

Acknowledgements

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What is RISE?

The challenge — Informal settlements are home to more than a billion people who suffer from poor health and wellbeing as a result of inadequate water and sanitation services, and environmental exposure to pathogens, pollutants and disease vectors.

Our vision — Our vision is to improve human, environmental, and ecological health in informal urban settlements across the developing world through a new approach — a water-sensitive approach — to the delivery of urban water services, bridging the gap between WASH and big pipes infrastructure.

Our aim — RISE is a research program that aims to collect the first-ever rigorous scientific evidence if a localised, water-sensitive approach to upgrading informal settlements can deliver sustainable, cost-effective improvements to health and the environment.

Our method — We are conducting a randomised control trial involving 12 informal settlements in Suva, Fiji and 12 in Makassar, Indonesia. In the first phase of the trial, six settlements in each country will undergo a water and sanitation upgrade. The impacts of the upgrades on the health of the environment and the health of the communities will be monitored, and compared against the other six settlements in each country.

Our demonstration projects — In parallel to the randomised control trial, we have also upgraded a settlement in Makassar and Suva to demonstrate the approach and range of technologies. The content of this report draws from this experience.

Want to know more? — visit our website at: www.rise-program.org

RISE is aligned with the ADB Strategy 2030's Operational Priorities to achieve prosperous, inclusive, resilient and sustainable Asia and the Pacific <https://www.adb.org/documents/strategy-2030-prosperous-inclusive-resilient-sustainable-asia-pacific>. RISE is supported by the Urban Climate Change Resilience Trust Fund (UCCRTF) in Makassar, Indonesia and the Urban Environment Infrastructure Fund (UEIF) in Suva, Fiji.

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Acronyms and key terms

ADB	Asian Development Bank
CRCWSC	Cooperative Research Centre for Water Sensitive Cities
MSDI	Monash Sustainable Development Institute
PDAM	Perusahaan Daerah Air Minum; local government-owned water utility
RISE	Revitalising Informal Settlements and their Environments program
SDG	Sustainable Development Goals
UCCRTF	Urban Climate Change Resilience Trust Fund
WASH	Water, Sanitation and Hygiene
WSC	Water-sensitive cities (approach)
Bio-filtration	The process of using beneficial bacteria to clean water on a molecular level to remove contaminants. Biofilters contain grains (e.g., sand, granular activated carbon) that are covered with biofilms, which break down nutrients and organic carbon as well as capture other unwanted contaminants in the influent water.
Blackwater	Solid and liquid waste from toilets that contains faecal matter and urine.
Cluster (servicing)	The households in a group that are connected to one pressure tank.
Co-benefits	Achieving multiple positive outcomes from a single intervention/investment.
Co-design	A participatory and inclusive process of involving all relevant stakeholders, especially community members, in the conceptualisation, planning, design and implementation, and monitoring and operation/maintenance of programs and projects that affect their lives.
Demand Management	Encouraging households to reduce (water) consumption and adopt energy efficiency measures.
Greywater	Wastewater that has been used for washing, laundering, bathing or showering.
Informal settlements	Defined as having at least one of five deficiencies according to UN-Habitat's (2003) criteria: poor quality of housing, unsafe water, unsafe sanitation, overcrowding, and/or lacking tenure security.
Intersectionality	A theoretical framework for understanding how aspects of a person's social and political identities (e.g., gender, sex, race) combine to create notes of discrimination and privilege.

Land tenure	The rights that determine who can use land, for how long and under what conditions based both on official laws and policies, and on informal customs.
Nature-based solutions	Actions that work with and enhance nature, harnessing the power of nature to help people adapt to change and disasters and protect, sustainably manage, and restore natural or modified ecosystems.
PANRITA	‘PerencanaAN RI kampung TA’ which means planning in your neighbourhood and is the RISE term adopted to describe the suite co-design activities with the communities.
Pressure tank	A rotomolded plastic tank, one of the components in a pressure pod.
Pressure pod	The unit that collects, stores and discharges wastewater, as part of the treatment train. It houses a grinder pump and level sensor and float switch.
Resilience	The capacity to recover quickly from an acute or prolonged event of shock.
Retention time	The length of time that a compound remains in a wastewater treatment tank or unit.
Reticulated water supply	The pipes-water network (as opposed to well water).
Safeguards	A framework to help to ensure that, at the very least, a project doesn’t inadvertently harm people or the environment.
Septic tank	A chamber through which domestic wastewater flows for basic treatment where settling and anaerobic processes reduce solids and organics.
Subsurface wetland	An engineered system that uses vegetation, soil and organisms to treat wastewater which is below the surface of the soil, with the interaction between the plant roots removing contaminants.
Surface (flow) wetland	Saturated engineered systems with wastewater above the soil exposed to the atmosphere for final treatment.
Social capital	A set of shared values that allows individuals to work together in a group to effectively achieve a common purpose.
Tenure security	A continuum of tenure with multiple forms, underpinned by the ability of residents to remain and utilise the land and dwelling they occupy.
Treatment train	An engineered sequence of multiple wastewater treatment technologies to treat and safely discharge wastewater.
Wastewater	Water that has been contaminated by human use, including blackwater and greywater.
Water-sensitive	Actions to complement conventional approaches to deliver services by working with nature to improve urban liveability, access to services, and restore the natural environment. The water-sensitive approach includes ‘nature-based’ technologies such as constructed wetlands, rainwater harvesting, and bio-filtration gardens.



Water-sensitive infrastructure can deliver water and sanitation services, while also delivering co-benefits such as improved access and flood protection

Executive summary

Improving access to affordable and safe water and sanitation services in urban informal settlements is urgently needed to improve human health, the environment and city resilience and liveability. Conventional trunk infrastructure approaches alone, however, are not meeting the demand in rapidly urbanising countries and therefore innovative approaches are needed. A water-sensitive approach, which adopts a holistic approach to managing the urban water cycle can achieve multiple co-benefits beyond the provision of water and sanitation services.

A water-sensitive approach is the integration of conventional engineering approaches with nature-based technologies to provide site- and context-specific solutions for improved urban water management. Nature-based technologies include constructed wetlands and biofilters and use natural filtration processes to effectively

treat wastewater on-site to reduce faecal contamination, as well as provide co-benefits of improved stormwater management, flood protection, and increased water security and climate change resilience.

This Report provides an overview of the technical and design considerations of water-sensitive technologies for urban informal settlements with a core design goal to reduce exposure of residents to faecal contamination. The Report details the components and design standards of the suite of potential nature-based technologies across seven strategies: blackwater, greywater, water supply, drainage, access and open space, operation and maintenance, and climate change. Drawing on extensive project implementation experience between 2017–2020, the Report pays particular emphasis on the city of Makassar, Indonesia. This experience and the knowledge presented in this Report demonstrate that water-sensitive technologies can be a key part of the solution to provide services for all in line with the targets and goals in the Sustainable Development Goals (SDGs) to ensure no one is left behind.

A three-part series

This report, *Water-sensitive informal settlement upgrading: description of technologies* provides foundational knowledge of the technical requirements and considerations for implementing nature-based technologies in urban informal settlements, with particular emphasis on Indonesia. It provides an overview of criteria and design considerations for technical audiences, answering common technical questions regarding the functioning of nature-based technologies and interventions. The Series has three volumes.

The series is *not* intended to be a step-by-step guidebook. Rather, it aims to showcase the possibilities, principles, best practices and main considerations for policy makers and practitioners. It draws on experiences since 2017 with the Revitalising Informal Settlements and their Environments Program (RISE), a decade-long transdisciplinary impact research (TIR) endeavour that aims to improve human and environmental health in urban informal settlements by trialing the water-sensitive cities (WSC) approach to water and sanitation servicing (www.rise-program.org).



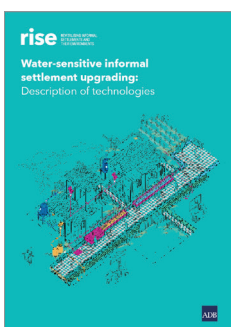
Part One

Water-sensitive informal settlement upgrading: overall principles and approach provides the entry-point for understanding the rationale and concepts for a WSC approach, and a high-level summary of the main components and considerations for policy-makers and practitioners interested to utilise the approach in Asia and the Pacific.



Part Two

Co-design of water sensitive settlement upgrading, provides more detailed information and guidance on how to design and deliver a community-based, participatory process for project implementation. This Part equips the reader with an understanding of the tools and techniques that can foster meaningful participation of settlement residents, as well as government, industry and service provider stakeholders, into the design and delivery of WSC upgrading projects.



Part Three

Water-sensitive informal settlement upgrading: description of technologies builds on the other two reports by providing foundational knowledge of the technical requirements and considerations for implementing nature-based technologies in urban informal settlements, with particular emphasis on Indonesia. It provides an overview of criteria and design considerations for technical audiences, answering common technical questions regarding the functioning of nature-based technologies and interventions.

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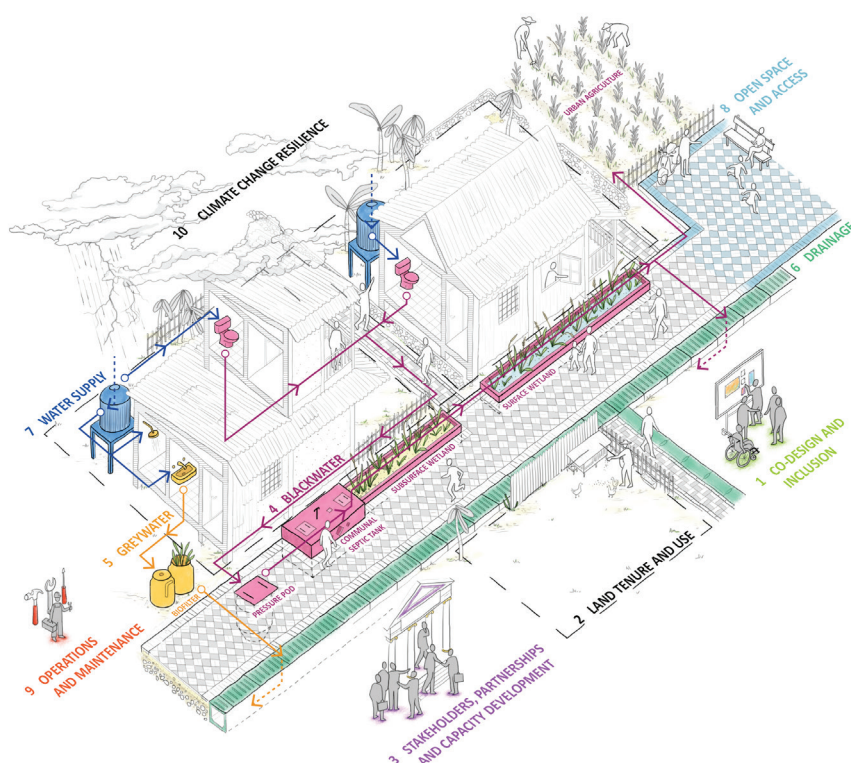
1. Introduction

A water-sensitive approach is the integration of conventional engineering approaches with nature-based technologies and smart systems to provide site- and context-specific solutions for improved urban water management. By applying the social and technical strategies described in this report, the water-sensitive cities (WSC) approach aims to make a material improvement in the lives of urban informal settlement residents.

The WSC approach seeks to achieve multiple co-benefits for people and the environment, improving water and sanitation services, and community health and wellbeing, by:

- ✓ reducing faecal contamination in the environment and vector habitats;
- ✓ improving drainage and flood management;
- ✓ environment protection and rehabilitation (particularly for groundwater, local waterways and bays);
- ✓ climate resilience through the diversification of water supplies and flood management;
- ✓ improved micro-economies and urban farming (agriculture and horticulture) opportunities;
- ✓ liveability (particularly improved access and opportunities for use of community spaces); and
- ✓ providing infrastructure that is resilient to predicted changes in climate.

To achieve the Sustainable Development Goals (SDGs) and ensure 'no one is left behind' requires 21st century technologies, innovation and new engineering approaches to upgrade informal settlements. Informal settlements are home to almost one billion people and urgently need scalable solutions for water. Urbanisation brings with it great economic opportunities and potential for national global poverty reduction, but also increasing concentrations of poor and vulnerable. These are the people most at-risk to being 'left behind' unless innovations are developed in the way we deliver some of the most basic services of clean water and sanitation to those most in need.



The 10 components of a WSC upgrading approach.

The WSC approach is tried and tested in many cities of industrialized countries and is now starting to be implemented in developing countries, including in urban informal settlements. Water-sensitive technologies focus on addressing multiple issues, often through combining traditional engineering approaches to water and sanitation services with the use of nature-based technologies that are scalable and can fit into relatively dense urban landscapes.

The technologies are context specific and adapted to the characteristics and constraints of the existing land and water environments to ensure they are fit-for-purpose. The types of technologies include:

- ✓ wastewater treatment including constructed wastewater treatment wetlands (subsurface and surface flow); biofilters and biofilter drains

- ✓ stormwater drainage and treatment including swales and raingardens; constructed stormwater treatment wetlands (surface flow); permeable paving
- ✓ water supply security, including rainwater tanks and collection; water supply disinfection; protection of existing shallow well water supplies
- ✓ flood resilient access roads and utility corridors, and public space amenities.

This Report outlines the technical elements of a WSC approach and their interconnection within a system. It draws from the experience with the RISE program in Makassar, Indonesia. Importantly, the cross-cutting components (co-design, land tenure, stakeholders and partnerships) are also explored with specific emphasis on how these relate to the technical design and planning aspects of the WSC technologies.

Example of a WSC upgrading project implemented at Batua, Makassar, implemented under the RISE program, supported by ADB and the UCCRTF.

SEPTEMBER 2017



NOVEMBER 2019



Access

Greywater biofilters

Pressure Sewer

Rainwater tanks and water supply

Stormwater drainage

Wastewater treatment

Private toilets

Box 1: What is a 'water-sensitive' cities approach?

The water-sensitive cities (WSC) approach aims to address management of the urban water cycle in a holistic way. Broadly, the WSC approach is framed around three pillars and can be applied across both developed and developing cities:



In the context of informal settlements, applying this approach involves assessing a range of technologies and strategies in the context of local climate, neighbourhood size and population density and the permanency of its residents.

These documents provide a description of the WSC approach as applied in the RISE program, and are broadly applicable for the Asia and Pacific context. The application of the WSC approach should start with an analysis of the local context as described above and, depending on the local context, may lead to the selection of a different suite of technologies and strategies for different locations.

Box 2: Overarching intent and objectives of the Water-Sensitive Cities approach to upgrading

The WSC approach to delivering urban water services for improved health of inhabitants in informal settlements is based on the premise that reducing exposure to faecal contamination will improve community health and wellbeing, and the environment. Therefore, understanding the social-biophysical context and prioritising the interventions towards critical faecal contamination pathways is a key underpinning objective.

The WSC approach to upgrading is underpinned by three key design goals:

1

Reducing direct contact with faecal contamination, including by providing toilets which encourages good hygiene practices, and physical barriers including raised pathways to avoid contact with contaminated floodwaters and drainage upgrades to reduce local ponding;



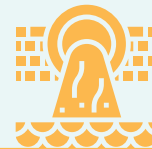
2

Reducing exposure to faecal contamination generated by residents within the target community by safely managing wastewater (both liquids and solids and greywater), and protecting local groundwater resources and downstream environments and communities;



3

Reducing exposure to contaminated water from external environments, including by improving catchment scale water management, and providing safely managed wastewater upstream and/or physical barriers to reduce inflows of contaminated drainage and floodwaters from upstream communities.



To this end, mapping and understanding the relative significance of faecal contamination pathways is fundamental to formulating a fit-for-purpose urban water and sanitation strategy. Urban planning and design presents a platform for integrating the biophysical designs for concurrently addressing these contamination pathways. For example, green corridors and drainage wetlands can detain floodwaters and improve water quality. The spatial design/layout of urban informal settlements would be based on a common set of design principles, but the solution is site specific and influenced by the (i) site biophysical condition opportunities and constraints; (ii) the relative dominance of the contamination pathways; and (iii) the deliberation of a community-based co-design process.



Co-designing water-sensitive infrastructure in Makassar, Indonesia

2. Cross-cutting components: Co-design, land tenure, and stakeholders and partnerships

As outlined in the first Report in this series, *Water-sensitive informal settlement upgrading: Overall principles and approach*, there are three cross-cutting components to the WSC approach that interface with the seven technical components detailed in this report. The technical/engineering aspects, such as blackwater and greywater treatment, cannot be addressed without understanding how co-design, land tenure and partnerships impact on and shape the options and potential for various technical approaches. In this section, then, we unpack these three fundamental components as they relate to the technical design.

At the core of the WSC approach are two critical assumptions. First, projects must be undertaken in close collaboration with stakeholders, including residents and relevant authorities. Successful implementation of a culturally appropriate co-design model, which builds community capacity for decision-making, fits with the long-term vision of the community, and generates meaningful engagement and participation, is critical to the approach. Second, the physical interventions should be designed with a thorough understanding of the local urban water management context, including current practices, stakeholders and potential opportunities.

2.1 Community co-design in technical decision-making

Community co-design is a core principle of an effective water-sensitive intervention. It is not an optional ‘add-on’ to the WSC technical elements. Co-design activities should achieve genuine and meaningful engagement with all residents, particularly the poor and vulnerable who often do not have a strong voice within existing formal and informal governance structures.

As the second Report in this series, *Co-design of water-sensitive settlement upgrading* explains, co-design activities should focus on ensuring:

- ✓ Participants can freely share the challenges and opportunities faced by their community, their tacit knowledge of existing water practices and associated challenges, and their preferences for solutions for these;
- ✓ Discussions are broad and include identification of challenges within the community beyond water and sanitation. The co-development of infrastructure solutions should aim to address broader challenges wherever possible. For example, poor access (foot-paths and roads) is traditionally addressed separately from the challenge of providing water and sanitation, but the two can in many cases be solved together with improved flood management and drainage; and
- ✓ Participants can gain a sufficiently deep understanding of the proposed technical solutions (pressure sewers, wetlands, biofilters etc.) to ensure they can make informed choices about the location of any such infrastructure, and with an understanding of long term commitments for operation and maintenance.



Community members identifying critical contextual issues for their neighbourhoods, and vulnerabilities.



RISE team and local children demonstrating the arrangement and function of the water-sensitive technologies through the RISE system theatre.

2.2 Land tenure considerations for locating infrastructure

Finding sufficient space to locate infrastructure in urban informal settlements is a key challenge and there are many competing interests to consider. Understanding the trade-offs between locating infrastructure on private land versus public land is important. It is generally preferable to locate communal infrastructure on publicly-owned land such as streets, vacant land zoned for public utilities, or public gathering spaces. This creates clear boundaries for long-term ownership, operation and maintenance of infrastructure and, in many cases, these public spaces are larger parcels of land which allow for a more consolidated approach to the provision of infrastructure. Reducing the complexity of the infrastructure, by having larger but fewer individual components can improve the functionality and long term operation of infrastructure. Locating infrastructure in public spaces also provides an opportunity to achieve the co-benefit of improving accessibility and creating valuable public spaces.

However, informal settlements often develop and grow incrementally, over long periods of time, and usually outside the context of formal municipal planning and development frameworks. While there may be some public land in or beside informal settlements, streets, accessways and gathering spaces are often informal and utilise private land. Therefore addressing the challenge of finding suitable land for public infrastructure investment should not be underrated in any informal settlement upgrading project.

Locating infrastructure on private land is often necessary, and can provide benefits to residents in the form of securing access routes, improved services, increased property values and improved amenity of public and open space. While not formally documented, private land boundaries are usually well understood among adjacent landowners and may be marked out and recorded in relation to the proposed infrastructure. Care should be taken, where existing and/or emerging land disputes and grievances may be present. The co-design process provides a platform for developing a common understanding and promoting communal cooperation.



RISE team and community members discussing and marking possible locations for infrastructure

Furthermore, locating infrastructure on private land requires a level of community ownership and management for long term sustainability of the proposed solution. Informal settlements are highly variable in terms of their social cohesion and strength of familial relationship which consequently influence preferences for infrastructure governance levels (ie household, cluster, community). The scale of infrastructure on private land (i.e. how many houses a wastewater water treatment system will service) must be informed by meaningful discussions with all residents, with the design best reflecting the level at which operation and management tasks can be managed and decisions around land use can be made. Refer to Box 3: Land and family relationships shape water-sensitive infrastructure in Makassar, Indonesia.

Formalising land use agreements

Whether infrastructure is located on public or private land, there must be a clear process to formally document any land use or land donation arrangements, which also clearly states who is responsible for the long term upkeep of each infrastructure component. Land agreements should be developed within the constraints of donor safeguards and local and national laws. Within communities, residents have differing views on locating communal infrastructure on private property and preferences for land agreements options based on their individual circumstances. As such, land agreements should include a range of solutions with sufficient flexibility to cater to the needs of different residents and protect land area as a key household asset. Key considerations for the selection of appropriate land agreements include:

- ✓ existing tenure type and security
 - ✓ ownership of the infrastructure asset (e.g a new household toilet facility is a private asset and therefore will not require a land agreement)
 - ✓ donor safeguards and local and national laws
 - ✓ community desire for formalisation of access networks and public space areas
 - ✓ change in landownership, in the event a landowner want to sell or pass on property
 - ✓ long term risks are transferred from the community and onto the project (e.g. in the event of infrastructure failure, residents are able to reclaim land)
 - ✓ compensation for vulnerable households
- Appendix 2 outlines the range of land use agreement options developed for RISE in Makassar that may be applicable in other circumstances.

Social safeguards

Utilising private land for water-sensitive infrastructure needs delicate attention and adherence to social safeguards to ensure no harm is done. Safeguards frameworks, as a first principle, should aim to protect residents' long term interests (particularly the poorest and most vulnerable households) while being nuanced enough so as not to limit residents' desired outcome for infrastructure locations (eg safeguards that limit the amount of land that can be used by the project on an individual plot, may inadvertently prevent residents from receiving both wetland and access infrastructure). While each project will have its own safeguards framework, the broad principles for locating infrastructure on private land are as follows:

- ✓ Participation in the project, and any location of infrastructure on private land is completely voluntary;
- ✓ Participants must gain a sufficiently deep understanding of the proposed solution to enable them to make informed choices regarding the location of any infrastructure, and with an understanding of long term commitments for operation and maintenance;
- ✓ All households are made aware of compensation entitlements for any land used by the project;
- ✓ All discussions with households regarding the location of infrastructure on private land, including potential options and trade-offs are documented with photos of proposed infrastructure locations;
- ✓ External stakeholders, including government authorities and adjacent landowners, are included in all parts of the design and land regularisation process.

- ✓ Particular emphasis is placed on identifying vulnerable households, and ensuring they have a voice in the process and their needs are considered.
- ✓ Efforts should be made to ensure that contributions to the project in the form of land donation and land leasing are equitable. That is not to say that all residents should contribute equally, but the contributions should be in proportion to the total assets and wealth of individual households.

Genuine and meaningful engagement with residents through co-design activities is critical to the successful implementation of safeguards. For more information on how co-design activities can support the safeguards framework see Volume 2 in this series: *Co-design of water-sensitive settlement upgrading*.

Environmental safeguards

Environmental Safeguards aim to identify risks of long term environmental impacts of the project and potential for negative environmental impacts during construction. Throughout all stages of the design, the principle of avoiding environmental impacts should be applied and balanced with community preferences for locating infrastructure, and feasibility of construction and maintenance. For typically small scale decentralised infrastructure this might include avoiding the removal of significant trees and vegetation, and considering

a hierarchy of water supply sources that takes into account long term environmental impact. The design should comply with local environmental laws and policies. Best practice construction management should be applied to manage the risk of short term environmental impacts during construction.

2.3 Stakeholders and partnerships

Engagement across different stakeholder groups is critical across the full program timeline – this includes during pre-project planning and co-design of the intervention. Successful engagement of local stakeholders is also critical to ensure successful long term operation and maintenance of any infrastructure.

Key stakeholder groups include: national and local government, local authorities and agencies responsible for infrastructure; the target communities and existing local organisations or groups within those communities. These relationships must be nurtured, with genuine intent for collaboration and an understanding of the internal drivers and objectives of each stakeholder to ensure the project aligns with these and the sense of ownership is fostered. Further information on the importance of stakeholder and partner engagement is outlined in Volume 1 of this series: *Water-sensitive informal settlement upgrading: overall principles and approach*.



Project team members and residents of informal settlements discussing and co-developing social safeguards

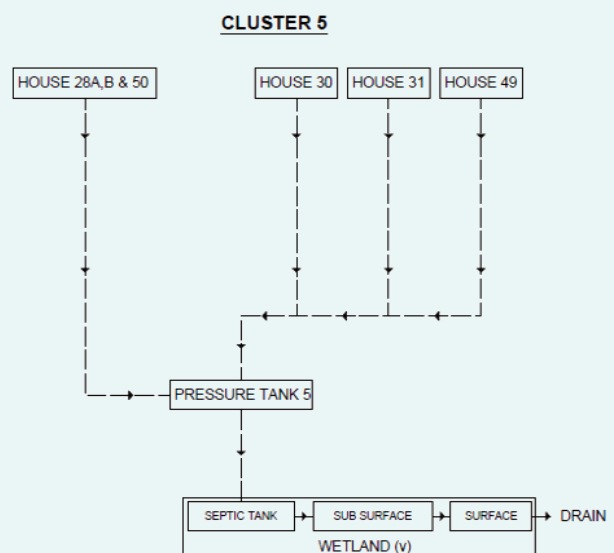
Box 3: Land and family relationships shape water-sensitive infrastructure in Makassar, Indonesia

In the RISE Makassar project, a dedicated team of RISE community architects worked side-by-side with residents over a period of 12 months to identify potential land available for water-sensitive infrastructure. They held discussions with every household to understand their perspectives and their preferences for the infrastructure locations and the number of households in a group (cluster) connected to each wastewater treatment system.

The density of Makassar's informal settlements and the limited land documentation required a detailed and careful assessment of the current situation – including household vulnerabilities, land-use and family relationships - prior to proposing any water-sensitive upgrade.

All of the settlements have limited public land and therefore when the communities were asked to identify their preferred location for communal infrastructure it was usually within the land owned by their family group, and typically in an area not currently in use. The residents showed a strong preference for household and cluster scale (1-7 houses) infrastructure, rather than whole-of-community scale infrastructure. All efforts have been made to ensure infrastructure is provided with clear ownership (i.e. no pumps or pressure pods have been included in the design that do not have a designated responsible owner).

The RISE Makassar experience shows the importance of understanding the intersection of land tenure and use, with community engagement, and the technical infrastructure design. This takes time to unpack and understand the full complexity, however this is crucial to design a technical intervention that has widespread connection to the system in a retrofit scenario, successful long-term operation and maintenance, and true community ownership over the process and output.



Box 4: Building community understanding of exposure pathways and good hygiene



Co-design is not only important to make decisions on the locations and types of infrastructure. It is also important to build residents' understanding of environmental contamination and the value of improved wastewater management and good hygiene practices. Hygiene behaviour change programs have been shown to play a critical role in addressing the multiple exposure pathways for faecal contamination. Poor hygiene can be a key transmission pathway for disease. Good hygiene practices to reduce these exposure pathways include handwashing with soap, safe water storage, good food handling practices, and solid waste management.

In the RISE program, Makassar communities were engaged when mapping faecal contamination pathways which provided important local knowledge about how the community interacts with the environment on a daily basis. This activity has the added benefit of fostering greater understanding by residents of their collective and individual exposure and vulnerability to oral–faecal contamination. This has the potential to influence their day-to-day decisions including where children play, responses to wet weather conditions, location of community outdoor activities, solid waste management, diseases vector habitat reduction etc.

Behaviour change programs can also accompany new water-sensitive infrastructure, to ensure proper use and maintenance in the future. Installing a toilet or hand basin, for example, is effective only if they are used and maintained appropriately. The co-design approach can enhance the efficacy of behaviour change elements of an intervention and proved important in the RISE program to build local understandings of the link between human health and the environment.





3. Urban water management in Makassar

This Report draws heavily from the experience of the Revitalising Informal Settlements and their Environments (RISE) program in Makassar, Indonesia. Given the WSC approach is underpinned by the principle of a tailored, context-specific implementation it is important to outline the environmental and water management context of Makassar to situate the technical description that follows. A summary of the Makassar context is presented here; further details can be found in Appendixes 2 and 3.

Makassar's climate is highly seasonal with a strong dry season which results in significant water stress in many neighbourhoods, particularly informal settlements without PDAM (regional water utility) water supply. Makassar's dry season rainfall has reduced by more than 30 per cent since 1950 and become more variable. Climate models suggest an increase in temperature and a reduction in rainfall into the future.¹

Water supply sources and availability vary across the settlements and consist of a mix of municipal supply (PDAM), bottled water, bores, shallow wells, and rainwater collection using a variety of ad hoc methods from simple buckets to rainwater tanks. Approximately 23 per cent of the households in the RISE program have access to piped water from the PDAM. The vast majority of residents rely on alternative sources, such as groundwater and bottled water to provide all their daily water needs. Households often use a variety of water sources, with sources differing according to use and often changing with season. Most houses use bore and shallow well water for non-potable activities and municipal or bottled water for drinking. Some residents drink shallow well and bore water and some use bottled water for bathing babies.

There is currently no sewer network in the City of Makassar. Most residents (93 per cent) in the selected informal settlements have a private toilet facility, although many of these do not meet basic hygiene standards. Sanitation systems typically consist of blackwater (toilet water)

discharged to unlined 'septic tanks' and pit latrines on individual properties. In the selected informal settlements, 67 per cent of households do not have adequate sanitation and untreated wastewater is discharged from an unlined 'septic tank' or unlined pit latrine into the surrounding soil. These unlined systems cause significant contamination of the local groundwater sources and nearby drains and waterways. Many settlements are located in areas with a high groundwater table, often leading to the expression of contaminated groundwater at the surface.

High population densities and limited land availability render current local best practice approaches (lined septic tanks with an infiltration field) unworkable. Raw faecal sludge contaminates shallow wells and untreated effluent is discharged to both the stormwater drains² and directly contaminates groundwater supplies.

Seventy per cent of the households in the RISE program rely on a groundwater source to provide or supplement their daily water needs. During the dry season, as the groundwater level recedes, shallow wells and bores become increasingly turbid and, in some cases, completely dry up. The use of groundwater as a water supply in Makassar is unregulated so there is little to no data on the extent of groundwater extraction.

A snapshot of the water quality of various water sources across the settlements in Makassar suggest that: (i) in sites that had access to PDAM supplies, the microbiological water quality was good. The PDAM supply satisfied Indonesian and international potable water standards; (ii) Deep bore water quality was variable and would require further treatment for safe potable consumption; and (iii) Shallow wells had very poor water quality and would require significant treatment for safe potable consumption.

Greywater (wastewater from bathroom, kitchen, and laundry) is generated in designated wet areas of the household. Most households have an on-ground concrete slab (with or without tiles) used for washing and kitchen activities, and in some cases for urinating or defecating. Disposal pathways for greywater in informal settlements are often not formalised and this results in greywater accumulating in stormwater drains or simply



pooling in depressions. Greywater is typically discharged untreated by: (i) collecting in bowls and throwing into stormwater drains or external areas; (ii) draining via a hole in the wall or a pipe into stormwater drains or external areas; (iii) draining into a basic rock filled soakaway; (iv) discharge through gaps between floorboards to underneath the house.

Many of the settlements experience regular pluvial and fluvial flooding during periods of high rainfall. Flooding occurs at a localised (household), settlement and regional scale, often exacerbated by high groundwater tables and/or high tides in coastal areas. During heavy rains, floodwater mixes with blackwater and unmanaged solid waste inundating residential areas. Residents come into contact with floodwater while moving around the site, or when floodwater enters their homes. Often after heavy rains, floodwater can remain for several days, attributed in part to poor site drainage, which increases breeding sites for human disease vectors, particularly mosquitos.

Drainage within the informal settlements is highly variable, ranging from large formal channels through to small informal, hand-dug channels. The terrain is typically very flat and, as a result, in many locations during dry weather, both septic tank leachate and untreated greywater pool in stormwater drains which are often partially or fully blocked with municipal waste. Solid waste disposal to waterways and canals is a large problem compounding issues, because they impede drainage, create standing water and cause regular floods and contaminated water supply wells.

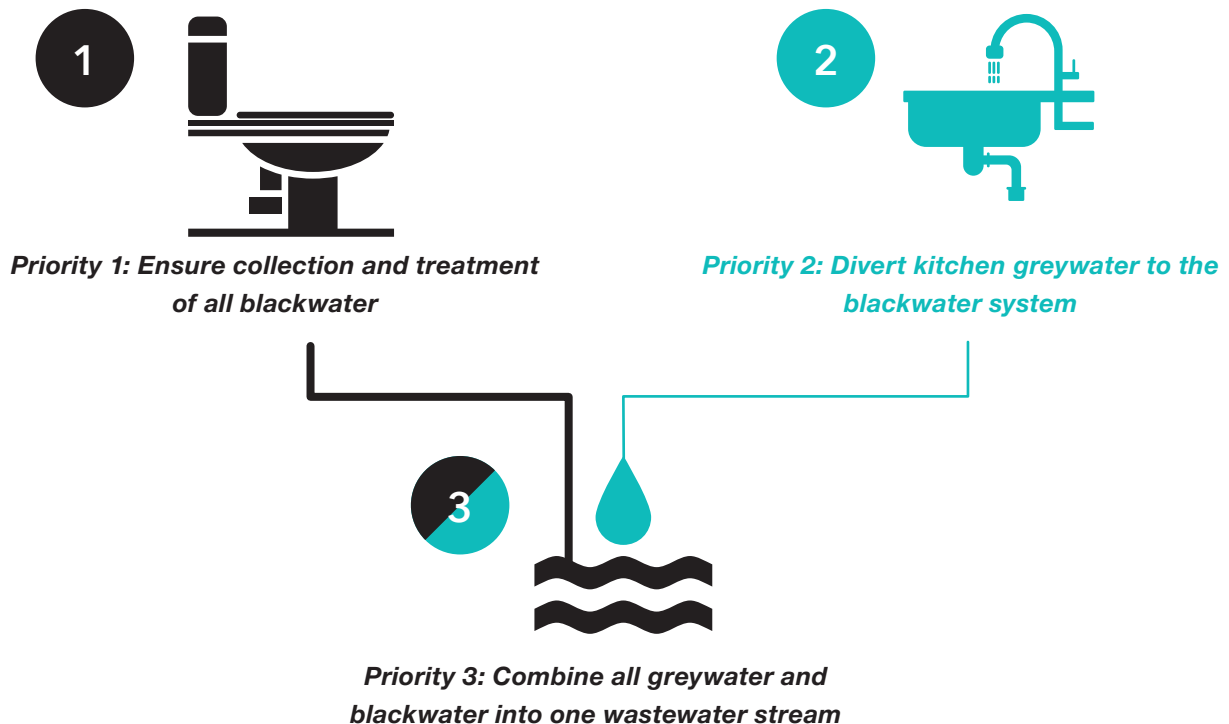


4. Wastewater management: principles of practice

The WSC approach is complementary to conventional 'trunk' infrastructure approaches. What both have in common is a belief that it is inappropriate to allow sewage effluent to be discharged to the environment without treatment, as it contaminates the immediate environment and impacts downstream communities, resulting in serious negative health and environmental implications.

Not every informal settlement, however, will be best served by decentralised water-sensitive technologies. The technical solution needs to find the right mix of centralised and decentralised technologies and approaches that can deliver urban water services to greatest effect. Therefore, the first step in planning a WSC approach to upgrading is to understand the existing situation and identify existing or planned centralised systems that might be easily reached.

The wastewater principles of practice are:



4.1 Connection to centralised sewerage network

Where available, priority can be given to connecting household wastewater (black and grey) to an existing sewerage network. Under this scenario, wastewater will be collected from informal settlement houses and transported to a boundary sewer connection point for connection to the main municipal sewer line. Hybrid solutions may also be considered, where the implementation of a local pressure sewerage system can help a community reach an existing municipal sewerage network. Even in areas where centralised networks are not currently available, consideration should be given to the option to 'design in' the ability to redirect wastewater to a network sewerage system at a later date.

4.2 Decentralised wastewater treatment systems

Where centralised systems do not exist, or are unlikely to be able to service informal settlements in the immediate future, a decentralised approach can be adopted. There are a range of decentralised approaches, including faecal sludge management and WASH³, as well as a decentralised nature-based treatment train. Recent advances in integrating nature-based solutions for water into the built environment provide examples of modular construction that provides flexibility and scalability for integration into high density urban environments.

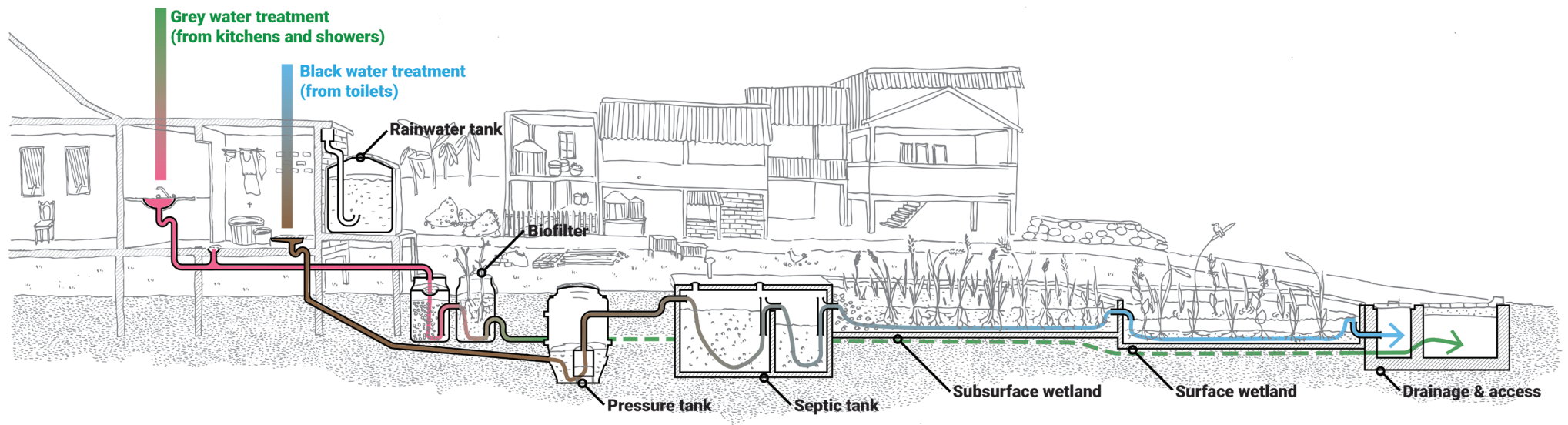
In the absence of a networked sewerage system, safely managed sanitation using a WSC approach follows a 'treatment train' model. This technological solution aims to:

- ✓ Meet the 'safely managed sanitation' metrics and performance standards as outlined in the SDGs;
- ✓ Ensure wastewater is collected and transported safely away from the immediate areas around the household to reduce the community's exposure to faecal contamination;
- ✓ Reduce downstream contamination by providing a level of onsite treatment to wastewater before discharge into the receiving environment;

- ✓ Utilise low-cost technologies, such as constructed wetlands, that can be implemented in short time-spans, rather than waiting generations for centralised systems to reach informal settlements; and
- ✓ Provide opportunity for the (treated) effluent to be used as a resource for horticulture and agriculture production; supporting the local economy.
- ✓ Reduce as much as possible the pump requirement, with a design objective to only pump once where ground conditions do not allow a system to rely on gravity flows alone.

Ideally, the wastewater stream to the local treatment system will consist of both blackwater and greywater. However, this has implications for the size of the treatment systems, more than tripling the footprint. In very dense neighbourhoods, land availability is the single most significant challenge to achieving the desired treatment outcome and, as blackwater contains the highest pollutant loading, priority should be given to ensuring its effective treatment.

National standards, for example, recommend primary treatment of combined greywater and blackwater in a septic tank followed by an infiltration field, vertical flow filter or vertical flow constructed wetland.⁴ However, it is often problematic to implement these systems in dense, informal settlements. Therefore, where the available space does not permit the full consolidation of blackwater and greywater, greywater can be managed separately.



'Treatment train' of wastewater management within the WSC approach

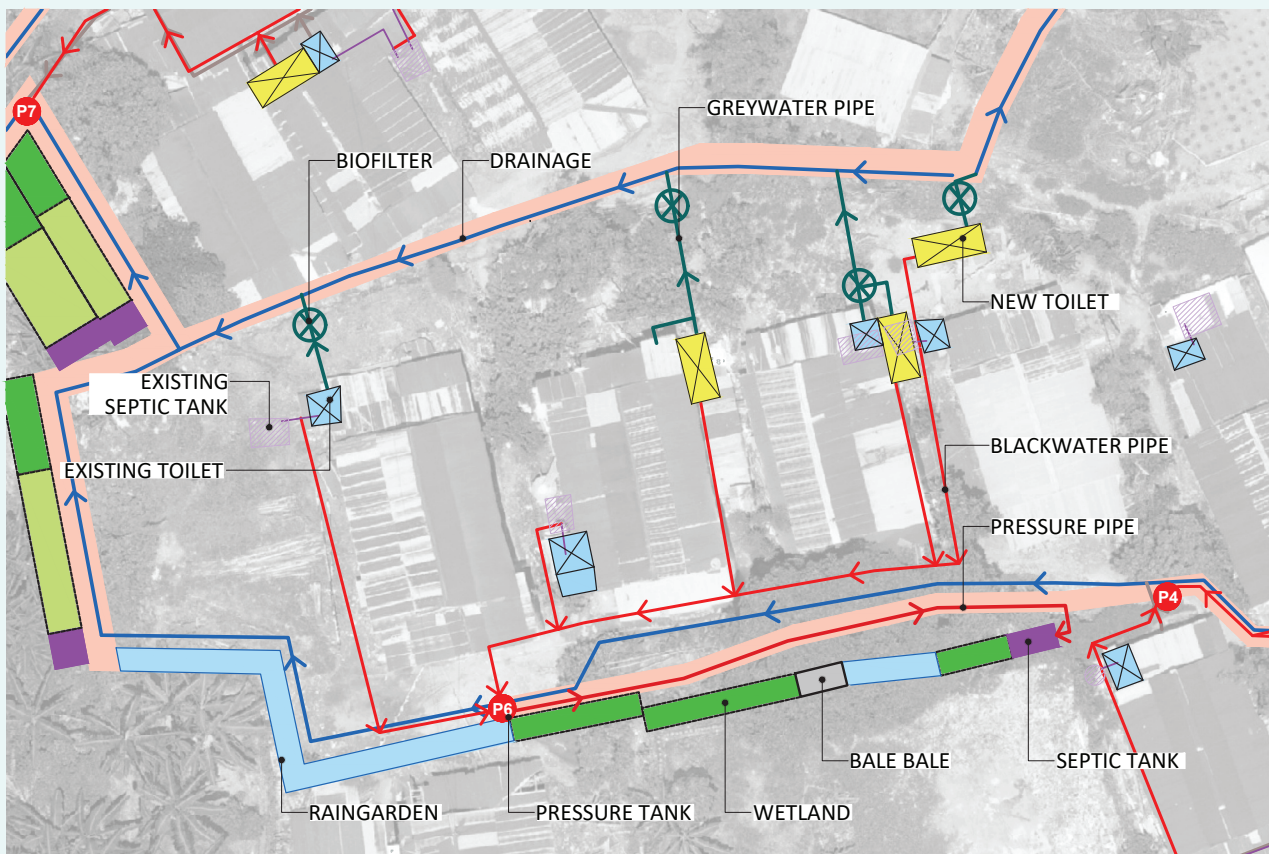
Box 5: Prioritising blackwater treatment in Makassar, Indonesia

During the co-design process for RISE in Makassar, it became clear that the space available for infrastructure was not sufficient to treat blackwater and greywater together at the settlement-level, while still maintaining sufficient detention times within the treatment system to meet the required discharge standards. Design responses were guided by the following priorities. The first priority was to ensure the collection and treatment of all blackwater. This offers the greatest impact, in terms of reducing exposure to faecal contamination, when compared with greywater.

As space did not permit the full consolidation of wastewater streams, greywater is collected separately and treated close to its source or along drainage lines where space allows. Where possible, greywater drainage was consolidated with stormwater drainage.

Another consideration was the cost of the pressure sewer systems, since combining blackwater and greywater increases the volume of flow for pumping, and the associated electricity costs. Based on early discussions around roles and responsibilities, it was agreed with the community that they would incur the electricity cost of running the pressure tanks. While the estimated cost of IDR 6,000 per households per month for operation and maintenance of the system was considered acceptable by households, increasing this cost could place additional financial burden on some households.

With the above prioritisation framework in categorising and assigning fit-for-purpose treatments of the waste streams, RISE preserved the whole-of-system treatment integrity by separating the blackwater and prioritising its effective treatment, directing the better-quality greywater to a less rigorous treatment process, while ensuring that all wastewater streams are treated.



Proposed layout for a servicing cluster for greywater and blackwater treatment infrastructure.

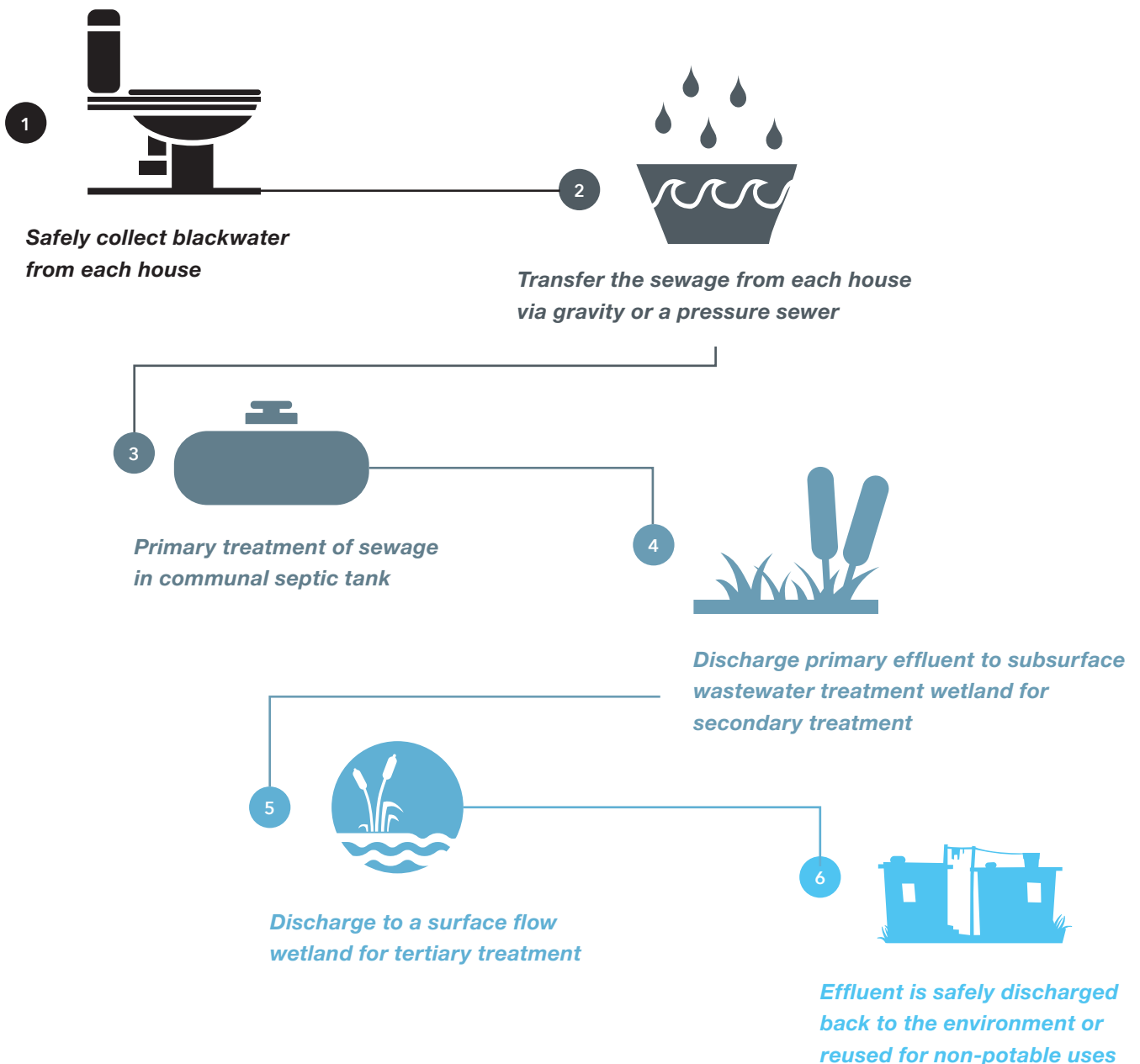
5. Blackwater strategy

As explained in the previous section, the WSC approach to decentralised wastewater management is based on a ‘treatment train’ approach, combining traditional grey infrastructure with nature-based solutions.

This involves ensuring everyone has the opportunity to connect to the system. This may involve a combination of connecting existing toilets, renovation existing toilets, and in some cases, providing a new private toilet facility.

Once all blackwater is collected, it is transferred to a communal treatment system. Many informal settlements are located on flat terrain, and often low in the landscape (along coasts and rivers) which does not allow for a system designed to operate solely on gravity flows.

An objective of the blackwater treatment train is to minimise moving parts, and to pump once wherever possible. Pressure sewers use small flexible HDPE pipes that can be laid with minimum excavation to transport sewage to the desired location and therefore have advantages in retrofit scenarios. A grinder pump located in the



pressure tank macerates the sewage and pumps it to a communal septic tank. From the septic tank, wastewater flows by gravity through two constructed wetlands, first a subsurface flow wetland and then a surface flow wetland. The sanitation system (pressure sewer, septic tank and constructed wetlands) should be sized to accommodate future growth, including the construction of new houses on empty plots and future increases in the number of people per household. Realistic predictions on future population growth (how many and where) should be agreed together with community leaders and informal governing bodies, as they will be key to managing and controlling future growth. This section describes in more detail each component of the blackwater treatment train.

5.1 Collecting blackwater from each household

An overarching aim of the WSC approach is the safe collection and treatment of all wastewater generated within a settlement. All residents should have access to a hygienic, private and safe toilet which is connected to the treatment system. To achieve this, the design may include:

- ✓ Connection of existing toilets that are in good condition and are located at a height that allows for gravity flow to the next step in the treatment train;
- ✓ Renovation of existing toilets to achieve a gravity flow connection to the next step in the treatment train (e.g. raising the slab of the existing toilet);
- ✓ Upgrade of existing toilets to provide an adequate level of hygiene, privacy and safety;
- ✓ Installation of a new private toilet facility if a household does not currently have access to a private toilet or their existing toilet cannot be retrofitted to safely connect to the system.

Connecting existing toilets

To support a comprehensive reduction of contaminants in the environment, all households should be given the opportunity to make a connection to the blackwater system. Each household should be provided with information on the impacts and benefits of connection. Each toilet should be visited individually to assess, agree (with the occupant and/or home owner) and document the location and extent of works required to make the connection.

Toilet renovations

Many existing toilets pose risks of contamination due to their fragile construction (e.g. poor floor drainage), lack of physical separation (e.g. toilets and other water related activities such as washing food occur in very close proximity), and their vulnerability to flooding. An in-situ renovation is a cost effective, less disruptive option that, in certain circumstances, can achieve the same health outcome as a new toilet facility.

Any renovation works should be assessed on a case-by-case basis, using a standard and transparent set of criteria established as part of the program documentation. Key criteria could include:

- ✓ the difficulty associated with making a connection (e.g. where septic tanks are located under the house floor slab);
- ✓ the adequacy of floor drainage to prevent ponding;
- ✓ the condition and usability of the toilet;
- ✓ the accessibility of the toilet (e.g. during flooding);
- ✓ the provision of existing handwashing facilities;
- ✓ the vulnerability of the household, and residents with specific access needs;
- ✓ observation of existing household contamination pathways (e.g. physical environment, hygiene practices).

New private toilet facilities

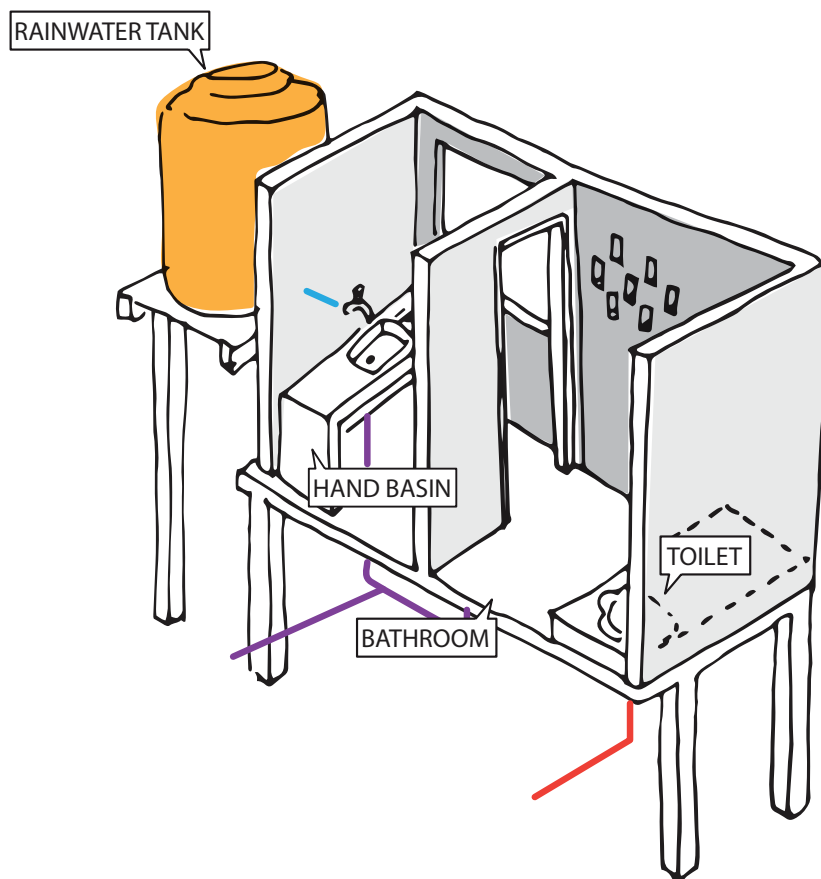
Where a toilet renovation is not possible, then provision of a new private toilet facility should be considered. The design and layout of a new toilet facility should be co-designed with communities to be culturally appropriate, gender inclusive and encourage good hygiene practices. As the existing houses vary in design and construction, a range of configurations should be considered and modified to suit household access and space availability. Where possible, new toilet facilities should include a rainwater collection system and tank with an alternative water supply top-up.

A standard and transparent set of criteria for identifying households eligible for a new toilet facility will form part of program documentation. Key criteria could include:

- ✓ the household does not have a toilet;
- ✓ a fragile, elderly or disabled member of the household is not able to access the existing toilet independently or there is difficulty accessing the existing toilet due to external factors such as flooding;

- ✓ more than nine people share the household's existing toilet;
- ✓ there is adequate available free space to construct a new toilet facility. 'Free space' includes land external to the existing building or existing ground floor space where no modification to the existing building's structural elements is required.

New toilet facilities should be designed according to local building codes, and designs should be based on an assessment of typical local construction materials and methods. Structures should be built at ground or first floor level and be accessible from the existing house. The finished floor level of the new toilet facility must have sufficient freeboard above the designated flood level to prevent ingress of floodwaters, regardless of whether the existing house floor is lower than this. Layout and location of a new toilet will be determined, and the area physically marked out with the household followed by an engineer's review of constructability and potential risk (e.g. existing fragile structures or poor ground conditions).



5.2 Pressure sewer

Blackwater from toilets flows by gravity to a pressure sewer system. The system consists of a pressure pod (rotomolded tank containing a grinder pump, level sensor and float switch), a specialised smart control system (OneBox) and a OD40mm HDPE pipe connection from the pod to the discharge point (the next step in the treatment train, typically a communal septic tank). The tanks are constructed of rotationally molded polyethylene (minimum thickness 8 mm). The pressure pod components and OneBox are configured and supplied by South East Water, a state government-owned water utility based in Melbourne, Australia.

A pressure sewer system has the advantage of not requiring fall for gravity flow and uses small flexible HDPE pipes that can be laid with minimum excavation to transport sewage to the desired location. Central control of the pump operation via smart technology enables the scheduling of the delivery of sewage flows and sends alerts when issues are identified.

Throughout the treatment train pumping is kept to a minimum, with a design target to pump once from the pressure pod, and positioning the remainder of the treatment train (i.e. septic tank and wetlands) within the landscape so as to provide gravity fall from the septic tank, through the wetlands and to final discharge point.

For RISE in Makassar, the pressure pod components used are the same as those used throughout South East Water's servicing area in Melbourne, Australia, which have been extensively tested and refined over the past decade. Over time, in-country manufacturing capability could be developed and some components of the pressure pod could be manufactured locally if there was sufficient market demand.

Key design considerations for pressure sewers

The number of households connected to a pressure pod will depend on community preference, project budget, and estimates of inflow volumes. A group of households connected to a single pressure pod is defined as a 'cluster'. A cluster may contain 1 - 7 households. Households within a single cluster will be in close spatial proximity to each other, and ideally have strong social bonds. A



Typical installation of pressure tank for domestic sewage discharge



Manhole within a new road containing the pressure tank: part of a newly installed pressure sewer network

maximum of 45 people per cluster has been selected in Makassar to provide an appropriate level of buffer storage for incidences of pump failure or periods of power disruptions.

An estimate of inflow volumes should be used to ensure each tank has sufficient buffer storage, so as to avoid overflows in the event of a short power failure. As a guide, a design storage time of 24 hours has been selected for systems in Makassar, in line with typical designs for Australian pressure sewer systems.

In areas where power outages are expected to be longer than 24 hours, Buffer storage time can be adjusted based on an analysis of response times and risk, undertaken in collaboration with local authorities responsible for the long-term operation and maintenance. A design response should be developed together with relevant responsible agencies. In such context, responses include (i) providing an additional shallow overflow tank to increase storage capacity and/or (ii) developing an emergency response plan with local authorities to ensure portable generators are available. A portable generator can be connected to the system relatively easily to engage the pump during long power outages.

A high-level alarm via email and/or text message (SMS) will be sent automatically to the agency or person/s responsible for maintenance to provide advance warning of an overflow event. The available (450 L) buffer storage should provide sufficient response time in advance of overflows.



In areas with a high water table, or in areas subject to flooding, tanks should be installed with a concrete ballast to prevent tank floatation. Tanks are either vented through the lid or, in areas known to be flood prone, via an external snorkel to prevent floodwaters entering the tank. Provision should be made to direct overflows to the local stormwater drains in the event of surcharge, to minimise the likelihood of human contact.

Pump energy consumption

The pressure pod requires 240V single phase power supply with a single, dedicated 20Amp circuit and pump isolation switch. Consultations with residents, government stakeholders and the electrical company are required to determine the most appropriate connection points for the power source.

Energy consumption is based on pump run times. The 0.75 kW pump has a low power consumption. Assuming 6 households are connected to a single pump, with a total of 720L/d discharging to the tank, the pump will run for around 20 min a day with an expected energy consumption of approximately 0.25kWh. This power demand is roughly equivalent to boiling a bench top kettle twice each day.

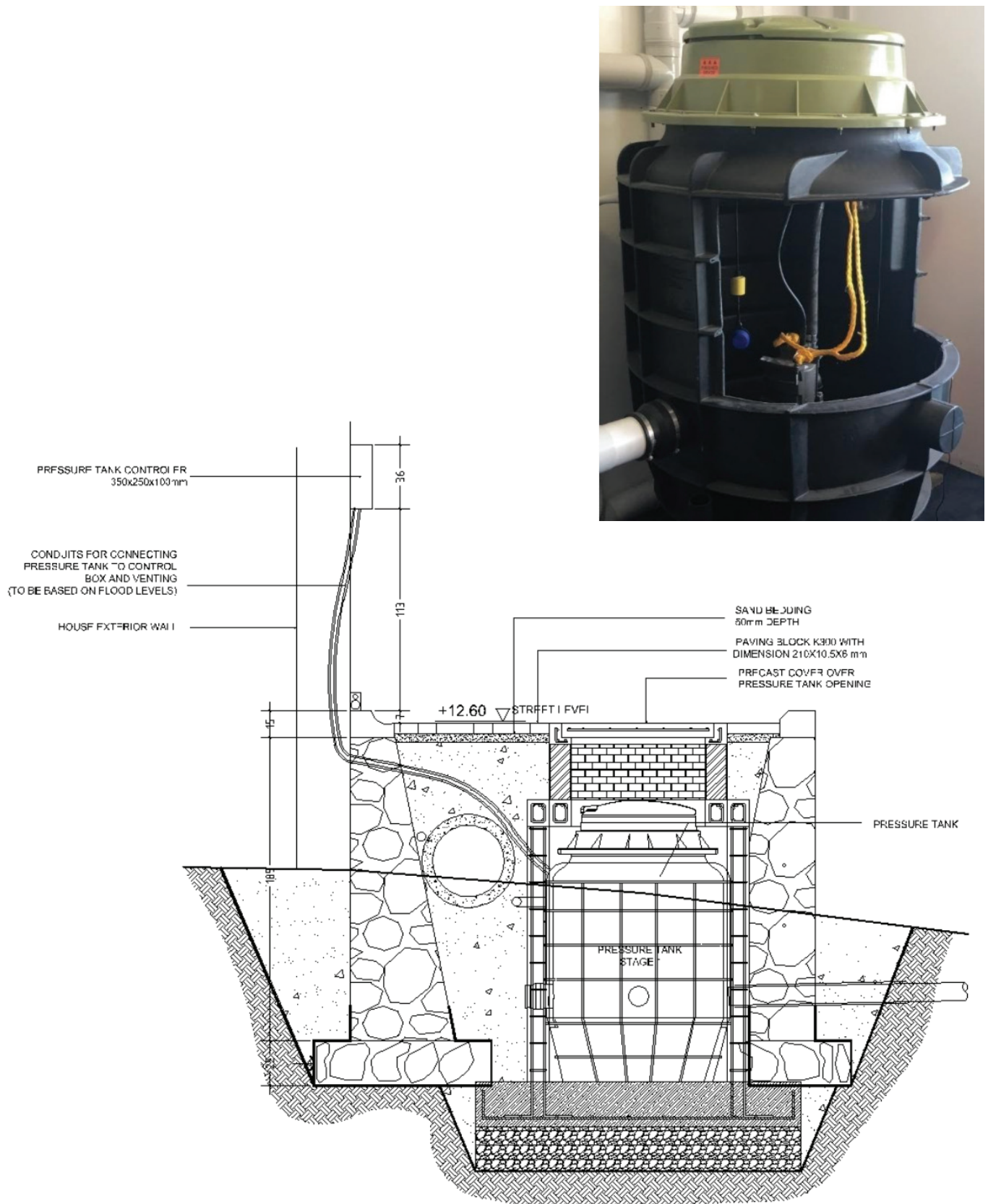
System alarms

The OneBox smart control system, connected via the 3G network, will send alarms via text and email to community members, local authorities, project team members (in the initial stages of the program) and the SEW control center in the event of: (i) pump blockage; (ii) component failure (level sensor or pump); (iii) power outage; (iv) higher than normal wastewater level within the tank. Each pressure tank has a OneBox located on a fixed structure (such as a building wall) at less than 15 metres from the tank.

Desludging requirements

The tank does not require bailing or desludging as all material is macerated and pumped to the septic tank.

A OneBox smart control system mounted to the wall of a house in Makassar, Indonesia



Sectional drawing of pressure tanks showing indicative construction details. Households connect to the pressure tank with gravity flow PVC pipes (a). An access hatch (b) enables access to the top of the pressure tank for maintenance.

5.3 Communal septic tanks

Septic tanks provide primary treatment of raw sewage. Based on traditional septic tank design and in line with national standards, septic tanks in the WSC approach include two compartments to promote the settling of solids and separation of fats and oils, prior to secondary and tertiary treatment using constructed wetlands (see section 5.4 for more details on secondary and tertiary treatment). Septic tanks are fully lined so no liquids can infiltrate into the environment. Regular desludging (every 2-5 years) is required to remove build up of accumulated sludge.

Septic tanks are typically constructed from reinforced concrete, brick or rotomolded plastic, depending on the availability, cost and local construction methods.

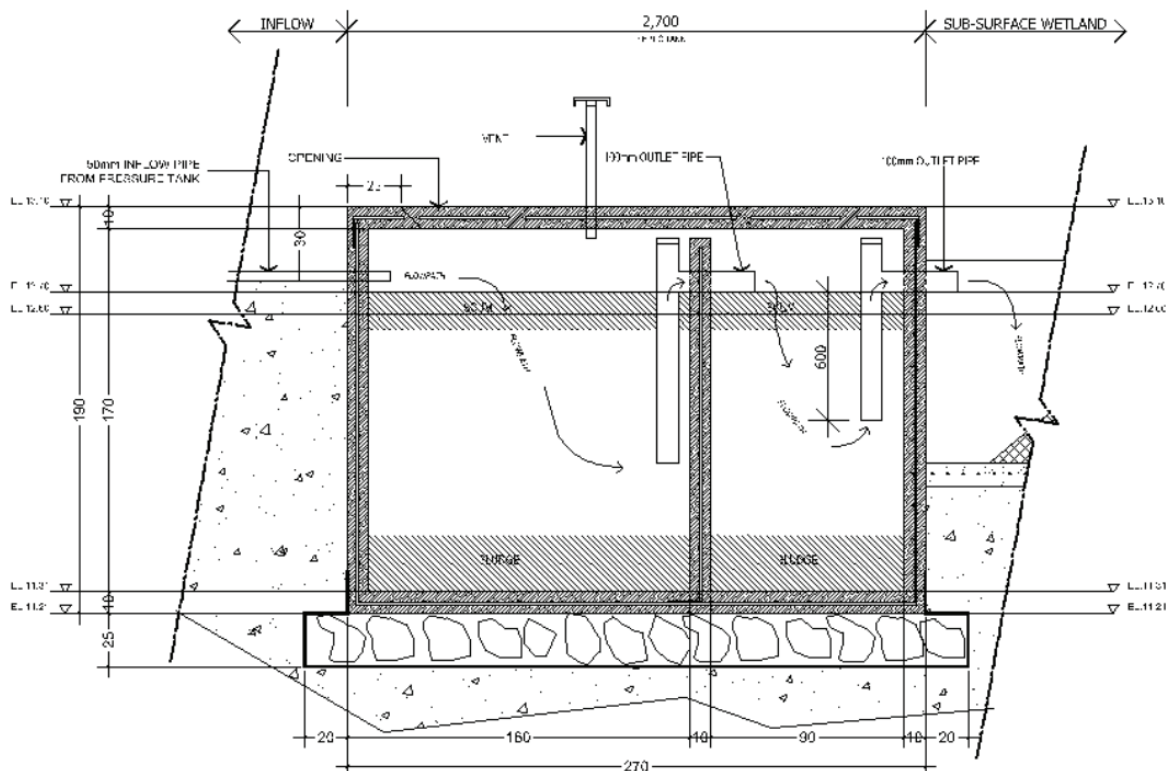
All septic tanks are connected to a constructed wetland treatment train, and may receive sewage from one or more pressure tank clusters. Depending on available space, access for maintenance, community's preference for governance and other biophysical factors (slope,

water table, stability) more than one communal septic tank may be needed, however the function and purpose remains the same with only the dimensions changing to reflect the required loading capacity.

Sizing septic tanks

Communal septic tanks should be sized for the design flow and appropriate detention time with an allowance for reduced volumetric capacity due to sludge accumulation. In line with Indonesian national standards, a blackwater design flow of 20 L per person per day, detention time of three days and a sludge accumulation rate of 30 L per person per year with desludging every two years has been chosen.

Septic tank performance is typically well understood, providing removal of solids and scum from raw sewage. It is anticipated that sludge will accumulate more slowly when septic tanks receive influent from a pressure sewer system; where solids are ground into a fine slurry. As a conservative estimate, calculations for septic tank desludging intervals and costs can be based on those of a standard septic tank.



Section drawing of septic tank in the Batua settlement. Key elements include: (a) inflow 50mm pipe from pressure tank; (b) 100mm outlet pipe; (c) vent; (d) two chambers each with access hatches to enable desludging.

5.4 Wastewater treatment wetlands

The WSC approach to upgrading informal settlements utilizes constructed wetlands for secondary and tertiary treatment of wastewater. This approach builds on decades of experience in designing, testing, piloting and scaling-up of these nature-based systems in many cities and countries, across a range of climatic conditions. They have been implemented at a range of scales: as part of the treatment train for wastewater flows from large trunk sewers, all the way down to their use with small cluster systems⁵, small communities and even single-family homes.⁶

Constructed wetlands are mechanically simple yet biologically complex, and are therefore capable of achieving high levels of treatment without the addition of chemicals or requirement for highly specialised technical wastewater treatment infrastructure. Furthermore, wastewater treatment wetlands can be constructed using local materials and local labor, which is a major co-benefit for their adoption in developing countries.⁷ Constructed wastewater treatment wetlands can treat wastewater to a sufficient standard for safe discharge to the environment and for safe reuse for non-potable purposes. Where reuse of wastewater is planned, designs can incorporate a simple post-treatment disinfection system.

There are a range of available technologies for secondary treatment of wastewater, however many of these have high operational costs or do not have the flexibility and scalability of wetlands to fit the available spaces. An infiltration field is commonly recommended for secondary treatment of wastewater discharged from a septic tank, but this solution is only applicable in areas with appropriate soil and groundwater conditions, and sufficient land area.

The WSC approach, therefore, relies on a system of secondary ('subsurface') and tertiary ('surface flow') constructed wetlands which are more appropriate given the local conditions (urban density, soil type, groundwater levels, vulnerability to flooding) common in informal settlements. Horizontal flow wetlands, rather than vertical flow wetlands, have been chosen due to their simplified inlet structure and reduced need for expert maintenance.

Biological treatment processes in constructed wetlands

The saturated subsurface wetland provides an anoxic environment to facilitate the key biological processes involved in reducing biological oxygen demand and further reducing total suspended solids (TSS). Nitrate removal via biological denitrification can also be very effective since the necessary anoxic conditions are always present and sufficient carbon sources are usually available.⁸ The use of the subsurface design also reduces the potential for human contact with secondary effluent since all effluent flows are below the surface of the gravel media (there are no areas of visible water).





In the Batua settlement, the subsurface and surface wetlands were optimized to align with the side of the new accessway. As with any nature-based technology, it takes several months for the plants to establish and reach peak performance.

The **surface (flow) wetland** provides tertiary treatment in an aerobic (oxygen rich) environment to promote further biological processing of the wastewater effluent. The aerobic conditions promote further breakdown and removal of residual biochemical oxygen demand (BOD), nutrients and bacteria.

Wetlands have a very high rate of biological activity and, as such, are very efficient at transforming typical wastewater pollutants into harmless byproducts or essential nutrients that are then available for further biological processing, such as uptake by plants. Wetlands support a wide range of processes that contribute to pollutant removal, including: (i) microbially mediated processes; (ii) chemical networks and transformations; (iii) volatilization; (iv) sedimentation; (v) absorption; (vi) photodegradation; and (vii) plant uptake.

Key design parameters

Wetlands should be designed to the standards set out in relevant design guidelines as listed. Some of the key design parameters are briefly described below.

Subsurface wetlands typically comprise inlet piping, a clay or synthetic liner, filter media, emergent vegetation, berms, and outlet piping with water level control.⁹ Larger cobbles are clustered at the inlet to reduce the likelihood of clogging. The desired detention time provided by the subsurface wetland is three days.

Surface flow wetlands typically comprise inlet piping, a clay or synthetic liner, a soil layer to support plant growth, emergent vegetation, and outlet piping with water level control. The desired detention time provided by the surface wetland is four days. Typical water depth in surface flow wetlands can vary up to 500mm, especially in large wetlands. In the smaller scale wetlands such as the one in the Batua settlement a depth of 300mm is maintained.

Plants are a critical component of both the saturated subsurface wetland and the surface flow wetland. Local plants, that are adapted to both the local climate and the saturated, high nutrient conditions, are selected. In this way, constructed wetlands can be easily adapted to many climates. The plants encourage the growth of the naturally occurring microbiological communities that are crucial in the pollutant removal processes.

Depth is a maximum 500 mm to increase the contact between the effluent and the root zone of the selected plants in subsurface wetlands. Width can be variable to the extent that uniform flow across the cross-section of the wetland can be maintained. The difference in elevations of the inlet and outlet must ensure that the hydraulic grade line does not lead to surface expression of water.

Inlet and outlet structures are simple PVC pipes with u-bends to set the water surface level within the wetlands.

Box 6: Plants – harnessing nature to reduce contamination

The selection, arrangement, and density of wetlands plants must be carefully considered when designing a constructed wetland to ensure the system meets the required performance standards.

Plants are an essential part of biofilters and wetlands, and play a key role in the treatment of water. The plants slow down and filter the water, which encourages sediment particles to break down and settle out, and increases the length of time water is in contact with the root surfaces. The plants also support slimy microorganisms called biofilms which grow on the surface of plants. The microbial communities in the biofilm break down different nutrients, such as phosphorous and nitrogen-containing compounds, carbonaceous materials as well as trap pathogens.

Maintenance of the plants is an important consideration. As with any garden, pruning can be beneficial to generate new growth, and ensuring that domestic animals do not trample, consume or damage the plants is important.

Constructed wetlands also provide opportunities for local economic development through horticultural businesses, especially for women-led initiatives. Sourcing plants for Batua was quite a challenge; a market for wetlands plants is a possibility to achieve multiple socio-economic co-benefits from a WSC approach to upgrading, implemented at a citywide scale.

The RISE program in Batua selected a range 6 of plant types that were a mix of native and introduced species. All these species were locally occurring, and some had socio-cultural values as well.

Plant establishment times in Batua were quicker than expected. It took only several months for plants to grow new shoots, likely a result of the tropical climate. This matches experience in other places in tropical climates such as Singapore.

Only certain plants have the particular characteristics required to grow in constructed wetlands and provide an adequate level of treatment. These characteristics are summarised below:

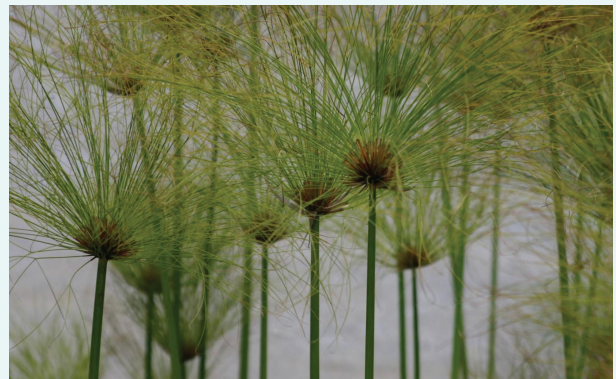
Subsurface wetlands

- ✓ have dense fibrous root systems (large root surface area)
- ✓ can tolerate/prefer permanent inundation of the root system
- ✓ have vigorous growth but are not invasive
- ✓ have limited senesce (die back)
- ✓ spread via rhizomes

Surface wetlands

- ✓ emergent plants that tolerate/prefer permanent inundation
- ✓ have clean, straight stems
- ✓ have evenly distributed stems (not clumping)
- ✓ high stem surface area (many narrow stems)
- ✓ have limited senesce (die back)
- ✓ spread via rhizomes
- ✓ mature height of at least 500mm (approximately – they need to be significantly taller than the 300mm depth of the permanent water)

In addition, a number of ornamental “accent plants” can be included for colour and biodiversity.

Box 6: continued***Schoenoplectus littoralis******Actinoscirpus grossus******Eleocharis dulcis******Cyperus papyrus******Cyperus javanicus******Canna x variety (accent)***

Examples of locally occurring plants species in Makassar with the characteristics required to grow in constructed wetlands and provide an adequate level of treatment.

Performance data

Subsurface wetlands will reliably remove biological oxygen demand (BOD), chemical oxygen demand (COD), and TSS. Metals are removed effectively and a one log reduction in faecal coliforms can be expected in systems designed to produce secondary or advanced secondary effluents.¹⁰ Surface flow wetlands remove residual BOD, nutrients and bacteria. The typical pollutant removal performance of subsurface and surface flow wetlands is illustrated in Tables 1 and 2 (data from US EPA tests of functioning wastewater treatment wetlands).

TABLE 1. SUMMARY OF PERFORMANCE FOR 14 SUBSURFACE FLOW WETLANDS SYSTEMS. SOURCE: US EPA (2000).

Constituent	Mean influent mg/L	Mean effluent mg/L
BOD5	28** (5–51)***	8** (1–15)***
TSS	60 (23–118)	12 (3–23)
TKN as N	15 (5–22)	9 (2–18)
NH3/NH4 as N	5 (1–10)	5 (2–10)
NO3 as N	9 (1–18)	3 (0.1–13)
TN	20 (9–48)	9 (7–12)
TP	4 (2–6)	2 (0.2–3)
Faecal coliforms (#/100 ml)	270,000 (1,200–1,380,000)	57,000 (10–330,000)

* Mean detention time three days (range 1–5 days)

**Mean value

***Range of values

TABLE 2. SUMMARY OF PERFORMANCE OF 27 SURFACE FLOW WETLAND SYSTEMS. SOURCE: US EPA (2000).

Constituent	Mean influent mg/L	Mean effluent mg/L
BOD5	70	15
TSS	69	15
TKN as N	18	11
NH3/NH4 as N	9	7
NO3 as N	3	1
TN	12	4
TP	4	2
Faecal coliforms (#/100 ml)	73,000	1,320

6. Greywater strategy

In most informal settlements greywater discharges either directly to the environment or, in more established settlements, to a network of open stormwater drains and canals that ultimately discharge to the environment without treatment. This poses a significant exposure risk for residents and - because of the high density of urban areas - significantly degrades the natural environment and ecosystems which do not have the carrying capacity to absorb these high nutrient and chemical loads.

Separating greywater and blackwater

As discussed in Section 4, the preference is to combine greywater and blackwater together in one treatment system. National standards recommend combined primary treatment in a septic tank followed by an infiltration field, vertical flow filter or vertical flow constructed wetland.¹¹ However, it is often problematic to implement these systems in dense, informal settlements.

Therefore, where the available space does not permit the full consolidation of blackwater and greywater, greywater can be managed separately. A simple option is to collect and treat greywater separately for each house.

Where space is particularly limited, communal greywater treatment along drainage lines can be provided. Greywater drainage can be consolidated with stormwater drainage along minor drainage lines. Treating greywater separately will ensure that the detention times for the treatment of blackwater are not compromised.

In Indonesian informal settlements, greywater treatment is best managed near its source, and at the household or cluster (2-7 houses) scale. Residents are responsible for the ongoing operation and maintenance of the greywater treatment systems. The treatment systems chosen must be technically simple, yet robust with little to no ongoing operational costs. As a priority, the system should collect and remove contaminated greywater from the area immediately around the house in order to reduce the potential for human contact, avoid odour emissions and reduce areas of stagnant water which can provide breeding sites for mosquitos.

Pre-treatment to remove oil, grease and grit should be implemented as a minimum before discharge. Greywater treatment and reuse at a household scale (i.e. for watering plants) may be possible and will depend on the individual household's willingness and capacity to operate the treatment system. Greywater treatment on a larger scale (multiple households) will primarily focus on providing pre-treatment to remove oil, grease and grit, followed by a minimal level of secondary treatment using planted gravel media beds.

Greywater discharging into a local roadside drain in Makassar Indonesia



6.1 Greywater collection

At an absolute minimum, greywater from each house should be collected and safely transported to the nearest drain. This will reduce contamination in and around houses that occurs as a result of continued, uncontrolled greywater discharge. While not an optimal solution this will go some way towards reducing human exposure to contaminated greywater in settlements where more substantial treatment solutions are simply not possible.

This involves working with all households to identify greywater discharge volumes and locations, providing them with a PVC pipe to install in order to collect and transport greywater flows to the nearest drain. This will remove stagnant, dirty greywater from around and under the house. Some minor works may be required at household level to facilitate this connection. A community-based approach can help achieve these connections and ensure ownership over the pipework to improve their operation and sustainability.

These minimal works will provide the benefit of removing contaminated water from immediately around houses. The ideal treatment train for greywater would also include the provision of a grease trap, followed by secondary treatment using a vegetated biofilter, either at the individual household scale, or in communal biofilter drains, as described below.

6.2 Grease traps - primary treatment

Wherever possible, an external household grease trap should also be provided to remove oil, grease and grit to reduce blockage frequency in downstream pipes, drains and treatment systems. Grease traps have a small footprint, can be installed externally below ground, and can be oversized to improve grit removal and reduce desludging frequency.

6.3 Biofilters - secondary treatment

Biofilters are a proven technology to effectively treat greywater. Biofilters use natural biological processes, primarily driven by soil and plant microbiological processes, to remove pollutants from stormwater and greywater. Plants are critical for maintaining the porosity of the filter media and the long-term pollutant removal

performance. Biofilter technology is used extensively around the world. In global technical literature, biofilters are also referred to as bioretention systems, bioswales and raingardens.

The WSC upgrading approach includes two main biofilter options. They have largely the same bio-physical function and performance standards but vary in their size: (i) household-level biofilters, and (ii) community-level biofilter drains and swales.

Household-scale biofilters for greywater treatment in Fiji (top) and Indonesia (bottom)



Key design parameters include:

- ✓ Screening – a removable screen filter to provide initial removal of large organic solids to be disposed of in the trash (kitchen scraps etc.) or buried;
- ✓ Depth – 600 mm media depth to maximise contact between pollutants and the plant root zone;
- ✓ Plants – local plants with dense root system that can cope with saturated root zones and are known to thrive in the local climate;
- ✓ Filter media - coarse to very coarse sand, with a sufficiently high infiltration capacity and able to support plant growth

The expected pollutant removal preference of biofilters for greywater treatment includes a reduction in flow concentrations of phosphorus by 90 per cent¹², nitrogen by 80 per cent, suspended solids by 80 per cent, and biological oxygen demand by 90 per cent.¹³

Household-level biofilters

Household-level biofilter technology can be used to treat greywater, reducing the hydraulic loading on the blackwater treatment wetlands, as described in the previous section. This technology includes a small domestic biofilter to treat greywater from an individual house. The design includes both a grease trap for pre-treatment, and dual tanks with both anaerobic and aerobic stages for secondary treatment.

Household-level biofilters should be sized for the design flows with adequate surge storage capacity. In Makassar, Indonesia, typical greywater generation is estimated to be 50 L per person per day with a peak flow of 10L per minute.

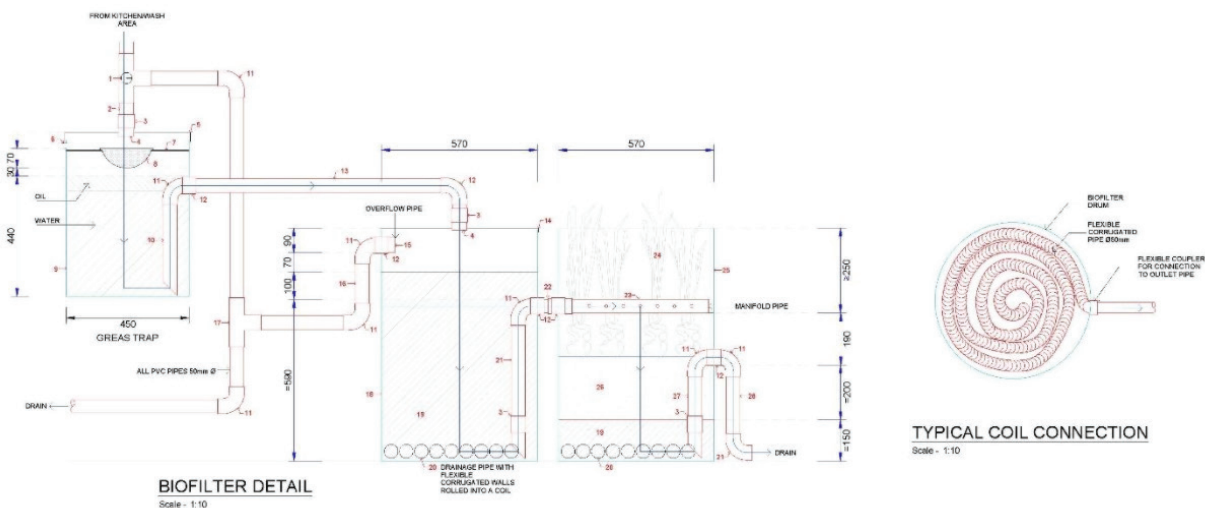
Biofilters should be constructed of locally available materials. In Makassar, a pair of 200L plastic drums house the filter media and plants.

Biofilter drains and swales

In cases where household-level biofilters cannot be used (e.g. where there is insufficient fall from greywater discharge points, or insufficient space on individual plots), a communal biofilter drain or swale can be applied.

Biofilter drains/swales are linear treatment systems that should be integrated into the existing streetscape. They are applicable in areas where limited head is available between the household point of discharge and the receiving drainage system. Upstream pre-treatment (via a grease trap) should always be included.

Biofilter drains/swales contain a layer of filter media (minimum 300 mm) that is planted with wetland plants. During dry weather, greywater percolates through the filter media and is treated as it comes into contact with the plant roots. Freeboard above the filter media allows for stormwater conveyance during wet weather flows. Detention times are variable depending on the length of the drain and the number of houses connected. Biofilter drains/swales are suitable in areas with gradients of up to 5 per cent (to avoid high velocities).



Sectional drawing of a household-scale greywater biofilter showing indicative construction details.

7. Water supply strategy

A WSC approach to upgrading aims to deliver fit-for-purpose, affordable, and environmentally-responsible water supply. Reducing water scarcity and vulnerability, strengthening resilience through the diversification of water supply sources, and improving water affordability for informal settlement residents is a priority. There is also a drive to ensure environmental protection and safeguard the quantity and quality of precious local and regional groundwater sources.

Cities are increasingly adopting 21st century approaches to water management that go beyond conventional models of centralised reticulated supply intended for all water uses (drinking, bathing, washing, etc.). These water-sensitive approaches include harnessing the water resources and natural water cycles within municipal, catchment and regional boundaries and utilising and managing rainwater, stormwater, groundwater and recycled water for better effect. These same principles of harnessing multiple water sources, increasing water resilience, and working with natural water systems can be adopted to build greater resilience in water supply in urban informal settlements by promoting multiple, diversified, fit-for-purpose sources of water.

In most informal settlements, a variety of water sources are currently used to meet household daily water demands. These are generally split into those used for drinking (potable) and those used for non-potable activities. Having access to multiple water sources can play an important role in increasing the resilience of communities during periods of water scarcity and reducing household bills by reducing municipal water or filtered bottled water usage. Households also benefit when they can access water from sources that are differentially vulnerable to climate-related hazards. (e.g. extreme weather events).¹⁴

Many informal settlements have the potential to increase rainwater collection capacity and utilise recycled water (both greywater and blackwater) as a way to diversify existing water sources without burdening households and water service providers with additional costs.

Effluent from constructed treatment wetlands (described in previous chapters) is expected to reach sufficient quality for discharge to the environment. It can also be considered for reuse for non-potable purposes (e.g. toilet flushing, garden watering etc.), however may require further treatment (disinfection) prior to reuse.

7.1 Water supply: principles of practice

With a wide variety of socio-technical options available, and considerable diversity in the conditions in informal settlements, the WSC approach includes a number of higher-level principles that outline the overall ambition for water supply and can guide technical decision-making. These include:

- ✓ promote and preserve a diversity of water supply sources, in line with best practices for increasing climate change resilience and improving affordability for households;
- ✓ promote and facilitate connections to potable (municipal) reticulated water supply where possible. This could include supporting the communities and households to apply for a connection and/or providing a settlement reticulation system;
- ✓ harness rainwater to the greatest extent possible to reduce pressure on other sources;
- ✓ ensure sustainable management of groundwater resources in cases where over-extraction is likely occurring; avoid further depletion of groundwater sources by not constructing new bores or shallow wells except in the case where it is to replace or relocate an existing structure;
- ✓ adopt demand management strategies (provision of water efficient appliances and a fit-for-purpose approach to water use) where appropriate;
- ✓ consider future reuse of wetland effluent in the design of new infrastructure;
- ✓ improve existing water sources and their use to improve the health and dignity of residents (i.e. provide each household and/or cluster with a proprietary disinfection treatment system for low quality water sources in order to bring it to potable water drinking standards; provide concrete upstands, well rings and

improved drainage to unlined/unprotected shallow wells; provide information on the risk hierarchy for different water sources and safe water management advice).

Importantly, in developing and finalizing any design response, the following two factors need to be taken into consideration: (i) an assessment of existing water sources, including a snapshot of the likely water quality of each source and how it is used by residents, and understanding of the sustainability and long-term viability of each source; (ii) ensure that existing water supply demands can continue to be met, even where existing water supply options are less favourable (i.e. groundwater extraction). These two factors are essential to ensure that no resident is worse off as a result of a water-sensitive upgrading project and that the **intervention** is fit-for-purpose, based on local conditions, and builds on existing practices.



7.2 Connection to reticulated supply

Where available, preference should be given to providing connections to the formal reticulated water supply network (often provided by municipalities or water service providers). A WSC upgrading project should work with local governments to identify where access to the municipal water supply network is currently available, or is likely to become available in the future. These connections should ideally be included in the project, or at a minimum, the design should allow for future connections through the provision of servicing trenches or installation of the supply pipeline.

The three design options for reticulated supply include:

- ✓ Connection now – collaborating with water providers to provide a reticulated water supply to each household where it is available;
- ✓ Provision of a pipe network – where reticulated supply is likely to be provided in the near future (i.e. one to three years) a network of water supply pipelines throughout the community should be included in the design;
- ✓ Provision of servicing trenches for future connection – typically services are provided by households and are laid across the settlement in an ad hoc fashion making subsequent operation and maintenance difficult since location of services are not clearly marked (especially when buried). Services are also informally laid in drainage lines, introducing a risk of contamination through leaky pipe networks. Formalising the servicing of trenches allows for ease of connection in the future (not only for water supply but also other services, without severe disruption to new infrastructure).

Typical water supply sources in Makassar, Indonesia. Water from communal shallow wells is often used for non-potable uses, but also sometimes for drinking (top) and bottled water delivery (bottom).

7.3 Rainwater harvesting

Harvesting rainwater for non-potable domestic uses has multiple benefits and is one of the most cost-effective interventions to improve water access in informal settlements. For households, rainwater harvesting can: (i) reduce household water bills; (ii) improve resilience through diversity of supply and (iii) reduce localised nuisance flooding around the house and settlement.

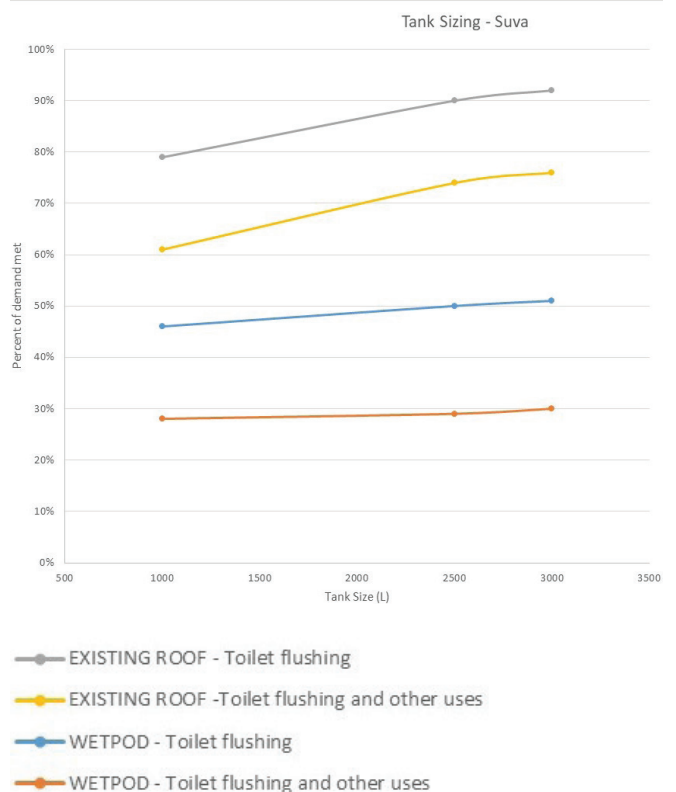
For cities and ecosystems rainwater harvesting is beneficial for a number of reasons, including: (i) increase city-wide resilience to changes in climate through increased diversity of water supply sources; (ii) reduce demand for potable mains water, which can significantly delay the need to upgrade mains water supply networks and treatment plant capacity; (iii) reduce infrastructure operating costs associated with supplying potable quality mains water; and lastly reduce nitrogen loads in local waterways and bays.

In informal settlements, rainwater tanks play an important role in diversifying water supply options for households to increase the resilience during periods of water scarcity. They also provide a critical water supply source in settlements where the municipal supply is not available.

For households where a new private toilet facility will be installed, the new roof area will be plumbed to the rainwater tank. In addition, wherever possible, existing dwellings will be retrofitted with gutters and downpipes (using locally available materials) to increase the roof catchment area for the rainwater tank. Where reticulated water supply is available, a simple interchange device (manual or automatic) can be installed to ensure a continual supply of water is available. To the extent possible, the tanks will be sealed to reduce the incidence of mosquito breeding. A tank overflow to the drain should be provided.

Sizing of rainwater tanks

Rainwater tanks will be sized based on the available space, calculations of daily rainfall volumes, roof area and daily fit-for-purpose water demand to ensure efficiency in the tank size selection. Residents will be given flexibility on how they choose to use the tank. In Makassar, for example, some residents decided to use tanks as buffer storage where they have intermittent reticulated supply.



A rainwater tank supplied to a resident in the neighbourhood of Batua, Indonesia to increase the diversity of household water sources (top) and a typical rainwater tank sizing curve used to optimise tank size based on expected usage volumes and catchment (roof) area (bottom).

7.4 Sustainable management of groundwater resources

Many informal settlements rely on groundwater for their daily water needs, either through deep and/or shallow wells. For example, groundwater is a source of water for 30% of the population in the city of Makassar. The use of groundwater is largely unregulated and information and water quality data is limited. There is little data to understand how much groundwater is being taken and the long-term impact on groundwater availability over time.

Population growth and urban development deplete groundwater resources and reduce groundwater recharges. This will be exacerbated by deterioration in the quality of groundwater resources due to sea water intrusion in coastal areas and contamination from domestic wastewater in urban areas.¹⁵ Despite groundwater being a vulnerable source, given its quality and continued decline due to over-extraction, in many informal settlements it remains a critical source for many non-potable activities – sometimes with very few alternatives.

A balance should be sought between the overarching goal of sustainable groundwater management while acknowledging that existing groundwater supply sources (private bores and shallow wells) will continue to be an important source in the short- to medium-term for residents of informal settlements. Where groundwater depletion and poor quality cannot be mitigated by groundwater recharge programs, the following steps are recommended: (i) Provide concrete upstands, well rings and improved drainage to existing unlined/unprotected shallow wells; (ii) Provide a means of household level disinfection to limit risks associated with this source; (iii) Raise community and household awareness of the health and environmental challenges associated with groundwater use.

7.5 Disinfection of existing water sources

Point-of-use disinfection can be a viable option to protect human health when faced with limited resources and options for providing potable water in the immediate term. While point-of-use disinfection can be part of a comprehensive solution to achieve the immediate goal of improving public health and wellbeing while longer-term technologies and potable water connections are implemented. There are a range of options available on the market that are efficacious in treating water. Options include household scale or family cluster scale treatment devices, for example hollow fibre filtration (Vestergaard LifeStraw Family 2.0 or equivalent) and membrane ultra filtration (Lifesaver Jerrycan or equivalent).

Key considerations in selecting the type and scale of disinfection are: (i) feedback during co-design with the community on the preference for household or family cluster scale interventions; (ii) the degree of variability and seasonal changes in water supply sources that require disinfection; (iii) the preference for a disinfection solution is based on ease of operation power, requirements, rates of disinfection and storage times between disinfection and use.

7.6 Water supply demand management

In countries where most households have access to piped water supply, demand management forms a critical part of a holistic approach to city water supply strategies. Strategies can include providing water efficient fittings, educating on water use and encouraging people to reduce potable demand, and encouraging a fit-for-purpose approach, including using rainwater and stormwater or recycled water for toilet flushing, washing clothes, irrigating food crops and other non-potable activities.

8. Drainage strategy

Flooding and poor drainage are key challenges facing urban informal settlements as these areas are often located on marginal, low-lying land. The socio-economic impacts of seasonal flooding, extreme weather events, tidal inundation, and poor drainage are significant, and disproportionately impact women and girls and vulnerable residents living in informal settlements.

Flooding redistributes contaminated soils and water across settlements which contributes to poor health outcomes, especially when residents have no other option but to wade through floodwaters to access their homes. Flooding and extreme weather events can cause significant economic damage to houses and property. Climate change is projected to exacerbate the challenges associated with flooding and extreme weather events, making the need to improve drainage in urban informal settlements even more urgent.

A WSC upgrading approach aims to manage stormwater and floodwater in a way that reduces the negative impact on settlement residents, downstream households within the catchment, and on the environment. The drainage strategy should be informed by an understanding of stormwater management and flooding management/mitigation at a range of cascading spatial scales, including the catchment, precinct, and settlement.

8.1 Flood management and drainage design

In order to reduce the negative health impacts of flooding, a drainage and flood management strategy should be developed for each settlement with the overarching objective of limiting human exposure (particularly physical contact) with floodwater and avoiding damage to buildings and household assets. This should include the following steps: (i) detailed site assessment, (ii) hydrologic and hydraulic analysis, (iii) local knowledge input, and (iv) selection of interventions.



Flooding during the wet season in the neighbourhood of Batua, Indonesia

Flood modeling and data sources

Flood inundation within many of informal settlements is influenced by a combination of pluvial, fluvial and coastal flooding. A detailed site assessment should be undertaken to guide appropriate decision-making on the types and hierarchy of interventions required for each settlement. Catchment areas should be mapped using topographic information which can be obtained using a combination of drone survey, feature survey, lidar data or Google maps information. Site walkovers can subsequently verify catchment areas and flow paths. Ground conditions (e.g. profile, strength and infiltration capacity) should be understood and verified through testing. Where available, local rainfall data should be obtained from a nearby weather station with regular measurements of preferably 15 minutes to 1 hour intervals for a period of 20 years or more. Where this information is not available; local daily rainfall, existing Intensity Duration Frequency (IDF) curves or global rainfall data sets can be used but these are generally considered less accurate. Where available, local tidal data can be obtained from a nearby tide station or a tidal survey may be required.

Analyses often need to be undertaken in data-poor environments and therefore expert knowledge is required, particularly in the selection of modelling assumptions. Hydrologic and hydraulic analysis should be undertaken to understand existing flow paths and network capacities. In some cases, a one or two dimensional flood model may be developed to better understand how water moves within the environment during flood events. Where reliable data is available, river basin scale modelling can also be undertaken but these types of models are time-consuming and require significant resources to develop and calibrate.

The importance of local knowledge

Local knowledge is an additional powerful source of information which can be used alongside traditional engineering analysis. Anecdotal and visual observations can be obtained during co-design to better understand local flood history, impacts, coping strategies and construction techniques. While anecdotal evidence may be fragmented and lack consistency, it provides an important contribution to the verification and diversification of

information sources. Drainage interventions should be planned, marked out, and co-designed with residents who will play an important role in its operation and maintenance.

Managing catchment-scale flooding

Low lying sites that experience flooding are impacted by contamination from both within the settlement and from upstream sources. For many informal settlements, localised interventions will not be able to address severe flooding issues as these require a watershed or catchment-scale response and potentially large scale, costly infrastructure solutions. In these cases, interventions should focus on works that enable the site to drain effectively following flood events, elimination of residual localised ponding of floodwater, community resilience and response, coordination with local and provincial water authorities, and link drainage designs and strategies to broader catchment and precinct level interventions.

Infrastructure to manage flood impacts and improve drainage

The type of WSC upgrading interventions that should be considered:

- ✓ designated raised pathways to reduce human contact with floodwaters
- ✓ a network of drains and subsurface drains including works to upgrade existing drainage
- ✓ low level flood barriers to prevent floodwaters entering households
- ✓ backflow prevention (flood gate, flood valve)
- ✓ check dams for steep drainage to control flow and reduce erosion
- ✓ soakaways or infiltration devices
- ✓ localised fill of low lying depressions, where natural flow paths have been cut, off to reduce long term ponding (this should be considered against any potential to reduce flood storage capacity)
- ✓ rainwater harvesting
- ✓ raising of existing toilets to achieve freeboard above regular flood levels

Drainage design standards

Drainage design standards vary depending on land use and economic risk assessment. A suitable average recurrence interval (ARI) should be chosen based on the impact caused by above-design events. In urban slum/informal environments with poor existing drainage and comparatively low economic risk associated with frequent inundations, a two-year ARI design standard is likely to be appropriate and commensurate with such considerations as community affordability and practicality.

Blackwater treatment systems and flooding

The blackwater system should be designed to function during regular flood events by placing the septic tank and wetlands above the designated flood level and ensuring that the gravity and pressure system is well sealed. Wetlands and biofilters will tolerate some level of flood inundation but this should be minimised to only extreme flood events. The lid of the pressure tank should be sealed and an external snorkel provided to vent above the designated flood level.

Box 7: Weather Warriors - citizen science flood tracking

Throughout 2018 and 2019 the RISE team worked with RISE's informal settlement residents in Makassar, Indonesia and Suva, Fiji, to begin crafting a systematic data collection framework to document water level variations using photos taken by community members. The RISE Design & Engagement team decided that flood gauges needed to be staked in the ground across seven informal settlements in Makassar and six in Suva. The aim was to gain a more accurate understanding of water flow and levels, to eventually inform the design of RISE's infrastructure intervention.

A group of enthusiastic and engaged community members led the RISE team around, showing them where to position the gauges based on their own experiences with flooding. In Fiji, these residents came to self-identify as the *bati ni draki* – or 'Weather Warriors'. In Indonesia they became the

KePoAir, the 'Water Monitor Group'. Ibu Jannah has lived in Kampung Ce'de settlement for 12 years and put her hand up to join the Water Monitor Group for her community.

The dedicated RISE Indonesia and RISE Fiji teams were instrumental in coordinating the groups, and were committed for them to be as diverse as possible to reduce the burden on women and the elderly. Community members, like Ibu Jannah, were trained to take frequent photos of the flood gauges with their smart phones, and send them to the RISE team, via internet messaging. By the end of the rainy season in 2020, the residents in Fiji and Indonesia shared more than 5,000 photos with the RISE team. Of those, more than 500 photos provided researchers with water level references documenting the floods experienced by the communities in 2018, 2019 and 2020.



A resident, and KePoAir member, records the water level by taking a photo of the local flood gauge in Makassar Indonesia"

9. Access and open space

Open spaces are the areas around the neighbourhood that are freely accessed and used daily by the community for social, cultural and economic activities. These include access routes, shops, places of worship, areas of agricultural production, security posts, communal water sources and places for social interaction and relaxation, etc. Open spaces and shared accessways carry significant social-cultural values for men, women and children, strengthening community cohesion and sense of identity.

Access routes provide important spatial linkages within neighbourhoods and safeguard livelihoods. They are also important spaces for infrastructure such as piping, wetlands and drainage services. Formalisation of access routes (by way of physical upgrading and tenure strengthening) is often a high priority among residents, particularly the most poor and vulnerable who are

often those least served by formal access networks, or have intermittent access as a result of hazards such as flooding or pollution. Physical upgrading can have the co-benefit of improved community safety, access security and reduced exposure to contamination in the surrounding environment.

The design and management of open spaces can affect the way people experience and use their local environment. The WSC approach incorporates the principles of placemaking, a collaborative, community-led approach which pays particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution. Through a co-design process, residents are asked to identify positive and negative elements of their environment and visualize how these spaces can be re-created. New or upgraded infrastructure elements are marked out by residents in response to the existing use of space and the technical requirements of the infrastructure. Once elements have been located, the choice of details, materials and finishes can further enhance function, enjoyment, and safety.



Residents in the Batua neighbourhood meet with the local fishmonger outside their house, on the newly constructed road which incorporates constructed wetlands into the road design

Urban informal settlements are typically very densely developed with little or no existing public space. As such, most infrastructure components are located along access routes and open spaces around the settlement, on land owned by residents or neighbouring developers.

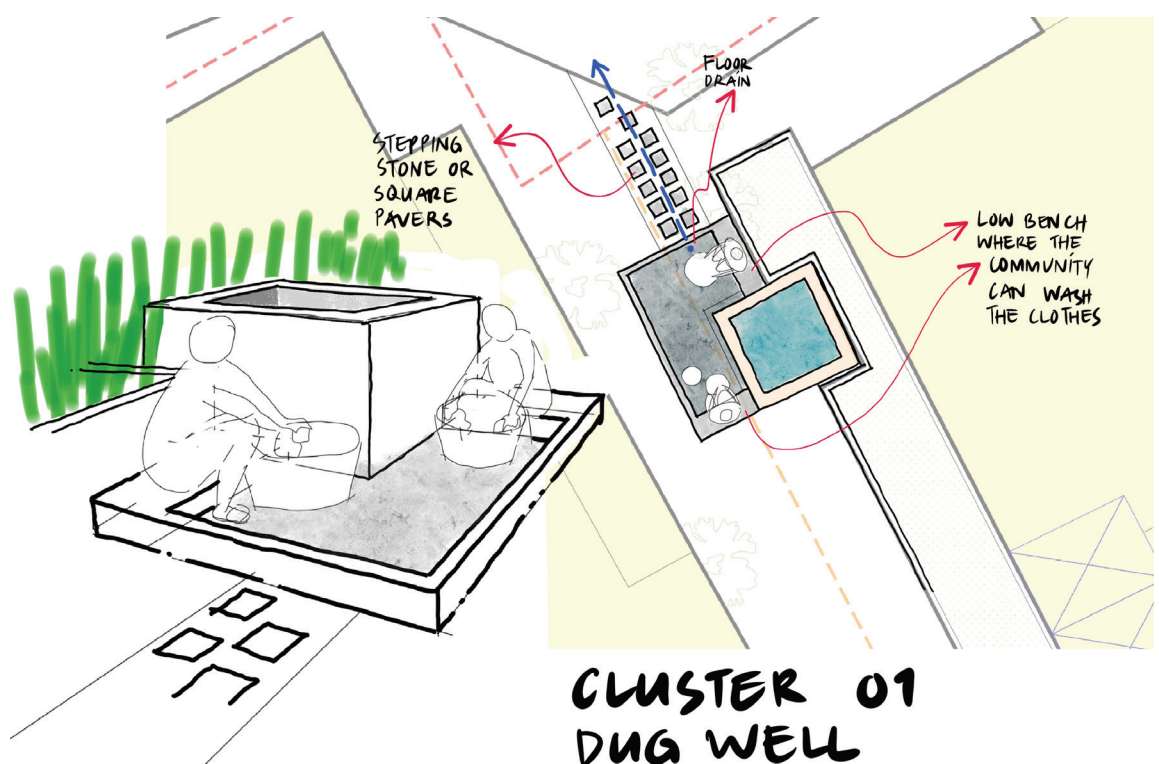
Constructing infrastructure in informal settlement can radically change the physical appearance of a neighbourhood and therefore the choice of details, materials and finishes should be carefully considered to maximise long-term success.

Key considerations when developing an open space and access strategy:

- ✓ With all residents and community members, undertake a detailed audit of existing space use, values and aspirations to feed into the design of the WSC intervention;
- ✓ Encourage increasing and formalising open space and accessways to improve mobility and urban amenity;
- ✓ Design for a diversity of space uses and functions, that can provide for the wide range of leisure, cultural

and economic activities as well as the technical requirements of the infrastructure;

- ✓ The size and scale of infrastructure should be marked out with residents to help them easily visualise and decide how it can be best integrated into the existing spaces;
- ✓ Infrastructure elements should reference neighbourhood identities and support individual customisation, in order to generate a strong relationship between people and space;
- ✓ Design for projected expansion and growth (i.e. street networks that can be extended over time);
- ✓ Ensure materials, finishes and detail choices are durable and minimise ongoing maintenance burden for communities;
- ✓ Encourage appreciation of green infrastructure by showcasing its attractiveness and adaptability for open space design and potential co-benefits such as improved wellbeing and urban heat island cooling effects.



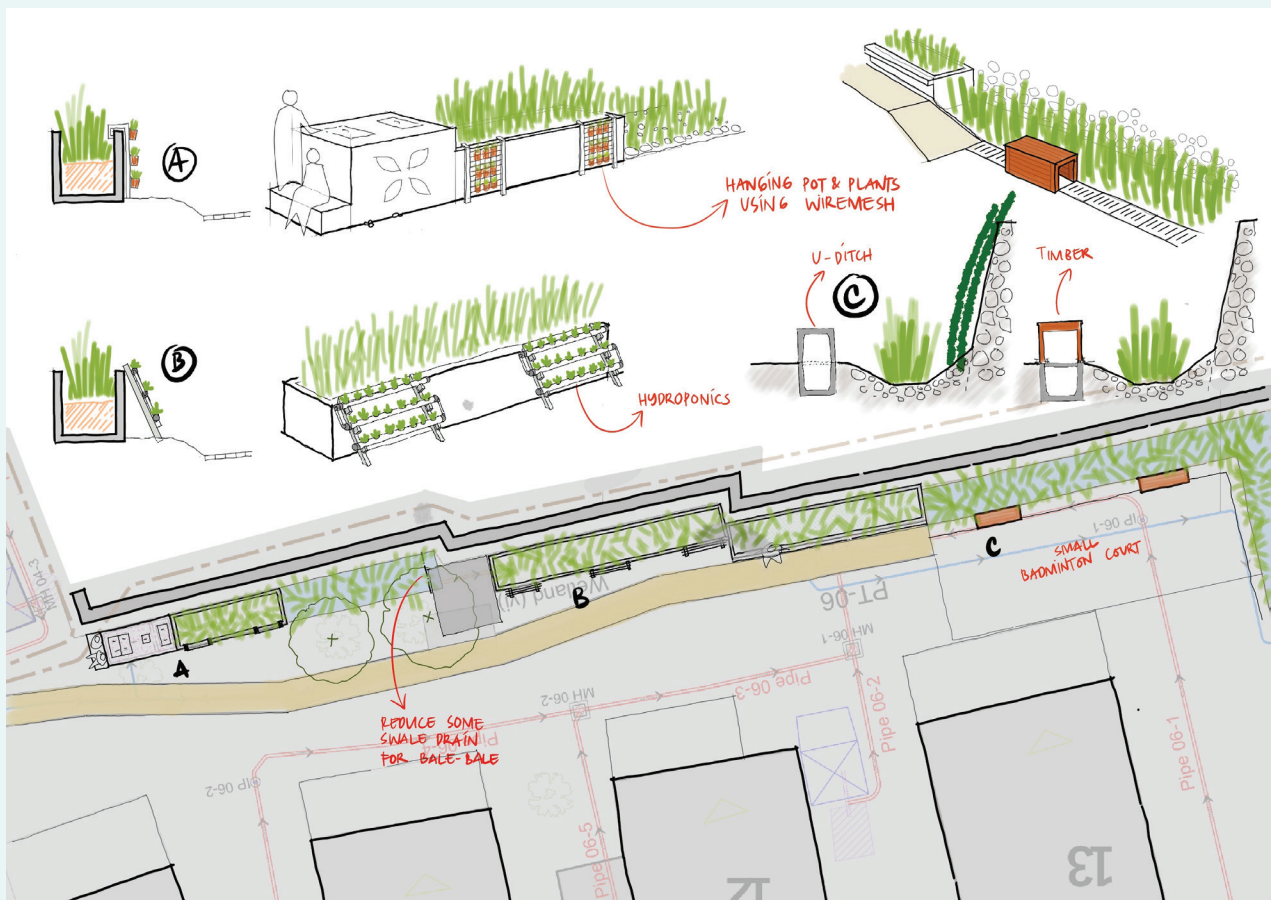
Sketches of architectural designs which incorporate the principles of placemaking and a collaborative, community-led approach to the design of water infrastructure upgrades

Box 8: Creating liveable cities through water-sensitive placemaking

The Community Map, developed through the Panrita process, records the important community spaces within the neighbourhood, such as bale-bales for social gathering or wide accessways that allow for passing of motorbikes or carts (pa'gandeng). This map acts as a guide for the location of infrastructure, reflecting which spaces should be preserved, as well as identifying opportunities to address problems and deliver co-benefits. Wetlands were seen as a valuable asset to the community and in many cases residents requested to have both improved accessways as well as wetland infrastructure located on or nearby their land. Wetland locations were selected by the community based on their perception that the wetlands provided an opportunity to

clean up the environment, create more usable open space and improve the existing aesthetics. In some cases the location of the wetlands also formalised plot boundaries or reinforced existing infrastructure (such as retaining walls) that were in poor condition.

The core aboveground RISE infrastructure elements include pavements, drains, septic tanks, wetlands and small private toilet facilities. A consistent approach is used across all six sites, with typical infrastructure elements receiving similar materials and finishes. Within each settlement, feature areas have been identified where additional elements such as seating or decoration (including coloured pavers) are used to create and define spaces and corridors to enhance the public realm, creating new and enhancing existing community gathering spaces.



10. Operation and maintenance strategy

As with any upgrading intervention, the operation and maintenance (O&M) of any infrastructure is a crucial aspect that needs to be considered from the very early stages to ensure successful local institutionalisation and long term sustainability of the infrastructure and the service it provides.

The WSC upgrading approach as outlined in this report presents unique challenges in terms of the governance requirements for O&M, as well as the technical operational requirements for the treatment train components, notably the pressure sewer system and constructed wetlands. Their installation in cities in developing countries - such as Makassar, Indonesia within the RISE program - present additional challenges regarding technology transfer given that these systems are new to such contexts and local capacities for decentralised systems need to be nurtured and developed over time.

The core **O&M principles** of a WSC upgrading approach are:

- ✓ Integrate O&M into the design of projects from their inception, rather than see O&M as something to be agreed upon during infrastructure completion/handover;
- ✓ Institutionalise O&M within formal and informal governance structures at the right level (i.e. communities can do some elements, yet more technical and expensive elements should be the responsibility of formal authorities);
- ✓ Ensure the right stakeholders are engaged and involved in co-developing a common understanding of the required capacities and skills to effectively deliver the O&M activities;
- ✓ Formalise handover of infrastructure upon completion and integrate it with other city water, sanitation, and public assets and infrastructure registries;
- ✓ Ensure an operating budget line item is allocated in future budgets of the responsible authorities for O&M expenditures.

The overall ambition of the WSC approach is to minimise as much as possible the ongoing O&M requirements for the system and its respective components. All components have been carefully selected based on their robustness and minimal maintenance requirements. Indonesian communities often undertake organised weekly activities (*kerja bakti*) on Sundays (or *Sabtu bersih* on Saturdays) that involve cleaning drains, roads and footpaths, along with clearing rubbish and vegetation which typically involve men, women and youth. It is anticipated that RISE infrastructure O&M activities will be included in this. Most of the water-sensitive infrastructure does not require considerable ongoing maintenance or any significant operating costs.

The main O&M requirements for key components include:

- ✓ The pressure tank requires regular checking and monitoring to ensure optimum operations. The pump inside the tank which grinds the effluent is a moving part that requires a source of power supply and periodic maintenance and replacement of parts.
- ✓ The septic tank requires the same periodic cleaning as a normal septic tank, for which the skills and equipment are readily available in most cities. Access for desludging of the septic tanks and removing pipe blockages should be carefully considered in the design.
- ✓ The biofilters, wetlands and swales require periodic maintenance. As natural systems they must be kept free of solid waste or other materials that may reduce their effectiveness.
- ✓ The new and renovated private toilet facilities, and rainwater tanks, do not require significant operation and maintenance. The existing skills, capacities and equipment for repairs to these components are available at the household and community levels.

Box 9: Building operation and maintenance (O&M) capacities for long-term sustainability

The RISE program in Makassar, Indonesia has been engaging with government and community stakeholders since the programs inception to discuss and agree on the division of O&M responsibilities between all parties. A range of options and modalities to address the operation and maintenance for infrastructure were generated. The preferred option is to institutionalise the technologies into the city government asset system, which would take on responsibility for the ongoing operation and maintenance of the system. The relevant authorities have been closely involved in the planning and design of the systems to enable asset transfer in the future. This includes ensuring allocation of an annual budget for operation and maintenance of any communal infrastructure.

In the short term, operation and maintenance by the RISE communities is also being advanced. As part of the PANRITA (co-design) process, residents are provided with detailed information on the system including maintenance requirements and costs. The formation of new or strengthening of existing community operation and maintenance teams (or water committees) has been suggested by communities as an effective model during early consultations with the possibility of applying for monetary assistance from government programs.

Supported by the Asian Development Bank and Urban Climate Change Resilience Trust Fund, the RISE program designed and implemented a series of structured training and capacity development sessions with local partners. These regular sessions have proved essential to building local capacity to design and implement WSC technologies in the city and highlight what is required to ensure successful long term operation and maintenance.

Training for government stakeholders and community representatives on the operation and maintenance of the green infrastructure and pressure sewer components



11. Climate change strategy

The urban poor living in informal settlements stand to suffer most from some of the impacts of climate change. Informal settlements are more vulnerable to the impacts of climate change due to their limited access to formal services, utilities and infrastructure, low lying conditions, existing and protracted service deficiencies and vulnerabilities, and limited coping capacity.¹⁶ Key climate change hazards include higher and increasing average temperatures, increasing rainfall intensities, reduced potable water availability, sea level rise, and increasing extreme weather events of regional floods and droughts, and a deterioration of ecosystem services. Upgrading interventions, therefore, need to design for resilience to climate change effects.

The WSC approach offers potential to mitigate and adapt to the major threat of climate change by:

- ✓ supporting a diversity of water supply sources within communities;
- ✓ providing disinfection technology that allows all water sources to be used for a greater number of end uses, including potable demand;
- ✓ providing treated wastewater as an alternative water source;
- ✓ in some situations, providing raised pathways to reduce flood depths in trafficable areas;
- ✓ not increasing reliance on stressed groundwater resources;
- ✓ reducing the flood frequency of existing sanitary systems and reducing the associated contamination of floodwaters.

The key areas where the WSC approach aims to achieve climate change benefits include:

Water supply

Interventions should support a diversity of water supply options, including mains water, rainwater, bottled water, deep bore water and shallow wells. Proposed water supply interventions should include providing a range of technologies to treat raw water supplies to potable standard where necessary. Disinfection technologies reduce community members' reliance on any one source for

potable water. Providing rainwater tanks creates opportunities to increase rainwater harvesting capacity and store water.

The treatment of blackwater and greywater can create an alternative water source that was previously lost to the community. Treated wastewater is suitable for use as an irrigation supply for agricultural or horticultural production and has the ability to address the potential impacts of climate change on food production.

Drainage and flood management

Improving the site drainage system and removing pockets of standing water will reduce local exposure pathways. In some locations, providing raised pathways and roads will significantly reduce flood inundation depths in trafficable areas and improve community safety, but many informal settlements, including many in Makassar, will be at significant risk of future flooding because of predicted sea level rise.

Landscape design can also provide designated floodway corridors for passage of large flood events, especially from external upstream areas, to reduce prolonged post-flood impacts.

Wastewater

Improved collection and treatment of wastewater, the introduction of new toilets, sealed septic tanks and constructed wetlands will reduce exposure to contaminated floodwaters.

Urban heat island

The planted wetlands may help increase urban greenery, which may help mitigate increasing incidents of urban heat waves to improve public amenity, liveability and the potential for heat stress. In addition they may contribute to improved biodiversity.

Solutions must be developed that reduce the impacts of climate change on vulnerable populations, including water scarcity and increased extreme weather events. These solutions must also take in to account these predicted climate impacts to ensure the solutions themselves are resilient. This includes, ensuring drainage design is appropriate given increased rainfall intensities, and ensuring sanitation infrastructure can withstand predicted future flood levels, for example.

TABLE 3. PROJECTED CLIMATE CHANGE IMPACTS ON URBAN INFORMAL SETTLEMENTS

Climate change hazards	City-scale vulnerability	Additional effects in informal settlements
Higher (and increasing) average temperatures	General exposure to extreme heat and related heat stress, particularly for at-risk populations	Worsened localised heat impacts due to compact, poor quality built form and a lack of utilities
Increasing rainfall variability and intensity, including extreme rainfall events	Stormwater infrastructure and water supply capacities limited to existing variability. Recurrent transport and services disruptions, localised damage	Impacts exacerbated due to a lack of regulatory compliance and formal drainage infrastructure. Proximity to informal water sources (rivers, springs, ocean) heightening exposure
Potable water quality and availability	Risk of utility shortfalls in supply, potable water importation needs, price spikes and expensive infrastructure investment	Limited income capacity to pay for potable water price spikes, dependencies on variable informal water sources with additional risk of contamination
Sea level rise and coastal inundation (including extreme events, eg. storm surges)	Demand for enhanced coastal defences, loss of previously insurable urban areas, long-term relocation strategies in conflict with local short-term interests and market structures	Limited options for retreat and reinforcement due to spatial and financial constraints, as well as a lack of state resourcing/subsidies. Tendency to be located in already at-risk areas, including intertidal zones. Lack of sanitation leading to secondary risks (e.g. disease)
Increasing frequency of more intense tropical cyclones/hurricanes	Building standards superseded by new return periods and intensities, heightened demand for state evacuation facilities, disruptions to urban food supplies	Direct dependency on localised food production with limited capacity to enter the cash economy. Poor quality/non-compliant housing construction. Frequent exclusion from evacuation and relief supply considerations.
Ecosystem services deterioration	Increasing demand for imported goods and pressure on peri-urban surrounds.	Widespread dependency on ecosystem services for primary or secondary income and subsistence.
Climate-induced migration	Rapid urban growth risks outpacing development planning and government capacities	Heightened pressure on informal areas outside of government housing and land release programs

Adapted from: French, M. et al (2020) Climate resilience in urban informal settlements: Towards a transformative upgrading agenda.

Appendix 1: Pressure sewer system

The pressure sewer system comprises a pressure pod (rotomolded tank, grinder pump, level sensor and float switch), a specialised digital (OneBox) control system developed by SEW, and OD 40 mm HDPE pipe connection from the pod to the discharge point (septic tank). SEW will configure and supply the pressure pod components and OneBox. SEW is a state government-owned water utility based in Melbourne, Australia.

SEW provides clean water supply and removes and treats waste for its residential and business customers. SEW is installing the world's largest pressure sewer network consisting of 16,200 connections and has undertaken extensive research and development leading to the design of the patented control system, specifically for pressure sewer to monitor the system. This is critical to the integrity of the sewer collection system to avoid spills and provide visibility of the sewer system performance. SEW also has valuable experience in pressure sewers linked to nature based solutions, including that they're trialling the use of a proprietary nature based system (not part of RISE) fed by a pressure sewer and demonstrating, via a comprehensive monitoring program, successful treatment performance in relation to effluent quality.

Iota, a commercial subsidiary of SEW, exclusively manufactures and sells the monitoring controller (OneBox ©) under licence by SEW. The other components (the tank, pump, level sensor and float switch) are commercially available from various vendors. The application of decentralised small scale pressure sewer systems is novel and the RISE Program is the first to trial and secure proof-of-concept of the water-sensitive approach to revitalising informal settlements in Indonesia. Limiting the risk of equipment failure is an essential consideration for the first batch of the interventions prior to upscaling of the solution once proof-of-concept is successfully completed.

The components that have been selected and assembled for the RISE Program are the preference of SEW after an exhaustive selection and tendering process in compliance with Victorian State Government procurement policy and which took into account value for money, including durability and ease of maintenance. The other components could be purchased separately but the OneBox currently needs to be purchased through Iota.

The cost of the complete units (including tanks, pumps, float switches etc.) takes advantage of SEW's buying power and includes a modest handling fee levied by Iota for inventory, procurement, administration etc. as a Partner Organisation of the RISE Program.

The **pumps** used are EOne Extreme series pumps. They come with a two-year warranty and a 20-year design life. SEW's first pressure sewer scheme in 2001 has about 80 per cent of pumps still in service. Over the approximate 20 years of pressure sewer operation, SEW has a 3 per cent annual maintenance response rate, with over half being blockage related (i.e., householder causes blockage rather than it being a pump failure). Blockages are easily removed with three bolts to remove cutter blades. A 1.5 per cent annual pump replacement rate is estimated.

The **OneBox controller** comes with a two-year warranty and a 20-year design life. SEW has five years of data on the OneBox controller. Controller failure rate of 1.5 per cent per year is currently average, but this is improving as failure modes are designed out. A failure rate of 1.5 per cent per year and a 15-year design life are assumed. It is too early to provide data on design life performance. Sealing of the cable entry glands is critical to prevent moisture and ant entry which is a potential failure source.

The **level sensor** is the Measurex Transducer. It comes with a one-year warranty and a 10-year design life. SEW has five years of data for these level sensors. The current failure rate is 2.3 per cent per year. A 2.3 per cent replacement per year and an eight-year design life are assumed. It is too early to provide design life performance.

The float switch is a back-up and very robust. Replacement on a 20-year cycle is assumed.

SEW is continuously working to design out failure modes. Ant ingress due to seals being compromised and poor cable connections contribute to the above data historically, but are easily resolved through careful installation and commissioning.

Appendix 2: Land utilisation options in RISE in Makassar

A range of options were considered regarding land use for the RISE intervention. These include:

- ✓ land leasing
- ✓ land acquisition
- ✓ voluntary land donation
- ✓ agreement to construct, formal handover back to the resident
- ✓ permission for use of public land

They are detailed here to showcase the various options, and highlight some of their benefits and drawbacks.

Land leasing

This is an approach used in other local upgrading programs in Indonesia. Residents retain ownership of their full land parcel and agree to the construction of infrastructure for water, sanitation, drainage etc on a small portion of their plot. The infrastructure remains an asset of the local authorities, who are responsible for its upkeep but the land on which the infrastructure sits remains the property of the landowner. The length of the lease can be negotiated to suit the various stakeholders and there is an option to renew the lease based on long term successful operation of the infrastructure.

This model has the benefit of:

- ✓ allowing landowners to retain ownership over the full plot area; protecting their most valuable asset.
- ✓ allowing formal handover of the asset (but not the land on which it sits) to the local authorities, making operation and maintenance responsibilities clear (this is especially important for larger or more technical infrastructure components such as pressure sewers, larger accessways and new drainage assets).
- ✓ preserving a landowners control over the land; ensuring it continues to be used for water and sanitation infrastructure for the benefit of their community for the foreseeable future.

- ✓ protecting residents and landowners in the event that the infrastructure fails. While all efforts are made to ensure the longevity of infrastructure, in the event that the infrastructure fails (even in 5-20 years time) the resident still owns the same land area and will not be worse off as a result of their participation in their project
- ✓ providing a mechanism for compensation as part of the leasing arrangement, ensuring landowners are appropriately compensated for their contribution to the project, as well as for the loss of the use of the land for a significant proportion of time.
- ✓ avoiding a scenario where local government holds many small, highly distributed parcels of land across the city

Land acquisition

This approach involves the formal donation of (a portion of) land from the original landowner to the local authorities. This land becomes part of the existing network of state-owned land. This model has the benefit of:

- ✓ formalisation road networks, accessways and utility corridors; securing long term access for households that currently rely on access through private property due to a lack of formal planning of roads and pathways in many settlements
- ✓ supporting pathways to formal land certification (by meeting the requirements of formal access provision, which is often a precursor to land certification)
- ✓ reducing annual land tax payable by the landowner
- ✓ aligning with existing models for asset ownership – where larger assets such as new roads and drains are owned and maintained by local authorities.
- ✓ providing a mechanism for landowners to receive compensation for the loss of the land

Voluntary Land Donation

This approach involves the formal donation of (a portion of) land from the original landowner to the local authorities. This land becomes part of the existing network of state-owned land. In contrast to the model described above, this arrangement allows landowners to formally donate land to the local authorities without compensation. This model has the benefit of:

- ✓ providing a mechanism for more wealthy landowners and small developers, living within or adjacent to the area, to voluntarily donate land to their community as a community service.
- ✓ providing a mechanism for large land developers or corporations to voluntarily donate land as part of a broader program of corporate social responsibility.

Agreement to construct, formal handover back to the resident

This model is similar to traditional models used for constructing pipe connections from existing residential dwellings to citywide water and sanitation networks. It allows landowners to grant access for the construction of assets that will ultimately become private infrastructure, and that are important components of a successful intervention. It is a sensible model for the construction of small decentralized infrastructure, including rainwater tanks, private toilets, pipe connection from existing dwellings to the communal system, and the upgrading of small pedestrian pathways between houses to improve drainage – in these situations, formal land donation or land leasing may be an unnecessary burden on the residents for only a small gain (e.g. improved drainage), or may make long term asset responsibilities less clear (i.e. requiring a lease for the provision of a private toilet)

Permission for use of public land

Relevant local authorities managing nearby public spaces, such as waterways and adjacent road easements, should be engaged throughout the design process. These open space areas can be important spaces for infrastructure locations, and buy-in from the relevant authorities means the feasibility of using these areas can be assessed quickly after which a formal process for receiving permission to construct and retain water and sanitation assets can be followed.

Appendix 3: Climate change in Makassar

Makassar is projected to be significantly affected by climate change.¹⁷ Makassar has a humid wet–dry tropical climate with mean annual temperature of 27.8°C. The mean annual rainfall in Makassar is 2600 mm (August low (20) to January high (700)). Mean monthly evaporation varies between approximately 100 mm and 200 mm and exceeds rainfall from June to July.

Historical climate changes:¹⁸

(i) Historical rainfall – Analysis of rainfall data since 1950 shows no clear trend for the wet season, but a decrease trend of around 36 per cent relative to the long term mean for the dry season rainfall.

(ii) Historical temperature – Available data since 1981 in Makassar indicates an increase in mean annual temperature at a rate of 0.27°C per decade.

Future climate projections:

(i) Temperature projections – Regional climate model simulations over South Sulawesi indicate that Makassar’s annual mean temperature will increase around 0.29–0.39°C per decade.

(ii) Rainfall projections – There is uncertainty in the rainfall projections but the majority of the models suggest a decrease in rainfall over the Makassar area. The wet season onset is unchanged but its retreat is expected to occur earlier, with the length of the wet monsoon expected to shorten by 12 days. Potential evaporation is projected to increase by around 12 per cent. Intensity of extremely high rainfall in Makassar is projected to decrease slightly.

Makassar’s dry season rainfall has reduced by more than 30 per cent since 1950 and become more variable. Climate models suggest an increase in temperature and a reduction in rainfall with the end of the wet season occurring earlier.¹⁹ This suggests an extremely high risk of water supply shortage in South Sulawesi for the 2025–2030 period while areas of Makassar will become increasingly vulnerable to flooding.

Sea level projections – Between 1993 and 2001, sea level in the Makassar Strait rose by 7.5 cm. Based on simulations it has been estimated that the sea level rise

in Makassar will reach 88.16 cm by 2025, 1.14 m by 2050, and 1.44 m by 2100 (BPPT 2008).²⁰

Water supply

The combination of population growth and climate change has a high risk of resulting in water supply shortage. In Makassar in 2010 the water demand ranged from 140ML/d to 167ML/d depending on the population assumed. Average daily demand is predicted to rise to 408ML/d in 2050. Water balance analyses suggest an extremely high risk of water supply shortage in South Sulawesi for the 2025–2030 period.

Drought

Reduced dry season rainfall, and a shortened and delayed wet season, indicate a high risk of drought for the 2025–2030 period. Changing rainfall and temperature patterns have the potential to adversely impact on food production.

Makassar’s dry season rainfall has reduced by more than 30 per cent since 1950 and become more variable. Climate models suggest an increase in temperature and a reduction in rainfall with the end of the wet season occurring earlier.

Flood

Large areas of Indonesia are vulnerable to flooding. The Tallo River passes through the city of Makassar. The Tallo River has a very low channel slope (1/10,000) and is tidal for 30 km inland. While climate change impacts on rainfall may not significantly change flood risk, predicted sea level rise (88.16 cm by 2025, 1.14 m by 2050, and 1.44 m by 2100) creates an extreme future flood risk.

Groundwater

Groundwater is a source of water for 30 per cent of the Makassar population. The use of groundwater is unregulated and information on the resource is limited. The facts and observations that generally apply to groundwater in Makassar are:

- ✓ Levels are generally high (< 2.5 m), but vary seasonally.
- ✓ Shallow wells (< 20 m) frequently dry out in the dry season.

- ✓ Shallow well water quality is frequently poor and not potable due to contamination from septic tank and pit latrine leachate.
- ✓ Deep bores are generally better quality and a more secure source, but generally still not potable quality.
- ✓ Abstractions in coastal areas result in seawater intrusions and increased salinity.
- ✓ Groundwater availability has been declining over time and is expected to continue to decline with population growth and decreased dry season rainfall.

Wastewater

Sanitation in Makassar is generally addressed using septic tanks or pit latrines. Development density typically means there is inadequate space for septic system absorptions fields. Septic tanks are typically built with holes in the base, so leachate simply percolates to groundwater. Where septic tanks are employed, blackwater is directed to the tank and greywater is typically discharged untreated to stormwater drains. In many locations, poor maintenance often results in septic tank leachate and untreated greywater pooling in stormwater drains partially or fully blocked with municipal waste. Climate change predictions have relatively little impact on wastewater management strategies compared with population growth.

Appendix 4: Water management in Makassar

Makassar has a population of 1.8 million and the official estimate of households living in areas defined as informal settlements by the Ministry of Cities and Climate Change Initiative Environment is 58,268. The population density of Makassar is about 8,200 people per square kilometre and is significantly higher in informal settlements.²¹ In general, population growth and urbanisation are overwhelming the city's existing system capacity for water supply and wastewater management. In Makassar, as in many developing cities, informal settlements are located in areas of the city that are most affected by climate change hazards – including along the coast, along rivers, around the port, and behind commercial districts and large residential areas.

Makassar's climate is highly seasonal with a strong dry season which results in significant water stress in many neighbourhoods, particularly informal settlements without PDAM (the regional water utility) water supply. Makassar's dry season rainfall has reduced by more than 30 per cent since 1950 and become more variable. Climate models suggest an increase in temperature and a reduction in rainfall with the end of the wet season occurring earlier.²²

Water supply

About 72 per cent of Makassar has access to water from PDAM and consumption is estimated to be 117 L/p/d, but most residents, industry, and commerce also use groundwater as a supplementary water source.

Lack of distribution infrastructure, 30 per cent leakage in existing distribution systems, and intermittent supply restrict the availability and quality of water reaching some customers. Groundwater is widely used but there is very little knowledge about the sustainability of current groundwater reserves. There have also been reports of salinisation of groundwater in coastal areas, which may indicate potential over-extraction.²³

Water supply sources and availability vary across the settlements and consist of a mix of municipal supply (PDAM), bottled water, bores, shallow wells, and rainwater collection using a variety of ad hoc methods from simple buckets to rainwater tanks. RISE baseline survey results indicated that only 23 per cent of the households in the RISE program have access to piped water from

the PDAM. The vast majority of residents rely on alternative sources, such as groundwater and bottled water to provide all of their daily water needs. Households often use a variety of these sources to meet their daily water needs, with water sources differing according to use and often changing with the season. Household activities that use water include: drinking (people and livestock), cooking, washing dishes, washing food, washing clothes, washing vehicles, washing babies and young children, watering plants, and ablution before prayer. Observation and information collected during the co-design process suggest that most houses use bore and shallow well water for non-potable activities and municipal water or bottled water for drinking. But some residents also drink shallow well and bore water and use bottled water for bathing babies.

Household bottled drinking water is typically supplied in 5-gallon (US gallon) bottles (approximately 19 L) and household use is approximately 3–5 bottles per week (approximately 80 L); 4160 L per year (4.16 m³). Five-gallon drinking water bottles cost around Rp4,000–6,000 per bottle. Therefore, bottled water cost is around Rp80,000 per month and Rp250,000 per m³. PDAM cost is approximately Rp1500–3100 (2,500) per m³ including a fixed cost of Rp12500–20,000 (16,000) a month. Equivalent cost of 0.32 m³ of PDAM water is around Rp16,800.

Water from shallow wells and bores is extracted using a manual rope and bucket system or with a pump and rising main directly to the house or storage tank. In some settlements, a simple funnel and hose system provides flow from the source into the wet areas of the house. Reticulation systems are observed in settlements where municipal water is available or where there is a common bore. Supply pipes are often placed directly inside drainage channels to avoid having to dig trenches. This practice risks contamination of the reticulation system during periods of low or no pressure in the pipe system.

Many households use a form of storage to provide a buffer for water use; those observed include plastic bowls (both with and without lids), plastic jerry cans, clay pots and/or 500 L or 1000 L water tanks. Water tanks are sometimes located on an elevated stand to provide gravity flow into the house. Water is generally stored separately according to its intended use. In some settlements, shallow wells are treated using chlorine or limestone to

reduce turbidity and odour. At a household level, boiling water before drinking is reported. While boiling provides very effective treatment for pathogens, adherence to the practice and post-boiling storage (re-infection of stored water) has been shown to be problematic in protecting against disease.

Government and international aid programs (e.g. KotaKu, Pamsimas) have installed water supply infrastructure in a number of the settlements, mainly comprising of community bores. In most cases, the infrastructure is not working due to pump malfunctions and/or residents not able to afford ongoing operational and maintenance costs (e.g. electricity, pump repair).

Ownership and operation of water supply infrastructure is evident at household, cluster (group of 2–7 households, who are generally related) and community scale, with the most common being the cluster group. At cluster scale, households will split the cost of electricity for a pump. In one settlement, the community bore is operated by the community leader who charges others a varying fee (usage plus electricity) depending on their relationship with the particular household. In this case, the infrastructure functions more like a private business and inadvertently reinforces existing power dynamics within a community.

Groundwater

Groundwater water supply is a major source of water for the population of Makassar city, particularly for those living in informal settlements without access to the mains water supply coverage or in districts subject to mains water shortage. The baseline survey results verified that 70 per cent of the households in the RISE program rely on a groundwater source to provide or supplement their daily water needs. During the dry season, as the groundwater level recedes, shallow wells and bores becomes increasingly turbid and, in some cases, completely dry up. In coastal areas, saltwater intrusion is evident, likely due to over extraction from groundwater pumping. When this happens, residents will either find an alternative source within the neighbourhood or travel outside their village for water.

Across the RISE settlement, wastewater is typically collected in ‘tanks’ most of which are deliberately constructed without a base and therefore promote leaching of untreated wastewater into the surrounding soil and groundwater. It is not uncommon to see a septic tank or pit latrine in close proximity (less than 5 metres) to a groundwater supply source and is predicted to be a key pathway for human exposure to faecal contamination.

The use of groundwater as a water supply in Makassar is unregulated, which means that there is little data to understand how much groundwater is being taken and the long term impact on groundwater availability over time. Population growth and urban development will further deplete groundwater resources and exacerbate deterioration in groundwater resources quality due to sea water intrusion (in coastal areas) and contamination from domestic wastewater.²⁴

Water quality snapshot

Independent of project performance assessment monitoring, the design team undertook a water quality sampling snapshot consisting of 31 points across the 12 settlements to provide a snapshot of the water quality of various water sources across the settlements and to guide intervention design. Sample points included:

- ✓ PDAM reticulated potable supply (sampled from in-house taps)
- ✓ deep bores (sampled at the point of access)
- ✓ shallow wells (sampled at the point of access)
- ✓ rainwater tank (at the time of sampling only one tank had water).

Where possible, the range of water sources available at a particular site were sampled. Bottled water was not included for sampling.

The results from the snapshot suggest:

- ✓ In the sites that had access to PDAM supplies, the microbiological water quality was good. The PDAM supply satisfied Indonesian and international potable water regulations.

- ✓ Deep bore had the next best water quality, but water quality was variable and would require further treatment for potable consumption.
- ✓ The only rainwater tank sampled was contaminated and would require further treatment for potable consumption.
- ✓ The shallow wells had the worst water quality and would require significant treatment for potable consumption.

It is noted that this snapshot is highly limited in scope, and specifically has not taken into account the seasonal and settlement specific variations in water quality.

Wastewater management in informal settlements

In Makassar, sanitation is estimated at 85 per cent coverage. There is currently no sewer network in the City of Makassar.

Most residents (93 per cent) in the selected informal settlements have a private toilet facility, although they are highly variable, with many not meeting basic hygiene standards. Sanitation systems typically consist of black-water (toilet water) discharged to unlined 'septic tanks' and pit latrines on individual properties. In the selected informal settlements it is estimated that 67 per cent of households do not have adequate sanitation; wastewater is discharged without sufficient treatment using an unlined 'septic tank' or unlined pit latrine.

The unlined septic tanks are usually brick or concrete structures built without a base in order to promote infiltration. These unlined systems severely reduce treatment capacity and cause significant contamination of the local groundwater sources and nearby drains and waterways. High population density and limited land availability render even current local best practice approaches (lined septic tanks with an infiltration field) ineffective. This results in raw faecal sludge contaminating shallow wells and, in many instances, untreated effluent is discharged to both the stormwater drains²⁵ and directly contaminates groundwater supplies.

Greywater (wastewater from bathroom, kitchen, and laundry) is generated in the wet areas of the household. Most households have an on-ground concrete slab (with or without tiles) used for washing and kitchen activities

and in some cases for peeing and pooing. Disposal pathways for greywater in informal settlements is typically poor and results in greywater accumulating in stormwater drains or simply pooling in depressions. Greywater is typically discharged untreated by:

- ✓ collecting in bowls and throwing into stormwater drains or external areas
- ✓ drainage via a hole in the wall or a pipe into stormwater drains or external areas
- ✓ drainage into a basic rock filled soakaway
- ✓ discharge through floorboards to underneath the house.

Additional observations on the wastewater situation in Makassar:

- ✓ In river and seaside settlements, there are many instances of direct defecation, where a 'hanging toilet' discharges directly to the river or sea.
- ✓ Open defecation is still common practice in many of the settlements, particularly for households with no existing toilet or where the toilet is in a very bad state and/or has limited access, or where the family is large and might have to wait a long time to use the toilet.
- ✓ Where there are existing septic tank systems, they are not watertight and therefore flooding and high groundwater table during the rainy season cause water levels in the system to rise, making it impossible to flush toilets.
- ✓ Wet areas are commonplace in a home (used for preparing meals and washing dishes among other things) but can also be used for peeing or for little children peeing and pooing, and for washing babies.
- ✓ The wet areas are often located directly adjacent to the toilet, requiring residents to step through the wet area to get into the toilet and vice versa. In some cases there is no separation between these two spaces (e.g. raised edge or toilet door). Therefore the risk of faecal cross contamination is high.
- ✓ The older generation sometimes prefers outdoor toilets because they are more typical to what they used in the past and in rural areas, but this can create problems with access during periods of flooding.

- ✓ Dorm houses typically have a wet area in each room with shared toilet facilities.
- ✓ Family groups living in different buildings and households will often share a toilet if not all buildings have a toilet.
- ✓ Cost of construction and water supply access are key constraints for residents when considering building elevated toilets (i.e. aboveground floor level).
- ✓ There are examples of shared communal septic tanks (funded through government programs), however poor quality construction and a lack of clarity of operation and maintenance responsibilities have resulted in these systems not functioning well (residents have reported bad experiences with these types of systems).

In Makassar, typically there are six people per dwelling. For designing sanitation facilities, the estimated rate of blackwater generation is 20 L/per person per day. The estimated greywater generation is 50 L/per person per day, of which 15 L/per person per day is kitchen greywater.

Solid waste disposal to waterways and canals is a large problem compounding issues, because they impede drainage, create standing water and cause regular floods and contaminated water supply wells.

Diarrhoea remains an important challenge in the public health sector. In 2007, diarrhoea was the number one cause of death in infants (31.4 per cent) and children aged under five (25.2 per cent), and the fourth cause of death overall (13.2 per cent). The total reported case of diarrhoea in 2012 was 29,265 cases (or 52.7 per cent), which decreased from 37,940 reported in 2011. Overall there was a relatively considerable decrease (about 35 per cent) in diarrhoea incidents throughout 2009–2012.²⁶

Drainage and flooding

Many of the settlements experience regular pluvial and fluvial flooding during periods of high rainfall. This can be observed at a localised (household), settlement and regional scale, often exacerbated by high groundwater tables and/or high tides in coastal areas.

During heavy rains, floodwater mixes with both blackwater and unmanaged solid waste and inundates the site. Residents come into contact with floodwater while moving around the site, or when floodwater enters their homes. Often after heavy rains, the floodwater can remain for several days, attributed in part to poor site drainage, which increases breeding sites for human disease vectors, particularly mosquitos.

Drainage within the informal settlements is highly variable, ranging from large formal channels through to small informal, hand-dug channels. The terrain is typically very flat and, as a result, in many locations during dry weather, both septic tank leachate and untreated greywater pool in stormwater drains which are often partially or fully blocked with municipal waste.

Appendix 5: Relevant Standards and Design Guidelines

Toilet Facilities

- ✓ SNI 03-2399-2002, Standard for Public Toilet Building Design
- ✓ SNI 03-1733-2004, Standard for Housing Environmental Planning in Urban Area
- ✓ Makassar local standard for Muslim toilet facilities (the direction for closet is not facing the Qibla).
- ✓ SNI -7394-2008, Standard for Concrete Cost Calculation
- ✓ SNI 03-1726-2002, Standard for Building Structure Design based on Earthquake
- ✓ SNI 7973-2013, Standard for Wood Construction Specification
- ✓ SNI 03-6481-2000, Standard for Plumbing System
- ✓ SNI 03-6572-2001, Standard for Ventilation System
- ✓ SNI 03-1746-2000, Standard for Fire Protection Design
- ✓ SNI 03-6571-2001, Standard for Smoke Controlling System
- ✓ SNI 03-1745-2000, Standard for Pipe Installation Design.

Pressure Sewer

All equipment, including the tanks, will be constructed to meet relevant Australian Standards, including structural certification in accordance with AS 1546.1:2008.

Septic Tank

Indonesia – Badan Standarisasi Nasional, 2002. Tata Cara Perencanaan Tanki Septik dengan Sistem Resapan, SNI 03-2398-2002, Jakarta

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Rainwater Tanks

There are a wide variety of rainwater tanks on the market. The rainwater tanks will be selected and installed (including associated connections and plumbing) according to relevant local standards (where applicable).

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