October 2024

Western Sydney Planning Partnership

Smart Infrastructure Paper 2

(Specifications and Procurement)

Acknowledgement of Country

The Western Sydney Planning Partnership acknowledges more than 60,000 years of continuous Aboriginal connection to the land that makes up NSW.

We acknowledge and pay our respects to the traditional custodians of Country within Western Sydney. As part of the world's oldest living culture, the traditional Aboriginal owners and custodians share a unique bond to the Country – a bond forged through thousands of years of travelling across lands and waterways for ceremony, religion, trading, and seasonal migration.

We acknowledge that Western Sydney is home to the highest number of Aboriginal people of any region in Australia and that the primary Aboriginal custodians with obligations for Country and connection to the place for many generations including the Dharug/Darug, Dharawal/Tharawal, Gundungurra/Gandangara, and Darkinjung people.

This paper is delivered in collaboration with Smart Places, Transport for NSW, the Western Sydney Planning Partnership, the eight local government areas that comprise Western Parkland City and Blacktown City Council as part of the Smart Infrastructure Policy Acceleration Program. The Program received a co-contribution of funding through the Smart Places Acceleration Program, a special reservation of the NSW Government's Digital Restart Fund.

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Table of Abbreviations

Abbreviation	Description
AI	Artificial intelligence
AMS	Asset Management System
API	Application Programming Interface
BCC	Blacktown City Council
BMCC	Blue Mountains City Council
CAPEX	Capital expenditures
CCTV	Closed circuit television
COTS	Commercial off-the-shelf
GIS	Geographic information system
IPWEA	Institute of Public Works Engineering Australasia
LGA	Local Government Area
OPEX	Operating expense
ML	Machine learning
QCV	Quick coupling valve
RFQ	Request for quotation
SaaS	Software as a Service
SI	Smart infrastructure
SIMPaCT	Smart Irrigation Management for Parks and Cool Towns
ST	Smart technology
TfNSW	Transport for New South Wales
WSAA	Water Services Association of Australia
WSPP	Western Sydney Planning Partnerships
WSSIM	Western Sydney Smart Infrastructure Manual

Executive summary

The Western Sydney Planning Partnership (WSPP) is collaborating with nine local councils to assess the financial costs and benefits of adopting Smart Infrastructure.

A core focus of WSPP is to promote and guide the implementation of Smart Infrastructure (SI) to enhance service delivery and promote sustainability across Western Sydney. The Western Sydney Smart Infrastructure Manual (WSSIM) was delivered in 2023 as part of Stage 1 of the Smart Infrastructure Policy Acceleration (SIPA) program. It aimed to lay the groundwork for smart infrastructure planning and adoption across local councils in Western Sydney.

Stage 2 of the initiative aims to complete the planning and assessment of SI applied to two asset classes in different councils through a series of detailed papers. Paper 1 established the foundation by consolidating baseline financial and operational information for stormwater condition assessment in Blacktown City Council (BCC) and sports fields irrigation in Blue Mountains City Council (BMCC). Paper 2, the focus of this summary, builds on Paper 1 and dives into the technical specifications, procurement strategies, data management, and cost analysis associated with various scenarios for smart technology solutions (ST) and SI for stormwater CCTV inspections and sports fields irrigation. A subsequent Paper 3 will finalise the assessment by presenting a detailed cost-benefit analysis and recommending a monitoring framework.

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For BCC, machine learning (ML)-assisted CCTV data analysis has been trialled to assess the condition of stormwater drains. This promising technology automates defect detection, reducing inspection time and costs compared to traditional CCTV methods. ML-assisted data management can provide streamlined workflows through interactive applications that enhance the condition assessment review process and facilitate data extraction for upload into the council's Asset Management System (AMS). A more advanced scenario considers further integrating ML-assisted data into the AMS via APIs (Application Programming Interface), which could streamline data management and decision-making. However, this would require a higher level of SI maturity, disciplined data management, and substantial resources for integration support

The BCC case study illustrates potential efficiencies through ML vision systems to filter and interpret imagery, enabling more extensive coverage of the stormwater network and better data management. Despite its promise, the technology is still in its infancy and requires further development to deliver scalable benefits. Additionally, the usefulness of this technology can be limited by the relatively small scope of assets that individual councils manage. By establishing cross-council collaboration, there is an opportunity to streamline and standardise procurement processes, as well as group inspections in neighbouring councils into larger scope packages. This may also enable standardise cross-councils works specifications for repairs and renewal work that will result from CCTV inspections.

For BMCC, managing irrigation for sports fields is challenging due to the labour-intensive nature of manual systems. Conventional smart irrigation systems, which automate scheduling based on weather data and soil moisture sensors, have been successfully implemented in some fields. These systems, though slightly more costly, significantly reduce labour and can improve water efficiency. As commercial off-the-shelf (COTS) products these are typically 'out of the box' solutions that do not require complex procurement or system configuration. A more advanced solution considered in this paper, the Smart Irrigation Management for Parks and Cool Towns (SIMPaCT), leverages a digital twin, real-time data analytics, and machine learning to dynamically optimise irrigation and urban cooling. While this pilot system shows potential, it requires significant CAPEX investment, advanced skill levels for dynamic modelling and system integration, and high ongoing costs.

The BMCC case study demonstrates the advantages of simpler smart irrigation systems, highlighting their accessibility and the potential benefits of COTS technology. The implementation of the more sophisticated SIMPaCT-like solution may be beneficial in the future but is at an early stage. Its costs and commercial viability are not yet clear and the integration of systems and supporting the core platform will be a major factor in the long-term viability of this solution.

There are potentially significant benefits from introducing these technologies into other councils, but there are also complexities and challenges. Up-front investment and ongoing support are required to improve the maturity and sophistication of infrastructure solutions, and a thorough appraisal of return on investment is necessary. While the specific case studies are promising, these improvements are currently at the pilot stage and need to be developed into mature, commercially viable solutions to fully understand the costs. Therefore, for any implementation, many planning considerations must be addressed upfront before making a decision to proceed. These include available CAPEX and budget impact, staff resources, skills and organisation, and overall SI maturity of the councils. A more rigorous cost-benefit analysis is provided in the subsequent Paper 3.

1. Introduction

1.1. Background and objectives

As part of a council-led initiative in Western Sydney, the WSPP was established in 2018 as a vehicle for delivering outcomes via collaborative planning. The members of the WSPP include nine local councils[1], the Department of NSW Planning, Housing and Infrastructure, TfNSW and Sydney Water.

One important focus for the WSPP is the implementation of SI across the councils. The WSPP has commenced a project, involving the nine local councils to develop an operational policy and guidance for the planning and adoption of Smart Infrastructure in these councils.

WSPP's stated goals for this project are as follows:

a) appraising the asset lifecycle costs and benefits accruing to local councils from adopting SI

b) developing an approach to monitoring these costs and benefits on an ongoing basis as part of the implementation of SI

c) providing guidance on the incorporation of SI in asset management systems including guidance on how SI data can be effectively and efficiently collected, stored and analysed.

Stage 1 of this project involved the development of the WSSIM. The purpose of Stage 2 is to complete the planning and assessment process, resulting in the following Papers.

1. Baseline asset lifecycle cost identification
2. SI specifications, procurement approach, implementation methodology, data collection and analysis, AMS integration, financial cost
3. SI financial costs and benefits appraisal and monitoring framework
4. Operational policy and guidance on adoption of SI in AMS (Optional by WSPP)

More background to this project is provided in Paper 1.

This Paper will focus on the technical specifications, procurement and financial considerations and data management needs for implementing smart infrastructure. As in Paper 1, two specific local council asset class examples are used, namely (1) the stormwater drainage infrastructure comprising underground pipes and stormwater pits subject to CCTV analysis for BCC and (2) the irrigation system for sports fields in the BMCC.

For each local council example, this Paper provides the following: technical specifications, procurement approach, implementation methodology, data collection and analysis, AMS integration and financial costs.

[1] Blacktown City Council, Blue Mountains City Council, Camden Council, Campbelltown Council, Fairfield City Council, Hawkesbury City Council, Liverpool City Council, Penrith City Council, Wollondilly Shire Council

1.2. Scope

The scope of Paper 2 is to outline the following information:

- Smart Infrastructure technological and engineering specifications for each asset class
- Procurement approach and implementation methodology
- Data collection and analysis requirements, including pathway for integration with extant AMS
- Estimate of the financial cost of specifying, procuring and implementing SI for the selected asset classes

1.3. Methodology

1.3.1. Determining SI Technological and Engineering Specifications

To establish the technological and engineering specifications for each asset class, a comprehensive research process was undertaken. This involved gathering and reviewing available information from councils, suppliers, and other industry sources. The information was collected through literature reviews, interviews with key stakeholders, and consultations with industry experts. Various scenarios were considered, including traditional methods, ML-assisted approaches, and enhanced integration systems, to ensure a thorough understanding of the available technologies.

1.3.2. Developing the Procurement Approach and Implementation Methodology

The procurement approach and implementation methodology were developed by investigating the market, gathering lessons learned, and assessing the council's procurement context. Innovation opportunities that could foster industry partnerships were also considered. A comparative assessment of different procurement options was conducted to identify the most suitable approach. Based on this assessment, an implementation methodology was developed, aligning with the preferred procurement option to ensure efficient and effective deployment.

1.3.3. Determining Data Collection and Analysis Requirements

To define the data collection and analysis requirements, including pathways for integration with existing AMS, the data management needs for reporting and analysis were assessed. This involved evaluating the types of data required, the methods for data collection, and the tools needed for analysis. The integration needs and capabilities of existing AMS were also reviewed to ensure seamless implementation and ongoing support. This was determined through system audits, vendor consultations, and analysis of current workflows.

1.3.4. Estimating Financial Costs

To estimate the financial cost of specifying, procuring, and implementing SI for the selected asset classes, the baseline financial model was expanded to include SI adoption costs. Data was obtained in collaboration with market sources and the council to determine internal costs. This included quantifying and assessing the design specifications, procurement, implementation costs, and council change management costs. The cost implications of the transition, including barriers to change, were also considered. This comprehensive financial assessment provided a clear understanding of the investments required for successful SI implementation.

1.4. Source of data and information

Through consultation with both Councils, industry partners, education partners and other Government agencies, a wide array of information was obtained to assist in the development and analysis of both Council's asset management systems and costs.

Appendix A outlines the data sources used throughout this paper.

1.5. Assumptions

In developing this paper, we have relied on documents and information provided by each of the Councils, interviews with representatives of Councils and other stakeholders. We have assumed that this information is accurate and there is no cause for us to use third party verification methods.

Where cost information was lacking, assumptions were made based on industry knowledge.

2. Blacktown City Council – Stormwater Condition Assessment (CCTV)

2.1. Potential Benefits from Stormwater Condition Assessment Technologies

Stormwater systems are essential for removing water from roads and community areas and in the process providing safety and continuity of services. However, they consist of infrastructure that is largely out of sight from the community and fairly inaccessible to council workers. Condition assessment using technologies such as CCTV is essential to gain visual access to underground areas and identify defects and plan remediation required, thus preventing major failures and incidents from occurring.

2.2. Current Practices and Challenges

The key challenges are in trying to best understand the condition of stormwater assets to monitor and manage deterioration risks. Current practices are focused on performing CCTV inspections. However, the process is expensive and time-consuming. It typically involves a crew feeding a camera along the pipelines, while an analyst reviews the footage in real time and identifies potential defects.

The key challenge is that a significant proportion of the overall assets in the stormwater system have unknown condition due to the difficulty and cost of performing assessment. This is difficult to remedy with current techniques. It is desired to find a way to streamline the assessment of assets in order to allow more length of pipe to be assessed each year with CCTV.

2.3. Scenarios for Smart Infrastructure Assessment

We note that fixed SI solutions cannot be readily deployed on stormwater systems, since the pipelines are mostly buried and there is no cost-effective solution that would enable the fitment and maintenance of monitoring devices and telemetry.

The key scenarios for improving the assessment of this infrastructure are associated with improving the processes around collecting and analysing CCTV footage, as well as considering integration of such a solution with the existing AMS.

The technological solution applied currently to BCC's drainage networks involve a combination of traditional and advanced methods, leveraging both conventional CCTV inspections and cutting-edge machine learning (ML) algorithms to enhance the identification and quantification of defects.

In this Paper, we will assess the following scenarios:

- Base Case: Traditional CCTV Inspections and planning (baseline)
- Scenario 1[2]: Machine Learning-Assisted CCTV Data Analysis
- Scenario 2: As per Scenario 1 plus enhanced integration with council systems

2.4. Summary of Changes to Infrastructure Assessment Process

The technologies being assessed in this paper aim to improve the process of performing condition assessments to support repairs, remediation decision-making, and planning by collecting, analysing and displaying data in a format that reduces the administrative effort of engineers making decisions. Each technology influences different steps of the overall process to varying degrees.

[2] As currently being used by Blacktown City Council

The renewal planning and assessment and delivery process typically involves the steps and activities outlined in Figure 1.

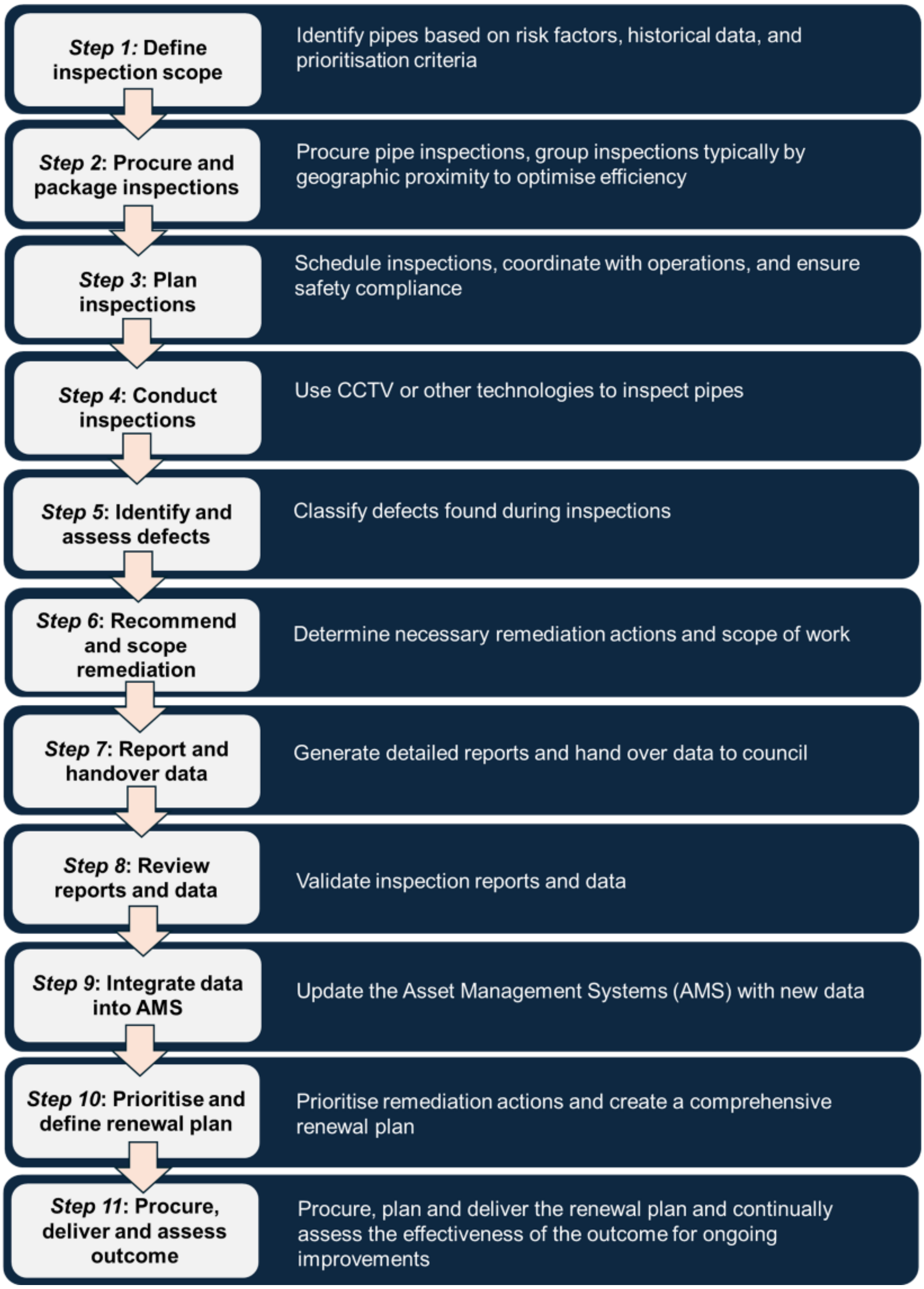


Figure 1: Summary of renewal planning process

A comparison of how these steps change with the different scenarios is presented in Appendix B.

In summary, the second scenario ML-assisted CCTV alters the activities and potentially improves on the baseline for the conduct of steps 4 to 9. This is done by automating the identification of defect candidates, allowing the inspection to continue with minimal delays and reducing the analyst's time, as well as systemising the capture and organisation of data into user-friendly interfaces for review and system-friendly formats for integration into the AMS.

2.5. Specifications for Technical Solutions

2.5.1. Technical Solution for the Base Case (Traditional CCTV Inspections)

Traditional CCTV inspections are a fundamental method for assessing the condition of stormwater drainage networks. This method involves the use of standard or high-resolution cameras to visually inspect and document the state of pipes and other drainage components. Despite being labour-intensive, this method provides direct visual evidence of pipe conditions and is widely used for both planned and reactive inspections.

CCTV inspections should adhere to established standards to ensure consistency, reliability, and accuracy. Key standards include:

- WSA 05-2020 Conduit Inspection Reporting Code of Australia (Version 4.1): Guidelines for inspecting and reporting on the condition of drainage conduits
- IPWEA Practice Note 5 – 2015 Stormwater Drainage: Best practices for managing and maintaining stormwater drainage systems.
- Safety and Quality Standards: adherence to equipment manufacturer specifications and council requirements.
- CCTV field testers should have NATA accreditation under the Sydney Water Field Testing Services Program for Colour Closed Circuit TV inspection

Figure 2: Example of “pipeline crawler” used for drainage pipe CCTV inspections (left) and CCTV footage (right). Photos courtesy of VAPAR, July 2024.

2.5.2. Technical Solution for Scenario 1 (ML-Assisted CCTV Inspections and Analysis)

ML-assisted CCTV data analysis enhances traditional CCTV inspections by running the video through algorithms to automatically detect defects and conduct a preliminary condition assessment of the drain asset. It then summarises and organises the defects and inspection outcomes in a user-friendly condition assessment application that enables a human-assessor to efficiently assess the highlighted defects and validate or overwrite the ML assessment.

In this scenario, there is no automated integration with the council’s systems. Select data from the assessment platform is manually downloaded and then uploaded to the council AMS.

The standards applicable to CCTV inspection and condition assessment are the same as for traditional CCTV inspections. However, by using a service with cloud storage for the transfer of large amounts of potentially sensitive data, the following should be considered:

- Council data security policies and requirements
- Data retention timeframes, availability and disaster recovery requirements
- Data handover requirements, timeframes and format
- Data handling upon contract termination and data destruction requirements

Users of the CCTV assessment application should undergo training provided by the service provider to ensure its effective use.

The team managing the contract and service provider should understand data service contracts and be supported by council's IT and procurement departments to navigate SaaS or similar requirements and ensure alignment with council data policies.

Additionally, the team managing the assets should become knowledgeable in using tools like Power BI to leverage additional data for advanced reporting and deeper insights.

2.5.3. Technical Solution for Scenario 2 (ML-Assisted CCTV Inspections plus AMS Integration)

In this scenario, the inputs and outputs from the ML-assisted technology and inspections are automatically integrated via API with council AMS, comprising of TechnologyOne, Brightly, ArcGIS and BI, creating a data ecosystem that reduces the need for manual data transfers, and ensures information is systematically aligned across all platforms. By automating these processes, the integration supports efficient data management, enhances decision-making capabilities, and streamlines the overall workflow.

With enhanced integration into council systems, additional considerations and best practices are required:

- Compliance with council data security policies and requirements with an increased focus on secure APIs for data transfer between systems.
- Disciplined approach to documenting data requirements, including defining the asset information requirements, business and systems workflows, systems architectures and data mapping.
- BAU operational support for the system integration and systems change management.
- Regular auditing and quality reviews to ensure data integrity, security, and compliance with established standards and requirements.
- The team managing the assets should build advanced capabilities in complex database reporting to extract the required information from the integrated systems.

2.6. Procurement and Implementation Approach

The procurement and implementation approach for ST and SI should follow iterative steps to allow the council to develop capabilities and maturity in this space.

2.6.1. Procurement and Implementation for the Base Case (Traditional CCTV) and Scenario 1 (ML-Assisted Technology)

Currently BCC has been running a pilot project for its approach to implementing CCTV improved with the assistance of machine learning. To achieve this, it has adopted a procurement strategy to consolidate a medium-term contract for inspections over three years, with the possibility of extension (1+1 years) based on performance. The RFQ structure was focused on outcomes (for example specifying number of kms inspected per year and deliverables to the WSA 05-2020 standard) rather than any particular methodology. This approach provides service providers with opportunities to deploy innovative methods that require initial effort and capital investment (e.g., configuring systems, training operators, scaling data systems) but that can minimise long-term effort on a larger scale.

For future engagements with other councils, it is proposed that an approach be adopted similar to BCC, involving the conduct of the following steps.

- Determine the overall CCTV objectives to be achieved over a period in terms of stormwater CCTV coverage and identify a list of priority areas to focus on (ideally based on a criticality grading linked to GIS)
- Determine the type and quality of deliverables in terms of reporting and data transfer from the service provider
- Prepare a request for quotation (RFQ) for target service providers, specifying an outcomes-based contract with schedules for a rate per lineal metre / km and minimum mobilisation fees
- For Scenario 1, specify that the council has preference for artificial intelligence (AI) / ML-assisted CCTV processes, particularly if they lead to demonstrable savings
- Evaluate the RFQ using council procurement procedures; identify the preferred proponent, negotiate, commence and manage the engagement.

Implementation of traditional CCTV and ML-assisted CCTV requires a maturity level of 3 to 4 in SI, as per the WSSIM maturity levels. The procurement and implementation approach should adhere to the guidelines outlined in the WSSIM, particularly section 3.2.3 of that document.

2.6.2. Procurement and Implementation for Scenario 2 (ML-Assisted CCTV Inspections plus AMS Integration)

To achieve enhanced integration and process digitisation, such as a "Whole of Council Systems" (refer to section 3.3.1 of the WSSIM), there will need to be a significant amount of additional work done up-front by council staff. In addition, the transition should be managed within a proper project delivery framework to ensure that council requirements (for data integration and management) are well defined, and the improvements are properly planned, designed, implemented and supported.

A council-wide approach is necessary to avoid duplicating efforts and to leverage existing expertise and resources. Up-front planning work for this integration includes the following activities:

- Establishing a smart infrastructure steering committee for managing, implementing and monitoring SI projects within the council's SI framework.
- Determining the feasibility / business case for the improvement
- Establishing a project framework supported by project delivery resources and an appropriate governance structure (linked to the SI steering committee)
- Planning the project, with the following features:
    - Develop a clear integration roadmap aligned with the council's SI policies and objectives
    - Use of a phased / step-by-step approach for system integration
    - Consult and as required, leverage existing partnerships to understand integration requirements and system compatibilities

Initially, integration scope should be based on a limited and fairly simple solution. This could be based on facilitating one-way data integration between the ML system and systems like ArcGIS and Brightly, which are prepared for API integrations. This would automate the transfer of defect and condition assessment data to the council's systems.

The procurement approach for Scenario 2 should follow a step-by-step approach, avoiding large-scale commitments that could lead to overly complex projects or ones that fail to deliver value and/or be fit for purpose. This ensures that staff managing ICT systems agreements can build skills, gather lessons learned, and develop advanced ICT procurement processes.

Once the project is properly planned, it will be necessary to procure the services of specialist service providers and/or contractors to deliver the integration. This would be based on best-practice methods used for IT / software solution providers and include the following steps:

- Define a clear but limited scope for the integration work that avoids unnecessary complexity and maximises value to council from minimum investment.
- Develop a project budget that has sufficiently large contingency to cover unknowns, which are very common for integration projects.
- The commercial delivery model should be appropriate to the level of risk for the engagement. If the integration is scoped and sized to minimise risks to council, then a lump sum price for the work may

be appropriate. Where there is much more uncertainty, then it may be suitable to consider a model based on capped rates.
- Prepare a requirements specification based on desired functional and non-functional (performance / quality) requirements for the solution as well as obligations for project management and reporting.
- Prepare a RFQ for target service providers with a suitable track record and performance in delivering similar services.
- Evaluate the RFQ consistent with council procurement procedures. Ideally a multi-criteria assessment should be employed to score tenders against the requirements of at least the non-price criteria. Once a preferred tenderer is identified then the processes of negotiation, contract award and initiation should be carried out.

Allowance must be made for post-implementation support, which is a crucial factor in all successful IT system and integration projects. Finally, the benefits and maintenance efforts of this integration should be measured. If proven beneficial, further integrations can be explored, such as two-way data integration. A bulk integration approach should be avoided unless the council can demonstrate high SI maturity.

To implement this scenario, the council should reach maturity level 4, and it is critical that the council has the appropriate skills available (either staff or external service providers) to supervise the project and that the council systems have the necessary fields and modules available in the asset management system as well as appropriate functional system and API capabilities.

2.7. Data Management Approach

2.7.1. Data Management Approach for the Base Case (Traditional CCTV)

In traditional CCTV inspections, data is collected manually using standard or high-resolution CCTV cameras. Defects are logged on paper or spreadsheets by the inspection team during the inspection. The collected video footage and report are then stored on physical drives or a cloud storage service. Data is handed to the council via email or hard copy DVD. The council will then upload the files to its own document management system. Some summarised information may be entered into the AMS, although this is not done in a systematic manner. The data flow and associated systems are illustrated in Figure 3.

This data approach does not require substantial data management policies. Utilisation of the data involves manual reporting, with limited visualisation capabilities. Training for this method includes basic instruction on equipment use and data entry procedures.

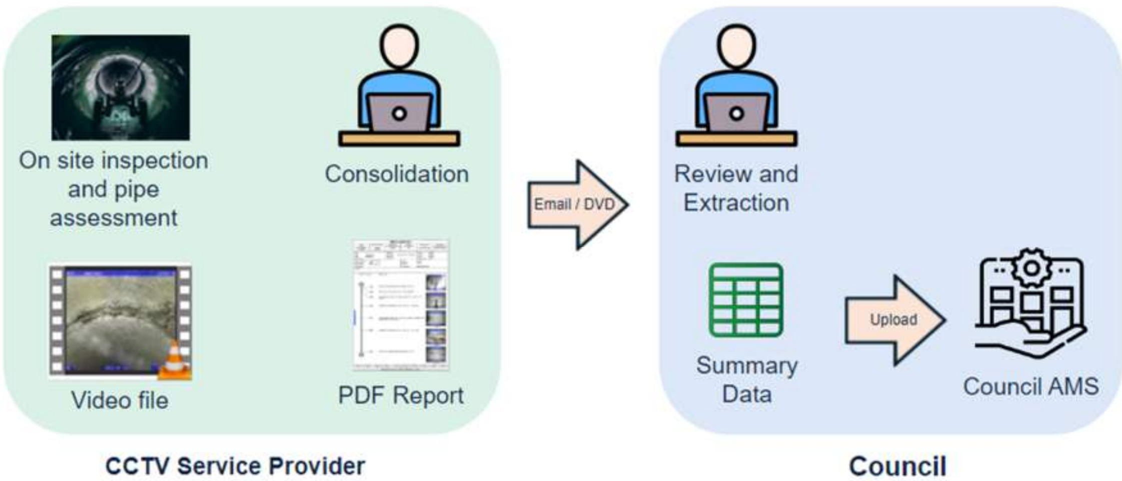


Figure 3: Data flow for Traditional CCTV Inspections

2.7.2. Data Management Approach for Scenario 1 (ML-Assisted CCTV Data Analysis)

For ML-assisted CCTV data analysis, the video collected by the CCTV service provider is uploaded to ML service provider cloud and run through machine learning algorithms. A preliminary assessment is performed by the ML algorithms, with engineers reviewing the results for final validation. The data flow is illustrated in Figure 4.

Data and interface are made available through the ML provider's online application, with access being granted to users, including the client, via password-protected credentials. This data is stored securely in the cloud with encryption.

Integration with AMS is semi-automated, allowing for ad-hoc data exports from the assessment software in system-friendly formats which are then manually uploaded to the council's systems. Defined data retention policies include automated archiving and deletion processes managed by the ML service provider's cloud storage service. Data ownership arrangements, including making the data available for the ML provider to train its ML algorithm requires clear definition in the agreement.

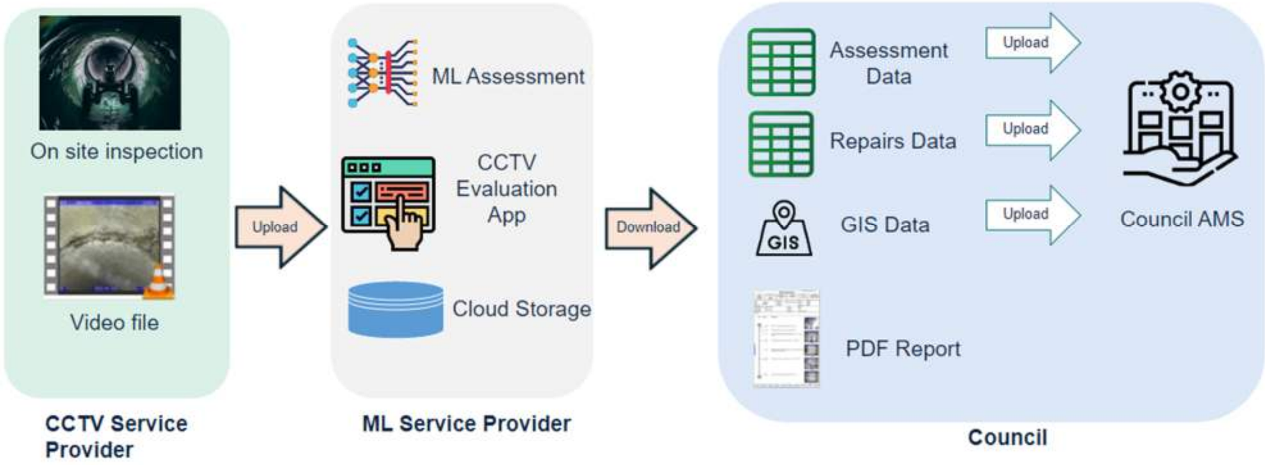


Figure 4: Data flow for ML-Assisted CCTV Data Analysis

2.7.3. Data Management Approach for Scenario 2 (ML-Assisted CCTV Inspections plus AMS Integration)

In this scenario the data flows between the ML Service and the council's AMS are integrated and automated via APIs and would flow one-way into the council's systems.

Data could be stored in hybrid environments if the council maintains some on-premises system. However, it is expected that this integration would primarily be done in more mature and up-to-date cloud-based environments managed by the council and the ML service provider.

Automated syncing via APIs requires clear definition and mapping of process workflows, along with stringent hold points for data transfer and quality control. Council personnel will need advanced skills and resources to manage these integrated systems and provide ongoing technical support. Maintaining high data quality is crucial, as poor data quality, even if sporadic, can significantly reduce confidence in the system and compromise the overall data management efforts. This approach therefore requires a mature organisation capable of supporting sophisticated data integration and quality assurance processes effectively. The data flow and associated systems are illustrated in Figure 5.

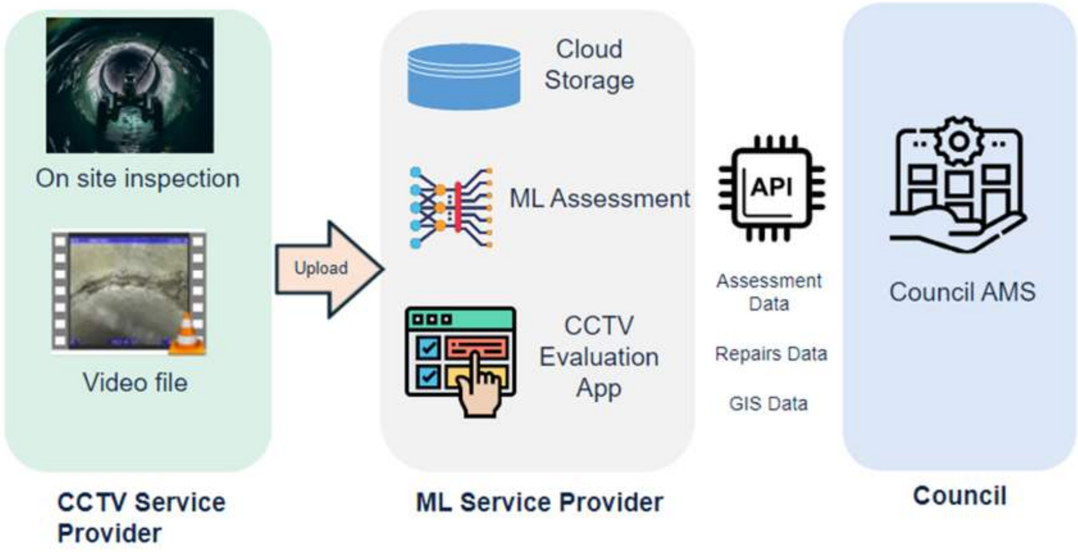


Figure 5: Data flow for ML-Assisted CCTV Data Analysis with AMS integration

2.8. Cost Breakdown and Analysis

2.8.1. Summary of financial / cost assumptions:

In the development of the financial assessment, the following cost assumptions have been made:

- All costs are in AUD applicable to FY2025 and unindexed
- All costs exclude GST
- The relevant costs being quantified are for the CCTV inspection, assessment and associated data management.
- The coverage of the CCTV is based on an average inspection of 50km per year.

The following rates form the basis for the estimated costs:

External Items	Unit cost	Cost basis
Traditional CCTV inspection cost	$3.20 per linear metre	External cost per linear metre for completing stormwater pits and underground pipe inspection. A minimum length per day and quantum per year is mandated in the contract.
ML-Assisted inspection cost	$2.90 per linear metre	External cost per linear metre for completing stormwater pits and underground pipe inspection. A minimum length per day and quantum per year is mandated in the contract.
Software Consultant	$200/hour/staff	External costs for a software consultant to plan, design and deliver systems integration from the council-side

Table 1: BCC Estimated External costs

Internal Resources		
Council Systems Manager	$200/hour/staff	Internal hourly cost for a systems manager responsible for the council's AMS
Council Engineer	$140/hour/staff	Internal cost for an experienced civil engineer responsible for stormwater asset management
Junior Officer	$100/hour/staff	Internal cost for a junior officer or engineer supporting stormwater asset management and data analysis

Table 2: BCC Estimated Internal costs

Key assumptions applicable to the development of the models are as follows:

- Excluded costs associated in getting the organisation to become mature in SI.
- Excluded costs of integration between council systems (e.g. enterprise asset management (EAM) with GIS)
- Excluded licensing costs for all existing council systems
- Excluded upgrades, licensing or customisation that may be required for council systems to integrate with external systems.
- The rate of CCTV coverage is between 6 to 12 linear metres of pipe per minute, based on information from VAPAR.
- The average length reported on in the CCTV inspection report is a total length of 35 linear metres of pipe, based on information from VAPAR.

2.8.2. Costs for the Base Case (Traditional CCTV)

The estimated cost for traditional CCTV inspection from BCC is $3.20 per linear metre of stormwater pipe. For 50km per year of coverage, the costs are estimated as follows:

- External costs $160,000
- Internal labour: $21,337

2.8.3. Costs for Scenario 1 (ML-Assisted CCTV)

The estimated costs from BCC aggregate to $2.90 per linear metre of stormwater pipe. For 50km per year of coverage, the costs are estimated as follows:

- External costs: $145,000
- Internal costs: $4,363

2.8.4. Costs for Scenario 2 (ML-Assisted CCTV Inspections plus AMS Integration)

Scenario 2 utilises the same ML technology as in Scenario 1, but there would be some efficiencies in the data administration. For 50km per year of coverage, the costs are estimated as follows:

- External costs: $145,000
- Internal costs: $3,243

The cost of system integration varies depending on the complexity of the integration and the technologies used to link the systems. For the purpose of this Paper a low complexity one-way data integration has been assumed.

It is assumed that the integration would be made with the EAM and would be based on the following data:

- One-way integration of asset data, including asset creation, and asset data update (condition data, assessment date, etc)
- Inspection events
- Identified defects
- Applicable CCTV images and associated data

The costs associated with the integration work are based on the following activities and summarised as follows:

- Project Management: $17,280
- Workshops and Planning: $12,000
- Systems Configuration and Testing: $8,000
- Change Management, Handover and Training: $7,600
- Council internal costs: $15,000
- Contingency: $10,650

The estimated ongoing annual costs associated with the integration are as follows

- Ongoing support: $13,600
- Licencing: $10,000

2.8.5. Summary of breakdown costs

The costs from the scenarios are summarised in the table below.

Item	Cost Category	Base Case Traditional CCTV	Scenario 1 ML-assisted CCTV	Scenario 2 Advanced Integration
CCTV inspection (contracted)	**OPEX (per annum)**	$160,000	$145,000	$145,000
Internal costs for engineering review and data administration	**OPEX (per annum)**	$21,337	$4,363	$3,243
Integration implementation (internal and external costs)	**CAPEX**	$-	$-	$70,530
Integration licensing and support (internal and external costs)	**OPEX (per annum)**	$-	$-	$23,600

Table 3: Cost breakdown summary for technology scenarios in BCC

The cost breakdown of the scenarios is detailed in Appendix C

3. Blue Mountains City Council – Sports Fields Irrigation

3.1. Potential Benefits from Irrigation Technologies

Irrigation is essential for maintaining the health and playability of sports fields, ensuring that turf remains green and resilient throughout the year. The key changes that advanced irrigation technologies provide include improved water efficiency through automated adjustments to watering and real-time monitoring, and significant reductions in labour costs by minimising the need for manual operation. These technologies also support environmental sustainability goals by optimising water usage and contributing to urban cooling, thereby enhancing the overall community experience.

3.2. Current Practices and Challenges

BMCC currently operates a mix of manual, timed-actuated and smart irrigation systems. The smart technological solution currently applied is a conventional smart irrigation system — a plumbed irrigation system with a centralised site-based control system which can be remotely operated.

BMCC faces several challenges with its current manual irrigation practices for sports fields, used in 12 out of 21 parks. They are labour intensive to operate and require operation during working hours, leading to inefficient water usage due to water evaporation.

The council has begun transitioning to ‘smart irrigation’ systems in nine parks, which allow for remote monitoring and control via cloud-based platforms. Also, these systems integrate with weather forecasts to optimise irrigation schedules, avoiding watering when rain is predicted, thus improving water efficiency and reducing labour costs.

The primary focus for BMCC is to improve water efficiency and reduce labour costs by adopting smart irrigation technologies. This transition aims to enhance environmental management and urban cooling, supporting the council's sustainability goals while better serving the community.

3.3. Options for Smart Infrastructure Assessment

Several potential options and scenarios were considered for open spaces that focused on improving operational costs, such as smart lighting and smart waste management, or enhancing the availability of data for planning decision-making, such as utilisation monitoring. Other options aimed to provide community benefits, including environmental monitoring and smart poles. However, the technology that seemed to have the most significant impact on open spaces was smart irrigation. This was due to its perceived ability to address higher operational costs, align with sustainability targets, and minimise water usage, coupled with a clear operational cost/benefit consideration.

In this Paper, we will assess the following scenarios:

- Base Case: Conventional plumbed irrigation with manual control
- Scenario 1: Conventional ‘smart irrigation’
- Scenario 2: Advanced ‘smart irrigation’, using SIMPaCT (a pilot innovative smart irrigation management solution, explained below) as the example

3.4. Specifications for Technical Solutions

3.4.1. Technical Solution for the Base Case (Manual Irrigation Systems)

The irrigation systems for sports fields vary in design, but usually comprise of a connection to a water source (which could be potable, natural surface water, or bores), water storage tank, a pumping system, pipework with manual valves and sprinklers.

Manual irrigation systems require direct human operation to manage watering schedules and monitor the irrigation process. These systems typically involve operating the pumps, manually turning valves and/or using quick coupling valves to connect hoses and sprinklers. The manual operation of these systems often necessitates the presence of two people on-site for the entire duration of the watering cycle, which can take several hours.

Watering must be conducted during business hours, leading to inefficiencies due to increased water evaporation. Operational decisions regarding when to water are often based on fixed schedules and the best judgment of the operators, such as avoiding watering when rain is expected. However, there is a significant lack of operational data to support decision-making and track water usage. Combined with varying topography and temperature ranges in the Blue Mountains, this makes site-specific watering profiling difficult and largely dependent on the experience and intuition of the operators.

The design and installation of these systems should be done by Irrigation Australia-certified irrigation designers and installers. Compliance with the *Plumbing Code of Australia* and standards such as *AS/NZS 3500.1:2021 Plumbing and Drainage Part 1: Water Services* is essential, ensuring proper use of devices like reduced pressure zone (RPZ) valves and incorporating rainwater harvesting where applicable.

3.4.2. Technical Solution for Scenario 1 (Conventional Smart Irrigation Systems)

Conventional smart irrigation systems utilise automated controls and remote monitoring to manage watering schedules more efficiently. These commercial irrigation systems use off-the-shelf equipment, sensors and controls integrated with real-time weather forecast data to optimise watering schedules and reduce water wastage. This approach helps improve water efficiency by making real-time adjustments based on current weather and environmental conditions.

Smart irrigation systems require minimal human intervention to operate compared to manual systems. The internet-control capabilities allow park managers to monitor and control the system in real-time from any location via operational dashboards, reducing the need for on-site presence. Additionally, the water management software provides enhanced monitoring capabilities, enabling operators to access real-time data, detect anomalies requiring maintenance, and make informed decisions regarding optimal water use.

In these systems, there are actuated valves (typically solenoid valves), flow switches or flowmeters, sensors, an irrigation control system, and a software for remote system monitoring and operation. The control requires an internet connection, typically via cellular service plans but could also be through Wi-Fi or LAN. Sensors can enhance the system's performance by providing accurate local data The controls either stop or adjust irrigation scheduling based on weather conditions using data from both sensors (soil moisture, etc.) and weather stations.

The design and installation of these systems must be done in accordance with the Original Equipment Manufacturer (OEM) recommendations by someone holding a design or installation certificate from the OEM. These solutions are pre-configured and do not require a systems engineer for setup. Suppliers provide comprehensive documentation, online training and materials, including specialist certificates for their products, to facilitate the design and installation process. Using equipment from the same supplier is recommended to avoid compatibility issues and simplify installation and maintenance. It should also be noted that retrofitting manually operated systems is often impractical because the piping configuration and equipment differ significantly.

There are several providers of commercial smart irrigation systems including Hunter Irrigation, Rain Bird Corporation, Toro Company, Aquamonix, Libelium, Waterwise, Think Water, OneWiFi, Arduino, Orbit, and Galcon. Most products available today include low-cost sensors connected to automated controllers through wireless communication technology, with a basic level of weather forecast integration. Providers offer connectivity options such as Wi-Fi and Bluetooth, and some provide long-range connectivity like long-range wide area network (LoRaWAN).

Some providers (Hunter, Rain Bird, Libelium, and Aquamonix) feature controllers with manual or automatic operation connected to low-cost sensors monitoring parameters including soil moisture, humidity, temperature, and evapotranspiration. Advanced features that distinguish more sophisticated products (offered by Libelium, Waterwise, and Aquamonix) include long-term predictive modelling, machine learning, artificial intelligence, cloud-based data storage, data analysis and visualisation and LoRaWAN technology. The table in Appendix C provides a quick comparative overview of some of the key features prevalent in the products currently available in the market.

3.4.3. Technical Solution for Scenario 2 (Advanced Smart Irrigation, e.g. SIMPaCT Solution)

Advanced smart irrigation systems, such as the Smart Irrigation Management for Parks and Cool Towns (SIMPaCT), are the forefront of water management in urban parks and green spaces. Systems of this kind integrate the features of conventional ‘smart irrigation’ into a broader smart infrastructure ecosystem incorporating advanced data analytics and digital twinning to further enhance water management, promote urban cooling and improve user experience.

For the purposes of this review, we have selected the SIMPaCT system as representative of these technologies. SIMPaCT was chosen due to its comprehensive set of features and its successful application in real-world settings, making it an ideal detailed example for assessing the potential costs and benefits of such technology.

SIMPaCT is an advanced smart irrigation solution designed to optimise irrigation processes for urban parks and green spaces. The solution was developed through a collaborative pilot project led by Western Sydney University (WSU) in partnership with several key organisations, including the University of Technology Sydney (UTS), Sydney Olympic Park Authority (SOPA), Sydney Water and other industry stakeholders. The pilot, conducted at Bicentennial Park, Sydney Olympic Park, was funded by the Smart Places Acceleration Program under the NSW Government's Digital Restart Fund and ran from November 2021 to July 2023.

SIMPaCT leverages cutting-edge technology to automate and fine-tune irrigation based on real-time data and predictive modelling. The system aims to enhance water efficiency, mitigate urban heat, and improve the management of green infrastructure while maintaining high public amenity levels.

Compared to conventional smart irrigation systems, the SIMPaCT system offers several advanced features and capabilities (Tovey, 2023):

- **Integrated Digital Twin**: At the core of the SIMPaCT system is a digital twin, an integrated package of hardware and software components that includes real-time data collection, data management, advanced analytics, dynamic feedback, and smart irrigation control. This digital twin models the irrigation environment and continuously adapts to changing conditions.
- **Advanced Data Analytics and Machine Learning**: The SIMPaCT system uses advanced data analytics and machine learning algorithms to dynamically optimise irrigation schedules. By analysing data from soil moisture sensors, weather forecasts and other environmental inputs, the system can make precise adjustments to irrigation in real-time.
- **Dynamic Environmental Adaptation**: Unlike conventional systems that rely on fixed schedules or basic weather data, the SIMPaCT system can 'learn' and adapt dynamically based on a comprehensive understanding of current and forecasted environmental conditions, including changes in weather, plant needs and microclimate variations.
- **Enhanced Public Dashboards**: The system provides both operational and public dashboards. Operational dashboards allow park managers to monitor and control the system in real-time, while public dashboards offer park users information about environmental conditions, promoting better use of park spaces.
- **Scalability and Flexibility**: Designed with scalability in mind, the SIMPaCT system can be adapted to various sizes and types of green spaces. Its modular data architecture allows for easy integration with existing irrigation systems and future technological upgrades.

Notably, the SIMPaCT system is interoperable with many sensors, connectivity options and software tools. Because it is equipment agnostic, the SIMPaCT system can be retrofitted to an existing conventional smart irrigation system or be implemented with new equipment. In essence, the installation would be as per conventional smart irrigation, but the data management and decision-making algorithms would be done by SIMPaCT.

At a high level, the deployment of SIMPaCT, in addition to conventional smart irrigation, would require (Tovey, Wilmot, & Phansalkar, 2023):

- IoT System Design and Integration Management: detailed design and integration management of IoT systems and documentation and configuration of data flows from sensors to the digital twin.
- Platforms and Services: platform usage, instantiation and customisation of platforms and models, hosting of the platform and database establishment, customisation of IoT and data management platforms, training of biophysical models, creation and optional first-year hosting of dashboards.

- Operationalisation and Handover: integration of workflows to ensure smooth operation, training programs for irrigation contractors and landowners to ensure effective use and maintenance of the system.

3.5. Procurement and Implementation Approach

The procurement and implementation approach for SI should follow iterative steps to allow the council to develop capabilities and maturity in this space. The strategies should be compliant with the procurement recommendations of the Western Sydney Smart Infrastructure Manual.

3.5.1. Procurement Strategy for Scenario 1 (Conventional Smart Irrigation Systems)

Currently, BMCC has rolled out smart irrigation to nine of its sports fields, primarily as part of the irrigation systems renewal process. These projects are typically carried out on a case by case basis. Irrigation systems can be opportunistically upgraded if they are deteriorated, reducing the inefficiencies of manual irrigation. Ideally these projects are partially funded by grants aimed at improving open spaces, promoting sustainability, or applying smart technology.

For each sports field, BMCC engaged an Irrigation Australia-certified consultant to design the systems and select the best-value suppliers. They also procured the specialist irrigation equipment (controller, valves, sprinklers, etc) as specified by the consultant and sought lump sum quotes from certified installers for the installation.

For future engagements by other councils, it is proposed to adopt a similar approach to that of BMCC, involving the following steps:

- Determine which sports fields need irrigation renewal based on the condition and performance of the existing irrigation system and the manual effort required to irrigate. Ideally a program of upgrades should be identified to leverage potential economies of scale.
- Engage Irrigation Australia-certified irrigation design consultants to design the irrigation systems, conduct an optioneering analysis of appropriate irrigation system suppliers, and develop installers RFQ documentation, including scope of works, design drawings, a bill of materials (BOM) for the client and the client-supply equipment list.
- Prepare a request for quotation (RFQ) for the irrigation system installation, including the supply and installation of items such as pipework and electrical cabling, and testing and commissioning of the equipment, specifying which will be the client supplied items, and including the design and BOM prepared by the consultant.
- Use council procurement procedures to evaluate the RFQ responses, identify the preferred proponent, negotiate terms and manage the engagement. Ensure the installers are certified by Irrigation Australia and the OEM.
- Procure the client-supplied equipment, considering lead times to prevent delays in the installation timeframe.

The standards and skills requirements for the designer and installer should be as per sections 3.4.1 and 3.4.2. It is crucial that the equipment procured meets internationally recognised standards, particularly since much of the equipment may be sourced from overseas.

It is doubtful whether cross-council procurement of conventional smart irrigation systems would deliver significant benefits. The ‘park by park’ approach to irrigation system upgrades across Western Sydney councils and the lack of scale (offered mainly by the asset renewal works pipeline), means cross-council procurement of conventional smart irrigation is unlikely to deliver significant cost savings or operational efficiencies.

3.5.2. Procurement Strategy for Scenario 2 (SIMPaCT Solution)

The roadmap for scaling the SIMPaCT solution outlines several potential scenarios for broader adoption and implementation (Tovey, Wilmot, & Phansalkar, 2023). The scenario being considered at this initial stage involves replicating the SIMPaCT solution as a commercial package for individual installations. The system would be offered as a complete solution to new customers in different locations. The degree of customisation required for each new site will be determined through further testing, known as SIMPaCT 2.0 implementation.

SIMPaCT 2.0 is currently in the planning stages and aims to be trialled in partnerships with entities such as local councils. It is intended to be a more refined and scalable version of the initial pilot system, incorporating feedback and improvements identified during the initial deployment to make the technology more accessible and cost-effective. However, the expected high costs associated with SIMPaCT 2.0 mean that it will likely require grant funding and strategic partnerships for broader implementation by councils.

Nonetheless, the roadmap identifies several potential applications for SIMPaCT 2.0 in councils, including development precincts, multiple park groupings, prestigious buildings, homes or sites, golf courses, large outdoor sports facilities, defence grounds, or locations with highly valuable plants. For example, LGAs with large developments where the developer already has deployed resources skilled in cloud-based automation, smart meters and fast connectivity (e.g., 4G or LoRaWAN) may find SIMPaCT an attractive retrofit solution. Additionally, councils managing multiple water sources (dams, rivers, reservoirs) may find value in enabling smarter water management without manual intervention through predictive modelling and machine learning.

To leverage the SIMPaCT solution, the following approach is proposed:

- **Identify Viable Opportunities**: Determine which sports fields or green spaces are suitable for SIMPaCT, considering single or multiple site combinations.
- **Liaison with SIMPaCT**: Engage with SIMPaCT to assess the suitability of the identified sites for a SIMPaCT 2.0 trial. Direct liaison is essential due to the significant number of variables involved.
- **Develop Project Scope**: If preliminarily suitable, develop a project scope in partnership with SIMPaCT.
- **Seek Grant Funding**: Explore grant funding opportunities in partnership with SIMPaCT to support the project.
- **Design and Contracting**: The design of the system should be led by SIMPaCT. Establish a contract or memorandum of understanding as appropriate.
- **Refine Project Scope and Costs**: Refine the project scope and detailed costs in collaboration with SIMPaCT

Opportunities for cross-council procurement of the SIMPaCT solution need to be weighed up against each council's unique needs, site-specific requirements to verify fitness for purpose and value for money for each council.

3.6. Data Approach

One of the key considerations for establishment of the data solution architecture is based on the need (or not) to establish systems for data capture, storage and analysis, which can significantly increase the costs and complexity of the overall solution. Another item is the use of standardised protocols for data communications which affect the ability of components to share data in real time.

3.6.1. Data Approach for the Base Case (Conventional Manual Irrigation Systems)

There are no data considerations for manually operated irrigation systems under this scenario.

3.6.2. Data Approach for Scenario 1 (Conventional Smart Irrigation Systems)

The conventional irrigation system operates using pre-set schedules adjusted by sensor data, third-party data, or remote app controls. The key data architecture components are:

- Sensors collect data and transmit it to the local controller via wired or wireless communication (e.g., LoRaWAN, Wi-Fi, Bluetooth, etc)
- Local Controller adjusts irrigation schedules or triggers operations based on sensor inputs (e.g., rain sensors can stop watering).
- Actuators (e.g. valves) are controlled by the local controller to run or stop the system.
- Cloud-Based platform aggregates data from the site and third-party sources (weather forecasts), analyses it, and provides operational instructions to the local controller.

- User Interface allows users to visualize system status, view trends, and operate the system remotely via an app or web interface.

Data flows for a conventional smart irrigation setup are shown in the figure below:

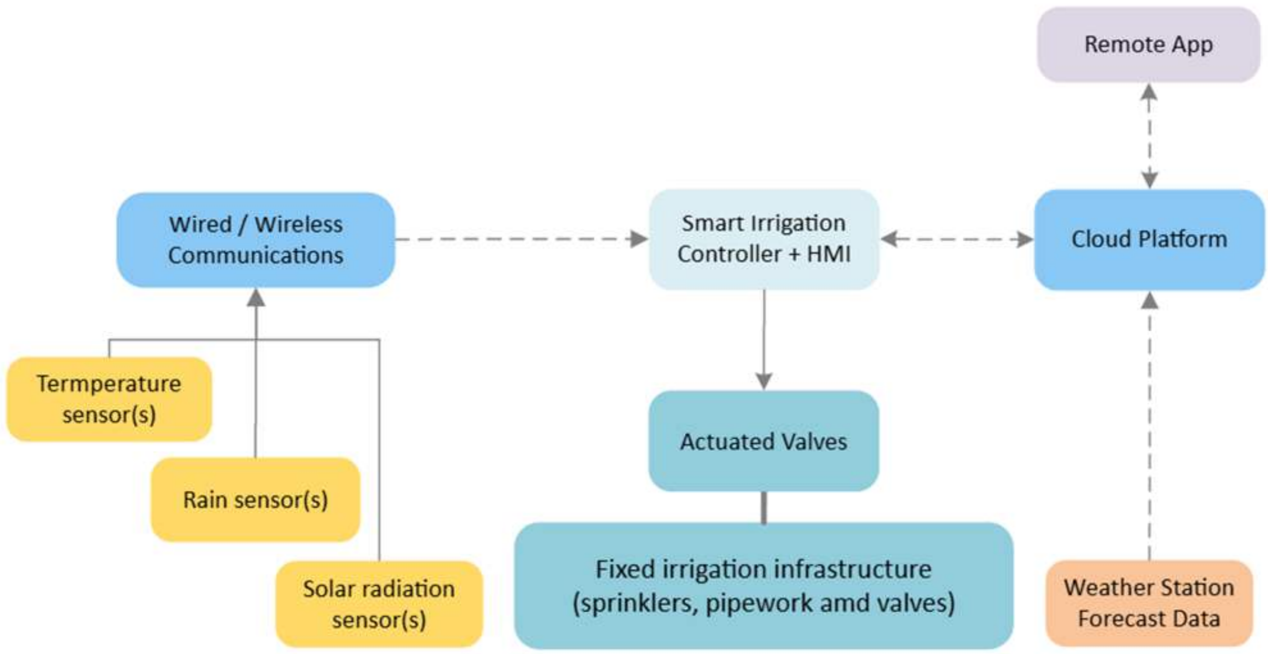


Figure 6: Example of Data flow for a conventional smart irrigation setup.

3.6.3. Data Approach for Scenario 2

While conventional smart irrigation systems offer improvements over manual systems by using sensor data and remote control, SIMPaCT provides a more sophisticated and adaptive approach. It leverages advanced analytics, machine learning, and a digital twin to continuously optimise irrigation, making it more efficient and responsive to environmental changes. The key data architecture aspects that are different to conventional smart irrigation are as follows (Tovey, 2023):

- Integrated Digital Twin: SIMPaCT uses an integrated digital twin that models the irrigation environment and continuously adapts to changing conditions.
- Advanced Analytics and Machine Learning: Utilises advanced data analytics and machine learning to dynamically optimise irrigation schedules; analyses comprehensive data sets including soil moisture, weather forecasts and environmental conditions.
- Dynamic Environmental Adaptation: the system learns and adapts in real-time to changes in weather, plant needs and microclimate variations.
- User Interface and Remote Operation: Offers enhanced public and operational dashboards.

As a key component, SIMPaCT requires an irrigation adapter, which forms a connection between the Digital Twin and the existing irrigation management platform and converts soil moisture predictions into operational commands. Figure 8 illustrates the data architecture diagram. Appendix F shows an expanded version of this graphic, including a short explanation of each component.

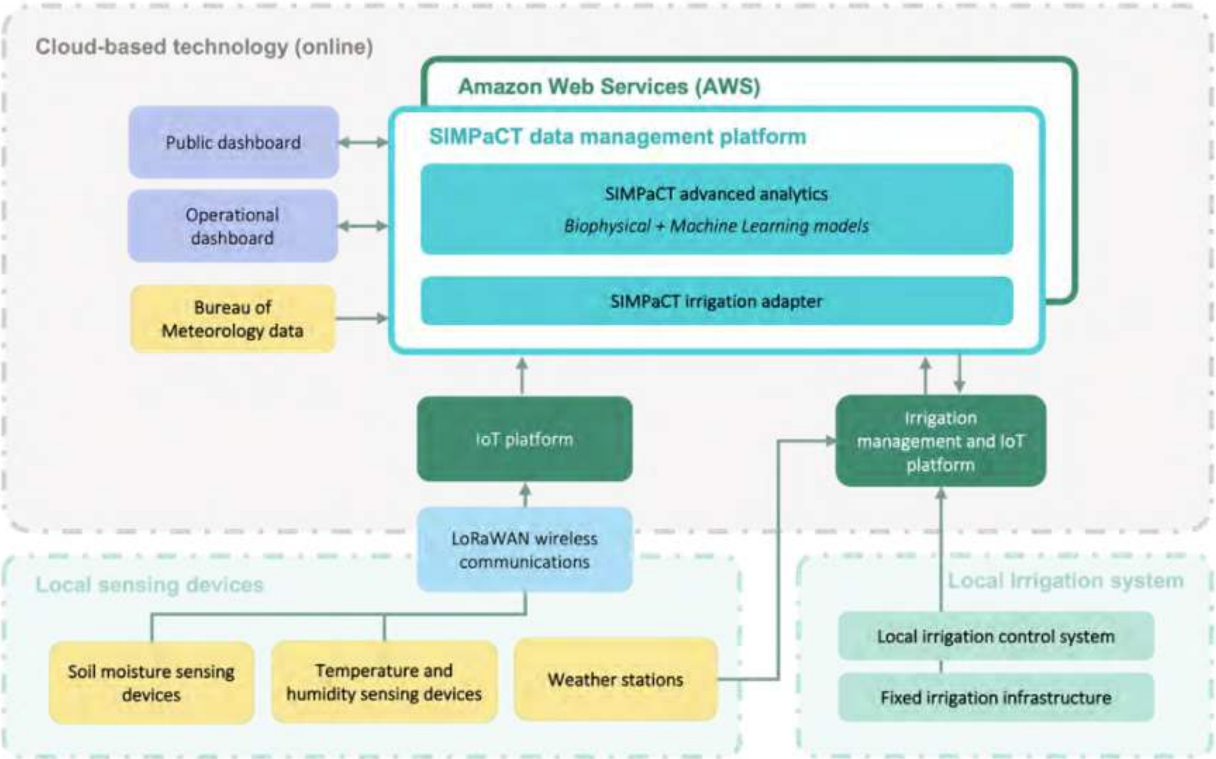
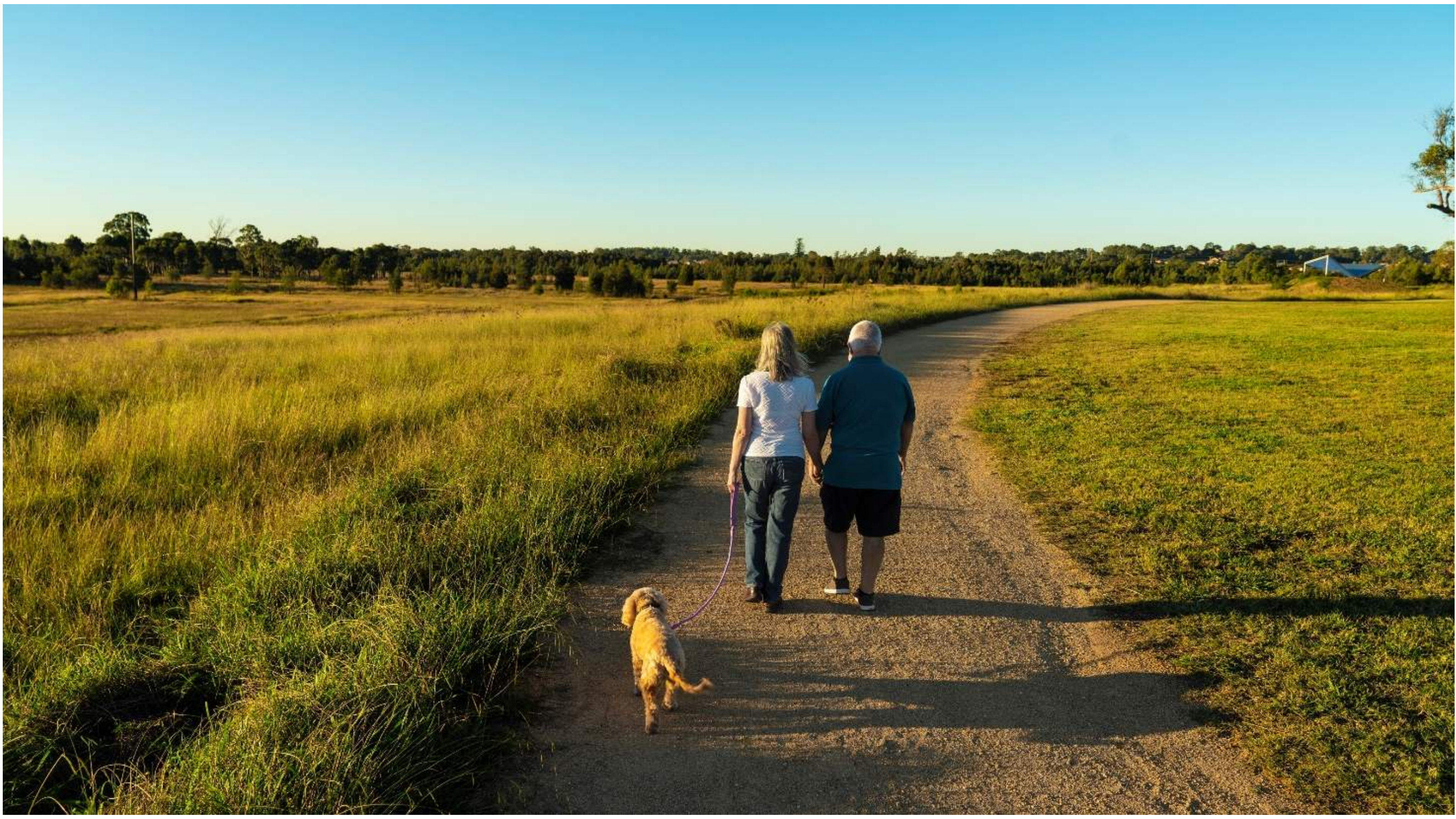


Figure 7: Simple SIMPaCT data architecture (source: Tovey, 2023)

It should be noted that due to the complexity of this system for most councils, adopting the SIMPaCT system would require additional skilled resources to implement and support the data system and interfaces.



3.7. Cost Breakdown and Analysis

3.7.1. Summary of financial / cost assumptions:

In the development of the financial assessment, the following cost assumptions have been made:

- All costs are in AUD applicable to FY2025 and unindexed
- All costs exclude GST
- The relevant costs being quantified are for the installation and operation of irrigation systems for a 14,200m² sports field, which is the average for BMCC.

The following rates form the basis for the estimated costs:

Items	Unit cost	Cost basis
Water consumption costs for smart irrigation systems	$0.69/m²/year	Average water bill costs for sports field in BMCC in 2022 and 2023, where costs were provided.
Council maintenance staff member	$75/hour/staff	Cost of BMCC employees to water the recreational parks with manual irrigation
Vehicle	$82.00/day	All-inclusive vehicle cost to transport BMCC employees between each of the recreational parks with manual irrigation

Table 4: BMCC Estimated costs

Key assumptions applicable to the development of the models are as follows:

- Excluded costs associated in getting the organisation to become mature in SI.
- Estimated costs for the installation of manual and conventional smart irrigation systems were based on Bill of Materials for the smart irrigation system for Knapsack Park (2017), Gloria Park (2022) and Tom Hunter Park (2019).
- Costs for the installation of the SIMPaCT system are based on estimated costs from the SIMPaCT roadmap (Tovey, Wilmot, & Phansalkar, 2023).

3.7.2. Costs for the Base Case (Manual Irrigation)

The estimated costs are based on the installation of a manual irrigation system in a 14,200m² sports field and its operation.

The costs are estimated as follows:

- Costs for procurement and installation of irrigation system: $201,311. This includes pumping system, tank, water supply and irrigation pipework and valving. It includes 10% contingency.
- Internal costs for manual operation: $33,332 per annum
- Water consumption costs: $12,248 per annum
- Maintenance costs: $1,006 per annum, based on 0.5% of asset replacement value (ARV)

3.7.3. Costs for Scenario 1 (Conventional Smart Irrigation)

The estimated costs are based on the installation of a conventional smart irrigation system in a 14,200m² sports field and its operation. The costs are estimated as follows:

- Costs for procurement and installation of irrigation system: $240,541. This includes the same equipment as the Base Case, plus the irrigation control system and advanced valuing and sprinklers It includes 10% contingency.
- Water consumption costs: $9,798 per annum based on 25% water efficiency.
- SIM Card cost: $500 per annum
- Maintenance costs: $3,608 per annum, based on 1.5% of asset replacement value (ARV)

3.7.4. Costs for Scenario 2 (SIMPaCT Solution)

The costs associated with the implementation of SIMPaCT 2.0 solution in a 14,200m² sports field and its operation.

The costs are estimated as follows:

- Costs for procurement and installation of irrigation system: $298,540. This includes additional design costs, sensor equipment and data communications. It includes 25% contingency given it is currently a pilot and has not been commercially proven.
- Water consumption costs: $9,798 per annum, similar to Scenario 1.
- Licensing: $28,850 per annum
- Maintenance costs: $4,478 per annum, based on 1.5% of asset replacement value (ARV)

Item	Cost Category	Base Case	Scenario 1	Scenario 2
Water consumption	OPEX (per annum)	$12,248	$9,798	$9,798
Watering labour	OPEX (per annum)	$33,332	$-	$-
Irrigation system procurement and installation	CAPEX	$201,311	$240,541	$298,540
Irrigation systems communications / licensing	OPEX per annum	$-	$500	$28,850
Irrigation system maintenance	OPEX per annum	$1,006	$3,608	$4,478

Table 5: Cost breakdown summary for technology scenarios in BCC

The cost breakdown of the scenarios is detailed in Appendix E.

4. Findings and Conclusion

4.1. Summary

This Paper summarises the specifications, approach to procurement, data architecture and budget costs associated with the different scenarios for ST / SI solutions for Stormwater Condition Assessment and Sports Fields Irrigation. The basis for the analysis is in the case studies for BCC and BMCC respectively.

There are potentially some significant benefits from introducing these technologies into other councils, but there are also challenges. Up-front investment and ongoing support are both required to improve the maturity and sophistication of infrastructure solutions and there needs to be a proper appraisal of return on investment.

While the specific case studies are promising, these improvements are pilots at this stage only and require conversion from technical piloting exercises to more mature commercially tested solutions in order to understand fully the costs.

For any implementation, there are many planning considerations required to be carried out up front before making a decision to proceed. These include: the available CAPEX and budget impact, staff resources, skills and organisation and overall SI maturity of the councils.

At a broader level, transparency of the upcoming pipeline of smart infrastructure works involving renewals and improvements could provide benefits to council/s in competitive pricing in return for economies of scale. Grouping of such SI works may also enable leverage grant funding opportunities.

A more rigorous cost-benefit analysis is provided in Paper 3.

4.2. Stormwater Condition Assessment

The BCC case study (illustrated in Scenario 1) demonstrates that there are potential efficiencies to be gained through the introduction of machine learning vision systems to filter and interpret imagery and identify defects. With a well-developed ML model, the CCTV operator can potentially save analysis time by identifying and classifying defects automatically, with expert review brought in at the end. The benefits are not only potentially saving money to do the work, but also allow for more of the stormwater network to be covered, thus reducing risk to the council.

However, the pilot indicates that the technology is still in its infancy and requires more development and maturity to deliver benefit at scale. It is thus recommended that councils rely on major commercial partners to do the development, since these companies have access to potentially many more clients and asset networks to improve and refine their algorithms and make the delivery of these solutions more cost-effective.

For the third scenario associated with integrating CCTV analysis with AMS systems, there are some potential benefits but also considerable costs. It is likely that only councils with very high SI maturity will benefit from such undertakings.

An additional challenge observed for drainage assets surrounds the procurement processes for inspections, and renewals and repairs. ML-assisted inspections are only viable for larger scopes of inspections, typically more than 50km/year, which is too large for many councils. Additionally, the procurement of repairs and renewals is typically done on an ad-hoc basis and can take up to six months to finalise.

By establishing cross-council collaboration there is an opportunity to streamline and standardise the procurement processes for:

- CCTV Inspections. This involves establishing multi-council standardised specifications and procurement processes and grouping inspections of neighbouring councils into larger scope packages. By doing so, councils can benefit from economies of scale, making ML-assisted inspections viable even for councils that individually might not meet the minimum scope requirements.

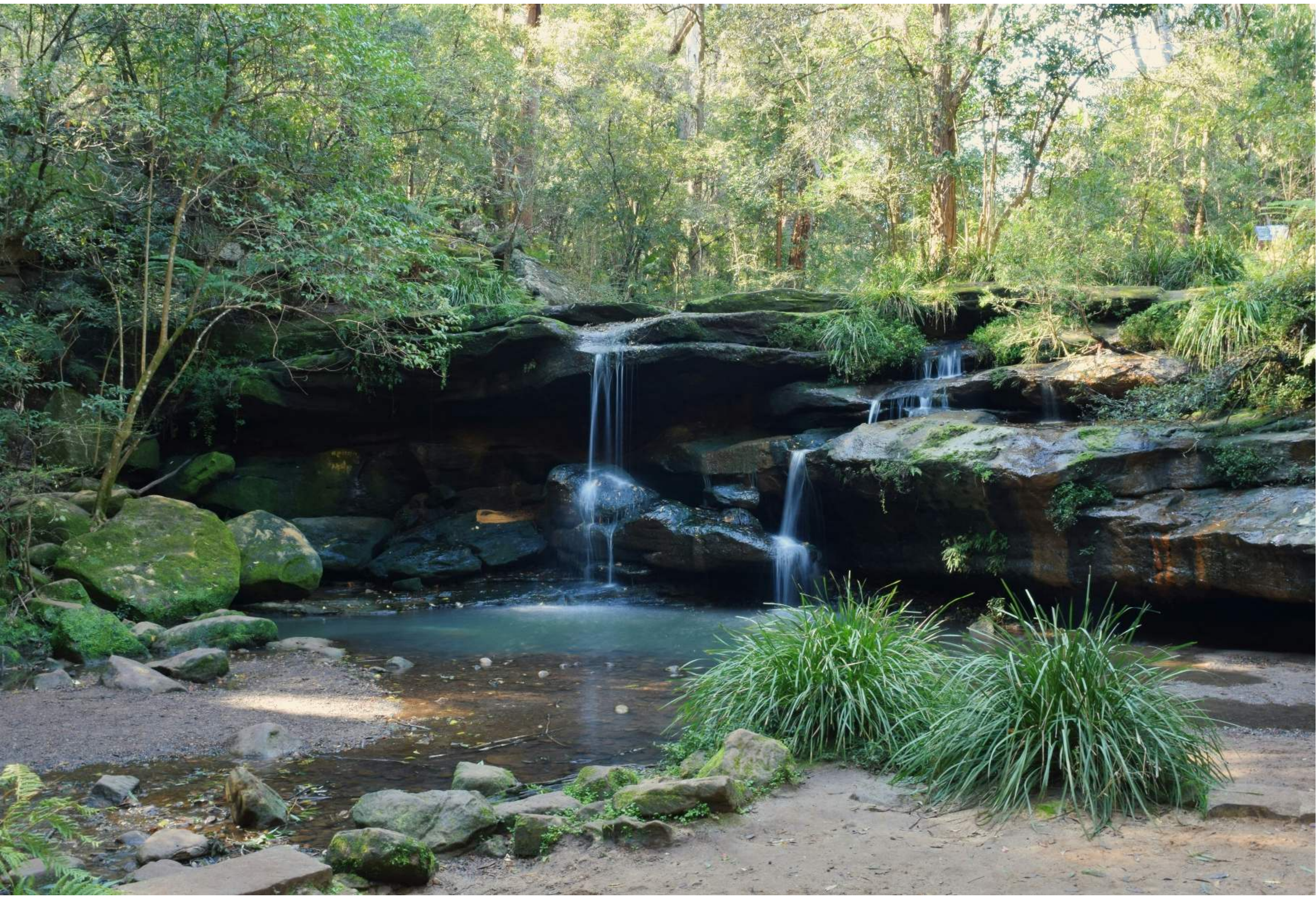
- Repairs and Renewals. This involves establishing multi-council panels with standard repair rates, that can ideally be aligned to the outcomes of the CCTV inspection and repair recommendations. Such a structure ensures that repair and renewal processes are streamlined and expedited, reducing the typical ad-hoc nature and lengthy timelines currently experienced.

4.3. Smart Irrigation

The BMCC case study (illustrated in Scenario 1) shows the advantages of implementing simpler smart irrigation systems. With most of these products being commercial-off-the-shelf (COTS), the technology is relatively mature, and accessible to councils. Importantly the costs are not significantly more than those of manual irrigation systems with many more potential benefits provided. It is however doubtful whether cross-council procurement of conventional smart irrigation systems would deliver significant benefits that would result in cost savings and operational efficiencies.

For the second scenario, the use of a much more sophisticated solution based on SIMPaCT may be beneficial in the future but is at an early stage and the costs are not yet clear. This smart infrastructure solution involves the integration of multiple smart technologies and systems, establishing data-driven models that enhance operational efficiency and decision-making. Setting up integration of systems and supporting the platform will be a major factor in the long-term viability of this solution.

Appendices



Appendix A – Source of data and information

Blacktown City Council

- Blacktown resourcing strategy
- Asset database
- Example of traditional inspection reports
- Example of ML-assisted inspection reports
- ML-assisted CCTV Inspection information: VAPAR, and others.
- GIS mapping of Blacktown City Council network
- Interview with Blacktown City Council staff

Blue Mountains City Council

- Blue Mountains resourcing strategy 2022-2032
- Blue Mountains operational plan 2023-2024
- Blue Mountains delivery program 2022-2026
- Commercial irrigation installation information: Hunter industries, and others
- Open Space and Recreation Asset Management Plan 2023
- Asset database

Transport for NSW

- Western Sydney Smart Infrastructure Manual – March 2023

SIMP@CT

- Project overview
- Project blueprint: Tovey, A. (2023). The SIMPaCT Blueprint. Prepared for the NSW Department of Planning and Environment, Water. Retrieved from https://opus.lib.uts.edu.au/handle/10453/173669
- Project roadmap: Wilmot, K., Tovey, A., Phansalkar, A. (2023) SIMPaCT Roadmap to Scalability. Prepared for the NSW Department of Planning and Environment, Water. Retrieved from https://opus.lib.uts.edu.au/handle/10453/173670

Appendix B – Comparison of Smart Technology Scenarios for Stormwater CCTV

The following scenarios are assessed against the renewal planning process:

Subsection	Traditional CCTV Inspections	ML-Assisted CCTV Data Analysis	Enhanced Integration with Council Systems
Definition of Scope of Inspections	Determined by mainly by expert knowledge. Supported by available information on risk, criticality, flood mapping, and others.	Potential benefits of better-organised supporting data from previous inspections but lacks a systematised approach.	Historical data from ML inspections are embedded in EAM and GIS systems, allowing for more consistent analysis.
Packaging of Inspections	Grouped geographically and based on local knowledge.	No significant improvements in this step.	No significant improvements in this step.
Planning Inspection	Inspection plans focus on physical inspection, with minimal data focus.	Accurate asset data provided digitally.	Automatic syncing of asset data to the inspection system, including operational data and previous knowledge.
Pipe Inspection	Standard- or High-resolution cameras capture video footage; operators log defects manually.	No manual logging of defects, video uploaded to cloud after inspection for ML processing.	Real-time ML algorithms provide feedback to the operator, enhancing data accuracy and on-site efficiency.
Defect Identification and Assessment	Manual review and classification of defects based on footage, according to WSA 05-2020 Conduit Inspection Reporting Code of Australia.	Preliminary defect identification and assessment conducted off-site by ML algorithm; defects organised in a user-friendly interface for human review.	Additional integration of asset data from AMS to assist engineers with assessment, providing better context and additional insights.
Remediation Recommendations and Scoping	Recommendations made by engineers based on identified defects, following industry best practices; scope of work defined, including estimated costs.	Heavily reliant on engineer's expertise, assisted by predefined rules and repair values in the assessment software.	Heavily reliant on engineer's expertise, assisted by historical data on previous repairs.
Reporting and Data Handover	Detailed inspection reports generated manually, provided in PDF and digital video formats.	Automated report generation from assessment interface and supporting data in CSV format; video footage downloadable.	Additional emphasis on data quality management, with larger amount of data integrated in the AMS.
Review of Reporting and Data	Senior engineers review PDF reports for accuracy of the assessment and completeness.	Similar review process but using the dedicated software interface.	Similar to ML-assisted, but with a strong focus on data quality control due to AMS integration
Integration of Outcomes and Updated Information into AMS	Inspection outcomes are recorded in document management system. Ad-hoc spreadsheets are used for data tracking.	Data exported in database-friendly formats for manual uploads to AMS, consistent organisation of inspection outcomes. No advanced integration with EAM or BI systems.	Automatic syncing with AMS, ensuring current state of assets and data captured during inspections and assessment. Robust data management workflows established, more effort in quality control required due to increased data volume. Standardised BI reports support analysis and decision-making.

Subsection	Traditional CCTV Inspections	ML-Assisted CCTV Data Analysis	Enhanced Integration with Council Systems
Prioritisation and Definition of Renewal Plan	Prioritisation based on manual analysis of inspection data and risk factors.	Interface outputs in predefined format for efficient data analysis and prioritisation	Comprehensive data analysis using integrated systems and standardised BI reports facilitating efficient prioritisation and definition of renewal plans. Integration supports coordinated approach across internal departments, such as drainage and roadworks.
Standards, Best Practices, and Skills	Compliance with established standards, including WSA 05-2020 Conduit Inspection Reporting Code of Australia and IPWEA Practice Note 5; adherence to safety and quality standards; NATA accreditation.	Similar standards, with additional considerations for cloud storage and data transfer; training provided by the service provider; understanding of data service contracts and SaaS requirements.	Additional considerations for secure APIs for data transfer, documentation of requirements and workflows, BAU operational support of systems, regular audits and quality reviews, and advanced capabilities in complex database reporting to extract information from integrated systems.

Appendix C – Cost Breakdown for Stormwater Condition Assessment Scenarios

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
CCTV Inspection, reporting and data collection by contractor.	OPEX (per annum)	**$160,000**	**$145,000**	**$145,000**	Costs for CCTV Service based on contractor rates. Assumed 50km per year at $3.20 / m	Costs for CCTV Service and ML Service, based on contractor rates. Assumed 50km per year at $2.90 / m	As per Scenario 1.
Internal Costs for Engineering review and data administration	OPEX (per annum)	**$21,337**	**$4,363**	**$3,243**			
Internal Costs: quality control	*OPEX (per annum)*	*$2,593*	*$1,296*	*$1,296*	Estimate that Council engineer will watch 20% of the videos and reports for QA.	Estimate that quality control can be done 50% quicker, due to interface	As per Scenario 1.
Internal Costs: data extraction	*OPEX (per annum)*	*$11,905*	*$400*	*$-*	Estimate 5 mins per inspection report to extract summary data	Estimated 4 hours to bulk download data	No manual data extraction required
Internal Costs: data preparation and upload	*OPEX (per annum)*	*$6,840*	*$2,667*	*$1,947*	Estimate: - 8 hours to quality control by Council Engineer - 15% error rate for asset mapping and 10 mins to correct - 4 hours for data format verification and bulk upload by systems manager.	Estimate: - 2 hours to quality control by Council Engineer - 5% error rate for asset mapping and 10 mins to correct - 4 hours for data format verification and bulk upload by systems manager.	Estimate: - 2 hours to quality control by Council Engineer - 5% error rate for asset mapping and 10 mins to correct
Integration Implementation (internal and external costs)	**CAPEX**	**$-**	**$-**	**$70,530**			

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
Project Management	*CAPEX*	*$-*	*$-*	*$17,280*	Not applicable	Not applicable	Estimate 100h for systems manager for 3 months.
Workshops and Planning	*CAPEX*	*$-*	*$-*	*$12,000*	Not applicable	Not applicable	Defining asset information requirements, conducting workshops, and mapping business processes. Estimate for systems consultant: - Business systems discovery: 20h - Requirements workshops: 20h - Define Specifications: 20h
Systems Configuration and Testing	*CAPEX*	*$-*	*$-*	*$8,000*	Not applicable	Not applicable	Estimate 40h for systems consultant to configure the interface on the council side and perform testing
Change Management, Handover and Training	*CAPEX*	*$-*	*$-*	*$7,600*	Not applicable	Not applicable	Estimate for a systems consultant: - 10h for final documentation - 8h for change management planning and communications - 20h for training provided by systems consultant
Council internal costs	*CAPEX*	*$-*	*$-*	*$15,000*	Not applicable	Not applicable	Estimate 100 hours for council staff to participate in workshop, review requirements and perform UAT at an average rate of $150/hr

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
Contingency	*CAPEX*	*$-*	*$-*	*$10,650*	Not applicable	Not applicable	Estimate 25% for CAPEX costs on IT project.
Integration Licencing and Support	**OPEX (per annum)**	**$-**	**$-**	$23,600			
API Access Fees	*OPEX (per annum)*	*$-*	*$-*	*$10,000*	Not applicable	Not applicable	There are no costs available because this system has not been implemented. Based on similar products it assumed that a system provider would charge between $5k and $20k to provide access to an interface.
Integration Support (external)	*OPEX (per annum)*	*$-*	*$-*	*$8,000*	Not applicable	Not applicable	Estimate 40h per year for systems consultant
Integration Support (internal)	*OPEX (per annum)*	*$-*	*$-*	*$5,600*	Not applicable	Not applicable	Estimate 40h per year for council engineer consultant

Appendix D – Overview of smart technology offered by major providers in the Australian market

Table 6: Overview of smart technology offered by major providers in the Australian market. Those shaded in dark green indicate the features of an advanced system (Tovey, Wilmot, & Phansalkar, 2023)

Providers / Features	Hunter	Rainbird	Galcon	Aquamonix	Libelium	Waterwise	Orbit	OneWifi	Arduino	Dragino	Easy irrigation	Irritrol	Jeffery Electronics	Fieldmouse
Communication technology														
Wired/USB	√								√				√	√
WiFi	√	√		√	√	√	√	√	√	√	√	√		√
LoRaWAN					√				√	√				√
4G					√									√
5G								√						√
Radio												√	√	√
Bluetooth				√	√		√		√		√			√
Cellular transmission/SIM cards			√								√			√
Controllers														
Manual		√									√			
Automated	√	√		√			√	√	√	√	√	√	√	√
Weather integration														
BoM or internet based	√	√	√	√	√	√	√	√				√		√
Scheduling management														
Alerts and notifications	√			√			√	√	√	√		√		√
Scheduling timeframes						√		√						√
Daily	√		√	√	√	√					√	√	√	√
Calendar/selecting days of the week		√		√		√								√

Providers / Features	Hunter	Rainbird	Galcon	Aquamonix	Libelium	Waterwise	Orbit	OneWifi	Arduino	Dragino	Easy irrigation	Irritrol	Jeffery Electronics	Fieldmouse
Event based	√	√							√			√		√
Up to a week	√		√			√		√			√			√
Week or more		√									√			√
Logic Control														√
Predictive modelling more than two weeks	√	√		√	√	√								
AI and Machine learning features				√	√	√								
Cloud data storage	√	√	√	√	√	√		√						√
Data analysis		√		√	√	√	√							

Appendix E – Cost Breakdown for Sports Fields Irrigation Scenarios

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
Water Consumption Costs	OPEX (per annum)	**$12,248**	**$9,798**	**$9,798**	Estimate around 25% inefficient water usage compared to	Based on a 14,200m² sports field using $0.69/m²/year for watering costs	Based on available literature, there are no measurable water efficiencies compared a properly implemented Scenario 1
Watering Labour	OPEX (per annum)	**$33,332**	**$-**	**$-**	Estimate 4 hours labour per week for 2 council officers + vehicle	Not applicable	Not applicable
Irrigation system procurement and installation	CAPEX	**$201,311**	**$240,541**	**$298,540**			
Project Management and Design Management	*CAPEX*	*$16,637*	*$19,879*	*$25,000*	Estimate around 10% of CAPEX, based on low-risk council projects	Estimate around 10% of CAPEX, based on low-risk council projects	Lower estimate from SIMPaCT roadmap, Table C5 (calculation of for establishing a new standalone instance of the SIMPaCT Solution at a new site). Cost breakdown items included: "Project Management", "oversight" and "IoT system design and integration management"
Pump installation	*CAPEX*	*$42,847*	*$42,847*	*$42,847*	Estimate based on average for cost item in sample BMCC projects. The range was from$28k to $55.5k	As per the Base Case	As per the Base Case

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
Tank installation	*CAPEX*	*$60,825*	*$60,825*	*$60,825*	Estimate based on average for cost item in sample BMCC projects. The range was from $44k to $77.5k	As per the Base Case	As per the Base Case
Water Supply Connection	*CAPEX*	*$7,678*	*$7,678*	*$7,678*	Estimate based on average for cost item in sample BMCC projects. The range was from $5,500 to $10,700	As per the Base Case	As per the Base Case
Irrigation pipework	*CAPEX*	*$38,579*	*$38,579*	*$38,579*	Estimate based on average for cost item in sample BMCC projects: $2.72 per m². The range was from $2.00 to $3.41 per m²	As per the Base Case	As per the Base Case
Irrigation control	*CAPEX*	*$-*	*$15,249*	*$28,270*	Not applicable	Estimate based on average for cost item in sample BMCC projects: $1.07 per m². The range was from $0.95 to $1.23 per m²	Lower estimate from SIMPaCT roadmap, Table C5 (calculation of for establishing a new standalone instance of the SIMPaCT Solution at a new site). Cost breakdown items included: "Smart sensing devices", "Planning and delivery of an onsite smart sensor network", "Data communications"
Valving and sprinkler system	*CAPEX*	$14,796	$29,593	$29,593	Estimate 50% cost. Only basic manual valving and irrigation systems installed.	Estimate based on average for cost item in sample BMCC projects: $2.08 per m². The range was from $1.42 to 2.52 per m²	As per Scenario 1

Item	Cost Category	Base Case	Scenario 1	Scenario 2	Description Base Case	Description Scenario 1	Description Scenario 2
Mobilisation, Demobilisation, Commissioning and Handover	*CAPEX*	$1,647	$4,023	$6,040	Estimate based on low end of sample BMCC projects: 1%	Estimate based on average for cost item in sample BMCC projects: 2.1% of total installation costs. The range was from 1 to 3%.	Lower estimate from SIMPaCT roadmap, Table C5 (calculation of for establishing a new standalone instance of the SIMPaCT Solution at a new site). Cost breakdown items included: "Operationalisation and handover"
Contingency	*CAPEX*	$18,301	$21,867	$59,708	Estimate 10% for a proven technology.	Estimate 10% for a proven technology.	Estimate 25% for pilot technology
Irrigation Systems Communications / Licencing	**OPEX per annum**	**$-**	**$500**	**$28,850**	No ongoing fees	Estimate for SIM Card usage	Lower estimate from SIMPaCT roadmap, Table C5 (calculation of for establishing a new standalone instance of the SIMPaCT Solution at a new site). Cost breakdown items included: "Platforms and communications services"
Irrigation System maintenance	**OPEX per annum**	**$1,006**	**$3,608**	**$4,478**	Estimate 0.5% of CAPEX for plumbing assets	Estimate on 1.5% of CAPEX costs for assets comprising of plumbing, sensors and control systems	Estimate on 1.5% of CAPEX costs for assets comprising of plumbing, sensors and control systems

Appendix F – Expanded SIMPaCT data architecture

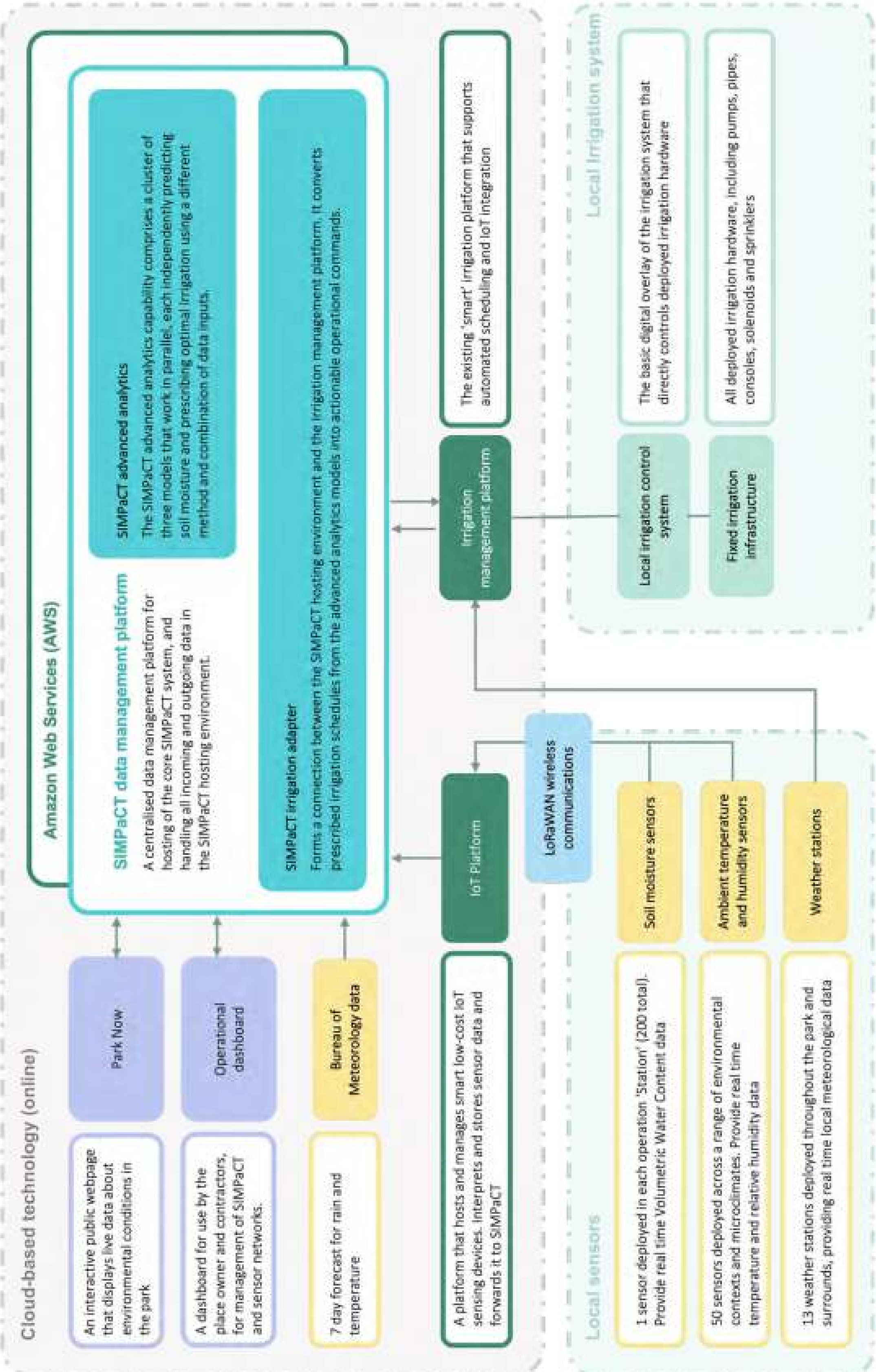


Figure 8: Expanded version of Figure 7 including a short explanation of each component (Tovey, 2023)

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