Using Citizen Science to Protect Natural Untreated Drinking Water Sources: Natural Springs in Rural Catchments and B3 Municipalities in the Eastern Cape

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

Citizen science is a well-known mechanism used by researchers to collect scientific data working together with citizens. It can also be used by interested and concerned citizens (social activists regarding environmental threats) to protect natural occurring things like biodiversity, rare species that are threatened extension and much more. It can be a natural occurring process that evolves with time but it can also have some guidelines of how to monitor, collect, analyse and disseminate data. In this project we used participatory action research processes to co-develop tools (co-create being one of the types of citizen science) with local communities, using their knowledge of their area to monitor and protect natural springs. Springs are useful for providing drinking water for people but also for livestock. In rural areas and small towns where service delivery is not reliable, natural occurring water sources become the reliable supply for these communities. Springs also provide ecosystem services as they are a keystone ecological infrastructure. These natural water sources can be threatened by pollution, especially that of livestock which is mostly unattended, because they are sometimes shared by people and animals. This poses health risks to the users. This study co-developed the “spring protection and sustainable use” tool/s that can be used to guide communities and local government on how to protect these important water sources. Citizen science also creates opportunities for learning to take place among the participants as well as the researchers involved.

AIMS

1. To review the literature on “new paradigm” thinking and practice in relation to citizen-science and participatory governance.
2. To scope and finalise the case-study sites. (Considering the Tsitsa River catchment as a rural site and Makhanda as B3 municipality)
3. To use the review from Aim 1 to develop a framework and seed ideas for a citizen science “spring protection and sustainable use” citizen science tool/s.
4. To i) present the project plan and co-develop refinements with local communities, focusing in the Case Study areas with existing strong, trusting relationships (Tsitsa and Makhanda), and ii) specifically probing whether, and how, citizen science existing tools can work effectively in disadvantaged rural and municipal contexts.
5. To collaborate with residents to i) refine these tools and ii) apply them in one village in Tsitsa and one site Makhanda East
6. To produce Draft 1 of the “Spring protection and sustainable use” tool/s.
7. To monitor, evaluate, learn from and reflect on, the results from applying the Draft 1 tool/s.
8. To identify key stakeholders and build relationships using Tsitsa Project process and protocols.

KEY INSIGHTS FROM THE SPRING PROTECTION TOOLKIT

The following are key lessons the project learnt from participants. We learnt about how communities, in the rural context, differentiate types of springs

Umthombo wedwala (*under a rock*) (Depression spring) – The water is nice. Water is always clean and cold even in summer.

Umthombo wedongwe (*clay spring*) (Contact spring) – Water is not as nice and it smells like mud.

Umthombo womhlaba (*Soil spring*) (Contact spring) – the water is not clean enough and water is not nice. Water is easily disturbed, so when collecting water, you have to keep waiting for the soil particles to settle. Vulnerable to livestock trampling.

Umthombo wesanti (*sand spring*) (Artesian spring) – the sand cleans the water underground and it comes up clean.

Umthombo womgxobhozo (*water from wetland or seep wetland*) (Artesian spring) – the water is not nice and vulnerable to trampling by livestock.

The following section presents reflections from the participants about the co-developed spring protection and sustainable use toolkit. The toolkit can be useful but will need champions to facilitate the uptake. It will be difficult at first, but in time it will get easy. The name changed from tool to toolkit as this was more relatable to participants. It was noted that the toolkit should be adjusted according to contexts, it is not a solution for all.

Difficulties were expressed mostly by the Makhanda community who had limited knowledge of springs and their importance. It was reportedly difficult to use the cross-section drawings and that someone needs background knowledge of springs to easily identify the type. The participants also requested a list of invasives in Makhanda to be able to know what to clear.

It is worth noting that at the end of the project the participants from Makhanda expressed that they had learnt a lot and were still interested in further engagements to learn more about their springs and how they can protect them.

One of the key outputs was a research report by an honours student. The topic was "*Exploring effective capacity development and learning processes for citizen science tools for monitoring and sustainable use of springs*"

RECOMMENDATIONS

- Use previous geomorphological research that is available
- Include geologists to help with the identification of the type of springs
- Have examples the type of springs that can be found in Makhanda
- There must be a differentiation between rural and urban springs

- Have engagement with local leadership, councillors, political leaders, officials, etc.
- A tool with constitution that can ascribe responsibility to the user to protect the spring
- Get ambassadors to share info about the resource that is available. Enhance coordinated effort
- Maps showing spring sources and the water cycle. Do contextual profiling of the study site
- Technical tasks such as IAP need to have pictures of already known IAPs around the place. Provide a clear understanding of what IAPs are (especially in Makhanda)
- It is important to work community members from the beginning. They play a big role in gathering participants and different stakeholders

ACKNOWLEDGMENTS

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The team appreciates the opportunity to be able to undertake this study thereby building their own capacity through it. The team also appreciates the participants listed (who agreed to be mentioned in the report) below as this report would not have been possible without their input.

Hlankomo participants	Makhanda participants
Mziwonke Rasmeni	Shanice Oikers
Nonceba Sicangca	Moira Peters
N. Booi	Monica Israel
Nandipha Xoza	Celine Carlo
Ntomboxolo Tyhaliti	Rolene Fortuin
Phuthumani Rhorho	Nontsikelelo Ncula
B. Mrwetyana	Salina April
P. Xoza	Brenda April
Ntombevangeli Nkani	Elizabeth Davies
Vuyokazi Mgedezi	E.N. Jackson
Noluvo Masangweni	Obusitswe Seage
Nomawethu Sigagayi	Michelle Lang
Nothobile Machanyane	Jeffeng Lackcy
N. Mthembu	Elizabeth Davies
Jongikhaya Mdewu	Funeka Nesi
Molele Falatsa	Beatrice Faurie
V. Rhorho	Anna Visage
S. Pacela	Nomaphelo Booi
M.W. Tshaka	Elowy Enqelbrechlo
M.D. Thonga	Mirincta Peters
P.J. Ndamane	Helen Holleman
Zandise	Jeromy Thomas
Thobile Nyokoi	Phumzile Smile
Chris Matsoso	Vuyokazi Jack
Elizabeth Toto	Tessa Swarts
Velile	Lucinda Hendricks
Mathole	William Delonge
Mlungwana	Demone Davies
M. Baliso	Siphosethu
Vumbi	Songezo Elvis Mdoko

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ABREVIATIONS AND ACRONYMS

CBWQM	Citizen Based Water Quality Monitoring
IWRM	Integrated Water Resource Management
NGO	Non-Government Organisation
NWA	National Water Act
PWM	Participatory Water Management
SES	

CHAPTER 1: Introduction and contextualisation

1.1 Contextualisation

The Eastern Cape is confronted with major environmental threats including water scarcity (Shackleton et al., 2001, Rasch et al., 2017). The focus of this project was to look at natural spring protection in a small town and a rural landscape of the Eastern Cape where natural resources such as land, water, and biodiversity play an important role in local economies and human well-being (Wolff et al., 2019). This project focused on the overall context of catchments as socio-ecological systems with people being dependent on healthy Ecological Infrastructure for well-being and livelihoods. The project focused on two component contexts in selected catchments: 1) the Tsitsa River catchment, a rural landscape where landscape restoration is needed to protect source water quality and natural springs are heavily used and require careful community maintenance for sustainable use, and 2) Catchment landscape around small towns with springs that are used as a source of drinking water (Makhanda).

The Tsitsa River catchment includes three small towns, many villages, and mainly communally owned land with some commercial farming in the other half of the catchment. Municipal and traditional leadership governance is concurrent. As in many rural municipalities, water service delivery is poor (Elundini Municipality, 2016). Most communal areas rely predominantly on captured rainwater, as well as groundwater from springs or rivers (for those that have) for their water supply (Braid et al., 2019). Hlankomo Administrative Area, study site, falls under Elundini Municipality.

Makhanda is located in the Eastern Cape Province in South Africa. It is approximately 120 km east of Port Elizabeth, one of the major industrial cities in the Eastern Cape (Hamaamba, 2004). Residents living in Grahamstown, the main urban centre of the Makana Local Municipality in the Eastern Cape of South Africa, have been struggling with water service issues for decades (Weaver, 2019). Issues range from in-house access to water, frequent water outages, leaking pipes, water that comes out of the pipes brown, green or opaque, over-flowing sewage pipes and polluted streams (ibid.).

Small municipalities (B3) do not experience reliable service delivery. These municipalities have challenges that are interdependent to water and these include high unemployment rates, socioeconomic inequality, local dams with inadequate water supply, etc. (Wolff et al., 2019). When the water supply fails people use available ecosystem service of natural water supply. It is therefore important to work with these communities to develop skills and capabilities of protecting their natural drinking water resources.

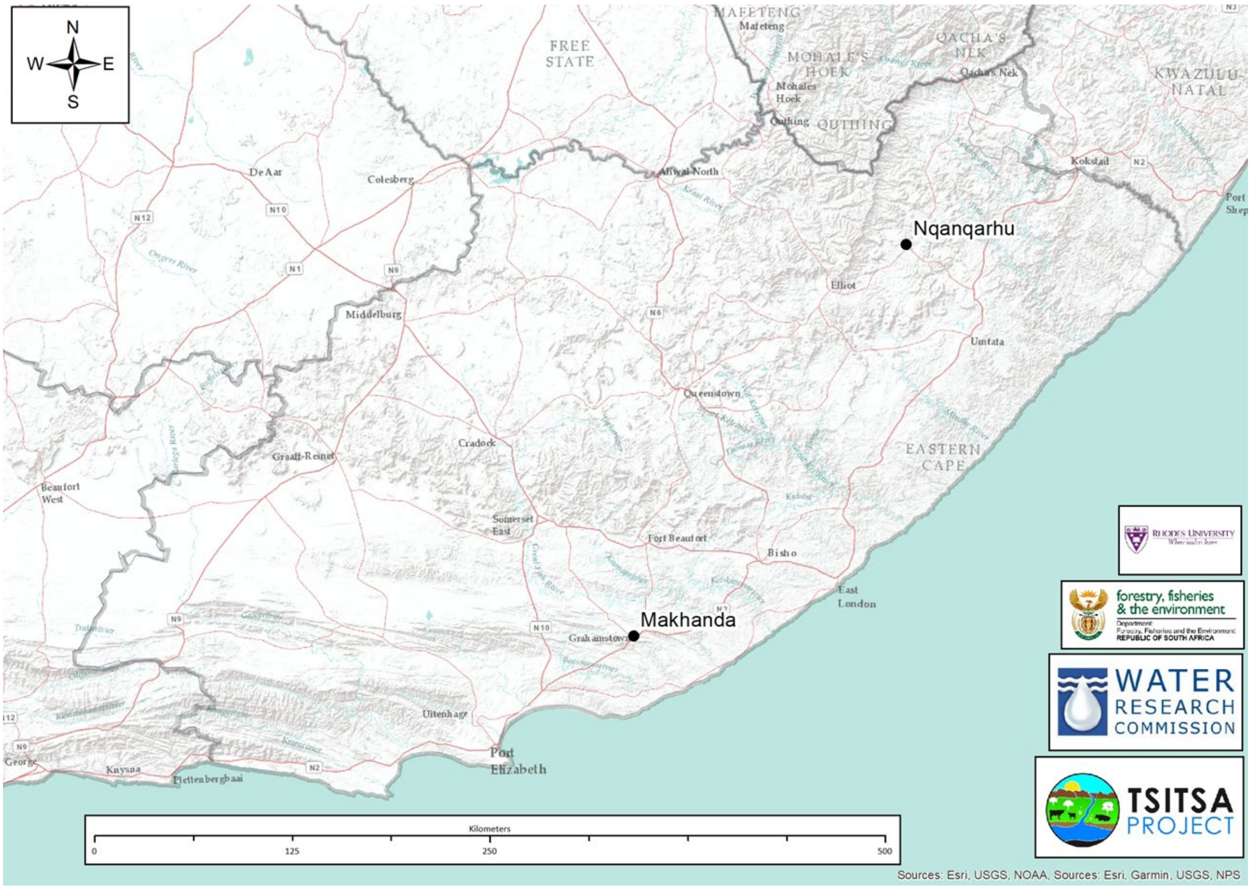


Figure 1: A mapping showing the study sites

1.2 Project aims

1. To review the literature on "new paradigm" thinking and practice in relation to citizen-science and participatory governance.
2. To scope and finalise the case-study sites. (Considering the Tsitsa River catchment as a rural site and Makhanda as B3 municipality)
3. To use the review from Aim 1 to develop a framework and seed ideas for a citizen science "spring protection and sustainable use" citizen science tool/s.
4. To i) present the project plan and co-develop refinements with local communities, focusing in the Case Study areas with existing strong, trusting relationships (Tsitsa and Makhanda), and ii) specifically probing whether, and how, existing citizen science tools can work effectively in disadvantaged rural and municipal contexts.
5. To collaborate with residents to i) refine these tools and ii) apply them in one village in Tsitsa and one site Makhanda East
6. To produce Draft 1 of the "Spring protection and sustainable use" tool/s.
7. To monitor, evaluate, learn from and reflect on, the results from applying the Draft 1 tool/s.
8. To identify key stakeholders and build relationships using Tsitsa Project process and protocols.

9. To address the research question: Is there a difference in tool/s needed in small towns and rural areas?
10. To produce in English and IsiXhosa "How to use citizen science to protect and sustainably use natural springs for drinking water."
11. To undertake one training session in each case study area with both communities and local government, and other relevant government participants.

1.3 Project team

Table 1: The research team

Name	Affiliation	Interest/expertise
Ms Nosiseko Mtati	Project Leader	Stakeholder engagement. Landscape and catchment management
Dr Jessica J. Cockburn	Academic	Landscape and catchment management, stewardship, multi stakeholder collaboration, social learning
Mr Paulose Mvulane	Research assistant	Social Vulnerability assessments and Research
Dr Matthew J.T Weaver	Stakeholder Liaison	Water governance, Integrated Water Resource Management, stakeholder engagement, capacity development
Mr Preven Chetty	Research assistant	Environmental education. Citizen science
Dr Notiswa Libala	Research Assistant	Water governance; water resource protection; conservation practices;
Miss Thembalami Mazibuko	Honours student (completed 2022)	

CHAPTER 2: Methodology

Participatory action research involves sequences of planning, acting, and reflecting and, through a participatory orientation, seeks to facilitate personal and institutional change by participants, and may catalyse the emergence of trust among participants (Reason & Bradbury, 2006). Wals and Heymann (2004) suggest that when people with a variety of views, values, beliefs and assumptions are provided a safe, facilitated space in which to engage and discuss these views, the potential conflicts that emerge should be viewed as an opportunity for learning.

This project took a participatory action research approach which focused on co-development and use of spring protection and sustainable use tools. The project was guided by principles which include:

1. Understanding catchment as on-going interactions between humans and the environment.
2. Being open to different forms of knowledge and bringing these together to build a shared understanding.
3. Work together, take a questioning approach and be willing to adapt in response to change.
4. Learn and build skills together to respond to the unknown future.
5. Manage and make decisions in a way that involves all levels and centres of governance.
6. Involve all relevant stakeholders so that costs and benefits are shared fairly.
7. Use scientific knowledge as the guiding form of knowledge, while recognising that other forms of knowledge are equally important.

Table 2: Project timeline

No	Deliverable	Submission month
0	Inception report	August 2021
1	Review the literature on “new paradigm” thinking and practice in relation to citizen-science and participatory governance and why existing citizen science tools are not being taken up.	August 2021
2	Produce Draft 1 of the “Spring protection and sustainable use” tool/s. Lessons will be taken from the literature review.	March 2022
3	Produce in English and IsiXhosa “How to use citizen science to protect and sustainably use natural springs for drinking water.”	August 2022
4	Undertake one training session in each case study area with both communities and local government, and other relevant government participants.	December 2022
5	Produce final integrated research report.	February 2023

2.1 Methodology for literature review

An in-depth literature review was undertaken on the “new paradigm” thinking and practice in relation to citizen-science and participatory governance. The literature review also looked at existing tools and why they are not being used or applied. According to Ridley (2008) a literature review is a “systematic and thorough search of all types of published literature in order to identify as many items as possible that are relevant to a particular topic”. Literature reviews are conducted to evaluate the state of knowledge on a particular topic. They can be used to create research agendas, identify gaps in research, or discuss a particular matter. The aim is to provide an overview of a certain issue or research problem (Snyder, 2019).

There are a number of different approaches in conducting a literature review. In this study we will use a scoping review approach. A scoping review is an ideal tool to determine the scope or coverage of a body of literature on a given topic (Grant & Booth, 2009). Scoping reviews are useful for examining emerging evidence when it is still unclear what other, more specific questions can be posed and valuably addressed by a more precise systematic review (Munn et al., 2018).

A scoping review was selected over a systematic review in this study because the purpose was to identify studies that look into the citizen science approach in relation to freshwater and participatory governance, gaps in the literature as well as identifying tools that are available and why they have not been taken up, rather than extract data, or formally assess the quality of studies and make specific conclusions.

A two-part scoping review was conducted to inform the study on “new paradigm” thinking and practice in relation to citizen science and participatory governance. Specific string searches were used to look for literature. These are the strings: review "citizen science" AND "sustainability" AND tools AND (catchments OR basins OR watersheds) + Africa” and “review "citizen science" AND "sustainability" AND tools AND (catchments OR basins OR watersheds) AND "participatory governance". At the end of each string, the geographic location was added, i.e. + Africa or + South Africa, and for the international level, the search was open. Using the string searches, the literature review started by looking at the international context. The second context looked at the African and then the South African context. Further, this review analysed the relationship between citizen science and participatory governance in relation to the management of freshwater sources. The review touches on issues of equity and efficiency in water resources and services and the water uses between socio-economic activities. The review narrowed the search to 20 papers for South Africa (if available), 20 for the African context and ten for the international context outside of Africa. The electronic database, mostly Google Scholar, some with Scopus and Web of Science, was used for this overview.

The International and African review published studies search ranged from 2015-2021, while the South African search started from 2010-2021 The international and African range is shorter because there is much more literature for that context compared to the South African context. Published studies that were used included books, articles, academic journals, and reports.

2.2 Methodology for Spring protection and sustainable use' tool co-creation

For deliverable two (Draft of 'Spring protection and sustainable use' tool/s) we searched for existing tools to pull them together before engaging with community members. The draft tool was created with the guidance of existing tools like the 2018 WRC Report No. TT 763/18 by Graham and Taylor. The report is the first report that provides citizen science tools that can be used to monitor and assess groundwater resources in South Africa, and is, therefore, a key resource for our project to draw and build on. This report aimed to improve the management of water resources through the use of citizen science tools by developing such tools to enhance public understanding of water-related issues and how citizens can actively respond to freshwater resource impacts. One of the report's outcomes is the Spring Assessment Tool or Spring Health Index. The tool helps the user to identify the spring system, impacts on the spring and how the natural functions of the spring are affected by the identified impacts. Our project aims to build on this important groundwork.

To further identify other methods or tools for spring protection, assessment and sustainable use, an online search was done on Google, Google Scholar and Scopus using the keywords

- Spring Protection in Africa,
- Groundwater=Spring Protection,
- Springwater protection citizen science, and
- Freshwater=citizen science.

The aim was to identify academic and grey literature on spring protection and freshwater natural resource management using citizen science methods. Most of the literature speaks to spring protection using built structures or technology (https://www.ircwash.org/; deliverable 11 of K5/2719/4; UNEP-IETC, 1998; Davies, 2000; DWAF 2004; Oxfam, 2008; Xulu and Rose, 2019, Rose et al., 2021).

Once the draft tool was created engagements with communities in the study sites took place. During these participatory interactions which were in the form of workshops and interviews, the researchers and local communities discussed the proposed draft tool and ideas for citizen science spring protection and sustainable use tool/s. From these engagements the local communities together with the researchers defined and co-developed the draft (besides the one created prior engagements) of the framework. It was then refined and ideas both the local communities and the researchers were considered. A workshop was held to implement the co-developed “Spring protection and sustainable use” tools. During the engagement participants were asked to evaluate the whole process and the usability of the tool. As well as the name of the tool. Both contextual factors and reflections were factored into the final product.

When additions from both engagements were incorporated the toolkit was translated into isiXhosa and Afrikaans and designed to be user friendly to anyone who would be interested in using it. This was done with further engagement with some of the project partners and in collaboration with a graphic designer.

2.3 Objectives and methodology for honours research

This section will present the data collection method utilised by the honours student that was part of the project.

Table 3: Objectives, methods and data analysis

Objectives	**Data collection methods**	**Data analysis methods**
1. To investigate the successes and challenges of previous or current learning and capacity development processes for citizen science in water management.	Participatory Role-playing Workshops, based on Boal’s Theatre of the Oppressed (1985) (Österlind, 2008)	Thematic analysis (Braun and Clarke, 2006)
2. To explore stakeholders’ previous experiences of and preferences for learning and capacity development processes for citizen science in water management.	Narrative Interviews (Individual) (Stuckey, 2013) and Stakeholder Interviews	Narrative analysis (Earthy and Cronin, 2008)

Objectives	Data collection methods	Data analysis methods
3. To develop guiding principles for the design of effective learning and capacity development processes for citizen science tools in monitoring and sustainable use of springs.	Participatory reflection and synthesis workshop with the project team.	Derived from the results of the first two objectives

Data for this report was collected in two phases. To achieve the first objective of this report we roleplayed a skit using a theory by Boal (theatre of the oppressed), this was phase one. This method was used to help include all stakeholders that were present in the workshops be part of the decision-making process and in this process, everyone's opinions and views were recognized and addressed. We did this by role-playing a skit where we showcased a seemingly 'ineffective' learning process, this was 'ineffective' because at the end of the skit the character who was a 'community member' could not use the citizen science tool that he was given. In this process we allowed the workshop participants to interject and suggest changes for the skit to be better suited for the community (this was done in both communities). Data collected from the workshops was analysed using deductive thematic analysis. A search for already existing themes from an Ernst (2019) paper was undertaken, in the data.

Narrative interviews were then conducted to achieve the second objective, this was phase two. During these interviews the interviewer did not make a lot of intervention as the participants were asked to tell a story about their experiences. There was then an inclusion of key stakeholder interviews with four individuals from organizations that have experience overseeing learning and capacity building processes for water management within different communities. These interviews were included because the narrative interviews with community members did not yield a lot of information. Data from all interviews was analysed using narrative analysis.

CHAPTER 3: Literature review – citizen science and participatory governance

The literature review for this project is divided into two parts, focusing on two key concepts of relevance to the development of community-based spring protection tools, namely: 1. Citizen science, and 2. Participatory governance. As will become clear in the literature review below. Citizen science tools hold much promise but often fail in implementation. Similarly, participatory governance has seen much theoretical development and policy attention, yet in practice it remains elusive and challenging. According to the 'new paradigm approach' (Palmer & Munnik, 2018), complex social-ecological systems (SES) require more integrated approaches to science and governance. The complexity of the SES needs to be acknowledged and suitable forms of research, community engagement and governance need to be developed. Our proposition in this project is that these two key concepts can strengthen one another, and implementing them in an integrated manner can increase the likelihood of realising them in practice for the benefit of local communities and other relevant stakeholders.

3.1 Citizen Science – review of current literature

Citizen science has been used and defined in both social and natural science projects. When defining citizen science, the definition must reflect the purpose and context in which it is applied, project goals and objectives, and the extent of citizen science volunteers' involvement in the project (Fehri et al., 2020a; Haklay et al., 2021).

Generally, citizen science is defined as an active engagement of ordinary citizens in scientific research tasks, such as the gathering of scientific data that is environmentally, socially, economically and politically relevant (Vohland et al., 2021). Citizen science is also understood as a form of community-based monitoring system that has been widely used in environmental sciences and is popular in biodiversity (Peter et al., 2021), Water (Fehri et al., 2020*a* and *b*) and medical research (Oberle et al., 2019) to list a few. Citizen science has enabled scientists to access data that they would not otherwise get without the involvement of the general public or community in question (Peter et al., 2021). Citizen science can also be an avenue to address a wide range of social challenges and not just a data collection method for citizen science, projects or a way for ordinary citizens to contribute to scientific knowledge (Vohland et al., 2021). Walker et al. (2021) provide four approaches that can be used to understand citizen science, volunteer contributions in a project, and to formulate a coherent citizen science definition.

- Contributory projects (entirely designed by scientists while citizens are mainly participating in data collection),
- Collaborative projects (also designed by scientists while citizens are more involved in the scientific process such as collecting and analysing data),

- Co-created projects (designed in collaboration between scientists and citizens work together in partnership), and
- Collegial projects are designed and implemented by non-professionals (i.e. no scientists involved).

Fehri et al. (2020a) see citizen science as a complex process built on civic engagement into science, environmental monitoring and capacity building. Cele (2016) states that citizen science can be seen as the use of science tools by lay people with no formal training on the subject under investigation, and usually resident in the vicinity of research sites where they are trained to carry out science-related data collection. This definition and a few from above can also be a base to understand why citizen science projects fail or are not taken up after scientists have left.

3.1.1 Definition of citizen science in the South African context

"Most definitions describe citizen science as a process of scientific inquiry that involves the cooperation between members of the public and professional scientists. Public participation in scientific projects has a history dating over 100 years (e.g. the Annual Christmas Bird Count dating back to 1900)." König et al., 2021

Citizen science has been defined by several authors in different contexts. Some South African literature provides definitions of citizen science, but lacks a coherent definition and fails to consider the broader use of the term (Weingar & Meyer, 2021). The South African NRF (National Research Foundation) defines citizen science as 'scientific research conducted, in whole or in part, by amateur (or nonprofessional) scientists' (Osman, 2019: 29). A combined definition from various authors which we propose as a working definition here is as follows: citizen science involves the working with ordinary citizens in scientific data collection, which allows scientists to study a variety of natural phenomena in context.

Citizen science projects in South Africa are strongly associated with academic institutions. This might explain why citizen science projects often do not continue after the academics have stopped their research. This is not to say that there are no citizen science projects managed by citizens or private organisations, as it will be described below. Citizens have little or no contribution to knowledge production other than collecting data. citizens are viewed as another tool for data collection, rather than active participants in a collective knowledge co-production process.

3.1.2 Benefits of citizen science

We are currently in a global change era, characterised by diminishing natural resources, climate change and species extinction. Water quality and scarcity is also a major concern in South Africa especially as the threat of climate change looms even closer. The last decade of droughts has exposed the brittle nature of Southern Africa's resilience to water shortages.

In South Africa environmental pollution has always been geographically related to the position of its most marginal citizens which during apartheid were the original inhabitants of the land. Now in democratic South Africa the marginal ones are those who live in poverty below the minimum wage (or lack thereof), which has still largely remained the same segment of the population.

Apartheid South Africa created areas of social injustice amongst South Africans. These areas became sites of ecological degradation. There is a need to understand the rate at which change is happening, and what kind of interventions can be made to protect the remaining natural resources and improve livelihoods. This is possible with credible data. Thus, citizen science and/or community monitoring can contribute to natural resource management by providing data at more detailed and finer granular scales (Conrad & Hilchey, 2011; Peter et al., 2021).

Conrad & Hilchey (2011) list the benefits of citizen science projects to society, citizen scientist and local ecosystems;

- **Democratisation of the environment**: This speaks to making environmental science and expertise accessible to the public, and scientists becoming more aware of local knowledge and expertise. Scientists and local people are able to share knowledge and learn from the work they do. The democratisation view has also been noted by Sauermann*,* et al*.* (2020), they argue that citizen science challenges the separation between science and society through the premise that the value of knowledge is dependent on the needs and preferences of the public. In citizen science projects, citizens can shape research towards societal needs (Sauermann, et al., 2020).

- **Education**: Participation of citizen scientists in citizen science projects can increase their scientific knowledge by understanding the scientific processes of data collection and monitoring, and also their role in their local environment. Participants noted in Mtati's (2020) they began noticing things they were not noticing about their environment before.

- **Builds Social capital**: Participation in citizen science has the potential to build trust between the parties involved. Citizen science increases transparency of scientific research and allows citizens to learn in the process (Sauermann*,* et al., 2020). Engagements in citizen science processes and other interactions can build agency, leadership and problem-solving skills. Citizens involved in citizen science projects engage more in local issues and can have influence on policy makers. Thus, citizen science can be a way of including stakeholders in planning and management of local natural resource management.

- **Cost effective data collection**: Citizen Scientists are flexible and can carry out data collection even outside of office hours as compared to officials who work in an office with strict working hours. This is not to mean that citizen science data collection is cheap. Citizen science data collection can be expensive, especially when community outreach, training and support is required (Lämmerhirt et al., 2018).

3.1.3 Key enablers of citizen science

Citizen science has over time become popular within the scientific space and within communities (Jollymore et al., 2017). The data generated by citizens may have been criticised in terms of quality but it has been taken up by peer reviewed journals and universities. Sometimes Citizen Scientists gather together to do something for their communities like monitoring water quality locally (Carroll et al., 2019). Carroll et al. (2019) looks into citizens that have planned and managed their own activities without it being led by outside institutions. This way practices are based on local knowledge and cultural practices.

Citizen-driven water quality monitoring projects are not uncommon. Citizen science is used in various spaces mostly in the biodiversity research space but also in the fresh water quality monitoring for watershed health but also for healthy drinking water. An example, the tools mentioned by Hulbert (2016) are limited to geographical studies. Water pollution and water shortage is a global challenge but it is also a local issue, especially in small town municipalities like Makhanda and Nqanqarhu, which are the focus of this project, where service delivery is not always guaranteed (Carroll et al., 2019). Water monitoring has benefits of informal learning for communities like learning about insects and fish (Lowry et al., 2019). Involving citizens in the monitoring could develop to the point of freshwater decision making that improve the water quality and the availability of good quality data (Storey et al., 2016).

Citizen science does have the challenge of not looking at things from the citizen's perspective, as it is usually driven by scientists. The absence of the two-way dialogue between scientists and citizens can hinder meaningful delivery of goals (Jollymore et al., 2017). Baalbaki *et al*. (2019) wrote a paper showing an example of how most citizen science projects are initiated, with a university coming into a community to recruit for participants and it sometimes begins with a lot of participants and some dropping out along the way.

Reasons for citizens to participate include having a relationship with experts; knowledge gain and interpreting the data. Citizen Scientists around the world have different tools for different purposes but the common one is the use of technology to capture data. In South Africa there are existing tools such as:

i. iSpot, created by the South African National Biodiversity Institute (SANBI),
ii. "what species", created by a mother to help her children understand insects and plants better,
iii. virtual museum, which is a geographical project of organisms (Hulbert, 2016).
iv. In the Tsitsa Project citizens use a form based on Open Data Lit platform to capture data about sediment transportation along the Tsitsa River and its tributaries (Mtati, 2020).

Across the literature there is a widespread agreement that citizen science has a range of benefits from wide ranging data collection, citizen led initiatives, "increasing environmental democracy (sharing of information), scientific literacy (Broader community / public education), social capital (volunteer engagement, agency connection, leadership building, problem-solving and identification of resources), citizen inclusion in local issues, data provided at no cost to government, Ecosystems being monitored that otherwise would not, government desire to be more inclusive is met, support/drive proactive changes to policy and legislation, can provide an early warning/detection system" (Walker et al., 2016:720).

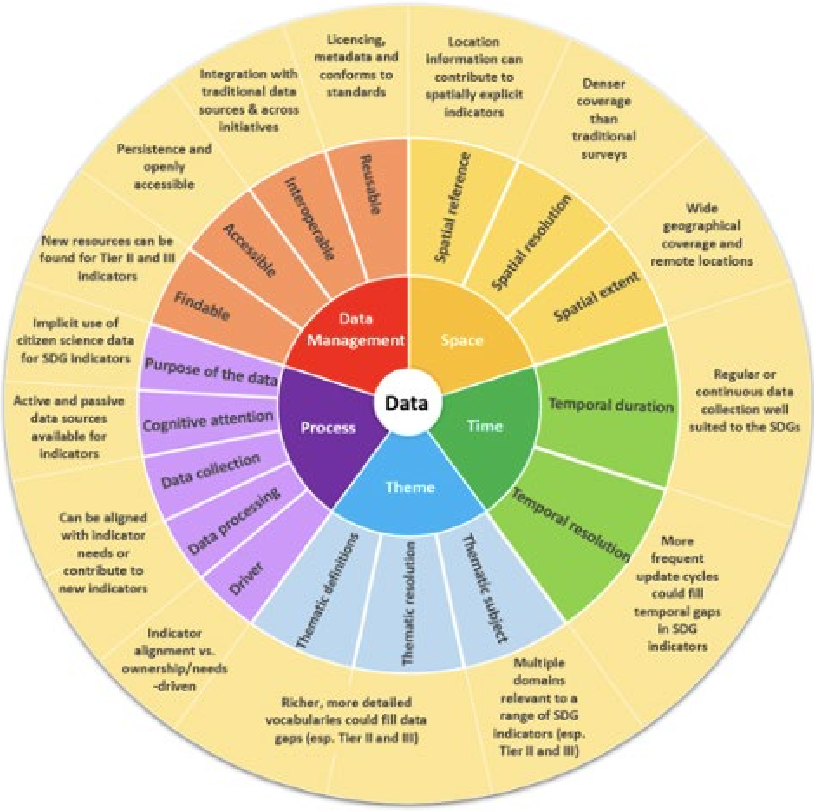


Figure 2*:* The five dimensions of citizen science data, their features and their value for the SDGs. Source*:* Fritz*,* et al. (2019:10).

As we can see from the above diagram citizen science has numerous applications that align with the Sustainable Development Goals (SDGs). Its benefits are wide ranging and affects a diverse range of stakeholders. The main question is why is citizen science not sustained or continued once funding stops as it is apparent that there are significant benefits and advantages to these interventions? The diagram above (figure 2) also displays that citizen science is mostly centred around data collection and not the citizens that collect this data. This could also have a role in the slow uptake of citizen science tools that have been developed.

3.1.4 Why is citizen science not taken up?

Monitoring is concerned with presenting accurate, complete and consistent data, which makes it reliable and valid. It has been pointed out that data collected by community groups is hardly used and not even taken seriously by decision makers due to a lack of credibility resulting from poor sampling procedures (Conrad & Hilchey, 2011). This shows the lack of transdisciplinarity in the field of science and that local ecological knowledge or culture are overlooked as a result.

In most cases citizen groups involved in collecting data often do not get a chance to meet with the decision makers (Conrad & Hilchey, 2011:281). Cooper et al. (2007) argue that the implementation of citizen science projects requires institutional capacity that is centrally located for data collection. This point indicates the limited co-creativity in most projects and little working together or inclusivity in most citizen science projects.

If Citizen Scientists could see the impact of their work both in their larger community and individually then there will be a greater likelihood that they will stay on the project for a longer time and they would feel like part of the project as a result of being included. Also, if they see that the issues they are engaged with is getting traction at local level be it socially, politically or economically then there is a greater likelihood that they will stay on the project.

Few volunteers are able to devote extended periods of time to scientific projects. Extremely frequent (e.g. daily) sampling needs therefore might discourage participation and increase turnover. This is an indication that Citizen Scientists need to be better valued for what they do and for funding to be secured to remunerate them for their time, especially disadvantaged contexts. Mtati (2020) found that although there are benefits attached to having citizens collecting scientific data, financial support is important as it helped them sustain their livelihoods and motivated them to continue participating. Bannatynne et al. (2017), stated that some participants remained within the community to assist with the data collection because of the benefits attached to the project.

In our experience in the Tsitsa Project, the most serious ethical and practical barrier to the success of the adoption of citizen science tools and participatory governance activity is that it depends on volunteers (Mtati, 2020). As stated by Cooperman et al. (2021), the uptake of monitoring tools is dependent on a range of factors which include benefits derived from monitoring, availability of alternatives, biophysical barriers and costs in terms of time. In their case study they found that communities that are exposed to precipitation variability are more likely to monitor common pool resources, in this case water. In many cases, where researchers or government departments are working with disadvantaged communities, this means that all the people involved in the project (researchers, students, government officials, private enterprise and even NGO employees), except the poorest and most vulnerable, have secure incomes. In South Africa the move towards citizen science and participatory governance work should be considered and be incorporated into government-supported processes where Citizen Scientists are remunerated. Recent research (Weingart & Meyer, 2021) confirms that most successful citizen science projects are managed by an institution or project that will monitor and manage how the work is going. However, often when the project comes to an end so does the engagement with the Citizen Scientists and any interaction and participation beyond the lifespan of the project is entirely dependent on individual’s enthusiasm or ability to continue to access the database or technology that formed part of the project. Weingart & Meyer (2021) also emphasise that in the South African context, basic literacy and scientific literacy severely hamper the engagement with tools or applications that would be beneficial to both researchers and Citizen Scientists.

3.1.5 Funding and retention of Citizen Scientists

Citizen science projects are trapped in a difficult cycle of attracting funding and recruiting citizen science volunteers/participants (Bloom & Crowder, 2020). Recruitment and retention of Citizen Scientists requires funding, and to attract funds Citizen Scientists need to be actively involved in the project or programmes (Lopez, 2021). In the South African context funding for citizen science projects may be coming from the public or private sector. Public funding tends to be long term with stringent stipulations that may impact on payments for participants and procurement of citizen science project goods and services. Private funding is more flexible and short term. These funding dilemmas can have a serious impact on the Citizen Scientist motivation and experience, and project performance.

Several authors have investigated the motivation and experience of Citizen Scientists on various citizen science projects on water monitoring (Lopez, 2021), Pollination (Bloom & Crowder, 2020), Biodiversity (Peter et al., 2021) Science and policy (Weingart & Meyer, 2021). Little or nothing is said on how funding affects the taking up of citizen science, tools, and citizen science, participants motivation, except for Lopez (2021) who highlights the impact of funding in citizen science, participant retention and motivation.

3.2 Participatory governance

South Africa is a country experiencing both land degradation and water-related crises. In many rural areas, people, livelihoods and landscapes are vulnerable and natural resources have been eroded. Despite numerous research projects and/or development interventions there is still a lack of diverse forms of knowledge such as inclusion of local people, government actors and researchers in management of natural resources. This provides a need for participatory governance as a requirement for the management of water resources. The National Water Act (NWA), No 36 of 1998, clearly requires and makes provision for public participation as an integral part of water resource management; public participation is a key feature of the National Water Policy. Participatory governance has been identified as a key principle to building a sustainable communities future, as it involves the inclusion of citizen participation in the process of decision making related to land and water.

3.2.1 Motivation for Participatory Governance – review of current literature

The development and governance of human societies has always been enhanced by collaboration between multiple parties. This collaboration entails an exchange of knowledge, ideas, experiences and discourses between multiple stakeholders, thus empowering the general public to influence decision-making processes that affect their lives. These processes and structures of public decision-making are defined as participatory governance (Newig et al., 2018). Indeed, this capacity for participatory governance is as much a human trait as the development and use of tools.

However, modern times show that participatory governance is still a novel concept to many because citizens have limited access to information and inadequate opportunities for meaningful dialogue in traditional representative democracies (Malena, 2006). Nevertheless, participatory governance is vital for the functioning of modern democracies as it seeks to enhance the effectiveness and legitimacy of policy making (Ansell & Gash 2007). It is also a means of adaptive management whereby modern democracies are cognisant of, and therefore responsive to, the changing needs, values and discourses among citizens (Holmes, 2011).

Despite the importance of participatory governance and its contribution for a more responsive, adaptive and resilient government that can serve its constituents at the highest capacity, there are still multiple barriers that limit, if not prevent, its implementation within broader society and these barriers exist at multiple scales. Governance refers to a set of institutions and actors that are drawn from but also beyond the Government. The government is a group of people who rule or run the administration of a country. Collaborative models of governance challenge the state's or government's authority in the traditional sense, arguing that the government is not the only power centre in a state. As long as the power exercised by a public or private institution is recognized by the public, it is possible to become a power centre at a specific level (Keping, 2018).

Below we are exploring examples of how barriers to participatory governance are manifesting at an international, regional and local scale.

3.2.2 Challenges to Participatory Governance: Global/regional scale

Collaboration and trust between local communities and decision-making bodies is currently lacking. Pareja et al. (2018) found that when examining a proposed framework from participatory water management (PWM) involving local communities and mining operations, noted that the framework lacked causal evidence to support the conclusion that PWM is a successful means of improving water governance and reducing barriers to community approval of mining operations.

Furthermore, this lack of trust between stakeholders is often exacerbated by the inclusion of stakeholders not representative of the local communities in question and the further empowerment of an already well entrenched stakeholder group at the expense of local communities in a process otherwise referred to as elite capture. This leads local stakeholders on the ground to believe that the notion of public participation is nothing more than a charade where no real engagement and public participation among different stakeholders take place (Poppe et al., 2018). In Ghana, for example, flood risk management has been found to still be reactive as opposed to proactive and there is a need for policies to introduce more inclusive community participation in planning and management (Almoradie, 2020). Similarly, there remains an absence of local-scale voice (e.g. riparian communities) and what Upadhyay (2020) refers to as “cultural governance” influence in transboundary water resource management policy and policy change. Upadhayay further emphasises that ensuring cultural sustainability (cultural governance and practices related to water) is an important promoting feature of sustainable water governance.

Issues of trust between local stakeholders and decision-making bodies are further illustrated by the fact that local communities have experienced a history of institutional exclusion from major decision-making processes (Cohen et al., 2021). In addition, these decision-making processes typically privilege certain knowledge systems over others (i.e. the promotion of western knowledge systems at the expense of traditional knowledge systems) (Cohen et al., 2021).

Tools and technology can serve as mediating objects that enable collaborative engagement between the public and government in the management of natural resources. However, there are also challenges in the use and application of tools and technology in the resource management and governance processes. The ability to make use of new technologies is another major barrier to participatory governance. When Mukhtarov et al. (2018) examined the relevance of Information and Communication Technologies (ICT) as a means of facilitating urban water governance, they found that ICTs provided very few opportunities for deeper discussion and deliberation. Furthermore, institutional structures of decision-making, information generation and management hinder the use of ICTs to their full potential (Pedregal et al., 2015). There are also financial barriers to the full use of technologies that aid in participatory governance.

Lack of clear goals and a uniform discourse has also proven to be a significant barrier to participatory governance. This lack of a common goal (and consequently a lack of co-creation) can also lead to differing expectations between researchers, stakeholders and decision-making institutions on the collaborative engagement process and its outcomes, which can lead to conflicting ideas of the management model that would result from the engagement process (Ferguson et al., 2017). This can also lead to a poor understanding of the context in which participatory governance can be applied. In the Nechako watershed, British Columbia, Bale (2016) found that opportunities for the youth in the community to engage and participate in watershed planning and management was hindered by a poor understanding of the barriers to youth participation.

3.2.3 Challenges to Participatory Governance: Local scale

At the local scale, these barriers can be further pinpointed to a fundamental level. Development deficits, weak governance and a lack of monitoring, enforcement and compliance were found to be critical barriers to participatory governance in the case studies analysed by Sutherland et al. (2016) when examining the utilisation of ecological infrastructure in relation to how water resources in the uMngeni catchment are managed. Furthermore, the paper states that the absence of industry in most collaborative forums is of serious concern, especially since they are major stakeholders in the management of water resources.

There is also a lack of scientific, practical and inclusive management models being incorporated into legislation and policy. Palmer et al. (2018) concluded that IWRM is “ground breaking: hard, slow, and *EFFECTIVE* and *IS* the way to achieve the balanced protection and use of water resources for the equitable and sustainable benefit of those who live in South Africa.” The authors further recommend the formal adoption and promotion of the term Adaptive IWRM and ensuring the single water law is consistent with Adaptive IWRM.

The lack of well-established national legislation that deals with critical environmental issues such as climate change is a considerable barrier to governance. Fortunately, in some areas, such as Durban, non-governmental actors’ step in to establish governance that converges water management and climate change adaptation (Martel & Sutherland, 2019). Nevertheless, government plays a critical role in participatory governance and thus legislation needs to be more encompassing and inclusive of the various aspects that promote a resilient socio-ecological system.

Overall, it is clear that governance is the complex process whereby some sectors of the society exert power, and enact and promulgate public policies which directly affect human and institutional interactions, and economic and social development. Therefore, managing land and water resources in complex social-ecological systems requires a new paradigm’ thinking.

3.3 Findings and recommendations in relation to poor uptake of citizen tools and the importance of participatory governance

A sense of ownership and sense of place needs to be more strongly cultivated in order to sustain interest in citizen science initiatives, i.e. citizen science initiatives need to be embedded within participatory governance processes which include and empower local people.

Lack of involvement of citizen scientists beyond data collection

- Monitoring of sites is not taken seriously and there is a sense of futility from citizen scientists that their work is not being acknowledged (Conrad & Hilchey, 2011)
- As previously mentioned above, citizen science has received little mention and is often overlooked (Travaline, 2012). As a result, citizen science has been found to be weak in mobilising stakeholders as well as influencing policies and collective behaviour conducive to participatory governance (Semjanová, 2020). Therefore, more rigorous engagement from local governments and its citizens with citizen science is required to further demonstrate the relevance of concepts such as collaborative resource management and environmental ethics (Bohle & Preiser, 2019).

- Citizen Scientists do not get to meet with policymakers or are not involved in the decision-making process after their data is produced, (Sharpe & Conrad, 2006) thus they are not empowered but often just treated as instruments of science.
- An overwhelmingly large focus on data and scientific outcomes (e.g. see 'Data' in the centre of the diagram for Figure 1) detract from the potential benefits of citizen science as a means of empowering people to participate actively in water management and governance (Mtati, 2020).
- The imbalance of benefits from the process: there is too much focus on the benefits to scientists in terms of data, scientific outputs, etc. and not enough focus on the potentially wide range of benefits to Citizen Scientists. We need to stop viewing and treating Citizen Scientists as instruments in service of scientific research, and start seeing them as active participants in knowledge co-production and participatory water governance process (Mtati, 2020).
- Hazardous conditions at sampling sites (especially at river monitoring sites) can deter many potential citizen scientists from being actively involved (Lambert & Reiss, 2014). This further indicates that citizen scientists are treated as instruments in the service of science.

Funding related limitations

- Citizen science projects are trapped in a difficult cycle of attracting funding and recruiting citizen science volunteers/participants (Bloom & Crowder, 2020).
- Not all Citizen Scientist projects attract the same level of engagement as those with charismatic conservation species (Clark et al., 2002), and this is particularly relevant when there is an emphasis on volunteerism. However, in the case of water, which is a fundamental human right, this might be easier to navigate, as long as institutions who are hosting and funding the citizen science initiatives acknowledge the shortcomings of the volunteerism model in a country like South Africa with high levels of poverty and unemployment.

Higher institution partnership or other partners

- An over-emphasis on high-end scientific equipment with limited longevity and requiring high-level skills limits the long-term sustainability of citizen science.
    - The use of high-end scientific equipment for conducting experiments after which the equipment is taken away with the investigators.

    - Production of low-cost monitoring tools that can be easily replicated and distributed will help mitigate this aspect of hindrances to uptake.
- Citizen Scientist initiatives also require a central institution for data upload and management (Cooper et al., 2007). Therefore, in addition to training and capacity building for citizen scientists, long-term investment and partnerships are necessary with relevant research institutions for the management and analysis of data collected through citizen science.

Participatory governance, despite the many barriers that limit its inclusion and implementation, remains a vital part of decision-making and its barriers can be addressed in the following ways:

- Building healthy relationships between citizens, industry and the state is vital for improving collaboration between multiple stakeholders and ultimately improving governance of natural resources (Sutherland et al., 2016).
- Improve learning opportunities and outcomes for citizens while also acknowledging and incorporating traditional and ecological knowledge systems relevant to the local communities (Egunyu & Reed, 2015).
- Careful selection of community representatives whose sole mandate is to represent the views and interests of the community. This will ensure that the local government takes the citizen's views and needs into account through decentralisation of responsibility and ensure that the focus on empowerment and social capital is further emphasised (Whelan & Oliver, 2005).
- Avoid assigning considerable authority and influence to private entities so as to limit the risk of communities being excluded from decision-making processes (Cohen et al., 2021).
- Quarterly reports as well as rapid and easy communication between stakeholders has proven to be effective in not only tracking progress in collaborative resource management progress, but also in encouraging all stakeholders to keep up with their respective work while also maintaining morale in the face of uncertainty (Kotschy et al., 2020; Kotschy & Mvulane, 2020).
- Community empowerment as well as capacity and skills building (especially in areas with high rates of illiteracy), to be prioritised if participatory governance initiatives are to be successful (Egunyu & Reed, 2015; Poppe et al., 2018).
- Participatory governance needs to be framed as an on-going, adaptive process in which all stakeholders are learning and diverse forms of knowledge are respected and incorporated. Principles of transdisciplinarity, equity, and social justice should be central in such initiatives (Palmer et al., 2018).

3.4 Conclusion

This chapter reviewed the literature on citizen science and participatory governance in the context of 'new paradigm' thinking for managing water resources in complex SES. Conventional definitions of citizen science emphasise the involvement of ordinary citizens in scientific data collection, allowing scientists to study a variety of natural phenomena in context. However, the strong association of citizen science with academic institutions, the on-going focus on volunteerism in citizen science, the undue focus on data at the expense of understanding the citizens and their context, and the imbalance of benefits from the process, mean that citizen science is not reaching its full potential.

According to the new paradigm thinking citizen science projects should also be understood in relation to relevant water legislation, policy, the rights and obligations around the provision of water, and the role of the local municipalities in implementing and realising these. Therefore, citizen science should be seen not only as a means of generating data and contributing to scientific research, but as an important means of empowering citizens to actively participate in water management, knowledge co-production, and decision-making. It therefore becomes necessary to see citizen science as a critical component within participatory water governance processes. And here too, while South Africa has strong water legislation and well-developed policy tools that should enable participation from citizens, the uneven implementation of these means that participatory governance is not having the desired effect of ensuring sustainable, equitable and efficient management of water resources.

For the ideals of participatory governance to be realised in practice, a context-sensitive approach that acknowledges the complexities of SESs needs to be adopted. This means that diverse forms of knowledge need to be brought together in transdisciplinary processes of knowledge co-production where learning and adaptation are central practices. To enable this kind of participatory governance, in which citizen science can and must play a central role, requires empowered and involved citizens and local governance actors. This will require careful identification of community representatives to represent the views and interests of the community, Moreover, traditional councils (where these are relevant), and local government, must be open to taking the citizen's views and needs into account when engaging in participatory governance initiatives for water management. This will only be possible if community and local governance empowerment and capacity and skills building, are prioritised within citizen science initiatives.

In a country like South Africa which is facing a multi-level water governance crisis, a singular focus on scientific and technological solutions, including academic and data-focused forms of citizen science, is no longer acceptable. Citizen science practices need to be responsive and adaptive to the realities of our context.

CHAPTER 4: Development of the spring protection and sustainable use tool

4.1 Introduction

Mel (2008) states that groundwater plays a major role in reducing the backlog for domestic water supply in South Africa (Mel, 2008). It contributes between 45% and 60% to domestic water supply but the contribution to rural areas and small towns, where the largest part of the basic water services is lacking. (ibid.). Bun et al., (2021) also mentions that groundwater is an optional resource in urban, semi urban, and rural areas where piped water supply is not accessible. However, groundwater resources are vulnerable to depletion and degradation if not protected and exploited in a sustainable manner (Mahlathini Development Foundation, 2020). Groundwater can be considered an alternative source because of its quantity and quality and the accessibility at the community level, which are mostly faced with limited to no infrastructure (Bun et al., 2021). This is why it is extremely important to protect and maintain freshwater and underground water sources like springs. Another motivation is that South Africa is not supplying water equitably to all citizens and therefore others rely on springs for water supply.

The involvement of users and other stakeholders such as civil society organisations, governments and experts is important in protecting and maintaining fresh water resources. It promotes the continuous protection, maintenance and monitoring of freshwater resources.

As highlighted in the literature review, involvement of users and the general public in monitoring activities is described as citizen science. Our proposed definition of citizen science involves working with ordinary citizens in scientific data collection, which allows scientists to study a variety of natural phenomena in context. Residents in small municipalities like these two, Makana Local Municipality and Elundini Local Municipality, experience unreliable service delivery related to water supply and sanitation. When the municipal water supply fails people use the available ecosystem services of natural water supply. It is therefore important to work with the communities to develop skills and capabilities for protecting their natural drinking water resources.

This section reports on existing citizen science tools in relation to water source protection in South Africa (we note that springs are one form of water source used by communities who access water directly from catchment sources). Furthermore, it will look at the challenges that may contribute to the limited use of these existing tools.

4.2 Overview of the existing tools that are used to monitor water resources and springs

Below we provide a brief overview of the citizen science tools that are available and have been used in the South African context for water resource management as noted by WRC Report No. TT 763/18. In this project we define "…a tool as any method or approach or physical instrument that is used for viewing, measuring, recording and interpreting the characteristics of certain natural resources" (Graham & Taylor, 2018, p. 12).

This project mainly focused on citizen science tools that can be used to assess and monitor natural water sources without creating or building structures to harvest water or protect, and keep it clean for human consumption.

Table 4: Existing citizen science tools for assessing the state of natural water resources

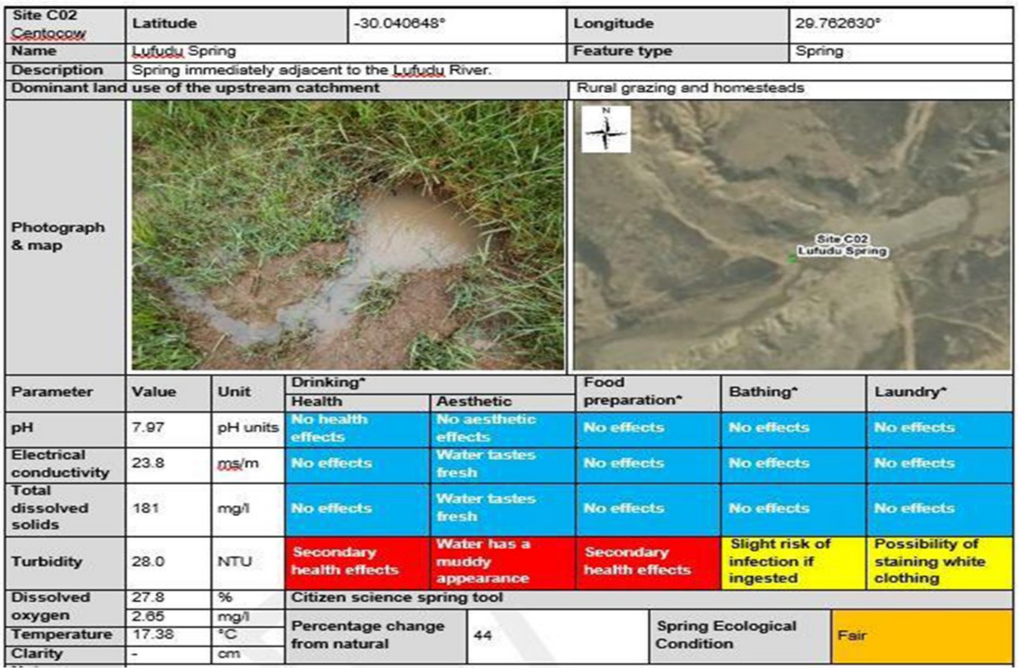
Tool	What it is	What it does	Advantages	Suitability
MiniSASS	This is the ‘mini’ version of the Stream Assessment Scoring System (SASS)	It is a simple tool that can be used by anyone to monitor the health of a river. One collects a sample of macroinvertebrates (see figure 3b below) from a natural river or stream, and depending on which groups are present, one can calculate a River Health Index (Taylor et al., 2021).	It is a simple, cost-effective tool to determine the health of a river or stream.	It can be used to monitor the health of the spring.
Clarity tube	This is a metre-long tube that measures the turbidity of the river water in centimetres (Graham & Taylor, 2018; Matthews, 2018).	Measures cloudiness or haziness of water, based on the amount of dissolved and/or suspended particles within a stream or river (EPA, 1996). Suspended sediment and other solids that affect the clarity of the water can occur naturally, but can also be worsened by human activities such as degradation of the riparian zone and the removal of vegetation which allows for erosion. “	Clear water can mean good quality and can be conducive for animal reproduction and foraging (Graham & Taylor, 2018).	It can be used to check turbidity for springs that may need it.

Tool	What it is	What it does	Advantages	Suitability
Riparian Health Audit	The Riparian Health Audit (RHA) is based on the scientific “Index for Habitat Integrity” (IHI) Method” (Graham and Taylor,2017; pg40).	Citizen scientists use this tool to assess the condition of the riparian area by looking at exotic plants, bank erosion, rubbish dumping, inundation, vegetation removal and, physicochemical, channel and flow modification (Graham &Taylor, 2018). The conditions are then rated from no impact to critical impact using a percentage (ibid)		It can be used to assess the spring health
The Spring Health Index tool	The tool identifies ten potential impacts within 60m around the spring (anthropocentric and natural) that may be impacting a particular spring in the location of interest (ibid).	The Spring Health Index Tool determines the current ecological condition of the spring and compares that with what it could be if the spring was not disturbed by activities around it (ibid).	Graham and Taylor (2017) noted that there was no standardised method or tool that dealt with springs, and that there was also a shortage of information about South African springs.	The Spring Health Index tool can be used in conjunction with the other listed tools to get a full picture of the impacts that are affecting the ecological integrity of the spring. The tool also can be supplemented with photographs to guide users on the impact and ecological ratings (ibid).

Figure 3a & 3b: Clarity cube with community members in Makhanda and Hlankomo

4.3 Implementation of the spring tool in KwaZulu-Natal

The Spring Health Index tool was used in KwaZulu Natal at Centocow (Figure 4) and Hlokozi areas, after a local civil organisation approached Ground Truth to assist in developing measures that would help their local community protect natural and water related resources utilised by the community (Graham and Taylor, 2018). It was found that the water from springs was of high quality compared to water from local rivers (ibid). The WRC Report No. TT 763/18 notes that the Spring Health Index tool can be useful for rural communities and that routine collection of spring data can help with managing freshwater sources for rural areas.



Site C02 Centocow	Latitude	-30.040648°	Longitude	29.762630°
Name	Lufudu Spring		Feature type	Spring
Description	Spring immediately adjacent to the Lufudu River.			
Dominant land use of the upstream catchment			Rural grazing and homesteads	
Photograph & map				

Parameter	Value	Unit	Drinking*		Food preparation*	Bathing*	Laundry*
			Health	Aesthetic			
pH	7.97	pH units	No health effects	No aesthetic effects	No effects	No effects	No effects
Electrical conductivity	23.8	ms/m	No effects	Water tastes fresh	No effects	No effects	No effects
Total dissolved solids	181	mg/l	No effects	Water tastes fresh	No effects	No effects	No effects
Turbidity	28.0	NTU	Secondary health effects	Water has a muddy appearance	Secondary health effects	Slight risk of infection if ingested	Possibility of staining white clothing
Dissolved oxygen	27.8	%	Citizen science spring tool				
	2.65	mg/l	Percentage change from natural	44		Spring Ecological Condition	Fair
Temperature	17.38	°C					
Clarity	-	cm					

Figure 4: An example of the outcomes of the Spring Health Index Tool (Graham and Taylor, 2018:60)

4.4 Challenge in implementing existing citizen science tool in South Africa

The language used to produce tools is also a challenge. Weingart and Meyer (2021) emphasised that in South Africa, basic literacy and scientific literacy severely hamper the engagement with tools or applications that would be beneficial to both researchers and citizen scientists. Literacy can be defined as one's competence or knowledge in a specified area (Merriam-Webster, 2017). One of the barriers listed by Graham & Taylor (2018) is the use of English not local language to produce the tools or materials.

Fehri et al. (2020) note that lack of step-by-step citizen engagement is another barrier. Fehri et al. (2020) claim that a step-by-step engagement approach showed promising outcomes in terms of effectiveness and assisted in spreading the word and motivated other community members about citizen science tools. It is also important to help participants/communities about the importance of environmental monitoring. Younger people are easily acquainted with using tools but the oldest participants need more training to help with data management and description. It is important then to improve our training and communications programs.

Inaccessibility of the tools is a huge barrier in the implementation or uptake of the existing tools. An example is that of an electronic platform created by Graham & Taylor (2018) known as the "virtual tool-box" where existing tools and new ones could be added on to it as they get developed. This platform was meant to give life to the project beyond its funding life. But, despite numerous attempts, we were unable to open the platform. Therefore, if we as researchers could not access the platform then it is less likely that community members or people looking to utilise the tools would be able to find or access them. Limitations in areas that may need these tools include lack of computer/internet except for the young people that are capable of coming up with ways of connecting. Accessibility of the tools may well depend on someone distributing the printed booklets or printouts of existing tools and that has its challenges/limitations (expensive). Communities also primarily have to be made aware of the existence of these materials and personnel are required to distribute and introduce the existing tools.

4.5 Contribution and building on existing citizen science tools

The collaboration between volunteers who have little formal training and scientists is increasing in many research fields. It has also been proven that citizen science activities can "increase participants' knowledge about the natural world, increase their ecological literacy, hone their observation skills, or learn to use new instruments" (Bela et al., 2016, p. 993). Ecological literacy was first coined by Risser (1996) who used it to urge ecologists to champion the understanding of ecological principles and to be responsible to elicit this type of thinking in the general public. Orr (ibid) in his book Earth in Mind states that every year universities and schools produce thousands of graduates who are ecologically illiterate. They may know how to acquire a job but do not possess basic skills in understanding and conserving nature. Orr (2004) took this idea further and suggested that everyone needs to be ecologically literate and it should be the main arc of current education systems. The term literacy seems to imply a sense of citizenship and responsibility for one’s own education. Thus, to become effective citizen scientists also requires a certain level of ecological literacy. McBride et al. (2013, p.2) state that over the last five decades the concept of literacy has extended to “include the ability to understand, and act with respect to complex topics and make decisions facing society today”. From this definition we start to see that literacy not only involves the responsibility for one’s own learning but also implies that the literate citizen has a responsibility to society.

Thus, responsible citizen scientists can be seen as the drivers of change in society, creating a better world socially, environmentally and economically by the work they do on the ground in the field. We also see the numerous applications of the term literacy to various disciplines such as computer literacy and maths literacy. It is from the application of literacy to the environmental and sustainability discourses that we get the terminologies for environmental literacy and ecological literacy.

“Fieldwork activities aim to heighten the learners' awareness and develop their personal response to a place” (Kinder, 2013 p.188). This also links back with the concept of sense of place and learners' deepening sense of connection and responsibility towards the natural environment. When learners gain a deeper sense of place and appreciation for their local places there is a curiosity to explore the natural world further. Thus, if one can also incorporate citizen science into the school syllabus primarily into the geography and natural science curriculum there is space to educationally revive citizen science. All of this reflects the importance traditionally attached to fieldwork within all levels of the discipline, including geography taught in schools. Citizen science primarily consists of fieldwork as well in the field gathering data, thus it is intrinsically linked within fieldwork activities and practical activities.

It should be noted here however that there is a difference between fieldwork and field trips. Woodcock and Bailey (1978, p.3) argued early on that a field-trip relies primarily on descriptive explanations' and is 'an inadequate substitute for real field-work, which involves the measurement and analysis of relevant aspects of information”. Ross (2001, p.86) however also argues that fieldtrips should encourage an appreciation of 'awe and wonder' and is designed to encourage students to “develop aesthetic responses to the world around them”. Fieldwork in geography education seeks to inform the learner about aspects of the curriculum by placing them in the landscape which the learners are studying. Thus, we see that fieldwork is essentially an investigative exercise rather than a pleasurable outing that focuses on aesthetics. However, increasingly across the world and in South Africa we see cases of fieldwork becoming intermittent, scarce or simply not there at all and citizen science tools are not being taken up at the rate required for real critical change. Cook, Philips and Holden (2006) state that many teachers have become reluctant to undertake fieldwork. This stems from the perception, often erroneous that there is a high degree of risk attached to fieldwork. Combined with the additional logistical and administrative burden that is loaded upon the teacher who wants to undertake an outdoor activity one finds that fieldwork becomes an unpalatable commitment to school based educators even in a fieldwork-orientated subject such as geography.

Here the input of institutions and NGO’s can create more sustainable citizen science focused fieldwork activities within the school framework.

Community members often do not see the value in citizen science and perceive it as an external agency that comes into the community, does the work and leaves. No real engagement in a meaningful sustained way is being achieved. Also, the tools themselves are sometimes too opaque to understand, not written in the vernacular and not made simpler for everyday usage and wear and tear. Simple solutions will go a long way like laminating materials for robust use, translating materials and creating inexpensive easy to make tools out of common household items will go a long way rather than imposing a hierarchical system upon the community. As Isidiho & Sabran (2016) state the” strategic objectives of community development should always include “empowering local communities, developing effective partnerships, working as multi-agencies, becoming learning organisations and improving the life and well-being of the rural communities and making them sustainable” (p.266).

4.6 Outcome of engagements with communities around the spring protection tool

This project worked with rural and B3 local municipality urban communities (coloured area) on spring protection, and Hlankomo Administrative Area (A/A), in Batlokoa Traditional Council area, in Mt Fletcher/Maclear and Makhanda. Existing spring protection tools and documents mainly focus on rural areas and with little reference to peri urban areas. The assumption might be that urban areas have a functional and well-established water infrastructure and service provision system. Below are the two sites that this project will be focussing on.

4.6.1 Hlankomo village

The Hlankomo village is located in the Tsitsa River catchment area, and the springs in the area are said to be flowing throughout the year. The Tsitsa River catchment is amongst some of the poorest areas of the Eastern Cape and people found in this region rely mainly on natural resources for livelihoods (Kakembo & Rowntree, 2003; Blignaut et al., 2010; van der Waal, 2015). Springs are one of the main sources of drinking water and other household general usage. In a participatory mapping workshop that was facilitated by the Tsitsa Project held in Batlokoa (Hlankomo), spring degradation as a result of trampling by livestock was listed as priority two for natural resource management (Lunderstedt et al., 2017). For the current project, we have identified four springs of interest with varying characteristics and water quality.

A MiniSASS was carried out at Ntlanjeni and Number 5 springs. At Ntlanjeni the MiniSASS results indicate that the spring is in good condition (score of 6.2), and Number 5 was found to be in poor condition (score of 5). It was not possible to do MiniSASS at Makgetheng and Ekwarini due to the water stagnant and the flow was not sufficient for the MiniSASS test. At Ekwarini water was muddy and also had a low flow.

Figure 5: Makgetheng (Depression spring). This spring is illustrating why a clarity tube could be a useful tool to use for spring monitoring, as the water is turbid.

Figure 6: Village Number 5 protected spring (Artesian Spring)

Figure 7: Ntlanjeni protected spring (Artesian spring)

Figure 8: Kwarini unprotected spring (contact spring)

4.6.2 Makhanda (previously known as Grahamstown)

Makhanda falls under B3 category municipality. The site forms part of what is locally known as 'the coloured area' in Makhanda East (this term is based on historic Group Areas Act spatial segregation which shapes current residential patterns and community language for different residential areas). Weaver (2018) stated in his thesis that this part of Makhanda is affected by poor water service delivery. Many people that reside in this area are poor and lack the capacity to mitigate this challenge (ibid).

The first spring, Figure 9a and b, is found in a peri urban area of Makhanda close to a road (Evan Street Spring). The second spring is found in an unhealthy environment full of litter and sewage seepage just below it (Sun City Informal Settlement Spring, see Figure 10a & b). The spring is used by the local people for drinking and cooking when there is no water in Makhanda, and they cannot afford to buy water for their households.

Figure 9a and 9b: Evans street unprotected spring

The second spring is found near a dumpsite and it is surrounded by waste. The spring is also used as a source of drinking water and for general household usage. The spring is generally used when there is no municipal water supply in the area.

Figure 10a and 10b: Sun City informal settlement spring

Protection and management of springs is important as it ensures water access, and it provides opportunities to benefit the health and livelihoods of users (Cockburn et al., 2020). The Department of Water Affairs and Forestry (Currently known as the Department of Water and Sanitation, DWS) guideline for spring protection provides that groundwater was previously not given much attention as it was not considered an important water resource (DWAF, 2004). Monitoring and collecting data on springs can provide valuable information on what kind of springs are available, where to find them and what they are used for (Graham & Taylor, 2018). A recent WRC working paper has noted the importance of citizen science in boosting the capacity of countries (especially low-income countries) to monitor and collect data on freshwater sources (Madikizela, 2022).

4.7 Taking the existing information and generating a new "spring protection and sustainable use Tool"

In response to these insights into citizen science, ecological literacy and the identification and protection of natural springs there is a need to develop a spring protection tool that actively promotes the conservation of the springs identified within the communities as well as be relatable to the citizen scientists/communities that will use it in the future. How is this accomplished effectively? Firstly, as we have seen, the top down approach as done in the past by universities, scientists and NGO's does not truly empower local action or commitment. There is a need to involve the citizen scientist in every step of the process and even in the creation of the tools themselves. There needs to be robust engagement with the community to understand their needs and future usage of the springs rather than assuming one understands the context. A deep contextual profile and needs analysis can also be conducted to aid the researchers into understanding the communities they work with.

4.8 Importance of protecting springs – community perspective

"Important to our livelihood, we can't live without water. It is like a clinic where we receive healing. Springs are where we get healing. We are dependent on it.

People would not survive without water. So, water is important

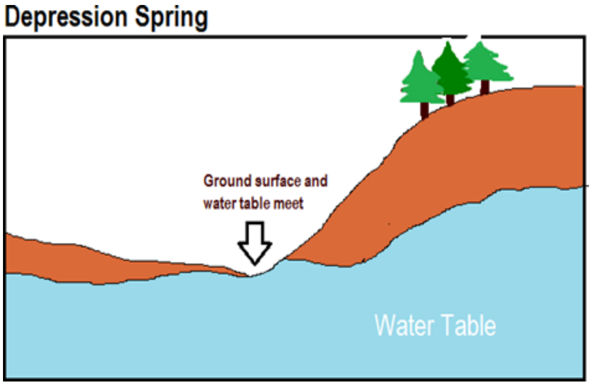
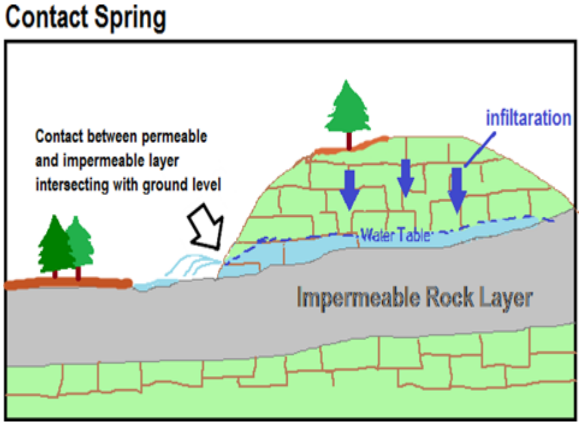
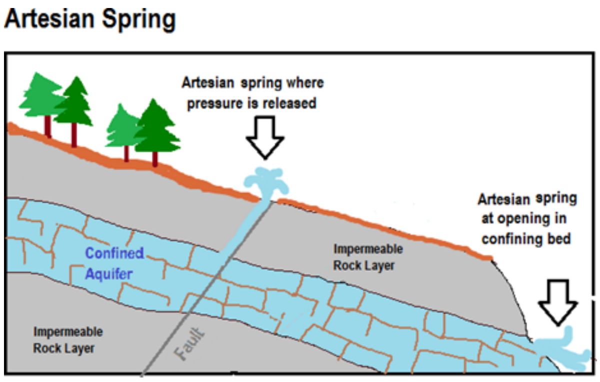
Some people do not have tanks and therefore depend on springs A lot, without water living would be difficult as we depend on the water.

We do not have any other place to collect water from when we need it.

We drink the water from it. We do not all have tanks and tanks dry up. We survive with the spring" – Hlankomo community members

Below is the presentation of the three steps of the spring protection and sustainable use tool that were presented to community members of the study sites.

4.8.1 Step 1: Identify the type of springs

	Formed where the ground surface intersects the water table
	Created by permeable water bearing formation overlaying a less permeable formation that intersects the ground surface
	Resulting from releases of water under pressure from confined aquifers either at an outcrop of the aquifer or through an opening in the confining bed

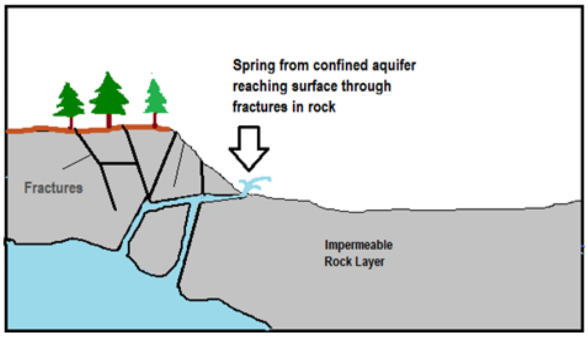
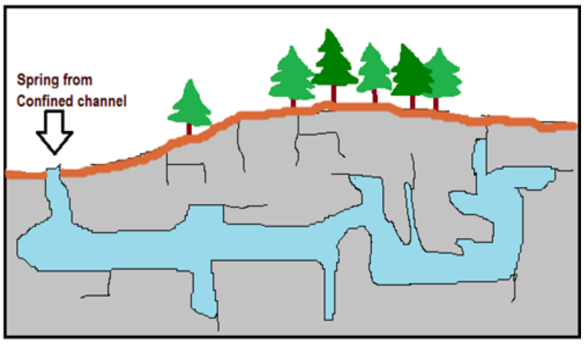
Fracture Spring 	Water issuing out of the ground where fractures lead water to the surface out of impervious aquifers
Tubular Spring 	Water issuing from confined channels, such as lava tubes or solution channels (where the rock has dissolved away), connecting with groundwater

Figure 11: Spring Assessment Tool WRC Project No. K5/2350:9

4.8.2 Types of springs from Hlankomo community – community perspective

Umthombo wedwala (under a rock) (Depression spring) – The water is nice. It comes from under the rock. Water is always clean and cold even in summer. It is easy to clean, all that has to be done is wash the rock and it is clean. Nothing can disturb the soil particles or make it dirty because it is protected by the rock.	
Umthombo wedongwe (clay spring) (Contact spring) – Water is not as nice and it smells like mud.	
Umthombo womhlaba (Soil spring) (Contact spring) – the water is not clean enough and water is not nice. Water is easily disturbed so when collecting water, you have to keep waiting for the soil particles to settle. This type of spring becomes affected by livestock trampling and we have to wait for it to clear up.	

Umthombo wesanti (sand spring) (Artesian spring) – the sand cleans the water underground and it comes up clean.	
Umthombo womgxobhozo (water from wetland or seep wetland) (Artesian spring) – the water is not nice and vulnerable to trampling by livestock.	

Figure 12: Different types springs according to Hlankomo participants

4.8.3 Step 2: Spring health assessment

This is the second step to be administered after the identification of the type of spring. This step was adapted from Spring Health Index Tool WRC Project No. K5/2350. Spring health assessment determines the current ecological condition of the spring and compares that with what it could be if the spring was not disturbed by usage and activities around it. The following impacts and activities are relevant in both the Hlankomo and the Makhanda sites and could be included in the assessment: livestock grazing; pollution near the spring; surface water diversion and changes in the flow of water; spring structure modification; vegetation removal; groundwater withdrawal; Invasive Alien Species (IASs)

1. Livestock grazing and Vegetation removal

Refers to the inappropriate or excessive livestock grazing affects springs by compacting or compressing wet soils, breaking down banks, increasing sediment and nutrients. This also reduces plant cover and the presence of desired riparian species. This is the removal of vegetation through activities such as livestock grazing, harvesting by people, excessive occurring fires, recreational activities and other activities that may cause the removal of vegetation near a spring.

2. Pollution near the spring

This refers to the disposal of solid waste around the spring. Waste can include detergents, motor oil, pains, pesticides, etc. (Nel, 2017). These solid wastes may infiltrate/percolate the groundwater with rain water and impact the quality of the water.

3. Surface water diversion, spring modification and development

This term refers to the alteration of water flow from the ground to the surface area, either by changing water flow direction, or volume. The modification can be installation of pipes to harvest water directly from the spring. Some species such as spring-snails like to live in a place that is not modified or impacted (McKnight, 2014). Altering a springs' discharge affects the productivity of aquatic and riparian habitats, in turn lowering the number of plants and animals on the site. Spring modification is the alteration of the natural physical shape of the banks by physical man-made structures, such as building walls around the spring. Development is a broad category, including all infrastructures and buildings around the spring, and also included in these are tracks created by livestock migration.

4. Groundwater withdrawal

This is the extraction of groundwater through boreholes and wells. Extracted water would be used for things such as irrigation, industrial and domestic use. Its impact affects the spring discharge and can reduce spring source discharge.

5. Invasive Alien Species (IASs) and Soil erosion

Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem and which may cause economic or environmental harm or adversely affect human health. In particular, they impact adversely upon biodiversity, including decline or elimination of native species through competition, predation, or transmission of pathogens and the disruption of local ecosystems and ecosystem functions (CBD, 2006). Soil erosion is the washing away of the earth's topsoil by wind or water. Invasive Alien Species also negatively influence the spring habitat as some invasive alien plants tend to utilise more water than indigenous plants and change natural temperature cycles through excessive shading of the channel. Erosion is a natural process, it can be accelerated by excessive human and animal activity. Accelerated soil erosion can also result in hostile conditions for indigenous plants needed for maintaining integrity of the natural ecosystem.

Table 5: Example of how to measure the spring assessment

	IMPACTS						
	Livestock grazing and vegetation removal: Are there animals grazing and trampling on the spring? Is there removal of vegetation around the spring?	**Pollution near the spring**: Is there dumping or waste around the spring? Is there a toilet close to the spring?	**Spring modification and water diversion**: Is the spring altered in any way for water collection and water is diverted by built infrastructure?	**Groundwater withdrawal**: Is there a borehole near or around the spring? Is water being withdrawn for big farms?	**Invasive Alien Species (IASs) and Soil erosion**: Is the ground near and around the spring covered with alien vegetation? Is the vegetation indigenous?	Percentage Changed (score/potential total) *100	Ecological condition
Score example	1	1	2	3	1	(8/25) *100=32%	Good
Potential Total	5	5	5	5	5	25	

Score	Percentage of Change	Ecological Condition
1	0-20	Natural
2	21-40	Good
3	41-60	Fair
4	61-80	Poor
5	81-100	Very poor

4.8.4 Step 3: Spring protection and sustainable use

Freshwater springs are readily accessible places of the planet's extensive groundwater resources. As such, springs have always been highly valued by human society (Barquin & Scarsbrook, 2008). Springs provide a reliable source of water for different human activities (as we have seen in the Eastern Cape, farming and potable drinking water needs are often met by natural springs), and in arid environments they may be the only significant source of freshwater for humans and wildlife. The importance of freshwater springs in society is illustrated by the link between these habitats and the establishment and survival of human populations.

4.9 Spring protection and sustainable use

The following are tools developed from literature and strengthened/adapted through community/stakeholder engagement inputs. How can the community protect the spring in its natural state?

Spring governance: have a platform or a place to discuss spring related issues. In the interviews it was evident that no one was solely responsible for protecting the spring. Therefore, having these challenges as part of traditional council meetings could get people changing how they do things and those who have livestock try to keep livestock away from the sources. Springs are important to everyone, especially in dry seasons, hence everyone should be involved.

Limit direct livestock to the eye: The eye of the spring is the place where humans can access its water; thus keeping the eye protected is vital in ensuring that the spring continues to be productive. The area immediately above and uphill of the spring eyes needs to be protected to prevent pollution from people or animals. To prevent livestock from getting in and contaminating the eye, a hedge of animal-resistant bushes usually makes a good permanent fence (Skinner & Shaw, 1992). As presented below these are ways that communities limit access to the point of collection.

Figure 13: Limiting livestock to the eye – Hlankomo

Create access points to avoid trampling: well defined pathways around the spring helps to prevent trampling by both humans and animals. The pathways can be constructed of materials that are readily available around the spring such as stone or wood, or it can be a cleared pathway with compacted earth (Skinner & Shaw, 1992). These access paths must also be maintained regularly and cleared of any obstacles such as gravel, stones or loose plant material that can enter the spring.

Figure 14: Pathway to collection point – Hlankomo

Manage litter around the spring: Litter around the spring needs to be managed as this is a prime way of contaminating natural spring water. Plastic pollution is the scourge across the planet and if it gets into the water supply it can leach microplastics which will also negatively affect human health. Also, litter is unsightly and leads to a decline in value for the users and in protection of the spring. Regular clean-ups and co-learning engagements amongst community members on proper usage of the spring is paramount to the success of the spring protection.

Figure 15: Pollution around spring

Veld sanitation: Adequate sanitation efforts around the spring need to be adhered to. Sanitary protection to prevent contamination of the spring water in the catchment area is essential. There should be no latrines or garbage dumps within 30 Metres uphill of the spring (ibid). The quality of the spring water is of importance. In particular with gravity springs, the water will generally be free from pathogenic organisms. However, if the water differs in temperature during the day and the night, the water quality is suspect.

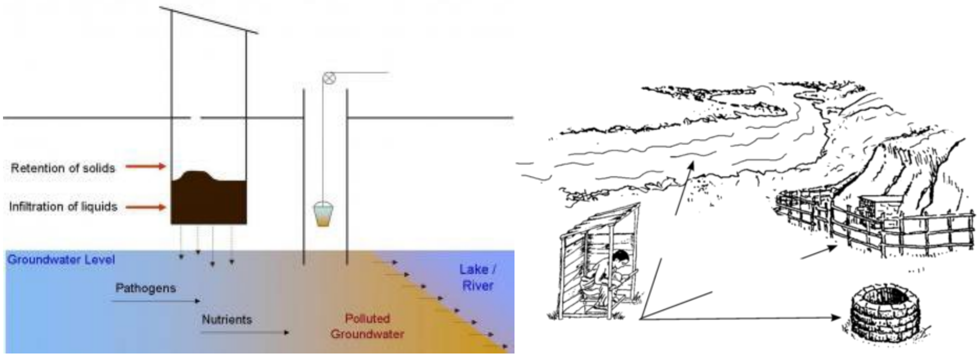


Figure 16: An example of what could affect veld sanitation

"Heavy rains also wash human faeces into the spring and rivers. There are people that still prefer to poop outside. They describe this as a peaceful and more comfortable ritual where there are no flies or smells – community member in Hlankomo.

Sometimes people poop above springs but we ignore that fact when we need to collect water. We just clean around the spring, the visible dirt and wait for it to clear and we collect. As long as you don't see the poop, you pretend it does not happen" – community member in Hlankomo.

Manage/eradicate alien vegetation: Alien vegetation is extremely damaging to the groundwater table and does deplete the reservoir (Skinner & Shaw, 1992). Alien vegetation also upsets the balance of the ecosystem and does not allow indigenous species to thrive, this damages the ecosystem over time. One needs to eradicate alien vegetation near the spring using cost effective methods to clear. How to identify alien vegetation workshops can be designed for community members using pictures and showing methods of eradication. Alien vegetation should not be present anywhere near the natural spring.

Figure 17: Alien Invasive Plant – Acacia mearnsii. source: Wikipedia

Co-learning engagements: on the importance of springs and spring etiquette. Practical and concise guidelines for efficient management and ownership of the spring needs to be implemented through mutual learning activities, such as field visits, co-learning workshops where context specific solutions to spring related challenges can be discussed among stakeholders as well as the production of accessible and creative information products (e.g. pamphlets, stories, poems, etc.) in vernacular language.

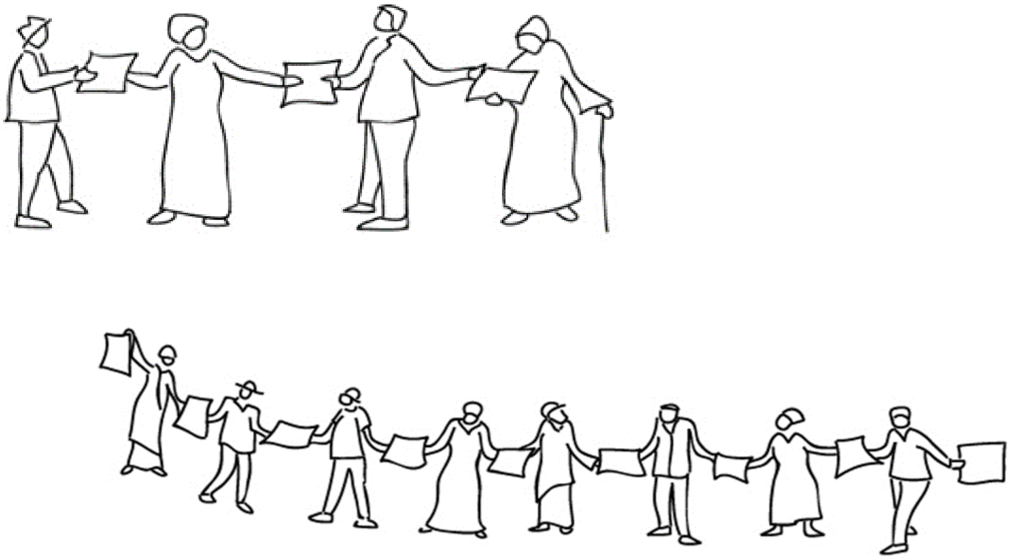


Figure 18: Knowledge sharing demonstrations

Findings from honours research

The findings of the first objective 'Investigate the successes and challenges of previous or current learning and capacity development processes for citizen science tools in monitoring and sustainable use of water resources' were represented in themes drawn from the Ernst (2019) social learning framework and coded during the analysis process. These themes included network building, facilitation, access to information, participation format, and diversity of participants. The findings of the second objective 'explore stakeholders experiences or preferences for learning and capacity development processes' were represented by a narrative text which summarizes the relationship between the community members and the springs and the interventions that they have implemented prior to our visit to protect the springs.

The participants showed much interest in participating and with this we were able to discover the various factors that would encourage learning in the different communities. It was during this process that the role and quality of 'facilitation' was noted as one of the key factors that influence learning. However, it may also be noted that the presentation and execution of facilitation does not mean that everyone must present the same ideas and agree to the same ideas. For social learning to be optimised, facilitation should encourage everyone to have equal opportunities to participate and be treated with respect. In addition, establishing a good level of trust between the stakeholders and the facilitators during the learning process is an important enabling factor to social learning (Pahl-Wostl et al., 2007).

The community members also expressed the desire to have the learning process be in two parts; first in theory through slides that are not filled with words but rather filled more with descriptive pictures and the second part be a practical demonstration where they get to use maybe one citizen science tool with the facilitators. Having individuals from the community who already have experience with citizen science tools showed to have a good influence on the other community members in Maclear as they became more motivated upon hearing that there are people in their community who have been using some citizen science tools and that these tools actually help them in their line of work. So, inviting these individuals again could be beneficial for the delivery of the tool.

It was also noted that knowledge about springs in the two communities was on different levels. The community members in Maclear are more knowledgeable about springs, while in Makhanda the community members did not have much knowledge about springs. This may indicate the need to first add/improve knowledge about springs in Makhanda before delivering the tool.

Something that stood out for me in one of the interviews with key informant was the five T's method that this key stakeholder normally works for her :1) Tune in with the people, 2) Talk about the issue, 3) Touch the water, 4) Try out (the tools), 5) Take act. Other key stakeholders indicated the need to provide feedback to show community members that their participation was not in vain, demonstrate in small groups so that the facilitator can be in tune with every individual to make sure that no one is being left behind during the demonstration.

Regular MiniSASS for testing the quality of the water can be effectively done by community members and uploaded to the MiniSASS website. This will also give an indication to community members of the quality and health of the local ecosystem. The MiniSASS can be updated for local purposes by the inclusion of the presence of frogs as a good indicator of water quality as it is not currently represented in the MiniSASS.

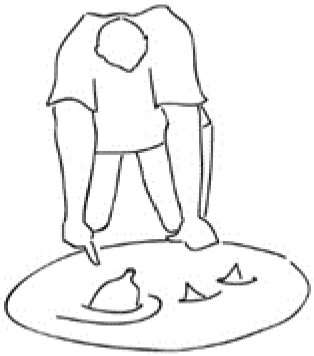


Figure 19: MiniSASS demonstration

Clarity tube – Measures cloudiness or haziness of water, based on the amount of dissolved and/or suspended particles within a stream or river.

Suspended sediment and other solids that affect the clarity of the water can occur naturally, but can also be worsened by human activities such as degradation of the riparian zone and the removal of vegetation which allows for erosion.

Figure 20: Clarity tube

Removal of freshwater Algae – Algae forms when the water is stagnant and the participants stated that they use Jik bleach to keep the water clear or they just scope the algae out of the water when they see it and then try to make sure that the water continues to flow to avoid the algae growing again.

Value of monitoring water quality

Communities currently do not have anyone who can monitor the quality of water resources. It is therefore important to have some tools that they can be trained to use and assess the integrity of water from springs. They can share their findings and knowledge t with their and other community members. This Draft Spring Protection Tool/Intervention is the beginning of how communities can keep their fresh water drinking sources at acceptable healthy levels.

4.10 Conclusion

Graham and Taylor (2018) began the journey of developing a tool that could be used to assess the health of the springs. This was an important step because surface and underground water sources are the main source of our country's freshwater, and their protection will feed into climate change adaptation and ecological restoration efforts. There was a platform, virtual toolbox that was created to try keep the project beyond its funding life span but that shortfalls. It not accessible which means no one can access it. Therefore, if we as researchers could not access the platform then it is less likely that community members or people looking to utilise the tools would be able to find or access them.

This report presents the existing tools with some new interventions that communities came up with from various workshops held. Communities also presented their own way of differentiating between the different types of springs which are listed under step 1. This tool or these interventions will be presented back to the communities to approve or make changes where they see necessary.

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CHAPTER 5: Engagements and implementation of the draft spring protection tool

The engagements began with an appropriate opening for the context, for example a prayer in Nqanqarhu). All round introductions, followed by a welcome. The purpose of the day was shared and the emphasis was shared on how this is a core-produced document with a lot of information from the participants at both sites.

Enviro picture building game produced by WESSA and Share-Net was played as an ice-breaker. When the game finished we went to the nearest spring for implementing the co-developed draft tool.

At the site the participants were group for this activity to make sure everyone can get a chance. They then used the tool to identify the type of spring; Practice completing the table; look for animal life – indicators of health (without scoring – just as indicators of general health, alerting participants to MiniSASS); clarity tube reading. Towards the end a discussion about what can be done to protect the spring.

Reflections

After the site visit a reflection session was facilitated by the research team. The following were guiding questions for the participants:

- Would you use it? No, why not? If yes, how do you think you would use it?
- Is the tool useful or helpful?
- What was easy to understand? What was difficult to understand?
- What made sense and what did not?
- What's missing?
- What was it like using the tool?
- How should it be used?
- How to make the tool more useful?
- Who is useful for?
- Should we translate it?
- Should we have more illustrations?
- What do you think is needed in the tool? List of equipment? Which ones?

5.1 Reflections on the tool and usability

5.1.1 Makhanda site reflections

The picture below was taken at the Makhanda site while showing the participants how to use the clarity cube. Below are the reflections on the tool and usability of the tool.

Figure 21: Site visit in Makhanda at the Evans Road Spring

- A tool is something that is tangible, this seems like a research process
- It needs a description of what a tool is
- The current tool can be perfected as time goes
- Adjust tool according to the context
- We can use the tool and share with others

5.1.2 Nqanqarhu site reflections

The picture below was taken at the Hlankomo site while showing the participants how to use the clarity cube. Below are the reflections on the tool and usability of the tool.

Figure 22: Site visit in Nqanqarhu, Hlankomo, Village No. 5

- It could work, it should be taken seriously and we must take upon us
- Everything is difficult at first
- It was easy because the questions revolve around anything you can see, e.g. no livestock; no pathway
- There should be an extra tool to verify the current tool to see if the results would be the same
- It should be translated into isiXhosa to allow for reflection and usability. English is short and easy for young people but it is still our mother tongue which we should strive to protect.
- Photos made it easy to interpret the spring types

5.2 Suggested Name changes

During the refection in Makhanda participants expressed that they could not relate to the name “Tool”. Therefore, they were requested to give suggestions of what they would better relate to. Spring toolkit is highlighted because it was that the one that was selected as the new name.

- Check tool
- Spring health Tool
- A “record”
- **Spring toolkit**
- Reporting tool

Figure 23: Reflection session at both sites

5.3 Difficulties with the current tool

- It was difficult to identify springs using cross section drawings
- One needs to have a background in working with springs
- Clarify the concepts and the scoring as it was clear to follow
- A list of common invasive in Makhanda would be useful

5.4 Traditional beliefs/local knowledge about springs

- Building structure around springs reduces or affects the water flow
- In the past, certain springs were not used after sunset. It was believed it could cause skin allergies. It was believed that you had to throw a stone before getting to the spring to chase away "*Mhlekazi, the snake*"
- There is a spring that flows throughout the year. The snake's (*Mhlekazi*) body can be seen but from afar. The collection point is below the snake's body
- Another belief was that a spring can only be cleaned by a single/widowed woman, not a woman with a man or married.
- Time matters for the traditional beliefs because people still did the things they were told not to do and nothing happened. Things have changed. For example, burials were done in the early morning or after 2pm but that does not happen anymore.

5.5 Recommendations

- Use previous geomorphological research that is available
- Include geologists to help with the identification of the type of springs
- Have examples the type of springs that can be found in Makhanda
- There must be a differentiation between rural and urban springs
- Have another session with local leadership, councillors, political leaders, officials, etc.
- A tool with constitution that can ascribe responsibility to the user to protect the spring
- Get ambassadors to share info about the resource that is available. Enhance coordinated effort
- Maps showing spring sources and the water cycle. Do contextual profiling
- Technical tasks such as IAP need to have pictures of already known IAPs around the place. Provide a clear easy to understand of what are IAPs (especially in Makhanda)

5.6 Suggestions for protecting the spring using local tools

5.6.1 Makhanda community

Below are suggestions of how the spring in Makhanda could be protected.

- If the spring has been identified it needs to be protected using local material
- Protecting the spring by covering it and putting a pipe for people to collect the water through while making sure that livestock has access to water
- Make sure the intervention does not disturb the natural flow of the spring.
- Cover the eye to limit direct damage and pollution
- Install a rubbish bin nearby for people

5.6.2 Nqanqarhu community

These are reflections or feedback of what could be done to protect the spring.

- Plant a tree/s near the spring to clean the water and protect it from pollution. People throw trash anywhere. Ingcula tree is a plant found in a wetland, imizi
- The spring area/overflow should be demarcated to avoid livestock trampling on it.
- The structure should be opened to allow flow, to keep the water moving and not stagnant
- Men within the community can source wood to protect the spring from pollution and a netted wire would assist
- The sediment inside should be removed when the flow of the spring is low or there is no rain
- Rethink the protection of the spring: remove the zinc because it rusts. The rust depositions are visible in the water. Use the sail or Paint the Zinc or Plant trees/ make a slab

5.7 General feedback

This is general feedback about implementing the tool and how the participants felt about it.

- There was a sense of responsibility around the use of the tool
- Participants felt empowered and learnt a lot from the process
- Could connect with the tool especially because there was a practical exercise
- Regular contact from environmentally related work motivates the community members [Nqanqarhu]
- Clearing wattle is a way of job creation as it consumes water [Nqanqarhu]
- Participants enjoyed the clarity cube activity. Makhanda was clear at about over 90 CM while Nqanqarhu was only above 70 CM.
- MiniSASS could not be done at the springs, but it was explained how it works and identified some things that could be used to determine the health of the spring. A frog was identified in the spring in Nqanqarhu.

CHAPTER 6: Concluding recommendations and lessons learnt

"The importance of co-development of citizen science tools that can be used to equip local people to both contribute to protection, and to engage with the management and governance of springs may significantly contribute to water security for vulnerable communities, the protection of keystone ecological infrastructure, the development of citizen science, and participatory governance skills" (Deliverable 1: page 2).

During this project there are several lessons learnt from engaging with the communities as well as practising participatory approach to gather data and co-create the toolkit. The main lesson was about the importance of context. Context matters in how things are done as well as how much people know about their surroundings. This was clear in in how different the rural (Nqanqarhu) context and Makhanda context. The rural context participants had a lot of valuable knowledge to share in about springs, their use and how they protect them. They had ways to differentiate between springs found in the area, could distinguish between the taste and how the water looks like as well as ways to try protect and keep it clean. Whereas the Makhanda context mostly did not have any knowledge about what springs are and were happy to learn about the springs and their importance to the ecosystem as well as for humans and livestock. Before the engagements, the participants had never thought about protecting the springs because they did not understand the value of the springs but after the engagements they were interested in finding ways to protect these water sources and to share what they know with other interested community members. The Makhanda participants also did not trust the spring water because they do not know where it comes from, whereas the rural context, the participants rely on rain water and springs when the tanks dry up. In Makhanda there were local government representatives at the workshop and they promised to work with the community find ways to protect the spring. This was an important link that was created between the two stakeholders. It is important to bring stakeholders like local leadership in the engagements about local resources in their landscape.

The toolkit creation was a process the participants enjoyed and they were engaged in early stages until the final creation. During the implementation or training on how the toolkit would work the participants reflected positively, mostly, about this resource. Part of the reflections showed that participants understood that it could be challenging at first but in time they would adjust to using the toolkit to assess and protect their springs. This showed the importance of inclusion in all stages can translate to better uptake.

This project took a participatory approach and that has helped with communities owning the product and relating to it as their own product. The project respected and treated different views, beliefs and knowledge. The different types of knowledge were included to try and the approach was a bottom approach rather than a top down approach. There is still a sense of "it will be used by those that are interested in it or affected by spring degradation". There is a need to continue engaging the Makhanda community around spring protection as well sharing more knowledge. Community members requested mapping of existing springs in Makhanda.

One of the challenges of the project was Covid-19. It limited engagements with communities because of the restrictions. The limited supervision was another challenge but the team managed to pull it together. The following are some lessons learnt by the team: *Learnt about the vast differences between the two contexts; leant about how township communities lack the relationship surroundings; providing advisory support to a team of early-career researchers, when one is oneself still "quite early-career" is quite daunting; the project relied heavily on pre-existing relationships and it's going to be necessary for us to continue to find ways to work with these two communities in order to show respect to them and to enable this work to have impact in the long run; there is no substitute for time spent in the field, engaging with the project stakeholders; simply convening spaces for different stakeholders to engage on a common problem (e.g. spring protection) is valuable.*

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Appendices

INTERVIEW SCHEDULE

STORYTELLING INTERVIEWS (UNSTRUCTURED INTERVIEWS)

Aim

To explore stakeholders' previous experiences of and preferences for learning and capacity development processes for citizen science in water management.

<u>Context: Story Telling Interviews</u>

Narrative interviews are unstructured and typically begin with a wide open-ended question about a participant's experience, where the participant is rarely interrupted in the telling of their story. These interviews will have a little guidance from the interviewer, the idea is to give complete control to the interviewee. The participants will be allowed to tell stories of their personal experiences about any involvement they have had with capacity development and learning processes.

Guiding questions

1. Have you taken part in a learning and capacity development workshop before?
2. How would you describe this experience?

* Note anything that you would have done differently in that workshop if it was being led by you.

3. How would you prefer to be taught about citizen science for water management?

<u>**KEY INFORMANT INTERVIEWS**</u>

My name is Thembalami Mazibuko, I am an honors student at Rhodes university. I am currently doing a research project around the topic "Exploring Effective Capacity Development and Learning Processes for Citizen Science Tools for Monitoring and Sustainable use of Springs". My project is part of a broad project that is being led by MS Nosiseko Mtati, titled "Using Citizen Science to Protect Natural Untreated Drinking Water Sources: Natural Springs in Rural Catchments and B3 Municipalities in the Eastern Cape". The aim of my project is to explore effective learning and capacity development processes for citizen science tools in monitoring and sustainable use of the springs. The findings of my research will be used when delivering the 'how to' booklet that is going to be the outcome of the broad project.

One of the objectives of my research is to explore stakeholders' previous experiences of and preferences for learning and capacity development processes. This is the objective that I hope to engage you in. I hope to use the findings from this research objective to possibly outline the factors that would influence learning and capacity development, which as I have mentioned will be used to deliver the ‘How To’ booklet to the two study sites of this research

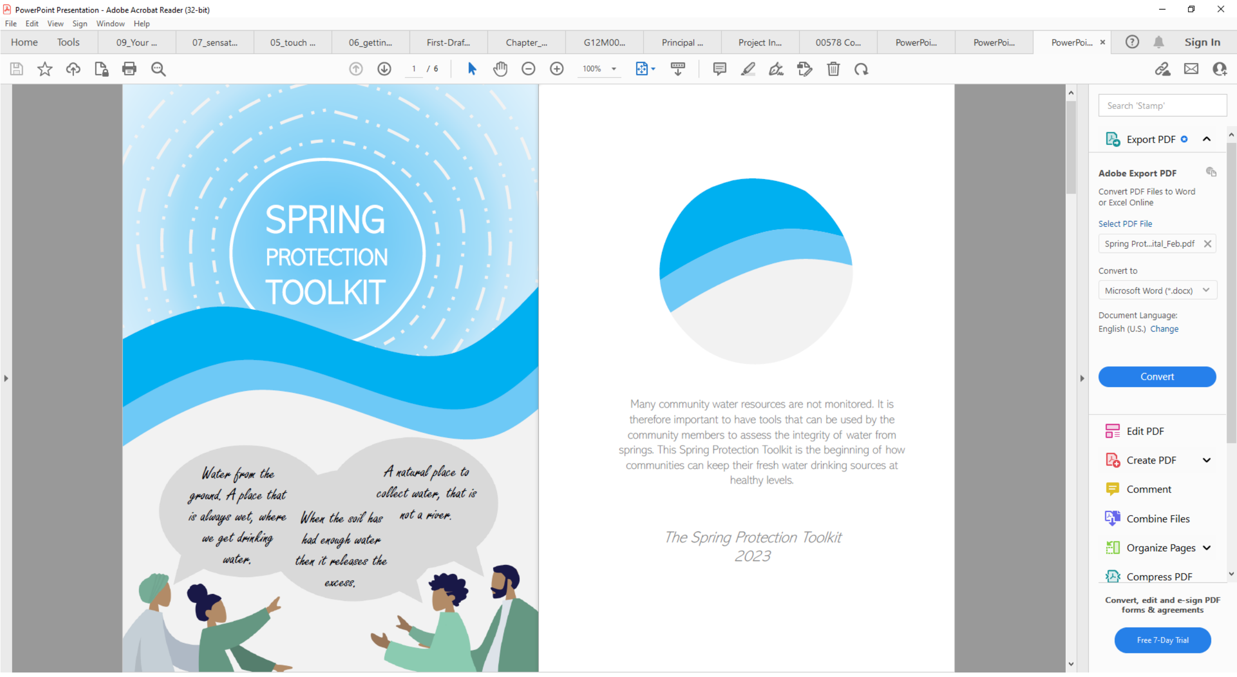
1. Have you conducted a learning and capacity-building process for citizen science for water management? How was this experience?

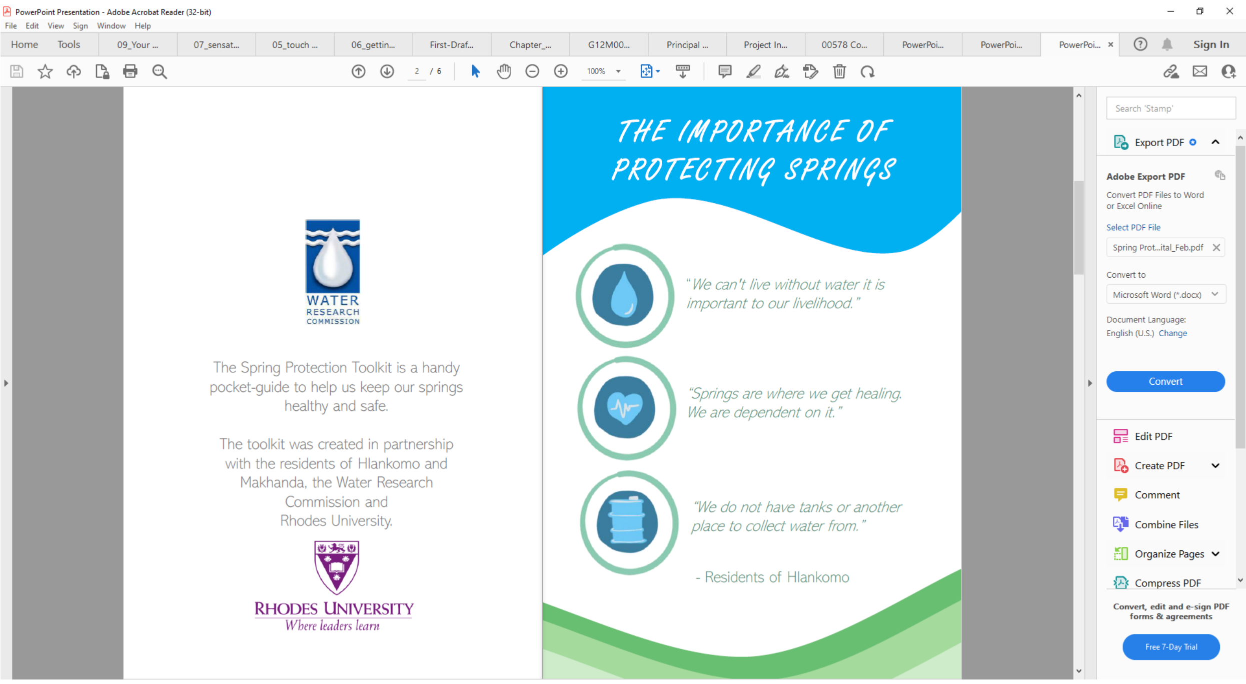
2. What methods did you use or would recommend that would encourage learning?

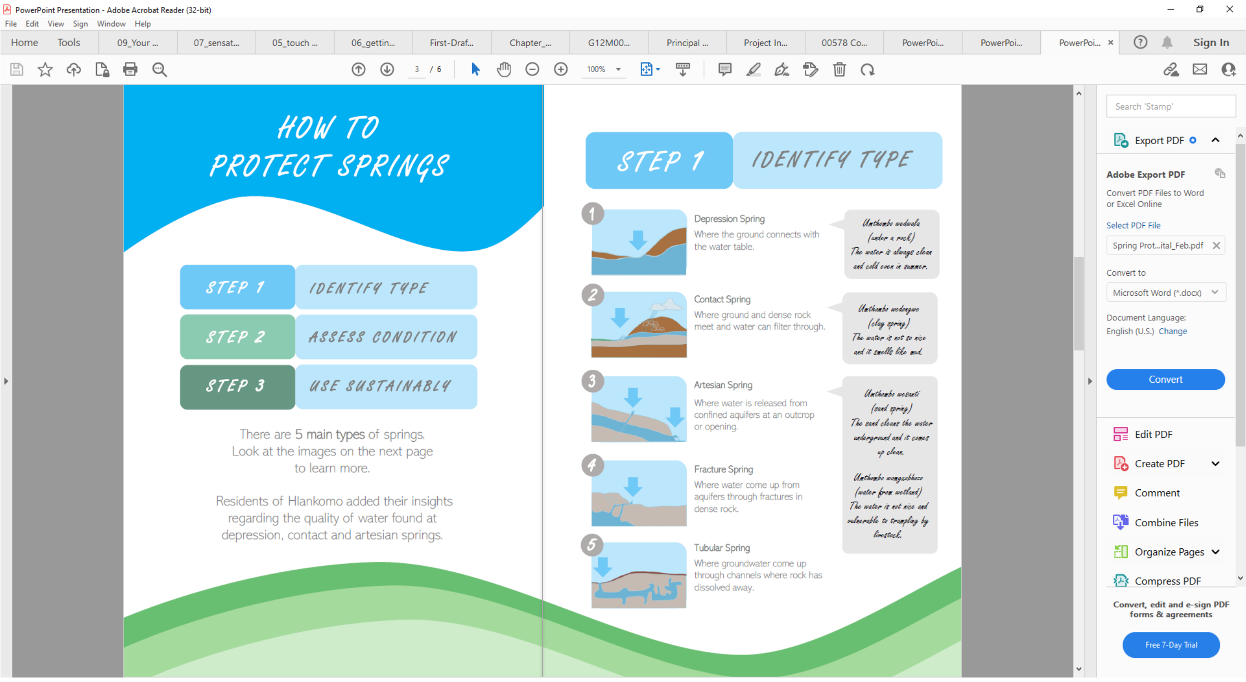
3. What are some of the challenges that you encountered during this workshop? How did you overcome these challenges?

4. From your experience what facilitation methods have been the most effective in enhancing learning during capacity development processes?

SPRING PROTECTION TOOLKITS







HOW TO PROTECT SPRINGS

STEP 1	IDENTIFY TYPE
STEP 2	ASSESS CONDITION
STEP 3	USE SUSTAINABLY

There are 5 main types of springs. Look at the images on the next page to learn more.

Residents of Hlankomo added their insights regarding the quality of water found at depression, contact and artesian springs.

STEP 1 IDENTIFY TYPE

1. Depression Spring
Where the ground connects with the water table.

Umthombo wedwala (under a rock) The water is always clean and cold even in summer.

2. Contact Spring
Where ground and dense rock meet and water can filter through.

Umthombo wedongwe (clay spring) The water is not so nice and it smells like mud.

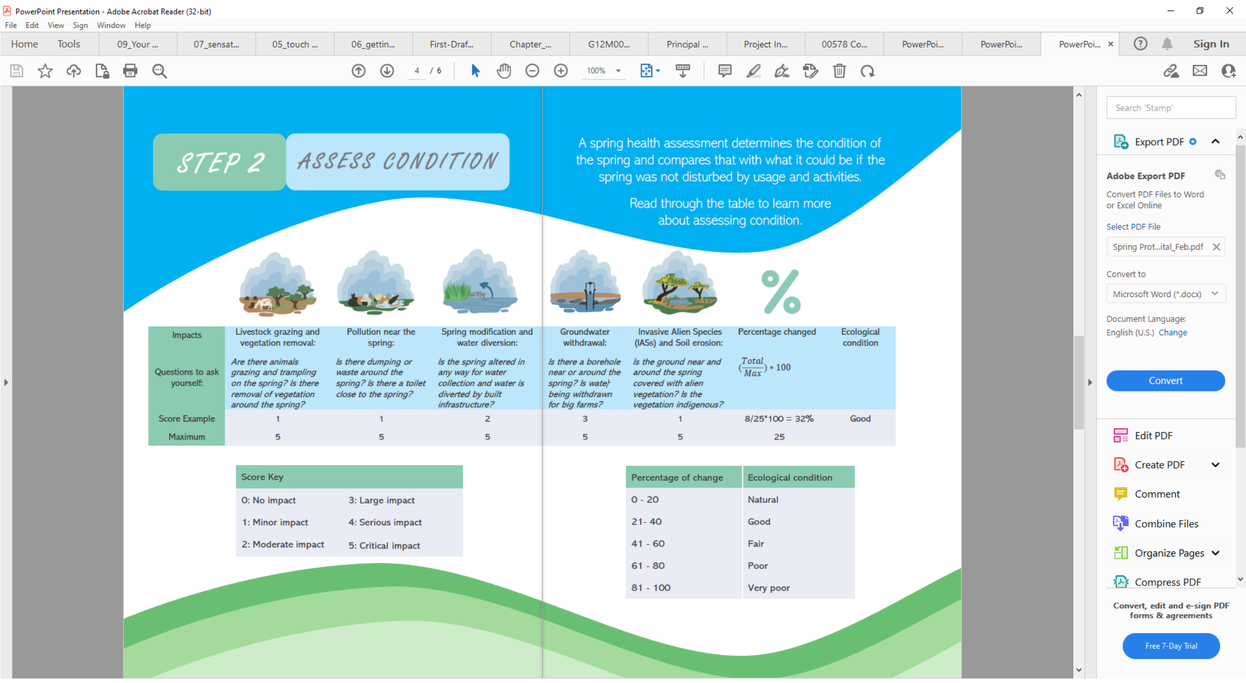
3. Artesian Spring
Where water is released from confined aquifers at an outcrop or opening.

Umthombo wesanti (sand spring) The sand cleans the water underground and it comes up clean.

Umthombo womgxobhozo (water from wetland) The water is not nice and vulnerable to trampling by livestock.

4. Fracture Spring
Where water come up from aquifers through fractures in dense rock.

5. Tubular Spring
Where groundwater come up through channels where rock has dissolved away.



STEP 2 ASSESS CONDITION

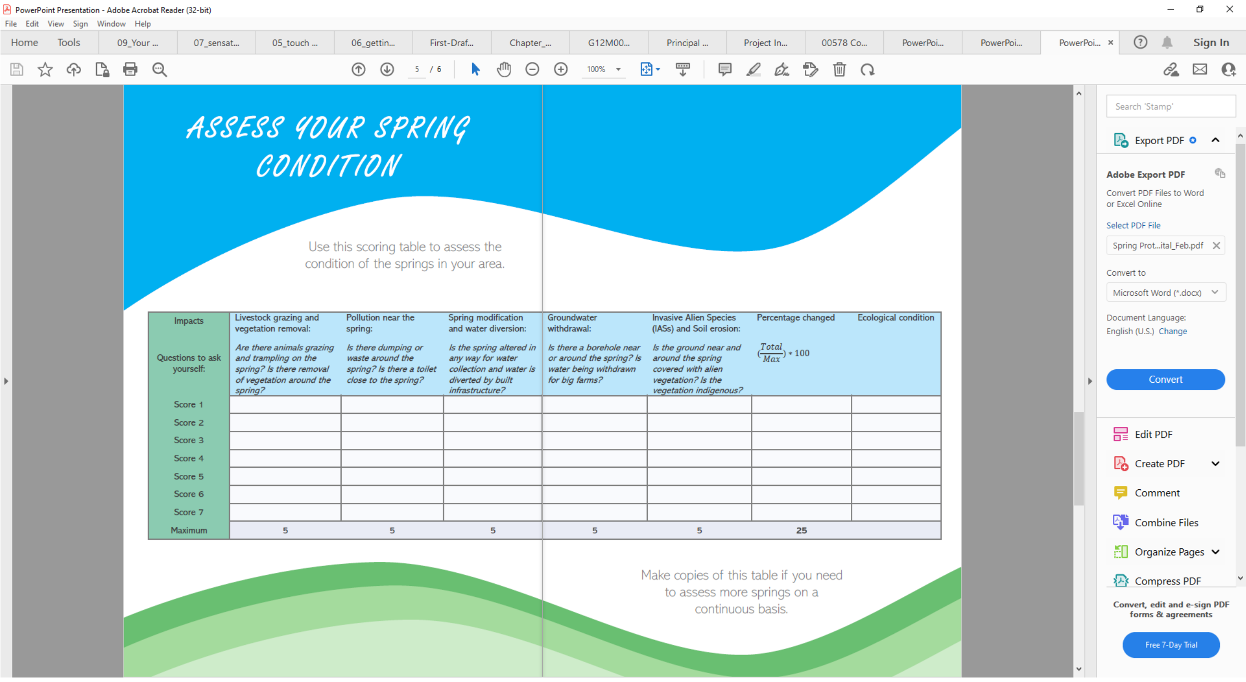
A spring health assessment determines the condition of the spring and compares that with what it could be if the spring was not disturbed by usage and activities.

Read through the table to learn more about assessing condition.

Impacts	Livestock grazing and vegetation removal:	Pollution near the spring:	Spring modification and water diversion:	Groundwater withdrawal:	Invasive Alien Species (IASs) and Soil erosion:	Percentage changed	Ecological condition
Questions to ask yourself:	*Are there animals grazing and trampling on the spring? Is there removal of vegetation around the spring?*	*Is there dumping or waste around the spring? Is there a toilet close to the spring?*	*Is the spring altered in any way for water collection and water is diverted by built infrastructure?*	*Is there a borehole near or around the spring? Is water being withdrawn for big farms?*	*Is the ground near and around the spring covered with alien vegetation? Is the vegetation indigenous?*	$(\frac{Total}{Max}) * 100$	
Score Example	1	1	2	3	1	8/25*100 = 32%	Good
Maximum	5	5	5	5	5	25	

Score Key	
0: No impact	3: Large impact
1: Minor impact	4: Serious impact
2: Moderate impact	5: Critical impact

Percentage of change	Ecological condition
0 - 20	Natural
21- 40	Good
41 - 60	Fair
61 - 80	Poor
81 - 100	Very poor

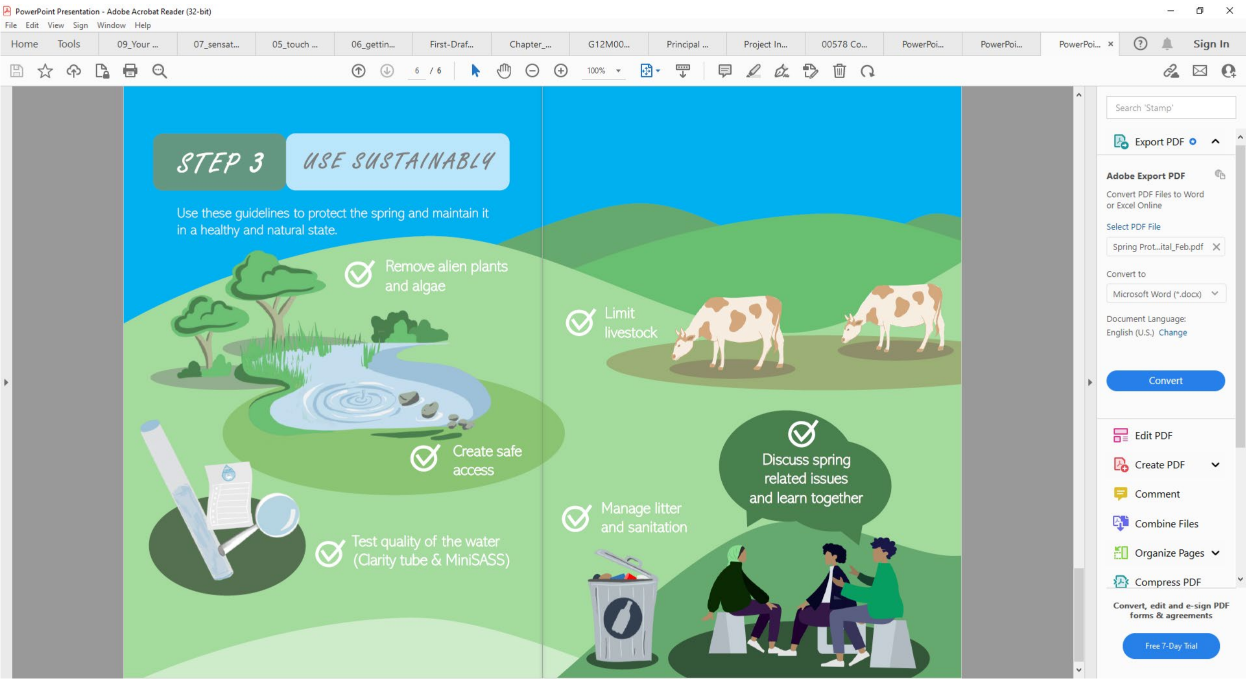


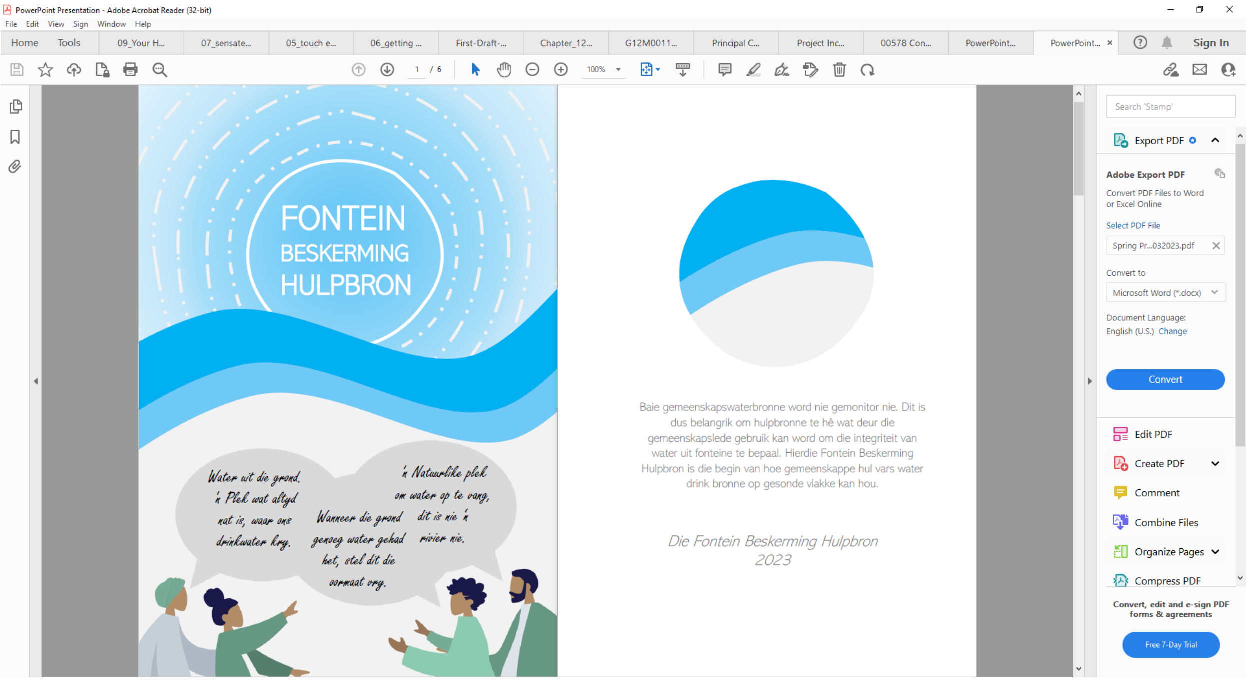
ASSESS YOUR SPRING CONDITION

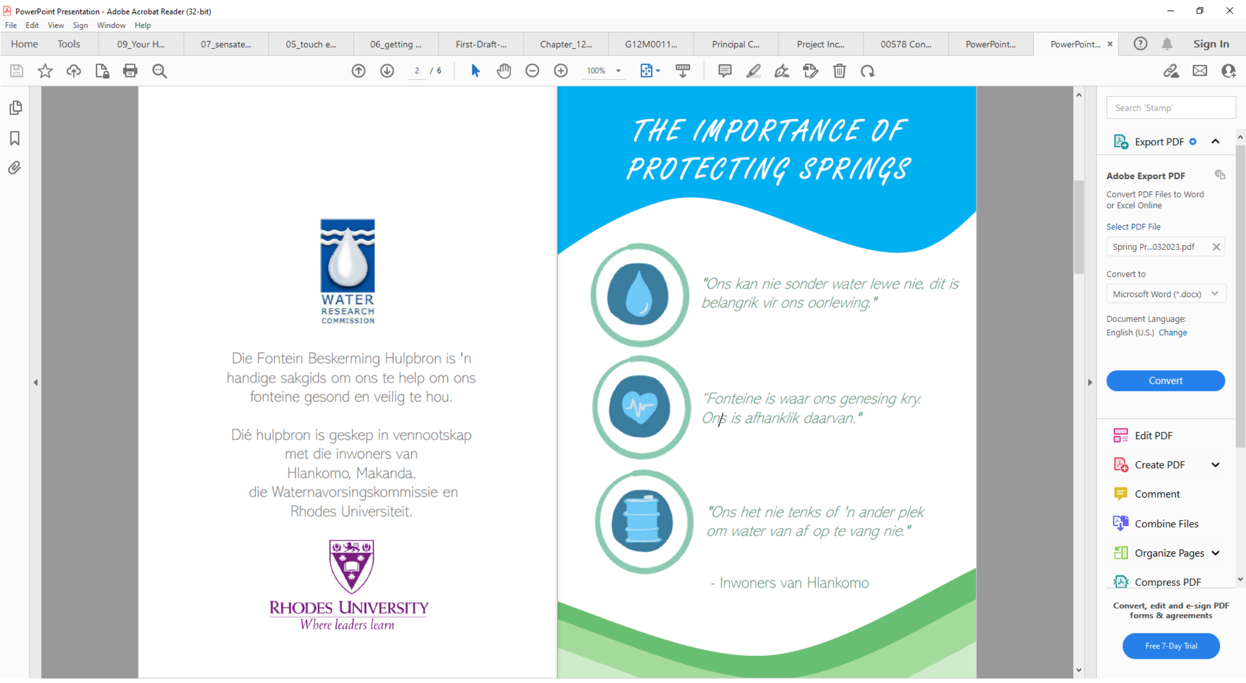
Use this scoring table to assess the condition of the springs in your area.

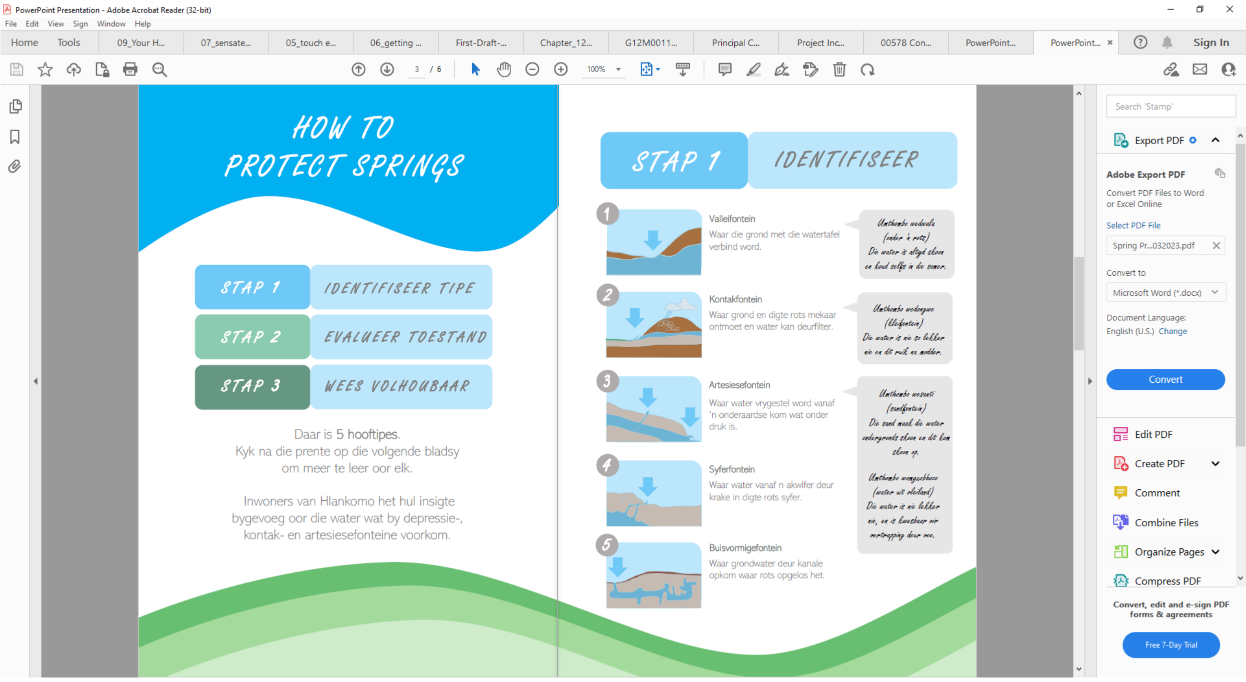
Impacts	Livestock grazing and vegetation removal:	Pollution near the spring:	Spring modification and water diversion:	Groundwater withdrawal:	Invasive Alien Species (IASs) and Soil erosion:	Percentage changed	Ecological condition
Questions to ask yourself:	*Are there animals grazing and trampling on the spring? Is there removal of vegetation around the spring?*	*Is there dumping or waste around the spring? Is there a toilet close to the spring?*	*Is the spring altered in any way for water collection and water is diverted by built infrastructure?*	*Is there a borehole near or around the spring? Is water being withdrawn for big farms?*	*Is the ground near and around the spring covered with alien vegetation? Is the vegetation indigenous?*	$(\frac{Total}{Max}) * 100$	
Score 1							
Score 2							
Score 3							
Score 4							
Score 5							
Score 6							
Score 7							
Maximum	5	5	5	5	5	25	

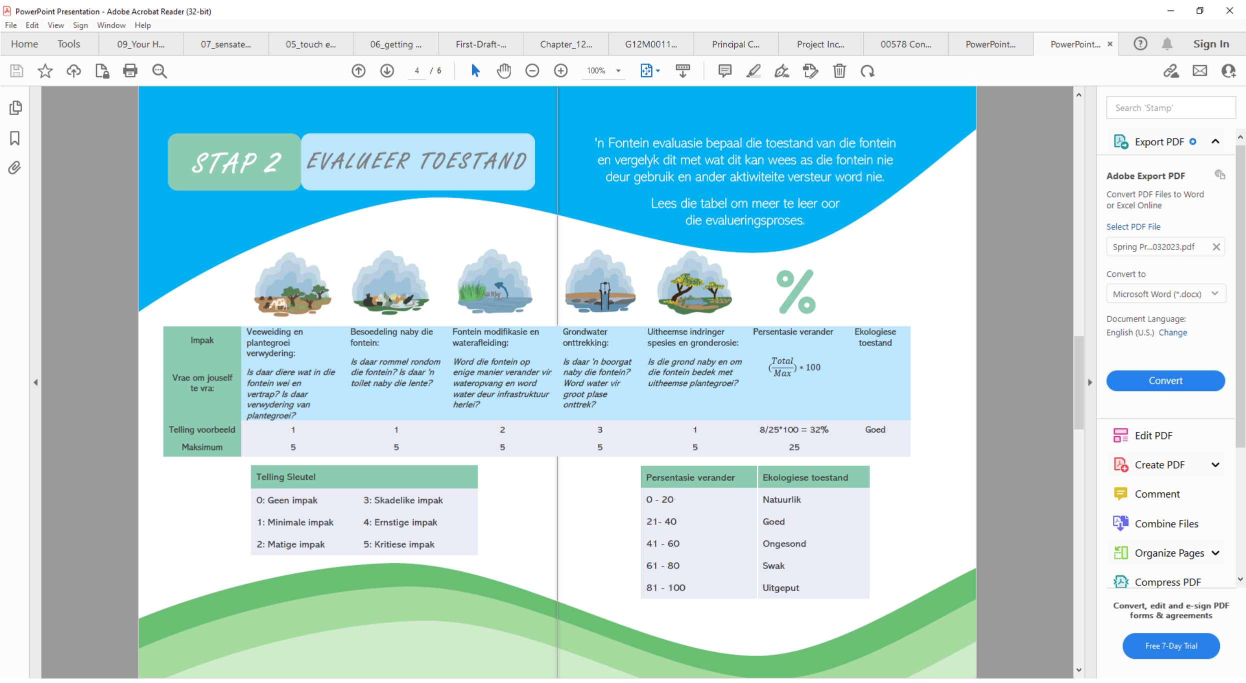
Make copies of this table if you need to assess more springs on a continuous basis.

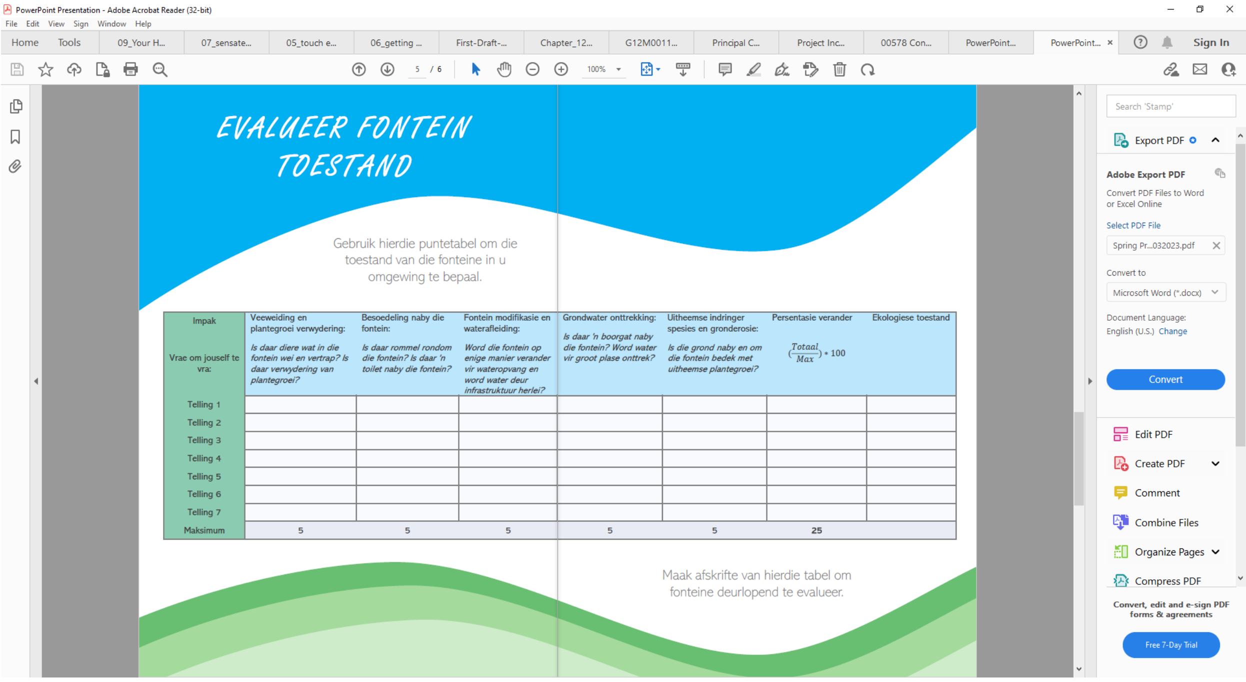



FONTEIN
BESKERMING
HULPBRON
Water uit die grond.
'n Plek wat altyd
nat is, waar ons
drinkwater kry.
Wanneer die grond
genoeg water gehad
het, stel dit die
oormaat vry.
'n Natuurlike plek
om water op te vang,
dit is nie 'n
rivier nie.
Baie gemeenskapswaterbronne word nie gemonitor nie. Dit is dus belangrik om hulpbronne te hê wat deur die gemeenskapslede gebruik kan word om die integriteit van water uit fonteine te bepaal. Hierdie Fontein Beskerming Hulpbron is die begin van hoe gemeenskappe hul vars water drink bronne op gesonde vlakke kan hou.
Die Fontein Beskerming Hulpbron
2023


WATER
RESEARCH
COMMISSION
Die Fontein Beskerming Hulpbron is 'n handige sakgids om ons te help om ons fonteine gesond en veilig te hou.
Dié hulpbron is geskep in vennootskap met die inwoners van Hlankomo, Makanda, die Waternavorsingskommissie en Rhodes Universiteit.
RHODES UNIVERSITY
Where leaders learn
THE IMPORTANCE OF
PROTECTING SPRINGS
"Ons kan nie sonder water lewe nie, dit is belangrik vir ons oorlewing."
"Fonteine is waar ons genesing kry. Ons is afhanklik daarvan."
"Ons het nie tenks of 'n ander plek om water van af op te vang nie."
- Inwoners van Hlankomo


PowerPoint Presentation - Adobe Acrobat Reader (32-bit)
HOW TO PROTECT SPRINGS
STAP 1
IDENTIFISEER TIPE
STAP 2
EVALUEER TOESTAND
STAP 3
WEES VOLHOUBAAR
Daar is 5 hooftipes.
Kyk na die prente op die volgende bladsy om meer te leer oor elk.
Inwoners van Hlankomo het hul insigte bygevoeg oor die water wat by depressie-, kontak- en artesiesefonteine voorkom.
STAP 1
IDENTIFISEER
1
Valleifontein
Waar die grond met die watertafel verbind word.
Umthombo wedwala (onder 'n rots) Die water is altyd skoon en koud selfs in die somer.
2
Kontakfontein
Waar grond en digte rots mekaar ontmoet en water kan deurfilter.
Umthombo wedongwe (kleifontein) Die water is nie so lekker nie en dit ruik na modder.
3
Artesiesefontein
Waar water vrygestel word vanaf 'n onderaardse kom wat onder druk is.
Umthombo wesanti (sandfontein) Die sand maak die water ondergronds skoon en dit kom skoon op.
4
Syferfontein
Waar water vanaf n akwifer deur krake in digte rots syfer.
Umthombo womgxobhozo (water uit vleiland) Die water is nie lekker nie, en is kwesbaar vir vertrapping deur vee.
5
Buisvormigefontein
Waar grondwater deur kanale opkom waar rots opgelos het.


PowerPoint Presentation - Adobe Acrobat Reader (32-bit)
STAP 2
EVALUEER TOESTAND
'n Fontein evaluasie bepaal die toestand van die fontein en vergelyk dit met wat dit kan wees as die fontein nie deur gebruik en ander aktiwiteite versteur word nie.
Lees die tabel om meer te leer oor die evalueringsproses.
Impak
Vrae om jouself te vra:
Veeweiding en plantegroei verwydering:
Is daar diere wat in die fontein wei en vertrap? Is daar verwydering van plantegroei?
Besoedeling naby die fontein:
Is daar rommel rondom die fontein? Is daar 'n toilet naby die lente?
Fontein modifikasie en waterafleiding:
Word die fontein op enige manier verander vir wateropvang en word water deur infrastruktuur herlei?
Grondwater onttrekking:
Is daar 'n boorgat naby die fontein? Word water vir groot plase onttrek?
Uitheemse indringer spesies en gronderosie:
Is die grond naby en om die fontein bedek met uitheemse plantegroei?
Persentasie verander
$(\frac{Total}{Max}) * 100$
Ekologiese toestand
Telling voorbeeld 1 1 2 3 1 8/25*100 = 32% Goed
Maksimum 5 5 5 5 5 25
Telling Sleutel
0: Geen impak
1: Minimale impak
2: Matige impak
3: Skadelike impak
4: Ernstige impak
5: Kritiese impak
Persentasie verander
Ekologiese toestand
0 - 20 Natuurlik
21- 40 Goed
41 - 60 Ongesond
61 - 80 Swak
81 - 100 Uitgeput

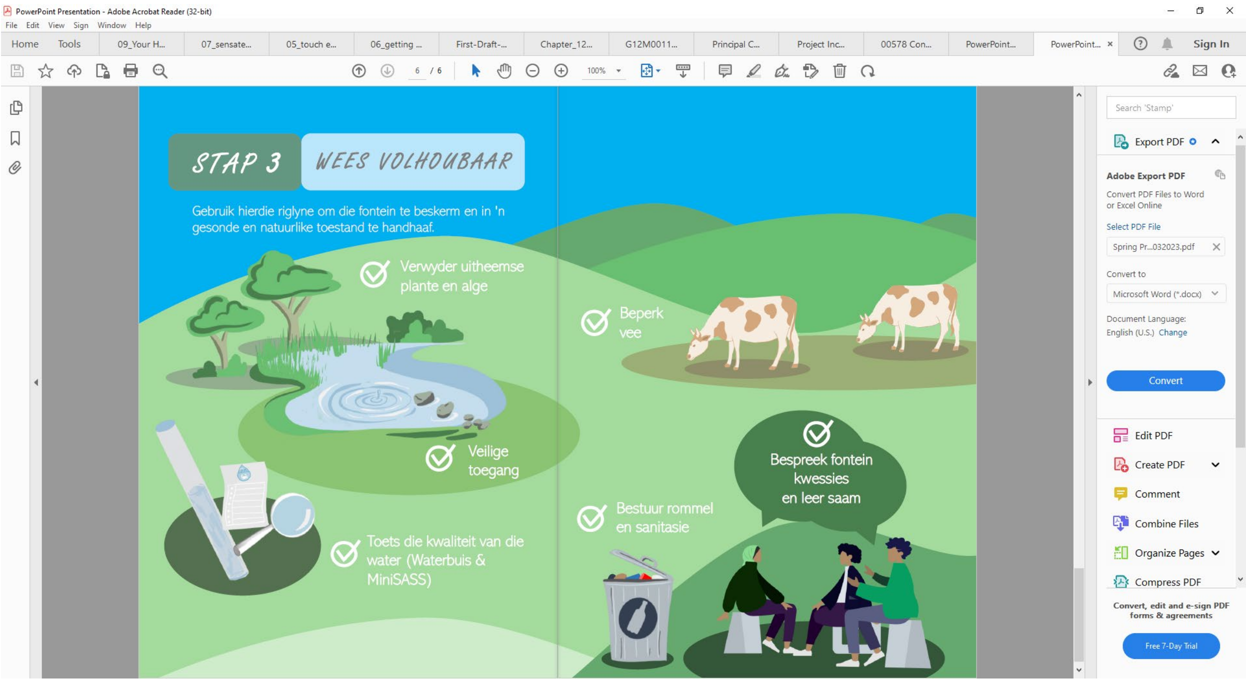


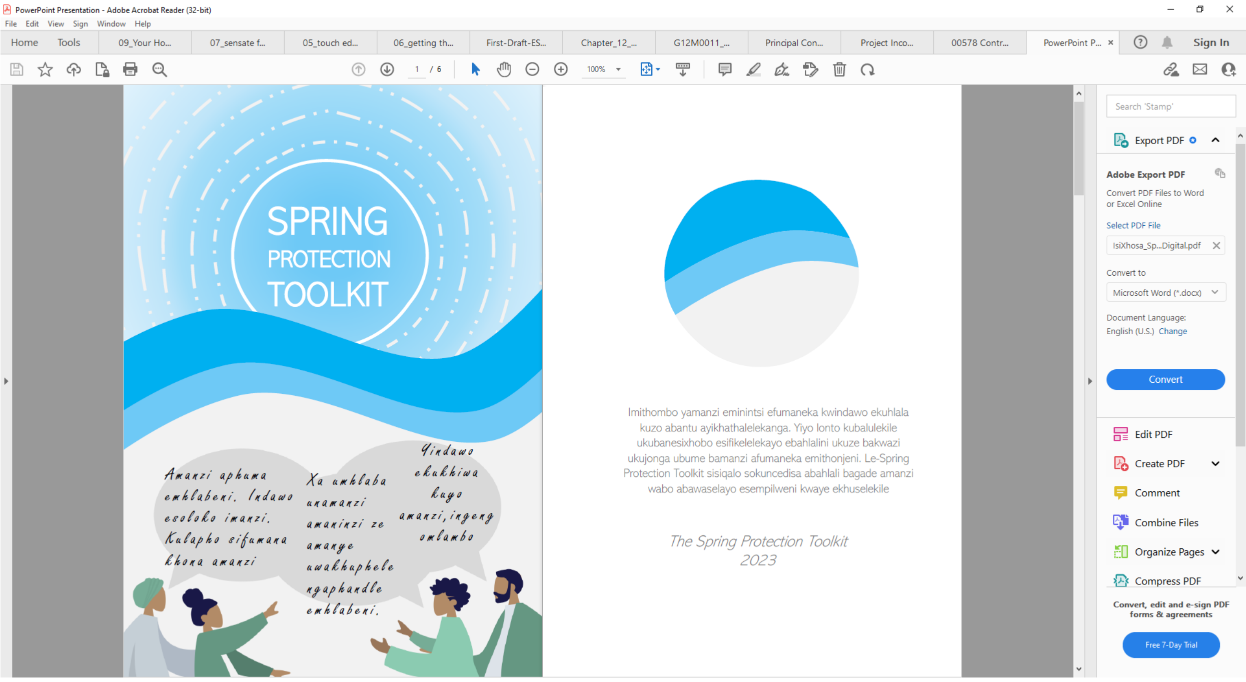
EVALUEER FONTEIN TOESTAND

Gebruik hierdie puntetabel om die toestand van die fonteine in u omgewing te bepaal.

Impak Vrae om jouself te vra:	Veeweiding en plantegroei verwydering: *Is daar diere wat in die fontein wei en vertrap? Is daar verwydering van plantegroei?*	Besoedeling naby die fontein: *Is daar rommel rondom die fontein? Is daar 'n toilet naby die fontein?*	Fontein modifikasie en waterafleiding: *Word die fontein op enige manier verander vir wateropvang en word water deur infrastruktuur herlei?*	Grondwater onttrekking: *Is daar 'n boorgat naby die fontein? Word water vir groot plase onttrek?*	Uitheemse indringer spesies en gronderosie: *Is die grond naby en om die fontein bedek met uitheemse plantegroei?*	Persentasie verander $(\frac{Totaal}{Max}) * 100$	Ekologiese toestand
Telling 1							
Telling 2							
Telling 3							
Telling 4							
Telling 5							
Telling 6							
Telling 7							
Maksimum	5	5	5	5	5	25	

Maak afskrifte van hierdie tabel om fonteine deurlopend te evalueer.




PowerPoint Presentation - Adobe Acrobat Reader (32-bit)
SPRING PROTECTION TOOLKIT
Amanzi aphuma emhlabeni. Indawo esoloko imanzi. Kulapho sifumana khona amanzi
Xa umhlaba unamanzi amaninzi ze amanye uwakhuphele ngaphandle emhlabeni.
Yindawo ekukhiwa kuyo amanzi, ingeng omlambo
Imithombo yamanzi eminintsi efumaneka kwindawo ekuhlala kuzo abantu ayikhathalelekanga. Yiyo lonto kubalulekile ukubanesixhobo esifikelelekayo ebahlalini ukuze bakwazi ukujonga ubume bamanzi afumaneka emithonjeni. Le-Spring Protection Toolkit sisiqalo sokuncedisa abahlali bagade amanzi wabo abawaselayo esempilweni kwaye ekhuselekile
The Spring Protection Toolkit 2023
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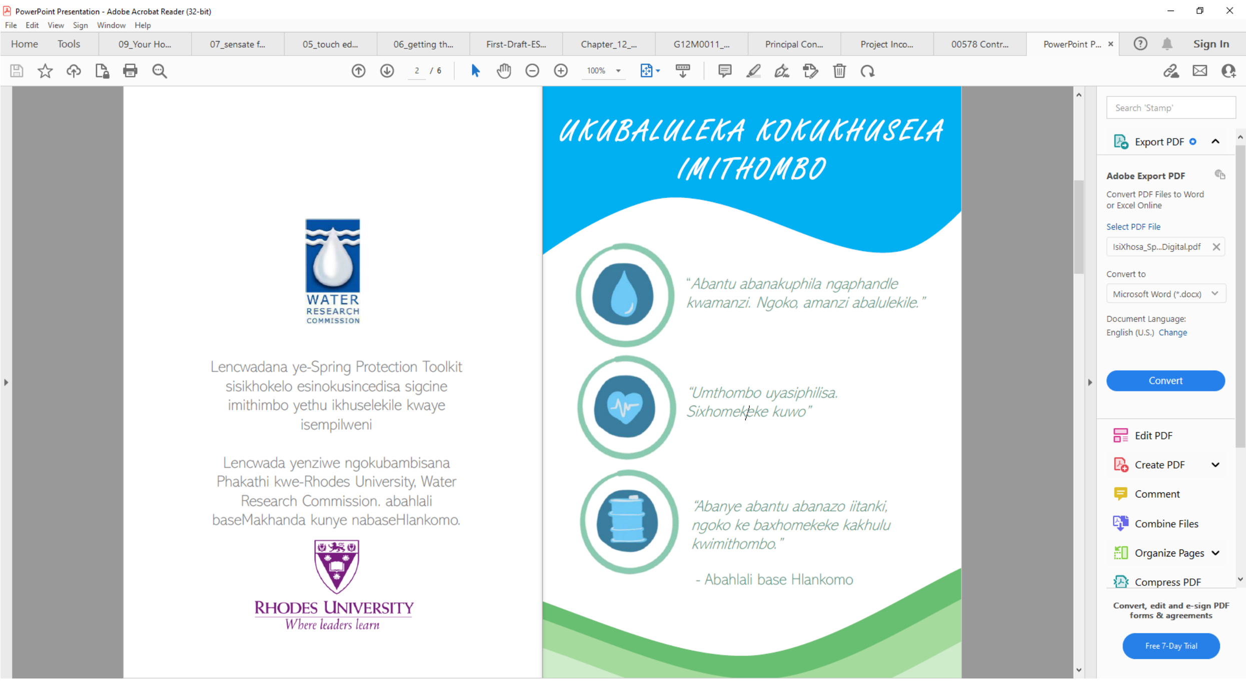
PowerPoint Presentation - Adobe Acrobat Reader (32-bit)
WATER RESEARCH COMMISSION
Lencwadana ye-Spring Protection Toolkit sisikhokelo esinokusincedisa sigcine imithimbo yethu ikhuselekile kwaye isempilweni
Lencwada yenziwe ngokubambisana Phakathi kwe-Rhodes University, Water Research Commission. abahlali baseMakhanda kunye nabaseHlankomo.
RHODES UNIVERSITY
Where leaders learn
UKUBALULEKA KOKUKHUSELA IMITHOMBO
"Abantu abanakuphila ngaphandle kwamanzi. Ngoko, amanzi abalulekile."
"Umthombo uyasiphilisa. Sixhomekeke kuwo"
"Abanye abantu abanazo iitanki, ngoko ke baxhomekeke kakhulu kwimithombo."
- Abahlali base Hlankomo
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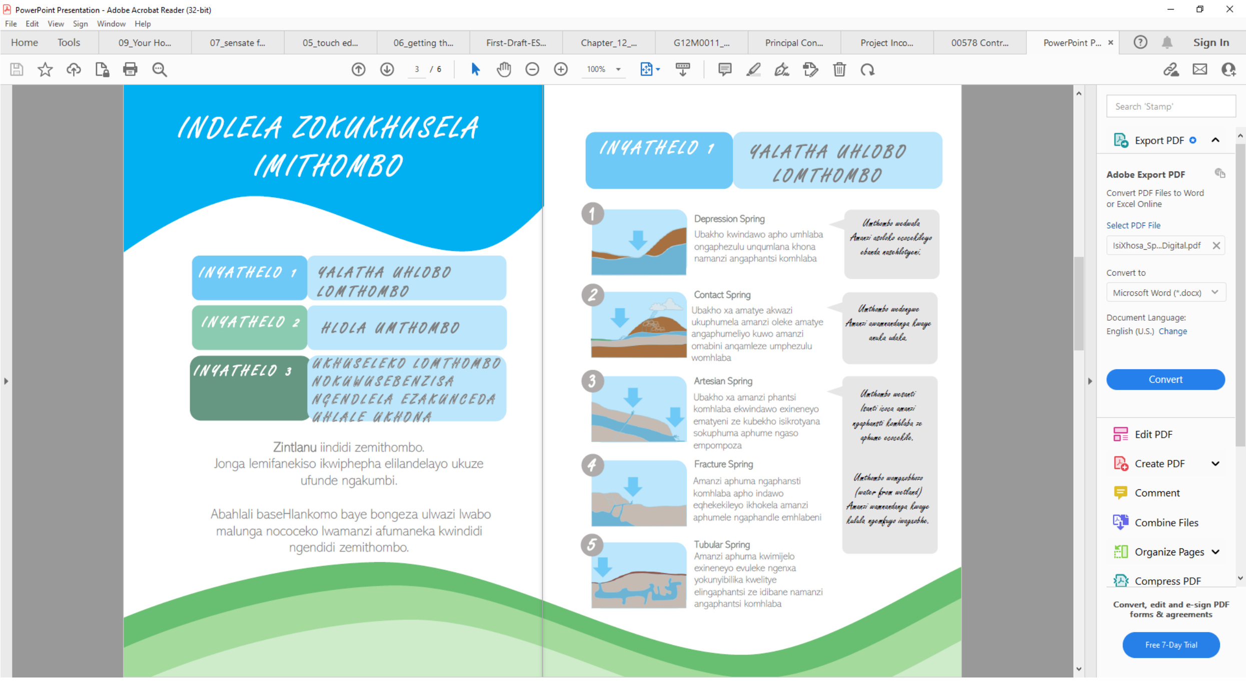
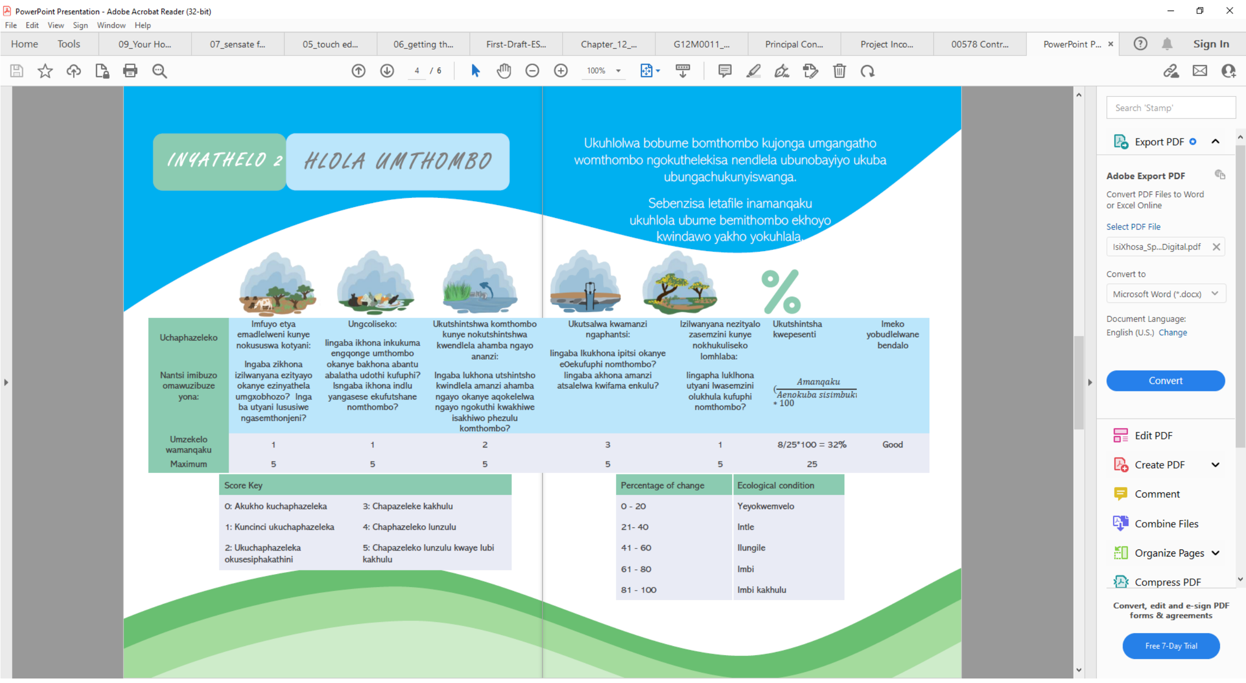
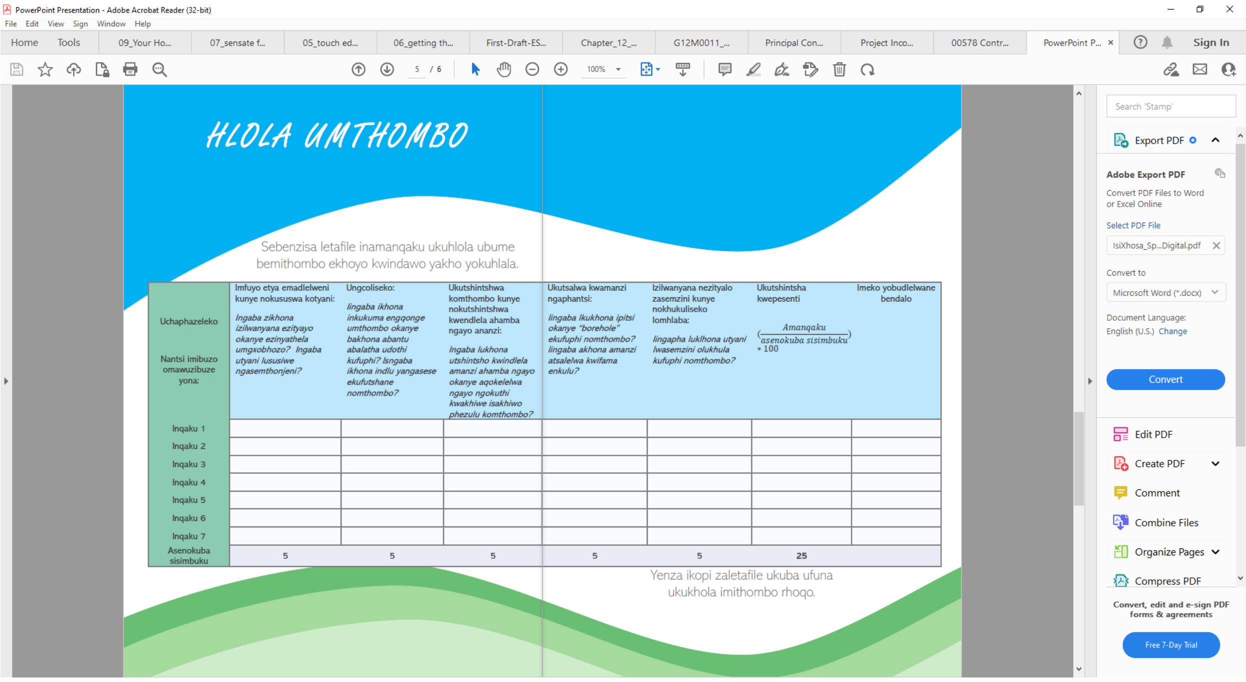

INDLELA ZOKUKHUSELA IMITHOMBO
INYATHELO 1
YALATHA UHLOBO LOMTHOMBO
INYATHELO 2
HLOLA UMTHOMBO
INYATHELO 3
UKHUSELEKO LOMTHOMBO NOKUWUSEBENZISA NGENDLELA EZAKUNCEDA UHLALE UKHONA
Zintlanu iindidi zemithombo.
Jonga lemifanekiso ikwiphepha elilandelayo ukuze ufunde ngakumbi.
Abahlali baseHlankomo baye bongeza ulwazi lwabo malunga nococeko lwamanzi afumaneka kwindidi ngendidi zemithombo.
INYATHELO 1
YALATHA UHLOBO LOMTHOMBO
1
Depression Spring
Ubakho kwindawo apho umhlaba ongaphezulu unqumlana khona namanzi angaphantsi komhlaba
Umthombo wedwala
Amanzi asoloko ecocekileyo ebanda nasehlotyeni.
2
Contact Spring
Ubakho xa amatye akwazi ukuphumela amanzi oleke amatye angaphumeliyo kuwo amanzi omabini anqamleze umphezulu womhlaba
Umthombo wedongwe
Amanzi awamnandanga kwaye anuka udaka.
3
Artesian Spring
Ubakho xa amanzi phantsi komhlaba ekwindawo exineneyo ematyeni ze kubekho isikrotyana sokuphuma aphume ngaso empompoza
Umthombo wesanti
Isanti icoca amanzi ngaphantsi komhlaba ze aphume ecocekile.
4
Fracture Spring
Amanzi aphuma ngaphansti komhlaba apho indawo eqhekekileyo ikhokela amanzi aphumele ngaphandle emhlabeni
Umthombo womgxobhozo
(water from wetland)
Amanzi wamnandanga kwaye kulula ngemfuyo iwagxobhe.
5
Tubular Spring
Amanzi aphuma kwimijelo exineneyo evuleke ngenxa yokunyibilika kwelitye elingaphantsi ze idibane namanzi angaphantsi komhlaba


INYATHELO 2
HLOLA UMTHOMBO
Ukuhlolwa bobume bomthombo kujonga umgangatho womthombo ngokuthelekisa nendlela ubunobayiyo ukuba ubungachukunyiswanga.
Sebenzisa letafile inamanqaku ukuhlola ubume bemithombo ekhoyo kwindawo yakho yokuhlala.
Uchaphazeleko
Nantsi imibuzo omawuzibuze yona:
Umzekelo wamanqaku
Maximum
Imfuyo etya emadlelweni kunye nokususwa kotyani:
Ingaba zikhona izilwanyana ezityayo okanye ezinyathela umgxobhozo? Inga ba utyani lususiwe ngasemthonjeni?
Ungcoliseko:
Iingaba ikhona inkukuma engqonge umthombo okanye bakhona abantu abalatha udothi kufuphi? Isngaba ikhona indlu yangasese ekufutshane nomthombo?
Ukutshintshwa komthombo kunye nokutshintshwa kwendlela ahamba ngayo ananzi:
Ingaba lukhona utshintsho kwindlela amanzi ahamba ngayo okanye aqokelelwa ngayo ngokuthi kwakhiwe isakhiwo phezulu komthombo?
Ukutsalwa kwamanzi ngaphantsi:
Iingaba Ikukhona ipitsi okanye eOekufuphi nomthombo? Iingaba akhona amanzi atsalelwa kwifama enkulu?
Izilwanyana nezityalo zasemzini kunye nokhukuliseko lomhlaba:
Iingapha luklhona utyani lwasemzini olukhula kufuphi nomthombo?
Ukutshintsha kwepesenti
(Amanqaku / Aenokuba sisimbuk * 100
Imeko yobudlelwane bendalo
1
5
1
5
2
5
3
5
1
5
8/25*100 = 32%
25
Good
Score Key
0: Akukho kuchaphazeleka
1: Kuncinci ukuchaphazeleka
2: Ukuchaphazeleka okusesiphakathini
3: Chapazeleke kakhulu
4: Chaphazeleko lunzulu
5: Chapazeleko lunzulu kwaye lubi kakhulu
Percentage of change
Ecological condition
0 - 20
Yeyokwemvelo
21- 40
Intle
41 - 60
Ilungile
61 - 80
Imbi
81 - 100
Imbi kakhulu



Uchaphazeleko Nantsi imibuzo omawuzibuze yona:	Imfuyo etya emadlelweni kunye nokususwa kotyani: *Ingaba zikhona izilwanyana ezityayo okanye ezinyathela umgxobhozo? Ingaba utyani lususiwe ngasemthonjeni?*	Ungcoliseko: *lingaba ikhona inkukuma engqonge umthombo okanye bakhona abantu abalatha udothi kufuphi? Isngaba ikhona indlu yangasese ekufutshane nomthombo?*	Ukutshintshwa komthombo kunye nokutshintshwa kwendlela ahamba ngayo ananzi: *Ingaba lukhona utshintsho kwindlela amanzi ahamba ngayo okanye aqokelelwa ngayo ngokuthi kwakhiwe isakhiwo phezulu komthombo?*	Ukutsalwa kwamanzi ngaphantsi: *lingaba lkukhona ipitsi okanye "borehole" ekufuphi nomthombo? lingaba akhona amanzi atsalelwa kwifama enkulu?*	Izilwanyana nezityalo zasemzini kunye nokhukuliseko lomhlaba: *lingapha luklhona utyani lwasemzini olukhula kufuphi nomthombo?*	Ukutshintsha kwepesenti $\left(\frac{Amanqaku}{asenokuba\ sisimbuku}\right) * 100$	Imeko yobudlelwane bendalo
Inqaku 1							
Inqaku 2							
Inqaku 3							
Inqaku 4							
Inqaku 5							
Inqaku 6							
Inqaku 7							
Asenokuba sisimbuku	5	5	5	5	5	25