Definition of Decentralised Systems in the South East Queensland Context

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The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South-East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South-East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South-East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

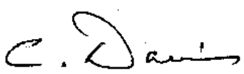
As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.



Chris Davis
Chair, Urban Water Security Research Alliance

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EXECUTIVE SUMMARY

Decentralised systems based on integrated urban water management (IUWM) and water sensitive urban design (WSUD) principles are being planned and implemented for urban developments, either as separate facilities or in combination with a centralised system. Adoption of decentralised systems in South East Queensland is primarily being driven by the pressure exerted on existing water resources and the environment from rapid urban growth and an extended period of below average rainfall.

Water professionals apply the terminology ‘on-site and decentralised systems’ in many ways, thus there exists some degree of confusion. Aiming to clarify understanding on terminology, this report explores the definition of decentralised systems, outlines the key aspects of a decentralised approach to water and wastewater services and investigates the scale of these systems in the specific context of South East Queensland (SEQ).

The definition was developed using a literature review and consultation with water professionals from state government departments, water authorities and consultants in SEQ using informal interviews and/or a questionnaire.

This report discusses identifying characteristics of decentralised systems in terms of technological options, features and scale. These characteristics were identified through analysis of cases studies in both SEQ and other regions of Australia.

In summary, the definition of decentralised systems is determined mainly by the process adopted for their design and implementation. Their characteristics range in technological features, system configuration and development size from a single lot to 8,500 lots or even higher, but most importantly are governed by the conditions of the development to which they are applied.

The general definition of decentralised systems recommended for adoption as follows:

> *Decentralised systems can be defined as systems provided for water, wastewater and stormwater services at the allotment, cluster and development scale that utilise alternative water resources, including rainwater, wastewater and stormwater, based on a ‘fit for purpose’ concept. These systems can be managed as stand-alone systems, or integrated with centralised systems. Wastewater streams are partially or completely utilized at or close to the point of generation. At cluster and development scale, stormwater is also managed as part of an integrated approach that aims to control the quality and quantity of runoff at or near the source to minimise the impact of the development on the natural ecosystem.*

1. INTRODUCTION

Decentralised systems involve the collection, treatment and use of rainwater, stormwater, groundwater or wastewater at different spatial scales, from individual homes, clusters of homes, urban communities, industries, or built facilities, as well as from portions of existing communities either independent from or as part of a larger system (adapted from Crites and Tchobanoglous, 1998).

In comparison, conventional municipal water supply systems are characterised by the acquisition of fresh water from protected catchments, purification of raw water and safe distribution in sufficient quantities. Similarly, conventional wastewater systems can be stereotyped by the collection of sewage via piped collection systems; transportation out of the urban area; and controlled discharge of treated wastewater into receiving water bodies, including management of waste sludge (Wilderer, 2001). Such approaches are commonly defined as centralised water and wastewater management systems.

In such systems, only a small fraction of high quality water supplied is used for drinking and cooking. A large amount of water is used for toilet flushing and transporting the human waste through sewers to treatment plants. The discrete collection of freshwater and disposal of wastewater may adversely impact the water balance of that area. Infiltration into sewers can cause overloading of treatment plants and exfiltration can contaminate groundwater and surrounding waterways. Centralised systems have provided considerable benefits to modern society, particularly for the safe and reliable supply of water, improved public health through removal and treatment of wastewater, and flood mitigation. However, centralised collection and treatment of wastewater restrict opportunities to harness this potentially valuable resource that can be used on a fit-for-purpose basis for a range of non-potable applications. Furthermore, rapid urbanisation, increased pressure on water resources and the need to minimise contaminant loads to receiving waters has meant that conventional centralised systems are not always the most appropriate solution for urban development.

Historically, decentralised systems have been provided in semi-urban, rural and remote areas, where the provision of centralised systems is not technically, economically or environmentally feasible. Decentralised systems also offer an alternative approach to providing water, wastewater and stormwater services to urban areas. The concept of integrating water and wastewater systems through separate collection and treatment of various water and waste streams and recovery of valuable water, nutrients and energy has been proposed (Wilderer, 2001). This helps to overcome the limitations of the centralised approach and to move towards more ecologically and economically sound water/wastewater management systems. Furthermore, innovative decentralised systems are being planned and implemented for new and future urban developments, either as separate facilities or in combination with a centralised system (Diaper, Sharma and Tjandraatmadja, 2008).

Mitchell and White (2003) provided some of the guiding strategies to be applied to urban water systems in order to move towards sustainability. Strategies included: recognising limits to water that can be extracted from a catchment; ensuring most efficient water use; ensuring adequate flows to local ecosystems; and maximising efficiency in the use of energy and materials to deliver a service. These guiding strategies provide a rationale to move towards decentralised systems, which in some cases may be integrated with a centralised system. Decentralised wastewater systems can also offer the significant advantage of enabling opportunities for localised water reuse (Gikas and Tchobanoglous, 2009).

There is a degree of confusion among many water professionals in the application of terminology related to on-site and decentralised systems. This report defines the key aspects of a decentralised approach to water and wastewater services in order to facilitate a clear definition of decentralised systems. The methodology used to define decentralised systems was determined by a literature review and through consultation with water professionals from state government departments, water authorities and consultants in SEQ using informal interviews and/or a questionnaire.

The objectives of this report are to define decentralised systems and investigate the scale of these systems in specific context to South East Queensland (SEQ).

2. DECENTRALISED SYSTEMS

Decentralised systems are generally understood as being localised wastewater systems or as systems supplying water resources that are sourced close to the point of use.

Decentralised water supply systems, such as rainwater tanks and groundwater extraction, are prevalent in servicing remote or small dispersed communities (UNESCO, 2008).

Historically, the literature uses the term 'decentralised systems' to refer to on-site, clustered or development scale decentralised wastewater systems. Figure 1 illustrates the concept of a decentralised wastewater system in comparison to a conventional centralised system. A decentralised approach that provides water and wastewater services can involve an amalgam of systems at the on-site (or allotment) scale and those at the cluster or development scale. The following describes the different scales that decentralised systems can operate at:

- Onsite scale. Treatment technologies and/or management systems that provide water and wastewater services at the scale of an individual lot (Mitchell et al. 2008). Approaches include rainwater tanks and greywater recycling. These systems are owned by allotment holders.
- Cluster or development scale. These systems generally operate under some form of common ownership model and service two or more dwellings or a whole development, with water sourced or wastewater treated in proximity to the dwellings (Geisinger and Chartier, 2005). Approaches include wastewater recycling with third pipe distribution and stormwater harvesting.
- Distributed systems. These systems generally provide services to very large developments and the services are owned and operated by water utilities.

Decentralised systems may or may not be integrated with a centralised system. Danielson (2008) referred to distributed wastewater management to describe systems where the management of several systems is undertaken by a single entity. In many cases where decentralised systems are deployed, they are integrated with the centralised system. For example, the Payne Road development in Brisbane's suburban fringe demonstrates an integrated approach to water services that includes rainwater harvesting, greywater recycling and demand management. The decentralised systems are integrated with the centralised system as rainwater tanks receive back-up from the mains supply and blackwater is discharged off-peak to an adjacent sewer main.

Gikas and Tschobanoglous (2009) introduced the term 'satellite wastewater systems'. These systems are usually located in the upper portion of a wastewater system and usually lack solids processing facilities. These satellite systems can reduce demands on centralised infrastructure, while enabling opportunities for localised wastewater recycling and reuse.

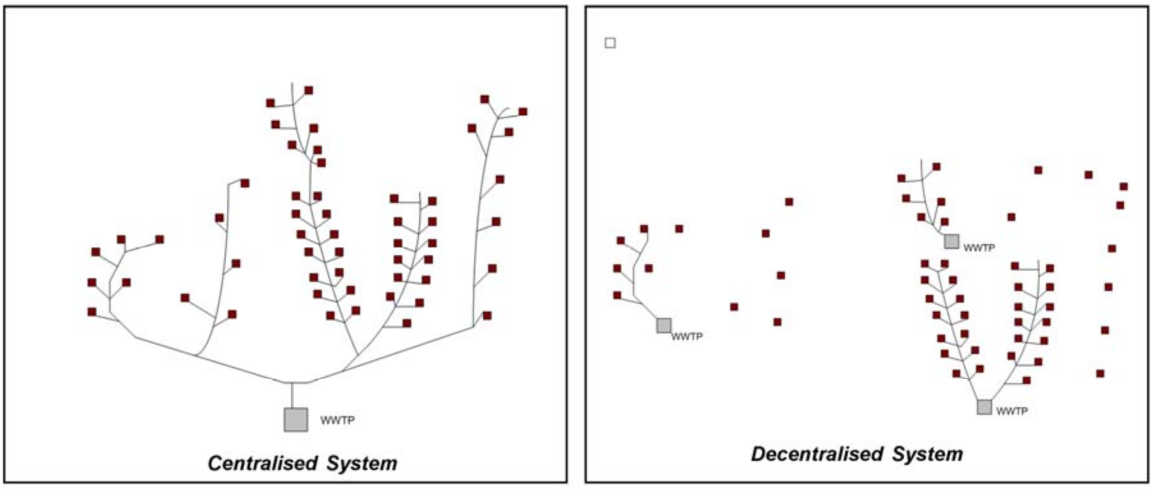

Figure 1: Centralised approach versus decentralised approach

Source: Adapted from Geisinger and Chartier (2005).

2.1. Definitions and Applications of Decentralised Wastewater Systems

In this section, definitions of decentralised wastewater systems taken from the literature are highlighted. Typical features of decentralised systems are then described, followed by a summary of feedback from a range of water professionals on defining decentralised systems.

Decentralised wastewater systems are well defined in associated government standards and in its code and guidelines which were developed to provide guidance on wastewater system design, installation and operations to ensure long-term treatment effectiveness and environmental protection.

Australian/New Zealand Standards 1547:2000 (*On-site domestic wastewater management*) defines an on-site domestic wastewater water system as:

> *A system receives treats and absorbs wastewater within the property boundaries of the site of generation.*

The application of the Standard is limited to wastewater flows up to a maximum of 14 kL per week from a population equivalent (EP) up to ten persons.

The Queensland Plumbing and Wastewater Code (2007) covering up to 20 EP defines an on-site wastewater management system as:

> *A system installed on premises that receives and treats wastewater generated on the premises and applies the resulting effluent to an approved disposal or re-use system.*

This code covers on-site wastewater systems capable of treating not more than 50 kL per day of wastewater generated on the premises.

The Interim Final Queensland Guidelines for Decentralised Wastewater Systems (2007) (unpublished) define decentralised wastewater system as:

> *A wastewater system serving any small to medium-scale development that is an Environmentally Relevant Activity (ERA) under the Queensland Environmental Protection Regulations (1998) and which operates independently of a centralised municipal wastewater collection and treatment system.*

These guidelines were developed for systems with capacity from 21 to 1,000 EP in order to be consistent with the systems defined as an Environmentally Relevant Activity (ERA) under the Environmental Protection Regulation and required Development Approval from the Environment Protection Agency (EPA).

Outside of Australia, Geisinger and Chartier (2005) define decentralised wastewater systems in the US context as:

> *Decentralised systems: An onsite or cluster wastewater system that is used to treat and dispose of relatively small volumes of wastewater, generally from individual or groups of dwellings and businesses that are located relatively close together. Onsite and cluster systems are commonly used in combination.*

The US EPA (2005) document, 'Decentralised treatment wastewater systems - A Program Strategy', defines decentralised wastewater systems as:

> *Decentralised wastewater systems, often called "septic" or "onsite" systems, derive their name from their location—they treat wastewater close to the source, typically providing treatment on the property of individual homes or businesses. Decentralised systems also include systems serving clusters of individual homes, large capacity septic systems, and small collection and treatment systems (including package treatment plants). These systems similarly treat wastewater close to the source, typically using small pipes for collecting small volumes of domestic wastewater, unlike centralised urban wastewater treatment systems that pipe large amounts of wastewater many miles through sewers prior to reaching the treatment facility.*

A similar definition is used by George Tchobanoglous for 'decentralised wastewater management', which even includes 'reuse':

Decentralised wastewater management may be defined as the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of generation (Tchobanoglous, 1995 and Tchobanoglous, 1996 in Crites and Tchobanoglous, 1998).

This can be contrasted with a definition of centralised systems, also provided by Crites and Tchobanoglous (1998):

Centralised wastewater management, on the other hand, consists of conventional or alternative wastewater collection systems (sewers) centralised treatment plants, and disposal/reuse of the treated effluent, usually far from the point of origin, although the liquid portion and any residual solids can be transported to a centralised point for further treatment and reuse.

It can be highlighted from the above definitions that decentralised wastewater systems are described as systems installed and operated to deliver effluent/wastewater services near to the point of generation in small to medium development areas. Traditionally, the main application of decentralised wastewater systems is for servicing areas that are difficult to service with centralised sewerage systems due to technical or economic considerations.

With the increasing awareness of water and energy conservation, decentralised systems are more often implemented to reduce flows to centralised wastewater treatment systems and to reuse wastewater for non-potable applications at the property level. An initiative, such as the Green Building Council of Australia's Green Star Rating system which allocates points for on-site wastewater treatment and reuse, is increasing the use of decentralised approaches in commercial buildings.

Historically, the most commonly adopted decentralised wastewater systems involved a septic system for collection and primary treatment and a leachfield for further treatment and disposal. A range of advanced wastewater collection and treatment systems and technologies are available for safe sanitation in small and medium communities. These systems are also applied in infill developments in urban areas to promote effluent (reclaimed water) reuse on a fit-for-purpose basis. Reviews on these advanced technologies can be found in Geolink (2005) and Landcom (2004).

Pinkham *et al.* (2004) highlighted opportunities to apply decentralised wastewater systems beyond the usual applications to small-town and rural communities. They indicated that the optimal architecture of wastewater systems should consist of a mixture of different scales of sewerage systems rather than what is commonly available today.

2.2. Features of Decentralised Systems

Decentralised systems are generally designed based on Integrated Urban Water Management (IUWM) and Water Sensitive Urban Design (WSUD) concepts. A number of structural features can be used to achieve IUWM and WSUD objectives, the selection of which is dependent on a large number of factors including the type and scale of development, proximity to existing centralised services, catchment conditions, climate, customer acceptance and allocation of financial resources (Sharma *et al.*, 2008).

A number of studies (Diaper, 2004; Tjandraatmadja *et al.* 2008) have described approaches used to achieve IUWM and WSUD objectives. Typically, these approaches include features which could be described as decentralised systems; they focus on the delivery of water and wastewater services at a localised scale separate from centralised systems or in combination with existing centralised facilities to reduce the load on freshwater resources and receiving environment.

2.2.1. Rainwater Tanks

Rainwater tanks have been installed at individual dwellings and can also be used as communal tanks in a small community. Based on regulatory requirements, rainwater can be used in the kitchen and can also be used for hot water supply, toilet flushing, washing machine and garden irrigation, which can contribute to significant reticulated water savings.

2.2.2. Stormwater Systems

Stormwater is surface runoff. Given appropriate treatment, stormwater can be used as an alternative water resource at subdivisional scales; however, the use of stormwater is currently still limited by factors such as the area required for storage. However, methods such as stormwater Aquifer Storage and Recovery (ASR) offer opportunity to store stormwater and recover it for reuse. Stormwater systems such as on-site detention tanks, buffers, swales, bioretention devices and ponds are operated mainly for environmental protection and enhancement.

2.2.3. Greywater Recycling Systems

Greywater is sourced from the bathroom and laundry, and to a lesser extent, from the kitchen as kitchen wastewater contains higher concentration of gross contaminants as well as fats, oils and greases. Reuse of treated greywater can significantly substitute reticulated water for non-potable use. An additional significant benefit from greywater recycling is the reduction of flow discharged to sewers. The application of recycled greywater is dictated by the quality of its treatment. There are many development examples demonstrating that greywater can be collected, treated and reused for non-potable applications at each household, or collected from multiple dwellings, treated on-site and reused for irrigation (Tjandraatmadja *et al.* 2008).

2.2.4. Wastewater Recycling Systems

Wastewater is the used water from exiting dwellings, including greywater and blackwater carrying toilet waste. On-site wastewater treatment systems at a small to medium scale have been reviewed under Section 2.1. Treated effluent can be used in non-potable applications including garden irrigation, and can also be used for toilet flushing after disinfection and potentially for household supply. The end-use applications are influenced by the wastewater characteristics and treatment methods used. At present, safe use of recycled wastewater still faces a greater challenge compared to greywater, due to the need for more advanced treatment for the high levels of faecal microorganisms and the potential presence of pathogens, persistent organic pollutants and pharmaceuticals (Tjandraatmadja *et al.* 2008).

2.2.5. Demand Management Strategies

Demand management strategies are an important component of achieving water supply/demand balance for an area. Demand management strategies reduce the total amount of water required to service a population. Strategies can include design and planting of gardens and public open space to minimise irrigation requirements, leakage management and encouraging water efficiency through behavioural change and increased uptake of water efficient appliances. Mitchell and White (2003) made the point that taking an integrated resource planning approach that considers opportunities for reducing demand through water efficiency measures offers the lowest cost per unit volume and provides the most sustainable way to obtain new water to meet population or environmental needs.

Table 1 and Table 2 summarise some of the typical developments, with a mixture of alternative water features incorporated, that occur across Queensland and other Australian states respectively (Tjandraatmadja *et al.* 2008; <<http://www.naiad.net.au>>). The tables illustrate a range of options used to integrate these features in the management of water systems at small to medium scales. It is interesting to note that most of the decentralised systems in Queensland (Table 1) are based in residential developments for water and wastewater servicing, while in the other states, the application of decentralised systems has also been extended to commercial developments. The provision of various physical systems and end use of alternative water sources are also listed in Tables 1 and 2.

The decentralised systems and technologies that enable the reuse of alternative water sources such as rainwater, greywater, wastewater and stormwater can be applied to a single dwelling or a cluster of dwellings. For example, rainwater tanks are widely used at a residential lot level. The Australian Bureau of Statistics reported that nearly 20% of Australian households have a rainwater tank installed, while in Queensland, 22.1% of households reported rainwater tank as a source of water (ABS, 2007). Permeable paving and reduction of paved areas are common stormwater techniques for source control at the cluster scale (Argue, 2004). Systems for wastewater treatment may range from on-site septic tanks to complex treatment trains including secondary treatment, membrane filtration and UV disinfection (the selection of which will depend on the reuse and disposal conditions).

Table 1: Queensland developments adopting the integrated urban water cycle management approach (Tjandraatmadja *et al.* 2008; <http://www.naiad.net.au>)

More information on these developments, including the drivers for adopting an integrated urban water cycle approach will be available in a concomitant report and can also be found in Tjandraatmadja et al. 2008.

Development	Location	Type	Size	Physical Features
Beachmere Sands Retirement Resort	Bribie Island, 45 km north of Brisbane CBD	Resort	55 lots	Wastewater treated by KEWT system.
Capo di Monte	Mt Tamborine, in Scenic Rim Regional Council, 30 km west of the Gold Coast	Residential (Leisure village)	46 houses	Reticulated rainwater with bore water top up used for all in house usage except toilet; this system includes filtration, UV and chlorination. Onsite treatment of wastewater by immersed membrane bioreactor, UV and chlorination; used for toilet flushing, garden irrigation and dedicated disposal areas.
Carindale Pines	east of Brisbane		31 Lots	25 kL rainwater tanks topped up with reticulated water for all uses including drinking.
Currumbin Ecovillage	7 km west of Currumbin Beach	Residential	144 lots	Rainwater tanks for all in-house usage except toilet. Reticulated dual pipe sewerage system with recirculating textile filter, microfiltration, UV and chlorine to provide A+ water for toilet, external use and fire fighting.
Healthy Home	Francis Avenue, Mermaid Beach, Gold Coast	Residential	1 house	Rainwater tanks topped up from Council mains, filtration and disinfection before use. Grey water system for toilet flushing and garden irrigation.
Manly Ecovillage	Manly, Brisbane, 15 km south east of the CBD	Residential	24 lots	Centralised rainwater tanks and treatment with topping up from council mains. Centralised wastewater collection and treatment by immersed membrane bioreactor, UV, chlorination and carbon filtration; the recycled water for toilet and garden. Stormwater treatment via swales and bioretention basin.
Noosa North Shore Resort	20 minutes from Noosa's Hastings Street Shopping precinct	Resort	250 residences	Wastewater treated by aerobic membrane bioreactor to produce A+ effluent for toilet flushing, laundry, garden watering and car washing.
Golf Estate	Bribie Island, 45 km north of Brisbane CBD	Recreational	43 lots	Rainwater tank at each lot. Dual pipe for future recycled water supply of toilets and external use such as lots and public open space irrigation. 25 lakes for stormwater detention, peak flow reduction, nutrient and sediment containment.
Payne Road	Payne Road, the Gap, Brisbane	Residential	22 lots	Rainwater tank at each lot for all in-house usage plus two centralised rain tanks which are topped up from Council supply. Greywater reuse from Biolytix system for subsurface irrigation. Low infiltration gravity sewer for blackwater to council sewer. Stormwater treatment via swales and bioretention basin.
Pimpama-Coomera Residential Estate	40km south of Brisbane	Residential	50,000 lots	Rainwater topped up from Council mains, used for hot water and laundry. Recycled water for toilet flushing, external household and public open space irrigation. Storm water treated by swales, bioretention, wetland and basins for nutrient reduction. Wastewater collected using low infiltration gravity sewer treated for reuse using membrane filtration and disinfection.
Sunrise 1770	10 km from the Town of 1770, one and a half hours drive north from Bundaberg	Residential	172 lots	Rainwater tanks are topped up with potable water from the Reedy Creek Aquifer. All waste water is reclaimed and treated to provide a secondary water supply for toilet flushing, exterior domestic uses, car washing and fire fighting.

Table 2: Developments adopting integrated urban water cycle management approach in states other than Queensland (Tjandraatmadja *et al*. 2008; www.naiad.net.au)

Development	Location	Type	Size	Physical Features
Forde development	ACT	Residential	1,100 blocks	Targeting 40% reduction in water usage by suggesting rainwater or greywater reuse. Stormwater used to irrigate parks.
Brindabella Business Park	ACT	Commercial	28 ha	Water conservation.
Rouse Hill	Sydney's north-western suburbs, 45 kilometres from Sydney CBD	Residential	36,000 houses	Wastewater is treated in the recycled water treatment plant which involves secondary aerobic systems with nitrogen removal, followed by tertiary treatment using flocculation, clarification and sand filtration. The effluent is recycled via dual pipe systems to households and is disinfected using UV and chlorination for toilet, garden and car wash. Any excess effluent is chlorinated and then de-chlorinated before being discharged to the constructed wetland.
Sydney Olympic Park	20 kilometres west of Sydney CBD	Residential/ commercial	640 ha site (can serve 20,000 people)	Sewer mining incorporating proven and emerging technologies such as biological treatment, MF and RO. Stormwater harvesting for local irrigation.
Mawson Lakes	12 km North of Adelaide	Residential and commercial	4,000 lots (650ha)	Recycled water is a combination of highly treated effluent from the Bolivar wastewater treatment plant and of stormwater harvested in Salisbury. Treatment at the Bolivar wastewater treatment plant includes biological nutrient removal, dissolved air floatation and filtration, while stormwater is treated in a series of wetlands. The combined reclaimed water is then disinfected before being recycled via dual pipe system for toilet, car washing and garden watering. Surplus stormwater is stored in the local underground aquifer for future reuses.
Parfitt Square	City of Charles Sturt, 5km North West of Adelaide	Recreational (public open space).	0.6 ha	Stormwater retention for aquifer recharge and irrigation. Stormwater treated using gross pollutant and sediment traps, infiltration swale, gravel based sub-surface wetland.
New Haven Estate	18 kilometres north-west of Adelaide CDB	Residential	62 lots	Dual pipe recycling for toilet and irrigation. Tertiary wastewater treatment with activated sludge, sand filtration and UV.
St Elizabeth Church	Oaklands Park, 10 km South West of Adelaide	Redevelopment of car parks and tennis courts	0.3 ha	Stormwater quality source control, grass-pave for hard standing area and soakways. Aquifer recharge and reuse in Church landscaped area.
New Brompton Estate	Brompton, 5km North West of Adelaide	Residential	15 lots	Roof runoff management – collection of roof runoff from 15 cluster houses and diverted to infiltration trench for aquifer recharge.
Municipality of Brighton	TAS	Stormwater Harvesting	80 ha catchment	Wastewater collected from households is biologically treated to secondary quality in the Brighton Wastewater Treatment Lagoon and the Green Point Wastewater Treatment, before being recycled for agricultural reuse.
Aurora (Epping)	Epping, VIC	Residential	8,500 lots	Rainwater tanks and rain gardens in allotments. Wastewater collected from households is treated using aerobic biological system plus sand filtration, ultra-filtration, UV and chlorination to produce Class A recycled water, prior to reuse through dual pipe for toilet and gardens. Stormwater is treated using bio-retention trenches and swales.

Development	Location	Type	Size	Physical Features
Brighton Eco Townhouses	Brighton, VIC	Residential	2 townhouses	Rainwater usage for toilet and garden. Rainwater from entire roofs, decks and paved pathways collected.
Docklands Business Precinct	VIC	Commercial	200 ha	Stormwater harvesting, treatment and reuse for irrigation. Stormwater quality control, such as bioretention swales and wetlands. Development guidelines encourage initiatives such as on-site greywater recycling.
60L Building	60 Leicester Street, Carlton, VIC	Commercial	3,375 m^2 area	Use of water efficient fixtures, waterless urinals, low flush volume toilets. Rainwater use to replace mains water (90% less usage). Reclaimed water for toilet and roof garden irrigation. Wastewater treatment system of biofiltration and clarification.
Sharland Oasis	Geelong VIC	Residential	1 house	Rainwater is for all non-potable household uses. Grey water is used for garden irrigation after being treated in the patent system, namely Biological Peat Cartridge and Sac System, which basically uses a peat as a biofilm carrier.
Investa Property Group	VIC	Commercial	9 properties across Melbourne	Waterless urinals, water flow restrictions to taps, hand basins and showers. 25% reduction in water consumption.
Council House 2	VIC	Commercial	12,536 m^2 (floor area)	Rainwater collected and used to supplement water mains. Sewer mining treated effluent supplies irrigation, cooling, toilet flushing and other Council water needs, e.g. equipment for street washing and open spaces. The sewer mining process involved ultra-filtration, desalination using RO systems and disinfection.
Beachridge Estate	WA	Residential	1,000 lots (2,000 ha)	Stormwater focussed development to maintain predevelopment catchment hydrology. Application of drainage swales landscaped in road median strips and opportunities for pollutant reduction. Public open space used as stormwater retention, detention and infiltration.
Bridgewater South Estate	WA	Residential	100 lots	The development is mainly stormwater focussed. Structural controls for stormwater infiltration, retention and detention at source through infiltration swales and vegetated buffers are provided. The stormwater system also includes soakwells. No direct storage.
Lakelands Private Estate	WA	Residential	2,500 lots	The development is devoted to sustain the natural wetlands and thus is stormwater focussed. The on-site infiltration of stormwater through basins, drains and swales are integrated with landscape of public open spaces. Bore water for POS.

Cluster scale options for decentralised water and wastewater services can be a combination of tools applied either at single household or communal scale, or both. The advantage of larger scale cluster systems, in comparison to centralised systems, is a greater level of control of the quality and quantity of water/wastewater entering the systems, which increases the flexibility and simplicity of the treatment process. Cluster scale systems also offer economies of scale (Naji and Lustig, 2006), as it will often be more efficient for a number of households to invest in and utilise a decentralised technology than for each household to own and operate its own system.

In subdivisional scale developments, rainwater tanks and greywater can be used in single household or clustered homes as the current techniques and technologies are more appropriate to these levels. Typical models for wastewater servicing at a subdivision scale include collection from individual homes and transport to a wastewater treatment system within the development area for treatment. Treated effluent is provided to households for non-potable applications via a dual pipe system. Subdivision developments, such as Pimpama Coomera and Rouse Hill (Tables 1 and 2), have adopted a combination of rainwater, greywater and wastewater systems.

2.3. Consultation with Water Professionals in SEQ

An online questionnaire was developed to elicit information from water professionals familiar with the SEQ context. Participants were asked their opinions on how to define decentralised systems, including what physical features should be included, what is unique to decentralised systems in SEQ and what system scale is appropriate. A semi-structured interview approach was also undertaken for selected participants. The semi-structured interview enabled the interviewer to collect information on specific areas, while also allowing the interviewer to take an active role in the process and seek additional insights when required. The water professionals who participated were not necessarily representative of the whole industry, but were approached based on their perceived knowledge and involvement in decentralised systems in the SEQ context. The privacy of individuals was protected through anonymity, and answers were not attributed to a specific organisation. A thematic analysis of questionnaire and interview results was undertaken to identify common themes and descriptors used for decentralised systems.

Professional staff from water authorities were contacted for their comments and views. Authorities included: Brisbane City Council, Gold Coast City Council, Toowoomba City Council; state government, including the Department of Infrastructure and Planning, EPA, Natural Resources and Water and Queensland Health; and consultants in water business based in Queensland, such as Bligh Tanner, Econova, GHD, Maunsell, WBM, Worley Parsons and Central Queensland University. Their comments are summarised as follows:

- Decentralised systems will need to include both decentralised water and wastewater systems. Current practitioners consider decentralised systems to be part of an integrated approach in managing urban water resources that crosses traditional functional boundaries.
- Keywords in the definition of decentralised systems should include ‘fit-for-purpose’ and ‘close to the source(s)’.
- System features need to be dictated by the context, local characteristics and each individual project’s scale and needs. Technologies can range across a diverse suite of measures such as harvesting and using rainwater, greywater recycling systems and partially or fully on-site wastewater treatment. Technology selection should be defined by the water/effluent quality required which implies appropriate robustness, operation and maintenance and risk management strategies.
- The system scale can range from a small development to a relatively large development such as a small suburb, depending on the characteristics of the development areas. The difficulty in incorporating scale in the definition of decentralised systems was highlighted during the discussion.
- Many of the descriptors (such as volume, scale and low cost) under the historical definition of on-site systems are too limiting when applied to today’s understanding of decentralised systems. These descriptors can be used to describe a part, rather than the whole, of the system, as per today’s understanding and greater focus is made on tailoring systems to each individual target area.

- Specific characteristics of decentralised systems in the context to SEQ were not highlighted for inclusion in its definition.

2.3.1. Consultation Results: Aspects of Decentralised Systems

Interviewees were asked to define what constitutes a decentralised system. In addition, they were asked about the relevance of terms which are traditionally alluded to in the definition of decentralised systems such as, volume of water/wastewater processed by the systems, size of population or area serviced, economic cost, integrated water management, etc.

The definitions of decentralised systems provided by interviewees highlighted the connections with broader sustainability objectives such as reduced reliance on imported water and the interactions between water, wastewater and stormwater services. The definitions adopted by the professionals are expansive, focusing on the wider water cycle, which is consistent with an integrated urban water management approach. However, the need for urban water regulatory and management frameworks to evolve to meet the needs of decentralised systems was not specifically raised during the interview process.

The definitions adopted by professionals include a range of common concepts: decentralisation of infrastructure; function; and the roles of scale, sustainability and proximity to source. These and other aspects mentioned in the definitions provided during the consultation were further explored.

(a) Infrastructure

One of the most common descriptors used for defining decentralised systems infrastructure was reduced dependency, or differentiation from the traditional centralised and linear provision of services, in recognition of a wider range of service models and resources. At the same time, it was recognised that decentralised systems do not necessarily have to be closed loop or stand-alone in all aspects. In many cases, decentralised systems are integrated with existing centralised services, which provide service reliability while addressing sustainability objectives such as reduced demand on imported potable water. A transition to an integrated urban water management approach, in comparison to a conventional approach, involves increased linkages and interdependencies between water, wastewater and stormwater infrastructure. Some of the descriptors of decentralised infrastructure mentioned by participants included: *stand-alone; non-linear; not restricted to a single source or treatment location; able to utilise multiple sources including large network collection/reticulation; partially or not centralised, but not necessarily a closed system*.

(b) Function

The responses highlighted that decentralised systems are aimed at fulfilling a function (mainly provision of water and safe management of waste) and should be designed accordingly. The details of specific systems will vary with each case, but are typically based on scale, context and required water quality. As with centralised systems, reliability and public health risk mitigation are essential to the function of decentralised systems. Respondents did not restrict function discussions to wastewater management. They extended the concept to include all aspects of the water cycle: water supply and wastewater management, as well as different streams (greywater, rainwater, stormwater, treated effluent, etc).

(c) Recycling and Sustainability

Sustainability was identified as a clear differentiator between centralised and decentralised systems with a greater emphasis given to the environmental and sustainability function provided by the systems, e.g. water reuse and reduction of bulk water transfer. Responses indicated a heavy emphasis on the optimisation of opportunities for recycling and sustainability as a characteristic of decentralised systems. Recycling and sustainability could refer to the provision of recycled water and reuse opportunities for meeting water demand. Decentralised systems, as part of an integrated urban water management approach, consider broader sustainability goals in evaluating options for servicing an urban area. The inclusion of sustainability aspects in the definition implies that the respondents recognise that the systems are to be evaluated over their whole life cycle, including operating expenditure and environmental costs over the total life cycle of the system, such as embodied and operational energy demands, nutrient discharge and recovery, and material consumption.

(d) Proximity to Source

The current definition adopted by interviewees emphasises proximity to source as a major characteristic. Operation within a restricted system envelope was highlighted among responses, and was associated with the minimisation of bulk transfer over distance or inter-basin, reuse or treatment at or near the point of generation with minimisation of the ecological footprint. For example:

> *"Meeting water demand and managing waste within area of generation".*
> *"Water supplied in an area to be reused in the same areas".*
> *"Produces drinking / non-drinking water for local reuse".*
> *"Minimise energy associated with long distance pumping".*

(e) Scale

The responses indicated that components of the system will vary based on specific context or scale. Decentralised systems can encompass a range of scales from allotment (high rise/house) to neighbourhood, suburb, cluster, etc, with unique characteristics for each project.

(f) Technology

Decentralised systems imply a certain level of technology and treatment based on the required end-use and purpose of the system. The responses indicated that such systems could adopt a range of technological options. These are not restricted to wastewater alone and can include water supply, treatment of different wastewater streams and control of bulk transfer.

Greater emphasis was placed on the tailoring of a system to the particular needs of a site/catchment and the design and provision of services based on specific ecological, physical, climatic and geographical aspects. Some responses also mentioned the role of technology management models in the definition.

(g) System reliability

Implicit in the definitions was the need for system reliability in order to provide a minimum level of service to customers. The design and operation of decentralised systems need to take a risk management approach that considers the consequences of system failure in terms of public health and environmental impacts. In cases of where there is a high consequence of failure, connection to traditional networks may be required as a fall -back position.

Decentralised systems fulfil the same functions as centralised systems in the provision of water demand and safeguard of public health in the disposal of wastewater. Requirements for reliability and risk management in the provision of services are also applicable in such systems.

(h) Independence

Overall, professionals defined decentralised systems as systems with a greater degree of independence from single sources and centralised water/wastewater provision. The degree of independence can range from a stand-alone closed loop to a semi-integrated system.

Some of the respondents differentiated between on-site systems and decentralised systems. 'On-site' systems generally refer to allotment scale systems, while decentralised systems can encompass a wider range of scales.

Respondents often defined on-site systems based on the volume of wastewater generated and occupancy rate as they have traditionally referred to allotment wastewater management. Such parameters have a lesser impact as the scale increases (medium and larger schemes); yet, as one of the respondents mentioned:

> *Some guidance in regards to size might be necessary to assist in the identification of projects that might be better incorporated in centralised service provision.*

3. SCALE OF DECENTRALISED SYSTEMS

Decentralised systems can be implemented in a wide range of development scales, including allotments, a cluster of houses and subdivisions. As described in Section 2.1, the guidelines for decentralised wastewater systems planning and design in SEQ are available for a single house, a development, up to a population of 1000. Considering an average household size of 2.6 persons, a decentralised wastewater system can be provided for a development of approximately 380 dwellings.

The list of existing developments with decentralised systems (listed in Table 1 and Table 2) ranges from just one house (e.g. Healthy Home in Gold Coast and Sharland Oasis in Geelong) to as large as 50,000 lots in Pimpama-Coomera residential estate (Gold Coast). As listed in Table 1, the developments with decentralised systems in Queensland vary from single allotment to a maximum of 250 lots, with an average of nearly 80 lots per development. The Pimpama-Coomera residential estate has not been included in this assessment due to the uncommon nature of the Greenfield development. Similarly, considering Table 2, the developments in other States vary from single allotments to 8,500 lots (planned Aurora capacity) with an average of nearly 1,700 lots. The Rouse Hill development of 36,000 lots is not considered due to its extensive nature.

Based on the above, developments up to 8,500 lots have been designed with decentralised systems. If the developments such as Pimpama-Coomera and Rouse Hill are included in scoping the scale of decentralised systems, the decentralised systems are able to provide services up to any scale. Thus, it can be concluded that the scale is not a determining issue in providing decentralised services either in isolation or in combination with centralised systems.

For demonstration purposes, Figure 2 depicts the building scale wastewater reuse and Figure 3, the cluster scale sewer mining and reuse. Figure 4 highlights development scale water and wastewater servicing options. Decentralised systems, such as those in Figures 2 and 3, can form part of a satellite wastewater system as described by Gikas and Tschobanoglous (2009), which generally occurs in the upper part of a wastewater system and can be used to reduce loads on centralised facilities and offer local opportunities for reuse.

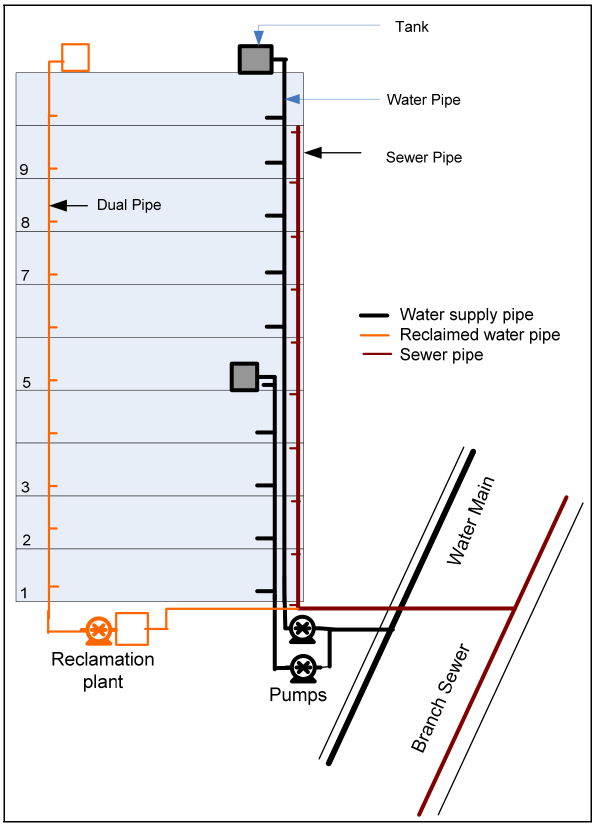

Figure 2: On-site wastewater system (Source: Sharma et al, 2005)

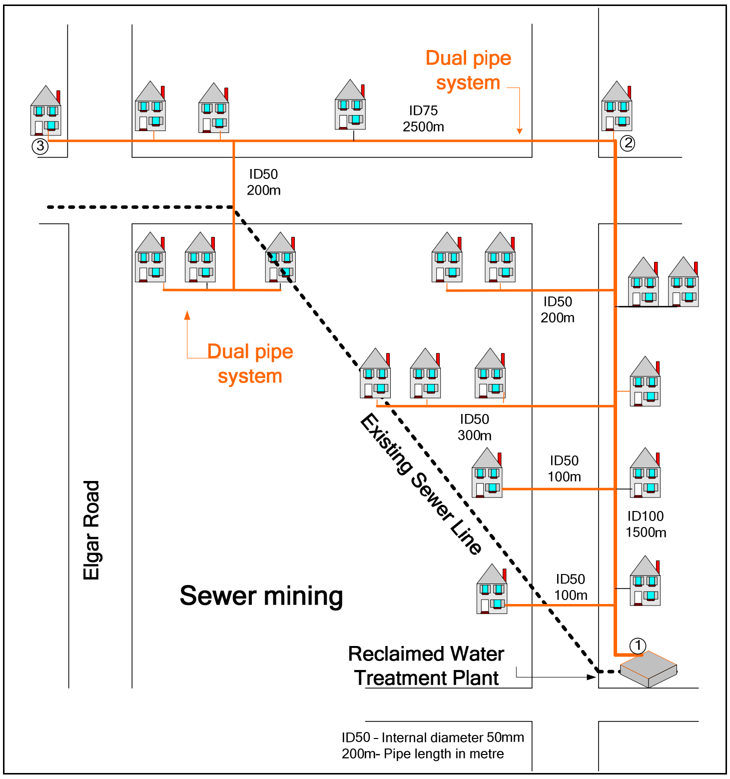

Figure 3: Cluster scale reclaimed water reuse system (Source: Sharma et al, 2005)

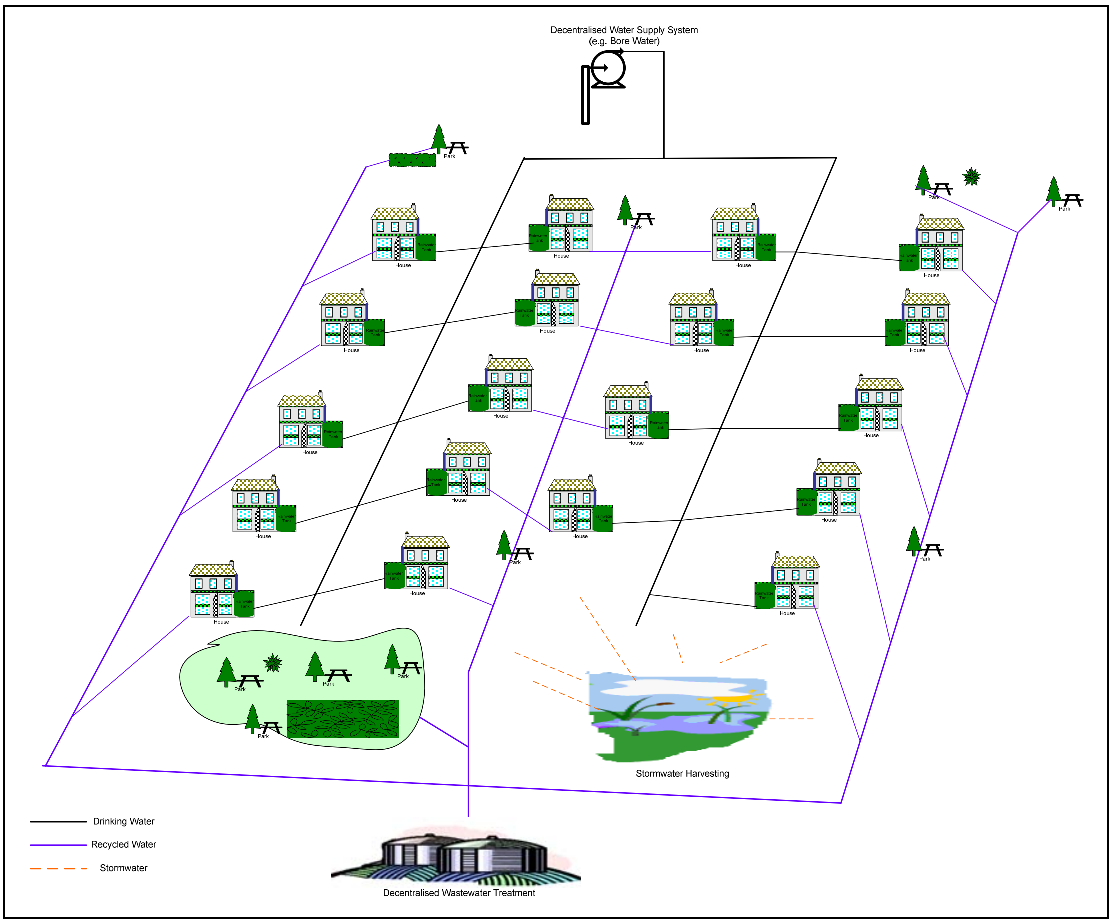

Figure 4: Development scale decentralised systems

4. DEFINITION OF DECENTRALISED SYSTEMS

Based on a review of the literature, the definition of decentralised systems from Crites and Tchobanoglous (1998) was considered suitable for adaptation, as it incorporates the integration between different water services and the varying scales that decentralised systems operate at. Furthermore, it captures the linkages that can occur with an existing centralised system:

> *Decentralised systems can be defined as the collection, treatment and use of rainwater, stormwater, groundwater or wastewater at different spatial scales, from individual homes, clusters of homes, urban communities, industries, or built facilities, as well as from portions of existing communities either independent from or as part of a larger system.*

However, the above definition has been modified to reflect that decentralised systems are provided to minimise environmental impacts caused by the increase in demand on fresh water resources and discharge of waste loads to a receiving environment (natural water systems, soil and atmosphere). The following generalised definition is suggested for adoption:

> *Decentralised systems can be defined as systems provided for water, wastewater and stormwater services at the allotment, cluster and development scale that utilise alternative water resources; including rainwater, wastewater and stormwater; based on a 'fit for purpose' concept. These systems can be managed as standalone systems, or integrated with centralised systems. Wastewater streams are partially or completely utilised at or close to the point of generation.*

At the cluster and development scale:

> *Stormwater is also managed as part of an integrated approach that aims to control the quality and quantity of runoff at or near the source to minimise the impact of the development on the natural ecosystem.*

In relation to SEQ, no specific characteristics were identified for inclusion in the definition of decentralised systems.

Highly variable scales of development with decentralised systems can be noted from the existing examples; therefore, it is inappropriate to specify any particular scale of development in defining decentralised systems. The suggested definition is simply based on the concepts of integrated urban water management applied to developments for the provision of water, wastewater and stormwater services such that the demands on freshwater sources and wastewater flows to receiving environments are reduced.

5. CONCLUSION

Decentralised systems with IUWM and WSUD concepts are being planned and implemented for new and future urban developments, either as separate facilities or in combination with a centralised system. This is due to an increase in urbanisation and industrialisation, resulting in unsustainable pressure on freshwater resources and the wastewater receiving environment.

The following general definition of decentralised systems is recommended for adoption in the SEQ Decentralised Systems project:

> *Decentralised systems can be defined as systems provided for water, wastewater and stormwater services at the allotment, cluster and development scale that utilise alternative water resources; including rainwater, wastewater and stormwater; based on a 'fit for purpose' concept. These systems can be managed as standalone systems, or integrated with centralised systems. Wastewater streams are partially or completely utilised at or close to the point of generation. At cluster and development scale, stormwater is also managed as part of an integrated approach that aims to control the quality and quantity of runoff at or near the source to minimise the impact of the development on the natural ecosystem.*

An attempt was made to estimate the scale of decentralised systems in terms of development size. It was concluded from the size of existing developments designed with WSUD, that it varied from a single lot to 8,500 lots or even higher. In summary, the process rather than the scale governs the definition of decentralised systems. Furthermore, the systems and technologies for providing decentralised water, wastewater and stormwater services can vary based on the scale of development and the conditions of the locality to which they are applied.

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