust and commitment' in UEIP</li> </ul>
Natural capital	Extent of remaining natural ecosystems Quality of water in river systems in the catchment	Ecosystems in good condition have higher potential to deliver ecosystem services (Grizzetti et al. 2019).	Change in current and historic natural land cover categories. <i>Escherichia coli</i> (E-coli) counts used as indicator of drinking water quality.
Financial capital	Capital and reserves available for water resource management	Loss or accumulation of financial capital (or access to money) used by other scholars to define phases of the adaptive cycle (see for example Abel et al. 2006).	Assessed at a catchment & organisational level. <ul style="list-style-type: none"> <li>• Catchment: Changes in gross profit margin of Umgeni Water.</li> <li>• Organisational: Level of resources allocated to the UEIP and its activities.</li> </ul>

goals, strategies or perspectives that were altered or reframed in a novel and different way in response to a new understanding, and for triple-loop learning, we note structural changes in management and government processes linked to other learning-loops.

We assess four different types of power: control, protean, ideational and agential. Our analysis of control power focuses on its institutional dimension. As suggested by Stahl (2011), we consider the implied power associated with institutional status. We base this assessment on the power of organisations in the uMngeni catchment determined through power mapping (undertaken by Rowlands et al. 2013) and local knowledge. To reflect on protean power, we identify situations where innovation emerges in relation to uncertainty and risk. We use dominant discourses (captured in policy and strategy documents) to explore the presence of three types of ideational power: power through ideas (or the 'capacity of actors to persuade other actors to accept and adopt their views of what to think and do through the use of ideational elements'); power over ideas (or 'the capacity of actors to control and dominate the meaning of ideas'; and power in ideas (or 'the authority of certain ideas in structuring thought at the expense of other ideas') (Carstensen and Schmidt 2016; Meissner and Warner 2021). We reflect on agential power as follows: whereas the other forms of power highlight either the actor or the structure, agential power simultaneously reflects on actors and structures and give both equal weighting. In other words, we identify examples when agents utilised structures, particularly their position in the network, to promote certain interests or bring about change.

We draw a distinction between agential power and agency, although acknowledge that the two are intertwined. While agential power relates to the capacity to embed into a network and to use that

embeddedness to mitigate structural impediments or to promote specific interests, agency translates into the capacity to act (Bandura 2001). This definition aligns with Ling and Dale (2013), who note that for agency to manifest, an individual must be sufficiently connected to other individuals in their community or to hierarchies of power, and must also have the intent, time, skills and self-efficacy to see problems and identify solutions. To reflect on agency, we considered the competence, skills and knowledge of key actors involved in the evolution of the UEIP as a measure of 'ability' (Alkire 2008). However, we acknowledge that this indicator is incomplete as it does not capture 'intent'. To assess strategic agency, we identify instances where groups of actors define shared values and interests and agree on a path to serve their interests. In addition, we note strategic actions taken by these groups, or individuals within the group, to achieve the transformation, such as leveraging support or mobilizing resources (see Dorado 2005; Westley et al. 2013).

We explore institutional structure through the presence of three different governance styles, which reflect different rules, values and logics (Keast et al. 2006; Pahl-Wostl 2019), namely (1) hierarchical governance that embodies control and regulation by the State; (2) network governance that is characterised by collaboration between independent actors within a self-constructed structure (den Ouden 2015); and (3) hybrid governance formations that mediate between hierarchical and network governance styles (Stuart-Hill et al. 2020). We further consider the development of policy instruments which mirror these different styles. To assess relational structure, we reflect on heterogeneity: the diversity of actors involved in the process during different stages of the transformative process (Sandström and Rova 2010).



## Results

We investigated the social processes underlying the transformation of water governance in the uMngeni catchment in two steps: 1) we mapped the evolution of the UEIP onto the adaptive cycle, and 2) we explored the processes of learning, power, agency, and structure in each phase of the adaptive cycle.

### Mapping the evolution of the UEIP onto the adaptive cycle

In this section, we describe the phases of the adaptive cycle identified during the evolution of the UEIP over the period 2000<sup>1</sup> to 2018/2019. We present changes in system potential and connectedness used to map the evolution of the UEIP onto the adaptive cycle. A timeline of significant events and milestones, (aligned to the phases of the adaptive cycle) during the evolution of the UEIP is included in [Appendix D](#).

### Trajectories in system potential and connectedness

We identified five trends in capitals in the uMngeni water governance system between 2000 and 2019. These trends suggest alternating periods of accumulation and release of capitals, with corresponding changes in system potential ([Table 2](#) and [Appendix C](#)). Within

these periods, we also identified changes in system connectedness.

The first period occurred between 2000 and 2009 and was characterised by fluctuating levels of trust in local government signalling variable levels of social capital. We identified high levels of financial capital as financial resources were accumulated by Umgeni Water. Although natural areas were rapidly transformed and water quality deteriorated, natural capital remained higher than at any other time during the transformation. Relatively high levels of all three capitals suggest that system potential was high. During this period, water resource management was controlled by a few actors (from DWS, Umgeni Water and the Municipalities) with strong relationships formed through continuous interaction. Low diversity was also reflected in the reductionist approach to water resource management. This low diversity coupled with strong interactions indicates a highly connected and vulnerable system.

The second period commenced in 2009, as trust in local government began to plummet. By 2012 it had reached its lowest level since 1998. Service delivery protests erupted in the catchment and across the country and social capital declined. Natural capital also declined as water quality deteriorated further and more natural areas were

**Table 2.** Criteria used to reflect on trends in the accumulation or release of social, natural, and financial capitals.

Time period	Social	Natural	Financial
Pre-2009	Fluctuating levels of social capital, with trust in local government close to doubling between 2001 and 2004 whereafter it declined rapidly to almost 30% but increased again around 2007 ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.1</a> ).	Declining natural capital, with the extent of natural land cover in the upper catchment decreasing from 53.62% in 2000 to 45.90% in 2008 ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.3</a> ) and water quality deteriorating in some parts of the catchment, with a 5% increase in the number of sites with results >10000 <i>E. coli</i> per 100 mL ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.4</a> ). Despite this deterioration, natural capital in this phase was in its best state relative to other times in the transformation.	Accumulating financial capital, as Umgeni Water's capital and reserves grew by 61% between 2005 and 2009 ( <a href="#">UW 2010</a> ) ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.2</a> ).
2009 – July 2012	Declining social capital, as trust in local government began to erode around 2009 and service delivery protests erupted in the catchment and across the country. By July 2012, trust in local government had reached its lowest level since 1998 ( <a href="#">Appendix 4</a> , <a href="#">Figure 4.1</a> ).	Declining natural capital, with continued loss of natural areas (from 45.9% to 42.23%) ( <a href="#">Appendix 5</a> , <a href="#">Figure 5.3</a> ) and further deterioration in water quality in parts of the catchment, with almost a 10% increase in the number of sites with results >10000 <i>E. coli</i> per 100 mL ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.4</a> ).	Releases in financial capital, as significant funds spent on chemicals to clean the highly polluted water ( <a href="#">UW 2013</a> ), resulting in Umgeni Water's gross profit margin ratio tumbling from 63% in 2009 to 54% in 2012 ( <a href="#">UW 2013</a> ) ( <a href="#">Appendix 5</a> , <a href="#">Figure 4.2</a> ).
September 2012 – October 2013	Increasing social capital, as actors mobilize around the concept of ecological infrastructure and commit to the concept of the uMngeni Ecological Infrastructure Partnership.	Declining natural capital, with a 5% increase in the number of sites with results >10000 <i>E. coli</i> per 100 mL ( <a href="#">Appendix 5</a> , <a href="#">Figures 4.3 &amp; 4.4</a> ).	Accumulation of financial capital, as finances committed to training and the implementation of pilot projects to demonstrate the benefits of ecological infrastructure
November 2013 – May 2015?	Increasing social capital, as the launch of the UEIP is attended by numerous actors and the 16 founding partners sign the MoU. Trust and commitment continue to increase as regular meetings of the UEIP are held.	Declining natural capital, with a 5% increase in the number of sites with results >10000 <i>E. coli</i> per 100 mL ( <a href="#">Appendix 5</a> , <a href="#">Figures 4.3 &amp; 4.4</a> ).	Release of financial capital by various actors including SANBI, to facilitate the start-up of the UEIP.
2015 (?) – 2019	Declining social capital, as commitment to the UEIP wanes (with DWS, eThekweni, Msunduzi and uMgungundlovu municipalities notably absent as signatories in the resigning of the Memorandum of Understanding).	Declining natural capital, with a 5% increase in the number of sites with results >10000 <i>E. coli</i> per 100 mL ( <a href="#">Appendix 5</a> , <a href="#">Figures 4.3 &amp; 4.4</a> ).	Declining financial capital, as the UEIP struggles to adopt a self-funding model.

transformed. Financial resources were released by Umgeni Water to counteract water quality challenges. The decline in all three capitals leads to the conclusion that system potential was low. Connectedness was categorised as high as the control exerted by a few tightly connected actors continued from the previous period. However, this control was weakened by the protests which permitted the entry of new actors (including SANBI and the Environmental Planning and Climate Protection Department (EPCPD) at eThekweni Municipality) and the formation of new relationships and interactions.

The third period took place between 2012 and 2013. In September 2012, the first steps were taken to mobilize actors around the concept of ecological infrastructure. Numerous actors committed to the concept of the uMgeni Ecological Infrastructure Partnership which signalled increasing social capital. Financial capital was accumulated as actors committed funds to the Partnership. Despite declining natural capital, the accumulation of social and economic capital suggests that system potential was high. A systems approach to water management emerged and new actors were invited to participate in water resource management (including non-profit organisations, civil society groups, and academia). Although their participation increased actor diversity, the strength of relationships between actors was relatively weak as many actors had not previously interacted with one another. Connectedness therefore began to decrease.

The fourth period started around November 2013, when the UEIP was launched at an event held in Durban. The attendance of the event by numerous actors and the signing of the MoU by the 16 founding partners suggests that trust and commitment to the UEIP was high. Trust and commitment continued to increase as regular meetings commenced. Financial resources were released to facilitate the start-up of the Partnership with a full-time co-ordinator appointed in May 2015. Although social capital was high, the release of financial resources coupled with poor natural capital was interpreted as reduced system potential. During this period, connectedness was low as the relationships between the diverse array of actors were still in their early stages.

We identified the final period between 2015 and 2019. However, it was difficult to determine the transition point between this and the previous period. During this time, social capital declined as commitment to the UEIP waned (with DWS, eThekweni, Msunduzi and uMgungundlovu municipalities notably absent as signatories at the resigning of the Memorandum of Understanding in May 2020). This

period was also characterised by continued deterioration of natural capital and declining financial capital, as the UEIP struggled to adopt a self-funding model. The decline in all three capitals leads to the conclusion that system potential was low, which some actors worry may limit the Partnership's capacity to capitalize on future opportunities for transformation towards desired goals. Reduced actor diversity, coupled with strong relationships (formed through enduring patterns of interaction) of those who remained, resulted in an increasingly connected system.

### *Connecting changes in system potential and connectedness to adaptive cycle phases*

Based on changes in system potential and connectedness, we mapped the evolution of the UEIP onto the adaptive cycle (Table 3). We summarise these results as follows:

- Pre-2009: High potential coupled with high connectedness suggests that the system was in a Conservation phase.
- 2009 – July 2012: Low potential and high connectedness indicate that the system was in a Release phase.
- September 2012 – October 2013: High potential together with low connectedness denote a Reorganisation phase.
- November 2013 – May 2015: Low system connectedness coupled with low potential suggests an Exploitation phase.
- 2015 (?) – 2019: Although system potential is in this phase is low, we determined that this period most likely corresponds with a second conservation phase.

### *The role of learning, power, agency, and structure in the different phases of transformation*

In the second part of the analysis, we identified distinct shifts in learning loops, power relations, agency, and structure during different phases of the transformation (Table 4). Evidence of these changes is included in Appendix F. In the following section, we discuss these changes and the connections and interplay between them. These dynamics highlight the non-linear nature of the transformation and are illustrated in Figure 3.

#### *Conservation phase (first)*

We found that the conservation phase was characterised by strong institutional structure evident in the hierarchical mode of governance. For example, in line with South Africa's 1996 Constitution (RSA 1996), specific organs of State including DWS, and provincial and local government departments, were mandated to develop legislative and other measures to achieve the

**Table 3.** Summary of the assessment of social, financial, and natural capital, and their links to potential and connectedness, used to map the evolution of the UEIP onto the adaptive cycle.

Time periods	Capitals				Potential	Connectedness	Phases of the adaptive cycle
	Social	Financial	Natural	Potential			
Pre-2009	<ul style="list-style-type: none"> <li>Variable levels of trust in local government</li> </ul>	<ul style="list-style-type: none"> <li>Accumulation of financial capital as reserves increase at Umgeni Water</li> </ul>	<ul style="list-style-type: none"> <li>Natural capital in good state (relative to other times in the transformation)</li> </ul>	<ul style="list-style-type: none"> <li>High trust</li> <li>Stored financial capital</li> <li>High natural capital</li> </ul>	<ul style="list-style-type: none"> <li>High actor diversity with regular interaction</li> <li>Reductionist approach to management</li> </ul>	Conservation (1 <sup>st</sup> )	
2009 – July 2012	<ul style="list-style-type: none"> <li>Declining trust in local government</li> </ul>	<ul style="list-style-type: none"> <li>Release of financial capital and shift towards financial threshold at Umgeni Water</li> </ul>	<ul style="list-style-type: none"> <li>Declining state of natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Low trust</li> <li>Released financial capital</li> <li>Declining natural capital</li> </ul>	<ul style="list-style-type: none"> <li>High actor diversity with regular interaction</li> <li>Reductionist approach to management</li> </ul>	Release	
September 2012 – October 2013	<ul style="list-style-type: none"> <li>Increasing commitment to UEIP</li> </ul>	<ul style="list-style-type: none"> <li>Accumulation of financial capital as funds from various actors committed to UEIP</li> </ul>	<ul style="list-style-type: none"> <li>Declining state of natural capital</li> </ul>	<ul style="list-style-type: none"> <li>High commitment</li> <li>Increasing financial capital</li> <li>Declining natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Increasing actor diversity with limited interaction</li> <li>Systemic approach to management adopted</li> </ul>	Reorganisation	
November 2013 – May 2015?	<ul style="list-style-type: none"> <li>Increasing commitment to UEIP</li> </ul>	<ul style="list-style-type: none"> <li>Release of financial capital from various actors including SANBI for start-up of UEIP</li> </ul>	<ul style="list-style-type: none"> <li>Declining state of natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Low commitment</li> <li>Released financial capital</li> <li>Declining natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Increasing actor diversity with limited interaction</li> <li>Systemic approach to management implemented</li> </ul>	Exploitation	
2015 (?) – 2019	<ul style="list-style-type: none"> <li>Decreasing commitment to UEIP</li> </ul>	<ul style="list-style-type: none"> <li>UEIP struggles to accumulate financial capital</li> </ul>	<ul style="list-style-type: none"> <li>Declining state of natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Decreasing commitment</li> <li>Limited stored financial capital</li> <li>Declining natural capital</li> </ul>	<ul style="list-style-type: none"> <li>Lower actor diversity with regular interaction</li> <li>Limited implementation of systemic approach</li> </ul>	Conservation (2 <sup>nd</sup> )	

**Table 4.** Summary of the dimensions of learning, power, agency, and structure identified in each phase of the adaptive cycle.

Phase of adaptive cycle	Learning	Power	Agency	Structure
Conservation (1 <sup>st</sup> )	<ul style="list-style-type: none"> <li>• Single-loop learning</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional power</li> <li>• Power over ideas</li> <li>• Limited agential power</li> </ul>	<ul style="list-style-type: none"> <li>• Limited individual agency</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional structure</li> <li>• Low relational structure</li> </ul>
Release	<ul style="list-style-type: none"> <li>• Double-loop learning by key individuals</li> </ul>	<ul style="list-style-type: none"> <li>• Weakening institutional power</li> <li>• Power over ideas</li> <li>• Limited agential power</li> <li>• Emergence of protean power</li> </ul>	<ul style="list-style-type: none"> <li>• Increasing individual agency</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional structure</li> <li>• Low relational structure</li> </ul>
Reorganisation	<ul style="list-style-type: none"> <li>• Double-loop learning by collectives</li> </ul>	<ul style="list-style-type: none"> <li>• Weakening institutional power</li> <li>• Power through ideas</li> <li>• Increasing agential power</li> </ul>	<ul style="list-style-type: none"> <li>• Strategic agency</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional structure</li> <li>• Increasing relational structure</li> </ul>
Exploitation	<ul style="list-style-type: none"> <li>• Triple-loop learning</li> </ul>	<ul style="list-style-type: none"> <li>• Changing institutional power</li> <li>• Power through ideas</li> <li>• Increasing agential power</li> </ul>	<ul style="list-style-type: none"> <li>• Strategic agency</li> </ul>	<ul style="list-style-type: none"> <li>• Changing institutional structure</li> <li>• Increasing relational structure</li> </ul>
Conservation (2 <sup>nd</sup> )	<ul style="list-style-type: none"> <li>• Single-loop learning</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional power</li> <li>• Power over ideas</li> <li>• Limited agential power</li> </ul>	<ul style="list-style-type: none"> <li>• Limited strategic and individual agency</li> </ul>	<ul style="list-style-type: none"> <li>• Strong institutional structure</li> <li>• Low relational structure</li> </ul>

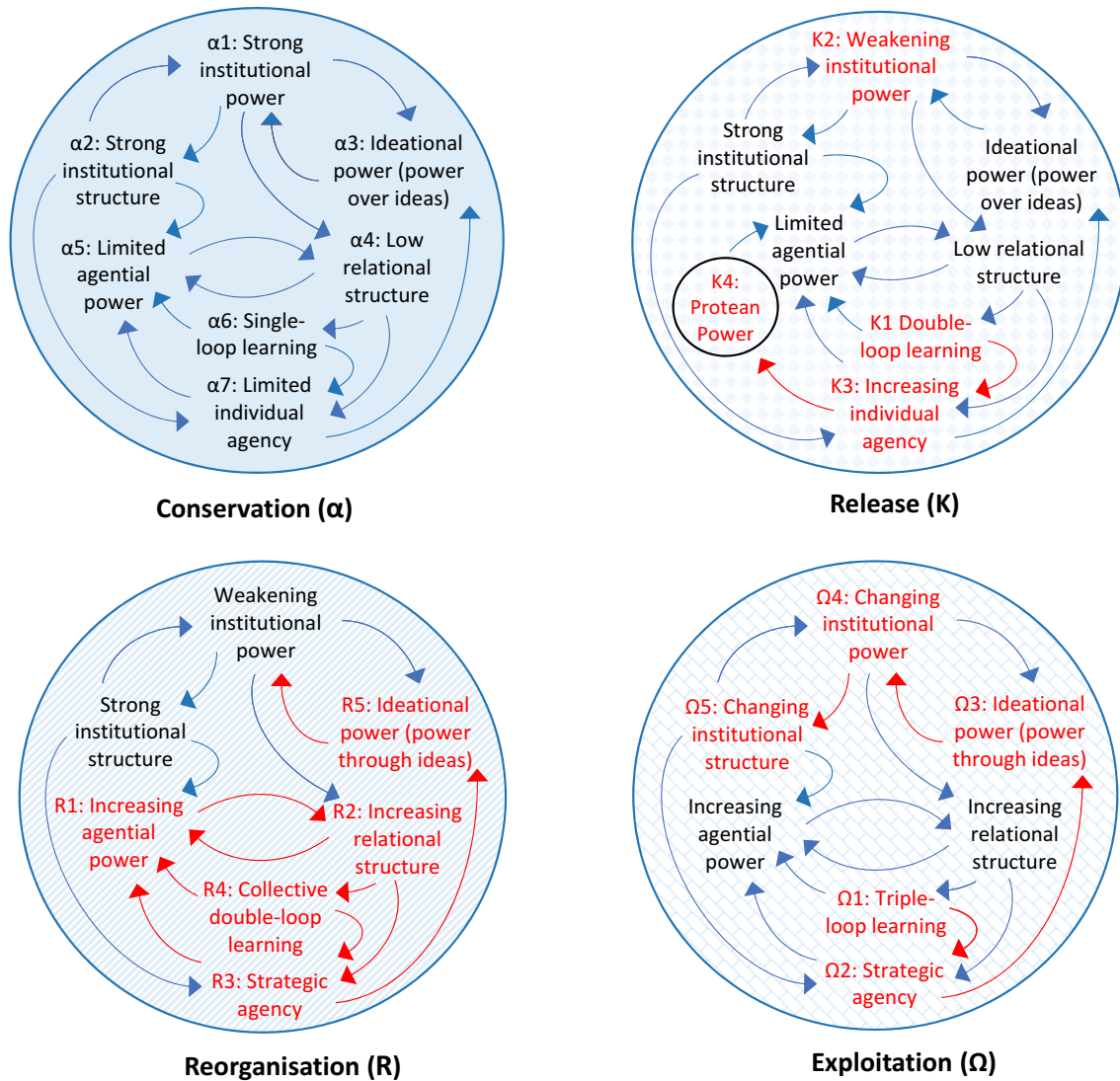
realisation of the right of access to basic water supply (Cameron 2014; SAHRC 2018) with few other actors involved in water management. We noted that this strong institutional structure ( $\alpha_2$ ) reinforced institutional power ( $\alpha_1$ ). For example, DWS, Umgeni Water and eThekweni Municipality were identified as some of the most powerful organisations in the catchment at this time, and controlled the distribution of water resources. The views of these dominant government organisations to development processes, such as the application of engineering solutions to achieve the right to water, were deeply entrenched and alternative discourses were largely excluded (Meissner and Turton 2003). This ‘power over ideas’ ( $\alpha_3$ ) is reflected in various policies and strategies such as the National Water Conservation and Water Demand Management Strategy (DWA 2004) which focused almost entirely on engineering options. These documents highlight single-loop learning in the form of improving existing practices ( $\alpha_6$ ). For example, Umgeni Water continued plans to build new dams and implement water management programmes (UW 2007). Single-loop learning was reinforced by the lack of involvement of other actors (expressed as low relational structure ( $\alpha_4$ )). This limited the diversity of views and prevented access to new information and experiences. Strong institutional structure also limited agency ( $\alpha_7$ ) and agential power ( $\alpha_5$ ) and together with single-loop learning and the lack of new ideas, reinforced ideational power as power-over ideas and the notion that engineering solutions were the only available solution. Initially, there was acceptance of the dominant institutions and discourses. Together, these factors reduced the capacity of

the system for self-organisation and the prevalent structure of domination was maintained.

### Release phase

We noted that the release phase was triggered by a movement of country-wide social protests, referred to by Alexander (2010) as the rebellion of the poor. The established institutions and dominant discourses were seen to have failed in meeting service delivery expectations, resulting in declining control power (K2). For example, the Water Reconciliation Strategy for the KwaZulu-Natal Coastal Metropolitan Area (DWA 2009) showed that engineering solutions alone were unlikely to meet the growing demand for water. The social discontent at a national scale, coupled with water supply and quality challenges in the catchment, was used to create a crisis narrative which was purported to require an organisational structure to correct. This led key actors in eThekweni Metropolitan Municipality’s Water and Sanitation Unit (EWS) and Environmental Planning and Climate Protection Department (EPCPD) to question conventional approaches to water management, signalling double-loop learning (K1). These actors began to reframe existing assumptions (that engineering solutions were the only option) which facilitated changes in underlying mental models. The changing context also permitted the introduction of the novel idea of restoring and maintaining ecosystems or ‘ecological infrastructure’ to address water quantity and quality concerns (Zunckel 2013; Hordijk et al. 2014; Sutherland and Roberts 2014; Manual et al.





**Figure 3.** The interaction of different dimensions of learning, power, agency, and structure in each phase of the adaptive cycle. Red text indicates critical processes; the hatched background denotes changing contexts.

2016; Gale 2020). This solution was offered by SANBI, an influential actor who was based outside of the uMngeni water management system pre-2009. The interaction of weakening control power and the changing context gave rise to protean power ( $K 4$ ), as key actors at eThekweni Metropolitan Municipality began to respond to the uncertain context and seek innovative solutions. Double-loop learning coupled with emerging protean power contributed to the release of the system from the conservation phase.

### Reorganisation phase

During the re-organisation phase, those actors with protean power also held agential power ( $R 1$ ). Agential power can be seen in the ability of key actors to utilise structures to promote certain interests. In the uMngeni catchment, the key actors who held agential power were both top-level managers with formal levels of authority at eThekweni Metropolitan Municipality, one of the most powerful organisations in the catchment

(Rowlands et al. 2013). They were also highly influential and connected into national and global networks. Thus, these actors occupied strategic positions in the network and utilised these structures to promote the concept of ecological infrastructure. These actors also used their agential power to mobilise other actors and in so doing altered the relational structure ( $R 2$ ). The change in structure was particularly evident in the formation of an informal actor group, which included the four initial partners (eThekweni Metropolitan Municipality, SANBI, KwaZulu-Natal DWS and Umgeni Water) and was later expanded to include World Wildlife Fund South Africa (WWF-SA), the Duzi uMngeni Conservation Trust (DUCT), uMgungundlovu District Municipality (UMDM), Msunduzi Municipality and the Wildlife and Environment Society (WESSA). The informal actor group displayed collective double-loop learning ( $R 4$ ) which was evident in their mobilization around the central idea of ecological infrastructure and the co-design of pilot projects

to showcase the benefits of ecosystem restoration. Importantly, the emergence, actions and learning of the informal actor group enabled a shift towards strategic agency (R3). Strategic agency is a critical ingredient for re-organisation of the system. As actors worked together to secure resources and support for the ecological infrastructure concept, they persuaded others to accept these new ideas and shifted ideational power from power-over ideas to power-through ideas (R5). As a result, the UEIP, which was better able to accommodate these new ideas, began to emerge.

### Exploitation phase

During the exploitation phase, ‘power through ideas’ ( $\Omega 3$ ) influenced institutional power ( $\Omega 4$ ) as multiple ideas were able to co-exist. This in turn influenced institutional structure ( $\Omega 5$ ), as hybrid governance formations were enabled. This was evident in the official launch of the UEIP in Durban in November 2013. However, the informal actor group held power in deciding who could participate in the process, as well as influencing the discourse, direction and functioning of the UEIP, while SANBI held power in controlling the appointment of the new UEIP co-ordinator. The UEIP provided a new structure and space for collective learning. Through this platform, a diverse array of actors were able to share their values and ideals, engage in the experimental pilot projects and critically reflect on their mental models and worldviews. The UEIP itself can therefore be categorised as an example of triple-loop learning ( $\Omega 1$ ). There were also signs of limited triple loop learning beyond the system. For example, several key actors (including representatives from SANBI) worked hard to ensure that the UEIP featured as a pilot project in the President’s Strategic Integrated Project Plan (under Strategic Infrastructure Project #19 [SIP19]) (Minister of Water and Environmental Affairs 2014), aimed at fast tracking economic development and growth, which was presented to Cabinet in October 2014. Although ‘SIP19’ was later abandoned, the concept of ecological infrastructure was included in the second edition of the National Water Resource Strategy for South Africa (DWA 2013). This collective effort also showcases the shared values and interests of the UEIP and provides an example of strategic agency. Although a full-time co-ordinator was appointed during this phase, her individual agency and power was constrained as she was new to the catchment with limited networks. She also played more of an administrative rather than a decision-making role.

### Conservation phase (second)

The second conservation phase commenced around mid-2015. During this phase, the crisis narrative of

deteriorating water quality and water security challenges in the uMngeni catchment (which shaped the context) continued (see, for example, Sutherland et al. 2019). This phase exhibited similar dynamics to that of the conservation phase in the first iteration of the cycle. Although the institutional structure had shifted to a more hybrid mode of governance, the UEIP as a structure within the broader system, encountered several challenges ( $\alpha 2$ ). By May 2020, the number of individuals attending the UEIP meetings had declined substantially, signalling a decrease in relational structure across the system ( $\alpha 4$ ). This significantly constrained strategic agency ( $\alpha 2$ ) as several of the most powerful organisations in the catchment (including DWS, eThekweni, Msunduzi and uMgungundlovu municipalities) were notably absent as signatories in the re-signing of the MoU in 2020. The reasons for not re-signing remain unclear, although it may be that they were no longer interested in going forward with the collaboration, or in eThekweni’s case, that they possibly decided to pursue their own investments in ecological infrastructure. Nonetheless, the lack of involvement of these powerful actors likely contributed to the stalling of collaborative governance efforts. We also noted that learning ( $\alpha 2$ ) was constrained. During this time, the experimental pilot projects were well underway and provided examples of a learning-by-doing approach. However, we found that knowledge and experience gained from these projects did not translate into changes in practices across the catchment more broadly. There were also no major structural changes in rules and actor networks in the overall uMngeni system. For example, although the UEIP was considered a leading voice in the development of the catchment management strategy (which spans several catchments including the uMngeni), the concept of ecological infrastructure did not actually feature in the document. It does, however, address broader catchment management issues as they relate to impacts on water resources. These examples provide evidence of single-loop learning, which likely enhanced ideational power ( $\alpha 3$ ), and reinforced both institutional power ( $\alpha 1$ ) and structure, thereby bringing stability to the system.

## Discussion

The aim of this study was to investigate the key social processes that characterise transformative potential at different stages in the change process in order to strengthen our analytical understanding of transformation. We used the adaptive cycle to describe the different phases of change, and then illuminated the connections and feedbacks between different facets of learning, power, agency, and structure over time. This

allowed us to identify the key dynamics that drive different phases of transformative change.

### *Insights into the social dynamics of different phases of change*

Our work adds to the existing body of work on transformation in two ways. Firstly, we highlight linkages between social processes and their role in transformation which are currently under-reported in the literature (e.g. protean power), and secondly, we provide a more holistic picture of the relationships and feedbacks which surface at different times during the transformation process.

Our analysis revealed that the conservation phase was characterised by strong control and institutional power as dominant actors sought to control the environment to meet their own ends. This was reinforced through legislated mandates and institutional structures. Dominant actors exhibited control over ideas (a form of ideational power) which reinforced their control power. Strong institutional power also enabled them to control who was involved in the decision-making process thereby limiting relational structure and agential power. This in turn prevented the introduction of new ideas which further embedded single-loop learning. Single-loop learning coupled with limited individual agency reinforced ideational and control power. Acceptance of these structures and ideas brought stability to the system and prevented it from shifting to an alternatively configured state. This finding confirms work by other scholars who have long argued that institutional structures and arrangements influence relational structure and control power by limiting who can meaningfully participate in debates, planning and decision-making processes (Fox 1976; Schafft and Brown 2003; Barnett and Duvall 2005). Less explored, however, are the connections between power and learning. In a study on the transformation of two urban centres in Mexico, Pelling and Manuel-Navarrete (2011) found that social learning was constrained by dominant structures created for centralizing power. Medema et al. (2014) and Johannessen et al. (2018) also argue that social learning is constrained by powerful structures and dynamics, while Mostert et al. (2007) noted that a balance of power was a pre-requisite for social learning. Our study adds to this work by providing a finer distinction between the types of power and learning that emerge at different times in the transformation process.

Our results also surfaced the importance of cross-scale dynamics and context in the transformation. Similar to other scholars, we found that the crisis occurred at a broad scale but triggered a transformative process at a local scale (Cash et al. 2006; Olsson et al. 2006, 2014; Beier et al. 2009; Tai

2015; Leach et al. 2018; Herrfahrdt-Pähle et al. 2020). We also found that an uncertain context was important for triggering the transformation. This reinforces a similar finding by other scholars (see, for example, Olsson et al. 2004; Westley et al. 2013; Chaffin et al. 2014; Johannessen et al. 2018). The importance of context is possibly best expressed by Dorado (2005) who notes that institutional change is contingent on the likelihood that a context will allow actors to both introduce novel ideas and enable the mobilization of resources to support them. Building on this work, Westley et al. (2013) linked shifting contexts to phases of the adaptive cycle and noted how such changes permitted the introduction of new ideas during the release phase. Our analysis revealed similar results, but also highlights how the changing context allowed for double-loop learning in which key actors began to question whether they were doing the right things, reframed existing assumptions and reviewed their underlying mental models. Individuals also questioned underlying rules, meanings and authority which led to weakened control power and instability of the system. This confirms observations in the literature that a crisis or changing context, may trigger critical reflections and a change in understanding of perceived risks (Biggs et al. 2010; Olsson et al. 2010; Westley et al. 2013; Johannessen et al. 2018). Our findings agree with Legro (2000) who argues that a shift in ideas of individuals is one of the first steps in changing ideational power.

We found that protean power was central to the release phase and emerged during a time of uncertainty. Protean power arose as the agency of key actors increased in response to the altered context and they began to search for solutions to local problems. The new context coupled with weakened institutional power (a form of control power) permitted the introduction of new ideas and solutions (in our case from outside of the system). We found that the implementation of these ideas and the effects of the actions (of those with protean power) on others and the system, were largely unpredictable. These findings again confirm the importance of context in transformation but further flag its interplay with different types of power. Similar findings have emerged elsewhere in the literature. For example, Katzenstein and Seybert (2018) argue that the fall of the Berlin wall was underpinned by a combination of failing diplomatic and control power, and the actualization of protean power. They suggest that control power and protean power often co-evolve and co-exist, and it is the confluence of these two types of power that enables transformation. However, the importance of protean power in transformations generally, but in social-ecological transformations specifically, is under-explored in the literature, and should form a critical line of enquiry in the future.

Our analysis showed that during the reorganisation phase, agents who held protean power also held agential power. This power was essential in mobilising other actors in support of the innovation and resulted in the emergence of an informal actor group or shadow network. The formation of the shadow network in turn, shifted relational structure and enabled strategic agency. Strategic agency is important as it allows actors to define shared values and decide on a particular course of action (Westley et al. 2013). The formation of shadow networks during transformation has been recognized by several other scholars, although few have noted the role of power in the emergence of these networks (see, for example, Olsson et al. 2006, 2014; Gelcich et al. 2010; Westley et al. 2013; Herrfahrdt-Pähle et al. 2020). They highlight that shadow networks are critical in preparing a system for change by exploring alternative system configurations, providing novel ideas, and developing strategies for alternative futures.

We found that during the reorganisation phase, the informal actor group worked strategically to persuade others through cognitive and normative arguments about the validity of their ideas. They employed a variety of strategies including the conception of pilot projects, which were used to draw in different actors and unify them around the central idea of ecological infrastructure. These findings concur with Westley et al. (2013) who noted that pilot or umbrella projects were used to create a bundle of knowledge that were sufficiently open-ended to attract a diversity of actors and allow them to work collaboratively together. Our results further suggest that the co-design of these pilot projects enabled collective double-loop learning, in which actors began to re-evaluate their initial assumptions. Similar examples of double-loop learning have been reported in other collaborative contexts. For example, Johannessen et al. (2018) found that a collaboration between individuals from the Kristianstad municipality and other local and national actors, led to changes in both perceptions and measures about floodlines. Importantly, in our case study, the uptake of these ideas resulted in a gradual shift in ideational power, from ‘power over ideas’ to ‘power through ideas’ which in turn affected control power. As the system reorganised, new organisations began to emerge. This finding supports Legro (2000) who reasons that ideational change is a two-step process that involves collapse and consolidation. Collapse occurs when actors reach agreement that old beliefs are inadequate while consolidation requires social coordination on a replacement set of ideas (Legro 2000). Both steps involve collective ideation problems, which we found were solved through strategic agency of the informal actor group.

Our results point to limited structural change facilitated by weakened control power and triple-loop learning, during the exploitation phase. The formation of the UEIP itself provides some evidence of triple-loop learning. This finding supports claims by Johannessen et al. (2018) that the formation of a governance structure that supports intersectoral communication and cooperation between different actors can facilitate triple-loop learning and the transformation of water governance systems. They document how the establishment of shared learning dialogues in Gorakhpur gradually changed the nature of relationships both within communities and external institutions, and also demonstrated how cross-sectoral dialogue in Kristianstad led to risk managers re-evaluating the value of wetlands. In the uMngeni, however, we found no evidence of major structural changes in rules and actor networks in the overall catchment. This calls into question the extent of the transformation. We suggest that the ability to transform the wider governance system was jeopardised by single-loop learning, which was evident in a failure to translate the knowledge and experience gained through learning processes into changes in practices more broadly across the catchment.

### *Reflections on the use of the adaptive cycle and the four social processes*

Although we found the adaptive cycle helpful for identifying distinct phases of change, we encountered challenges in quantitatively assessing dimensions of potential and connectedness. This was partly because social, economic and ecological capitals were conceptualised at different scales over the period of the transformation. In addition, some criteria were difficult to quantify and relied on a thorough understanding of the case study. Other scholars also reported difficulties in assessing the properties of potential and connectedness (see Abel et al. 2006; Daedlow et al. 2011; Salvia and Quaranta 2015) and noted that the assessment could be skewed depending on who was involved in the process.

We found the multi-faceted processes of learning, power, agency and structure helpful for elucidating the dynamics of change, thereby enhancing our analytical understanding of the broader transformation puzzle. In summary, we found that power shifted from ‘power over ideas’ in the conservation and release phases, to ‘power through ideas’ in the reorganisation and exploitation phases. Protean power also emerged as a key ingredient for change during the exploitation phase. We identified similar shifts in learning and agency. The conservation phase was characterised by single-loop learning which shifted to double-loop learning initially by individuals in the release phase, and then by collectives in the



reorganisation phase, while triple-loop learning surfaced in the exploitation phase. Linked to learning, we found that individual agency was limited during the conservation phase but increased during the release phase and shifted to strategic agency in the reorganisation and exploitation phases. These changes were influenced by, and facilitated, changes in relational and institutional structures. During the conservation phase, there was strong institutional but low relational structure while during the exploitation phase a more hybrid mode of governance was enabled, and relational structure increased.

These results confirm work by other scholars on the relationships between some social processes, for example between power and learning (see, for example, Pelling and Manuel-Navarrete 2011; Medema et al. 2014; Johannessen et al. 2018) and between structure and power (see, for example, Fox 1976; Schafft and Brown 2003; Barnett and Duvall 2005). Our results also contribute to the structure-agency debate and lend support to Giddens (1984) theory of the duality of structure where individuals are simultaneously constrained and empowered by existing social structure. We also concur with Pelling and Manuel-Navarrete (2011) who suggest that power is the outcome of the interaction between individual agency and structure. However, our results indicate that while this power is associated with agential power, other forms of power may simultaneously exist with varying effects on the transformation process. In line with other scholars, we also surfaced how different types of social processes contribute to transformation, such as the importance of triple-loop learning (see, for example, Johannessen et al. 2018) and the role of protean power (see, for example, Katzenstein and Seybert 2018).

## Conclusion

Our study strengthens our analytical understanding of transformation and highlights the social processes underlying the change process. We used the adaptive cycle to define phases of change and then identified how learning, power, agency, and structure vary and influence the different phases of transformation. Our findings suggest that the shift in water governance in the uMngeni catchment to a new configuration of collaboration, represents a transformation. In summary, we found the following in our case study, which we think may hold in other contexts:

- (1) During the conservation phase of the adaptive cycle, strong control power and institutional structure often limit relational structure and the introduction of new ideas, which reinforces single-loop learning. Acceptance of these structures and ideas brings stability to the system and prevents it from shifting to an alternatively configured state. In some instances, these

linkages and feedbacks may lock a system into an undesirable state.

- (2) A political, social, or environmental shock may trigger a shift from the conservation to the release phase. This change in context weakens control power, permits the introduction of new ideas, and sparks double-loop learning as key actors start to question their underlying assumptions. Importantly, the changing conditions create uncertainty which gives rise to protean power – a critical ingredient for change.
- (3) The emergence of protean power enhances agential power of key actors, who begin to mobilise other actors and resources in a rapid phase of reorganisation. In so doing, they alter relational structure and enable strategic agency through the creation of an informal actor group. Together, these actors engage in collective double-loop learning resulting in a gradual shift in ideational power from ‘power over ideas’ to ‘power through ideas’.
- (4) The exploitation phase is characterised by triple-loop learning that involves shifts in underlying norms and values. Triple-loop learning may be enabled through the formation of new collaborative institutions that are better able to accommodate innovative ideas and provide trusted platforms that encourage participation, integration, and learning. However, structural changes to the broader system may be constrained by failure to translate knowledge gained through learning processes into changes in practice more widely.

We contend that the emergence of different types of learning, power, agency and structure, such as those identified in this article, are essential for transformation. This understanding may help to inform actions that steer transformations away from less desired trajectories and lock-in’s, towards more sustainable and collaborative water governance in South Africa and elsewhere.

## Note

1. Umgeni Water financial data was only available from 2003.

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## ORCID

Reinette Biggs  <http://orcid.org/0000-0003-0300-4149>

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## APPENDIX

### Appendix A. Description of key organisations who have participated in the UEIP

Actor name	Acronym	Description
South African National Biodiversity Institute	SANBI	The South African National Biodiversity Institute (SANBI) is an organisation established in terms of the National Environmental Management: Biodiversity Act, No 10 of 2004, under the South African Department of Environmental Affairs. SANBI is tasked with research and dissemination of information on biodiversity and is legally mandated to contribute to the management of South Africa's biodiversity resources. Although SANBI has its headquarters in Pretoria, it still has a strong influence on ecological infrastructure in the uMngeni catchment.
eThekweni Metropolitan Municipality	-	eThekweni Municipality is a metropolitan municipality that is responsible for all local services, development and delivery in the metropolitan area of eThekweni. eThekweni is one of 11 districts in KwaZulu-Natal, and includes the city of Durban and surrounding areas. eThekweni Metropolitan Municipality is by far the largest water user in the uMngeni catchment. It also has a very active Environmental Planning and Climate Protection Department (EPCPD) and Water and Sanitation Unit.
Department of Water and Sanitation	DWS	The Department of Water and Sanitation is a national department and the custodian of South Africa's water resources. It is primarily responsible for the formulation and implementation of policy governing the water sector.
KwaZulu-Natal Department of Water and Sanitation	KZN DWS	Many of the policies and regulations of the National DWS are implemented through its 9 regional offices, including the regional office in KwaZulu-Natal. The KwaZulu-Natal DWS office is responsible for developments, projects and programmes within the Pongola to uMzimkulu Water Management Area.
Umgeni Water	-	Umgeni Water is a state-owned entity and provides water services (bulk potable/drinking water and sanitation services) to water services authorities (municipalities) in KwaZulu-Natal. These include eThekweni Metropolitan Municipality, Msunduzi Local Municipality and uMgungundlovu District Municipality, amongst others.
Wildlife and Environment Society of South Africa	WESSA	WESSA is a non-governmental environmental organisation in South Africa which focuses on environmental education and capacity building. The organisation has been active in the uMngeni catchment for a long time and has engaged in various projects that support environmental sustainability and ecosystem integrity.
uMgungundlovu District Municipality	UMDM	uMgungundlovu is one of 11 districts in KwaZulu-Natal and incorporates 7 local municipalities including Msunduzi. The purpose of the District Municipalities is to share the responsibility for all local services, development and delivery with local municipalities in their district, to ensure that all communities, particularly disadvantaged communities, have equal access to resources and services. The uMngeni River and its tributaries flow through almost all the Local Municipalities within the UMDM.
Msunduzi Local Municipality	-	Msunduzi Local Municipality is one of 43 local municipalities in KwaZulu-Natal and encompasses the city of Pietermaritzburg, the capital city of KwaZulu Natal and the economic hub of the uMgungundlovu District. The Msunduzi Local Municipality shares the responsibility for all local services, development and delivery with the uMgungundlovu District Municipality. However, Msunduzi Local Municipality often functions quite independently largely because of its substantial annual budget (which is four times higher than the District's) and large revenue streams which it generates through rates and the sale of electricity.
World Wildlife Fund – South Africa	WWF-SA	The World Wildlife Fund – South Africa is one of the largest independent conservation and environment organisations in South Africa. Within the uMngeni catchment, the organisation plays an active role in funding various projects that support ecological infrastructure.
Duzi uMngeni Conservation Trust	DUCT	DUCT is a non-profit public benefit organisation based in Pietermaritzburg that champions the health of the uMngeni and Msunduzi Rivers.

## Appendix B. Documents consulted during the analysis

### A2.1. UEIP Documents

Document Name	Date
Water security and service delivery through investments in natural infrastructure in the greater uMngeni catchment: Concept Note	27 September 2012
The Greater uMngeni Water Security Partnership (a discussion document to provide SANBI and eThekweni EPCPD with a basis upon which to plan for and arrange a key stakeholder workshop on the above scheduled for the end of February 2013).	30 November 2012
Joint Media Release, 28 February 2013, New solutions explored for water security and service delivery investments in ecological infrastructure in the greater uMngeni catchment.	28 February 2013
Minutes of the uMngeni Ecological Infrastructure Partnership – Strategy Meeting	29 April 2013
uMngeni Ecological Infrastructure Partnership – Strategy Meeting, Minute Summary	29 April 2013
Minutes of the 2nd uMngeni Ecological Infrastructure Partnership – Strategy Meeting	5 August 2013
uMngeni Ecological Infrastructure Partnership, The 2nd Partners Workshop – 10 October 2013, Invitation letter.	August 2013
uMngeni Ecological Infrastructure Partnership Workshop, Proceedings of the 2nd UEIP Stakeholder Workshop held on 10 October 2013 at KZN-Wildlife Head Office, Queen Elizabeth Park.	10 October 2013
The uMngeni Ecological Infrastructure Partnership, Memorandum of Understanding, V3	18 November 2013
The uMngeni Ecological Infrastructure Partnership (UEIP), Progress Report, November 2013 – March 2014	March 2014
UEIP List of signatories: Annexure A: Contact details and information exchange	June 2014
The uMngeni Ecological Infrastructure Partnership, Research Sub-Committee Meeting, Draft Minutes.	19 November 2014
Terms of Reference, Research Sub-Committee of the uMngeni Ecological Infrastructure Partnership (UEIP), V4	19 November 2014
uMngeni Ecological Infrastructure Partnership summary, 2015	n.d.
The uMngeni Ecological Infrastructure Partnership, Research Sub-Committee Meeting, Draft Minutes.	15 April 2015
The uMngeni Ecological Infrastructure Partnership (UEIP), An Overview of Progress, September 2015	September 2015

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Document Name	Date
Proceedings from the National Biodiversity and Business Network (NBBN) and the uMngeni Ecological Infrastructure Programme (UEIP): Investment in Ecological Infrastructure – the relevance for business, South African Sugar Association	1 October 2015
The uMngeni Ecological Infrastructure Partnership (UEIP), A strategy	July 2016
The uMngeni Ecological Infrastructure Partnership (UEIP), Research Sub-Committee Meeting, Draft Minutes.	15 November 2016
The uMngeni Ecological Infrastructure Partnership (UEIP), presentation given by Dr Pearl Gola (co-ordinator of the UEIP) at the KZN Biodiversity and Business Indaba	17 March 2017
The uMngeni Ecological Infrastructure Partnership (UEIP), Annual Progress Report 2016– 2017	May 2017
The uMngeni Ecological Infrastructure Partnership (UEIP), Research Sub-Committee Meeting, Draft Minutes.	19 May 2017
The uMngeni Ecological Infrastructure Partnership (UEIP), Research Sub-Committee Meeting, Draft Minutes.	14 November 2017
The uMngeni Ecological Infrastructure Partnership (UEIP), Research Sub-Committee Meeting, Draft Minutes.	5 June 2018
The uMngeni Ecological Infrastructure Partnership (UEIP), Research Sub-Committee Meeting, Draft Minutes.	23 May 2019
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Douwes, J. 2018. Exploring transformation in local government in a time of environmental change and thresholds: a case study of eThekweni Municipality. MSocSci thesis. University of KwaZulu-Natal, Howard College campus.

Gale, M. 2020. Water governance in South Africa: capacity development in river basin management. Master's thesis. Utrecht University, Netherlands.

Hordijk, M., L. M. Sara, and C. Sutherland. 2014. Resilience, transition or transformation? A comparative analysis of changing water governance systems in four southern cities. *Environment and Urbanization* 26(1): 1–17. doi: 10.1177/0956247813519044.

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### Appendix C. Criteria, linked to capitals, used to determine system potential

Capital	Criterion	Justification	Application in our study	Data source
Social capital	Trust and commitment	Trust and social capital are mutually reinforcing, with social capital enabling trusting relationships that in turn produce social capital (Putnam 2000; Fu 2004; Myeong and Seo 2016). Trust and commitment are regarded as two key attributes of relational capital and are suggested as a proxy for potential (Nkhata et al. 2008; Tadesse and Kassie 2017)	Assessed at catchment & organisational level. <ul style="list-style-type: none"> <li>Catchment: we used trust in local government as a reflection of trust in other tiers of government mandated to manage water resources in uMngeni catchment.</li> <li>Organisational: we inferred the level of 'trust and commitment' in UEIP</li> </ul>	<ul style="list-style-type: none"> <li>Human Sciences Research Council (HSRC) Evaluation of Public Opinion Programme (EPOP) 1998–2001 and the HSRC South African Social Attitudes Survey 2003–2018.</li> <li>Document analysis together with collective experience in Partnership.</li> </ul>
Natural capital	Extent of remaining natural ecosystems  Quality of water in river systems in the catchment	Ecosystems in good condition are generally regarded as having a higher potential to deliver important ecosystem services (Grizzetti et al. 2019).	Change in natural land cover categories between current and historic land cover data for the uMngeni catchment  We used long-term data sets of <i>Escherichia coli</i> (E-coli) counts, as this is a reliable indicator of drinking water quality and is regularly monitored at multiple sites in the catchment.	<ul style="list-style-type: none"> <li>National Land Cover data 2000 &amp; KwaZulu-Natal Land Cover 2008, 2013 (adapted from Namugize et al. 2018)</li> <li>Laboratory Information Management System data extract of routine Umgeni Water River sampling site data (2000–2019).</li> </ul>
Financial capital	Capital and reserves available for water resource management	The loss or accumulation of financial capital (or access to money) is considered by other scholars an important criterion in defining phases of the adaptive cycle and has been applied in other cases (see for example Abel et al. 2006). In our case study, water resource management is funded through budget allocations to DWS, Umgeni Water and municipalities. Other sectors such as agriculture, environment, energy, and industry also play a role but do not explicitly receive funds for water resource management. The scope of our assessment was limited as there is currently no water-related government function with its own finances (independent of national government) operating at a provincial scale (the regional office of DWS in KwaZulu-Natal is an extension of the National DWS).	We assessed financial capital at a catchment & organisational level as follows: <ul style="list-style-type: none"> <li>Catchment: We used changes in gross profit margin ratio (a financial metric that compares the gross margin of a business to the net sales) of Umgeni Water as an indicator of the accumulation or release of financial resources.</li> <li>Organisational: we assessed the level of resources allocated to the UEIP and its activities.</li> </ul>	<ul style="list-style-type: none"> <li>Financial statements in Umgeni Water Annual Reports 2003 to 2019</li> <li>Document analysis together with collective experience in Partnership.</li> </ul>



## Appendix D. Summary of significant events and milestones in the formation of the UEIP, aligned with phases of the adaptive cycle

Date	Event	Outcomes	Reference*
<i>Conservation phase 1<sup>st</sup></i>			
Pre-2009	In the uMngeni catchment, management of water resources dominated by formally mandated institutions including Department of Water Affairs and Water Services Authorities with little involvement of other actor groups. Management adopted a reductionist approach and only focused on engineering solutions.	Reductionist approach to water resource management with little to no involvement of stakeholder or actor groups.	Manual et al. 2016; Gale 2020.
<b>Release phase</b>			
2009	Reconciliation Strategy for the KwaZulu-Natal Coastal Metropolitan Area Water Supply System finalized.	Supply/demand challenges in the catchment highlighted and series of technocratic solutions proposed.	DWA 2009; Zunckel 2013.
2009 and 2010	Numerous service delivery protests in eThekweni Metropolitan Municipality and across South Africa.	Social discontent making managers more receptive to alternative solutions to meet service delivery mandates.	Alexander 2010; Shezi 2013.
2011	SANBI explores Payment for Ecosystem Services approaches and introduces concept of 'natural infrastructure'.	Innovative approach to water resources management emerges.	DEA and SANBI 2011; Zunckel 2013; Swilling, Musango, and Wakeford 2016; Manual et al. 2016; Meissner 2021.
2011	eThekweni Metropolitan Municipality publish their 2011/2012 Integrated Development Plan highlighting the deteriorating state of natural resources.	Heightened awareness of deteriorating state of natural capital.	Ethekewini Municipality 2011.
July 2012	Meeting between SANBI and the head of eThekweni Metropolitan Municipality's Environmental Planning and Climate Protection Department EPCPD, followed by a meeting with SANBI, EPCPD and head of eThekweni's Water and Sanitation Department.	Recognition that engineering solutions alone were unlikely to address the problem.	Zunckel 2013; Manual et al. 2016.
<b>Reorganization phase</b>			
September 2012	Concept note on natural infrastructure prepared to draw KZN DWA Regional and Umgeni Water into the process.	First steps to mobilize other actors and leverage resources.	Zunckel 2013; UEIP Concept note 2012.
October 2012 - January 2013	Series of engagements between SANBI, eThekweni's Water and Sanitation Department and Environmental Planning and Climate Protection Department, KZN DWA Regional and Umgeni Water.	Formation of the initial informal actor group. Shift from technocratic solutions to natural infrastructure as the latter added as an additional option for water delivery to the water reconciliation strategy. Preparation to mobilize additional and high-level actors.	UEIP Discussion document 2012.
February 2013	First stakeholder workshop high-level inception workshop held in Pietermaritzburg and attended by almost 80 people representing 35 organisations	Additional actors, synergies and knowledge gaps identified, and a common vision for a catchment wide partnership developed.	Zunckel 2013
April 2013	First meeting of expanded informal actor group to discuss roles and responsibilities of core partners [World Wildlife Fund South Africa WWF-SA, Duzi uMngeni Conservation Trust DUCT and the uMgungundlovu District Municipality UMDM added as additional partners].	Informal actor group expanded to include local and provincial actors across scientific and management domains. Resources committed and significant effort by partners to leverage more funds.	UEIP Minutes 29 April 2013.
August 2013	Second meeting of expanded informal actor group	Three Water Service Authorities eThekweni, Msunduzi and uMgungundlovu committed to supporting pilot projects in their areas and SANBI and WWF commit funds to support the UEIP coordinator position.	UEIP Minutes 5 August 2013
October 2013	Second stakeholder workshop held in Pietermaritzburg and attended by 55 participants from a variety of organisations.	Pilot projects to demonstrate benefits of ecological infrastructure identified.	UEIP Workshop proceedings 10 October 2013; Cobinnah and Addaney 2019.
<b>Exploitation phase</b>			
November 2013	Launch of the UEIP at an event held in Durban including a high-level dialogue on ecological infrastructure, the signing of the MoU by 16 founding partners, and the launch of the pilot projects.	Paradigm shift towards a more inclusive and systemic approach to managing resources	UEIP Progress Report 2014; Hordijk et al. 2014; Vogel et al. 2016 ; Chu, Anguelovski, and Roberts 2017; Douwes 2018; Gale 2020.
2014	First meeting of the official UEIP	UEIP officially established as a successful collaborative partnership with a diversity of views and partners.	UEIP Minutes November 2014.

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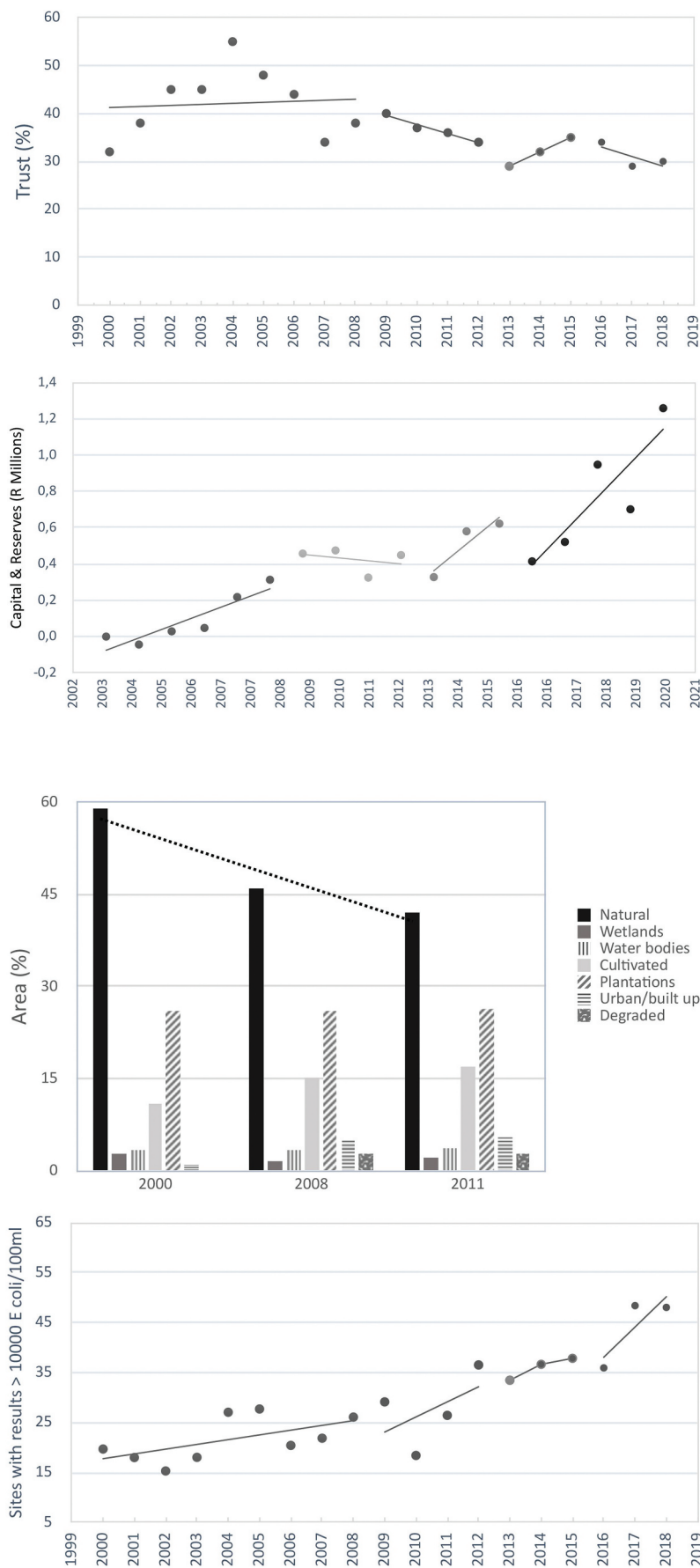
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Date	Event	Outcomes	Reference*
2014–2015	Implementation of pilot projects begins	Start of innovations to create shared knowledge and meaning between different interest groups.	UEIP Progress Report 2015; Sutherland, Jewitt et al. 2019; Sutherland, Maseka et al. 2019; Cobinnah and Addaney 2019; Sutherland et al. 2019; Meissner 2021.
May 2015	Full-time UEIP coordinator appointed and a coordinating committee and a research sub-committee, established.	Funds released to support the coordinator position	UEIP Progress Report 2014; Sutherland, Jewitt, et al. 2019.
<b>Conservation phase 2<sup>nd</sup></b>			
2015 onwards	Biannual meetings of UEIP held	Regular meetings held which facilitated trust and relationship building between actors within and beyond the catchment.	UEIP Various minutes
July 2016	UEIP strategy document drafted which set out the purpose of the UEIP and provided direction to the partnership by defining the objectives of the UEIP and approaches towards achieving those objectives	Group consolidated around shared purpose and objectives.	UEIP strategy 2016.
2016 <sup>1</sup>	UEIP establishes an online presence and the activities and outputs of the work done under the umbrella of the UEIP presented at several conferences and symposia	The Partnership begins to share knowledge beyond the immediate group.	UEIP Progress Report 2017.
March 2019	5-year celebrations of UEIP	The UEIP is well established and has become a way of life.	
May 2020	Re-signing of the MoU by only 16 partners with DWS, eThekweni, Msunduzi and uMgungundlovu municipalities notably absent as signatories	Few organisations become dominant limiting options for novelty and innovation.	

Note. <sup>1</sup> Note that between 2016 and 2020 the UEIP continued to hold regular meetings although no other significant events were identified during this period other than those listed in the table.

\*Full references given in [Appendix B](#).

### Appendix E. Summary of data used to determine phases of the adaptive cycle



**Figure A1. 1.** Trends in trust in local government (Data source: (2021a), 2021b). Figure 4.2. Trends in financial capital of Umgeni Water (Data source: Umgeni Water Annual Reports 2003 to 2019). Figure 4.3. Trend in land cover in the upper uMgeni catchment (adapted from Namugize et al. 2018 (Note that land cover data was only available to 2011)). Figure 4.4. Percentage of river sampling sites in the Msunduzi municipal area of the uMgeni catchment with results >10000 E Coli/100 ml (Data source: (2021)).

## Appendix F. Overview of criteria of learning, power, agency and structure in the uMngeni case study

Component	Facet	Conservation (1st)	Release	Reorganisation	Exploitation	Conservation (2nd)
Learning	Single, double or triple loop learning	Single single-loop learning with focus on improving existing water management practices such as building dams (see examples in various documents such as Umgeni Water's Annual Report 2007).	Individual double-loop learning by key actors in eThekweni Municipality reframe their existing assumption that engineering solutions were the only option.	Collective double loop learning evident in mobilisation of the informal actor group around the central idea of ecological infrastructure and the co-design of pilot projects.	Triple loop learning evident in structural change as the UEIP is formed, and the concept of ecological infrastructure is included in the President's Strategic Integrated Project Plan (under Strategic Infrastructure Project #19 (SIP19)).	Single-loop learning signalled by limited change in practices on the ground. The ecological infrastructure concept also doesn't feature in Catchment Management Strategy, although broader catchment management issues are considered as they relate to impacts on water resources.
Power	Control power	Strong control power as DWS, Umgeni Water and eThekweni Municipality (regarded as some of the most powerful organisations in the catchment) have full control over the distribution of water in the catchment.	Local and country-wide protests signal weakening control power as powerful organisations are seen to have failed in delivery of water (and other) services. However, the Regional Department of Water and Sanitation and Umgeni Water still hold power in respect of the 2009 Reconciliation Strategy, and through that could influence licensing and allocation	Control power weakens as other powerful non-state actors are invited to participate in water resources management such as DUCT, WESSA and civil society (See Rowlands et al. 2013).	UEIP seen as powerful structure and hailed as a flagship collaborative governance structure that could be transferred to other catchments (See Sutherland and Roberts 2014). Power emerged through the involvement of numerous partners (including powerful DWS, Umgeni Water and municipalities) and its location in an economic powerhouse.	Power of UEIP wanes as powerful actors (including DWS, eThekweni, Msunduzi and uMgungundlovu) absent as signatories in the re-signing of the MoU. These organisations retain their strong control power.
	Agential power	Limited agential power with no examples of actors using structures to promote change.	Limited agential power with no examples of actors using structures to promote change.	Increasing agential power as key actors used their positions to promote the concept of ecological infrastructure. For example, top-level managers at eThekweni Municipality (one of the most powerful organisations in the catchment – see Rowlands et al. 2013) gave various presentations and press releases on the benefits of ecological infrastructure. These actors had also been embedded in the system for a long time, had extensive networks and were internationally recognized.	Increasing agential power as representatives from powerful organizations to promote the concept of ecological infrastructure. However, high ranking municipal officials either retired or designated responsibilities to less senior members.	Limited agential power as the Partnership lacks political champions in high-ranking positions and instead comprises low-ranking officials.

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Component	Facet	Conservation (1st)	Release	Reorganisation	Exploitation	Conservation (2nd)
	Protean power		The innovative solution of ecological infrastructure emerged during a time of uncertainty and risk (created by country wide protests, the story of the catchment running out of water (captured in the 2009 Reconciliation Strategy), deteriorating state of ecosystems, and looming local government elections) giving rise to protean power for those actors proposing the innovation.			
	Ideational power	Through various policies and strategies such as the National Water Conservation and Water Demand Management Strategy, DWS and Umgeni Water exerted control over the idea that engineering solutions were the only solution.	Through policies and strategies, such as the Reconciliation Strategy for the KwaZulu-Natal Coastal Metropolitan Area Water Supply, DWS and Umgeni Water continued to exert 'power over the idea' that technocratic solutions were the preferred option.	'Power through ideas' evident as key actors (at DWS, Umgeni Water, eThekweni Municipality and SANBI) sought to persuade others through technical and scientific reasoning that ecological infrastructure was a feasible alternative solution.	'Power through ideas' reflected as key actors (including both state and civil society groups represented in the UEIP) lobbied for the inclusion of the ecological infrastructure concept in national strategies such as the President's Strategic Integrated Project Plan (under Strategic Infrastructure Project #19 (SIP19)). The concept also featured in the National Water Resource Strategy 2.	'Power over ideas' as SIP19 is abandoned. The ecological infrastructure concept is also excluded from the Catchment Management Strategy although the document does address broader catchment management issues, as they relate to impacts on water resources.
Agency	Individual and/or strategic agency	Limited individual and strategic agency with no examples of key actions by skilled actors or collective mobilisation around shared interests.	Two key individuals at eThekweni municipality were critical in initiating processes linked to the launch of UEIP. These actors were highly educated and experienced individuals who were internationally recognized.	Strategic agency evident as actors mobilised around the concept of ecological infrastructure. They began to leverage resources to promote their collective interest and committed funds to train 200 people in ecological infrastructure, to appoint an external coordinator for the partnership, and to implement pilot projects.	Strategic agency is reflected in the shared values and interests of the UEIP and was further enhanced by the pilot projects. A new UEIP co-ordinator was appointed but was new to the catchment with relatively few networks which limited her individual agency.	Limited strategic agency evident as commitment to the UEIP wanes and the Partnership struggles to adopt a self-funding model. SANBI is fully financing the coordinator position at this point in time.

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Component	Facet	Conservation (1st)	Release	Reorganisation	Exploitation	Conservation (2nd)
Structure	Institutional structure	Institutional structure characterised by a hierarchical mode of governance with specific organs of State including DWS, and provincial and local government mandated to undertake water management with few other actors involved.	Institutional structure continues to reflect a hierarchical mode of governance with water resource management dominated by state organisations.	Institutional structure starts to shift towards a hybrid governance mode as independent actors begin to organise themselves into a self-constructed collaborative structure.	The launch of the UEIP signals a hybrid governance mode which mediates between the hierarchical and network governance styles.	Institutional structure continues to reflect a hybrid mode of governance.
	Relational structure	Low relational structure as few actors involved in water management	Low relational structure as few actors involved in water management	Relational structure increased with the formation of an informal actor group, which included four initial partners (eThekweni Metropolitan Municipality, SANBI, KwaZulu-Natal DWS and Umgeni Water) and was later expanded to include World Wildlife Fund South Africa (WWF-SA), the Duzi uMngeni Conservation Trust (DUCT), uMgungundlovu District Municipality (UMDM), Msunduzi Municipality and the Wildlife and Environment Society (WESSA).	Increasing relational structure as almost 40 organisations commit to the UEIP in November 2013.	Decreasing relational structure as commitment to the UEIP wanes with DWS, eThekweni, Msunduzi and uMgungundlovu municipalities notably absent as signatories in the resigning of the Memorandum of Understanding.