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Community-based water demand management: socio-technical strategies for improving water security in Australian Indigenous communities

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Abstract

Sustainable water management in remote Australian communities is a delicate balance between sufficient and acceptable supply options and appropriate and effective demand approaches. This paper focus on the evaluation of community-based water demand management strategies piloted in four remote Aboriginal and Torres Strait Island communities in Australia. Findings of the pilot demonstrate that from a systems perspective, community-based demand management centred around education and encouragement of residents to conserve and use water efficiently, provide greater opportunities for long-term sustainable water management outcomes that support building of social capital. To ensure truly transformative management outcomes, a toolbox of socio-technological strategies should be used including, where possible, smart metering of water consumption and use of water-efficient devices. A key element of this approach to demand management calls for a shift away from business-as-usual policy towards a flexible learning approach that involves genuine collaboration between water managers and Indigenous communities.

1. Introduction

1.1. Remote water management challenges

Equitable access to acceptably treated drinking water is a fundamental human right embedded in the United Nations Declaration of the Rights of Indigenous Peoples (United Nations 2015) and one of the seventeen 2030 Sustainable Development Goals (e.g. SDG 6), (United Nations 2015). While generally, there is an association between poor and inadequate supplies of drinking water with developing countries elsewhere in the world, there exist many remote communities in Australia that struggle to access clean (suitably treated) and reliable drinking water (SCRGSP 2016, Beal *et al* 2018, Hall 2019, Hall *et al* 2022, Wyrwoll *et al* 2022). The complex reasons behind this inequality reflect the broader ongoing struggles to *close the gap* between Aboriginal and Torres Strait Islander people, and non-Indigenous Australians.

Community water management, whether in urban, regional, remote, or isolated areas needs to be resilient and meet triple bottom line benchmarks of being environmentally, socially, and economically sustainable. A two-pronged, supply and demand approach of water supply solutions are, therefore, relied on to achieve these water supply aims (Beal *et al* 2019). In the case of remote Australian communities, both supply management and demand management approaches need to be tailored to the unique cultural, environmental, geographical, economic, and political contexts of these communities, which are typically quite different to urban Australian settings in which much demand management is developed and tested. The SDG's call for inclusivity, participatory, and representative decision making towards partnerships between various stakeholders to achieve the sustainable development goals (Target 16.7) (United Nations

2015). Partnership and collaboration are critical to enable and overcome marginalisation of Indigenous people in resource governance (Jackson *et al* 2019a).

A reliable energy supply is of paramount importance to the continuous supply of treated drinking water in off-grid communities. Supplying energy to remote and isolated communities is costly and to ensure costs are not passed on to consumers in remote areas, energy is subsidised by state government through the Community Service Obligation which covers the shortfall between the cost and revenue for providing these services. Given that there are hundreds of off-grid communities relying on diesel powered water supply in Australia, community water demand management (CWDM) is a tool to improve both water and energy use efficiency in Indigenous communities. Further, it has the potential to engage communities in learning about critical essential services and resources, facilitate a reduction in demand and greenhouse gas emissions from diesel gas generators, as well as associated costs of supply that are currently footed through public monies. There is potential for these financial savings arising from successful CWDM to be reinvested back into communities through community building activities such as improvements in infrastructure, education and health.

In this paper, we present findings from a project that collaboratively identified and implemented CWDM strategies, tailored for the local context, to secure the long-term, reliable water and energy supplies that are critical to generational health and wellbeing of people in remote communities.

1.2. Research aim and scope

The Remote and Isolated Communities Essential Services (RICES) project was a response to the need to address water security in remote Australian Aboriginal and Torres Strait Island communities through locally and culturally appropriate CWDM strategies.

The overall aim of the project was to develop an empirically-based and community-driven management approach to facilitate the efficient use, and secure long-term supply, of water and water-related energy in remote and isolated Aboriginal and/or Torres Strait Islander communities. The objectives were (i) to gather baseline data to characterise water consumption and water-related energy use, (ii) to trial and evaluate co-developed CWDM strategies, and (iii) to identify CWDM strategies suitable in remote communities.

When referring to 'remote' in this paper, we use the definition to the distance from the nearest urban centre and include both 'remote' and 'very remote' categories as classified by the Australian Bureau of Statistics (see ABS 2016b). The term 'isolated' refers to the potential for minimal or no access into or out of the community during certain times (e.g. flooding during the wet season).

2. Background

2.1. Australian remote communities and water management

There are approximately 1187 remote communities in Australia, with the majority in Queensland, Western Australia and the Northern Territory (ABS 2006). More than one fifth of Indigenous peoples of Australia live in remote, isolated, and regional communities and make up over half the population in those areas; this includes mainland Aboriginal communities and those island communities of the Torres Strait Island peoples (ABS 2016a). Indigenous communities are usually not well provided for, and suffer from negative impacts of health, disunity, and gaps in education and health services (Moran and Corpus 2014). This has led to a significant gap between Indigenous and non-Indigenous health and wellbeing that, despite significant government investment, remains far from being closed (Altman 2006, Hunt and Smith 2006, Grey-Gardiner 2008, Hunt 2013a, 2013b, Australian Government Department of Prime Minister and Cabinet 2020).

Water management has been largely left out of the Closing the Gap framework (Vanweydeveld 2022), with a preliminary report by the Water Services Association of Australia confirming earlier empirical research (Bailie and Wayte 2006, Beal *et al* 2019, Jackson *et al* 2019a, 2019b, Lansbury and Crosby 2022) that people living in remote communities have issues with water supply delays and quality maintenance of drinkable water, and concerns about the health of their communities.

These structural vulnerabilities are exacerbated by climate change for those living in isolated and remote communities in Australia and the Torres Strait, particularly in relation to water security (Hoverman and Ayre 2012, Lansbury Hall and Crosby 2022). Sources of drinking water for remote Australian communities is largely surface (dams) or groundwater (bores), depending on location. Remote and isolated community access to drinking water is impacted by the complexities of increasingly unreliable rainfall, and variable groundwater recharge, more extreme weather events such as cyclones and floods which all affect supply and quality of water to communities. Indigenous social and emotional wellbeing are also linked to the access of safe, reliable, clean water supply as it impacts Indigenous peoples ability to practice cultural ceremonies and maintain responsibilities in Caring for Country (Brugess *et al* 2005, Hunter 2007, Hoverman and Ayre 2012, Hall 2019, Lansbury Hall and Crosby 2022). The inequities on exposure, sensitivity and adaptive capacity towards climate change impacts on Aboriginal communities (Standen *et al* 2022) reinforces the need to address water security issues.

To bridge the divide between health and wellbeing in Indigenous and Non-Indigenous Australian communities, addressing the issues of water security in a sustainable, systemic way that considers all aspects and actors within the system is necessary (Jackson *et al* 2019b). Significant challenges exist such as: balancing a sustainable water supply with increasing demand; meeting the costs of delivery and maintenance; managing uncertainty due to lacking baseline consumption data; meeting energy demand; managing reliability of local services; and variable skills for repairs and maintenance (Jackson *et al* 2019b).

Despite the constraints to water availability and access outlined above, many Australian Indigenous communities have a high per capita water consumption e.g. >700l per person, per day (Yuen 2005, Beard *et al* 2013, Beal *et al* 2018). Under current trends of increasing population growth in remote Indigenous communities (Taylor *et al* 2021) this high water demand is expected to continue to rise. As a result, the economic and environmental consequences are becomingly increasingly unsustainable, with impacts already being experienced at the community (severe water restrictions), local government (poor supply resilience) and state and national government levels (massive subsidy costs). Implementing effective CWDM strategies and improving water use efficiency is therefore critical to addressing the long-term cost-effective and ensuring a sustainable, secure and resilient water and energy future for remote Indigenous communities.

Several prior studies have highlighted water supply and demand issues in remote Aboriginal and Torres Strait Island community contexts (Grey-Gardiner 2008, Grey-Gardner and Taylor 2009, Centre for Appropriate Technology Limited 2010, National Health and Medical Research Council [NHRMC]; National Resource Management Ministerial Council [NRMCC] 2018). Willis *et al* (2006), Ross *et al* (2014) and Jackson (2021) observed leaking pipes and poorly functioning system parts; often identified as symptoms of ageing infrastructure and poor maintenance. Further, (Pearce *et al* 2007) found that children playing with water in hot weather to cool down was a main contributor to high water use; flagging cultural usage and water habits as contributing factors (see also Yuen 2005).

In relation to high water Beal *et al* (2014, 2018) highlighted that outdoor use of water was disproportionately large compared to household use in a remote Aboriginal community in far north Queensland. Many of these outdoor water use drivers related to health and well-being such as dust suppression and cleaning, cooling surfaces in the absence of air conditioning and cultural activities (hunting, fishing, ceremonies) (Beal *et al* 2018). Beal *et al* (2016a), demonstrated though high-resolution smart metering data empirically-based modelling that a 35% reduction in water demand is achievable by applying targeted demand management strategies. These shifts in demand have the potential to save up to AUD$100 000 per annum for diesel- reliant island communities alone (Beal *et al* 2016a).

Despite a growing body of literature on Australian Indigenous water rights (Toussaint *et al* 2005, Jackson and Altman 2009, Tan and Jackson 2013, Jackson 2019), more is needed to understand remote and isolated community residential water use and drivers of consumption (Beal *et al* 2016a, Jackson 2019). Accompanying this water demand research, is a greater need to focus on attitude and behaviours of citizens on water use; particularly how community participation and ownership can be enabled alongside education on water issues—which we discuss later in this paper.

2.2. Improving water security through demand management

Water demand management broadly defines any actions or strategies that aim to promote and improve water conservation or efficiency (Brooks 2006). Several studies across the globe have compellingly demonstrated the effectiveness of demand management strategies in reducing potable water consumption through: technical approaches such as installation of water-efficient devices (e.g. Liu *et al* 2017, Stewart *et al* 2018, Hutton *et al* 2020), voluntary and behavioural approaches such as tariff structures (e.g. Sahin *et al* 2018, Rahim *et al* 2021), social-based marketing (e.g. Walton and Hume 2011, Tourigny and Filion 2020), and mandatory behavioural approaches such as water restrictions (e.g. Grafton and Ward 2008, Browne *et al* 2021).

There are multiple benefits to CWDM other than conservation of local water sources. A major benefit is reducing the energy use associated with providing water to communities, which in turn has multiple benefits including reducing diesel use many remote communities are reliant on high cost, greenhouse gas emitting diesel powered electricity generation (Beal *et al* 2016b, Hall *et al* 2022). In the Torres Strait Islands, for example, energy-intensive desalination plants are operated continually through dry season and much of the wet seasons to supplement supply. An estimate of costs to supply water in these regions are as much as up to seven times that of urban supply costs (Beal *et al* 2016a). As rainfall patterns become less predictable, desalination has shifted from being a supplementary supply to a critical supply source in these island communities (Richards and Schäfer 2003, Werner and Schäfer 2007). In addition to high costs, there are reliability issues, and communities relying on diesel generation may regularly experience power interruptions for more than 24 h (Longden *et al* 2022). This has flow on effects to the water supply and health and safety implications for communities.

There is increasing focus on community participation in water governance and decision-making processes however, service providers are proceeding at varied rates and in different ways as they navigate delivery programs and goals (Jackson *et al* 2019b). Top-down, hierarchical, and technocratic frameworks of decision making often clash with meaningful community engagement and deadlines (Commonwealth of Australia 2014, Queensland Productivity Commission 2017). Water management still preferences a technical, engineering approach, often at the expense of understanding the complex social nuances of water systems, including diverse cultural understandings and meanings people attribute to water, (Checkland 1993, Jiménez *et al* 2014, Howarth and Monasterolo 2017).

In recognising the need to move towards systemic and community-based collaborative management of water and energy in remote Indigenous communities, research conducted by Jackson *et al* (2019b) identified a range of challenges; including constraints from within governance arrangements and processes that perpetuate or arise from narrow thinking and short-term solutions and poor coordination across agencies; Economic and financial barriers included the power imbalances between community members and government employees, ultimately limiting their agency to effectively engage in water management processes. Issues related to poor data and information management and limited skills and capacity were identified as barriers within communities, as well as cross-cultural and community engagement skills within agencies. Limited connection into employment pathways and training, was also identified as being important for long-term sustainability and motivation for communities. The final category of cultural values and norms highlighted that at the core the differing worldviews and relationships with water between Western and Indigenous management as well as the sheer diversity of languages and cultural differences across Indigenous Australia were all challenging.

With this paper, we share findings from the RICES research project that sought to address some of the complexities and challenges ensuring year-round water security while balancing the water needs of the community. In the next sections, we will outline the methods and key findings of the three stages of the RICES project, before explaining in more detail, the management strategies and general approach to CWDM that have emerged from Stage three.

3. Methods

3.1. Research approach

To achieve the aim, the project was designed in three stages with each stage aligning to the research objectives. A participatory action research approach included community and stakeholder involvement across the research stages and activities. Stage one gathered baseline qualitative and quantitative data to characterise water consumption activities, attitudes, and challenges as well as water-related energy use in remote and isolated Aboriginal and Torres Strait Islander communities. Stage two trialled co-developed CWDM strategies in four remote Aboriginal and Torres Strait Islander communities (two mainland and two island communities). Stage three evaluated the CWDM strategies and identified which CWDM strategies were suitable and pragmatic for the context and suggested a pathway to promote long-term, efficient use of water in remote communities. Community engagement was a major component across all stages of the CWDM trial and included individual and group activities, combined and separate community and stakeholder events and the use of a range of social media and face-to-face communications.

The project methods, including participant recruitment, survey methodology and implementation, data generation, storage, and management, was reviewed by the Griffith University Indigenous Research Unit and cleared by the Human Ethics office (GU Ref No: ENG/15/14/HREC). As part of this ethics approval, individual participants are not identified.

3.2. Overview of communities

The key characteristics for each of the communities are provided in table 1. Community 1 (C1) is situated in the Central Australian arid (desert) zone in the Northern Territory. Community 2 (C2) is a mainland tropical coastal town in Cape York, Queensland (Qld). Community 3 (C3) and Community 4 (C4) are a tropical island communities located in the outer (C3) and inner (C4) Torres Strait Island group in the Coral Sea, Far North Qld. Data on the number of participating households for each community are also presented in table 1. Overall, given the acknowledged challenges inherent in recruiting remote and isolated Aboriginal and Torres Strait Island households (Jamieson *et al* 2012), and due to the small populations, the participating household sample size was statistically solid, representing between 17% and 40% of total Aboriginal and/or Torres Strait Island households in each community (table 1). In terms of family composition, age, gender balance, and household stock, the participating households were generally representative of each community

Table 1. Summary information for participating RICES communities.

	Population[a]	Household No.[a]	Governance arrangements[b]	Main water supply & treatment	Approx. distance from: small town[c] Major city[c]	Access
C1	444 ($n = 59$)	70 ($n = 12$) (17%)	Non-Indigenous regional council	Groundwater—advanced filtration & chlorination	180 k kms (road) 1160 kms (road)	Road/air
C2	269 ($n = 58$)	71 ($n = 17$) (24%)	Indigenous shire council	Groundwater—sand filters and chlorination	67 kms (road) 630 kms (air)	Road/air (only in wet season)
C3	254 ($n = 121$)	58 ($n = 23$) (40%)	Indigenous regional council	Surface/sea/rain—desalination and chlorination	165 kms (boat/air) 965 kms (air)	Air/boat
C4	268 ($n = 92$)	78 ($n = 25$) (32%)	Indigenous regional council	Surface water—sand filters and chlorination	2 kms (boat) 800 kms (air)	Boat

Notes: [a] Approximate from 2016 ABS Census. Numbers in parenthesis indicate RICES project participant numbers and % indicates percentage of total community households that were part of the project.
[b] Indigenous refers to Aboriginal or Torres Strait Island Councils within Queensland.
[c] Refers to towns with urban features and populations >2000 people (small) and >100 000 people (major) (ABS 2016b).

when comparing numbers from previous studies of Aboriginal and Torres Strait Island households (Yuen 2005, Beal *et al* 2014, Ross *et al* 2014).

3.3. Household recruitment process

Based on discussions with local project industry partners (Indigenous and non-Indigenous) a number of local council members and community representatives from several Aboriginal and Torres Strait Islander communities, were approached about their willingness to be involved in the project. Four communities across the Northern Territory and Queensland agreed to participate in the project which represented a total of 330 people from 77 households across the four remote communities (table 1).

Household participants were recruited through door knocking, public workshops and/or were approached by council and/or the RICES team and invited to participate. All recruitment was conducted through a process of free, prior, and informed consent according to the Griffith University research ethics approval. In some communities where required, an interpreter (e.g. community-based Indigenous Engagement Officer or Environmental Health Officer) was present for the recruitment and the participant interviews process.

3.4. Stage one: baseline data gathering and analysis

Residential-scale water consumption was monitored using state-of-the-art, high-resolution, digital water meters and logging equipment installed at all the participating households. Smart energy meters were also installed to measure total household energy and hot water-related energy for a sub-sample of houses in each community. Using the high-resolution datasets from the participating households, a sample of received data was extracted from the database for two, two-week periods selected to represent the wet and dry seasons, and disaggregated into all end-use events (e.g. shower, clothes washer, tap, leaks, outdoor, bath, toilet) using the flow trace software Autoflow (Nguyen *et al* 2015). Concomitantly with meter and logger installation, a water fixture/appliance stock (e.g. clothes washer, toilet, shower) survey was conducted at each participating home which facilitated the disaggregation of trace flows from each home and provided a valuable snapshot of water consumption behaviours within each home.

Semi-structured interviews were administered face-to-face and standard demographic information and water use-related questions were designed to evaluate the existing uses of water by each household, as well as the knowledge and attitudes of different water users, and the capacity they had to conserve water. Questions were designed for the following categories of information relating to water demand management: water consumption; water values and behaviours; and attitudes toward community water security. Further details of this can be found in supplementary file A and Aldirawi *et al* (2019).

3.5. Stage two: trialling community-based water demand management strategies

Informed by a discussion of individual household water use patterns generated from smart meters (see figure 1 as an example) participants identified a range of potential water demand management activities (both technical and behavioural). The technical strategies were deliberately limited to devices that could be

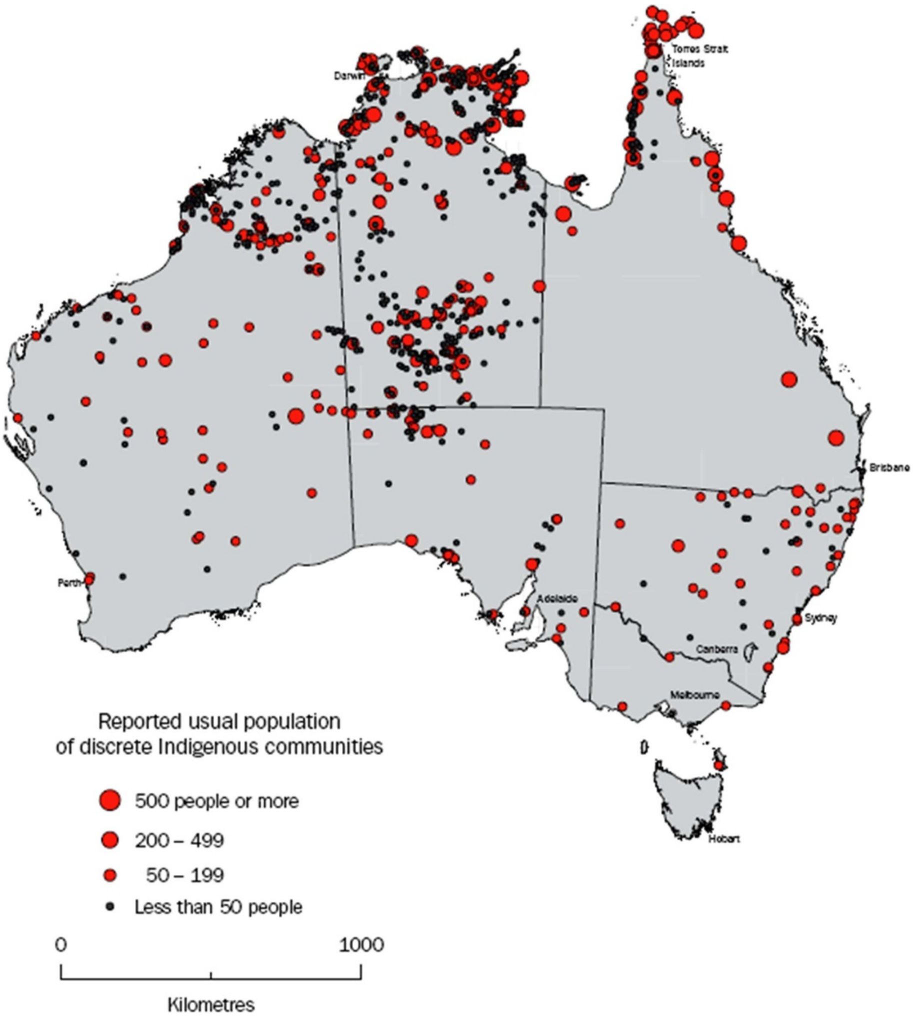


Figure 1. Discrete Indigenous communities in remote Australia (ABS 2006). This Map from the Australian Bureau of Statistics of discrete indigenous communities by remoteness areas in Australia for 2006 image has been obtained by the author(s) from the Wikimedia website where it was made available by Australian Bureau of Statistics under a CC BY-SA 2.5 AU licence. It is included within this article on that basis. It is attributed to Australian Bureau of Statistics.

accessed by the community from their local shop or closest town: a tap timer, a soaker hose and a 'trigger-gun' hose nozzle. (Note, all these were provided free of charge to the participants during the trials). The behavioural WDM actions were s were co-developed with project participants with input from council staff, water managers, state government and RICES industry partners (see table 2).

The key steps of the trial were:

1. Smart water meter monitoring and analysis
2. Co-designing CWDM strategies with participants
3. Seeking community participant commitment to trial at least two CWDM strategies
4. Prompts and encouragement
5. Monitoring changes to water use
6. Participant and council evaluation of the CWDM trial.

The CWDM mechanisms proposed were co-designed with participants and informed by community engagement and change theories including community-based social marketing (McKenzie-Mohr 2000) and social practice theory (Shove *et al* 2012). The trials were carried out in four communities between 2016 and 2019. The participating householders themselves selected at least two CWDM strategies that they felt were the most suitable for their household water use activities (e.g. if the baseline data indicated that garden watering was a major activity then often a tap timer was trialled).

Table 2. CWDM strategies that were implemented in the trial (stage 2 of RICES project).

CWDM strategy	CWDM tool description
Smart water meters	Existing traditional water meters were substituted with higher resolution water meters in participating households. A total of 20 smart meters were installed.
Water use feedback	Pie charts of individual household water use (per person and per household) were created from smart metering data and were shared with all participating project households.
Benchmarking of household water use	A comparison of individual household water use (per person and per household) with the average of all participating households in each community were provided to households.
Water-efficient devices	Simple and inexpensive water-efficient outdoor devices were provided to the project participants e.g. manual tap timers and soaker hoses.
Leak reporting	Householders taking a more active role in identifying and reporting leaks to their local council and/or relevant state authority.
Education and awareness material	Discussion on water conservation tips and efficient use of water outdoors with other members of the household. Includes communicating with children to turn taps off and tell parents about any leaks.

3.6. Stage three: evaluating and assessing the most appropriate CWDM strategies

As with the baseline water consumption patterns and household water use behaviour data, the CWDM strategies were evaluated using both qualitative and quantitative methods. Smart meter data enabled monitor of any water demand changes from the participating households during the trial period. Semi-structured surveys were used to illicit participant observation and opinions of the CWDM strategies that were employed in each household. Council officers were also consulted on their preferred CWDM strategies perspective. It was important to seek a service provider perspective to be consistent with the premise of the CWDM general approach which encourages feasible and practical options that would be embraced by both the water users and the water providers within a community.

Following an evaluation by participants and council officers, CWDM strategies were identified as appropriate for further piloting in mainland and island communities. In addition to the trialled CDWM strategies, a number of other approaches, generated from the qualitative data were also considered.

3.7. Limitations

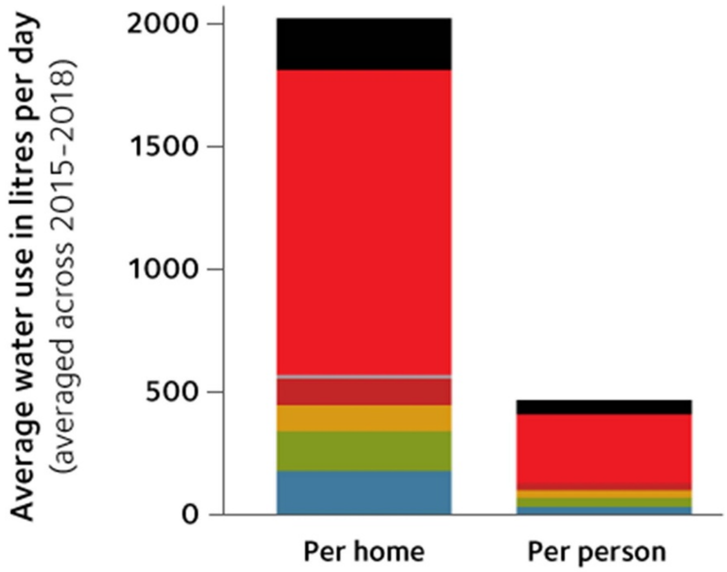
Project limitations related primarily to sample size and potential social desirability bias (Russell and Fielding 2010) (i.e. respondent tending to bias their responses to make themselves appear in a more favourable light), in the qualitative data responses. Over time, the number of participating households declined due mainly to technical and maintenance issues with the metering technology and some participants moving house. For example, in the C1 community, the attrition of households was significant by the end of the project due to unexpected hardware faults in the water meters and sorry business (in this situation, no-one occupied three houses for at least 6–12 months after family members had deceased in the houses as per cultural practises). The consequence of a lower sample size is the reduced confidence that the results are representative of community variability or are statistically robust. However, due to the inherently small community size in remote Australia, the number of participating households ranged from 20% to 40% of total community households for much of the project for at least three of the four communities. We have indicated where we are not confident with the C1 results due to low sample size. Social desirability bias on water use behaviours was able to be minimised by validating the survey responses with measured water use data from the smart meters.

4. Results

4.1. Baseline data (stage 1)

4.1.1. Water consumption from smart metering data

Over the four-year monitoring period, across the four communities, per household water use averaged 2017 litres per household per day (l/hh/d) and 467 litres per person per day (l/p/d). A breakdown of average water end uses for the monitoring period shows that outdoor water use, leaks and showers were the main activities on both a per household and per person basis (figure 2). Overall, outdoor water use comprised most of the consumption, averaging 60% of total use, with an average of 50% used in summer (wet) and 70% in the winter (dry) months.



	Per home	Per person
Leak	205	51
Outdoor	1235	281
Bathtub	13	2
Toilet	111	26
Clothes washer	102	25
Tap	164	37
Shower	187	44

Figure 2. Breakdown of average water end-use from four remote communities.

Comparing water use both spatially and temporally provides more understanding of the patterns of use at different times of the year (figure 3). In this respect, water use (mainly outdoor) varied over time between each community. Outdoor water use was higher during prolonged periods of dry weather, which is usually associated with the winter months in Northern Australia (figure 3). Indoor water use activities generally remained homogenous over time and location. Results show that outdoor water consumption should be the focus of water conservation efforts rather than indoor use.

In many Torres Strait Island communities there are severe water restrictions during the dry season (May–November) and this can result in the treated, piped water supply being physically turned off by the council for up to 16 h a day (i.e. controlled access to the mains water supply). This is not the case for the C2 community which has 24 h a day, 7 d a week (24/7) access to treated drinking water, although water restriction notifications are issued in the hot and dry winter months in Cape York. For this community, where was no alternative water supply (unlike C3 and C4) to offset mains water use for outdoor activities during the dry season, such as dust suppression, cleaning and cooling purposes (see Beal *et al* 2018). For the C1 community, the opposite is true where the hot, dry period is in summer (December–February) which typically sees high water use, especially for outdoor use (figure 3).

4.1.2. Health and well-being drivers of water use

The results from the qualitative data indicate that outdoor water use is inextricably linked to health and wellbeing (table 3). From analyses of the survey responses, participant discussions, water end-use data and council consultation it emerged that several key drivers were contributing to the observed high outdoor water use activities. Following baseline analysis, interviews were conducted with all participants to further explore and identify the drivers (i.e. reasons and motivations) behind the different outdoor water uses. The analysis of those results identified that drivers of high outdoor water use are closely linked to necessary day to day functioning e.g. (group celebrations and festivities, tombstone openings, sorry business, children's play,

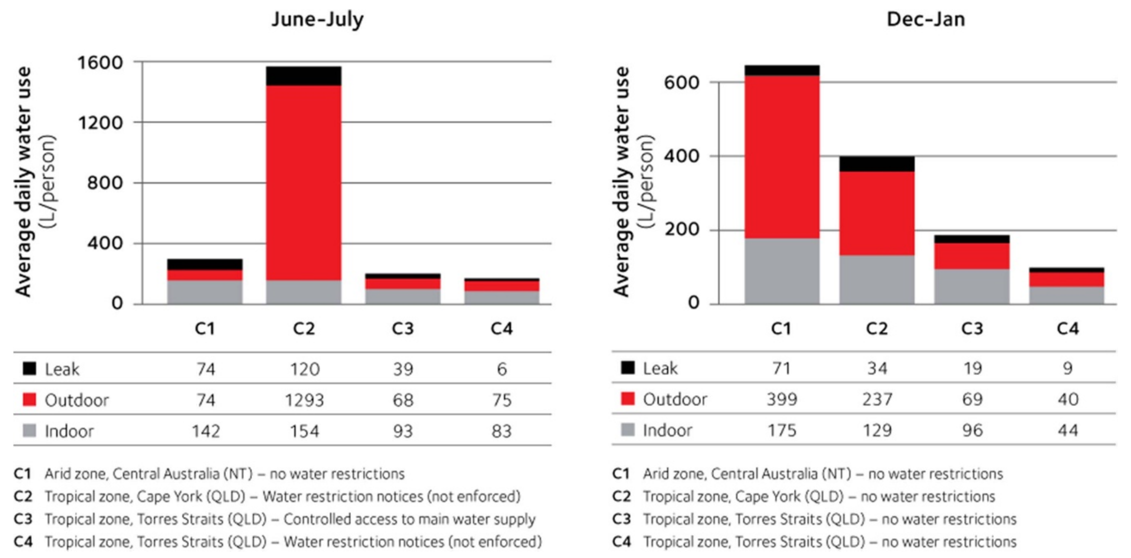


Figure 3. Spatial and temporal water end-use breakdowns.

Table 3. Description of outdoor water usage.

Water usage	C1	C2	C3	C4	Total
Heat relief/cooling buildings	0	3	0	2	5
Social and cultural gatherings	6	7	10	12	35
Watering gardens and establishing ground cover	2	15	8	18	43
Dust control	1	6	1	5	13
General cleaning/food/fishing/hunting equipment	14	44	46	12	116

watering gardens, trees and establishing ground cover). Results highlighted in table 3 indicate that outdoor cleaning including cleaning food and hunting equipment was the most prevalent use of outdoor water, followed by watering gardens, social and cultural gatherings, dust control and heat relief. However, it must be noted that there are likely multiple uses for the same water use label. For example, children's play and using the swimming pool was categorised under social and cultural gatherings, it is also likely that swimming was also used for heat relief. This may also explain the lower numbers in the heat relief category—where researchers observed and heard anecdotes of participants soaking the ground to cool earth and generate an evaporative cooling effect with the prevailing wind—especially important to provide a cool area during social gatherings. The links between water use and health are discussed in more detail in Beal *et al* (2018).

4.2. Trialling CWDM strategies (stage 2)

This section provides a general summary of the findings of Stage two in relation to the effectiveness of how each step could enable CWDM implementation. In this regard, the findings of the six steps of the trial (detailed in the Methods section) are described in table 4. Note that the qualitative and quantitative evaluation of the CDWM strategies are discussed in the following section 4.3 (stage 3).

4.3. Evaluating suitable CWDM strategies (stage 3)

4.3.1. Quantitative evaluation—water consumption reductions

Overall, there was a 33% reduction in average water demand following the CWDM trial (table 5). Comparisons of water end-use 12 months after the CWDM trials for C2, C3 and C4, at the same time of the year (thus controlling for weather influences) indicated a reduction in water use across most end-uses, leaks, and outdoor use. The average water use readings for C1 indicated a slight increase in water demand following the CWDM trial. This slight increase (12%) in water use could be due to several factors including the hot and dry weather at the time of the trial, the absence of some participants during the trial period, and the consequently very low sample size toward the end of the project which reduced the reliability of the data.

Table 4. Summary of findings from the six key CDWM trial steps from stage 2 of the research.

Trial steps	Details	Findings in relation to effectiveness/enabling CWDM
1. Smart water meter monitoring (baseline and throughout CWDM trials)	Monitoring baseline water use, identifying water end-use patterns, near-real time monitoring of changes to baseline water use during and post trials	Enabled effective, near-real time management and feedback to communities which assisted in encouraging behaviour change and engaging with their chosen CDWM strategies during the trial period.
2. Co-designing CWDM strategies with participants	Activities included information, engagement with different water savings technologies, encouraging family discussion	Enabled participants to self-select tailored strategies to be trialled—thereby supporting longer-term uptake and buy-in.
3. Commitment to trial at least two CWDM strategies	A written statement with photo taken to support the commitment during the period of the trial.	Verbal or written commitment supported participants in remembering and engaging with ongoing uptake in trial period.
4. Prompts and encouragements	Included written letter and visual feedback from the project team; public council notices of community-wide water levels.	Enabled keeping the program front of mind for participants and ensuring continued action from householders.
5. Participant and council evaluation of the CWDM strategies	Survey questions to all participants, workshops for volunteering participants to discuss the process, overall results and next steps.	Enabled objective (e.g. non-researcher) viewpoint of the success of the program and its different elements as well as learning outcomes.

Table 5. Summary of water use data for pre and post CWDM trial periods (l/p/d).

	Average daily use pre-trial	Average daily use post CWDM trial (until end of project)	Average per person reduction post CWDM trial	% reduction pre and post CWDM trial
C1 ($n = 2–9$)[a]	420	476	—	—
C2 ($n = 17$)	881	772	109	12
C3 ($n = 22$)	355	218	144	39
C4 ($n = 20$)	256	131	125	49
Overall[b]	**497 l/p/d**	**374 l/p/d**	**126 l/p/d**	**33%**

[a] Due to meter malfunction there was only a small number of metered homes (e.g. by end of project $n = 2$).
[b] Excluding C1 where there was insufficient data post CWDM trial resulting from unoccupied households and meter malfunction.

4.3.2. Qualitative evaluation—survey responses

The RICES team sought feedback about the appropriateness and usefulness of the CWDM strategies that were trialled. In response to the question 'How useful did you find the actions that you used during the trial' participants reported feedback of actual water consumption data and benchmarking of individual household water use with others in the community as favoured CWDM options from RICES participants (figure 4).

Participants were also generally in favour of CWDM strategies including: (1) council-led community workshops, (2) schools water conservation education, and (3) social and traditional media community announcements about current (real time) community water use and ways to save water (especially during the dry season). Each of these was employed in at least one community.

4.3.3. Identification of suitable CWDM strategies

In general, CWDM activities that involve feedback on household water use, and education and encouragement around how, why, and when to save water were popular with participants and were relatively low cost. Providing feedback on water use and benchmarking with other households, can still be done without smart meter water data, however, this would require more training and coordination by councils and service providers—though still at a generally low cost.

There was general support for the idea of creating local *water champions* in the community; to provide regular communication and feedback, and to promote a proactive community approach to water conservation. It was however, seen as important that this responsibility not be devolved from council/service provider to community members, and that leadership be shown by responsible parties to improve

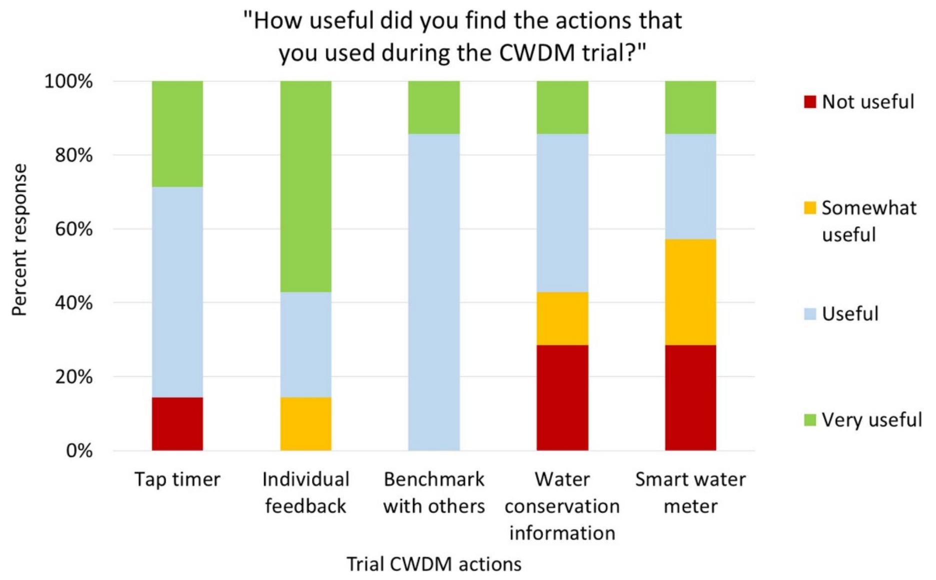


Figure 4. Household participation responses (C4) for trialled CWDM actions.

communication and coordination. There is potential to explore expansion of the scope of existing water officer (technical) role to incorporate more community engagement and partnership.

Many participants agreed that sharing water stories with friends and family, and even as a school activity for example, sharing stories was an appropriate and effective way for the Elders and Traditional Owners to transfer some of their traditional stories of accessing and saving water. This story sharing approach would also highlight the existing strengths of traditional (existing) water literacy in the community, with a view to further embedding local Indigenous knowledge into water conservation strategies.

5. Discussion

The trialled CWDM strategies were discussed with the project participants and council officers to test likelihood of engagement by community members, usefulness in terms of change outcomes and acceptability within Aboriginal and Torres Strait Islander culture and alignment with cultural protocols. It is acknowledged however, that these strategies may not be culturally or otherwise appropriate or workable across the breadth, depth and diversity of Australian Indigenous communities and language groups. Socio-demographics, existing household water infrastructure, proximity to major cities, and other household characteristics will influence preferences for CWDM strategies. Additionally, not all the CWDM strategies in isolation would work with all households in a community, although used in combination there is increased likelihood of a long-term change in how water is valued and used in communities. Below is a discussion of a range of factors to consider that may improve uptake of CWDM strategies in remote communities.

5.1. Policy and planning considerations for future CWDM programs

Each community had locally-specific limitations and opportunities for achieving water efficient outcomes. In addition to geography and environment, barriers specific to more effective engagement in demand management in remote Indigenous communities have been identified under categories of governance arrangements, cultural norms and values, economic and finance factors, capacity, education and awareness and data management and availability (Jackson 2019). Successful, and long-term water demand management strategies require a suite of tools to be implemented over time that acknowledge these barriers and seek to overcome them. As identified in Jackson *et al* (2019a), and drawing from the RICES project findings, water management policy in remote communities needs to broaden beyond the current model to consider the following:

- Knowledge of the existing enabling environment (e.g. available funds, resources, expertise, past programs, community will and buy-in) and how this can assist or impede new water demand management directions. This knowledge will identify the realistic goals and manage expectations for both community and external parties. This is essentially the *fit for purpose, fit for place* rule that is critical for setting pragmatic and community-based water demand management approaches.

- Co-designing water demand management programs with Aboriginal and Torres Strait Islander representation from the start—not just consultation, there needs to be involvement of Indigenous peoples from the inception of the program.
- Water demand management programs must budget sufficient costs for relationship building and community engagement (including repeat travel and in-community events).
- As part of the collaborative approach, government needs to draw on local Indigenous knowledge about weather patterns, water supplies, historical water literacy around water conservation, water quality and relationships with water to make a demand management program relevant, culturally appropriate, and beneficial to local community.
- Local capacity building where community members have the opportunity to become trained and knowledgeable in water management processes, e.g. this may include future consideration of a traineeship enabling environmental health workers to carry out minor plumbing repairs in emergency situations in remote Aboriginal and Torres Strait Island communities that do not have ready access to a licensed plumber such as the current Western Australian model (Government of WA 2016).
- There must be an open policy of *safe to fail* for the community-based approach to demand management. Not just financially (again this needs to be budgeted into programs) but also technically (e.g. water efficient devices may not be immediately used) and socially (communities may not initially engage strongly with education workshops). Research shows that unrealistic expectations, inadequate budgeting and an insufficient enabling environment are key ingredients for poor outcomes from water management programs in Indigenous communities (Jackson *et al* 2019a). Allowing some room to fail would include (yet not be limited to) the following approaches:
    - having a flexible budget;
    - realistic expectations for outcomes;
    - identifying and learning from 'poor' outcomes;
    - setting realistic timelines for programs; and
    - conducting a pilot CWDM program prior to a main roll out.

5.2. Re-thinking water restrictions and disconnections

Water restrictions (either fully controlled disconnections or through public notices with no strict enforcement) is currently the main demand management approach in remote Indigenous communities. It is generally agreed that water restrictions, especially ones that involve disconnection of town water supply for prolonged periods during the day such as in some outer Torres Strait islands (Beal *et al* 2019), are currently considered the only effective option to ensuring there is sufficient water supply during the dry season. Limiting access however, to a community's only treated drinking water source is not a preferred option based on participant feedback as is not consistent with the SDG 6.1 goal of 'equitable access to safe and affordable drinking water for all'. Discussions with participants revealed that many householders would fill baths and buckets with water prior to the mains water cut off to ensure drinking water was available throughout the day. However, not everyone had the opportunity to store water or access alternative drinking water sources during the restriction times, most notably the elderly community members. This has also been reported in other studies where inaccessible and/or intermittent of drinking water supplies has been a barrier achieving SDG6.1 (Zozmann *et al* 2022). Therefore, water demand management strategies beyond enforcement measures are likely to yield a more equitable, sustainable, and resilient water supply. These findings further emphasise the need to consider alternative options for managing the long-term security of remote Australian water supplies using community-based education and encouragement approaches (see supplementary file B).

5.3. Balancing water conservation and public health

The research presented here focusses mainly on community approaches to ensure safely managed drinking water supplies are used in an efficient and sustainable way. Equally important, however, is ensuring an adequate supply of safely managed drinking water for positive environmental and public health outcomes in communities. For example, while it is essential that excess outdoor water use is curtailed through leak management and appropriate outdoor water conserving behaviours, there still needs to be a reliable supply for water use activities associated with healthy living practices such as dust and temperature control (Torzillo *et al* 2008).

Similarly, results show that indoor water use is also used for 'healthy living practices' (Torzillo *et al* 2008) such as washing bodies, clothes, bedding and towels. In this respect, water conservation messages should be very clearly directed towards leak reporting and repairs of water-based health hardware rather than indoor water consumption reduction in general. Further, Beal *et al* (2019) reported data demonstrating how in many communities with alternative water supplies, rainwater is the preferred drinking water source—not the treated town water. The balance between managing demand to ensure sustainable water supplies while continuing strong health promotion messages around using water to encourage healthy living practices, is a challenging element of demand-side management in remote communities. Nevertheless, there are excellent opportunities to address this type of challenge through broader roll out of community-based water management approaches.

5.4. Energy and cost implications

Previously reported data has demonstrated the reduction in energy and operating costs from applying smart metering and community-based approaches (see Beal *et al* 2016a, 2019). For example, reduced bore pumping and desalination energy demand from lower water use (from CWDM) were estimated at 24% and up to 65%, respectively (Beal *et al* 2019). Associated savings of 22% of business-as-usual costs have been reported from decreased energy (and water) consumption (Beal *et al* 2016a).

5.5. Suggested approach for community-based WDM

Building on the key insights from the research, the suggested approach toward community-based water demand management for remote Aboriginal and Torres Strait Islander communities is shown in figure 5. There are important elements to the approach, noted here:

- Community-based demand management tools.
- Council/Service provider-based CWDM tools.
- External funding (this relates to a reduced reliance on capital and operating funding from local and state government and external providers but it must be emphasised that on-going strategic support for remote community councils is essential and that any saved costs through successful CWDM programs could be redirected to other community services).
- Essential, ongoing collaboration between council/service provider and community.
- Time, trust, and safety to fail.

Each of the elements above are shown in figure 5; they are a pathway that is deliberately simple and broad; recognising that each community will require tailored CWDM programs, co-designed with local community and stakeholders. The five key elements are considered critical, overarching principles for transitioning to a more community-based approach to not only water demand management but to overall security and resilience of water and water-related energy supplies. The suggested pathway acknowledges that creating sustained behaviour change is not a simple and short-term process in any community, particularly in remote settings that require strong cultural, historical, governance, geographical and environmental considerations.

5.6. Key elements of the approach

Essential, ongoing collaboration between council/service provider and community. As an Indigenous community transitions to a resilient and sustainable water system, there must be an equal and ongoing relationship between community and council/service provider to ensure optimal engagement with CWDM tools. For example:

- Council ensuring up to date water use notices are available through preferred community channels.
- Community aware of and adhering to water alerts about low water supply or temporary restrictions to outdoor use.
- Residents, non-residents and council use of tap timers and other water efficient devices.
- Running (council) and attending (community) local workshops and water conservation education activities.

Capital and operating costs to local and state government and external providers. As the CWDM tools that are adopted in communities' transition from engineering and technical focus to more community-based CWDM tools, there will be a concomitant reduction in the reliance on money, resources, energy demand and associated direct and indirect expenses of high, ongoing water consumption.

Time, trust, safe to fail. Over time as the emphasis on council/service provider based CWDM approaches reduce and there is room for community-based CWDM approaches to 'fail and improve', there is likely to be an increase in trust and confidence within the community that they have a sustainable, resilient, and ultimately independent water supply.

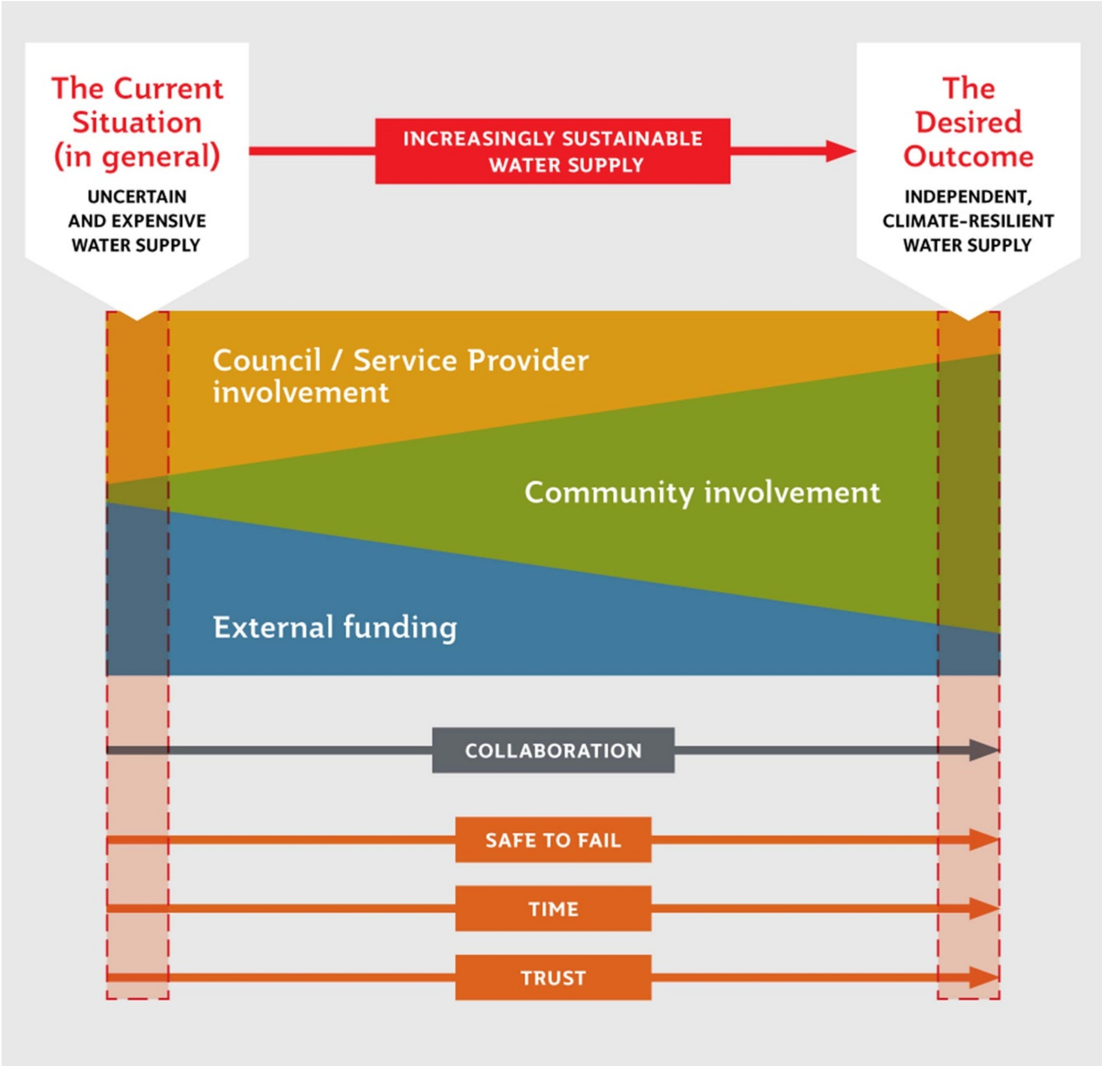


Figure 5. Suggested community-based water management approach.

6. Conclusions

This paper has presented and discussed the findings from a large collaborative project investigating community-based approaches to water management in remote and isolated communities in Australia and the Torres Straits. Socio-technical approaches were employed to trial and evaluate a number of water demand management strategies. Water reductions up to 40% of pre-CWDM trial consumption were achieved in individual communities—though long-term reductions will require sustained and consistent efforts from councils/service providers to provide positive messaging to support community action e.g. they need to include the *why* and *how* of water conservation in their on-going messaging to community. Importantly, outdoor water use activities were found to be associated with cultural and environmental health practises, prompting the concern that simply enforcing water restrictions, or cutting off mains water supplies for prolonged periods of time, could result in detrimental health and wellbeing. The following are key conclusions from the research:

- To help address the range of high-water use drivers, behaviours and attitudes, both community and council/service provider-led water conservation actions is needed within a broader water demand management program.
- In all four communities, individualised water use feedback, including comparisons with the water use of other households was a CWDM strategy from both the community and council/service provider perspective.
- Successful and long-term water demand management strategies require a suite of tools to be implemented over time. This is especially true for CWDM in remote Indigenous communities. Each community also has

different limitations and opportunities for achieving water efficient outcomes and these must be understood and respected.
- In the early-mid stages of implementation, communities need a *safe to fail* approach to allow some long-term behaviour change patterns to occur and to promote greater trust between local community members, council/ service providers, and external parties.
- There is a need to co-design any WDM program with Indigenous representation from the start and for collaboration to be truly effective. Governments must budget sufficient community engagement costs into any water demand management program.
- Indoor and outdoor water conservation messaging needs to avoid discouraging the use of water for key healthy living practices essential for human health (washing bodies, washing clothes, washing bedding etc).

A suggested community-based water demand management approach was described that acknowledges that creating sustained and sustainable changes in management inclusive of communities is not a simple and short-term process in any community, particularly in remote settings that require strong cultural, historical, governance, geographical and environmental considerations.

Data availability statement

The data cannot be made publicly available upon publication because no suitable repository exists for hosting data in this field of study. The data that support the findings of this study are available upon reasonable request from the authors.

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