SIMP@CT

Smart Irrigation for Parks and Cool Towns

THE BLUEPRINT

JULY 2023

Document Title	The SIMPaCT Blueprint	**Reference #**	SIMP2301-B001

	Name	Signature	Date
Prepared by	Andrew Tovey (UTS)		7 August 2023
Reviewed by	Kat Vanderwal (WSU) Kerryn Wilmot (UTS)		July 2023
Approved by	Sebastian Pfautsch (WSU)		August 2023

Contributors	Kerryn Wilmot (UTS) Aditi Phansalkar (UTS) Kat Vanderwal (WSU) Cameron Owen (SAPHI) Joe Pasanen (Eratos) Christian Ulrich (HARC) Sebastian Pfautsch (WSU) Hassan Narimani (SOPA) Oliver Obst (WSU)	**Contributor organisations**	University of Technology Sydney (UTS) Western Sydney University (WSU) Sydney Olympic Park Authority (SOPA) Hydrology Risk and Consulting (HARC) SAPHI Engineering (SAPHI) Eratos

Date	Version	Amendment Description

Citation

This report should be cited as:

Tovey, A. (2023). *The SIMPaCT Blueprint.* Prepared for the NSW Department of Planning and Environment, Water

Acknowledgements

The SIMPaCT project team would like to thank the NSW Smart Places team for their deep commitment to the project and its vision.

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Executive Summary

Figure 1. Irrigation in Bicentennial Park. Image credit: WSU

This report documents the Smart Irrigation Management for Parks and Cool Towns (SIMPaCT) project, describing its purpose, structure, and implementation for a general audience including the project funder and those who may wish to implement SIMPaCT in the future. It summarises the project activities and knowledge, recording the conditions that should be met for a future successful application of the SIMPaCT solution.

The SIMPaCT pilot project ran between November 2021 and July 2023. It saw the establishment of SIMPaCT as a demonstrable solution to four key challenges facing parklands: urban heat; water efficiency; urban green infrastructure (UGI) management; and the maintenance of public amenity.

Communities across NSW are experiencing the extreme impacts of climate change. Both heat stress and water scarcity are predicted to intensify in the next decades. Urban parks and green infrastructure make a significant contribution to mitigating urban heat so their maintenance using irrigation water efficiently is increasingly important. The SIMPaCT pilot project uses smart technology to induce physical cooling of the environment in Bicentennial Park at Sydney Olympic Park (SOP) and optimise irrigation water usage. It takes an approach that optimises soil moisture conditions to maximise the delivery of coolth inside and downwind of the park. A digital twin of the site uses a combination of geo-spatial modelling and machine learning to optimise irrigation management for the best soil moisture conditions for different vegetation types under a wide range of weather conditions. The goal is for the plants in the park to operate at their maximal rates of transpiration, which in turn results in the highest degree of air cooling. SOPA staff can view conditions on an operational online dashboard and SIMPaCT issues them daily status reports. SIMPaCT also live streams environmental data to a public online dashboard to support decision making by park users about when and where to spend time in the park.

The aim of the pilot was to design and implement a fully operational demonstration of the SIMPaCT solution, capable of delivering ongoing long term value to SOPA. It serves as the start of a scalable expansion of the SIMPaCT solution. The project opens new pathways for how public parks can be designed, managed and experienced.

SIMPaCT was funded through the NSW Smart Places Acceleration Program under the Digital Restart Fund, and co-funded by SOPA and Sydney Water with in-kind contributions from most of the other partners. The project was co-designed and delivered in a multidisciplinary partnership with several organisations from government, tertiary education and private industry, led by Western Sydney University.

Project details

The SIMPaCT Solution is defined as a combination of:

- An existing irrigation system onto which the SIMPaCT solution is retrofitted and integrated with its irrigation management platform.
- SIMPaCT digital twin: an integrated package of hardware and software components, for data collection, data management, advanced analytics, dynamic feedback and smart irrigation control.
- SIMPaCT dashboards: public and operational dashboards for viewing and dynamically interacting with live data feeds from the SIMPaCT Digital Twin.
- SIMPaCT methodology: a set of approaches to the provision of data, the management of data (data schema), and the integration of the SIMPaCT digital twin with operational workflows.

A critical component to the success of SIMPaCT has been the collaborative spirit among the partners and the parallel operation of several specialised teams, although the extensive and diverse SIMPaCT team made collaboration a real challenge. To manage the delivery and coordination of the multi-partner multidisciplinary project, work was divided into several workstreams addressing technical coordination, advanced analytics, environmental data provisioning, environmental science, irrigation management and solution scalability.

The SIMPaCT digital twin is designed as an automated system, but it requires ongoing operational maintenance to ensure normal system functionality. An operational version of the project dashboard includes live data feeds and a link to full project documentation, including extensive operational guidance, and the system issues automated daily reports. The project delivered workshops to share with SIMPaCT users and managers the information and skills that are required to effectively administer and operate the SIMPaCT digital twin and maintain its function over several years.

The future of SIMPaCT

A key focus of the project was to assist other government agencies and water utilities in transitioning to smart irrigation management. To this end, the SIMPaCT pilot project developed an actionable Roadmap for scaling SIMPaCT, which included consideration of the testing that will be required to ready the technology and ascertain the realistic costs of future uses. The Roadmap defined five possible scenarios:

- Replicate the SIMPaCT solution as a commercial package for stand-alone place-based installations.
- Creative commons – make SIMPaCT open source.

- Licensing – for commercial use or for interstate or international application.
- Subscription model - a district scale digital twin that offers SIMPaCT services on a subscription basis.
- Public good big data – a publicly owned and managed metro-scale smart irrigation digital twin that delivers affordable and accessible services to place owners while also establishing powerful new water management capabilities for the water utility.

The project has defined six phases to scaling SIMPaCT, commencing as soon as possible with a mature business model available from around early 2026 for the replication scenarios, and mid-2027 for the large-scale digital twin.

Lessons

The project has been a deep learning experience which has produced extensive insights relating to process and methodology and has developed capacity to expand SIMPaCT as a valued high-impact solution.

Because the project spanned two very wet La Niña summers, at times the irrigation system did not operate when it normally would so by the end of the project, very little of the data corresponded with 'dry conditions'. As a consequence, the delivery of the four value propositions for SIMPaCT (urban cooling, water efficiency, public amenity and improved management outcomes) remains an untested hypothesis that needs data from a hot summer in order to prove the designed capabilities.

There were delays in the procurement of sensing technologies that led to delayed deployment of sensing devices and knock-on effects to data collection and other project deliverables.

The use of emerging technology is critical to innovation but carries unavoidable risk. Smart low-cost sensing technologies presented a range of challenges relating to the operation of devices and their ability to reliably report data, in part tied to their relative immaturity as products and in part due to a lack of clearly defined best practice methodology for their use. Despite these challenges, devices successfully delivered usable data. Indeed, the design of the SIMPaCT digital twin was developed around the constraints of these technologies, demonstrating new modelling approaches that may have the potential for broader application to other types of smart low-cost sensing.

The project is a meaningful science-based project that addresses an important issue impacting many communities, with the potential to deliver great benefit to Australian society. The science and technology developed during the proof-of-concept phase of the project has translated into a feasible, real-world setting and bridged the gap between research and industry. By the end of the pilot project, a fully functional instantiation of the SIMPaCT digital twin was operating in Bicentennial Park, with a tangible impact on irrigation operations. This early success has the potential to improve the quality of the park environment, and in turn, the health and well-being of visitors and residents. It promises to reduce water use and improve park management processes, both outcomes with the potential to contribute to a net positive business case for SIMPaCT.

The project celebrated winning the national 2023 IoT Impact awards for "Research" and "IoT for Good".

1 Background to the SIMPaCT pilot project

Bicentennial Park

Figure 2. A view across Bicentennial Park in 2022, with a residential tower in the background. Image credit: WSU

Bicentennial Park is a 40-hectare parkland located within Sydney's Olympic Park precinct, sixteen kilometres west of Sydney's CBD. It is predominantly reclaimed landfill, which was converted to parkland in the late 1990s, ahead of the Sydney 2000 Olympic Games. The Park is managed by Sydney Olympic Park Authority (SOPA), a state government agency. As the largest parkland in the Sydney Olympic Park precinct, Bicentennial Park provides important open space and public amenity to nearly 6000 residents and over 18,000 workers who live in or visit the area. The park receives around 1.5 million visitors per year and is the most visited park within the wider Olympic precinct1.

The growing pressures of climate change, extreme heat, drought and water scarcity are all critical challenges for Bicentennial Park that impact SOPA and the tens of thousands of residents and visitors who use the park each year. These challenges are recognised by the NSW Government as severe disruptors to public health, community wellbeing, and local economies, and are predicted to continue to intensify over the coming years. Bicentennial Park is highly susceptible to heat, drought and water scarcity, due to being on capped landfill means that it has very shallow soils. These thin soils can dry out rapidly and drought conditions in the park can begin after just a few hot days with no irrigation. Plants in the park are therefore entirely reliant upon one of the largest installed irrigation systems in Australia, which replenishes soil moisture on a daily basis throughout the summer. Operation of this irrigation system is critical for maintaining the continuous health of plants, ensuring that the value of green assets is secure, and that the public can continue to experience the positive amenity that the parkland can provide.

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1 Sydney Olympic Park Authority 2021–22, Annual Report https://www.sopa.nsw.gov.au/-/media/files/sopa/sopa/publications/current-annual-report/sopa-annual-report-2021_22-v1.pdf

Figure 3. A wetland area with boardwalk access in Bicentennial Park. Diverse green infrastructure delivers vital public amenity to visitors and residents but is stressed by water scarcity and drought. Image credit: Getty Images

The biggest challenge for SOPA is that visitor numbers are increasing much more than predicted. As a result, management of the park needs to respond to the stressed landscape with limited water resources and be operationally responsive, made worse in times of drought. To ensure efficiency of the irrigation network in the park, SOPA needs the capability to audit the performance of the system. To date lack of data like soil moisture has been one of the challenges in monitoring and operating the system.

SIMPaCT contributes to delivering SOPA's vision for Bicentennial Park because it addresses SOPA's current priorities in the following ways:

- SIMPaCT's automation of irrigation control and the availability of data make the operation and maintenance of the green infrastructure and irrigation system more efficient, helping with budget management.
- SIMPaCT maintains the green infrastructure, helping to protect and improve amenity of the park for the community. For SOPA it is important to ensure the existing assets are maintained at the highest levels and the condition of these assets are improved.
- Energy and water consumption is reduced through the smart controls of SIMPaCT.
- The real time data promptly notifies maintenance staff about issues, reducing maintenance response times.

The SIMPaCT pilot project

Introduction to the SIMPaCT pilot project

Figure 4. Delegates from the 2023 Water Research Australia national conference receive a walking tour of Bicentennial Park, to learn about the SIMPaCT pilot project. Image credit: Water Research Australia

The SIMPaCT pilot project ran between November 2021 and July 2023. It saw the establishment of SIMPaCT as a demonstrable solution to four key challenges facing Bicentennial Park: urban heat; water efficiency; urban green infrastructure (UGI) management; and the maintenance of public amenity (refer Section **Error! Reference source not found.**).

The SIMPaCT pilot project uses smart tech to induce physical cooling of the environment in Bicentennial Park, optimise water usage, and inform the activities of park irrigation operators and users. It takes an approach that optimises soil moisture conditions to maximise the delivery of coolth inside and downwind of the park. A digital twin of the site uses a combination of geo-spatial modelling and machine learning to optimise irrigation management for the best soil moisture conditions for different vegetation types under a wide range of weather conditions. The goal is for the plants in the park to operate at their maximal rates of transpiration, which in turn results in the highest degree of air cooling. SOPA staff can view conditions on an operational online dashboard and SIMPaCT issues them daily status reports. SIMPaCT also live streams environmental data to a public online dashboard to support decision making by park users about when and where to spend time in the park.

The aim of the pilot was to design and implement a fully operational demonstration of the SIMPaCT solution, capable of delivering ongoing long-term value to SOPA. It serves as the start of a scalable expansion of the SIMPaCT solution. The project opens new pathways for how public parks can be designed, managed and experienced.

Funding

SIMPaCT was funded through the Smart Places Acceleration Program under the Digital Restart Fund, administered by the Department of Customer Services of the NSW Government. SOPA was awarded $2.5M to finance SIMPaCT. The project was co-funded by SOPA and Sydney Water, with in-kind contributions from most of the other partners, towards the establishment of environmental sensor networks and a SIMPaCT digital twin.

SIMPaCT partners

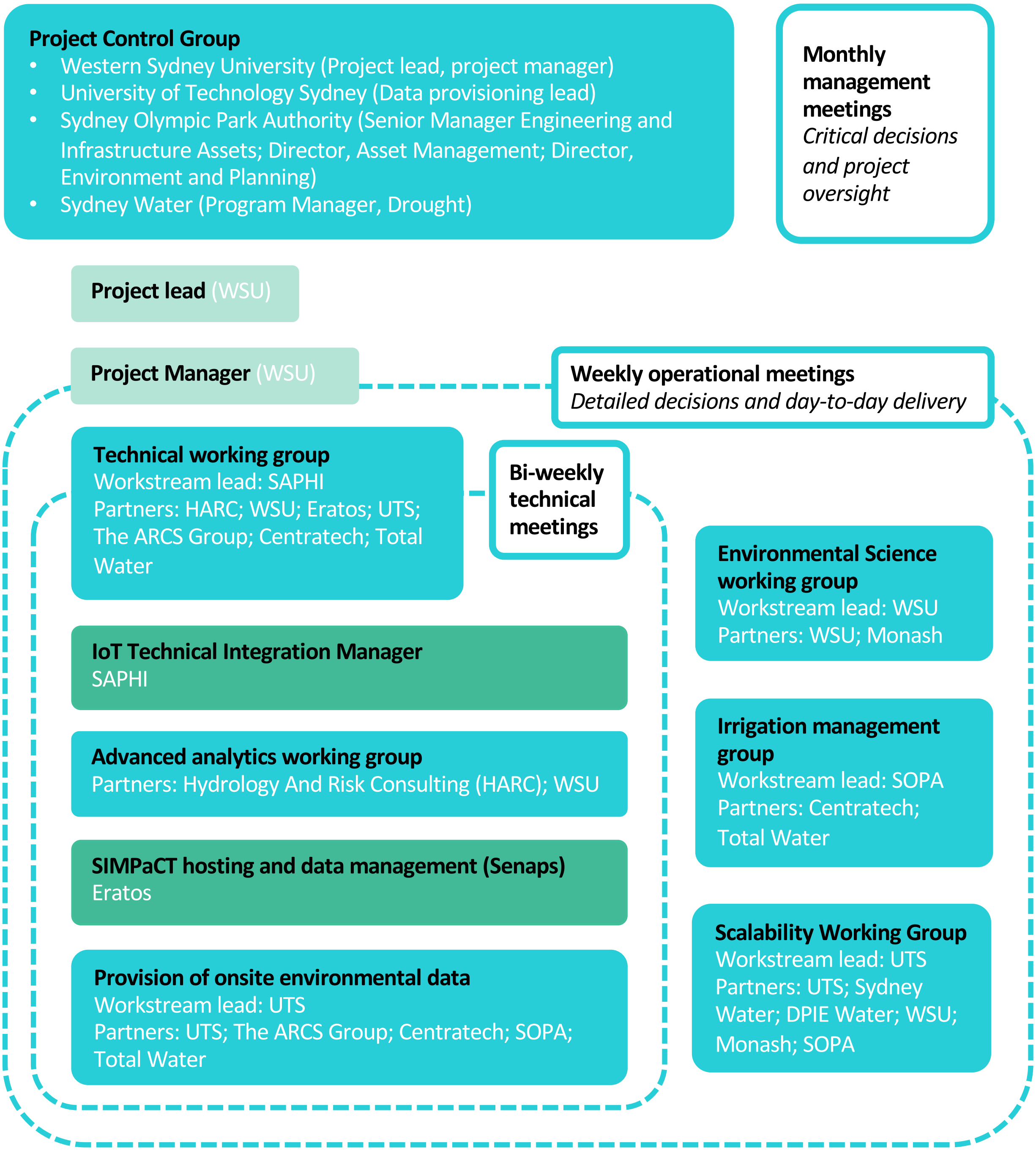
Partners for the SIMPaCT pilot project were selected during the development of the project framework and were agreed upon by the funding organisations. The project was led by Western Sydney University (School of Social Sciences), and was delivered in partnership with the following organisations:

Project lead	Western Sydney University (WSU)
Place owner	Sydney Olympic Park Authority (SOPA)
Project design, management and delivery partners	WSU University of Technology Sydney (UTS)
Irrigation model developers/providers	Hydrology and Risk Consulting (HARC) Monash University WSU
Internet of Things (IoT) providers	The ARCS Group Eratos
IoT Technical Integration Manager	SAPHI
Irrigation manager	Centratech Systems (CTS)
Strategic advisor	Sydney Water
Lead government agency and principal sponsor	NSW Department of Planning and Environment (DPE) Water

In addition, the irrigation contractor, Total Water (TW) worked closely with the researchers throughout the pilot, contributing to the practical outcome.

SIMPaCT governance and working groups model

Figure 5 shows the project structure of working groups under the direction of a Project Control Group, with a Project Manager as the formal communication link.



Project Control Group
- Western Sydney University (Project lead, project manager)
- University of Technology Sydney (Data provisioning lead)
- Sydney Olympic Park Authority (Senior Manager Engineering and Infrastructure Assets; Director, Asset Management; Director, Environment and Planning)
- Sydney Water (Program Manager, Drought)

Monthly management meetings
Critical decisions and project oversight

Project lead (WSU)

Project Manager (WSU)

Weekly operational meetings
Detailed decisions and day-to-day delivery

Technical working group
Workstream lead: SAPHI
Partners: HARC; WSU; Eratos; UTS; The ARCS Group; Centratech; Total Water

Bi-weekly technical meetings

IoT Technical Integration Manager
SAPHI

Advanced analytics working group
Partners: Hydrology And Risk Consulting (HARC); WSU

SIMPaCT hosting and data management (Senaps)
Eratos

Provision of onsite environmental data
Workstream lead: UTS
Partners: UTS; The ARCS Group; Centratech; SOPA; Total Water

Environmental Science working group
Workstream lead: WSU
Partners: WSU; Monash

Irrigation management group
Workstream lead: SOPA
Partners: Centratech; Total Water

Scalability Working Group
Workstream lead: UTS
Partners: UTS; Sydney Water; DPIE Water; WSU; Monash; SOPA

Figure 5. SIMPaCT governance and working groups model

Workstreams

SIMPaCT is a multi-partner multidisciplinary project that relied on advice from a large expert team. To manage project delivery and coordination, work was divided into several workstreams, described in Table 1.

Table 1. A list of pilot project workstreams and their roles

Working Group	Role
Technical	• An overarching technical working group to bring together all partners working on the development of the SIMPaCT technical solution. This included partners from the Advanced analytics working group, the SIMPaCT data management platform, and the environmental data provisioning working group.
Advanced analytics	• Developed a model for the prediction of soil moisture that incorporates: a virtual biophysical model of the location, based on rolling data input from soil moisture sensors, weather forecast, and geospatial factors; and a fully integrated Machine Learning model.
Environmental data provisioning	• Provided fit-for-purpose environmental data from sensors deployed within Bicentennial Park, to meet the specific needs of the project. • Other responsibilities included sensor selection; deployment methodology and planning; device provisioning; wireless communications; device hosting and management; raw data capture, interpretation and quality control.
Environmental science	• Investigated relevant environmental processes at Bicentennial Park that relate to the interactions of water, vegetation, landscape and microclimates. • Conveyed insights to the Advanced analytics and Environmental data provisioning working groups. • Provided scientific oversight, and verification that the technical solution was capable of supporting desired environmental outcomes.
Irrigation management	• Integrated irrigation commands from the SIMPaCT Irrigation control module with the existing irrigation management system installed at Bicentennial Park. • Provided a working operational knowledge of the existing irrigation system, which informed the design of the SIMPaCT core system. • Responsible for the operational delivery of irrigation outcomes that incorporate SIMPaCT into the workflow.
Scalability	• Reviewed the perspectives and requirements of prospective end users of SIMPaCT in locations and contexts beyond Sydney Olympic Park. • Reviewed the current smart city and smart irrigation landscape to help inform a scalability strategy. • Developed scenarios and pathways for scaling SIMPaCT over short, medium and long-term. • Production of a detailed and actionable roadmap for scaling of the SIMPaCT smart irrigation solution to other locations and contexts

Key deliverables of the SIMPaCT pilot project

Key deliverables of the SIMPaCT pilot project can be divided into:

- **Asset delivery** - the delivery of the SIMPaCT solution as a replicable and scalable digital twin and associated methodology.
- **Activity delivery** - the demonstration of SIMPaCT in an operational context within Bicentennial Park, plus supporting documentation.

Asset delivery

Establishment of a *SIMPaCT Digital Twin (all technical components)*

- Establishment of **a network of smart sensing devices** in Bicentennial Park.
- Design and instantiation of a combined **Biophysical model** and **Machine Learning model** for soil moisture prediction at a highly localised scale of microclimates within Bicentennial Park.
- Design and instantiation of a **SIMPaCT irrigation adapter**, which forms a connection between the Digital Twin and the existing irrigation management platform. Converts soil moisture predictions into operational commands.
- Design and instantiation of a **centralised data management platform** for hosting of the core SIMPaCT system and handling all incoming and outgoing data.
- Design and delivery of **a complete end-to-end digital architecture** that integrates all technical elements above.

Establishment of a *SIMPaCT Methodology*

- The creation of **a data collection methodology**, for the collection of fit-for-purpose data using smart sensing devices.
- The creation of **an operational sensing strategy** for data verification and sensing device troubleshooting and maintenance.
- The creation of **a metadata schema** to support data modelling within the SIMPaCT Digital Twin.
- The design of **an operational model for irrigation delivery and control** in Bicentennial Park, that informs the function and settings of the SIMPaCT irrigation control module, the irrigation management system, and irrigation contractor workflow.

Activity delivery

Demonstration of the fully integrated SIMPaCT Digital Twin, in Bicentennial Park

- The **flow of live data from sensing device networks** in Bicentennial Park into a centralised data management system.
- The **ingestion of live weather forecast data** from the Bureau of Meteorology into a centralised data management system.

- The **effective storage and management of data** from all sources, including the Biophysical model and Machine Learning model outputs.
- **Training of the Biophysical model** that uses data from the park to accurately predict soil moisture at a spatial scale granular enough to inform optimised irrigation scheduling.
- The **flow of live data into the SIMPaCT Biophysical model and the Machine Learning model**, and the subsequent processing of that data to produce optimal irrigation requirements at the scale of individual 'stations' within the park.
- The conversion of irrigation requirements into **executable commands** that are delivered to and actioned by the existing irrigation control system.
- **Complete control of the existing irrigation system**, for the entirety of Bicentennial Park, switched to SIMPaCT by the end of the project.

Operationalisation and handover of the SIMPaCT solution

- **Integration of the SIMPaCT solution** with existing irrigation management workflows in Bicentennial Park, in collaboration with irrigation contractors and SOPA.
- **Training** of irrigation contractors and SOPA staff.

Project documentation

- **SIMPaCT Blueprint** (a plain-language public-facing record of the project, created as a primary reference for future replication of SIMPaCT in new locations/contexts).
- **Detailed technical documentation** relating to the design and operation of the SIMPaCT solution deployed in Bicentennial Park (internal, shared amongst project partners. Included operational manuals for workflow management, troubleshooting, etc.).
- **SIMPaCT Roadmap** (a plain-language public-facing document that outlines an evidence-based prescriptive strategy for developing and scaling SIMPaCT).

2 The SIMPaCT value proposition

SIMPaCT was designed to address the challenges of irrigation at Bicentennial Park. These challenges exist within a broader context of growing environmental pressures that affect the whole of Greater Sydney, as well as other cities, towns and regional areas across Australia.

The SIMPaCT pilot project at Bicentennial Park was built around four key value propositions:

- Mitigating urban heat

  The optimisation of irrigation to support maximum potential evapotranspirative cooling.

- Improving water efficiency

  Irrigation control informed by data and predictive modelling, that optimises irrigation delivery, avoiding waste while ensuring plant health and cooling outcomes.

- Managing green infrastructure

  Well maintained and thriving green infrastructure assets, combined with operational efficiencies.

- Maintaining public amenity

  Maintaining cool, green places for public health and wellbeing through drought conditions.

The SIMPaCT solution is scalable and its ability to deliver value in these four areas can be expanded to other locations and contexts.

Figure 6. A pop-up sprinkler in a garden bed at Bicentennial Park. Image credit: WSU

Mitigating urban heat

Figure 7. Large green spaces with significant tree canopy cover can create a Park Cool Island Effect. View of a cycle path through a section of bushland in Bicentennial Park. Image credit: WSU

The big picture

Western Sydney suburbs are facing serious Urban Heat Island (UHI) challenges. These suburbs can be up to 6-10°C hotter during extreme summer heat events compared to suburbs in Sydney's east[2]. The heat challenge in Western Sydney is mostly caused by Sydney's geography and weather patterns, such as hot westerly winds and lack of cooling sea breezes, and this is accelerated by rapid urbanisation and significant decrease in vegetation cover from urban development[3]. Unfortunately, this has the potential to exacerbate the UHI effect and worsen the local impacts in Western Sydney as climate change intensifies over the coming decades[4].

Increased urban heat is expected to have a direct negative impact on the health and wellbeing of people living in and visiting Sydney Olympic Park. Greater frequency of very warm temperatures reduces the time in summer that is safe and comfortable for enjoying the outdoors, limiting social and physical activities that are important to wellbeing. Extremely hot weather can lead to life-threatening illness or exacerbate existing chronic conditions, with the elderly and the young at higher risk[5].

Regular irrigation can effectively improve the cooling effect of green space by ensuring the availability of adequate water[6][7]. Water transpired from shrubs and trees will cool ambient air, reducing the

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[2] UNSW, Sydney Water, & Low Carbon Living CRC. (2017). *Cooling Western Sydney*. https://www.sydneywater.com.au/content/dam/sydneywater/documents/cooling-western-sydney.pdf

[3] WSROC. (2021). *Urban Heat Planning Toolkit*. https://wsroc.com.au/media-a-resources/reports/send/3-reports/306-wsroc-urban-heat-planning-toolkit

[4] Ibid

[5] NSW Health, 2022 https://www.health.nsw.gov.au/environment/beattheheat/Pages/default.aspx

[6] Coutts, A., & Harris, R. (2012). A multi-scale assessment of urban heating in Melbourne during an extreme heat event, VCCCAR;

[7] Spronken-Smith, R. A., & Oke, T. R. (1998). The thermal regime of urban parks in two cities with different summer climates. International Journal of Remote Sensing, 19(11), 2085–2104

temperature of the surrounding air by up to 4°C. Even when the vegetation in urban areas is replaced by drought-tolerant vegetation, water is still crucial for providing cooling[8].

The challenge in Bicentennial Park

Urban parks and green spaces like Bicentennial Park are one of the most important defences we have against rising temperatures in our cities. The Park Cool Island Effect (a counter to the Urban Heat Island), can only be achieved if plants receive sufficient water supply, and are maintained in optimal health regardless of how hot or dry conditions become.

Standard irrigation scheduling in Bicentennial Park may deliver enough water to keep plants alive. However, during hotter weather this may not always be enough to maintain optimal plant health or support maximum potential evapotranspiration – the process through which plants create a cooling effect in addition to shade from tree canopies. As such, the maximum cooling effect of the park during hot weather has often not been realised.

The SIMPaCT solution

A key goal of SIMPaCT is to create urban cooling via vegetation transpiration. By modelling water requirements for an area at a detailed resolution[9], SIMPaCT can maximise the Park Cool Island Effect by delivering precisely enough water for optimal plant health and maximum potential evapotranspiration across all areas of the park, relative to current and forecasted environmental conditions. Designing a system capable of delivering a measurable increase in cooling was a primary aim for the SIMPaCT pilot project.

For a detailed explanation of the science behind the Cool Park Island Effect, please refer to APPENDIX 3.

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[8] Vahmani, P., & Ban-Weiss, G. (2016). Climatic consequences of adopting drought-tolerant vegetation over Los Angeles as a response to California drought. *Geophysical Research Letters*, *43*(15), 8240–8249. https://doi.org/10.1002/2016GL069658

[9] Bicentennial Park is divided into 200 operational 'stations', each with its own unique mix of plants and physical attributes. SIMPaCT modelling occurs at the scale of individual stations, allowing each one to be managed as a separate operational area within the park.

Improving water efficiency

Figure 8. Irrigation in action at Bicentennial Park. Image credit: WSU

The big picture

As Sydney grows the need to meet growing water demands becomes more complex when intertwined with increasingly dynamic climatic conditions. Sydney Water is faced by a confluence of challenges associated with peak demands during heat periods, a warming climate, and a growing Western Sydney region. Sydney Water has an imperative to ensure per capita demand for water continues to reduce. There are no new water resource options for Sydney so as the city expands the cost to supply increased water needs will increase. As a result, it will increasingly become more financially attractive to use water efficiently, at all times.

Urban green infrastructure supports more resilient communities through increased amenity and cooling capacity but creates a demand for water to maintain it. This demand is expected to increase over the coming decades as the amount of irrigated green space increases and the impacts of climate change worsen. To support this increasing water demand, against a backdrop of increasing water cost and scarcity, new approaches to water efficient irrigation must be developed.

There is a political driver to irrigate efficiently because during periods of drought-induced water stress historically, restricting outdoor water use has presented the greatest, lowest cost way to rapidly reduce water demand, often forcing the shutoff of publicly maintained irrigation systems leading to damage and loss of UGI. Water authorities may allow special dispensation to maintain public amenity. This is often contentious but more readily supported when the irrigation system uses water efficiently. Indeed, such optimisation may become a pre-requisite condition for dispensation, and a foundation of a social license to operate irrigation during water restrictions.

The challenge in Bicentennial Park

Irrigation water used in Bicentennial Park is predominantly from recycled sources and tends to be in plentiful supply, even during drought conditions. However, supply can still be threatened by infrastructure faults, such as the shutdown of a main pump system that occurred in January 2023.

When recycled water is unavailable the system reverts to using potable water. If this occurs during a period of water restrictions, a tension will arise between maintaining the health, cooling capacity and amenity of the parkland, versus complying with water restrictions. While such a situation has not yet arisen in Bicentennial Park, the risk of it doing so in a climate constrained future is not insignificant, and it demands that any water use by the irrigation system is optimised for maximum efficiency. This optimisation would support practical best use of a limited water supply, and a defendable political position for SOPA and Sydney Water.

Additionally, the other main driver for water efficiency of the Bicentennial Park irrigation system is to reduce water supply costs for SOPA. Whether using recycled or potable water, and regardless of environmental conditions, minimising costs is a full-time driver for optimising water consumption.

The SIMPaCT solution

SIMPaCT directly improves the water efficiency of an irrigation system by delivering precisely the amount of water required for optimal plant health in a given ‘station’ (an operational area defined by a relatively uniform vegetation type, soil type, slope and aspect). This precision is made possible through the accurate modelling of soil moisture on a per-station basis, combined with a seven-day weather forecast that prevents unnecessary irrigation ahead of rain events. Real-time data from soil moisture sensors acts as an empirical cross-check, allowing the system to adjust its scheduling to fine tune upcoming water delivery.

In theory, the water efficiency optimisation offered by SIMPaCT should counter the challenges for Bicentennial Park that are outlined above. However, during the pilot project phase, SIMPaCT has not been operational during a hot summer period, a period of water restrictions, or a period where the system needed to revert to a potable water supply. As such, it has not been possible to demonstrate its water efficiency capability within these contexts.

Managing green infrastructure

Figure 9. (left) A sprinkler prevented from functioning by a piece of rubbish; (right) A leaking sprinkler head. Faults in irrigation hardware can go undetected, leading to poor management outcomes for green infrastructure. Image credits: UTS

The big picture

Place owners such as SOPA often manage large UGI assets. These assets deliver considerable value for public amenity and urban cooling, and for their positive contribution to urban ecology. Active irrigation is often required to ensure that this value is maintained, such as in the case of Bicentennial Park. There are three key challenges with the management of UGI using active irrigation.

Firstly, poor or sub-optimal management of an irrigation system can result in damage to or loss of UGI assets, and a resulting loss of the value that those assets provide (notably, reduced urban cooling and public amenity such as playing fields).

Secondly, poor or sub-optimal management of an irrigation system can equate to poor water efficiency, resulting in over-watering of certain areas. This can include delivery of more water than a location requires during dry conditions, or the unnecessary delivery of irrigation prior to rainfall.

Finally, the operational costs of UGI management can be substantial, particularly where irrigation systems have manual input and labour costs are high. Sustaining operations to ensure the ongoing health and maximum potential value delivery of UGI can be a significant financial burden, and may be a disincentive for the expansion of green infrastructure for some place owners.

The challenge in Bicentennial Park

During the last drought a significant number of mature trees in Bicentennial Park died due to a lack of watering, and loss of turf has also been a challenge. These issues can arise from a failure to deliver the irrigation water that plants require, which is generally the result of undetected faults in the irrigation system (e.g. leaks and damaged hardware). SOPA experiences a financial burden from plant damage and loss that is direct (replacement of plants and rehabilitation of the landscape) and indirect (reduced amenity, which can reduce income related to rental rates and the ability to hire out venues in the park).

Sub-optimal management of the irrigation system at Bicentennial Park results in unnecessary water use, with consequential costs. This may be especially true during wetter periods, such as the La Nina years of 2021 to 2023 when the SIMPaCT pilot project ran. Despite heavy and regular rainfall, the pre-SIMPaCT irrigation system did not compensate for rain forecasts and would deliver irrigation according to a fixed schedule.

The SIMPaCT solution

SIMPaCT can improve the management of large green infrastructure assets like Bicentennial Park through the use of live data and the optimisation and automation of an existing irrigation system. There are three main management benefits.

Firstly, SIMPaCT captures real-time data about soil moisture from an extensive network of smart low-cost sensing devices deployed throughout Bicentennial Park. This sensor data, combined with data from the irrigation system, can be used to check the current functioning of the irrigation system and detect leaks and faults that would otherwise go undetected. SOPA believes that many of the historical plant losses in the park occurred due to undetected faults; SIMPaCT addresses this issue.

Secondly, SIMPaCT can ensure that all areas of the park are irrigated optimally, in accordance with their particular needs and weather forecasts, enabling the park to deliver maximum benefit for amenity and cooling while optimising water efficiency and keeping the costs of water supply to a minimum.

Finally, increased automation of the irrigation system can potentially reduce labour demand. While this may not translate directly into reduced operational costs in real terms, it may free up contractors to spend more time on tasks that they previously had little time for, improving overall management outcomes[10].

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[10] Due to SIMPaCT being a newly introduced system during the pilot project, there was not enough time available for the irrigation contractor to fully integrate it into its existing workflow. The idea that SIMPaCT can reduce manual labour and improve management outcomes needs to be tested over a longer period of trial operations, and is dependent upon the management approach of the contractor and the technical capacity of SIMPaCT.

Maintaining public amenity

Figure 10. Families enjoy the shade and amenity of the Bicentennial Parklands. Image credit: UTS

The big picture

The NSW government has acknowledged high-quality urban green infrastructure as a major contributor to public amenity, which promotes public health and increases the climate resilience of cities (Premier's Priorities 10 and 12). Since 2019, the NSW Government has invested more than $30M to improve and expand UGI across Greater Sydney. As urban density increases and there are smaller and fewer private outdoor spaces and gardens, public parks become more necessary for recreation, connection to the natural environment, and respite. The value of usable, healthy, cool UGI increases.

In order to maintain high-quality UGI and ensure that it delivers ongoing public amenity, many municipalities across NSW need to use active irrigation systems. Thus, it is responsible and timely for NSW to develop optimised irrigation strategies that help reduce water use while still maintaining healthy green infrastructure, maintaining public amenity and supporting climate resilience.

The challenge in Bicentennial Park

Adjacent to a concentration of high-rise residential towers, Bicentennial Park experiences intense public use and is a vital area of green infrastructure for urban amenity, offering a range of public health and social wellbeing benefits. It is also a highly valuable asset for SOPA. The value of residential and commercial tenancies within the immediate area corresponds in part to the health and amenity of the parkland. Additionally, nearly 3000 outdoor site bookings are made each year within SOP parklands, for weddings and various other public events[11]. The income from these bookings is also

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[11] Sydney Olympic Park Authority 2021–22, Annual Report https://www.sopa.nsw.gov.au/-/media/files/sopa/sopa/publications/current-annual-report/sopa-annual-report-2021_22-v1.pdf

contingent upon the park looking green and healthy, even during the hottest and driest of conditions, so the provision of irrigation is critical to sustain this.

Irrigation management for maximum public amenity is another challenge for Bicentennial Park. Different areas of the park have different 'presentation standards' based upon their location, use and value as an asset. These areas also have different watering requirements based on vegetation type, soil and aspect. If water restrictions are in place, strategic choices need to be made about where to deliver limited irrigation water based upon an area's presentation standard.

Under the pre-SIMPaCT irrigation system, this information has existed as tacit knowledge held by contractors and SOPA staff. The application of such tacit knowledge is inherently imperfect and is also at risk of being lost through staff and contractor turnover.

The SIMPaCT solution

SIMPaCT can directly improve the maintenance of public amenity in Bicentennial Park, through the optimisation of water use for UGI management at a detailed level. The optimisation of water efficient irrigation also supports a social license to maintain UGI assets during droughts for their public amenity value, when efficiency is a prerequisite for irrigation.

The SIMPaCT data model contains metadata for the presentation standard and water requirement of 200 operational 'stations' within the park. The supply of water to each station can be prioritised (or de-prioritised) based upon this metadata so that areas with the highest public amenity value can be kept healthy and usable, at the expense of less used or less visible areas, during periods of water restrictions. Due to this information being embedded within the system, a 'public amenity preservation' mode can be created as an automated and comprehensive setting within SIMPaCT, which also mitigates against the loss of tacit knowledge via staff or contractor turnover.

3 The SIMPaCT solution

High-level definitions

The SIMPaCT Solution is defined as a combination of:

- **An existing irrigation system:** the SIMPaCT solution is retrofitted onto and integrated with an existing irrigation system, which consists of fixed irrigation infrastructure (pumps, pipes, consoles, solenoids and sprinklers), and an irrigation management platform.
- **SIMPaCT digital twin**: an integrated package of hardware and software components, for data collection, data management, advanced analytics, dynamic feedback and smart irrigation control.
- **SIMPaCT dashboards:** public and operational dashboards for viewing and dynamically interacting with live data feeds from the SIMPaCT Digital Twin.
- **SIMPaCT methodology**: a set of approaches to the provision of data, the management of data (data schema), and the integration of the SIMPaCT digital twin with operational workflows.

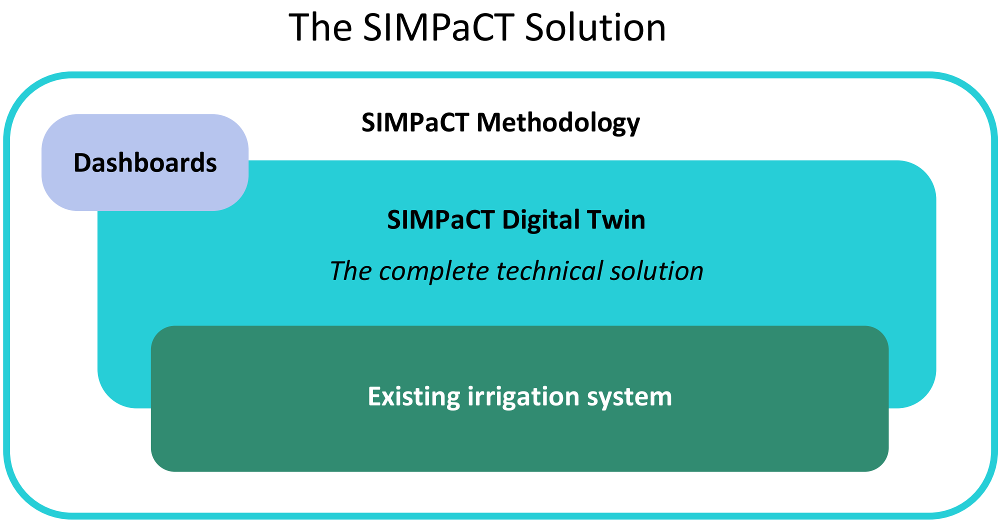

Figure 11. An overview diagram of the SIMPaCT Solution

The existing irrigation system

Fixed irrigation infrastructure

The fixed irrigation infrastructure in Bicentennial Park is a large network of pipes, connected to a pump room. Water supply for irrigation during standard operation of the system is recycled, sourced from the 'brick pit' reservoir 1.3km to the north.

The reticulated pipe network is divided into five areas, each defined by a 'console' (a pumping booster station for maintaining water pressure). Each console comprises 30 to 60 'stations', with a total of 200 stations in the park.

A station is an operational area defined by a relatively uniform vegetation type, soil type, slope and aspect. Each station contains a series of sprinkler heads, connected to a 'solenoid' (a controllable open/close valve), with all solenoids connected back to a console. A station can be managed based upon the specific needs of the soil and plants within it.

The irrigation infrastructure is controlled though wired communication between each solenoid and the Irrinet local control system.

Irrigation management platform

The Fieldmouse irrigation management platform is a centralised, cloud-based system that manages irrigation scheduling and incorporates a range of baseline smart functionality. The SIMPaCT Digital Twin integrates with Fieldmouse.

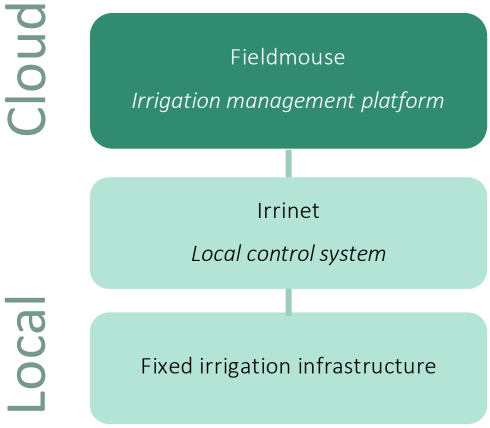

Figure 12. A section of Bicentennial Park, illustrating the density of the irrigation network. Image credit: SOPA

SIMPaCT digital twin

Overview

The SIMPaCT digital twin refers to the complete integrated end-to-end technical system of SIMPaCT. The following section will explore:

- The digital twin data architecture
- Sensing devices
- Wireless communications networks
- Telemetry flow
- SIMPaCT advanced analytics models
- SIMPaCT irrigation adapter

The digital twin data architecture

The SIMPaCT digital twin is built around a modular data architecture that connects multiple platforms, data models and digital services with an existing irrigation system, forming a single integrated functional system of data flows, analytics, command generation, and feedback.

The modular approach supports technical and commercial flexibility and scalability, as it means that various components of the architecture may be swapped out for alternative options that provide similar or expanded functionality.

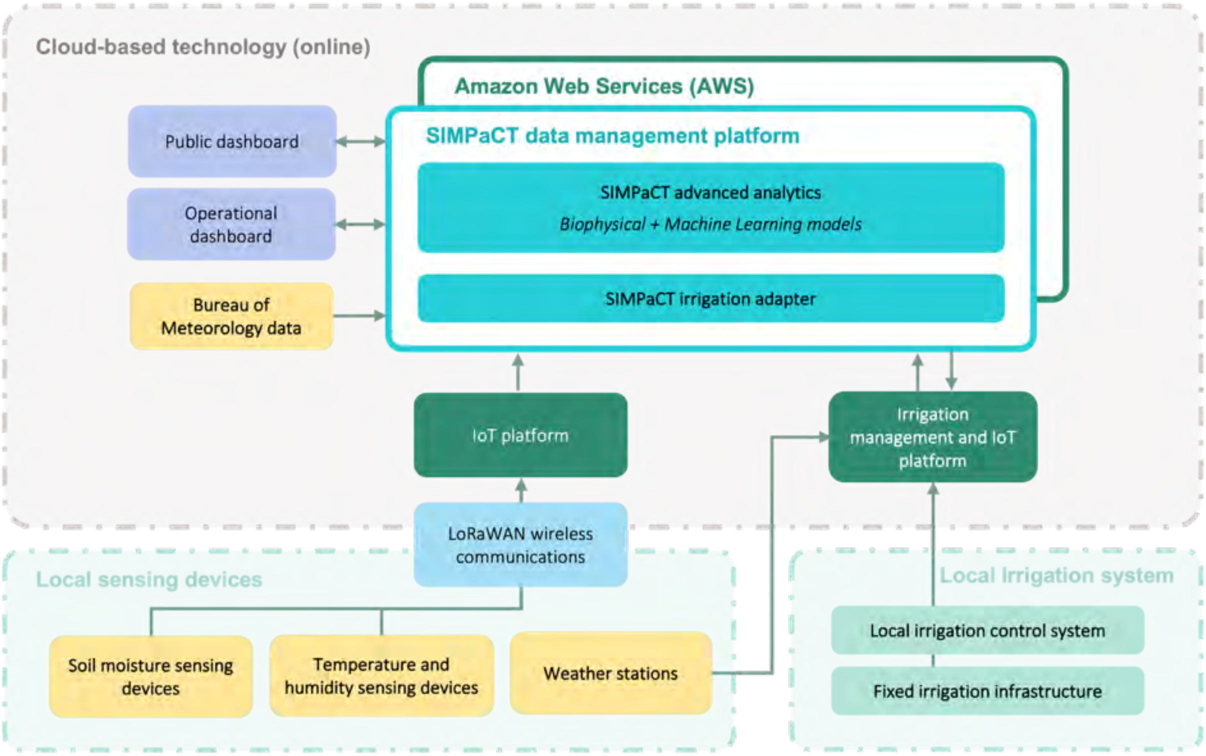

Figure 13. Simple SIMPaCT data architecture

APPENDIX 4 has an expanded version of this graphic, including a short explanation of each component.

Sensing devices

Quick facts

15 min	Reporting intervals[12]
202	Soil moisture sensing devices
>19K	Daily soil moisture readings
13	Weather stations
50	Temperature and humidity sensing devices
>20K	Daily meteorological readings

Soil moisture sensing devices

Figure 14. SSM20 Sensedge Soil Moisture Senstick

Device manufacturer	Sensedge
Device model	SSM20 Sensedge Soil Moisture Senstick
Telemetry	Soil moisture (VWC) Soil temperature Battery voltage
Communications	LoRaWAN
Reporting interval	Between 15 min and 1 hour (site dependent)
Power supply	2x AAA batteries
Battery life	Variable due to communications settings (relating to site and signal strength). Ranged between 2 and 7 years.

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[12] A reporting interval refers to the period of time between reported measurements from a sensing device. A 15 minute reporting interval means that devices send new data every 15 minutes.

Temperature and humidity sensing devices

Figure 15. SMC30 device with radiation shield

Device manufacturer	Sensedge
Device model	SMC30 Sensedge Microclimate Senstick
Telemetry	Ambient temperature Relative humidity Battery voltage
Communications	LoRaWAN
Reporting interval	15 min
Power supply	2x AAA batteries
Battery life	~ 7 years.

Weather stations

Figure 16. A weather station deployed in Bicentennial Park. Image credit: UTS

Device Integrator	Centratech Systems
Components	Lufft WS400-UMB/ WS600-UMB solid state weather station + Fieldmouse device (data management and comms) + 12V DC battery + Charge controller
Telemetry	Full range of meteorology (wind, precipitation, solar radiation, temperature, humidity, pressure, etc.)
Communications	4G
Reporting interval	60 min
Power supply	80W Solar panel

Wireless communication networks

LoRaWAN

The soil moisture and temperature/humidity sensing devices deployed in Bicentennial Park communicate wirelessly via LoRaWAN (Long Range Wide Area Network).

LoRaWAN uses local 'gateways' that transmit and receive data from nearby devices using the designated 923MHz radio band. Bandwidth and power use are low, restricting data exchange to small packets of a few dozen bytes of information at a time, transmitted in short periodic bursts (every 15 minutes for most devices in the network). This is ideal for large, distributed networks of smart low-cost sensing devices and the technology is seeing widespread uptake for smart city applications.

The range of communications from a LoRaWAN gateway is a radius of up to a few kilometres, however this can be reduced by hilly terrain and dense vegetation. To ensure maximum communications coverage across the park, three LoRaWAN gateways were installed. Gateways, and an associated managed service, were provided by Meshed, via a custom account with The Things Industries.

Meshed conducted a radio frequency mapping exercise during the network planning stage, identifying practical locations for gateway deployment that afforded the greatest possible communications coverage.

Gateway deployment locations

1) The roof of a 40-storey tower block with open views of Bicentennial Park (0.5-1km away)
2) Treillage Tower (a 17m lookout tower on a ridgeline)
3) A barbeque pavilion within the eastern *Concorde West* area of the park (pictured)

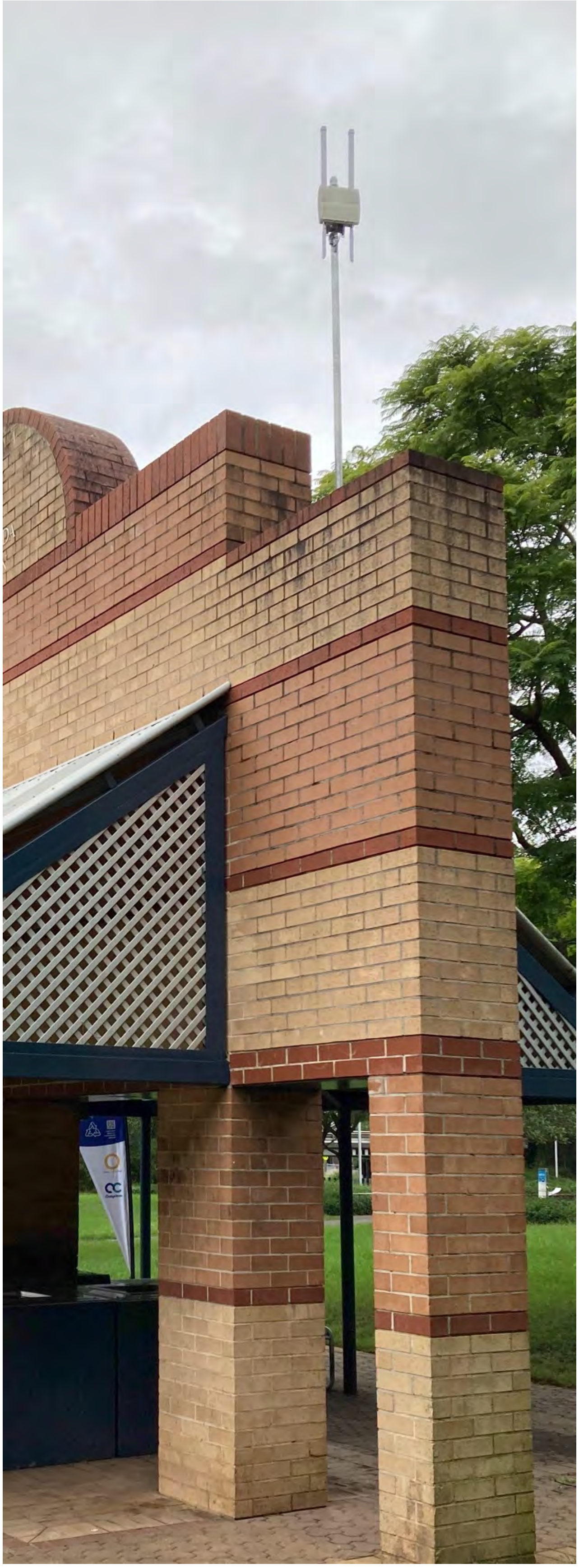

Figure 17. A LoRaWAN gateway deployed on top of a barbeque pavilion in Bicentennial Park. Image credit: UTS

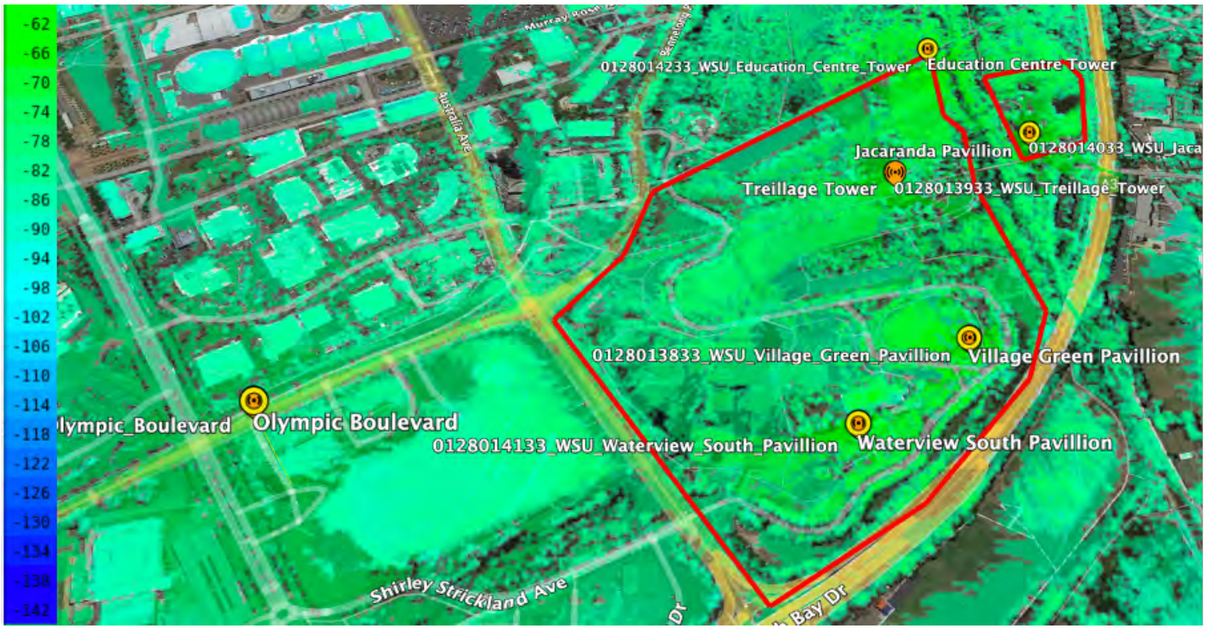

Figure 18. The Radio Frequency map used to identify optimal locations for LoRaWAN gateway deployment.

The benefits and challenges of LoRaWAN in the SIMPaCT Context

Benefits	Challenges
• **Low power** Very low power use means that communications can be supported by small battery-powered devices, with batteries lasting for several years. • **Zero marginal cost per connected device** The business model of Meshed and The Things Industries has a fixed service fee irrespective of the number of connected devices[13]. • **Simple device onboarding and management** It is simple to add a new device to the network and manage its connection. This can be done directly by the project team. • **Reliability** The Things Industries provides a managed service on a private server, with guaranteed availability and 24hr support.	• **Signal strength** Signal strength can be unviable in many locations across the park, due to being blocked by terrain or trees. Connectivity was particularly challenging for soil moisture devices because the ground (which was dense with clay) often blocked or strongly attenuated the LoRaWAN signal. • **Connectivity vs battery life** Optimisation of device LoRaWAN settings was always a trade-off between signal viability and battery life.

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[13] The service fee increases with bracketed numbers of devices; however the first bracket covers several hundred connections. This offered a cost-effective approach to the connection of ~250 devices.

Telemetry flow

Telemetry refers to near-real-time environmental data (soil moisture and meteorology) provided by sensors or a third-party source such as the Bureau of Meteorology (BOM). Telemetry flows through wireless communications networks and APIs (Application Programming Interfaces), passing through multiple platforms and services within the data architecture.

Sensor data must pass through an IoT platform (provided by The ARCS Group and Centratech Systems), which decodes and formats raw data. Multiple data sources (including sensor data and BOM data) are ingested by the Senaps data platform (provided by Eratos), which standardises data formats and manages data storage and database access.

All data in the SIMPaCT Digital Twin is stored and made available via the Senaps platform. Senaps is a cloud-hosted platform running on Amazon Web Services (AWS). Senaps in turn hosts the Biophysical model of the park and the associated Machine Learning model for soil moisture prediction. These advanced analytics models access telemetry through Senaps, which also receives, stores and manages model outputs.

Finally, a telemetry feed connects from the AWS database to the ‘Park Live’ public dashboard, displaying live information about the ambient temperature, humidity, wind and rain in different areas of the park.

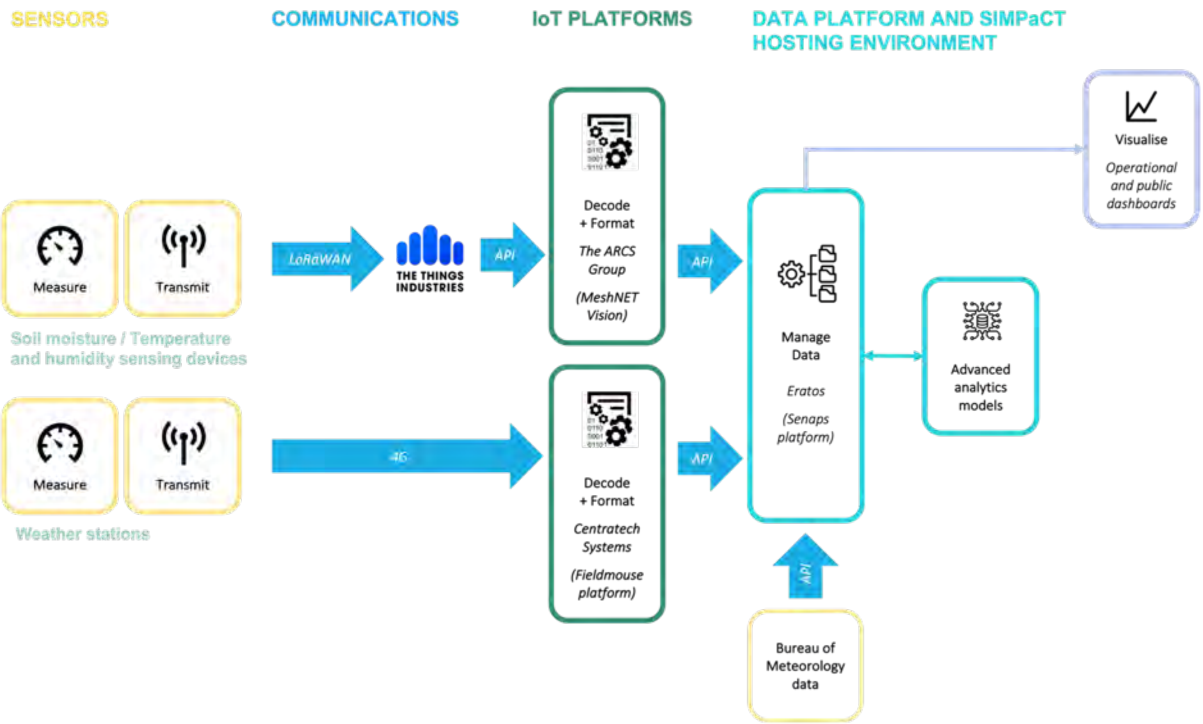

Figure 19. Simple telemetry flow diagram within the SIMPaCT Digital Twin[14]

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[14] Note that this diagram only shows the flow of incoming telemetry, not the flow of model outputs back to the irrigation system (please see the following section on advanced analytics models for an explanation of this)

SIMPaCT advanced analytics models

The SIMPaCT digital twin uses advanced analytics models to determine an irrigation schedule that maintains a desired level of soil moisture within each of the 200 stations within Bicentennial Park

An overview of data flow and system logic for advanced analytics

The SIMPaCT advanced analytics capability comprises a cluster of three models that are all hosted within Senaps. These models work in parallel, each independently predicting soil moisture and prescribing optimal irrigation using a different method and combination of data inputs to produce slightly different outputs. Each model sends its output (a prescribed irrigation schedule for each of the 200 stations in the park) to a ‘decision-making module’.

On a station-by-station basis, the decision-making module prioritises *one* of the three model outputs and forwards this to the irrigation adapter, which then passes the command to the irrigation management platform, which then updates the existing irrigation schedule.

Three models are used to produce the same result because their different approaches rely upon different data inputs. By running multiple parallel models, the SIMPaCT digital twin is adaptable to changing data availability. This adaptability is critical for a system that relies upon data from low-cost sensing devices, which carry inherent challenges relating to data availability and data quality.

The telemetry from a network of low-cost sensing devices can be intermittent or of questionable quality for a wide variety of reasons, ranging from communications issues in poor weather, to physical damage of a device due to water ingress. The machine learning model requires near-complete and trusted sensor data from the past two weeks, in order to produce a reliable output. If there is not enough data to reliably run the Machine learning model (1; the default primary choice) then the system reverts to using the Biophysical model (2), which only requires a single recent soil moisture reading to produce an output. If there is no single recent soil moisture reading *and* data from the past two weeks is unusable (e.g. a sensing device has gone offline), then the system reverts to the Fallback model (3), which does not require any sensor telemetry.

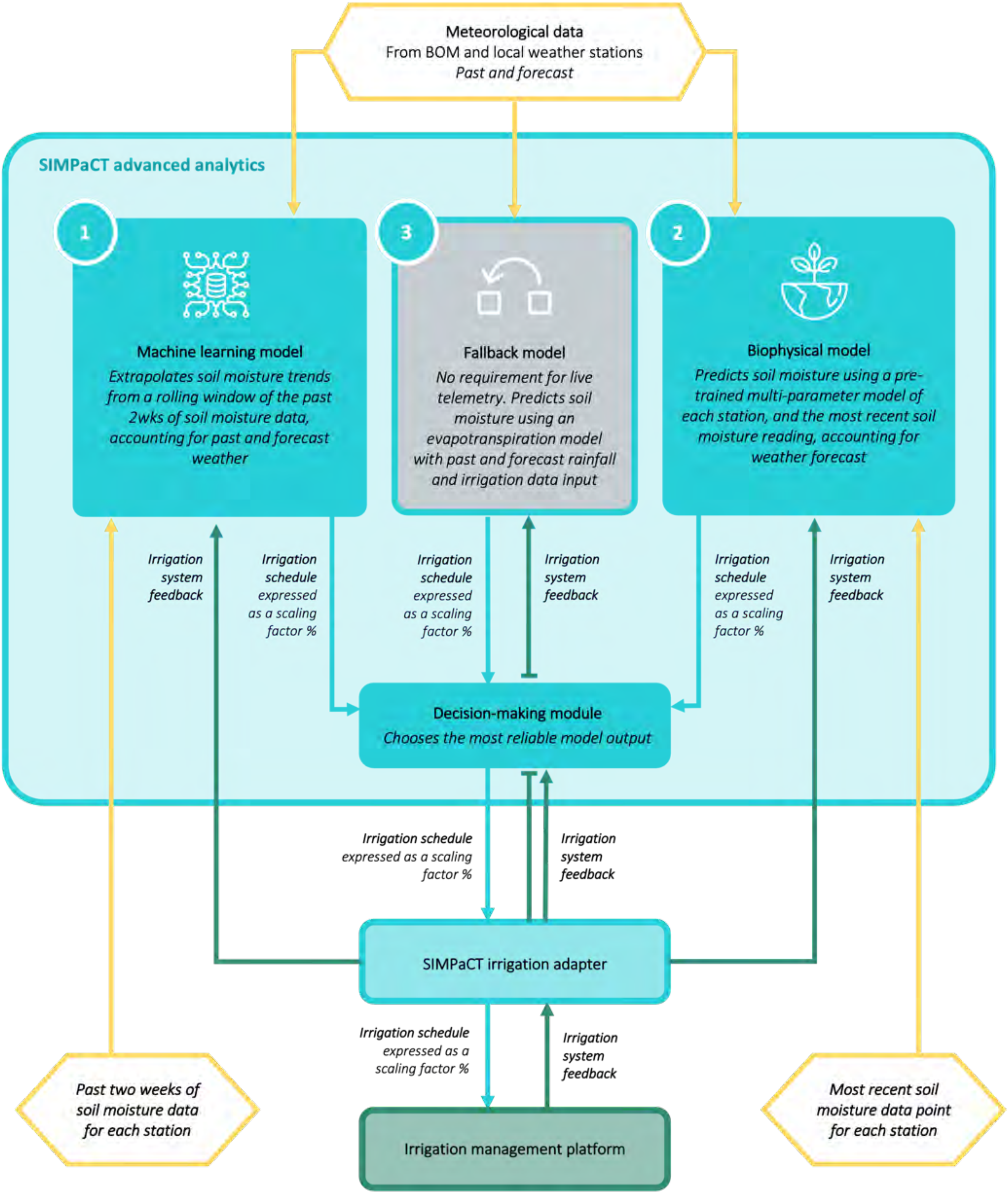

Figure 20. A diagram of the SIMPaCT advanced analytics models and data flow

The machine learning model

The machine learning model is the most accurate predictor of soil moisture and the default priority choice for actionable irrigation scheduling if suitable data is available.

Data inputs

- Two weeks of reliable and trusted soil moisture data, provided by a low-cost sensing device deployed in the station.
- Rainfall data from the past two weeks (from BOM/local weather stations), plus the seven-day forecast (BOM).
- Irrigation system feedback that includes actual irrigation delivered to the station over the past two weeks, plus the next seven days of existing irrigation schedule.

How the model works

a) **Predicts the next 3 days of soil moisture:** The model predicts soil moisture for the next three day rolling window, based on a rolling window of data from the previous two weeks. It checks the correlation between past rainfall/irrigation and past soil moisture response. It then extrapolates a soil moisture trend line for the next 7 days, factoring in the effects of any forecast rainfall and the existing irrigation schedule.

The machine learning model is not pre-trained, relying only the past two weeks of data. It does not become ‘smarter’ or more accurate over time. However, by focusing only on recent conditions and a seven-day forecast, the model constantly adjusts to seasonal variation.

b) **Determines an optimal seven-day irrigation schedule, for achieving desired soil moisture:** This is the same process for all three models - see below for an explanation.

The biophysical model

The biophysical model is a reliable predictor of soil moisture. It is slightly less accurate than the machine learning model but is not dependent upon a two-week data record. It is the second choice if the machine learning model cannot be run reliably.

Data inputs

- One recent soil moisture data point, provided by a low-cost sensing device deployed in the field.
- The seven-day meteorological forecast (BOM).
- Irrigation system feedback that includes actual irrigation delivered over past two weeks, plus next seven days of irrigation schedule.

How the model works

a) **Predict the next 7 days of soil moisture:** The model predicts soil moisture for the next seven day rolling window, based on a single recent soil moisture reading from a station.

The model incorporates a wide variety of biophysical variables, such as vegetation type, soil type and slope. The combination of these variables is unique to each of the 200 stations in the park. The biophysical model is pre-trained using a three-month period of soil moisture, rainfall and irrigation data. It develops an understanding of how soil moisture responds to rainfall and irrigation in each station, relative to the biophysical variables that define it. It thus comprises 200 station-specific models of soil moisture dynamics. For each station, a recent soil moisture reading can be extrapolated based on the biophysical model for that station, the rainfall forecast, and the existing irrigation schedule.

The biophysical model is updated/re-calibrated each month based on new data, allowing it to adapt to seasonal variation.

b) **Determine an optimal seven-day irrigation schedule, for achieving desired soil moisture:** This is the same process for all three models - see below for an explanation.

The Fallback model

The fallback model is the least accurate predictor of soil moisture. It is the third choice if the machine learning model and biophysical model cannot be run reliably.

Data inputs

- Rainfall data from the past week (from BOM/local weather stations), plus the seven-day forecast (BOM).
- CSIRO Penman Monteith evapotranspiration (ET) model for ET.
- Irrigation system feedback that includes actual irrigation delivered over past two weeks, plus next seven days of irrigation schedule.

How the model works

a) **Predict the next 7 days of soil moisture:** The model predicts soil moisture for the next seven day rolling window, based on the previous seven days of rainfall and irrigation, and the seven-day rainfall forecast.

b) **Determine an optimal seven-day irrigation schedule, for achieving desired soil moisture:** This is the same process for all three models - see below for an explanation.

Determine an optimal seven-day irrigation schedule for achieving desired soil moisture

The following process is the same for all three models:

a. **Simulate:** the model runs thousands of simulations of slightly different irrigation schedules for the next seven days. Each simulation will result in a different soil moisture profile for that period.

b. **Select one simulation that delivers desired outcomes:** each station in the park has a target soil moisture value that the digital twin seeks to maintain across varied environmental conditions[15]. One of these simulations will result in a soil moisture profile that most closely maintains target soil moisture values across the seven-day period.

c. **Determine a scaling factor that matches the chosen simulation:** each day, park stations have an existing scheduled irrigation event, which specifies an amount of water to be delivered, and this extends across seven days. This existing schedule is communicated to each model. When the simulated irrigation schedule differs from the existing irrigation schedule, the model determines a 'scaling factor' between the two for each event. The easiest way to understand this is to think of the existing irrigation schedule as being 100%. A scaling factor of 110% would mean that the scheduled irrigation event should be adjusted to deliver 10% more water, in order for it to align with the model simulation.

The outcome of this process is an irrigation schedule that maintains soil moisture **at or above a minimum defined threshold**, while avoiding the over-delivery of water. It is possible for system parameters to be adjusted and operational rules implemented, to achieve different priority outcomes.

For example:

- Under drought conditions, with water restrictions, the minimum soil moisture threshold might be the minimum amount required to keep plants alive, albeit not thriving. This ensures that plants do not die, while conserving water.
- Under non-drought conditions, when temperatures exceed a minimum threshold (e.g. 30°C), the minimum soil moisture threshold might be the minimum amount required to ensure the maximum potential evapotranspiration. This optimises urban cooling.
- Under standard conditions, the minimum soil moisture threshold might be the amount required for optimal plant health. This ensures that the park stays looking lush, supporting public amenity, while minimising water wastage and reducing water bills.

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[15] This can be adjusted to support different outcomes, such as: keep the plants alive; keep the plants in prime health; or optimise evapotranspirative cooling.

The SIMPaCT irrigation adapter

The SIMPaCT irrigation adapter forms a connection between the SIMPaCT hosting environment (Senaps) and the irrigation management platform. It converts a generic prescribed irrigation schedule from advanced analytics models into actionable operational commands that are formatted for a specific commercial irrigation management platform.

The irrigation adapter hosts connector applications that are designed for integration with particular commercial irrigation management platforms. For example, the connector application developed for the SIMPaCT pilot project was for the integration of SIMPaCT with the Fieldmouse platform, which manages irrigation for Bicentennial Park.

If SIMPaCT is applied at a new location that runs a different irrigation management platform (e.g. Rainbird or Hunter), then a different connector application would be developed (e.g. see ‘Connectors B and C’ in figure 21). This application would run within the irrigation adapter, based on the same underlying principles, but with a few design changes.

This application-based approach helps to make SIMPaCT adaptable to new contexts. It decouples what SIMPaCT is, and how it works, from any particular commercial irrigation management system, and ensures that new connector applications can easily be written and added as the need arises.

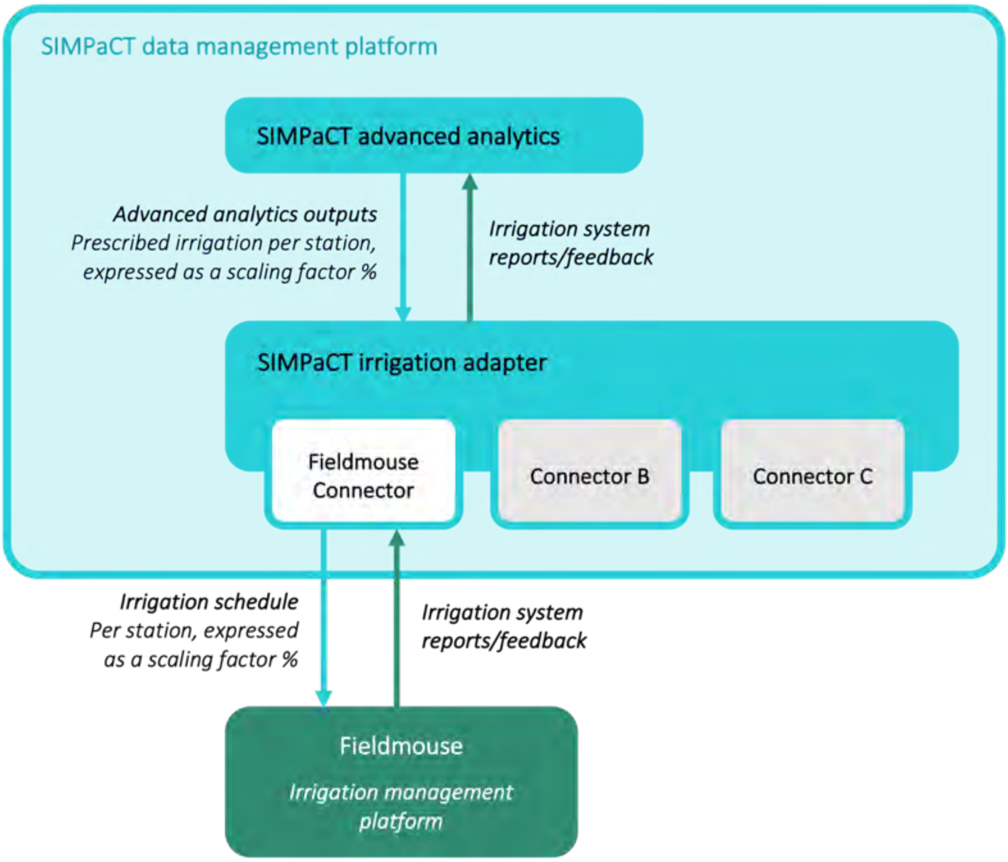

Figure 21. Diagram illustrating the design of the SIMPaCT irrigation adapter, including bi-directional data flows and modular connector applications.

SIMPaCT dashboards

SIMPaCT Website

Winner of the **IoTAA 2023 Research Award** and **IoT for Good** Award.

Figure 22. A screenshot of the SIMPaCT website home page.

www.simpact-australia.com

The SIMPaCT website shares information and builds awareness about the SIMPaCT pilot project. By using plain language, large images and an intuitive modern layout, the website ensures broad accessibility of information about this important public-facing project. It is designed for a mixed audience that includes professionals working across government, research and technology sectors; and the broader general public (including local residents and workers in the Sydney Olympic Park precinct).

Overview of website content

- Introduces partners and collaborators
- Explains the science and technology behind SIMPaCT
- Reports on project activity and insights via a blog
- Showcases media coverage, with links to interviews, articles, radio shows and webinars
- Embeds the *Park Now* dashboard

Park Now public dashboard

[Park Now](#) is a dynamic public dashboard that delivers a view of live data from the SIMPaCT Digital Twin of Bicentennial Park.

Park Now empowers the public with a deeper understanding of environmental conditions and dynamics within the park, fostering an awareness and appreciation of urban green space.

The dashboard is designed for accessibility and can cater to diverse user interests and needs. It features easy-to-understand summary information for non-technical viewers, combined with more detailed customisable displays that can be revealed through an interactive map.

Coolest Location
Lake South and Waterview
Currently the coolest location in Bicentennial Park.

Warmest Location
Treillage
Currently the warmest location in Bicentennial Park.

Coolest Temperature
10.7 °C
Coolest current temperature in Bicentennial Park observed in Lake South and Waterview at 9:30 AM

Warmest Temperature
12.9 °C
Warmest current temperature in Bicentennial Park observed in Treillage at 9:30 AM

Heat Stress
No stress
The current heat stress level is low.

Figure 23. Summary tiles from the Park Now *dashboard.*

Summary tiles

Summary tiles capture information about current conditions in Bicentennial Park, based upon sensor data and digital twin outputs. These user-friendly visualisations include plain-language interpretation of data and inform the public about the warmest and coolest temperatures and locations within the park, as well as the park's cooling effect, the current "feels-like" temperature, and heat stress conditions.

Summary tiles are built as modular 'widgets' that can be embedded on third party websites (e.g. see the landing page of the main [SIMPaCT website](#)).

Interactive map view

A map with multiple data layers that can be toggled ON/OFF to show sensing device locations, recent sensor data and heat maps relating to temperature and soil moisture. A time slider allows for the exploration of data over the past three days. This feature is particularly useful in demonstrating the cooling effects of urban trees throughout the day.

Soil Moisture Map
Interpolated soil moisture map using sensor data from the last hour.

Temperature Map
Interpolated temperature map using sensor data from the last hour.

Irrigation Zone Map
Park irrigation zones.

Contour Map
2m contour map of the park.

Soil Sensors
All sensors that have reported a value in the last hour.

Lufft Temperature Sensors
All sensors that have reported a value in the last hour.

Senstick Temperature Sensors
All sensors that have reported a value in the last hour

Show Park Summary
Show a summary table of live summary data and planned irrigation adjustments

Figure 24. The interactive map from the Park Now *dashboard.*

Operational version of Park Now

A standalone operational version of *Park Now*, accessible via user login, was developed for staff and contractors working in Bicentennial Park. It includes a user manual and documentation relating to the ongoing operation and maintenance of the SIMPaCT Digital Twin.

The SIMPaCT methodology

The provision of data from Bicentennial Park

The provision of soil moisture data

Location

A total of 202 soil moisture sensing devices were deployed, across 200 stations. Stations are predefined operational areas of the park that correspond to the design and layout of the irrigation infrastructure, each station comprising one or more sprinkler heads connected to a controllable solenoid valve.

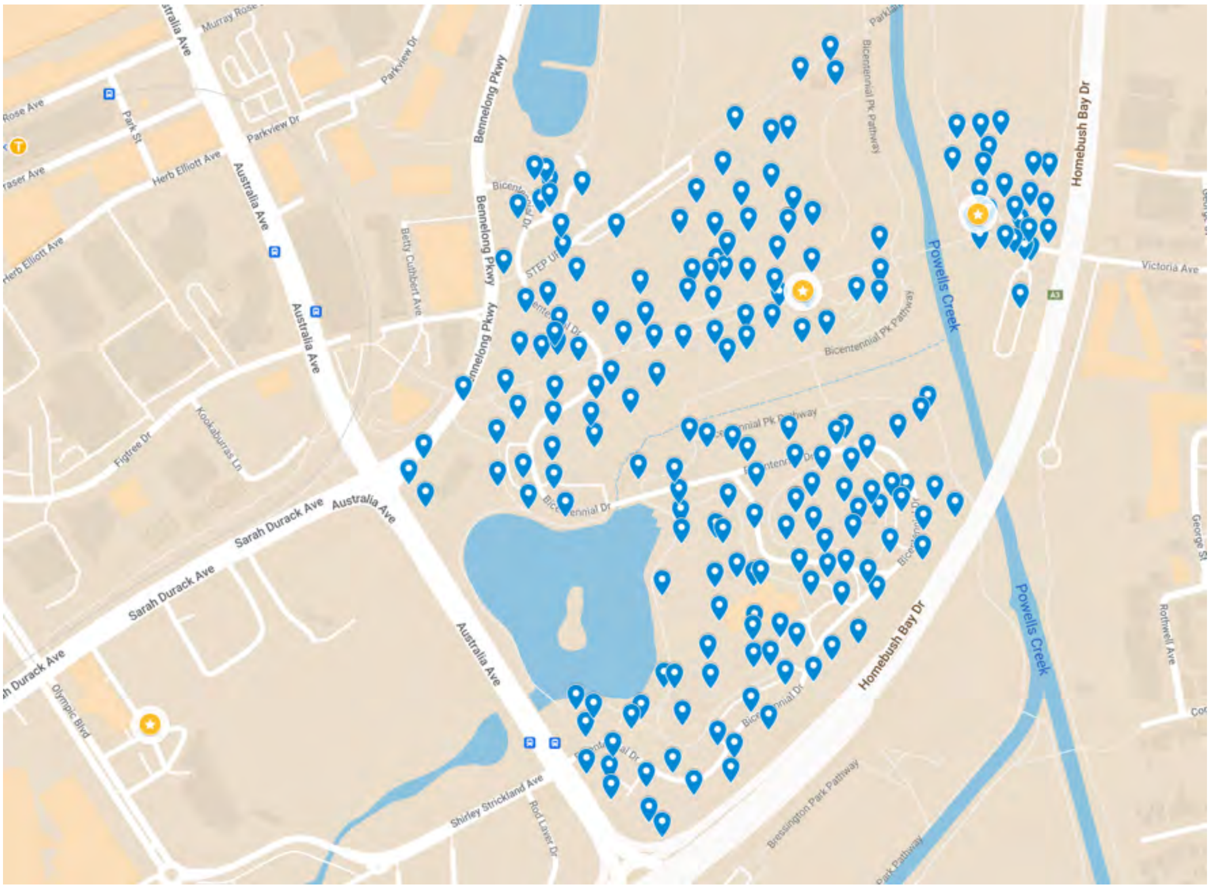

Figure 25. A map showing the location of soil moisture sensing devices deployed in Bicentennial Park. (blue icon = sensing device; yellow icon = LoRaWAN gateway)

Deployment decision-making

A decision was made about precisely where to locate a soil moisture sensing device within each station, based upon direct on-site observation of the site and of irrigation delivery (i.e. sprinkler range). A series of factors affected this ‘micro-siting’ decision, including:

- Distance from sprinklers
- Slope
- Ground cover (e.g. mulch)
- Distance from various types of plants and trees

- Tree canopy (which can block rainfall, resulting in variation within a station)
- Physical blockages (e.g. trees) which might create irrigation ‘shadows’

The aim was to locate a device to achieve a soil moisture reading that was representative of the station as a whole (at least in terms of trends and the responsiveness to rainfall and irrigation).

Co-located devices

A location was chosen on the Village Green (a large flat area of recreational turf) for the co-location of three soil moisture sensing devices. The purpose was to obtain data about the variability of device performance, and to explore the difference in soil moisture trends and response at two different depths.

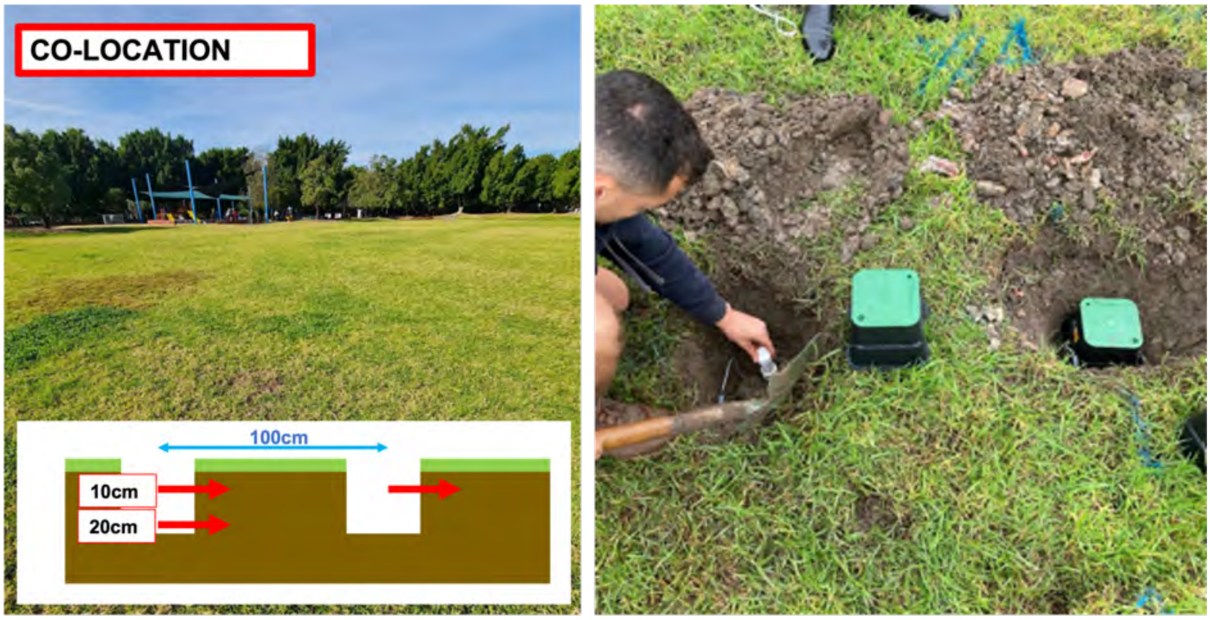

Figure 26. An illustration of soil moisture sensing device co-locations. Image credit: UTS

Deployment methodology

The deployment methodology for soil moisture devices proved to be something of a challenge, for the following reasons:

- Devices needed to be completely below ground and invisible, to avoid tampering or theft.
- Locating buried devices was a concern, because GPS coordinates are not accurate enough to pinpoint such a small object.
- Deployment of LoRaWAN devices at (or below) ground level makes them more susceptible to the effects of terrain, which blocks signal.
- Burying a device places soil between its radio antennae and the LoRaWAN gateway that it needs to connect with, attenuating and often entirely blocking the signal. This effect increases with waterlogged soils.
- Waterlogged soils cause the build-up of water inside any hole dug to house a device, resulting in its permanent submersion. This increases the risk of water ingress and damage.

- The ground in Bicentennial Park is full of rocks and dense clay, making it difficult to dig and to insert probes in many locations.

The solution that was eventually used at scale (for all 202 devices) was arrived at after some experimentation and a number of iterations (see figure 27).

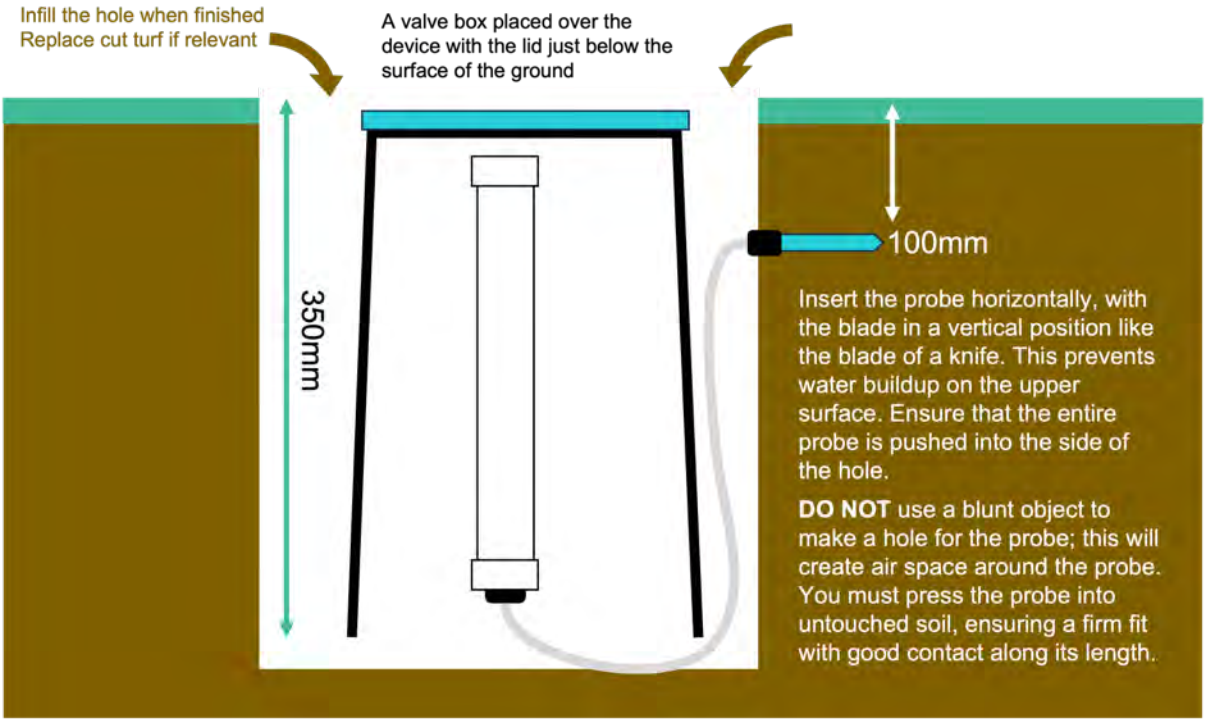

Figure 27. A schematic illustrating the deployment of soil moisture sensing devices.

Two design features are worth noting:

- **External casing for the device:** An external casing was made using PVC pipe with a gland fitting for the sensor probe cable. This was designed to help mitigate water ingress.
- **Valve boxes:** Valve boxes are a standard piece of equipment, commonly used in the irrigation industry, consisting of an open-bottomed trapezoid with a removable lid that measures roughly 15x15cm. The main reason to use it was to aid in locating devices once they were buried because it is considerably easier to find than is a 4cm diameter tube.

The precise location of a soil moisture sensing device was recorded using various techniques, depending on the context. Examples of these techniques include:

- A GPS coordinate (the accuracy can be significantly off, however it still provides a general indication).
- A photograph of the open hole, aligned with nearby contextual objects.
- Triangulation from nearby objects, including sprinkler heads, solenoid pits, trees or other infrastructure.

Figure 28. Deployment of a soil moisture sensing device. Note the white PVC external casing, the black valve box (with lid removed), and the probe inserted into the side of the hole. Image credit: UTS

The provision of ambient temperature and humidity data from low-cost sensing devices

Location

A total of 50 temperature and humidity sensing devices were deployed across Bicentennial Park. Deployment locations did not align with stations. Rather, the aim was to capture a representative range of micro-climates within the park. This was balanced against achieving a roughly uniform coverage of the total park area.

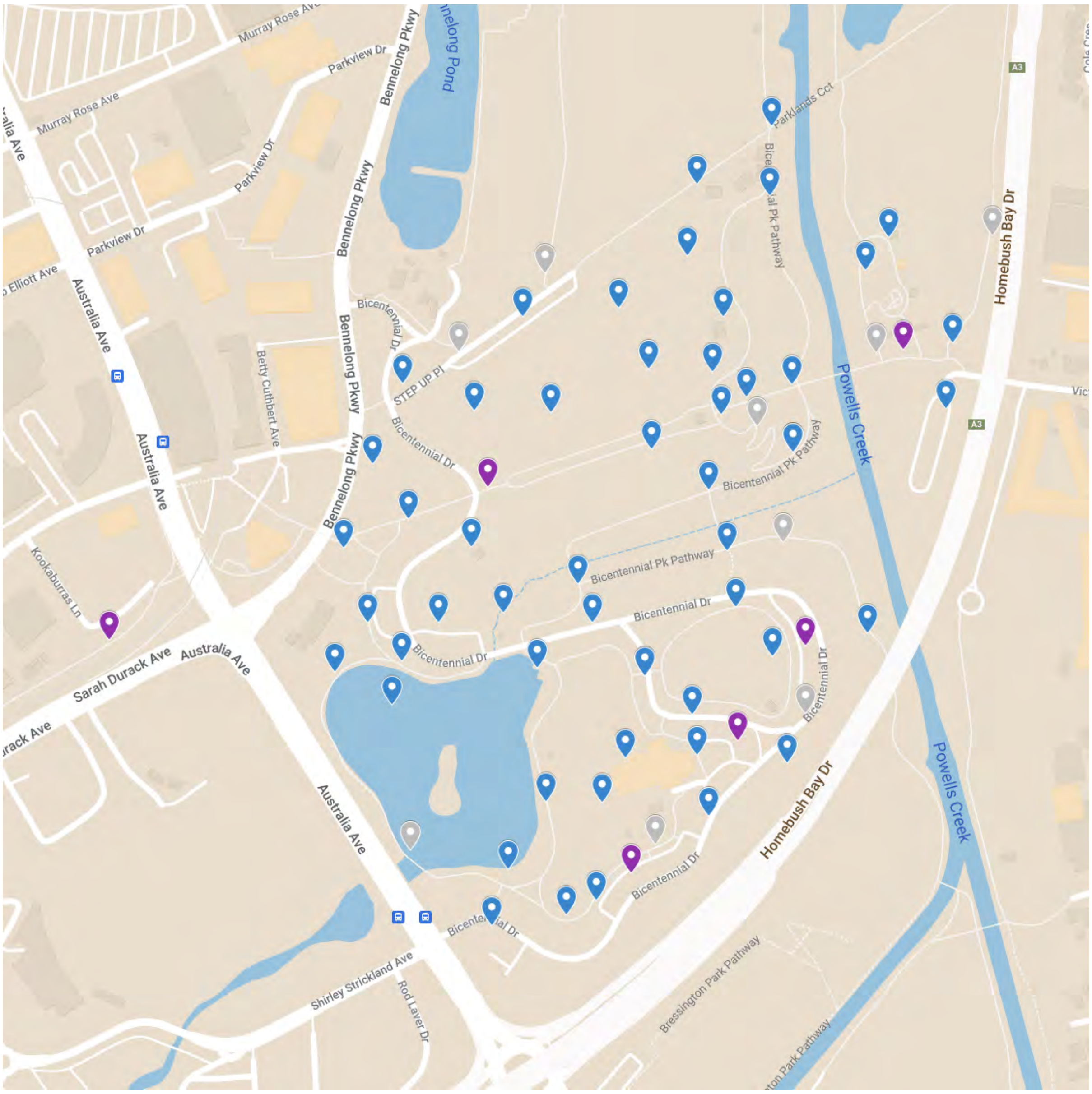

Figure 29. A map showing the location of ambient temperature and humidity sensing devices deployed in Bicentennial Park. (blue icon = temp/humidity sensing device; purple icon = weather station)

Deployment decision-making

The park was extensively surveyed on foot, providing the project team with an understanding of the range of microclimates. Locations were chosen that would capture this range (see figure 30 for examples). Deployment locations were constrained by available mounting infrastructure, such as existing poles and signage. Trees offered a wider range of options in forest blocks.

Figure 30. An illustration of the range of micro-climates where temperature and humidity devices were deployed. Image credits: UTS

Table 2. A summary of considerations for the location of temperature and humidity sensing devices

Consideration	Description
Height above the ground	All devices were installed at a height between 3.0 and 3.5m as a balance between monitoring ambient conditions at a height that is meaningful to people (1.5m) and out of reach for tampering, vandalism, or theft. A range of 0.5m allowed for variation in specific mounting situations (e.g. not clashing with a sign on a street pole).
Avoid blocking existing signage	No device installation was allowed to block line of site to existing installed signage. This was a non-negotiable requirement and took primacy over other factors such as orientation and height.
Objects and surfaces near to the device	Locations next to solid objects or surfaces with a high thermal mass (e.g. walls) were avoided, as they can raise the air temperature in their immediate vicinity, causing a sensor to give an unrepresentative reading. Devices came fitted with a radiation shield[16] that helped to block the effects of localised infrared heat, as well as preventing the heating up of the device in direct sun.
Line of sight to gateway	LoRaWAN devices need to have a direct line of sight to one or more nearby gateways. Topology, trees and buildings can all block this line of sight and are considerations when selecting a deployment location.
Orientation	Orientation on a pole or tree can impact direct sun exposure, and in some cases can affect the amount of localised thermal radiation that a sensor is exposed to. The key factors here are the width of the mounting asset, and the material that it is made from.
Risk of vandalism, tampering or theft	Devices deployed in public spaces are at risk of vandalism, tampering or theft. Choices can be made about the installation of a device to reduce this risk. The main mitigation is to install the device at least 3.0m above the ground. Other approaches include ‘hiding’ the device on the far side of an asset.
Visual impact	There was a desire to minimise the visual impact of devices in public spaces. In some cases, it was possible to ‘hide’ a device from view, for example by placing it on the far side of a pole or tree, relative to a footpath or road. Attention was also paid to the aesthetic standard of the design and execution of installations.

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[16] Often referred to as a Stevenson Screen

Deployment methodology

A mounting asset is any fixed permanent structure upon which a sensing device is mounted, needed by all above ground sensing devices. Mounting assets used for temperature and humidity devices were diverse and included:

- Light poles
- Parking signs
- Park signage (various designs)
- Trees

For devices mounted on park signage, a variety of low-profile custom brackets were designed and fabricated to a high professional standard. The cost of these custom solutions was often significantly greater than the cost of the device itself.

Parking signs were generally too short to reach the desired minimum installation height of 3.0m. An extension pole was added to address this.

Several devices were deployed on trees in protected natural areas. A custom mounting solution was developed that prevents damage to the tree (see figure 31, bottom right).

Figure 31. Examples of mounting assets and mounting solutions used for the deployment of temperature and humidity sensing devices in Bicentennial Park.

The provision of meteorological data from weather stations

Location

A total of thirteen weather stations were deployed across the Sydney Olympic Park precinct. Seven of these were deployed within Bicentennial Park and six were deployed in the town centre. The aim was to capture localised meteorology in these two general areas and directly compare it; the hypothesis being that the park would be generally cooler and more humid than the town centre.

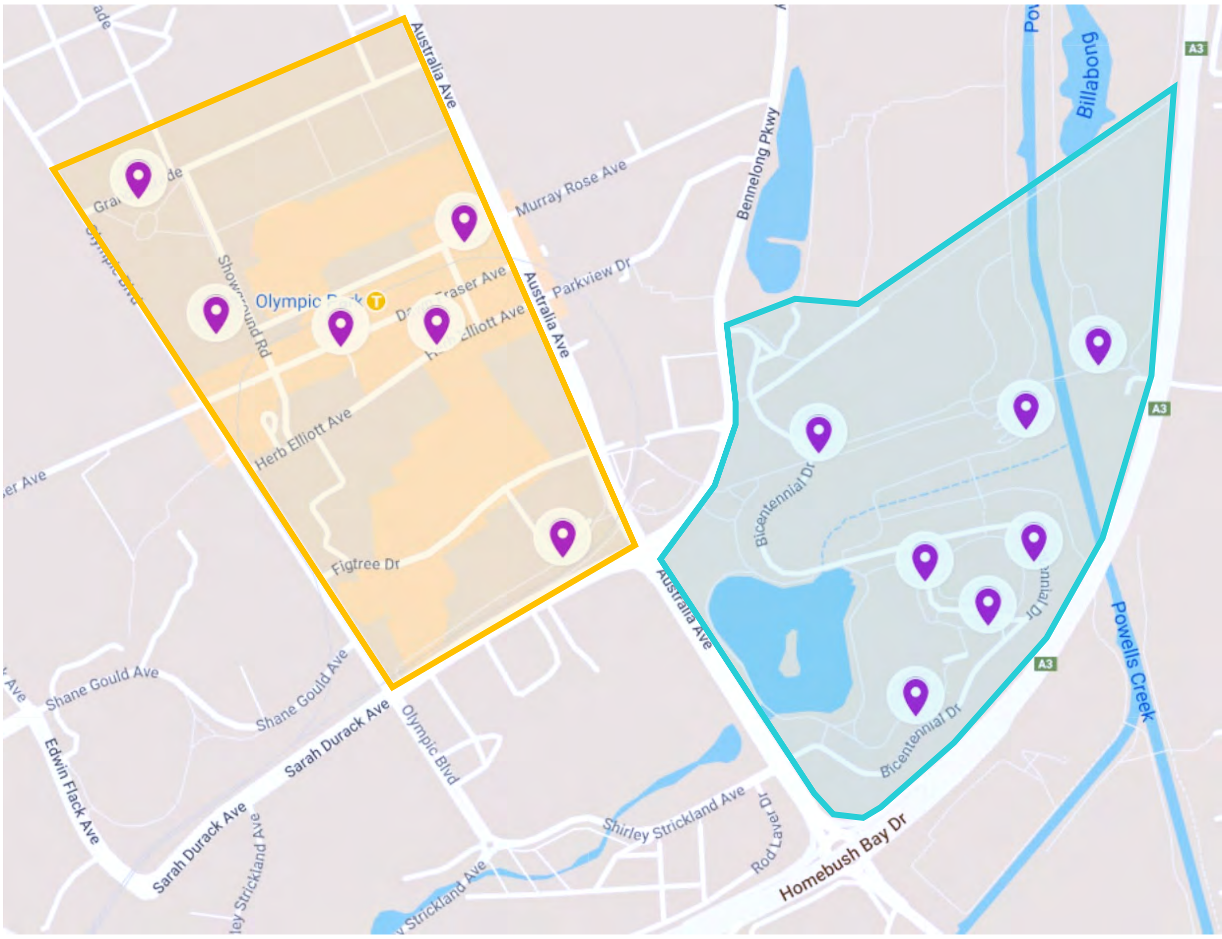

Figure 32. A map showing the deployment locations for all thirteen weather stations. The green area is Bicentennial Park and the orange area is the town centre.

Deployment decision-making

Weather stations deployed in Bicentennial Park were sited to capture the variation in microclimates due to topology, aspect, nearby vegetation and buildings. Locations with high foot traffic were also favoured.

Weather station locations in the town centre focussed on locations with high public use, where data would be most meaningful to people (e.g. outside the train station and in major parks). Variation between sites also captured a range of urban microclimates such as: open space versus enclosed by buildings and trees; concrete versus grass; high solar exposure versus high shade (due to the proximity of high-rise buildings).

Figure 33. A solar-powered weather station deployed on a ridgeline and major thoroughfare within Bicentennial Park. Image credit: UTS

Table 3. A summary of considerations for the location of weather stations

Consideration	Description
Power supply	Weather stations were powered by mains power in town centre locations and by a solar/battery system in Bicentennial Park. Locations with mains power were restricted to street poles owned by SOPA, which somewhat constrained available options. Locations for solar-powered weather stations required viable solar exposure during winter, with redundancy for prolonged poor weather. This ruled out many locations with high tree shadow and selected for more open locations with northerly aspects.[17]
Orientation	Orientation of solar panels was critical for ensuring reliable power supply. It also impacted the positioning of the weather station sensing unit so as to maximise fetch for a location
Vandalism, tampering and theft	As with temperature and humidity devices, weather stations were deployed with their lowest component at 3.0m above the ground, to mitigate against vandalism, tampering and theft.
Visual impact	Visual impact of weather stations was of greatest concern in the town centre so they were connected to mains power to reduce the profile and visual clutter that comes with an added solar panel. Visual impact was less of a concern within the park, which was justified by there being so few (7).
Fetch length	Fetch length refers to the length of uninterrupted space, across which wind can travel prior to it being measured by the weather station. Meteorological measurement standards stipulate a minimum fetch, however this could not be practically achieved in the kinds of dense urban and tree-filled settings found within Sydney Olympic Park, particularly given the project focus on micro-climates (which by definition, diverge from the kinds of representative locations identified by methodological standards). The approach taken was to accept compromised fetch in most deployment locations and to interpret wind data as highly localised, rather than as representative of the surrounding area.

Communications viability was not a concern for the selection of weather station deployment locations, as they used 4G, rather than LoRaWAN.

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[17] It is noted that due to tree shadow, reliable solar power supply proved to be a challenge for a few weather stations following initial deployment, requiring adjustment to their orientation or location.

Deployment methodology

Weather stations deployed in Bicentennial Park were mounted on large lighting poles capable of withstanding the relatively high wind loading created by a solar panel. Installations comprised three components: a control cabinet (containing a Fieldmouse IoT device, battery and charge controller); a solar panel; and the Lufft solid state weather station (see figure 34).

Weather stations deployed in the town centre were also mounted on large lighting poles. Installations comprised two components: a control cabinet (containing a Fieldmouse IoT device, battery and charge controller); and the Lufft solid state weather station (see figure 35).

All components for both types of installation were fixed in place with heavy steel straps or clamps. The weather station was mounted at the end of a 1m horizontal arm that distanced it from the thermal mass and wind interference of the pole.

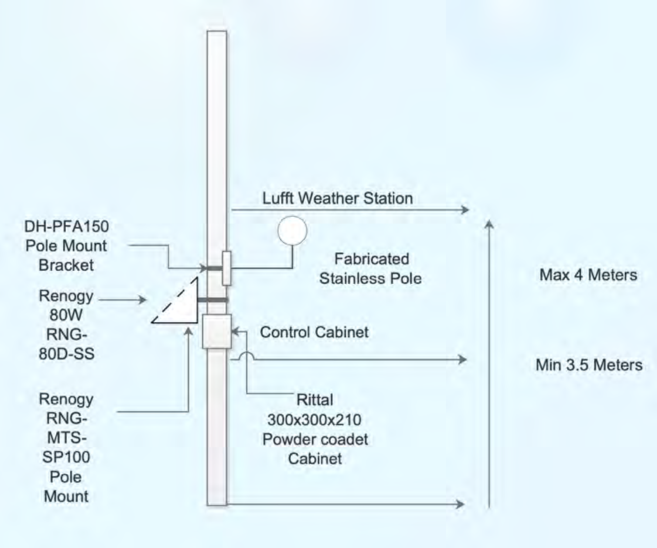


Figure 34. A schematic of solar-powered weather station installations used in the park

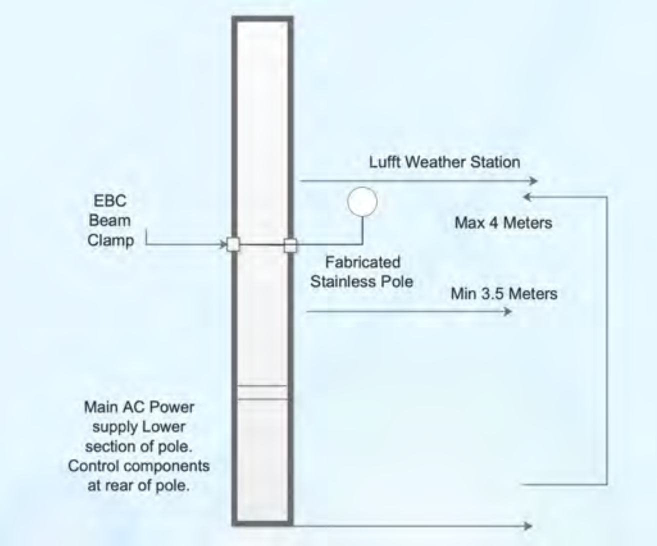


Figure 35. A schematic of mains-powered weather station installations used in the town centre

Digital Trust for Places & Routines (DTPR)

Digital Trust for Places & Routines (DTPR) is an open-source communication standard to increase the transparency, legibility and accountability of digital technology in the built environment.

The core of the DTPR communication standard is a classification of concepts around digital technology and data practices, and a set of icons to communicate those concepts quickly and clearly. Icons can be used to label smart sensing devices deployed in the public realm. They are seeing uptake around the world and the hope is that they will become established as a universally recognised standard.

In 2023 SOPA began piloting the use of DTPR icons to communicate with the public about three digital technologies deployed throughout its public spaces: SIMPaCT, Closed Circuit Television (CCTV), and Dynamic Crowd Measurement (DCM).

SOPA's aim is to be more transparent around the use of digital technology and data capture, and to improve the organisation's understanding of community attitudes towards it.

The pilot project has co-located signs with visible digital technologies across the park. Signs feature DTPR icons and contain information about what the technology does and who implements it. A QR code links to a webpage with more detailed information that is structured using the extended DTPR information taxonomy. The webpage features a quick survey to capture how people feel about the technology and gather feedback about how effective the icons were.

Figure 36 An example of the signs, featuring DTPR icons, that have been deployed on poles at head height to interpret SIMPaCT technology for the public.

Data verification and troubleshooting

The data verification process

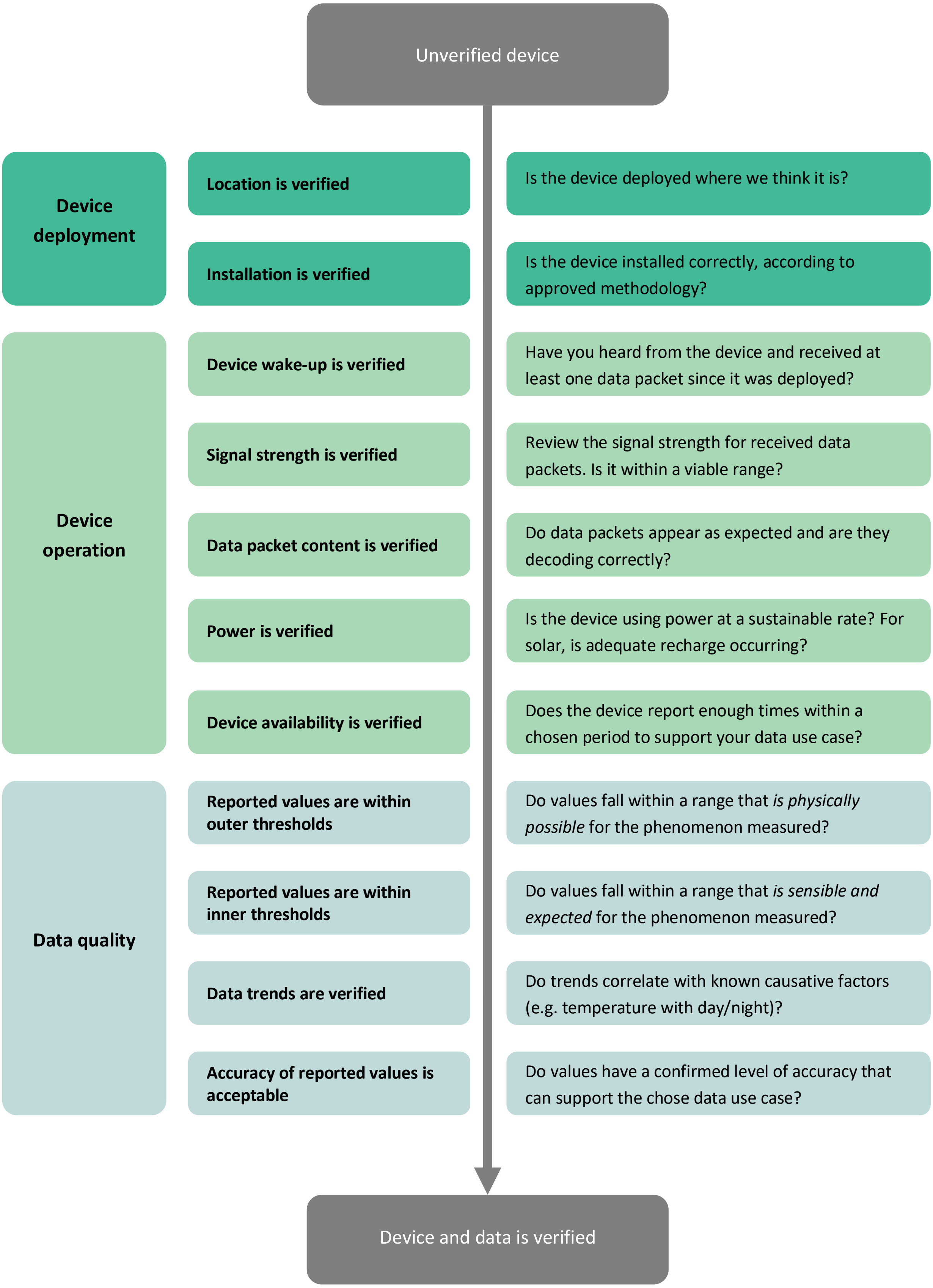
Following deployment of a sensing device, the data verification process includes three main stages:

A) **Verify device deployment:** Has the device been deployed in the correct location, and are recorded coordinates of that location as accurate as possible? Has the device been installed correctly, in accordance with the approved methodology?

B) **Verify device operation:** Does the device connect and transmit data as expected, on a continuous and ongoing basis, and with appropriate availability? This is primarily a focus on IoT, electronics, communications, and software coding. It tends to include a detailed review of deployment locations, micro-siting and communications coverage.

C) **Verify data quality**: Can we trust that the data we are receiving is accurate and able to support our defined data use case? This includes a focus on device performance, sensor micro-siting, data interpretation and environmental science.

Each verification stage can be divided into a number of steps (see figure 36). Each step must be passed before progressing to the next step. If a step cannot be passed, troubleshooting must commence. Following successful troubleshooting, one must revert to the verification step that was previously failed and work forwards from there. Only when all verification steps have been cleared can the data from a device be considered verified and 'usable'.



Unverified device

Device deployment	**Location is verified**	Is the device deployed where we think it is?
	Installation is verified	Is the device installed correctly, according to approved methodology?
Device operation	**Device wake-up is verified**	Have you heard from the device and received at least one data packet since it was deployed?
	Signal strength is verified	Review the signal strength for received data packets. Is it within a viable range?
	Data packet content is verified	Do data packets appear as expected and are they decoding correctly?
	Power is verified	Is the device using power at a sustainable rate? For solar, is adequate recharge occurring?
	Device availability is verified	Does the device report enough times within a chosen period to support your data use case?
Data quality	**Reported values are within outer thresholds**	Do values fall within a range that *is physically possible* for the phenomenon measured?
	Reported values are within inner thresholds	Do values fall within a range that *is sensible and expected* for the phenomenon measured?
	Data trends are verified	Do trends correlate with known causative factors (e.g. temperature with day/night)?
	Accuracy of reported values is acceptable	Do values have a confirmed level of accuracy that can support the chose data use case?

Device and data is verified

Figure 37. The data verification process used for the SIMPaCT pilot project

The experience of data verification for the pilot project

The verification of soil moisture data was a considerable challenge, due to various practical deployment challenges, combined with the limitations of low-cost sensing devices and the complexity of the environment being measured. Particular challenges were as follows:

- Verification of deployment location (installers often made inaccurate records).
- Verification of device installation (e.g. air gaps around probe due to the way it was inserted, resulting in very low soil moisture readings and strange response to rainfall and irrigation).
- Large lumps of clay, either with the probe inserted into them, or positioned above the probe. This resulted in very unresponsive 'flat' data, as the clay essentially sealed the probe away from the surrounding soil and water.
- Many devices failed to wake up due to poor communications signal issues.
- Many devices provided data for a short period, then went silent. This was commonly due to loss of battery power (resulting from a communications setting that caused a device to rapidly drain its battery as it tried to communicate under very marginal signal conditions), and/or water ingress shortly after deployment.
- Data received often fell outside of 'outer threshold values', meaning that the values were not physically possible (e.g. soil moisture synonymous with oven baked soil; values higher than 'absolute saturation'). These were either diagnosed as calibration errors or issues with the installation of a sensor probe.
- Extreme saturation of the ground resulted in unresponsive 'flat' maximum soil moisture at some locations. These sensors reported no discernible response to rainfall and irrigation, raising verification questions.

Data verification for temperature and humidity devices and weather stations was uncomplicated and no major challenges arose.

Figure 38. An illustration of how water-logged many of the soil moisture sensing devices became. Permanent submersion led to water ingress and complete loss of function. Image credit: UTS

Troubleshooting soil moisture sensing devices

Figure 39. Using near field communications from a smart phone to reconfigure the communication settings of a soil moisture sensing device. This was one of the most common troubleshooting activities undertaken and was a response to loss of signal or highly intermittent signal. Note the large lump of clay in the image. Heavy clay proved to be a major challenge that impacted device communications and the collection of reliable soil moisture data. Image credit: UTS

Troubleshooting is the active response to a non-verification issue. It involves the diagnosis of an issue, and an action that resolves it.

The troubleshooting process for soil moisture sensing devices was prolonged, lasting for around six months. During this time, UTS worked with The ARCS Group (the device provider) and Total Water (the installer), remotely and on the ground. Repeated site visits were required, firstly to verify deployment locations, and then to physically access a variety of problem devices.

The main troubleshooting tasks for soil moisture sensing devices were:

- Updates to communications settings to support more reliable connectivity while also preserving battery life.
- Hard re-set of many devices.
- Reinsertion of probes to obtain better contact with the soil or to avoid large lumps of clay.
- Replacement of drained batteries (that resulted from early issues with communications. Settings and/or water ingress).
- Replacement of devices damaged by water ingress.
- Relocation of devices to new locations with more viable LoRaWAN connectivity.

SIMPaCT Data Schema

Definitions

There are two main types of data in a smart city project like SIMPaCT: telemetry and metadata.

Telemetry

Telemetry describes a measurable phenomenon that changes over time, expressed in a time series. It refers to all dynamic information reported by a sensing device, and includes sensor data (e.g. soil moisture or temperature) as well as device functionality variables (such as battery voltage and communications signal strength). Telemetry can also include data from third-party sources, such as meteorological data received from the Bureau of Meteorology. Telemetry values are dynamic and can change every time a device reports. They can be viewed as an archival data set, or as a near-real-time data stream.

Metadata

Metadata is 'data about data', and is defined by 'fields', each of which describes a specific attribute of project data (or other aspects of a project). Each metadata field needs to serve a clear purpose that is tied to a data use case and the operation of a sensing device network. In the SIMPaCT context, metadata is critical for: installing, administering and operating a sensing device network; managing and formatting data; interpreting data; and sharing data. Metadata can be updated over time but tends to remain relatively fixed compared to telemetry.

Metadata and telemetry are generally characterised in a ***data schema*** that defines fields and their intended applications. A data schema is critical for describing what data is available and in what format and provides a reference for all project collaborators that aids with the development of an integrated technology solution. It is also the blueprint for all data labelling within a project, which enables storage, retrieval, interpretation, and sharing of data in a productive, safe, and secure manner.

The SIMPaCT data schema provides a record of device and spatial metadata, and sensor telemetry, produced as part of the SIMPaCT pilot project. It primarily covers:

- Metadata relating to functionality and deployment of sensing devices.
- Metadata relating to locations and operational areas of the irrigation system (stations).
- Data payloads from sensing devices.
- APIs that carry data from IoT platforms into SIMPaCT.

The schema is compiled from the perspective of data provision from smart sensing devices, into the Senaps data management platform. It does not cover APIs, data schemas or ontologies *within* Senaps.

The SIMPaCT metadata schema

The SIMPaCT metadata schema is built around a nested structure of metadata categories that align with increasing physical scale (see figure 39).

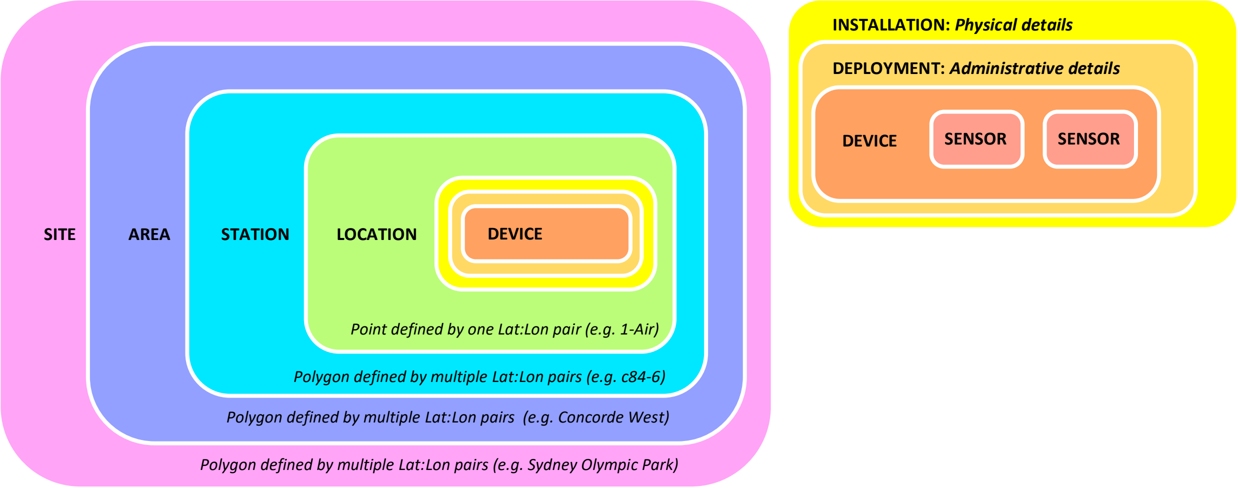


Figure 40. The nested structure of the SIMPaCT data schema. The bright colours align with colours used in the 'SIMPaCT master metadata record' and provided a quick visual reference for metadata categories across different technical documents.

Metadata categories contain collections of descriptive metadata fields (see table 4 for examples). Each field is defined within the metadata schema. The final design of the metadata schema was resolved from a collaborative process of enquiry amongst the technical team; all fields and field definitions needed to serve a clearly defined purpose within the SIMPaCT digital twin, and each field needed to have an agreed methodology for the collection of entries against it.

Table 4. Examples of metadata fields within the main metadata categories

Category	Examples of fields
Device	Device name; Device ID; Device type; Device owner
Deployment	Deployment status; Deployment date
Installation	Mounting asset type; Mounting solution type; Installation notes
Location	Latitude; Longitude; Height above ground; Orientation; Soil type; Groundcover
Station	Station ID; Presentation standard; Dominant vegetation; Water requirement

The process of collecting and verifying certain metadata field entries for SIMPaCT was prolonged and complex for several reasons. Notably, initially inaccurate locational coordinates for soil moisture sensing devices required updating, which took several months and was exacerbated by the need to relocate many devices. Meanwhile, the collection of station metadata required extensive fieldwork, and was delayed until late in the project due to a delay in agreement about what it should be and how it should be used by the digital twin.

The SIMPaCT telemetry schema

The SIMPaCT telemetry schema describes all telemetry produced by sensing devices (soil, temperature and humidity, and weather stations) and sent to the Senaps data management platform. This information is treated as a standard within Senaps and is used as a template for the harmonisation of data from different sources; it does not necessarily reflect the data format from sensing devices.

Each telemetry field within Senaps requires its own sub-set of metadata to describe it. Table 5 illustrates this using soil moisture as an example.

Table 5. An example of telemetry metadata for soil moisture

Field name	**Soil moisture (VWC)**
Unit	%
Range	0-50
Description	Volumetric Water Content is the volume of water per unit volume of soil, and is used as a standard measure of soil moisture.
Purpose	Expresses soil moisture in a standardised format for use by the SIMPaCT digital twin: for model training and calibration; for soil moisture prediction.
Example	20%

The telemetry schema also takes a **device perspective**, listing all of the telemetry produced by each device (e.g. see table 6), as well as the structure of the device's data payload.

Table 6. The data payload of an SMC30 Sensedge Microclimate Senstick (the temperature and humidity sensing device used)

Parameter	Name	Range	Size	Type	Description
Status	Stat	0-255	1B	Unit8	Status codes: 0x00 – OK Bit0 – Movement Detected Packet Bit1 – Movement Detected Confirmed Bit2 – Battery Low Power Etc…
Temperature	T	-128.00 – 127.00	2B	Int16	Temperature (T/100)
Relative Humidity	Rh	0.00 – 100.00%	2B	Unit16	Relative Humidity (rh1/100)
Battery	bat	1 – 3.55V	1B	Unit8	Battery Level (bat/100+1) (min 2.2V)

Finally, the telemetry schema includes details of the APIs that share telemetry from IoT platforms into the Senaps data management platform, acting as a general reference for developers.

Operationalising SIMPaCT

Working within constraints

The SIMPaCT digital twin prescribes optimal irrigation scheduling based upon advanced analytics modelling. Commands are issued to the irrigation management platform in the form of scaling factors (expressed as a %) which indicate required changes to the existing irrigation schedule.

The ability for digital twin outputs to result in changed irrigation conditions and impact creation (e.g. improved cooling; maintained plant health) is limited by constraints of the irrigation system, and biophysical constraints.

Constraints of the irrigation system

The physical infrastructure of the irrigation system, combined with various operational 'rules', constrain its ability to act upon irrigation commands received from the SIMPaCT digital twin. Table 7 provides an overview of these constraints.

Table 7. A overview of constraints imposed by the design and operation of the irrigation system

Irrigation windows	Irrigation in Bicentennial Park can only occur at certain times of the day. An irrigation window is generally in place through the night, to avoid wetting park visitors and to ensure optimal infiltration of water into the soil. This limits the number of hours available for irrigation. It is not always possible to water every station, for as long as it requires, within every irrigation window, due to the other constraints below.
Station coupling	An existing constraint of the Fieldmouse platform is that each of the 200 stations within the park is coupled with another station (100 pairs). Coupling means that both stations must be treated operationally in the same way; if one is irrigated then the other must be irrigated at the same time, for exactly the same period. This places a major constraint on the ability to optimally irrigate stations, as a pair must be delivered a volume of water that meets the requirements of whichever station has the greatest water demand.
Station flow rate	Each station has a flow rate that is defined by the combined output of sprinklers within it. Flow rate cannot be exceeded and places a maximum limit on the amount of irrigation water that can be delivered to a station within a given time period.
Console pressure	There are five 'consoles' in Bicentennial Park, which work with the main pumping station to maintain a constant pressure within a closed loop of irrigation pipes. When irrigation begins within a station, the pressure drops in the pipes that connect to that station, and must be compensated for by the console. If too many stations on one console are opened at once then the console is unable to maintain pressure. To prevent this from happening, limits are placed on the number of stations that can be watered simultaneously.
Water supply	The irrigation system is constrained by the supply of water to it. This might occur from the failure of a pump, or from water restrictions.

Biophysical constraints

If the irrigation system constraints can be navigated and actual irrigation can be aligned with the prescribed irrigation commands from the SIMPaCT digital twin, various environmental and physical factors can still serve to constrain the ability of irrigation to deliver desired impact.

Table 8. Known biophysical constraints

Water availability in the soil	For plants to access water, or for optimal evapotranspirative cooling to be achieved, there must be sufficient water available in the soil. Irrigation does not necessarily ensure this. During hot weather, poorly time irrigation can lead to high evaporative loss of water from the soil surface before it is able to properly infiltrate and replenish sub-surface soil moisture. Prolonged dry periods can also harden the soil surface, reducing its permeability (the ability of water to soak in) and increasing direct run-off.
Drought conditions and plant stress	Prolonged drought conditions can cause plant stress and a reduction of normal biological processes like evapotranspiration. Plants can remain in this state even after an initial increase in soil moisture from irrigation. The effect is that plants will not respond to irrigation in the way that the SIMPaCT digital twin predicts.

The nature of biophysical constraints on the effectiveness of the SIMPaCT digital twin is still poorly understood, due to a current lack of longitudinal operational data over a hot summer period. It would be useful to study the examples outlined in table 8 once data becomes available.

Workflow integration

The SIMPaCT digital twin is designed as an automated system, but like all technical solutions it requires ongoing operational management and oversight to maintain data collection across the sensing device networks and ensure normal system functionality. Total Water are an irrigation management specialist contracted by SOPA and were positioned to take on the majority of these management and oversight responsibilities by the end of the pilot project.

Total Water was tasked with upskilling staff members to understand and build familiarity with the tools and interfaces of the SIMPaCT digital Twin, and to subsequently integrate these (and associated processes) into irrigation management workflow.

Two key tools were developed to support workflow integration:

1) Park Now (operational version)

   An operational version of the Park Now dashboard includes live data feeds and a link to full project documentation, including extensive operational guidance.

2) Automated daily reports generated by the Senaps platform

   Reports contain a condensed version of recent park data available via Park Now and are designed to provide a snapshot of current conditions and SIMPaCT-directed irrigation in the park. They include:

   - Irrigation volume delivery reported by the pump-house Flow Meter
   - Actual irrigation delivery
   - Upcoming irrigation schedules
   - Manual over-rides of SIMPaCT schedules
   - Sensing device availability/status
   - Soil moisture levels for all 200 stations
   - Sensing device battery life

   Reports help on-the-ground operators like Total Water to check that:

   - Irrigation is occurring as expected and that plants are receiving adequate water
   - The SIMPaCT digital twin is operating correctly
   - Sensing devices are online and operating correctly, and whether maintenance is required (e.g. battery replacement; device replacement)

Centratech Systems (CTS) are the owner of the Fieldmouse irrigation management platform that integrates with the SIMPaCT digital twin, and are also responsible for the ongoing management of the thirteen weather stations deployed for the project. CTS also receive daily Senaps reports to assist them with these responsibilities.

Training and handover

A series of workshop sessions were designed to share the information and skills required to effectively administer and operate the SIMPaCT digital twin and maintain its function over several years. Sessions helped SIMPaCT users and managers to become familiar with diagnostic tools, scheduling capabilities and limits, data flows, hardware management and available support, and general troubleshooting and remediation strategies. Sessions were also invaluable for hardening system maintenance processes, and for giving participants a clear understanding of the advantages and benefits of SIMPaCT.

Participants

- Irrigation contractor (Total Water), responsible for maintenance of the above and below ground sensing devices, and the operational tasks required by SIMPaCT.
- SOPA staff from Engineering and Infrastructure Assets, as well as Landscape & Horticulture

Sessions included information delivered by various project partners

- Using the operational version of Park Now, SIMPaCT's management interface
- Accessing and navigating available documentation for information on hardware location, maintenance, and troubleshooting
- An overview of the Senaps data management platform, and automated report interpretation
- Sensor replacement best practice, and overview of the MeshNet Vision IoT Platform
- Processes for manual override of SIMPaCT when required
- Results of an audit of flow meter data from the existing irrigation system
- Ongoing operational administration and documentation requirements

4 Achievements, challenges, and lessons

An overview of key achievements and challenges

Key achievements

Critical acclaim doesn’t come much higher than winning the national 2023 IoT Impact awards for “Research” and “IoT for Good”, and says a great deal about the achievements of the SIMPaCT pilot project, which can be summarised as follows:

Meaningful impact

The project is a meaningful science-based project that addresses an important issue impacting many communities, with the potential to deliver great benefit to Australian society.

A collaborative spirit and well-designed governance model

A critical component to the success of SIMPaCT has been the collaborative spirit among the partners and the parallel operation of several specialised teams. The project brought together a diverse coalition of talented researchers and industry partners who have had to effectively communicate and understand each other’s specialised language to reach the project goals. Partners have integrated various methodologies and approaches, knowledge, skills, agendas, and priorities into a larger, multidisciplinary project architecture to produce demonstrable, practical and fit-for-purpose outcomes.

A well-designed governance model proved to be a critical foundation for effective collaboration and project success. It ensured that the diversity of skills and knowledge in the room was able to come together effectively, allowing people to learn from and support each other.

The professional skills of the Project Manager and the Technical Integration Manager were instrumental in ensuring effective collaboration between all parties for the duration of the project

Exemplary science communication

The project demonstrates a capacity to communicate complex, positive, exciting and meaningful science to a diverse audience; something that is becoming increasingly important.

A fully functional operational system

Translating the science and technology developed during the proof-of-concept phase of the project, into a feasible, real-world setting and bridging the gap between research and industry has been incredibly exciting. By the end of the pilot project, a fully functional instantiation of the SIMPaCT digital twin was operating in Bicentennial Park, with a tangible impact on irrigation operations. This early success has the potential to improve the quality of the park environment, and in turn, the health and well-being of visitors and residents. It promises to reduce water use and improve park management processes, both outcomes with the potential to contribute to a net positive business case for SIMPaCT.

Extensive knowledge creation and capacity building

The project has been a deep learning experience which has produced extensive insights relating to process and methodology and has developed capacity to expand SIMPaCT as a valued high-impact solution. Please refer to the *Deeper critical reflections* section below for a record of these insights.

Key challenges

The achievements of the SIMPaCT pilot project have been realised despite several key challenges with project delivery, experimental technology, and adverse environmental conditions.

Figure 41. The project occurred over a prolonged period of exceptionally wet weather that created significant challenges. Image credit: UTS

Two wet La Niña summers

The project spanned two very wet La Niña summers. The ground in Bicentennial Park was almost permanently saturated and the irrigation system was non-operational on multiple occasions, at times when it would normally be running. The wet conditions delayed selection of locations for sensing device deployment, caused multiple delays to the installation of communications gateways, slowed the deployment of soil moisture sensors, and caused damage to those that were installed. Heavy rainfall and wet vegetation also negatively affect device communications resulting in intermittent data sets, and a lack of strong sunlight caused power failure for weather stations. This all served to reduce the amount of useful data available for developing the advanced analytics models, necessitating a temporary reliance upon ‘dummy data’ during the earlier development stages.

By the end of the project, the data collected from the park largely related to extremely wet conditions, with very little corresponding with what might be characterised as ‘dry conditions’. This meant that physiological patterns of plant water stress and an associated ‘effective’ irrigation response could not be established within the digital twin, because plants were never water limited. This posed a challenge for the calibration of the SIMPaCT advanced analytics models; while they should in theory adapt to function effectively under dry conditions, it has not been possible to test this assumption. By extension, the delivery of the four value propositions for SIMPaCT (urban cooling, water efficiency, public amenity and improved management outcomes) remains an untested hypothesis. The system is working, but it needs to run over a hot summer in order to prove the capabilities it was designed to deliver.

A complex location

Bicentennial Park is a diverse landscape that presented significant challenges for the deployment and operation of sensing device networks. The topology is highly undulating, which creates numerous communications black spots that impact the ability of sensing devices to reliably transmit data. This is exacerbated by widespread dense tree cover. Soils in the park are a rough artificial mix of dense clay and sandy topsoil used to cap a landfill site. The high clay content and high micro-variability compared to more standard soil profiles created challenges for the collection of useable soil moisture data.

Delays to technology procurement

The procurement of sensing technologies was delayed for several reasons. Delayed procurement began with a longer-than-expected design process for the sensing networks, combined with administrative and bureaucratic delays with contracts between major partners, which blocked the flow of funding at the start of the project. This all meant that orders for sensing devices were placed later than planned. The lead time for shipping of sensor technologies was also longer than expected, resulting in receipt of goods several months after the anticipated date. This led to delayed deployment of sensing devices and knock-on effects to data collection and other project deliverables.

Extensive challenges with sensing technology and methodology

The use of emerging technology is critical to innovation but carries unavoidable risk. Smart low-cost sensing technologies presented a range of challenges relating to the operation of devices and their ability to reliably report data, in part tied to their relative immaturity as products and in part due to a lack of clearly defined best practice methodology for their use. Despite these challenges, devices successfully delivered usable data. Indeed, the design of the SIMPaCT digital twin was developed around the constraints of these technologies, demonstrating new modelling approaches that may have the potential for broader application to other types of smart low-cost sensing.

Lessons from the pilot

Project governance and delivery

In-depth and complete trial technology deployments could be built into the project delivery process, combined with a more staggered approach to technology procurement

The solution for the large scale SIMPaCT pilot was developed from scratch, working with emerging and untested technologies, which carried inherent risk and a tension with the expected scale of the delivery. The time constraints of an eighteen-month project meant that technology procurement decisions for the entire park needed to be made early in the project, before products and methodologies could be tested and refined. Some of the technologies selected proved to have challenges (most notably, with soil moisture sensing devices). The project team worked with these early technology selections and achieved good outcomes for the project despite the challenges, through innovative thinking and effective collaboration.

One way to reduce this type of risk in future projects could be to adopt a more staggered approach to the selection of new technologies by running an in-depth and complete trial deployment in a small area, prior to full-scale rollout. Such an approach would need to be incorporated into a project delivery process from the very start, with complete pilot trials fixed as milestone deliverables. This creates an argument for grant programs that support longer project delivery timeframes capable of accommodating more iterative delivery pathways.

Digital twin architecture and system integration

A need for technology-agnostic consultation at project inception

The SIMPaCT digital twin architecture was the product of a coalition of partners that came together around a funding opportunity. Partners were included based upon their expertise and capabilities, but also on their ability to contribute in-kind value to the project. Contracts were negotiated with each partner based upon these contributions, and stipulated details of responsibility and deliverables. This fixed in place certain fundamental aspects of the architectural design at project inception.

The Technical Integration Manager (SAPHI) has recommended that, during the development of future project funding proposals, partner responsibilities and deliverables are left as open as possible, to allow time for high-level strategic solution design. An unbiased technology-agnostic consultant should be engaged as early as possible, to aid in the selection of the most appropriate technologies and ensure efficient system design and division of labour. Ideally, this engagement should occur during the business development phase of a project, when a coalition is still being formed and before a funding proposal is submitted. Alternatively, it should occur as close to the project start date as possible, before partner contracts are formalised.

Data provisioning

Temperature and humidity sensing and weather stations presented few challenges

There were few challenges with the temperature and humidity sensing and weather stations. These devices were simple to deploy and operate, verification was easy, troubleshooting was virtually non-existent, and data interpretation was clear. Weather stations are tried and tested technology. Although the technology of the temperature and humidity sensor devices is similar to that of the soil moisture devices, they worked significantly better for the project due to not having to be buried.

The SIMPaCT pilot project has made a significant contribution to collective understanding of smart low-cost sensing methodology that will serve future versions of SIMPaCT, as well as the wider smart cities sector

The provision of live environmental data from Bicentennial Park into the SIMPaCT digital twin relied upon the use of smart low-cost sensing devices deployed in a large network. These technologies are experiencing rapid uptake world-wide and show great promise for addressing a wide variety of pressing urban challenges. However, they are far from well-established and there were no clear references for best practice that could guide the project team as we experimented with them. As such, the process of refining a methodology to meet the needs of the project was extensive and iterative. Despite such challenges, it is a credit to the expertise, adaptability and perseverance of the SIMPaCT team that good outcomes were achieved. A great deal was learnt, and it is not unreasonable to assume that future SIMPaCT deployments will build upon the valuable lessons of the pilot project and avoid the need for more extended experimentation. This will be critical for achieving a lower cost of establishment as part of a maturing business case for SIMPaCT.

An extended period of verification and troubleshooting for soil moisture data provisioning should reduce in length as sensing methodology matures

The SIMPaCT pilot project has proven that a large and densely deployed network of smart low-cost soil moisture sensing devices can produce data to a level of reliability and quality necessary for running the SIMPaCT digital twin and delivering desired irrigation outcomes for Bicentennial Park. However, to achieve this, an extensive period of data verification and troubleshooting was required.

The iterative methodological learning process heavily contributed to the length of the verification and troubleshooting period in the pilot project (which was essentially the feedback loop on the effectiveness of the methodology). Future SIMPaCT projects will have the benefit of building upon a more mature sensing methodology (refined during the pilot), which should reduce the length of the verification and troubleshooting period.

Rigorous approaches are needed for recording the deployment location of soil moisture sensing devices

A majority of the 202 soil moisture sensing devices deployed during the SIMPaCT pilot project initially had inaccurate records of their deployment locations. Errors included switching of two devices (i.e. deployed in each other’s place), and inaccurate longitude and latitude coordinates (sometimes by tens of metres). This resulted in many days of manual site-based work to locate devices in the ground and update their deployment records, resulting in delays to the project of several weeks.

The challenge of accurately recording device deployment locations was anticipated during the deployment planning process and efforts were made to avoid it. However, the complexity of the landscape and the experimental nature of the task meant that, despite best efforts by all parties, inaccuracies occurred.

The use of high-performance GPS survey equipment proved to be problematic due to high tree cover across the park, which blocked the equipment from obtaining a reliable satellite fix. Indeed, it may have contributed to many of the inaccurate coordinates.

The most reliable approach would likely be to develop a standardised system for establishing and recording a device deployment location using survey tapes positioned relative to fixed nearby objects, combined with a standardised approach to photographing the deployment. Triangulation and site photography were used in the pilot project on a somewhat ad hoc basis. The experience from the pilot project emphasises the value of taking more time to develop, establish and implement a rigorous standardised approach to device deployment records in future projects.

LoRaWAN is a cost-effective communications technology for large sensing device networks, however there are major challenges to be aware of when it is used for soil moisture sensing

LoRaWAN is part of a family of communications technologies called LPWAN (Low Power Wide Area Networks). LPWAN is arguably the only class of communications technology able to support a large, localised network of distributed sensing devices, such as the one used for SIMPaCT, because LPWAN operates at very low power and is able to support battery-powered devices over periods of years. The LoRaWAN solution chosen for SIMPaCT also has the benefit of zero marginal cost per-connected device, making it cost competitive at scale.

While LoRaWAN proved to be a viable communications technology for supporting the SIMPACT sensing network, major challenges arose relating to its use with soil moisture sensing devices. The ground severely attenuates LoRaWAN signal. This is worse when devices are at or below ground level, where topography is more likely to block line of sight). Furthermore, a device buried in water-logged clay-heavy soil (which dominated Bicentennial Park) is almost guaranteed to experience communications issues. Various technical fixes, workarounds and functional trade-offs (e.g. battery life reduction in exchange for improved device connectivity) were experimented with, and towards the end of the project the LoRaWAN communications challenges resolved enough that they no longer disrupted the standard operation of the digital twin.

Lessons learned from this process would be applied in future SIMPaCT deployments that make use of LoRaWAN, though it would still be wise to anticipate some level of communication challenges. However, it should be noted that the undulating, tree-covered landscape of Bicentennial Park, with its dense water-logged soils, represented one of the most challenging environments imaginable for LoRaWAN. Flatter and more homogenous sites with sandier and less water-logged soils are unlikely to experience these challenges to the same degree. A notable approach for reducing the risks of poor and patchy LoRaWAN signal coverage include is to invest in more local gateways (though this carries additional costs). On-site radio frequency planning at the start of the project could also have informed the configuration of device communications settings (e.g. spreading factor and transmission power) and helped to standardise installation methodology suitable for site conditions. In future, this can help to avoid some of the iterative experimentation seen in the pilot project and may reduce the length and complexity of the device verification and troubleshooting phase of the project.

Alternative LPWAN technologies may also be worth considering for future sites. Narrowband IoT (NBIoT) is a low-power protocol designed for smart distributed device networks, which operates over existing mobile phone network infrastructure. NBIoT has slightly better penetration of solid objects than LoRaWAN, which may overcome many of the challenges experienced at Bicentennial Park. However, due to reliance upon existing 4G/LTE gateways there is no option to position gateways to ensure optimal coverage of an entire site, meaning that NBIoT might be ruled out for locations with highly undulating terrain or with limited 4G reception. For in-depth discussion of the NBIoT option, including comparative costings, please refer to the SIMPaCT Roadmap, Appendix C.

The insertion of batteries into soil moisture sensing devices should be the responsibility of the vendor

It was very easy to overtighten the cap following insertion of batteries into the soil moisture sensing device, damaging the seal and leading to water ingress. During battery insertion it was also possible to inadvertently loosen the gland where the probe cable exited the device, again leading to water ingress. These issues, which occurred in a high number of devices can be attributed to a design flaw in the SMC30 Senstick used for the project, which resulted in the need for many complete device replacements. Issues occurred despite the device having an IP68 rating[18], illustrating that an appropriate IP rating alone is no guarantee of against water ingress.

The issues with water ingress could have been mitigated by working with a local device vendor that directly oversees battery installation, removing responsibility for this task from installers. An alternative make and model of device could also be selected that has a design that is less susceptible to water ingress (noting that commercial options in the class of device chosen are somewhat limited).

The value of PVC outer cases for soil moisture sensing devices should be reviewed

The PVC outer case for soil moisture sensing devices was intended to provide a robust additional layer of protection from impact (e.g. from spades and turf aeration), soil acidity (which can corrode the aluminium casing), and water ingress. However, given the cost of materials and the additional complications of DIY assembly for 202 of these casings, the return on investment is unclear. The use of valve boxes (which formed a protective shell around each device) negated the need for impact resistance. The casing also failed to provide a barrier to water ingress that addressed the issues described above. Further tests to explore the performance of devices with and without the casings would be of value.

Soil moisture probes could be inserted at a shallower depth, if soil has high clay content

Bicentennial Park has soils with very high clay content. The standard depth for soil moisture probe insertion was 100mm below the surface. This may have resulted in many of the erroneous data trends that were the cause of much consternation for the project team. Around 20-30 devices showed little or no response to known rainfall and irrigation events. Direct observation of these devices in the field during active irrigation delivery confirmed that water was indeed falling directly onto the soil above the probes, and yet no significant change in soil moisture was reported. Careful excavation of probes and close attention to the soil profile confirmed the presence of heavy clay at shallow depths (and commonly at 100mm). If the probe is inserted directly into this clay, it was effectively sealed away from moisture fluctuations in the surrounding soil. In other cases, a layer of clay was found directly above the probe, preventing irrigation water from infiltrating down to it.

Where clay-heavy sites are a future focus for SIMPaCT, installation of probes at a shallower depth (40-50mm) is advisable. This is because clay rarely occurs at these shallower depths, which mostly comprise of humus-rich topsoil. Sensitivity tests at multiple depths are also advisable for any new site.

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[18] IP68 – International standard rating deemed fit enough to withstand dust, dirt and sand, and are resistant to submersion up to a maximum of 1.5m underwater.

There may be new methodological issues with measuring soil moisture at a shallower depth, as data about deeper soil moisture may prove to be critical to the accurate functioning of the digital twin. However, the use of a smaller number of multi-depth soil moisture sensing probes, to supplement the larger network of low-cost sensing devices, might provide a more complete picture of moisture through the soil profile and negate any new issues arising from shallower probe deployments. This topic would benefit from more robust enquiry as part of future SIMPaCT projects.

Focus on the collection of delta trends for soil moisture, rather than on accurate absolute values

It was determined that the accuracy of low-cost soil moisture sensors is not that important, because even a large bias in sensor performance is dwarfed by micro-variability in soil moisture, which makes the concept of accuracy lose its meaning in the deployment context.

This realisation emerged from an additional data collection exercise using a high-accuracy handheld reference sensor. In each of 50 locations, sets of readings typically showed large ranges in soil moisture of at least 10% between the driest and wettest points, and ranges of 20% or even 30% VWC were very common. This means that there is no ‘true’ soil moisture value for a station or even within 1 metre. It therefore seemed clear that a different approach was required for how the soil moisture data was understood and used.

There is an emerging methodological approach associated with the use of all low-cost sensing devices (regardless of what they measure), which downplays attention to absolute values and focuses on delta trends. This approach proved to be necessary for the SIMPaCT pilot project. While it was not possible to take a meaningful absolute value of soil moisture with a defined level of accuracy, it was possible to capture soil moisture variation over time, across short (15 minute) increments. It was the trend, and in particular the responsiveness to water input, that proved to be relevant to digital twin analytics. Importantly, the accuracy of the low-cost sensors appeared to have no impact upon the ability to collect reliable and useable trend data.

It should be noted that the scenario and understanding just described occurred within the context of a very wet period with high soil moisture across the entire park. It may be the case that the high micro-variation reduces during drier conditions, and that the range of change in data trends also reduces. That said, an irrigation event may still result in high micro-variation and high soil moisture response. Either way, it seems likely that the models' focus on delta trends (rather than absolute values) would remain just as effective under drier conditions, as it does under wet ones. Testing this over a hot summer should be a priority.

Data management

Inherent instability of data flows from low-cost sensing device networks

Large sensor networks are constantly changing. Sensing devices may occasionally malfunction, experience intermittent connectivity, get removed, or new devices might be added to the network. These changes necessitate continual updates within the digital twin, to ensure the correct flow and management of telemetry and alignment of predictive models. Currently, these updates must be carried out manually and represent an ongoing operational requirement that adds to the overall cost of system operations. While automation of this process is feasible, it would require the development of new custom software solutions. This is an example of an area that may be worth future focused investment as part of ongoing efforts to scale SIMPaCT.

The integration of sensor data with advanced analytics models was seamless

Senaps, the data management platform at the heart of the SIMPaCT digital twin, was able to ingest, reformat, store and supply data to the advanced analytics models precisely according to need. This enabled the model development teams to focus all of their attention and energy on the models, supporting the best possible outcomes for the project.

Advanced analytics

Co-development with the end user is essential for the development of a trusted and fit for purpose solution

The SIMPaCT advanced analytics models, the irrigation adapter, and the overall design of the Senaps platform, were all developed through active collaboration with the irrigation manager (Centratech Systems). This ensured that the SIMPaCT digital twin was fit for purpose and able to integrate effectively with the Fieldmouse irrigation management platform. It also built end user trust in the product.

The iterative development of an advanced modelling approach developed innovative solutions for working with low-cost sensors that may have significant widespread value

Smart low-cost sensing devices have inherent data accuracy and reliability challenges that must be overcome to access the deeper value of these emerging technologies. The project's technical working group has noted how their understanding of data utilisation in a low-cost sensing context evolved over the course of the project. The team went through a process of iterative experimentation, culminating in innovative new approaches to data analytics with potentially significant widespread value.

An accommodation of using soil moisture data trends, as opposed to absolute values was necessary for the advanced analytics models. The design of the Biophysical model went through multiple iterations to reach a point where it accommodated the high uncertainty in absolute values and focused on the use of trends and the way that soil moisture responds to rainfall and irrigation events of known quantity and duration.

Reliability of sensor data refers to its availability for modelling. The original design of the project was based around the provision of soil moisture data for each operational station within the park's irrigation system. The idea was to model soil moisture independently for each station. However, this idea of a one-to-one relationship between stations and sensing devices was quickly called into question due to the challenges of obtaining reliable and verified data. A high failure rate and intermittency of soil moisture sensing devices created a situation where, for a significant period of the project, between 30% and 50% of stations had no useable soil moisture data or highly intermittent data records. While these figures were improved upon towards the end of the project, through an intensive troubleshooting process, the situation still demanded a rethink in the way that sensor data was used by the analytics models.

The combination of three parallel predictive models for soil moisture, with each model having a different level of reliance upon recent soil moisture data, allowed for a more flexible approach to data availability and ensured that some degree of optimised irrigation scheduling could be maintained for all park stations.

In the later phases of the project, the technical working group explored what the limits of minimum threshold of total data availability were, and thus how many sensing devices, operating on a continuous and reliable basis, are required to maintain digital twin functionality. The answer seems to be strongly tied to the variability of environments found across the park (slope, soil, vegetation, etc.). As the highly variable and challenging environmental context presented by Bicentennial Park can be understood as something of an extreme case, future less variable sites for SIMPaCT deployment are likely to require fewer soil moisture sensing devices to reliably run the SIMPaCT digital twin.

New ideas for sensor data analytics and modelling have been discussed by the technical working group as potential future strategies for dealing with intermittent data availability and fewer available sensing devices. Ideas include spatial interpolation of soil moisture data by comparing trends and metadata between multiple devices and stations to fill in gaps in the network; and automated cross-verification of data streams between multiple devices in the network to help improve trust in data, making it more useable. These types of new functionality may address data reliability issues and could also enable the establishment of new SIMPaCT deployments using far fewer total soil moisture sensing devices (reducing the cost of new project establishment as well as ongoing operational costs). As such, these additional advanced data analytics functionalities may be worth further focused investment in future SIMPaCT deployments, as part of an ongoing effort to develop and mature SIMPaCT as a scalable solution.

The technical working group successfully achieved demonstrable operational outcomes using low-cost sensor data with inherent accuracy and reliability challenges. These achievements may be understood as an important contribution to the theory and practice of smart low-cost sensing in the smart city context.

5 The future of SIMPaCT

Context

The SIMPaCT pilot project has successfully demonstrated the SIMPaCT digital twin as a proof of concept and a fully operationalised working solution for Sydney Olympic Park. Looking to the future, the vision is for the SIMPaCT solution to scale and mature, to deliver urban cooling, water efficiency, improved public amenity, and optimal green infrastructure management for places and communities across Sydney, NSW and beyond.

A key focus is to assist other government agencies and water utility providers in transitioning to smart irrigation management. To this end, the SIMPaCT pilot project developed an actionable *Roadmap,* for scaling the SIMPaCT solution to other locations and contexts.

The Roadmap was developed through a process of collaborative enquiry that included:

- Reviewing broader end-user irrigation requirements in locations and contexts beyond Sydney Olympic Park, through an extensive series of interviews
- Researching the commercial landscape smart irrigation
- Investigating and advising on the hardening and maturation of the SIMPaCT system as a scalable replicable solution.
- Introducing SIMPaCT to other NSW water utility providers with a view to expansion of SIMPaCT across other parkland assets and in other contexts.

The Roadmap defined five possible scenarios for the future of SIMPaCT:

1. Replicate the SIMPaCT solution as a commercial package for stand-alone place-based installations
2. Creative commons
3. Licensing
4. Subscription model
5. Public good big data

Scenarios

1. Replicate the SIMPaCT solution as a commercial package for stand-alone place-based installations.

Under this scenario, the focus would be on the commercial maturation of the SIMPaCT solution developed at Bicentennial Park, which would be replicated to deliver equivalent smart irrigation services to new customers in new locations.

Further testing would be required to understand the degree of customisation that may be required for each new location, proposed as ‘SIMPaCT 2.0’ implementations. This testing will determine the duration of future involvement of the SIMPaCT research team before SIMPaCT can be offered on a commercial basis. SIMPaCT 2.0 is also required to test the cost for a new instance of the SIMPaCT digital twin, given the potential complexities inherent in assessing a new location, designing the installation scope and details, as well as the hosting and staffing implications. These costs will be incurred even if there is little customisation required for the central platform.

As this Blueprint describes, SIMPaCT is retrofitted onto a third-party irrigation management system. Our market scan found that these commercial irrigation control products are becoming increasingly smart, using cloud-based data analytics and responding dynamically to changing environmental conditions, with the incorporation of soil moisture data and weather forecasts. The SIMPaCT digital twin, with its advanced analytics models and machine learning capability, is more sophisticated than these commercial products. SIMPaCT also balances a focus on plant health and water efficiency with optimised urban cooling; a capacity that is not present within any commercial solutions. These factors currently provide SIMPaCT with a point of difference advantage. However, this advantage is narrowing with the rapid development of commercial IoT, sensing and data analytics technologies. Against a backdrop of climate change, worsening urban heat and increasing water scarcity, there is likely to be growing demand for smart climate-responsive irrigation solutions, and the commercial ability to meet that demand is growing. In short, SIMPaCT may soon find itself facing competition from the very systems that it needs to integrate with in order to function.

The simplicity of a ‘cut and paste’ model means it has the potential for widespread uptake and therefore widespread urban cooling. Its opportunities are in locations such as development precincts; multiple park groupings; prestigious buildings, homes or sites; golf courses; large outdoor sports facilities; defence grounds; or locations with highly valuable plants. Some of these place owners will value the extra functionality of SIMPaCT no matter the extra cost. However, if the functional difference between SIMPaCT and the underlying irrigation management system becomes too narrow, the cost of adding SIMPaCT may be too high for many to consider it.

Many of the possible future opportunities for SIMPaCT are for local government parks, gardens and sporting facilities. Even when the local government authority is also the local water authority (such as in regional NSW), or has suffered the effects of droughts, and therefore has a heightened sensitivity to water management issues, the cost constraints inherent in local government may preclude consideration of buying a SIMPaCT solution. Indeed, these same cost constraints currently preclude investment in more basic commercial irrigation systems by many local authorities.

The risk for this scenario is that SIMPaCT's cost as a stand-alone product will be too high for most place owners, and that it will be competing with commercial systems that offer enough similar functions to outweigh any value. As such, it may only be viable for a few years until the market catches up and then only for a few less cost-sensitive user groups.

2. Creative commons

There is the potential to expand SIMPaCT's reach and scope by making the solution open source under a creative commons license, allowing others to implement or grow it themselves. Standalone or grouped place-based installations are possible; or (depending on the nature of the creative commons license) commercial irrigation system providers may use SIMPaCT to improve their own product offerings. Other research teams may wish to build on the SIMPaCT solution under this scenario, which suggests the possibility of new functionality and applications.

3. Licensing

Use of the SIMPaCT solution could be licensed to a commercial irrigation system provider. Care would be needed in developing the licence conditions to ensure that the purpose of SIMPaCT is clearly defined and understood, and that it is marketed, installed and maintained in a way that does not detract from SIMPaCT's reputation.

Licensing also provides a mechanism to broaden the geographic reach of SIMPaCT such as through working with universities or agencies interstate or internationally to implement it in their own region. In this case, implementation may take the approach of stand-alone or aggregated scenarios.

The main benefits of this approach are that it enables wider distribution without much direct involvement of the initial team, and that licencing fees may help to fund development work on SIMPaCT.

4. Subscription model

This scenario is for a district scale digital twin that offers SIMPaCT services on a subscription basis. The concept was devised in anticipation that the cost of a stand-alone SIMPaCT solution will be found to be too high for most place owners. The idea is to share the cost of buy-in to SIMPaCT by establishing a shared service that enables to access for smaller-scale landowners.

A technology provider would establish a single centralised digital twin, into which any standalone smart or semi-smart irrigation systems within the district may be integrated. This system would be developed to cater for scale, servicing multiple commercial systems, sites, and clients at once. The central SIMPaCT digital twin would perform modelling and forecasting and issue commands back to the multiple irrigation systems, optimising their operation.

Further work is required to determine the effort, time and cost that would be entailed in expanding the SIMPACT pilot platform for this application. Also relevant to its feasibility will be SIMPaCT 2.0 testing, on what inputs would be needed for each new location, and therefore the complexity of adding each new subscriber.

As well as facilitating a wider distribution and sharing of SIMPaCT's benefits, the data aggregation that this makes possible may allow coordinated management of water consumption across the district.

This scenario could be privately run on a commercial basis, possibly under a licencing arrangement, with similar risks to those from licencing to an irrigation system provider.

5. Public good big data

Taking scenario 4 further, an exciting possible future pathway for SIMPaCT is the establishment of a publicly owned and managed metropolitan-scale smart irrigation digital twin that delivers affordable and accessible services to place owners while also establishing powerful new water management capabilities for the water utility.

In the case of metropolitan Sydney, Sydney Water (or DPE Water) would establish a single central SIMPaCT digital twin. The benefit to irrigators is that a low-cost subscription model with an annual fee dramatically reduces the per-user cost. Connection could even be free, where the 'cost' to an irrigator is an agreement to hand a degree of autonomy over its irrigation systems to Sydney Water, in exchange for the benefits that SIMPaCT delivers.

In addition to the standard SIMPaCT functionality, two additional outcomes may be sought:

a. Catchment and regional-scale modelling that improves the optimisation of individual irrigation systems at the local scale

Largescale public data aggregation represents a new form of value creation that is not accessible to the commercial sector. Such big data has the potential to support catchment and regional-scale modelling of soil moisture relative to larger-scale weather and climate trends. If such modelling can be used to improve the performance of the SIMPaCT digital twin when operating at a catchment scale, it has the potential to improve the optimisation of individual irrigation systems at the local scale.

An additional benefit may be the ability to reduce the reliance upon on-the-ground IoT sensors. Where the SIMPaCT pilot project used 200 soil moisture devices, a future site of comparable size, connected to a metropolitan-scale model with big data modelling (and more advanced analytics capabilities), might operate effectively with many fewer sensors. Indeed, as such a system achieves scale it may be unnecessary for certain kinds of new site to have any sensors at all.

a. Utility-scale demand management for irrigation water

The primary benefit for Sydney Water of a metropolitan-scale SIMPaCT digital twin is the capacity for metropolitan-scale water management, and the management of peak water demand associated with irrigation. Potential cost savings could be enormous and, in theory, justify the significant initial investment required to develop and operate such a system.

A precedent for utility-scale peak demand management has already been set by energy utilities. Water peak demand management can be achieved because:

- Irrigation can be staggered across multiple sites prior to a heat event.

- Pre-watering of soil aids in the future infiltration of water and slow irrigation over a longer period may be more effective at maintaining optimal soil moisture than short-period deluge, so water demand can be spread over longer periods.
- Optimising water delivery across multiple sites avoids over-watering around peak irrigation events.

Management of peak demand helps in the following ways:

- Avoids expensive water supply that is used to service peak demand (e.g. desalination water, recycled water)
- The need for pre-pumping of water in reservoirs, to meet demand, can be more effectively managed, and potentially reduced. Together with not having to treat as much water during heat waves when energy costs are high, this may have enormous energy cost savings, as well as carbon emission savings.
- Given that pumping of water for irrigation contributes to peak energy demand on hot days (when air conditioning use is also high), there are potential outcomes for reducing energy peaks that benefit electricity utilities.

While the focus above is on Sydney Metro, the scenario could easily be applied to other locations and water utilities, tying in to state and federal government water management policies. SIMPaCT could be owned and managed by DPE Water, with coalitions of smaller local water authorities coordinating water management in their own regions.

Scenario 5 is based around a core concept of big data aggregation, and the value that this can unlock. This is an emerging trend in IoT and smart cities that can be expected across multiple sectors in the coming years.

The pathway

The SIMPaCT Roadmap has defined six phases for scaling SIMPaCT. The implementation pathway accommodates making a start on all scenarios in the first three phases, deferring determination of one favoured scenario until further insights emerge from SIMPaCT 2.0 place-based project (Phase 3). These insights should relate to:

- The ease or difficulty of maturing the SIMPaCT solution in its current form
- The degree of additional development and customisation required to adapt the solution to new contexts
- The cost of delivery relative to various new contexts and key factors
- The business case for establishing and maintaining the solution in new contexts

Following phase 3, divergence may occur based upon insights and market conditions. It is possible that all scenarios continue to develop in parallel, or that certain ones emerge as more promising.

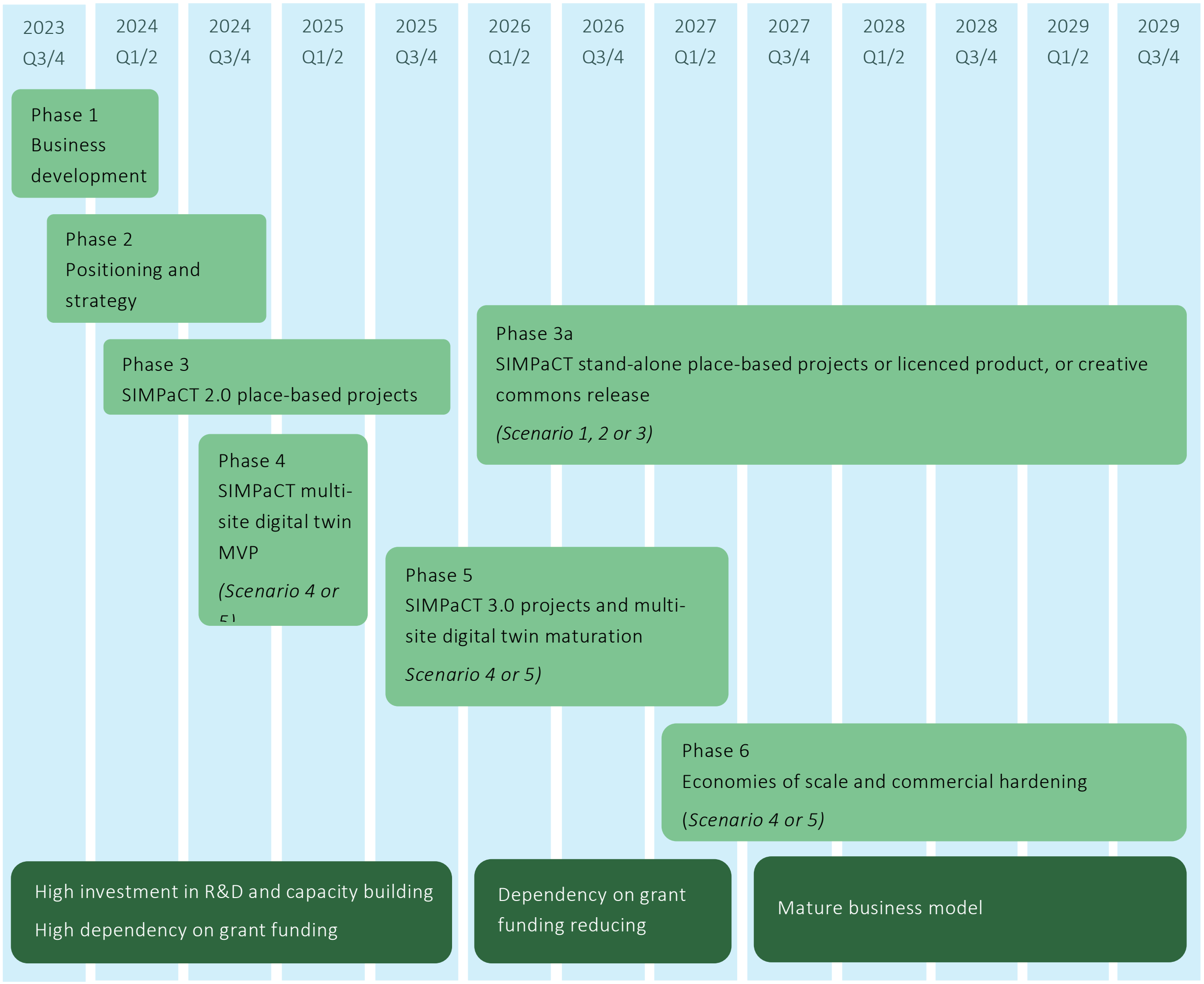


Figure 42. An overview of the six phases of the SIMPaCT scalability pathway

Phase 1 Business development

Leverage the initial success of the SIMPaCT pilot to flesh out new proposals and secure new support and funding.

Phase 2 Positioning and strategy development

Gather evidence, position key partners, confirm value propositions and further develop a longer-term strategy.

Phase 3 SIMPaCT 2.0 place-based projects

Secure new stand-alone place-based projects to test replication requirements with new place owners, new irrigation systems, and new contexts and challenges. These new projects will seek efficiencies in approach, design, methodology and costs.

Phase 3a SIMPaCT stand-alone place-based projects or licenced product, or creative commons release

Subject to the results of SIMPaCT 2.0 projects in Phase 3, SIMPaCT may be ready for a roll-out under one or any of Scenarios 1, 2 or 3. Phase 2 will inform which of these scenarios should proceed, and whether this would be the only future for SIMPaCT or if development towards scenarios 4 and 5 should occur in parallel.

Phase 4 SIMPaCT multi-site digital twin Minimum Viable Product

This progresses the metropolitan-scale data aggregation platform of scenarios 4 and 5. The Minimum Viable Product (MVP) is a proof of concept that will demonstrate SIMPaCT working as a single digital twin across multiple sites.

The MVP would initially be created as a standalone instantiation of the existing SIMPaCT digital twin that will operate in parallel with individual site instantiations of SIMPaCT to test and compare the system to address challenges of interoperability, data harmonisation and heterogenous data synthesis. This phase will also inform the viability and appropriateness of continuing with scenario 4.

Phase 5 SIMPaCT 3.0 projects and multi-site digital twin maturation

Secure new place-based projects that use only the Smart Irrigation Digital Twin from day one. Further testing of the model is required where site establishment is outsourced to the irrigator, to establish interoperability with diverse commercial providers, to develop advanced data analytics and demand management capabilities, and to harden the commercial model.

Phase 6 Economies of scale and commercial hardening

With the data from many sites connected across Sydney the optimisation benefits can be shown, measurable demand management benefits become apparent for Sydney Water, and an affordable subscription rate for SIMPaCT customers can be supported by economies of scale.

By Phase 6, SIMPaCT should be rapidly emerging as a ubiquitous central element in Sydney’s irrigation landscape. It should also be garnering significant international attention and acclaim.

6 APPENDICES

APPENDIX 1: Glossary

Irrigation	The provision of water to plants in managed landscapes. *Active* irrigation involves the provision of water using physical infrastructure (e.g. pumps, pipes, valves and sprinklers).
Application Programming Interface (API)	An Application Programming Interface (API) is a way for two or more computer programs to communicate with each other. It is a type of software interface, offering a service to other pieces of software. In the SIMPaCT context, an API is used for the transfer of data between any two components of the data architecture, above the level of the communications networks.
Console	The irrigation system at Bicentennial Park is divided into five operational areas, each of which is connected to a console (numbered 81-85). Each console has a number of stations associated with it.
Data architecture	Data architecture describes an integrated system of platforms, services, databases, dashboards, communications technologies and physical hardware that comprise a complete end-to-end digital solution.
Data schema	Metadata and telemetry fields are generally characterised in a data schema that defines their intended applications, validated field entries, and data formats. Any smart sensing project like SIMPaCT should develop its own data schema.
Evapotranspiration (ET)	Evapotranspiration is the biophysical process where water is lost through the leaves of plants, cooling the air.
Location	A 2D geospatial point defined by a latitude and longitude, associated with the deployment of a specific sensing device. There may be one or more locations within a station and each location should be associated with a station number.
LoRaWAN	Long Range Wide Area Network (LoRaWAN) technology is a bi-directional radio communications technology that has been developed for connecting distributed Internet of Things devices within a local area. LoRaWAN is widely used for supporting smart low-cost sensing device networks of the kind used for SIMPaCT.

Metadata	Metadata is ‘data about data’, and is defined by ‘fields’, each of which describes a specific attribute of project data (or other aspects of a project). Each metadata field needs to serve a clear purpose that is tied to a data use case and the operation of a sensing device network. In the SIMPaCT context, metadata is critical for: installing, administering and operating a sensing device network; managing and formatting data; interpreting data; and sharing data. Metadata can be updated over time but tends to remain relatively fixed compared to telemetry.
Park Cool Island effect	The Park Cool Island effect describes how the evapotranspirative cooling effect of plants in a park can lower the air temperature in and around the park. See Appendix 3 for a more complete explanation.
Sensing Device	A complete device, sold as a commercial product to end users. A sensing device will typically consist of: a housing; a microprocessor; a sensor board; one or more sensors; a power supply; a communications module; data storage. A sensing device such as a weather station includes multiple sensors and multiple component parts that are mounted alongside each other.
Sensor	A specialist component designed to capture empirical data about a directly observed phenomenon. A sensor is a *component* within a device that is generally sold to device manufacturers. A sensor cannot function separately to a supporting device.
SIMPaCT digital twin	The SIMPaCT digital twin is an integrated package of hardware and software components, for data collection, data management, advanced analytics, dynamic feedback and smart irrigation control.
SIMPaCT solution	The SIMPaCT Solution is defined as a combination of: an existing irrigation system; the SIMPaCT digital twin; SIMPaCT dashboards; and a SIMPaCT methodology.
Solenoid	A piece of physical hardware consisting of an automated irrigation valve. One solenoid services one station, which is an operational area watered by one or more sprinklers.
Sprinkler	An end point in the irrigation system that distributes water to an area of ground surrounding it.
Station	A geospatial polygon that defines an area of ground as a distinct operational domain of the irrigation system. Each station is serviced by one solenoid, which controls the release of water through one or more sprinklers within the station. Station boundaries are defined by the reach of water spray from sprinklers within that station. Stations are an existing operational category used by Total Water and are tied to the fixed irrigation infrastructure.

Telemetry	Telemetry describes a measurable phenomenon that changes over time, expressed in a time series. It refers to all dynamic information reported by a sensing device, and includes sensor data (e.g. soil moisture or temperature) as well as device functionality variables (such as battery voltage and communications signal strength). Telemetry can also include data from third-party sources, such as meteorological data received from the Bureau of Meteorology. Telemetry values are dynamic and can change every time a device reports. They can be viewed as an archival data set, or as a near-real-time data stream.
Urban Heat Island effect	The Urban Heat Island Effect (UHI) is an effect found in urban centres, where the ambient air temperature is slightly higher than the surrounding area. The effect is caused by the thermal mass of the built environment radiating retained heat back into the air. UHI is often most pronounced late in the day, when retained heat from afternoon sun keeps urban temperatures elevated into the evening.

APPENDIX 2: Associated SIMPaCT pilot project documents and resources

Document name	Description
SIMPaCT website	Access information about the SIMPaCT pilot project, including partners, explanations of the science and technology, links to news and media articles, a blog, and the Park Now live data dashboard.
SIMPaCT Roadmap to scalability	An extensive document that describes how to scale SIMPaCT for wider application.
Solution design document	A complete record of all aspects of the SIMPaCT solution, reasons for decisions, and compliance information. Primarily created for future reference by SIMPaCT team members.
Operations Manual	An easy-to-read and navigate guide for ongoing operations, maintenance and troubleshooting of the SIMPaCT solution in Bicentennial Park.
Sensing device installation guide	A guide to the installation of temperature and humidity sensing devices, soil moisture sensing devices, and weather stations at Bicentennial Park.
As-installed sensing device deployment: all soil moisture devices	A record of installation locations, deployment photos and deployment metadata for all soil moisture sensing devices.
As-installed sensing device deployment: all temperature and humidity devices	A record of installation locations, deployment photos and deployment metadata for all temperature and humidity sensing devices.
As-installed sensing device deployment: all weather stations	A record of installation locations, deployment photos and deployment metadata for all weather stations
Environmental Data Schema and Ontology	A complete record off the SIMPaCT Data Schema relating to the provision of environmental data from Bicentennial Park.
Presentation pack	A slide deck about SIMPaCT
SIMPaCT Smart Irrigation Management for Parks and Cool Towns	A shortform graphically formatted overview of SIMPaCT for general promotion and outreach.
SIMPaCT An assessment of soil moisture readings from Senstick and Acclima	A report on WSU investigations comparing the soil moisture content readings of a low-cost sensor with a high accuracy device to determine whether the data from installed sensors must be calibrated.

APPENDIX 3: The science of the 'Cool Park Island Effect'

Large bodies of water and plentiful vegetation in the form of parks, forests and gardens are considered the most effective way to tackle the Urban Heat Island [UHI] effect, where heat that is radiated from roads, carparks, buildings and other hard infrastructure contributes to rising temperatures, unhealthy living conditions and global warming. Trees are a particularly effective tool in urban cooling – by shading buildings and paving, and by transpiring water from their leaves, their effect is twofold. The best shade is provided by densely foliated, wide tree crowns that are low to the ground. These crowns belong to older trees that have had time, water, nutrients, and space to grow tall and expand their branches freely. On a hot summer day, dense tree shade can reduce the surface temperature of a road or walkway by more than 40°C. By blocking direct solar radiation, shade from a tree brings the temperature of any surface down closer to ambient air temperature. More tree shade in cities will lower surface temperatures, and cities with more trees are consequently cooler.

While shade-cooling is an easy concept to understand, transpiration cooling is a little more complicated. Trees suck moisture from the soil which evaporates through their leaves. This transpiration cools the leaves and their immediate surroundings. Wind mixes the cool air from inside and around the tree crown with the warmer air from the city. In this way, the millions of leaves from many trees provide enough cooling to reduce the air temperature of the surrounding area.

The Park Cool Island effect describes how the combination of all sources of cooling in a park lower the air temperature around the park. Not only trees, but also grass, shrubs, and any other vegetation usually transpire water. Some plant types in parks are more effective in cooling surfaces, while others cool the air, or both. Take lawn: it is effective in cooling the surface temperature, but not very effective in cooling the air as it is not tall enough to be much affected by wind. Take a tall tree with a large crown: it can transpire 300-600 litres of water in a single summer day, providing ample air cooling and surface cooling through its shade.

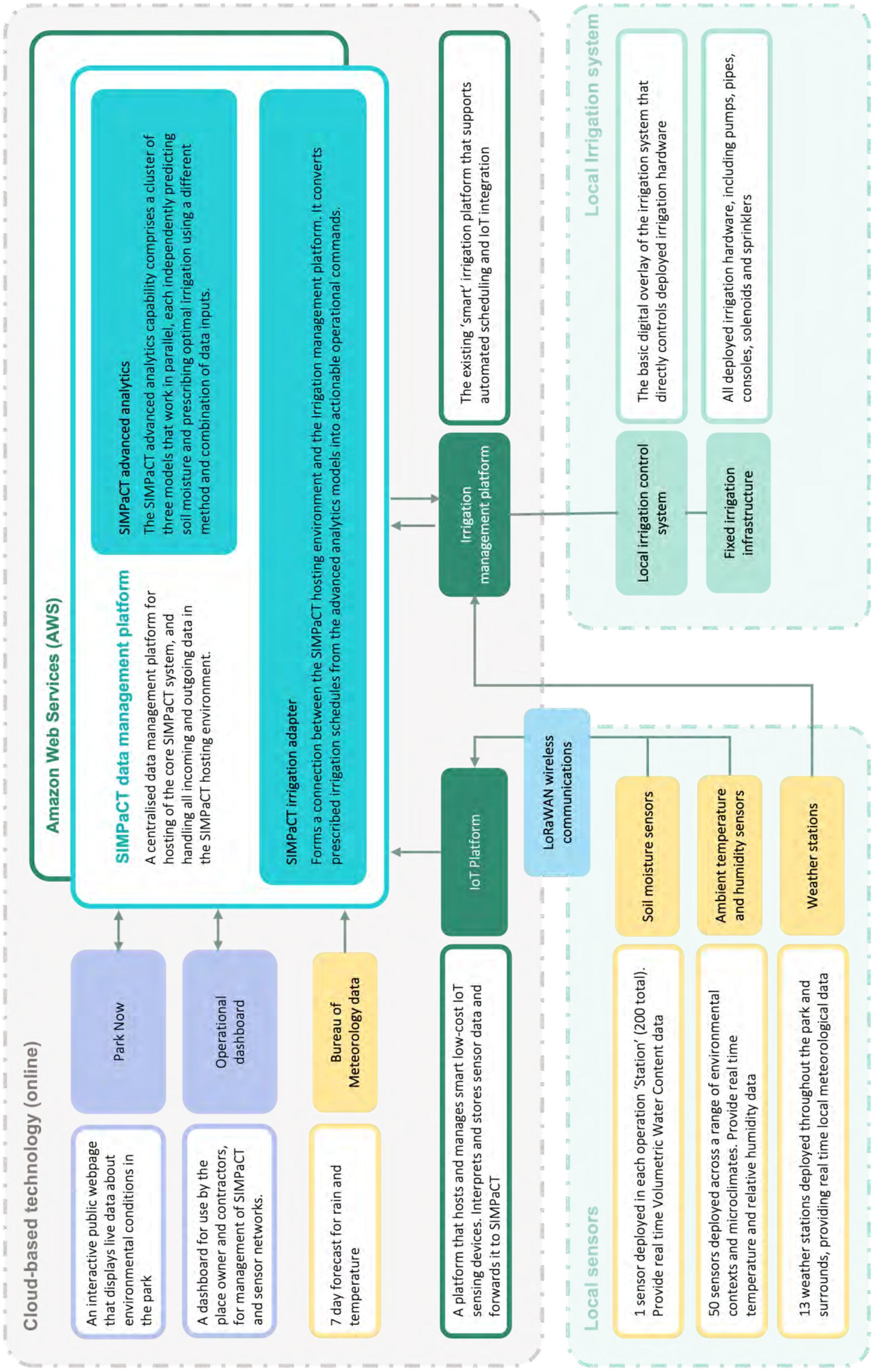
Studies have found that the type, age and density of vegetation, the way the vegetation is arranged, and the overall size of a park influences the PCI effect. In addition, the time of day, season, park geometry and morphology, as well as wind channels can have an effect.

Two parameters are usually used to describe the PCI effect: the *Cooling Effect Intensity* and the *Cooling Effect Distance*.

The *Cooling Effect Intensity* describes the amount of cooling that can be created by a given area. It varies according to vegetation, park size and land management. Irrigated parks are usually cooler than those that are not irrigated. The relationship with size was found to be curvilinear, whereby the Cooling Effect Intensity increased rapidly from a pocket park to about 10-15 hectares by up to 3°C, after which the park size had only a very small effect. Increasing the Cooling Effect Intensity to 4°C would require an irrigated park of at least 100 hectares in size.

Cooling Effect Distance describes the impact that the Park Cool Island effect can exert on downwind locations. Although not measured empirically yet, for a park the size of Bicentennial Park, this distance can be expected to be around 250 to 500 metres in summer. This will lower ambient air temperatures in adjacent residential and office precincts, which in turn lowers energy requirements for indoor cooling.

APPENDIX 4: Expanded SIMPaCT data architecture



An interactive public webpage that displays live data about environmental conditions in the park

A dashboard for use by the place owner and contractors, for management of SIMPaCT and sensor networks.

7 day forecast for rain and temperature

A centralised data management platform for hosting of the core SIMPaCT system, and handling all incoming and outgoing data in the SIMPaCT hosting environment.

The SIMPaCT advanced analytics capability comprises a cluster of three models that work in parallel, each independently predicting soil moisture and prescribing optimal irrigation using a different method and combination of data inputs.

Forms a connection between the SIMPaCT hosting environment and the Irrigation management platform. It converts prescribed irrigation schedules from the advanced analytics models into actionable operational commands.

A platform that hosts and manages smart low-cost IoT sensing devices. Interprets and stores sensor data and forwards it to SIMPaCT

The existing 'smart' irrigation platform that supports automated scheduling and IoT integration

1 sensor deployed in each operation 'Station' (200 total). Provide real time Volumetric Water Content data

50 sensors deployed across a range of environmental contexts and microclimates. Provide real time temperature and relative humidity data

13 weather stations deployed throughout the park and surrounds, providing real time local meteorological data

The basic digital overlay of the irrigation system that directly controls deployed irrigation hardware

All deployed irrigation hardware, including pumps, pipes, consoles, solenoids and sprinklers

Figure 43 An expanded version of Figure 13, including a short explanation of each component

Visit our website for
more about SIMPaCT

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Smart Irrigation for Parks and Cool Towns