PAPER 9

ADVANCING WATER SUPPLY AND SANITATION SYSTEM RESILIENCE THROUGH IMPROVED RISK MANAGEMENT APPROACHES

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ABSTRACT

In recent years there has been a significant increase in hazards to providing water and sanitation services within local municipalities, with several unexpected hazards materialising through shocks and stresses like the COVID pandemic, extreme weather events (droughts, heatwaves and floods) and the national energy crisis. The mushrooming of informal settlements and vandalism of infrastructure has been accelerated since the onset of the COVID pandemic and the rapid growth of the agricultural sector in rural towns. The recent drought conditions in Witzenberg Municipality contributed to a wildfire event that severely damaged raw water supply pipelines and the associated water treatment facility. When loadshedding resulted in twelve (12) hours per day of power outages, the operation of both water and sanitation systems were significantly affected, which took a heavy toll on operational staff for whom crisis management became the daily norm for weeks. Such shocks and stresses test the resilience of water systems to provide safe drinking-water whilst also protecting the environment. Risk management tools such as Water Safety Plans (WSP) and Wastewater Risk Abatement Plans (W_2RAP) are essential in understanding the impact of hazards on the municipal water supply and sanitation systems and enabling resiliency. Witzenberg Municipality, supported by Zutari, recently completed the review and updating of the municipality's risk management tools for all their water supply systems, and with a particular focus on climate change related risks.

The outcomes of the risk assessment and mitigation actions identified will be presented and will provide key insights to other municipalities facing similar challenges. Further, the paper will highlight:

1) the considerations and adaption of the nascent World Health Organization (WHO)/International Water Association (IWA) guidelines on Water Safety Plan (WSP) and Sanitation Safety Plan (SSP),
2) features of such plans that increase the utility and practicality of it for systems operators and mangers, and
3) lessons learnt that can be translated to other municipalities.

Keywords
Climate resilience; water safety plan; wastewater risk abatement plan

1. INTRODUCTION

South Africa, like many developing countries, faces significant challenges in the sustainable provision of adequate and safe water and sanitation services. It is well known that South Africa is facing a long-term security of water availability. Recent droughts and floods experienced in parts of the country have exacerbated the challenges that municipalities and water utilities face in delivering sustainable drinking water and sanitation services. Municipalities, however, struggle to interpret and incorporate climate data/information into their planning activities as in some cases data/information is not available at a local scale. Additionally, there is very little guidance on accessing, interpreting, and incorporating climate data/information in planning activities. Given the urgency of climate change impacts to the Western Cape region, this project was an ideal opportunity to test and implement an easy to use, robust methodology developed by the Water Research Commission (WRC) that can empower municipalities to take the necessary first steps to build climate resilience. This methodology helps municipalities (and other stakeholders) to access, analyse and interpret climate change related datasets to enable enhancement of risk management approaches (such as water safety plans (WSP) and wastewater risk abatement plans (W_2RAP)) currently utilised by municipalities) through introducing climate resilience aspects and thereby enabling a more holistic long-term planning approach.

2. RISK MANAGEMENT APPROACHES COMMONLY UTILISED FOR WATER AND SANITATION SYSTEMS

2.1 Water Safety Planning

A Water Safety Plan (WSP) is a systematic approach that comprehensively assesses and manages risks throughout the water supply system. The WSP process covers all aspects of the water supply system, from catchment to consumer, and was developed by the World Health Organization (WHO) and International Water Association (IWA). Since then, the WSP process has been well received by many countries and has been adopted and

FIGURE 1: *WHO/IWA/WRC WSP/W_2RAP/SSP manuals*

implemented at various levels in 93 countries around the world (WHO, 2017). In South Africa, the WSP process is a requirement of the Department of Water and Sanitation (DWS) Blue Drop Certification programme and is contained within both the Drinking Water Quality Framework and SANS 241 drinking-water quality standards.

2.2 Wastewater Risk Abatement Planning

A wastewater risk abatement plan (W2RAP) is a risk-based assessment that aims to identify wastewater related risks and ensures that effective plans are put in place to reduce the impact of these risks, thus ensuring that wastewater is adequately "collected, treated and discharged or reused" (vd Merwe-Botha and Manus, 2011). Simplistically, the W2RAP process could be considered like a WSP, but for wastewater. In South Africa, the W2RAP process is a requirement of the DWS Green Drop Certification programme (vd Merwe-Botha and Manus, 2011). There are three essential components to the W2RAP process including: (i) wastewater system assessment, (ii) risk assessment, and (iii) risk management.

There is a strong link to the WSP and W2RAP processes and they have similar steps in common.

2.3 Sanitation Safety Planning

In May 2015, WHO launched the Sanitation Safety Planning (SSP) manual. SSP is a step-by-step risk-based tool to ensure that sanitation systems are safety managed. As the sanitation sector moves towards "safely managed sanitation" under the SDGs, actors in faecal sludge management need to consider what "safely managed" means for service delivery model and how to incorporate this into daily operations with all actors along the sanitation chain. SSP assists users to systematically identify and manage health risk along the sanitation chain and prioritises system improvements and monitoring based on health risks. It provides assurance to authorities and the public on the safety of sanitation-related products and services based on sound management and monitoring processes. Importantly, SSP coordinates efforts of stakeholders along the sanitation chain.

NOTE: At the time of writing, Witzenberg have not yet completed the update of their wastewater risk abatement plans. The remainder of this paper will therefore focus on water safety planning aspects. Suffice to note that water safety planning, wastewater risk abatement planning and sanitation safety planning principles are very similar, and that the water supply and water safety planning experiences presented in this paper are also applicable to sanitation/wastewater services.

3. EVOLUTION OF THE WSP PROCESS

The WSP process has evolved since its inception in 2009. Initially, many practitioners only focused on water quality related issues, ignoring, for example, issues related to the quantity of water supplied or water security for an area. With time, some practitioners expanded their risk assessment to include these and other stresses or shocks to the water supply system. The WHO, IWA and other organizations also provided specific guidance including additional considerations related to, for example, climate resilience and equity.

3.1 Climate resilience considerations

In 2017, WHO and IWA released the guideline "*Climate-resilient water safety plans: Managing health risks associated with climate variability and change*" which placed a greater emphasis on ensuring that municipalities and water utilities consider and incorporate climate resilience into their WSP activities. The inclusion of climate resilience into the WSP process is to ensure continued sustainability of safe drinking water, under current and future climate conditions. Climate change is expected to introduce changes in temporal and spatial distribution of climate and weather-related events; as well as an increase in severe climate and weather-related events (such as floods, droughts, storms, etc.). This is expected to bring about challenges to water resources, as well as the ability of water utilities to provide adequate safe drinking water to consumers. Water scarce countries such as South Africa may be most affected as climate change will only worsen the current water scarcity issues. In the context of WSPs, the impacts from climate change may: (i) introduce new hazards to the system, and (ii) change the risk associated with pre-existing hazards (i.e. existing control measures may no longer be effective or change the likelihood or severity of the hazards). It is therefore essential that municipalities and water utilities in South Africa include climate resilience into their planning processes and prepare for such impacts.

There is also a need for the WSP (and W2RAP) processes to include climate resilience, as the uncertainty of climate change may result in systems being under- and/or over-capacitated and unable to respond effectively (e.g. to an increased/reduced hydraulic load; increased concentration of contaminants, etc.).

3.2 Enhancing water safety planning and climate resilience in South Africa

Through engagements with municipalities, it was noted that it is often challenging for municipalities to understand the relevance of climate data and information for planning their water and sanitation systems. Furthermore, some municipalities found it difficult to interpret the available information and incorporate the findings into their existing WSP (and W_2RAP) processes and day-to-day activities. This was either due to a lack of knowledge, expertise, or financial resources. Consequently, the WRC funded a project to develop a methodology that helps municipalities (and other water and sanitation sector stakeholders) to (i) interpret climate related data/information, and (ii) integrate climate change considerations into their existing WSPs/W_2RAPs.

The WRC methodology was based on the leading best practice methodology developed by the WHO and IWA, and which was amended to meet South African local conditions and experience. The methodology highlights the need to consider various sources of climate data and information, including (Damons *et al*, 2022):

- Working with stakeholders, expert groups to understand key climate risks
- Accessing existing climate reports (e.g. Climate Vulnerability Assessments)
- Working with existing web-based tools
- Accessing/analysing historical climate-related data

Most importantly, the methodology includes the provision of a detailed list of climate related data/information sources that municipalities can use to continue to refine their climate summaries or develop a climate summary for a different area. Ultimately, the methodology helps municipalities to draw basic climate impact conclusions, and then guides the user how to incorporate these findings into their water safety planning and wastewater risk abatement planning processes.

The inclusion of climate resilience into the WSP process is to ensure continued sustainability of safe drinking water, under current and future climate conditions. Climate change is expected to introduce changes in the temporal and spatial distribution of climate and weather-related events; as well as an increase in severe climate and weather-related events (such as floods, droughts, storms, etc.). This is expected to bring about challenges to water resources, as well as the ability of municipalities to provide adequate safe drinking water to consumers.

The process of incorporating climate resilience builds on seven (7) of the traditional 11 WSP modules. Modules 1 to 5, 8 and 9 have been identified as those that need to be revised to include consideration of the impact of climate change. When incorporating climate resilience into these modules, municipalities should consider which hazards and hazardous events are likely to worsen under the effects of climate change, and what climatic conditions are likely to cause them. This requires municipalities to source various datasets (e.g. rainfall, temperature), analyse and interpret the data, and importantly reach conclusions that allow appropriate action (Damons *et al*, 2022).

Importantly, the WRC study also emphasised that climate resilience needs to be built and coordinated at both the catchment and local government/water board levels to ensure adaptation measures for water and wastewater systems are effective and integrated (Damons *et al*, 2022). The study aimed to promote climate change resilient water services institutions and communities by increasing understanding of climate change and improving planning and co-ordination at local and catchment level, thereby facilitating implementation of required investments in climate change adaptation and contributing to the achievement of the Sustainable Development Goals (SDGs), particularly the specific goals of water (SDG6) and climate action (SDG13). Responding to climate change is also one of the key elements of the Department of Water and Sanitation National Water and Sanitation Master Plan (DWS, 2018). The study provided local government with access to easily interpretable climate information that can be used to improve their planning, and thereby facilitate increased local resilience through appropriate climate change adaptation investments.

3.3 WHO/IWA WSP manual (second edition)

The second edition of the WSP manual was released in 2023 and reflects the practical water safety planning experiences gained from around the globe. Water safety planning fundamentals remain, and the major changes include (WHO, 2023):

- Clarification on water reliability and water quantity issues
- Enhanced guidance on equity considerations
- Inclusion of aspects relating to water safety planning for climate resilience
- Greater emphasis on a progressive improvement approach to WSP development
- Expansion of the section on challenges in each module, reflecting key issues commonly encountered by water suppliers when developing and implementing WSPs, with addition of a section on practical solutions
- More emphasis on the sustained and effective implementation of water safety planning, through development of a 'water safety planning in action' concept (requiring continuous cycles of WSP development, operation, verification and review), and a greater focus on monitoring and other modules important for WSP implementation
- Inclusion of a toolbox section, which provides practical templates and tools to support completion of the modules by early-stage WSP practitioners

The manual emphasises that practitioners should use the WSP review process to progressively include the noted changes to their WSP processes and activities.

Use of effective risk management approaches such as WSP provides municipalities with a proactive, flexible and robust approach to assess and manage current and future risks (both climate and non-climate related).

4. WITZENBERG MUNICIPALITY: AN OVERVIEW

4.1 Background

Witzenberg Local Municipality (WLM) is a located about 150 kilometres North-East of Cape Town, in the Western Cape Province. The municipality has a population of approximately 167,258 consisting of 45,618 households of which approximately 53% are in urban settlements and the remaining in rural settlements. The Municipality includes five (5) towns, namely Ceres, Op-Die-Berg, Prince Alfred's Hamlet, Tulbagh and Wolseley, which are surrounded by agricultural activity in the rural areas within the municipal boundary. The Witzenberg Municipality is both the Water Services Authority (WSA) and Water Services Provider (WSP) within its municipal area.

There are five (5) distinct water supply and wastewater systems, each system centred around the five (5) towns, that delivery water and sanitation services in the municipal area. The source water for each water supply systems is local surface water resource(s) except for one system, whose source is groundwater.

4.2 Climate overview

According to the Köppen-Geiger climate classification most of Witzenberg experiences Mediterranean climate. Witzenberg experiences hot dry summers, and cool wet winters. Typical climate related hazards for Witzenberg include droughts, fires and floods.

Temperatures indicate an increasing trend for the Western Cape Province (Figure 3, top half). Increases over the past decade indicate an increase of about 1°C. Trends in ocean currents also indicates an increase with the Agulhas current temperature having increased by 1.5°C since 1980. Rainfall data for the Western Cape indicates a decrease in the number of rainfall days and that the rainy season is starting later each year (Figure 3,

FIGURE 2: *WHO/IWA CR-WSP, WRC Guideline, WSP version 2*

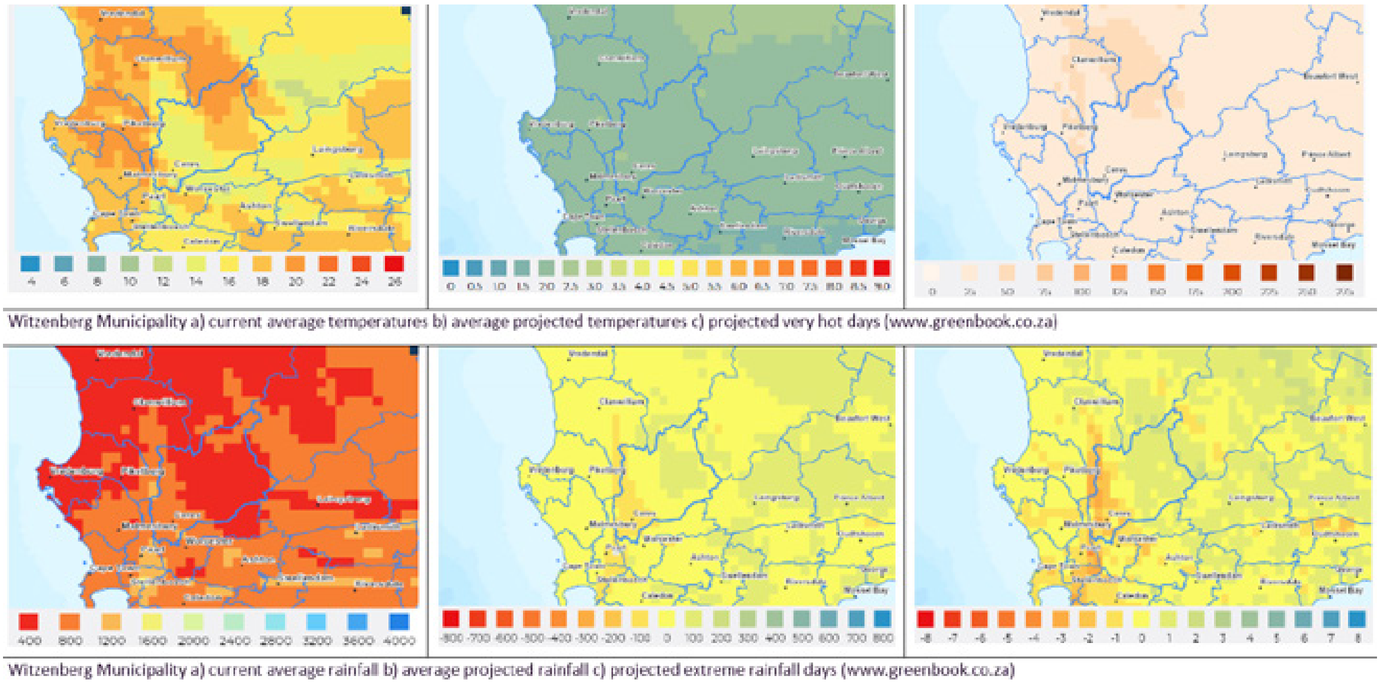


FIGURE 3: *Temperature and rainfall trends: Witzenberg*

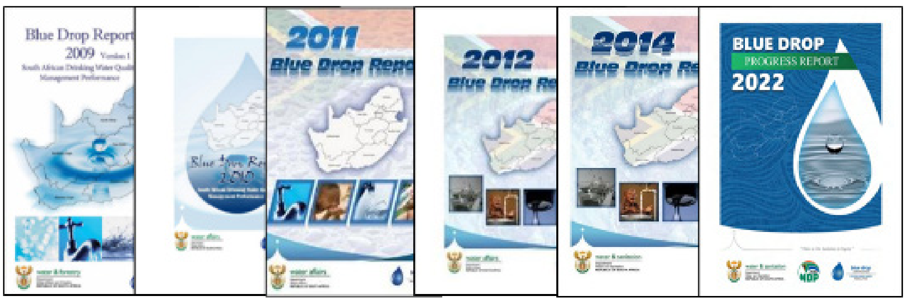
bottom half). Implications of the above is that there is increased risk of insufficient water being available for consumption.

Under the RCP4.5 scenario, temperature is expected to increase between 1.67°C – 2.26°C, whereas under the RCP8.5 scenario temperature is expected to increase between 2.19°C – 2.69°C. (***NOTE:*** RCP4.5 represents a scenario whereby greenhouse gas emissions have stabilized before 2100, while RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.) Under both RCP4.5 and RCP8.5 scenarios, rainfall is projected to decrease. These changes are expected to be well out of range of present-day climate variability. The major implication of the above is there will be decreased water availability. Other implications include the increased occurrence of wild fires.

In terms of adapting for climate change, Witzenberg water systems will therefore need to be more robust. Increased skills will be required from water managers and long-term water projections are required. Increased variability in the climate and frequency of extreme events, as well as increased temperature and wind could have an impact on water sources, particularly surface waters. Almost all the bulk water supplied

TABLE 1: *Witzenberg Local Municipality Overall Blue Drop Status*

Year	Blue Drop Score	Comments
2009	62.4%	No Blue Drops achieved.
2010	93.3%	Blue Drop achieved for 2 out of 5 systems (Ceres and Prince Alfred Hamlet)
2011	97.56%	Blue Drop achieved for 5 out of 5 systems (Ceres, Op Die Berg, Prince Alfred Hamlet, Tulbagh and Wolseley)
2012	97.63%	Blue Drop achieved for 5 out of 5 systems (Ceres, Op Die Berg, Prince Alfred Hamlet, Tulbagh and Wolseley)
2014	95.77%	Blue Drop achieved for 5 out of 5 systems (Ceres, Op Die Berg, Prince Alfred Hamlet, Tulbagh and Wolseley)
2022	*Blue Drop Risk Rating (BDRR) 25.3%*	*All 5 water supply systems (Ceres, Op die Berg, Prince Alfred Hamlet, Tulbagh and Wolseley) fell into the Low-Risk category.* **NOTE:** In 2022, and after a long hiatus, Blue Drop was re-introduced. For the 2022 round, a Blue Drop Risk Rating (BDRR) score was developed. This is different to a Blue Drop score and should not be compared with one another. In essence, a low percentage score indicates a low risk (i.e. desirable).



to the towns in Witzenberg Municipality's Management Area is from surface water sources, with limited use of groundwater resources.

It is necessary for WSAs to develop climate response strategies and include these in their WSDPs, implement WC/WDM and reduce levels of non-revenue water. Water-related climate change adaptation and mitigation planning should be considered through water safety planning and incorporated into all WSDPs and IDPs. The implementation of WC/WDM is a critical element of adapting to climate change.

Witzenberg Municipality has a defined role to play in the mitigation of and adaptation to the impacts of climate change. The Western Cape is particularly vulnerable to climate change and the hotter drier conditions predicted for the West Coast could have far reaching impacts. The Municipality's local economy is driven by agriculture and there is concern about the negative impacts of climate change on the agriculture sector which will turn impact on the local economy.

4.3 Department of Water and Sanitation: Blue Drop Certification

Witzenberg has been one of the top Blue Drop Certification performers since the programme's inception in 2008. The Blue Drop results indicate a proactive municipality with an impressive Blue Drop Certification performance record.

The most recent Blue Drop Progress Report (DWS, 2022) notes that, in general, WSP status in South Africa is currently far from ideal with only 9% of supply systems having excellent WSPs in place (i.e. comprehensive WSPs with all required components), and 81% of supply systems having inadequate or no WSPs in place. The average compliance for WSP is 24.5%, indicating a poor understanding of the WSP process amongst WSAs. This indicates that although South Africa might have quickly adopted development of WSP (through, for example, inclusion thereof in SANS 241 and the DWS Blue Drop Certification process), the lack of monitoring by the Regulator for a

FIGURE 4: *WSP a continuous and iterative process (WHO, 2023)*

lengthy period resulted in the WSP process not being prioritised, and resulting in a gradual deterioration in the quality of the WSP processes implemented.

5. APPROACH AND METHODOLOGY

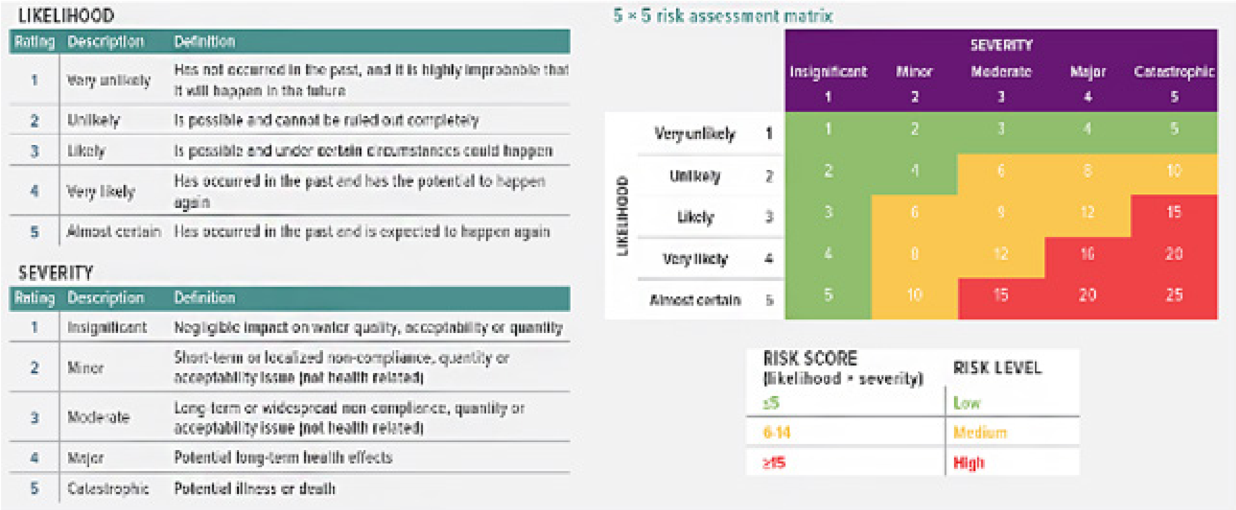
The recent iteration of the WSP not only aimed to incorporate climate resilience considerations, but also served to develop and document the WSP for each system anew. This necessitated that the approach taken by the project team address nine (9) of the ten (10) WSP modules, in line with the latest edition of the manual (as illustrated in Figure 4).

The methodology to develop the WSPs for the various water supply systems is briefly described below:

- Gather and review data/information and previous WSPs to understand the various water supply systems and key issues of concern.
- Conduct site assessments to:
  - Identify and confirm the respective components of the water supply systems
  - Identify and list all known hazards and hazardous events
  - Interview operational staff to determine operational constraints, if any
- Conduct a risk assessment, using the WHO risk management matrix, to:
  - Determine the raw risk without any control measures
  - Determine if any control measures are in place and the effectiveness thereof
  - Determine the residual risk with existing control measures in place
  - Recommend measures to improve the status quo
- Draft the WSP with consideration of the following sections (as per the proposed 10 modules defined in the *WHO/IWA WSP Manual – 2nd Edition*):
  1. Assembling the WSP Team
  2. Describing the system
  3. Identifying hazards and hazardous events
  4. Validating existing control measures and assessing risks
  5. Planning for improvement
  6. Monitoring control measures
  7. Verifying the effectiveness of water safety planning
  8. Strengthening management procedures
  9. Strengthening WSP supporting programmes
  10. Reviewing and updating the WSP
- Workshop the draft WSP with the WSP team
- Finalize the WSP for implementation

An overview of the methodology taken to complete the different modules is noted below:

- **Module 1**: To ensure that all aspects are considered and addressed, it was necessary to identify and assemble a multidisciplinary team with a thorough understanding of WLM's drinking water systems. The WSP team consisted of WLM's Water and Sanitation department's managerial team and operational staff for each system, which forms the core implementation team for each WSP. The core implementation team was supported by an extended team of water engineers, who were tasked to develop and document the new WSP for each system.
- **Module 2**: Reviewing the existing WSPs provided the team with a head start in describing the system concisely. However, site visits and validation from the core implementation team was needed to ensure that the system description was appropriately accurate.
- **Module 3**: Considering the similarity between all five (5) systems, a master schedule of hazards and corresponding hazardous events was developed (including climate change related hazards).
- **Module 4**: The site inspection to each system formed the basis for



LIKELIHOOD

Rating	Description	Definition
1	Very unlikely	Has not occurred in the past, and it is highly improbable that it will happen in the future
2	Unlikely	Is possible and cannot be ruled out completely
3	Likely	Is possible and under certain circumstances could happen
4	Very likely	Has occurred in the past and has the potential to happen again
5	Almost certain	Has occurred in the past and is expected to happen again

SEVERITY

Rating	Description	Definition
1	Insignificant	Negligible impact on water quality, acceptability or quantity
2	Minor	Short-term or localized non-compliance, quantity or acceptability issue (not health related)
3	Moderate	Long-term or widespread non-compliance, quantity or acceptability issue (not health related)
4	Major	Potential long-term health effects
5	Catastrophic	Potential illness or death

5 × 5 risk assessment matrix

LIKELIHOOD		SEVERITY: Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Very unlikely	1	1	2	3	4	5
Unlikely	2	2	4	6	8	10
Likely	3	3	6	9	12	15
Very likely	4	4	8	12	16	20
Almost certain	5	5	10	15	20	25

RISK SCORE (likelihood × severity)	RISK LEVEL
≤5	Low
6-14	Medium
≥15	High

FIGURE 5: *Risk matrix and associated definitions (WHO, 2023)*

identifying existing control measures, validating their effectiveness, identifying were gaps existing and assessing risks. The WSP team adopted a dual-stage risk assessment approach which considers both "raw risk" (sometimes referred to as the "inherent risk" – the risk before including consideration of the impact of the existing control measures) and "residual risk" (with consideration of the impact of existing control measures). That is, not all existing control measures are 100% effective, and additional control measures may need to be identified and implemented. The risk assessment was conducted by the WSP team and considered information gathered from municipal records, staff and stakeholder engagements and site inspections, and aimed to identify what could go wrong and where it could go wrong. The risk associated with each hazardous event is determined based on the product of likelihood and consequence (or severity). This assists in determining which risks are more important and which are less important. The WSP team has adopted a 5x5 risk matrix to determine WSS risks, as illustrated by Figure 5.

- **Module 5**: An improvement/upgrade plan is needed where additional control measures are required to address remaining significant risks. A significant amount of funds and time might be required to successfully implement appropriate control measures, and it is therefore sometimes more appropriate to consider stepwise implementation to enable incremental improvement (i.e., what is required for phase 1, what is required for phase 2, etc.). This required the WSP team to also consider and implement low/no cost control measures in the short-term while the necessary funds are secured to enable implementation of long-term control measures. A participatory process was followed between the core WSP implementation team and the extended WSP team to ensure that the appropriate improvement plan was developed per each water supply system.
- **Module 6**: Considering that WLM had in place a mature operational monitoring plan, the task required of the extended WSP team was in the main to identify any areas of improvement.
- **Module 7**: The overall effectiveness of the WSP was verified by assessing the adequacy of its compliance monitoring programme, auditing of the WSPs and consumer satisfaction surveys.
- **Module 8**: Considering that WLM had in place a mature management protocols in place, the task required of the extended WSP team was in the main to identify any areas of improvement.
- **Module 9**: Considering that WLM had successfully implemented water safety planning, the task required of the extended WSP team was in the main to identify any areas of improvement.

6. DISCUSSION

The table that follows provides a summary of the "raw risks" (the risk before including consideration of the impact of the existing control measures) and "residual risk" (with consideration of the impact of existing control measures) for each of the 5 water supply systems. The 2-step risk assessment approach highlighted the importance and efficacy of existing control measures, and emphasised the importance of ensuring that these existing control measures are in place and remain functional.

Both climate related risks and non-climate related risks were identified through the WSP process. In summary, key issues of concern in the Witzenberg water supply systems are noted below:

TABLE 2: *Raw and residual risks identified for the 5 water supply systems*

System	Raw Risks			Residual Risks		
	Low	Medium	High	Low	Medium	High
Ceres	101	20	5	110	15	1
Op die Berg	100	23	3	113	13	0
Prince Alfred Hamlet	97	24	5	107	18	1
Tulbagh	99	20	7	108	17	1
Wolseley	98	24	4	112	14	0

- The Western Cape drought had highlighted certain deficiencies in **water availability** in the municipality. Subsequently, Witzenberg investigated additional and alternative water sources and various demand side activities to ensure an adequate supply of water (including for example, new and diversified water sources, improved non-revenue water management, water restrictions, consumer education).
- **Vandalism** is one of the biggest challenges, breaking down the system and limiting efficient operation, degrading water quality and decreasing water quantity.
- At the time of the site inspections, there was a supply shortage of chlorine gas to disinfect the drinking-water. Although Witzenberg were able to immediately implement short-term disinfection using granulated chlorine, this was a **manual disinfection** process with limitations related to adequate control and dosing accuracy. The incident identified an area of weakness that needed to be urgently addressed to avoid long-term water quality issues.
- Although the municipality had put some measures in place to circumvent **loadshedding** issues, the municipality was not prepared for the scale of loadshedding, and this put excessive strain on both water and sanitation infrastructure and the ability of water and sanitation systems in the municipality to successfully operate. In the short-term, the municipality were not able to address shortcomings at all water and sanitation pump stations, water treatment works, etc. and had to prioritise providing back-up power to infrastructure having a direct and immediate impact on the health of the community or the environment.
- The above three key challenges have a negative impact on **staffing**, as the systems consequently need to be manually operated by the staff. This could lead to staff fatigue and burnout.

The above findings highlight that significant water supply (and sanitation) challenges exist even at municipalities such as Witzenberg that are considered well-resourced and well managed. By way of example, when loadshedding resulted in twelve (12) hours per day of power outages, the operation of both water and sanitation systems were significantly affected, which took a heavy toll on operational staff for whom crisis management became the daily norm for weeks. Such shocks and stresses test the resilience of water systems to provide safe drinking-water whilst also protecting the environment. The frequency of water supply system stresses and shocks (due to climate change and other unforeseen incidents/events such as pandemics, loss of consistent electricity supply, cyber-terrorism, etc.) are likely to increase, and municipalities need to be able to readily adapt to changing circumstance. It is anticipated that incorporating resilience thinking, "worst-case scenario" planning, and "out-of-the box" thinking will help municipalities to identify and address possible water and sanitation system vulnerabilities. These approaches are likely to play a key role in ensuring an appropriate mindset and a state of readiness to address the challenges of the changing world. This will help to continue to close the gap (and not widen the gap) and reaching a desirable state of water and sanitation service delivery.

7. CONCLUSIONS

This project has helped to promote climate change resilience in the municipality and associated communities by increasing the understanding of climate change and improving planning and co-ordination at both local and catchment level. This will help with facilitating implementation of required investments in climate change adaptation and contribute to the achievement of the Sustainable Development Goals (SDGs). The updating of water safety plans in Witzenberg has:

- Created improved awareness of the requirements for incorporating climate variability and change data/information into existing risk management approaches
- Emphasised the importance of and requirements for effective water quality monitoring and management
- Driven improvement in water safety planning processes and activities (and will also assist the W_2RAP process)
- Enabled improved planning and early intervention in areas facing immediate public health threats
- Provided strategic data and information related to the sustainability of water (and sanitation) services

Considering the success of this project, Witzenberg Municipality is eager to also review and update their W_2RAPs to incorporate climate resilience and other relevant stresses and shocks.

This work has stressed the need for an enhancement to current risk-based management approaches and methodologies, and feedback received by on the ground municipal teams to the initiative has been positive. Of importance to note, however, is that Witzenberg, despite being a relatively well resourced and well managed municipality, is not immune to challenges and weaknesses. The municipality has (i) leadership and management buy-in, commitment and support, (ii) are systematically and continuously addressing key issues of concern, and (iii) are proactively planning improvements. A combination of these elements is essential to help ensure that Witzenberg's water and sanitation systems remain successful now and in the future.

Improved risk management approaches alone cannot solve issues, and several key factors are also required, including *inter alia* awareness and prioritisation (from Mayor to Technician), on-going communications between role players, operational test equipment and proficiency therewith, water quality data collection and assessment, regular on the ground checks and assessments, and ongoing support and interaction. Witzenberg's Blue Drop performance over the years is an indication of a good system that is well supported. Witzenberg has not, however, been immune to recent extraordinary shocks and stresses such as COVID-19 and loadshedding, and these events have highlighted additional vulnerabilities and risks that the municipality might not ordinarily have considered within their risk management plans (e.g. staff fatigue due to manual operations because of vandalism). Indeed, the world is a different place, and municipalities need to be able to quickly adapt to changing circumstance. This is not always easy within the municipal environment.

Using a risk management approach, municipalities (and water utilities) are made more aware of issues of concern which therefore assists with directing limited resources to areas of need. Thus by using the approach, significant improvements in both water quantity and quality can be achieved despite little or no additional capacity. By simply using a structured risk-based management approach and working "smarter" with better information, municipalities (and water utilities) become more effective and thus make better use of the capacity it already has. Using these risk management approaches to their full potential will empower municipalities to master water supply and sanitation services.

Finally, climate resilience needs to be built and coordinated at both the catchment and local government/water board levels to ensure adaptation measures for water supply and sanitation systems are effective and integrated. The project has successfully improved understanding, planning and co-operation at both municipal and catchment level, but also highlighted the need for improved alignment, collaboration and communication between Witzenberg Municipality and the CMA. Therefore, although good progress has been made, there is still much work to do.

8. RECOMMENDATIONS

Through this project, Witzenberg have gained access to easily interpretable climate information that can be used to improve their planning, and thereby facilitate increased local resilience through appropriate climate change adaptation investments. It is recommended that municipalities, CMAs/WMAs and other sector stakeholders use the WHO/IWA and WRC approach and methodology to improve their risk management and resilience planning and help contribute to catchment wide strategies and plans.

By showcasing the achievements of Witzenberg, we hope to encourage and inspire other municipalities to do similar.

Finally, the water and sanitation risk management approaches described in this paper can easily be adopted or adapted to other municipal services including energy/electricity, solid waste or roads and transport, thus allowing for more municipal-wide resilient planning. These approaches will help municipalities to be more adaptable to the stresses and shocks of a changing world.

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