

**Resilience Community Wastewater Management Systems (CWMS)
through Data-Driven Awareness and Connectivity for Regional SA
Communities**

Final Project Report

Prepared for

Local Government Association South Australia

Oct 2025

Special Thanks To

**GTS Group
Northern & Yorke Local Government Association
City of Onkaparinga
District Council of Mount Remarkable**

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*This project has been supported by the Community Wastewater Innovation Fund
administered by the Local Government Association of SA*

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Executive Summary

Community Wastewater Management Systems (CWMS), which service approximately 80% of South Australian water entities outside of state service areas, are typically owned and managed by local councils. These systems, which manage sewage from on-site septic tanks or full sewer connections, face significant challenges driven by climate change and operational constraints

Key Challenges for CWMS

1. **Climate and Vulnerability:** Regional SA faces increasing risks from climate change, including intense heatwaves, bushfires, and droughts, making CWMS assets more exposed and vulnerable.
2. **Capacity and Load Issues:**
 - Population growth increases the volume of sewage requiring treatment.
 - Stormwater intrusion (illegal or unknown connections of rainwater/runoff) is a growing problem that significantly contributes to load issues, causing system overload, pipe blockages, overflows, and increased operational costs.
3. **Operational and Asset Management:** Maintenance is predominantly reactive, meaning operators only become aware of issues—like system overloads or service interruptions—when they are reported or equipment fails. Many CWMS assets are aging, and their conditions and locations (e.g. underground pipelines) are poorly understood, hindering effective asset management.
4. **Financial and Workforce Constraints:** Many councils undercharge for CWMS services, resulting in a funding shortfall. They often lack comprehensive asset management plans and long-term financial strategies specific to CWMS. Additionally, attracting and retaining qualified staff is a struggle, leading to reliance on contractors or poor system management.

Data Management and Regulatory Compliance

CWMS are overseen by multiple government agencies (SA Health, OTR, EPA, ESCOSA, etc.) and must comply with several acts and regulations (e.g., *Water Industry Act 2012*, *Public Health (Wastewater) Regulations 2013*).

- **National Performance Reporting (NPR):** Starting July 1, 2025, all councils operating CWMS must publicly report on their performance under the NPR Framework, requiring reporting on up to 60 indicators for benchmarking service quality and financial performance.
- **Multiple Reporting:** Council resources are stretched by duplicate reporting to individual agencies, as each has different data requirements that often overlap in scope.
- **SWIM System:** The Office of the Technical Regulator (OTR) is implementing the Statewide Water Information Management (SWIM) system starting with the 2024-25 reporting year. This online portal streamlines reporting by coordinating data requests into a single annual submission sent to the OTR, SA Health, NPR, ESCOSA, and ABS. The system includes built-in Quality Assurance and Quality Control (QA/QC) features to improve data accuracy.

Advanced Analytics for Resilience and Efficiency

The core focus for improving CWMS resilience is the better utilisation of collected data through advanced analytics.

- **Prediction and Optimisation:** Advanced analytics, including machine learning, can convert data into insights for real-time process monitoring, early anomaly detection, and predictive maintenance. For example, data on water level, flow, conductivity, and temperature can be used to detect and predict issues like stormwater intrusion and sewer chokes or overflows.
- **Corrosion Management:** Modelling using inputs like Hydrogen Sulfide concentration and pH can predict sewer corrosion rates and service life for proactive intervention.
- **Climate Resilience Planning:** A project is developing a data sharing framework and online portal to cross-link high-value data from disparate sources to build prediction models for climate resilience. This allows councils to:
 - Prioritise infrastructure upgrades (e.g., backflow prevention) by linking asset location, overflow incidents, and rainfall data.
 - Inform decisions on expanding recycled water schemes based on effluent volumes, reuse rates, and seasonal demand.
 - Evaluate GHG emissions and energy usage to achieve cost-effective service and align with SA's net zero targets.

By adopting digital data catalogues and an advanced analytics portal, councils can transform traditional reporting into a strategic tool to improve asset management, prioritise investments, and enhance climate adaptation capabilities in regional SA.

Introduction

Water industry entities in South Australia (SA) provide sewerage services to the community; about 80% of these water entities provide the service via Community Wastewater Management systems (CWMS), formerly known as Septic Tank Effluent Disposal Schemes (STEDS). These schemes typically consist of a gravity drain collection network connecting to customers' on-site septic tanks, which conveys effluent to a treatment system and disposal facility. CWMS can also be full sewer connections to households. The typical wastewater treatment approaches of CWMS in SA are lagoon-based systems, sequencing batch Reactor, and intermittently decant extended aeration. CWMS are typically owned, operated and managed by local councils as the water industry entities for the country towns not serviced by the state government (OTR, 2024). There are 175 CWMS across 50 councils in SA, with most owned and operated by the local councils. Water entities hold 'major', 'intermediate', and 'minor' licenses for providing sewerage services, based on the number of connections. A 'major' water entity serves more than 50,000 connections; an 'intermediate' water entity serves between 501 and 50,000 connections; a 'minor' water entity serves up to and including 500 connections. Most local councils hold either an 'intermediate' or 'minor' license.

Regional SA is facing complex challenges imposed by climate change, including an increase in intense and prolonged heatwaves, bushfires, and droughts caused by severe weather events. More CWMS assets are likely to be exposed and vulnerable, with increasing social and economic costs. To minimise these impacts and reduce risks, having high-quality, accessible and shared information is essential for regional councils, communities, and businesses to enable informed decisions on adaptation plans and mitigation actions and to collaborate with stakeholders.

Over the past decade, recurring drought conditions driven by climate change, along with periods of restricted access to potable water, have heightened community awareness of wastewater recycling (Loipersberger, M. 2020). This shift has led to the use of treated wastewater as an alternative water source, changing its role from disposal to reuse.

Many councils use water from the CWMS to irrigate parklands, golf courses, crops and other green spaces. For example, the Mount Barker District Council operates the largest council-run wastewater treatment plant and recycled water scheme in SA, targeting 100% reuse of treated wastewater. The cost of using recycled water is generally higher than that of potable water. Additionally, the treatment and operational costs for producing recycled water are significant. There is also a risk that recycled water may go unused during rainy seasons. However, with the increasing frequency and duration of droughts and the environmental benefits, more councils are recognising the value of recycled water.

Research Methodology

To understand the CWMS data management and analytics requirements, this research project consists of three stages based on two concurrent case studies with the City of Onkaparinga and the District Council of Mount Remarkable. The use of these case studies is critical because they:

- **Provide Contextual Depth:** They allow for an in-depth, real-life exploration of complex CWMS management and data challenges, which cannot be captured through theoretical study alone. By focusing on two distinct councils, the research gains a nuanced understanding of varying operational contexts, data maturity levels, and specific community needs.
- **Ensure Practical Relevance:** They ground the research in the practical realities of CWMS management in SA regional communities, ensuring that the developed data solutions (the visualisation portal and data catalogue) are fit-for-purpose, scalable, and directly address the on-the-ground challenges of climate resilience and improved management.
- **Validate Requirements:** The case studies serve as the primary mechanism for requirements gathering and validation for the entire project. Insights from the field visits and interviews directly inform the design of the later technical stages.

Research Stages

1. **Stage 1: Field visit and Case study interviews:** To confirm CWMS reporting requirements and understand the current use and specific data pain-points for SA regional communities. This qualitative and contextual stage is the foundation of the research. It provides the rich qualitative data (the 'how' and 'why') necessary to define the scope and function of the technological solutions developed in Stages 2 and 3.
2. **Stage 2: Develop a data visualisation and advanced analytics portal integrating locally collected CWMS data and external data (BOM weather data):** To demonstrate the value of applying advanced analytics in CWMS and exploring the potential use of data analytics to improve CWMS management for climate resilience. The case study data and identified needs are used to populate and pilot the portal. This practical application provides a proof-of-concept, allowing for real-time testing and stakeholder engagement with council staff. The case studies transform the portal from a generic tool into a contextually validated, high-value asset for the CWMS sector.
3. **Stage 3: Develop a digital CWMS data catalogue/metadata framework:** To capture CWMS data collection and analytics requirements for improved CWMS management in the future. The framework developed is based on the findings within the two case study environments. This ensures the resulting catalogue/framework is not abstract, but a practical standard capable of being implemented by diverse regional councils.

Findings and Discussion

CWMS Data Reporting Requirements

According to the case studies with the City of Onkaparinga and the District Council of Mount Remarkable, CWMS must comply with legislation relating to the operation of its CWMS, including *Public Health (Wastewater) Regulations 2013*, *Local Government Act 1999*, *Water Industry Act 2012*, and *Environmental Protection (EPA) Act 1993*. Oversight and enforcement are provided by several government agencies: SA Health, the Minister for Local Government, Essential Services Commission of SA (ESCOSA), the Office of the Technical Regulator (the OTR), and the EPA. Each of the agencies has a specific aspect to focus. SA Health oversees public health, approves new schemes and sets operational standards. Minister for Local Government focus on financial and asset management. ESCOSA regulates pricing and financial sustainability. OTR ensures safety and reliable operation as well as plumbing and technical compliance. EPA issues environmental licences. Additionally, the Local Government Association of SA (LGA) supports councils with scheme construction and technical advice. Beyond regulatory compliance, councils must meet various reporting obligations, including annual reporting, internal audits, and incident reporting to different agencies. While these reporting requirements often overlap, they differ in scope and data requirements.

Many of the local councils face a range of management challenges and issues in operating CWMS. These challenges span financial sustainability (Comrie 2022), asset management (AGD 2023), regulatory compliance, and technical capacity.

The common practice of operation and maintenance of CWMS assets is predominantly reactive, which creates challenges for operators as they can struggle with system overload such as service interruptions. Operators typically become aware of issues only when the problems are reported or equipment fails, leading to a heavy focus on troubleshooting rather than proactive maintenance (Cao et al., 2024). Advanced data analytics enable the vast amount of generated data from various datasets to be rapidly converted into informative insights, facilitate real-time process monitoring, early detection of anomalies and potential issues, and predictive analytics that can enhance decision-making and reduce downtime, costs and increase asset performance (Farooq et al., 2025). Data accuracy is critical for maintaining and operating the CWMS assets.

Many councils are facing increasing capacity and load issues with CWMS due to population growth and more intense rainfall events. Population growth has increased the amount of sewage and effluent requiring treatment. Stormwater intrusion is a significant issue contributing to the CWMS load problems for many councils. Stormwater intrusion occurs when rainwater or runoff from roofs, gardens, roads, or tanks is illegally connected to CWMS or septic systems. This can cause issues with systems, increased operational costs for handling increased volumes (van Rooyen et al., 2010), pipe blockages, and system overflows. For instance, Stormwater intrusion,

including illegally plumbed stormwater systems, is a growing issue in Port Augusta City Council.

CWMS schemes rely on a user-pays charging model to recover the costs of operation, maintenance, and replacement. This presents a challenge for communities with limited capacity to pay. Many local councils undercharge for CWMS service and have a smaller number of connections compared to the metropolitan area, leading to a funding shortfall (LGA 2023). In addition, many councils lack comprehensive asset management plans and long-term financial strategies specific to CWMS (LGA 2025). Some councils fail to align CWMS asset plans with broader municipal strategies, resulting in fragmented management. Many CWMS assets are aging and require upgrade or expansion to meet service requirements. The conditions and even the location of aging infrastructure are poorly understood. Better operation and maintenance, and asset management are needed. Relationships between maintenance, performance, condition assessment and asset management are poorly understood (LGA 2022). Some local councils also struggle to attract and retain qualified staff. Due to a lack of in-house expertise in managing CWMS, some councils rely on contractors for support, while others face operational challenges due to poor system management.

In addition, SA will become hotter and drier with more frequent and intense extreme weather events such as droughts and floods, which add a dimension of the complex challenges to managing CWMS. More CWMS assets are likely to be exposed to these risks and vulnerable.

SA Health primarily ensures public health protection and compliance with the South Australian Public Health Act 2011 and the Wastewater Regulations 2013. SA Health collects data on system design and infrastructure, effluent quality and monitoring, applications and approvals, and wastewater and recycled water incidents. EPA primarily collects data related to CWMS on environmental performance, pollution control, and licensing compliance. ESCOSA requires annual reporting on service performance, financial metrics and customer outcomes, depending on their licensee category. Without a centralised data collection system, the councils must report data separately to individual agencies. This often leads to duplicate reporting, which adds unnecessary burden to already limited resources.

In addition to the above reporting requirements, starting 1 July 2025, all councils in SA that own and operate CWMS are required to report publicly on their performance under the National Performance Reporting (NPR) Framework, as part of commitments under the National Water Initiative. The NPR Framework is managed by the Bureau of Meteorology and aims to benchmark pricing, service quality, environmental performance, and customer outcomes for water and wastewater service providers. Previously, only larger utilities participated. Now, smaller entities with fewer than 10,000 connections must report on a subset of indicators tailored to their scale (BOM 2024). Councils may need to report up to 60 indicators, including customer complaints,

service reliability, tariffs and costs, and environmental discharges, relevant to the service they provide. Government agencies are aware of the challenges in various reporting processes due to the lack of a systematic approach and understaffing in some councils. therefore, the OTR is coordinating this rollout and assisting them with the reporting in SA.

From the 2024-25 reporting year, the OTR will use the Statewide Water Information Management (SWIM) system for state and federal water industry reporting requirements in SA. The OTR supports the use of the SWIM annual online reporting portal for water industry entities in SA. The SWIM system allows entities to centrally report data to the OTR, SA Health Wastewater, NPR, ESCOSA and the Australian Bureau of Statistics (ABS) Water Supply and Sewerage Services Survey. The difference between having and not having a centralised data reporting system, such as SWIM, is illustrated in Figures 1 and 2. The SWIM system was developed by Qldwater (The Queensland Water Directorate), the central advisory and advocacy body within Queensland's water industry. SWIM has been used in Queensland by service providers for reporting their state and federal data since 2007-8. However, it costs the OTR approximately \$100,000 per year to use the SWIM system.

The SWIM online portal will provide the following benefits to water industry entities in SA:

- Streamlined reporting of state and federal reporting requirements.
- Simplified data submission by coordinating data requests from the various agencies into a single data request.
- Single annual submission with SWIM and is then sent by SWIM to the right department, at the right time and in the correct format.
- Up-to-date reporting requirements, with automatic updates for changes in indicators or definitions.
- Built-in Quality Assurance and Quality Control features to improve data quality.

Currently, apart from regulatory compliance reporting, there is no requirement for data sharing with other stakeholders. Improving online access to valuable information, including scientific and technical information, can help them better connect with and take advantage of opportunities for future-proofing land use, infrastructure, asset management and urban development projects.

Previously, data reporting was conducted using more conventional methods such as forms or spreadsheets. This made it challenging to verify the completeness and accuracy of submitted data. Some missing data or incorrect data were found, as some councils experienced issues such as faulty meters, a lack of meters, or incomplete records. While councils are encouraged to address these issues, penalties are rarely applied. A centralised data collection system can identify unusual data by comparing it with previously reported values. This enables water entities to verify the accuracy of their submissions and correct any discrepancies.

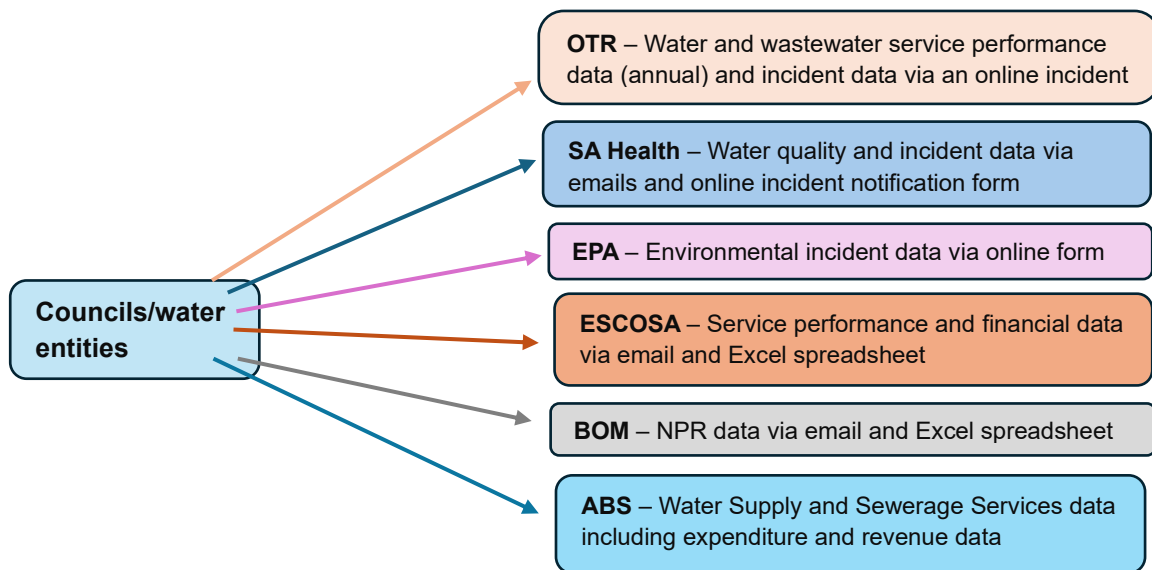


Figure 1: Data reporting of councils to various departments without SWIM system.

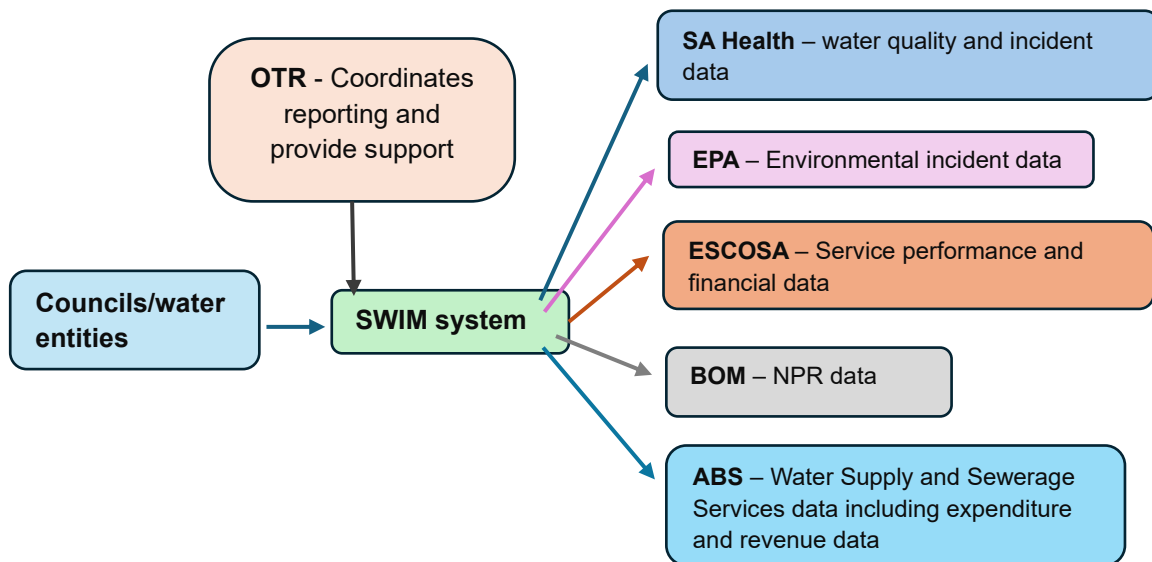


Figure 2: Current Data reporting of councils to various departments via the SWIM system.

CWMS Data Visualisation and Advanced Analytics Portal

In addition to the reporting requirements, the utilisation of advanced analytics in the CWMS space is found to be limited based on the case studies. However, the literature studies suggest that by combining data from various sources and utilising techniques such as machine learning and predictive analytics, CWMS can be managed more efficiently and effectively. Some examples of related studies (e.g. Stormwater intrusion, Sewer corrosion, carbon emissions and Energy Management) are discussed below.

Stormwater intrusion, also called rainfall-induced inflow or stormwater ingress, occurs when stormwater or surface runoff enters the sewer system directly through improper or unauthorised connections. It describes the overall problem of stormwater entering sewer infrastructure. Stormwater intrusion can be caused by sewer leakage, especially in low-lying areas; it can also be generated by intentional or unknown connections of stormwater to the sewer system (Ohlin Saletti 2021). In some older urban areas of Australia, combined sewer systems that transport both wastewater and stormwater are the only available infrastructure, yet these are not common in regional SA. Unknown connections occur when stormwater or drainage water from public and private areas is discharged into the sewer system, but the connections are forgotten, unintentional, or made without authorisation.

There are common approaches to detect stormwater intrusion into the sewer to better manage and reduce the ingress. For initial screening of stormwater intrusion, manhole inspections are commonly used to observe water entry during or after rain events to identify improper connections. Smoke testing, employed by some councils, involves flushing non-toxic and odourless smoke into the system to detect breaks, cracks, pipe defects and illegal stormwater connections. If smoke escapes from inappropriate locations such as roof drains and yards, it indicates stormwater intrusion. Dye testing is another method used to verify suspected stormwater connections by introducing dye into stormwater systems or surface drains (Beheshti et al., 2025). Its appearance in the sewer confirms a connection. Both smoke testing and dye testing are inexpensive and relatively simple methods, but they are not highly accurate and can be labour-intensive. CCTV pipe inspections is often used by water utilities with robotic cameras to travel through sewer lines and record detailed footage of pipe conditions.

Bechet et al. (2020) used deep-learning algorithms to code CCTV inspection videos of sewers in Victoria to automatically identify defects from inspection footage and the algorithm was significantly more accurate than the operator at grading the pipes, with an accuracy between 76.3-79.8% against 48.5-52.2% for the operator. CCTV inspections can be effective for identifying structural issues and more accurate intrusion points (Ohlin Saletti 2021), but it can be expensive and time-consuming to interpret results.

For continuous monitoring, flow meters or level sensors are used to detect real-time anomalies and identify potential stormwater intrusion. Collected flow data is analysed to assess the severity of ingress in each monitored catchment. Rainfall data is often overlaid with flow data to distinguish between direct stormwater ingress and actual wastewater inflow. For example, a study by van Rooyen et al. (2010) showed that stormwater intrusion was associated with periods of heavy rainfall. Ge et al. (2024a) developed a time-series reconstruction model using simulated data, including rainfall-induced inflow, pumping station operation and hydraulic, for wet/dry weather scenarios based on a real sewer system. The developed model was applied to hourly flow data collected over five months from a real-life application from the inlet of a wastewater treatment plant. It has successfully determined wet or dry conditions based on anomaly detections for stormwater intrusion. However, confirming the exact locations

of stormwater intrusion requires additional information, such as the age and type of pipes and other infrastructure.

Flow meters or level meters can be integrated with Geographic Information Systems (GIS) to map problem areas and create detailed profiles of network performance. Integrating these methods helps identify the root causes of increased flows and supports prioritising corrective measures (Najafi et al., 2025). These systems can analyse trends in water levels to identify potential stormwater intrusion and even predict future issues.

Despite their effectiveness, some researchers argue that flow rate-based methods require continuous monitoring using flow meters, which can be costly and prone to fouling (Ge et al., 2024b). In contrast, conductivity and temperature, as simple water quality parameters, are more easily measurable with cost-effective and reliable sensors. Detecting stormwater intrusion can be challenging, especially when overflow occurs simultaneously. However, studies have shown that stormwater intrusion can be analysed using simple parameters like conductivity, combined with data analysis. Ge et al. (2024b) used a Prophet-model-based analytic algorithm to reconstruct the temperature and conductivity profiles of base wastewater flow from measured time series data in two monitored catchments for a small real sewer based on 5 months of hourly data. The data used is a combination of real data from two catchments in an Australian city and simulated data to accommodate a wide range of conditions. These reconstructed profiles were incorporated into mass and energy balance equations to estimate inflow. This method shows promise for accurately identifying stormwater intrusion locations. Advanced techniques, including Fast Fourier Transform, were applied to analyse variations in data collected at 10-minute intervals over approximately one year. This included flow rate, water level, conductivity, and rainfall data. The analysis successfully identified stormwater intrusion during three distinct rainfall events (Zhang et al., 2018).

Smart monitoring technologies have emerged as powerful tools for managing stormwater intrusion into sewer systems. Online monitoring of wastewater quality parameters, when combined with advanced data analytics, including artificial intelligence, machine learning, genetic algorithms, and neural networks, can significantly enhance the identification of stormwater intrusion points (Moradi et al., 2025; Najafi et al., 2021; Wang et al., 2024). It enables accurate tracking of load changes due to population growth and seasonal variation, and helps identify areas that experience increased inflow during wetter months. Ultrasonic level sensors were installed in a manhole within a smaller reticulation network in Adelaide by SA Water. These sensors measured water depth at 5-minute intervals over a year and automatically transmitted the data to an analytics platform to an alarm dashboard. The system analysed the durations that the water level remains irregularly high to effectively detect possible chokes and overflow events before they occur (Do et al., 2023). This early detection of choke events enabled proactive maintenance scheduling and prevented overflows. The combination of sensors and analytics that detect

anomalies in the sewer system helps raise alarms and allows timely warnings, giving crews enough time to deploy necessary measures to prevent overflows. These technologies provide deeper insights into sewer flow dynamics and support targeted remediation efforts, particularly in areas experiencing significant inflow within mini catchments. By integrating smart monitoring with predictive analytics, utilities can support informed investment decisions, prioritise upgrades, and improve system resilience.

Sewer corrosion becomes increasingly important in CWMS management. The common detection methods for sewer corrosion include pH monitoring, Hydrogen Sulfide (H_2S) monitoring, and condition assessment through visual inspections and imaging (Wells and Melchers 2015). The pH of the sewer surface is a key indicator. Corrosion tends to accelerate when pH drops below 6 (Keller et al., 2013). Monitoring pH over time helps track the transition from abiotic to microbial corrosion phases. H_2S concentration in the sewer headspace is strongly correlated with corrosion severity. H_2S Sensors are used to detect the chemical levels continuously. Advanced analytics have been applied in various studies, particularly in Australia, to predict sewer corrosion for targeted interventions and proactive maintenance. The most commonly used inputs for modelling sewer corrosion are H_2S , relative humidity, and temperature, while the most common outputs are corrosion rate and corrosion depth (Nashat et al., 2025). A study compares multiple modelling approaches, including multiple linear regression, artificial neural networks, and adaptive neuro-fuzzy inference systems, using lab data from laboratory chambers simulating sewer conditions to predict corrosion initiation time and rate based on environmental inputs. The study showed that using the H_2S concentration as a single input, all three data-driven models can reasonably predict the sewer service life (Li et al., 2019).

Councils are not currently required by law to report their carbon emissions; however, mandatory climate-related disclosures are planned for the future, and many councils participate in the voluntary Net Zero Accelerate Program led by LGA SA to prepare for these future obligations and address climate risk (LGA and DEA, 2024). SA carbon emission targets include achieving a 50% emission reduction by 2030 compared to 2005 levels and net zero emissions by 2050. Data related to wastewater, including inflow, volume, biogas production, chemical oxygen demand, total Kjeldahl nitrogen, weight of biosolids, electricity consumption, and volume of recycled water, is needed for carbon emission reporting. These metrics contribute to Scope 1 (direct emissions), and Scope 2 emissions (indirect emissions from purchased electricity), and increasingly, Scope 3 emissions (indirect emissions from supply chains and services) are being considered. Early reporting enables councils to identify cost-saving opportunities, improve infrastructure planning, and align with both state and national climate goals. Councils are encouraged to adopt greenhouse gas calculators and emissions inventories to support consistent and transparent reporting.

Energy management is also a critical component of CWMS asset management due to the significant electricity consumption associated with pump stations, aeration

systems, and mechanical treatment processes. Asset management plans of councils incorporate energy management as it is a fundamental aspect of managing CWMS infrastructure sustainably and cost-effectively. Energy costs represent a substantial portion of CWMS operating expenses, making energy management strategies for assets like pumps and treatment plants essential to achieving cost-effective service delivery and long-term financial sustainability. Monitoring and optimising energy use not only reduces operational costs but also supports council sustainability goals and contributes to SA's net zero emissions targets. Councils are encouraged to integrate energy data into lifecycle costing, use SCADA systems or smart meters for real-time monitoring, and explore renewable energy options such as solar installations or biogas recovery (LGA 2025). Integrating energy performance data into CWMS asset plans enables proactive maintenance by identifying inefficiencies or abnormal energy usage that may signal equipment wear or failure, allowing timely interventions before costly breakdowns occur. It also supports informed infrastructure upgrades by highlighting underperforming assets and guiding investment decisions based on energy efficiency and lifecycle costs.

There are some data analytics products on the market but most of them are costly and too difficult to maintain for many water utilities. A platform that offers instant access to critical data is what operators and planners need, such as allowing forecasting overflow times during pump failures (McVey et al., 2025).

Regional SA Councils must ensure their community wastewater infrastructure/asset management is carried out efficiently and effectively to deliver their required service levels. A large volume of data is being collected for CWMS asset planning and operations. However, most of the data has not been fully utilised, let alone cross-linked for analytics purposes. This project provides mechanisms to create linkages between disparate high-value data for advanced analytics, including focusing on climate resilience, risk management and preventative CWMS asset maintenance. This project developed a data and information sharing framework and an online portal. With better data management and data analysis using the portal, councils can use their collected CWMS-related data to inform decisions at both community and council levels for climate-resilient planning and adaptation. Councils can use the developed tool to benchmark CWMS performance and prioritise investment options, and share best practices across regions. For instance, the combination of data from CWMS asset locations, pipeline capacity, overflow incidents and rainfall data is used to identify flood-prone areas where CWMS infrastructure is vulnerable. Councils can prioritise upgrades, such as backflow prevention and pump station elevation, and integrate this into stormwater and climate adaptation plans. Data on effluent volumes, reuse rates, seasonal demand, and treatment capacity can be used to determine if expanding the recycled water scheme is needed for irrigation or firefighting to reduce the reliance on potable water during droughts. A case study has been selected to build a demo portal for visualising information with advanced analytics across assets and climate change to improve the asset planning and maintenance program.

Based on the case study findings and literature review, an advanced analytics proof-of-concept demonstration portal (see below) has been developed to support prediction model building for climate resilience.

url: <https://data-visualisation.cwms.dns-cloud.net/>

user: admin

pass: O%>Ze\$mQj9D=?&Dd2y_OBMSK

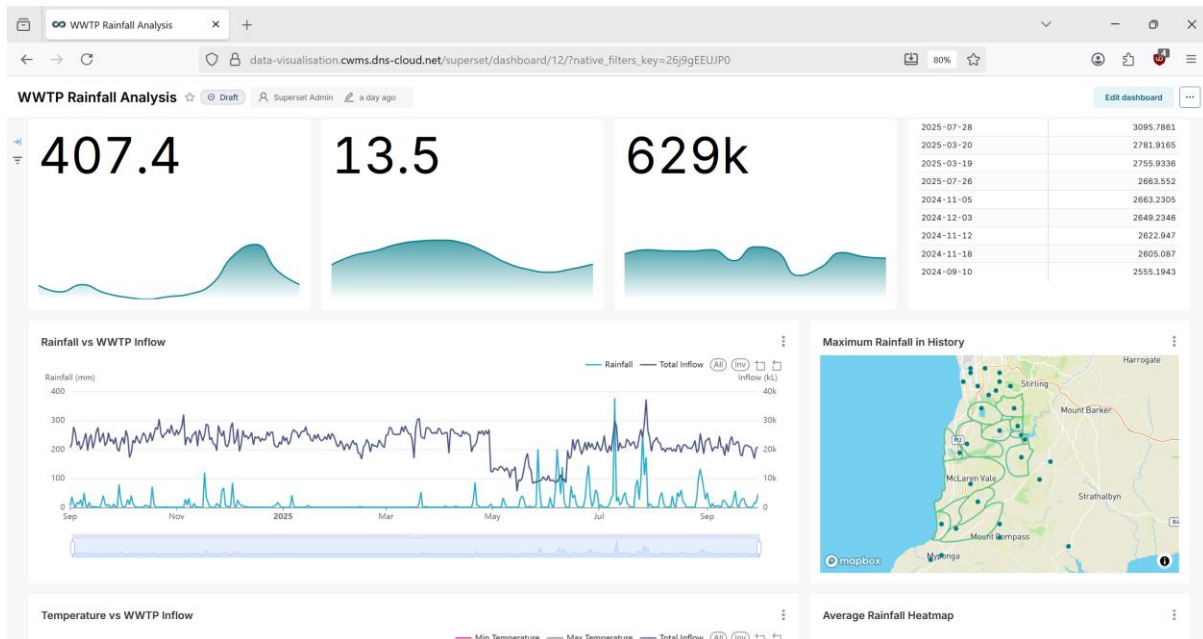


Figure 3: Rainfall and CWMS flow analysis – Selected Onkaparinga CWMS facilities

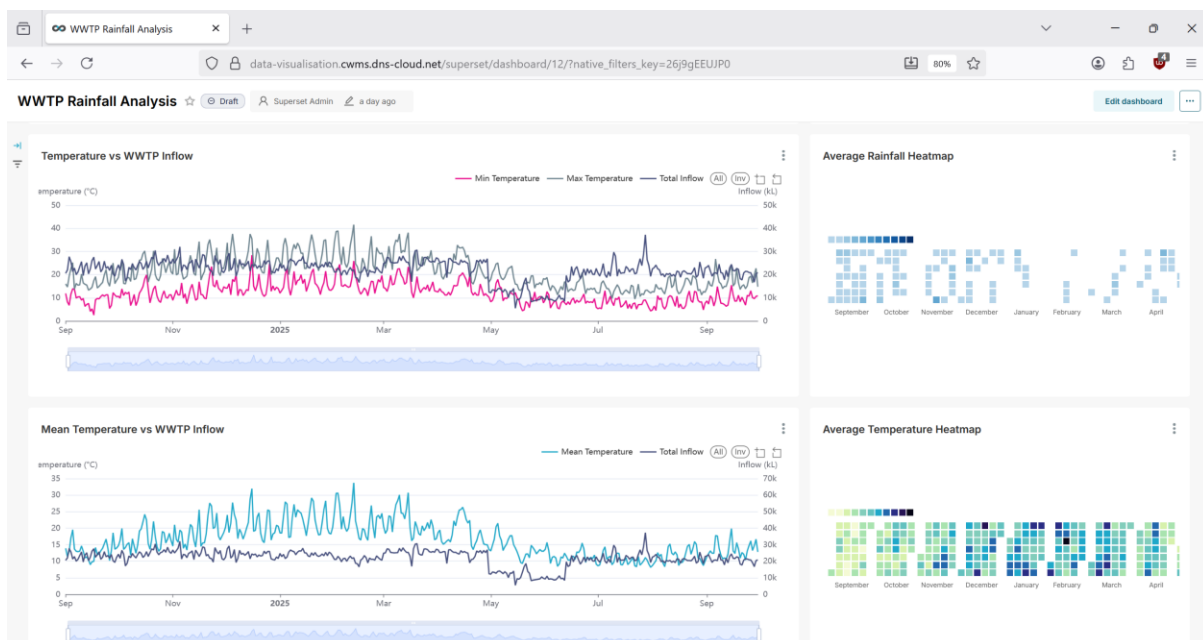


Figure 4: Temperature and CWMS flow analysis - Selected Onkaparinga CWMS facilities

CWMS Digital data catalogue

To capture all CWMS-related data for advanced analytics, it is essential to develop a digital data catalogue. A digital data catalogue is a collection of metadata, combined with data management and search tools, that helps analysts and other data users find the data that they need, serves as an inventory of available data, and provides information to evaluate the fitness of data for intended uses. In this project, the proposed digital data catalogue/metadata management includes both structured and unstructured data as well as how these data will meet the advanced analytics requirements to build prediction models of climate resilience and asset management.

The digital data catalogue also serves as the backbone of the visualisation and advanced analytics portal. In this portal, the local councils can take traditional data reporting to a different level. By linking different data, the councils can explore and create prediction models from various perspectives, such as how climate changes impact asset life span.

The development of the digital data catalogue takes inputs from both council and community groups, as well as the literature studies. The final deliverable consists of two sections.

Table 1 outlines the key climate-related data for CWMS. It identifies five main data categories: climate, system performance, demand, greenhouse gas emissions and infrastructure. Climate data includes precipitation, temperature, storm frequency and severity, as well as evaporation and evapotranspiration rates. System performance data covers flow rate, water level, and volume of wastewater collected, influent quality such as suspended solids and conductivity, and effluent quality: TDS, suspended solids, BOD, ammonia as Nitrogen (N), as well as infrastructure reliability such as the number of overflows. Demand data includes the number of connections, the type of customer, and growth trends. Greenhouse gas emissions (GHG) are divided into scope 1 - direct GHG emissions and scope 2 - indirect GHG emissions from electricity. Infrastructure data includes the age and condition of infrastructure, backup power availability, and redundancy in critical systems. The table also outlines the relevant to the CWMS, their source, typical data collection frequencies, and common data formats. For instance, system performance data such as inflow and water level can help detect infiltration issues. Each data type is linked to its relevance, source, collection frequency, and format, providing a comprehensive view of data needs for climate-resilient CWMS.

Table 2 outlines the potential advanced analytics that can be applied to climate-related data for CWMS. It links specific data types to analytical methods, use cases, and real-world examples. The table covers five key areas: climate and system performance, system performance alone, demand and infrastructure, greenhouse gas emissions, and infrastructure resilience. For example, climate and system performance data, such as precipitation, temperature, and flow rates, can be analysed using time series and machine learning techniques to predict peak inflows and optimise pump scheduling. System performance data, including influent and effluent quality, can be used to track

treatment efficiency and detect anomalies. Demand and infrastructure data support forecasting and system sizing, while GHG emissions data enable carbon accounting and energy efficiency assessments. Infrastructure data, such as asset age and backup power availability, can be used in risk-based asset management and scenario modelling. One specific case involved five years of data (2015–2019) from 16 wastewater treatment plants, which were combined with advanced reliability-based analytics to support strategic asset management decisions (Silva and Rosa, 2022). Each data category is linked to its analytical purpose, method, and practical application, providing a high-level framework for using data to enhance climate resilience, operational efficiency, and strategic planning in CWMS.

Table 1: Key climate-related data for CWMS.

Data category	Specific data	Relevant to CWMS	Data Source	Data collection Frequency	Common data format
Climate	Precipitation	- Determine flood or drought period, which can cause treatment disruption or infrastructure damage - Affects inflow and infiltration into sewer systems - Important for sizing storage and treatment capacity	BoM – Climate Data Online is best for localised rainfall history, flood/drought trend analysis, and CWMS planning	Daily/monthly	CSV (daily/monthly) Or NetCDF (gridded)
	Temperature	- Affects biological treatment efficiency - Increases risk of odours - Raises evaporation rates in lagoons - Impacts energy use for treatment systems	SILO Climate Data is best for Long-term climate trend analysis and modelling in regional areas		
	Storm frequency and severity	- Helps estimate peak stormwater loads - Supports overflow and flood risk planning - Informs infrastructure design (e.g. 1-in-100 year storms)	BoM – Severe Storms Archive		
	Evaporation and evapotranspiration rates	- Affect water levels in lagoons and ponds - Determine effluent reuse capacity in land irrigation - Help reduce effluent volume in dry climates	BoM – Water and the Land: Evaporation TERN (Terrestrial Ecosystem Research)	30m spatial, monthly temporal is available on TERN - Average monthly and annual pan	

		- Influence pollutant concentration in wastewater - Support climate adaptation and drought planning	Network) – AET Data	evaporation is available on BOM	
System Performance	Flow rate, water level, and volume of wastewater collected	- Determines system capacity needs (e.g. lagoon sizing) - Helps detect inflow/infiltration issues - Impacts chemical dosing and process control	Water entities/council internal databases or via third party who manages the CWMS	Daily	Excel and PDF
	Influent quality: suspended solids, conductivity, BOD ₅ , calculated BOD, ammonia as N, TKN as N, alkalinity	- Climate conditions affect influent quality - High pollutant loads can overwhelm treatment processes - Variable flow and quality require flexible operational strategies - Poor influent quality reduces treatment efficiency and effluent compliance	Water entities/council internal databases or via third party who manages the CWMS	Monthly or quarterly	
	Effluent quality: TDS, suspended solids, BOD, ammonia as N, Nitrate & Nitrite as N, TKN as N, Total Nitrogen, E. Coli	- Poor effluent quality can lead to regulatory non-compliance, and the need for costly upgrades or additional treatment - Climate factors influence effluent quality by affecting treatment efficiency, dilution, and pollutant concentrations	Water entities/council internal databases or via third party who manages the CWMS	Monthly normally	

	Infrastructure reliability: number of interruptions, number of breaks and chokes, number of overflows	• Extreme weather increases stress on infrastructure • Interruptions affect service continuity and public health • Breaks and chokes can cause system failures • Overflows lead to environmental pollution and regulatory breaches • Frequent failures increase maintenance costs and reduce system lifespan	Water entities/council internal databases or via third party who manages the CWMS	Data is updated upon change or reviewed annually	
Demand	Number of connections	Climate change can shift water usage patterns (e.g., more irrigation during heatwaves), affecting wastewater volume	Water entities/council internal databases	Data is updated upon change or reviewed annually	Excel
	Type of customer				
	Growth trends	Growth and demand patterns influence system capacity needs	Regional Development SA Infrastructure Prioritisation Reports	Update approximately every 5 years	PDF
Greenhouse gas emissions (GHG)	Scope 1 - Direct GHG emissions: Fuels, fugitive emissions from WWTPs, including wastewater loss, discharge to water, evaporation, rainfall, inflow, volume, volume of recycled water, chemical oxygen demand, total Kjeldahl nitrogen, number and type of lagoons, biogas	• Quantify the carbon footprint • Informs energy efficiency upgrades and low-carbon technology investments.	Water entities/council internal databases or via third party who manages the CWMS	Frequencies of the data varies, monthly or quarterly or annual	Excel or PDF

	production, weight of biosolids				
	Scope 2 - Indirect GHG emissions from electricity, including purchased electricity and renewable energy such as solar power, generated and consumed renewable energy				
			Electricity bills or online electricity data management system of water entities/councils or via third party who manages the CWMS	15 minutes or hourly or daily data	
Infrastructure	Age and condition of infrastructure	• Aging infrastructure may not have the capacity to handle climate-driven surges in water volume • Poor condition can lead to backups and inefficient treatment	Asset Management Plans or asset registers or condition assessment report of water entities/councils	Typical data update frequency is annually or every 4 or 5 years as part of the strategic planning cycles	Excel or PDF
	Backup power availability	• Backup power ensures critical CWMS operations (e.g., pumping stations) continue during outages			
	Redundancy in critical systems	Ensures operational continuity during climate disruptions			

Table 2: potential analytics of climate-related data and their purposes or CWMS.

Data Category	Specific Data	Potential Analysis	Analysis Method	Use Cases	Example Cases
Climate and System Performance	- Precipitation, temperature, storm frequency, evaporation/evapotranspiration rates - Flow rate, water level, conductivity, overflow	- Analysis of weather events on inflow volumes to determine how storm events affect system load and performance - Analysis of flow pattern to detect potential stormwater intrusion - Predictive modelling of inflow due to climate events to forecast peak loads using weather forecasts to optimise system operation (e.g., pump scheduling)	- Time series analysis and anomaly detection - Continuous monitoring with advanced data analytics including artificial intelligence and machine learning	- Infrastructure planning for climate resilience - Early warning systems for extreme weather events	Machine learning models successfully simulated temporal variations and accurately predicted peak flows and stormwater intrusion volumes (Wang et al., 2024).
System Performance	- Flow rate, influent/effluent quality - Infrastructure reliability (interruptions, breaks, chokes, overflows)	- Treatment efficiency trends by comparing influent vs. effluent quality over time to track plant efficiency and identify anomalies - Correlate system interruptions with flow or weather: use system failures and climate data to identify vulnerabilities (e.g., overflows during storms)	- Time series analysis - Efficiency Ratio Analysis for performance of the treatment - Statistical control / Anomaly detection - Correlation analysis	- Early detection of process inefficiencies or failures - Asset prioritisation for repair or replacement	Five years of data (2015–2019) from 16 wastewater treatment plants were analysed using advanced reliability-based analytics to support strategic asset management decisions (Silva and Rosa, 2022).
Demand, System Performance and Infrastructure	Number of connections, customer types, growth trends, flow and volume	- Demand forecasting: project future wastewater volumes based on customer growth trends and type - System sizing analysis: match current and forecasted demand with treatment capacity and infrastructure sizing - Load profiling by customer type: Understand BOD, TSS, and flow contributions by residential vs. industrial customers	- Trend extrapolation - Population-based forecasting - Time series analysis - Machine learning - Load projections by customer class	- Strategic capital planning and expansion - Price setting based on customer usage and load profiles - Targeted conservation or education program	Infrastructure sizing was determined based on projected flows and volumes through hydraulic and process modelling, using data on population growth, customer connections, land use, and flow rates (Senthilnathan, 2021).

GHG Emissions, System performance and Infrastructure	• Scope 1: direct emissions (fugitive emissions, biosolids, biogas, lagoons) • Scope 2: electricity usage, renewable energy • System performance, e.g., BOD	• GHG emissions inventory: quantify direct and indirect emissions from wastewater operations • Energy efficiency analysis: analyse electricity use patterns to detect anomalies that may indicate potential issue with assets • System efficiency: monitor and analyse biogas production to identify signs of process inefficiency or operational issues	• National Greenhouse and Energy Reporting method • Baseline comparison, statistical methods, time series analysis, and machines learning • Pattern recognition	• Carbon emission reporting and reduction strategies • Evaluate feasibility of energy recovery systems	• Tracks Scope 1 and 2 emissions for wastewater system using the National Greenhouse and Energy Reporting Scheme (DCCEEW 2025). • Biogas yield and digester efficiency were evaluated as part of for feasibility assessment to identify viable substrates for co-digestion (Bharambe and McKewen., 2020).
Infrastructure and Climate	• Age and condition of infrastructure • Backup power availability • Redundancy in critical systems	• Risk-based asset management: Combine age/condition with failure records and climate stressors to prioritise replacements • Resilience assessment: evaluate the impact of power or system failures on service continuity • Scenario analysis: test infrastructure resilience under stress (e.g., storm + power outage + peak inflow).	• Risk assessment framework • Condition rating systems • Criticality analysis • Scenario modelling	• Capital improvement planning • Design for resilience and redundancy • Emergency preparedness planning	Data on infrastructure vulnerability, backup systems, and operational flexibility is used to develop a framework for resilient assessment under climate stressors for capital planning (DELWP, 2022).

Conclusion

Based on the challenges and initiatives outlined, the future resilience of Community Wastewater Management Systems (CWMS) in regional South Australia hinges on transforming data management from a compliance burden into a strategic asset. Local councils, the primary owners and operators of these systems, face complex and compounding issues: operational challenges from reactive maintenance on aging infrastructure, financial strains due to undercharging and insufficient long-term asset planning, and increasing system loads from population growth and detrimental stormwater intrusion. Critically, these systems are increasingly vulnerable to climate change-driven events like droughts and floods, necessitating advanced planning and investment. The adoption of the Statewide Water Information Management (SWIM) system is a vital first step, streamlining the onerous and disparate reporting requirements to multiple government agencies, including the new National Performance Reporting (NPR) Framework.

Moving beyond compliance, the real opportunity lies in integrating this data to enable advanced analytics and prediction models focused on climate resilience and proactive asset maintenance. By cross-linking high-value data categories such as climate, system performance, demand, and infrastructure, councils can gain the necessary insights for informed decision-making. This includes using analytics to accurately predict peak inflows and stormwater intrusion, target infrastructure upgrades for flood-prone areas, and align operational strategies with the growing importance of wastewater recycling and net zero emissions targets. The development of a central portal that facilitates data discovery, visualisation, and prediction model building marks a transition from troubleshooting to a resilient, data-driven approach, essential for ensuring the long-term sustainability and service reliability of regional SA's CWMS.

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