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Climate Adaptation through Sustainable Urban Development in Makassar, Indonesia

Context and challenges in urban water and wastewater services for Makassar, South Sulawesi, Indonesia

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Source: G.Tjandraatmadja 2011

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NOMENCLATURE AND ABBREVIATIONS

	Bahasa Indonesia	English
AusAID		Australian Agency for International Development
B3	*Bahan Berbaaya dan Beracun*	Hazardous and toxic materials
BAPEDALDA	*Badan Pengendalian Dampak Lingkungan Daerah*	Provincial Environmental Agency
BAPPEDA	*Badan Perencanaan Pembangunan Daerah*	Regional Development Planning Agency
BBP		Technological Study and Application Institute
BBSPJ	*Balai Besar Sumapapua Provinsi Jeneberang*	Watershed Management Office for Jeneberang River
BKSDA	*Balai Konservasi Sumber Daya Alam*	Dept. of Forestry Natural Resources Conservation Unit / Watershed Area Management Office
BLH	*Badan Lingkungan Hidup*	Environmental Agency –province level
BAPPENAS	*Badan Perencanaan Pembangunan Nasional*	National Development planning Agency
BPN	*Badan Pertanahan Nasional*	National Land Agency
BPS	*Badan Pusat Statistik*	Statistics Indonesia
BMKG	*Badan Metereologi, kilmatologi, dan Geofisika*	Meteorological Climatological and Geophysical Agency
BOD		Biological oxygen demand
Ca	*Kalsium*	Calcium
Cd	*Kadmium*	Cadmium
CN	*sianida*	Cyanide
COD		Chemical oxygen demand
CSIRO		Commonwealth Scientific and Industrial Research Organisation
Cu	*Tembaga*	Copper
Cr	*Krom*	Chromium
D		Water requirements (L/day)
DTR	*Dinas Tata Ruang*	Spatial and Settlement Agency
DTK	*Dinas Tarkim*	Office and the Ministry of Public Works
DINKES	*Dinas Kesehatan*	Department of Health, at municipal and provincial level
DKK	*Dinas Kebersihan dan Keindahan Kota*	Municipal Sanitary and Landscape Office
DO		Dissolved oxygen
DPU	*Dinas Pekerjaan Umum*	Municipal Public Works
ENSO		El Nino Southern Oscillation
DP/KI	*Department Pertanian/Kantor*	Dept. of Agriculture and Irrigation

	Irigasi	office
f		Water requirement safety factor (between 1.05-1.15)
Fe	*Besi*	Iron
F.coliforms	*Coliform tinja*	Fecal coliforms
Free CL2	*Bebas klorin*	Free chlorine
GW	*Air tanah*	Groundwater
Hg	*Air raksa*	mercury
H2S	*Hidrogen sulfida*	Hydrogen sulphide
IPA	*Instalasi pengolahan air*	Water treatment plant
IPAL	*Instalasi pengolahan air limbah*	Wastewater treatment plant
IPCC		International Panel on Climate Change
IUWM		Integrated urban water management
JICA		Japan International Cooperation Agency
KIMA	*Kawasan Industri Makassar*	Makassar industrial complex
KmnO4		Potassium permanganate
L	*Kehilangan air*	Water loss in distribution (% total supply)
Lk		Correction factor for water loss during water distribution
Mg	*Magnesium*	Magnesium
MSL	*Berarti permukaan laut*	Mean Sea Level
n.d.		not determined
NGO		Non-governmental organisation
N-NH3	*Ammonia*	Ammonium nitrogen
NO2 or N-NO2	*Nitrit*	Nitrite
NO3 or N-NO3	*Nitrat*	Nitrate or nitrate nitrogen
NRW		non-revenue water
NTU		Nephelometric Turbidity Units
O&G	*Minyak dan lemak*	Oil and grease
Pb	*Timbal*	Lead
PDAM	*Perusahaan Daerah Air Minum*	Municipal Water Company
PKLH	*Pendidikan Kependudukan dan Lingkungan Hidup*	Ministry of Environment Regional Centre
RTRW	*Rencana Tata Ruang Wilayah*	Regional Land Use Plan
PLN	*Perusahaan Listrik Negara*	State Electricity Company
PLTU	*Pembangkit Listrik Tenaga Uap*	Steam Power generation
P		Number of people served
PSDA	*Dinas Pengelolaan Sumber Daya Air*	Water Resources Development Office
PTPA	*Panitia Tata Pengaturan Air,*	Committee for River Basin Water Resources Management
PO4	*Ortofosfat*	Phosphate
Pt	*Total populasi*	Total population (inhabitants)
q	*Air setiap hari komsumsi per kapita*	Daily water consumption per capita

RC	*Konsumsi domestik*	Domestic consumption (%Total supply)
S		Water supply service ratio (%)
SN		Social network
SNA		Social Network Analysis
SO4	*Sulfat*	Sulphate
ST	*Tangki septik*	Septic tank
T.coliforms	*Coliform tinja*	Total coliforms
TDS	*Padatan Terlarut*	Total dissolved solids
TSS	*Padatan Tersuspensi*	Total suspended solids
TPA	*Tempat Pembuangan Akhir*	Solid waste treatment plant
UNHAS	*Universitas Hasanuddin*	Hasanuddin university
UPTD	*Unit Pelaksana Teknis Dinas*	Provincial Technical Implementation Unit
WTP	*IPAL*	Water Treatment plant
Zn	*Seng*	Zinc

EXECUTIVE SUMMARY

The *Climate Adaptation through Sustainable Urban Development: Urban Planning; Makassar, Indonesia* project, commissioned by the CSIRO-AusAID Alliance is investigating potential climate change impacts on urban water services in Makassar and identifying some potential adaptation strategies. The Alliance partnership has been established to engage researchers and AusAID staff in a participatory manner to develop research products. This process provides a basis for collaboration and integration of effort between management staff at AusAID and scientists in CSIRO to enhance the efficiency and effectiveness of investment strategies.

To support decisions for water and wastewater infrastructure investment in coastal cities such as Makassar in light of anticipated impacts of climate change population growth etc, understanding of the water resource context is essential. The use of a transparent, valid decision-making process will deliver a variety of potential benefits for AusAID and partner countries including, access to reliable data sources and information, knowledge management and encouragement of collaborative efforts with water managers in partner countries.

This document is a review of the water resources and water and wastewater service context of Makassar developed collaboratively by the Research Centre for Climate Change Impacts in Eastern Indonesia, Hasannudin University (UNHAS) and CSIRO. The document provides background information on the urban water context in the city of Makassar and its water resources, which are part of the greater Mamminasata Area (comprised of the Makassar, Gowa, Maros and Takalar regencies), and is a key component for the analysis of the water management strategy. It also explores the issues and challenges that impact water and wastewater provision in the city of Makassar and the priorities and concerns of institutional stakeholders.

The review draws on: (i) the best information available including the published and unpublished literature and/or data; (ii) preliminary analyses based on the available data; and (iii) information obtained through the stakeholder engagement process and survey.

Water service status

The Metropolitan Mamminasata area relies on surface water and groundwater as their major water sources.

Piped mains water is the preferential source of water for majority of users, particularly for drinking and cooking. However, as water supply coverage is not available through the whole region and alternative water sources are widely adopted. In Makassar which is the most urbanised city and also has the most extensive pipe network coverage (72% in area and 62% of population serviced), the piped water consumption per capita is 117L/cap/day (equivalent to 62% of the national consumption average). Residential customers utilise mains water (when available) and shallow wells for non-potable uses. Industrial and commercial customers adopt typically bore water and mains water. Other regencies, within the Metropolitan Mamminasata, have a predominantly rural population which adopt well water and alternative sources, such as rainwater and shallow well water.

Data on groundwater is very limited and there is no information on the actual amount of groundwater adopted by households. Hence groundwater evaluation has not been included in this report.

Water supply to Makassar is derived from two major intakes, the Malenkeri intake, at the Jeneberang River, and the Lekopancing dam, at the Maros Rivers. These rivers feed five water treatment plants in Makassar. The largest of which are the Somba Opu and Pannaikang Water treatment plants (WTP), each with production capacity of 1000 L/s.

In the dry season, flow in the Maros river is reduced by 25%, decreasing supply in the Lekopancing dam. As a result additional extraction and transfer from the Jeneberang River to WTP Pannaikang is required. The Jeneberang River provides a reliable source of water supply thanks to the regulated flows from the Bili-Bili dam. However, upstream landslides in 2004 have increased the water turbidity of the river to levels up to 1000NTU. High turbidity increases the cost of water treatment at the WTP.

Water distribution is a major challenge. In 2010, 62% of the population of Makassar had access to mains water, with limited water distribution infrastructure and water shortage episodes common in the north of the city, where the industrial complex KIMA is housed. Real losses in distribution are estimated as 30%. In addition, water supply is intermittent in many areas resulting in re-contaminationd through the distribution infrastructure.

Sanitation

Sanitation is estimated to cover 85% of Makassar's area. The sanitation system in Makassar consists of blackwater (toilet water) discharged to septic tanks and pits on individual properties and greywater (wastewater from bathroom, kitchen, and laundry) discharged to a network of open stormwater drains. Septic tanks are supposed to be cleaned periodically upon request. However, the condition of the septic systems is unknown in many areas. High population density and limited land availability are placing constraints on the effectiveness of the system in a number of suburbs. It is believed that they are contributing to contamination of shallow wells; and in many instances that septic tank effluent is also discharged to the stormwater drains.

Stormwater drainage

Stormwater drains are often used for disposal of garbage. This reduces their drainage capacity and causes blockages. As a consequence, overflow of the drains and flooding during high rainfall intensity events is common and compounds the risk of well water contamination and overall public health.

Trade waste

On-site treatment is mandatory for trade waste generators and commercial dischargers located outside of the industrial zone. Wastewater from KIMA, the industrial zone, is treated by a localised treatment plant with Upflow Activated Sludge Blanket (UASB) technology. Monitoring of wastewater discharge quality at individual on-site treatment plants and overall water quality at waterways is limited by economic constraints. A number of hotels have also been reported to reuse the effluent produced on-site for irrigation.

Institutional set-up

The institutional set-up in the Mamminasata region is complex with multiple agencies at provincial, regency and municipal level sharing the jurisdiction over water resources, water delivery and sanitation. Informal networks are also highly complex, consequently any effective change strategies require participation and cooperation of multiple stakeholders. At municipal level, water treatment and distribution is the responsibility of PDAM, sanitation and solid waste management the responsibility of DPU, who is also responsible for delivery of water supply infrastructure to low income areas and environmental management the responsibility of BLDH.

Future development of water and wastewater services

Future masterplan planning for Makassar and the Mamminasata area recommends the construction of new dams and water storage, upgrade of the production capacity of the treatment plants and of the distribution system coverage to improve its condition in the next 30 years. The plans assume that mains water consumption will increase to the equivalent national level (190L/p/d) with increased urbanisation by 2030.

Municipal authorities recognise that the current on-site system will become unsustainable in the future as urbanisation and densification occur. Hence, for Makassar city, a three tiered sanitation system is planned. In high density areas blackwater will be collected via a sewerage system and directed to two treatment plants, in medium density areas communal treatment systems will be implemented and in low density areas the septic system will be maintained.

All infrastructure development is subject to external funding. Climate change impacts are currently not included in the assessment of future services. Climate projections for Indonesia indicate increase in temperature and evaporation and potential shift in rainfall periods, however no climate projections have yet been conducted specifically for Mamminasata to evaluate local climate impacts.

Current and future challenges:

- Limited access to mains water and sanitation. Financial constraints play a major role on the capacity for expansion of services.
- Population growth is increasing the pollution load on the environment due to limited sanitation infrastructure and illegal rubbish disposal on waterways and drainage channels.
- Status of groundwater exploitation is unknown. Groundwater resources exploitation is poorly regulated and could become unsustainable in the future. Population growth will contribute to depletion of groundwater water reserves, insufficient recharge will be exacerbated by deterioration in groundwater reserve quantity, due to sea water intrusion in coastal areas, and quality, due to contamination from domestic wastewater in urban areas. Scarcity of groundwater resources will place additional demand on mains water supply. More information is required on groundwater resources to evaluate the true vulnerability of the city.
- Many of the challenges which plague Makassar are caused by population growth and urbanisation which is overwhelming the existing system capacity. A number of issues are localised at specific reas, however due to their nature, their management would require participation of multiple stakeholders, including government often at various levels and private citizens/community. Whether the institutional and societal set-up in place is ready to tackle those challenges collaboratively is still to be confirmed.
- Data gaps: limited data is available on the status of the environment, e.g. water quality, groundwater condition and recharge levels, river flows, water consumption patterns, etc. In some cases, data record periods may not be continuous, and, in other cases data needs to be checked prior to use.
- Public awareness of the general community at large on environmental issues is deemed low.
- Stakeholders recognise that climate change is happening, but the impact of climate change on water resources has not been fully examined to date in Makassar. Climate change has not yet been included in the future planning of Makassar and its implications to future development of Makassar are yet unknown. However, the literature suggests that it might exacerbate water scarcity and alter rainfall patterns. Anecdotal evidence suggests changes to precipitation and increase in temperature and evapo-transpiration. A number of questions remain: (i) the impact climate change on precipitation, temperature and overall water resources and water demand has not yet been quantified; (ii) Groundwater supplies are likely to become more strained due to population growth and pollution. However, could rainfall frequency and reduced intensity further reduce groundwater recharge? Could this lead to the need for increased reliance on mains water supply? ; (iii) Could precipitation changes increase the vulnerability of catchment areas to further landslides?; (iv) Could river flows and frequency of extreme events change into the future? What

implications could this have on Makassar's urban planning or drainage capacity and could this lead to further competition for water resources among rural, industrial and residential sectors?

Future research to be carried in this project aims to be able to shed more light on some of the impacts of climate change to overall water security in the Mamminasata area.

1. INTRODUCTION

Countries in the Asia-Pacific region face many pressing social, economic and environmental issues. New ways of thinking and acting are required given the complexity of the issues and the fact that these problems remain problems despite the huge amounts of development aid invested in attempting to solve the problems to date (Sachs 2008). In this context, the CSIRO AusAID Alliance (www.rfdalliance.com.au) is a research for development initiative aimed at improving the impact of the Australian Government's international aid program. The Alliance intends to tackle important development challenges in the Asia-Pacific region through improved knowledge of climate, water and energy systems and by better understanding vulnerabilities and adaptation options. One of the research projects within this Alliance is the "*Climate Adaptation through Sustainable Urban Development"* which aims to explore improvements in spatial analysis and environmental impact analysis on decision making for major urban infrastructure projects and integrated urban environmental management, in the context of adaptation to projected global and regional climate change. The project is conducted through engagement with policy makers, urban managers and researchers in two collaborative urban case studies, one in Can Tho, Vietnam and the other in Makassar, Indonesia. The focus is on integrated urban water management (IUWM) of water services as a means of demonstrating the application of sustainable urban development principles that respond to multiple drivers such as climate change, population growth and rising demands on regional resources such as water and energy.

The IUWM framework, adopted in this research project, is a state-of-art approach for urban water utilities to plan and manage urban water system (Maheepala, 2010). The framework consists of four broad steps as follows.

1. Understanding the context of the case study area. In this step, the context and characteristics of the region are evaluated. This aims to understand the water and wastewater service challenges, the availability of data and to identify any additional knowledge gaps that may need to be investigated. The knowledge at this step is crucial as it underpins the following steps within the overall framework.

2. Indentifying objectives, indicator criteria and priorities. Based on the results obtained in step 1, stakeholders are engaged to identify the overall study objectives indicator criteria and assessment options.

3. Understanding the impact of climate change in the case study area. This process documents and identifies major challenges and opportunities for provision of water and wastewater services under climate change scenarios.

4. Developing and assess options for climate change adaptation.

This report describes findings from step 1 and 2 for the Makassar city case study. In particular, the document provides an overview of the current and planned water supply and wastewater context in Makassar city and of the water resources in the greater Mamminasata region (comprised of Makassar, Maros, Gowa and Takalar regencies). This includes an assessment of the water and wastewater infrastructure, economic, environmental social and institutional context and the challenges faced by authorities in Makassar. In this regard, the report does not only underpin the overall methodology of this project but it also contains information - which is of general interest.

Therefore, the report can be used by anyone interested with the water supply and wastewater context in Makassar city and the Mamminasata region.

It is worth to note that this review draws on: (i) the best information available including the published and unpublished literature: (ii) preliminary analysis from available data; and (iii) information obtained through stakeholders engagement. For example, a series of workshops (involving government at all levels, academia, water utilities, NGOs, etc) have been performed to verify the outcomes of (i) and to understand the major challenges in the region. Also, stakeholder mapping and network analyses have been conducted to understand the institutional context for water provision. More detail description of the methodology is given in each of the relevant sections.

This report provides an overview of Makassar, the water resources available in the area, the legislative and institutional set-up for water use and the current context of water supply, sanitation and stormwater services. Key challenges for water supply and sanitation identified from the literature and from stakeholder inputs are also presented.

The report is structured into chapters as follows:

- Chapter 2 - Overview of Makassar
- Chapter 3 - Water resources
- Chapter 4 - Water resource management
- Chapter 5 - Water supply capacity in Makassar city
- Chapter 6 - Water Demand in Makassar
- Chapter 7 - Wastewater management
- Chapter 8 - Stormwater
- Chapter 9 - Solid waste management
- Chapter 10 - Other environmental issues
- Chapter 11 - Stakeholder perception of key water issues
- Chapter 12 - Mamminasata masterplan
- Chapter 11 - Discussion and conclusions

2. MAKASSAR CITY

1.1 General background

Makassar is the capital city of the South Sulawesi Province, Indonesia. It is located on the west coast of Sulawesi Island (Figure 1), on a crossing route for maritime and air traffic from both north to south and from west to east Indonesia (hence it is well known as the “gateway to Eastern Indonesia”). The city has an area of 175.8km2 and is divided into 14 districts (*Kecamatan*) and 142 sub-districts (*Desa*) (BPS, 2010). Regionally, Makassar City is part of the greater metropolitan Mamminasata (Makassar, Gowa, Maros and Takalar regencies) region - which covers an area of 246,230 ha and hosts 2.1 million inhabitants (KRI International Corp and Nippon Koei Co. Ltd. 2006).

The Indonesian government has plans to develop Makassar and the Metropolitan Mamminasata region (Figure 2) into a model city for the region and an exemplar of urban development for Indonesia (National Spatial Planning in KRI International Corp and Nippon Koei Co. Ltd. .2006). Future development of the area aims to enhance the standard of living of the population, promote economic development and preserve the environment and amenities in the area through the adoption of best practices of urban development from around the world and consideration of available resources and capabilities. This will be achieved by the integration of transport, planning and major service infrastructure in the area across the three regencies and Makassar city (KRI International Corp and Nippon Koei Co. Ltd. 2006).

Yet, achieving Millennium Development Goals for water and sanitation access in the Mamminasata region is one of the key challenges for authorities in the region. In 2010, in Makassar city, the most developed city in the Mamminasata region, mains water service coverage was available to 62% of the population, whilst in the regencies of Maros, Gowa and Takalar, only 19.1%, 12.7% and 11% of the population had access to water services (Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011). Likewise, not all areas have access to sanitation services (McDonald 2011).

Population growth and increased urban development will increase the stress on water resources, water distribution, sanitation and the environment in Makassar and the Mamminasata region.

The next sections provide an overview of the characteristics of the region.

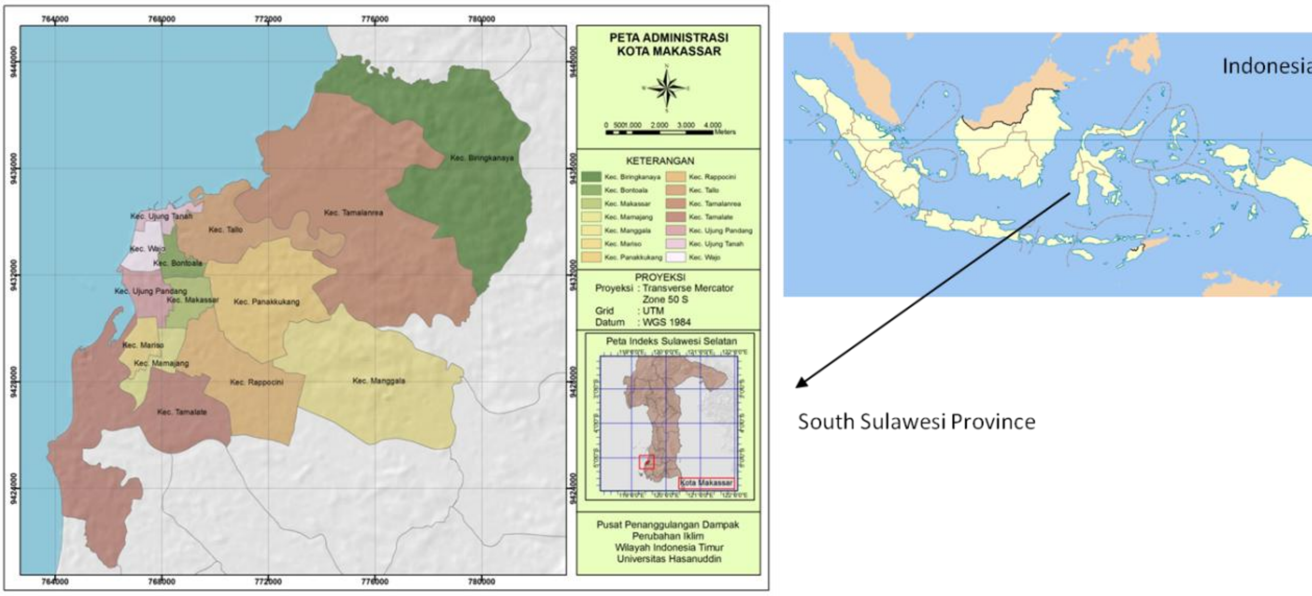


Figure 1: Makassar city's administrative map (Source: UNHAS, 2011)

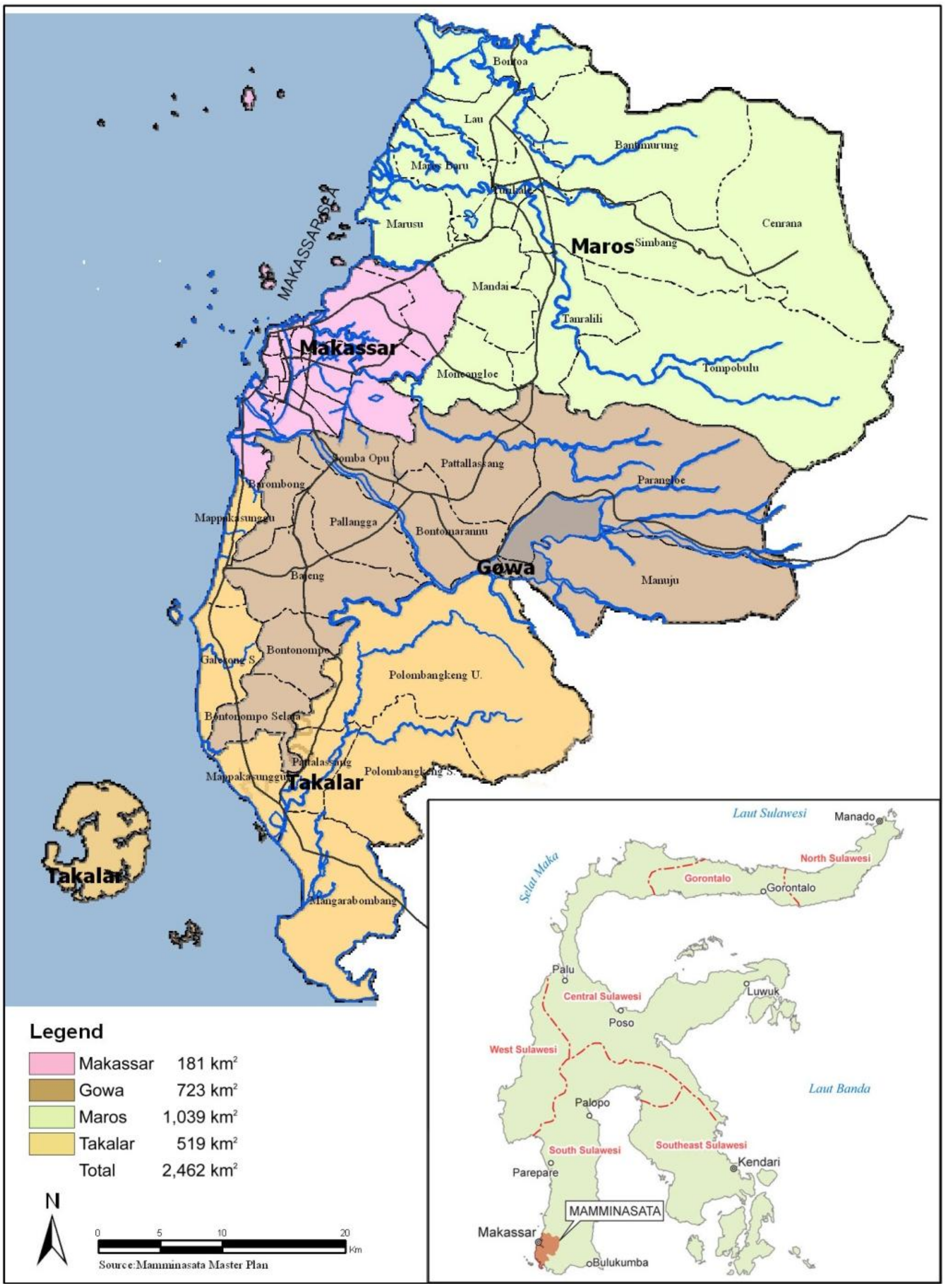


Figure 2: Metropolitan MAMMINASATA (Makassar-Gowa-Maros-Takalar) region (Source: Mamminasata masterplan, 2010)

1.2 Climate

The climate is warm and tropical characterised by high humidity (>70%) and mean temperature which varies very little throughout the year – at around 27.8°C. However, the diurnal (daily) temperature variation can be larger than the monthly variation, with the minimum and maximum temperatures range around 24°C and 32°C, respectively. The rainfall is dominated by the Asian monsoon, so that it has a distinct wet and dry season. The northwest monsoon (wet season) typically prevails in November-May, while the southeast monsoon (dry season) generally occurs in April-October. The rainfall pattern, therefore, resembles a U-shape with one peak and one low

(Figure 3). Figure 3 also plots the potential evaporation which is one of the key factors of the hydrological cycle. It provides an indication of maximum possible evaporation under saturated surface conditions. Apparently the potential evaporation exceeds rainfall between June and October.

Similarly over the Indonesian region, the year-to-year variability of the monsoon and total rainfall in this region can be large and is associated with the El Niño Southern Oscillation (ENSO) phenomena (McBride 1992; Kirono *et al.* 1999). An analysis conducted by the Indonesian Bureau of Meteorology and Climatology (BMKG) suggests that in El Niño years the wet season onset in Makassar is generally delayed by about 10 days and the wet season length is shortened by about 10-30 days. Meanwhile, the dry season rainfall is typically reduced by 51-80%. Historically, El Niño events occur every 3 to 7 years and often alternate with La Niña events. Since about 1976 there has been a tendency for El Niño phases of ENSO to dominate (Power and Smith 2007), and the negative correlation between Indonesian monsoon rainfall and ENSO has become enhanced since the late 1970s (Chang *et al*., 2004). This, in turn, contributes toward increase in water scarcity in many parts of the region.

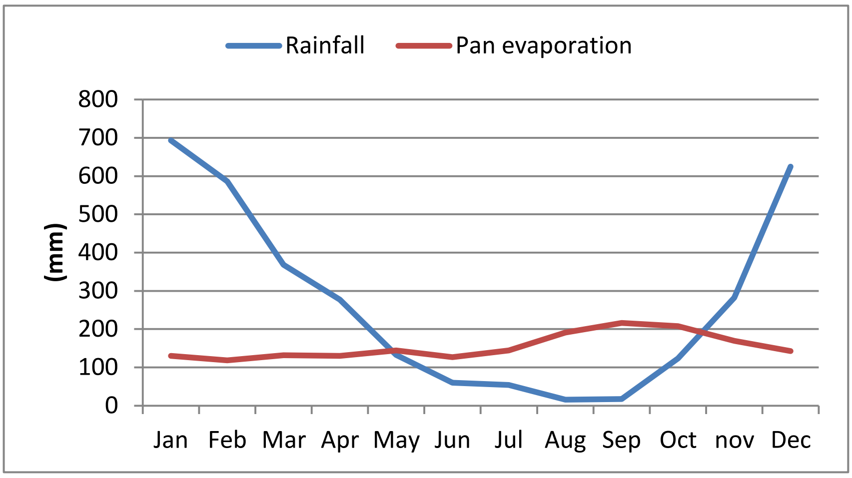


Figure 3: Long-term mean monthly rainfall (1970-2000) and pan evaporation (2005-2009) observed in Maros climatological station.

There are no studies of long-term historical climate data specifically for Makassar and South Sulawesi to provide evidence of whether and how its climate has changed. However, some studies in Indonesia are available for guidance. The global maps presented in the IPCC (2007) Fourth Assessment report suggests the linear trend of annual temperature for 1901-2005 over the Sulawesi region is around 0.5^{o} to 0.8^{o}C. An annual rainfall decrease of around 2-3 per cent across Indonesia for the 20^{th} century, with respect to the average 1961-90 value, has also been reported (Hulme and Sheard, 1999). This is confirmed by Kirono's (2002) study, which indicates that there is a decreasing trend in the 1879-1999 Indonesian rainfall index for both the dry and wet seasons (even though the decline in the wet seasons rainfall is statistically insignificant). The Manton *et al*'s (2001) study found there were no significant trends in the extreme rainfall indices in Indonesia for 1961-1998 period.

Using a shorter period of data, Nasrullah (2011) shows that Makassar's temperature has been increasing at around 0.03^{o} (January) and 0.02^{o}C (July) per year during 1972-2007. This author also notes that the onset of wet and dry season over the South Sulawesi region has shifted. The wet season onset in Barru (west Maros, Makassar) in 2001-2007 has been delayed for around 20 days, in comparison to that of 1971-2000. In north Gowa (east Maros), the delay is around 10 days.

With regard to climate projection, there are also no studies specifically conducted for Makassar and South Sulawesi to date. Considering the IPCC (2007) report, the annual temperature change, relative to the 1980-1999 period, suggest that the approximate figures for South Sulawesi are +0.5^{o} to +1.0^{o} and +1.5^{o} to +2.0^{o}C for 30 years centered on 2020 and 2050, respectively (for the A1B emission scenario) . By the 2090s, the projected warming is about +2.0^{o} to +2.5^{o} for A1B emissions, and +2.5^{o} to +3.0^{o} for A2 emissions. The projected changes for annual rainfall for the period 2080-2099 relative to 1980-1999 are around 0 to +5%. For annual potential evaporation, the change in 2081-2100 relative to 1970-2000 is 0.5 to 1 mm/day (Katzfey *et al*., 2010). It is not yet possible to state whether ENSO activity will be enhanced or dampened, or if the frequency of events will change: it could intensify, weaken, or even experience no change depending on the balance of changes in the underlying process (Collins *et al*., 2010). All of this information is approximated from coarse-to-medium spatial resolution climate model, therefore, they should be considered indicative only. Fine-resolution climate simulation and analyses for developing a more robust climate change projections for Makassar and South Sulawesi is currently being conducted, by this project, and will be reported in due course.

1.2.1 Topography, morphology and soil

The characteristic land morphology in the Mamminasata area is described in CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants (2001). Two landforms are prevalent in Makassar: coastal alluvial plains and undulating hills. These were formed by volcanic eruption rocks and by the deposition of sediment transported by the Jeneberang and Tallo rivers. For example, the flat land between Makassar city and Takalar regency is an old floodplain of the Jeneberang river formed in the Late Quaternary age (CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants, 2001). Small scale sandbars and swamps are prevalent in the vicinities of the river deltas and along the seacoast.

This flat landform has gentle undulation ranging from 5 to 40 m elevation above sea level (CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants, 2001).

The soil in Makassar is comprised of inceptisol and ultisol clay soils. Inceptisol is a clay structure soil formed by on-going sedimentation and wet-dry process. It can be found in most of Makassar in upland, river banks, swamps, alluvial plain and on some tectonic and volcanic structural landforms. The ultisol is a red colour acidic clay, rich in iron oxide (weathered soil), created by erosion of sedimentary stones (sandstone and claystone) and old volcanic rock. It typically has good drainage, but it is poor in nutrients, such as nitrogen, calcium and potassium, and has low organic content. It can be very erosive to metal pipes (Globalindo Consultama, 2006).

1.3 Demography, economic activity and urban development

Makassar is the largest and most urbanised city in South Sulawesi Province. It is also a major economic, government and educational centre for the province. In 2009, Makassar had a population of more than 1.272 million people (BPS Makassar, 2010).

The population in Makassar City is distributed over 14 sub-districts (*Kecamatan*) and 143 villages (*Desa*). These include:

- North: Biringkanaya, Tamalanrea, Tallo and Ujung Padang.
- South: Tamalate and Rappocini.

- East: Mangala and Panakkukang.
- West: Bontoala, Ujung Pandang, Makassar, Mariso, Wajo and Mamajang.

Seven districts are located on the coast: Mariso, Tamalanrea, Wajo, Ujung Tanah, Tallo and Biringkanaya. The largest area district is Biringkanaya (48.22 km^2), while the smallest is the district of Mariso (1.82 km^2). The majority of the population resides in the west: Tamalate, Rappocini, Tallo, Panakkukang and Biringkanaya districts, however the most dense areas are Makassar, Mariso, Bontoala and Mamajang districts with 33.4, 30.5, 29.9 and 27.2 thousand inhabitants per km^2 respectively (Figure 4). The average household across Makassar has 4.29 inhabitants per household, but average household size ranges from 3 to 5.3 inhabitants per household across districts (BPS, 2010).

South Sulawesi and in particular Makassar has experienced significant economic growth since 2002, at 4.8% and 14.5% GRDP respectively. Makassar city alone accounts for 77% of the economy in Mamminasata (KRI International Corp and Nippon Koei Co. Ltd. 2006). Economic activity in the Makassar province consists mainly of trade, manufacture and the service sectors, which contributed respectively to 29%, 21% and 16% of the 2009 economic activity as shown in Figure 5 (BPS, 2010). Industrial activity in the city is small and comprised mainly of processing for agriculture, wood, textiles and food (BPS, 2010). Makassar is also a major shipping hub, with activities concentrated at its port.

Future expansion of urban development for Makassar is expected to occur mainly to the north and the south of Makassar as shown in Figure 6 (KRI Iinternational Corp, NIPPON Koei Co. Ltd., 2006).

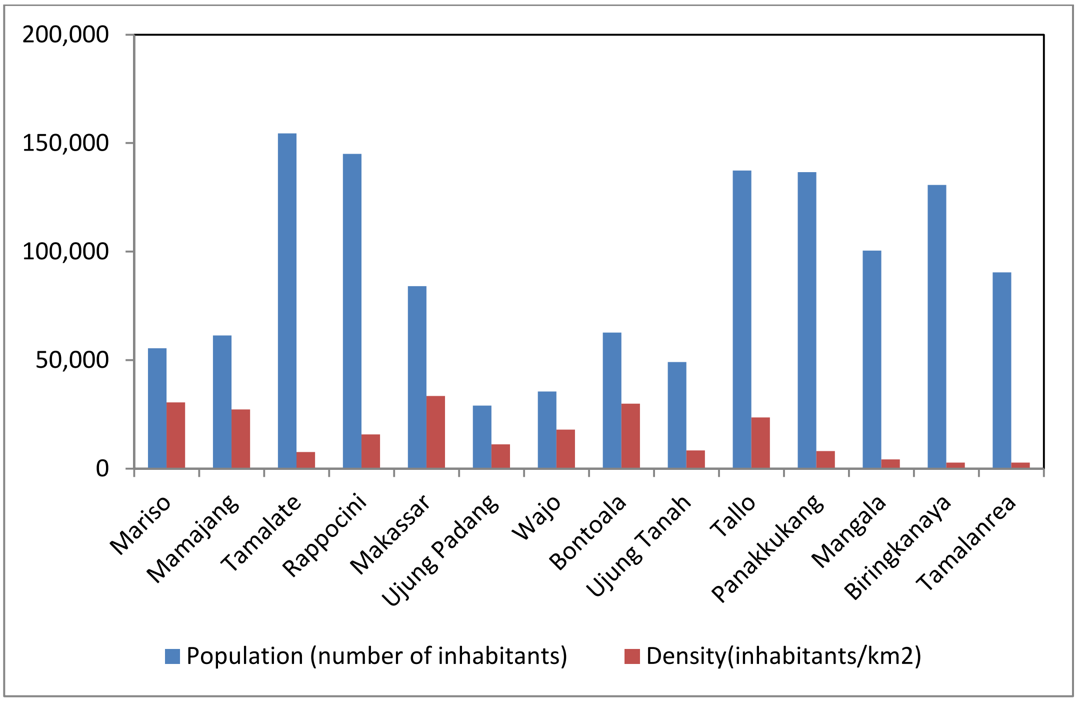


Figure 4 : Population distribution in each of the districts (*kecamatan*) in 2009 (Adapted from BPS 2010)

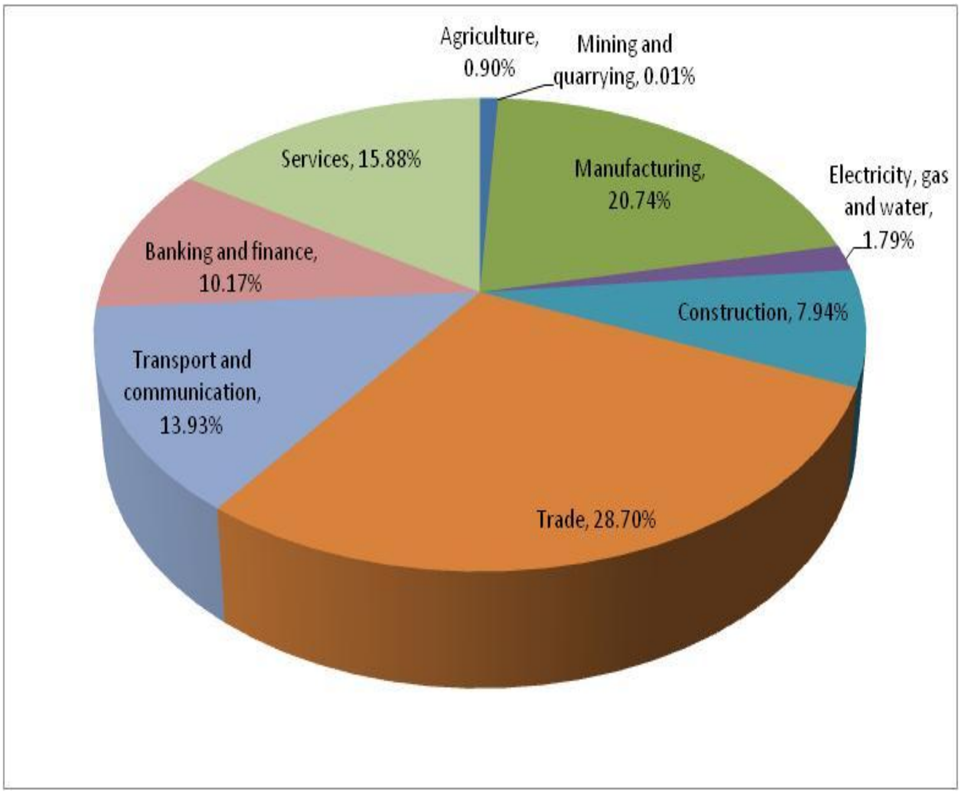


Figure 5: Economic activity of Makassar by sector in 2009 (Source: BPS 2010)

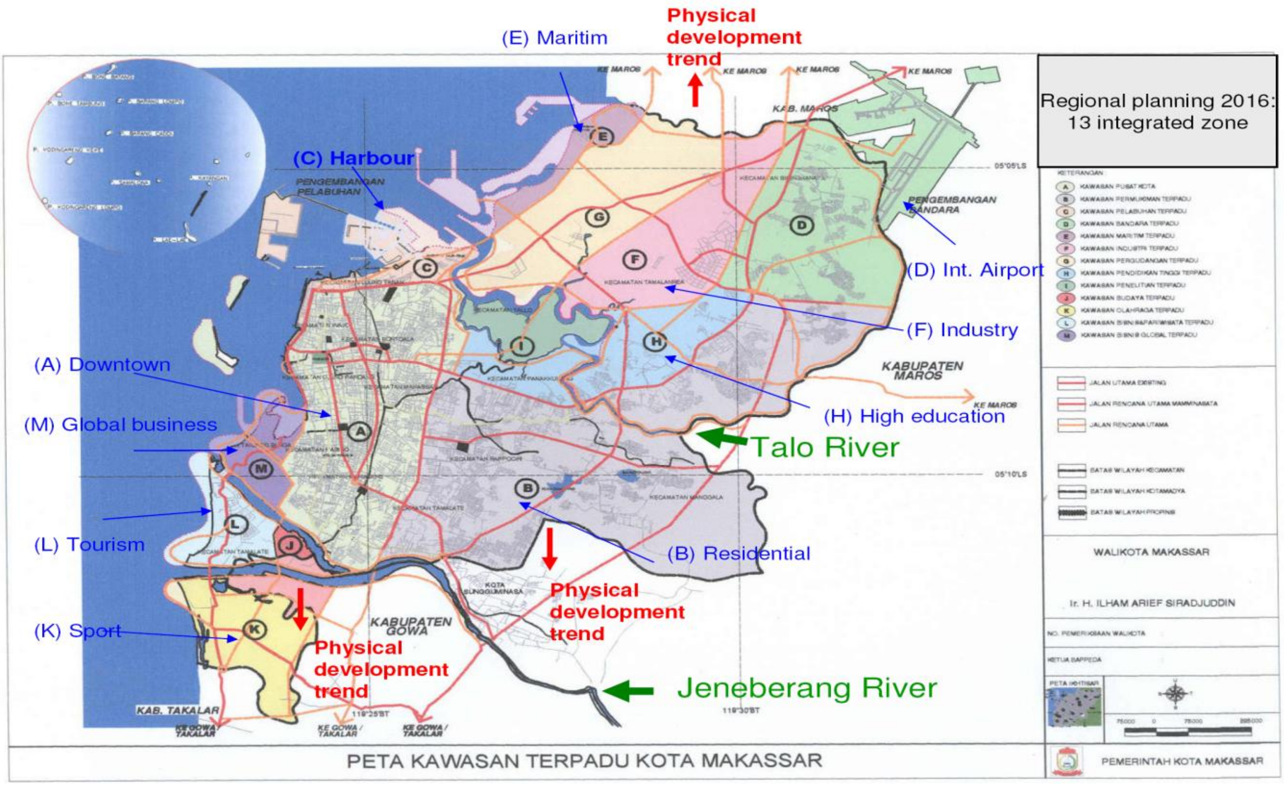


Figure 6: Map of the integrated zone planned development to 2016 (Adapted from SOER 2006).

2. WATER RESOURCES

Three major rivers are responsible for the water supply and drainage in Makassar city, the Jeneberang, the Tallo and the Maros Rivers (Figure 7). The Maros and the Jeneberang rivers are the main sources of water for Makassar and for Mamminasata. Ground water is a major water source for some population and economic activities. In addition a number of lakes provide additional storage capacity in the area. Examples include lakes Antang, Airport, Tanjung Bunga and Hasannudin University (UNHAS, 2010).

The regencies of Gowa and Takalar also source water from the Jeneberang River catchment and the regency of Maros from the Maros river catchment.

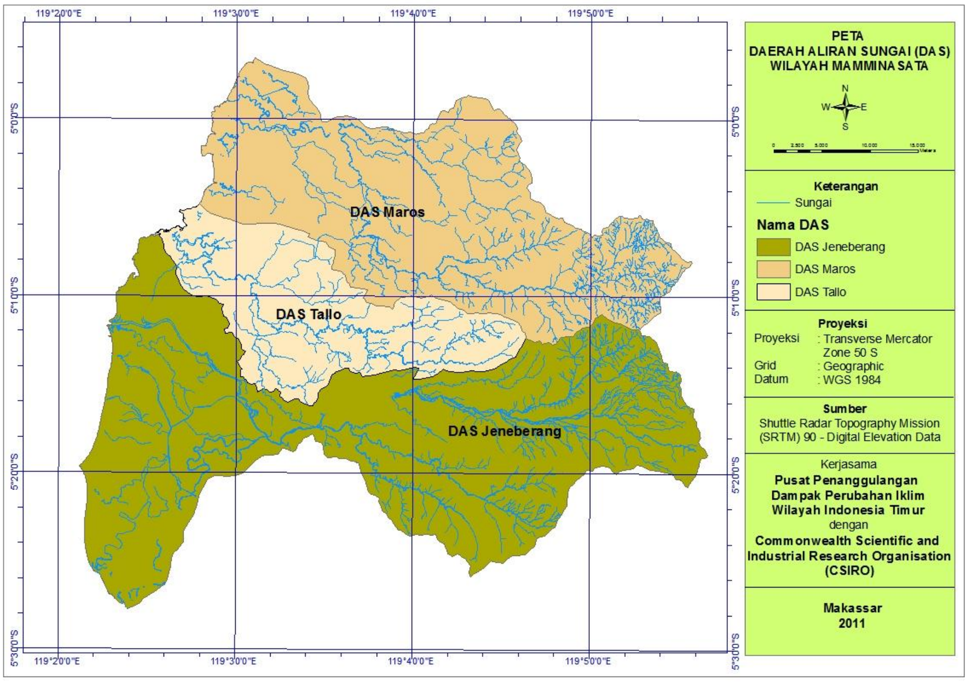


Figure 7 Three rivers that are important for the Makassar city: Jeneberang, Tallo and Maros rivers (Source: Unhas, 2011).

2.1 Surface water

2.1.1 Tallo river

The Tallo river is located to the north of Makassar. This 72 km-length river originates in Mount Kallapolompo (elevation of 725 m above MSL) and has a catchment area of around 407 km^2 (CTI Engineering CO Ltd, PT Virama Karya and PT DCC Consultants. Co. Ltd., 2001). The urbanized area of Makassar city is located in the lower reaches of the Tallo river, which has an extremely gentle channel slope of about 1/10,000, and hence it is prone to flooding. The Tallo river is a major drainage conduit for wastewater and urban stormwater drainage.

The river does not currently contribute to the drinking water supply, as salt water intrusion from the estuary of the river extends 30km inland and renders the water too salty for drinking. However, PDAM is conducting trials on the potential for water abstraction from the Tallo for water supply (PDAM, personal comm. 2011).

River flows are influenced by seasonality, with reduced flow in the dry season, and flooding common in January, during the wet season (November to January), particularly in the northern part of Makassar (Tallo, Biringkanaya, and Tamalanrea districts). There is no existing river gauge to monitor river flow on the Tallo river. But, typically the Tallo river floods when rainfall is equal or greater than 592.54 mm/month (UNHAS, 2010). Flooding typically occurs only once a year for approximately 2-3 days (UNHAS, 2010).

The Tallo river is also used for irrigation supply, aquaculture, hydroelectricity and water transportation (UNHAS, 2010).

2.1.2 Jeneberang river

The Jeneberang river is the main source of water supply in the Mamminasata area, providing almost 80% of the raw water supply to Makassar (JICA 2011). The Jeneberang river catchment covers an area of 762 km^2 in the Gowa and Makassar regencies (CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants. Co Ltd., 2001) and discharges into the sea to the south of Makassar city.

The river has an estimated annual rainfall depth of 2,727 mm and a run-off depth of 1,484 mm (CTI Engineering Co Ltd., 2001). There is only one river gauge station available to monitor the river flow of Jeneberang river. The station is located at Pattalikang off the Jenelata river tributary. The long-term (1980-1999) mean monthly flows recorded by this station are shown in Figure 8. Apparently, the river flows resembles the U-shape pattern of rainfall (see Figure 8) but with around one month lag-time.

The Bili- Bili dam is located 35km upstream of the Jeneberang River, in the District of Bontomarannu, Gowa regency. The dam is the major raw water source to the Makassar and also to the Gowa regency. It has a storage capacity of 380 million m^3 water and provides hydroelectricity, flood control, recreation and water supply for the urban population, water for agricultural irrigation and for aquaculture along the river (Selintung, 2000). The annual supply yield from Bili-Bili is 3,400 L/s (CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants. Co Ltd, 2001). A continuous flow of 1,000 L/s is released from the dam for the downstream environmental river management (Nihon Suido Consultants Co. Ltd., *et al*. 2011). Whilst approximately 2000L/s are extracted for urban water supply to Makassar and Gowa downstream from the dam (Nippon Coei and CTI engineering International Co Ltd, 2004). The Bili-Bili dam reduces the seasonality effect downstream on the Jeneberang river, providing water supply security particularly in the dry season, when stream flows in the Maros river are reduced.

A large landslide in 2004 at Mt. Bawakaraeng, 40km upstream of the Bili-Bili dam caused extensive damage and sedimentation of the upper Jeneberang impacting river water quality (Hasnawir *et al* , 2008). Remediation infrastructure for mitigating sediment transfer into the Bili-Bili dam has been implemented (Sabo dam and Sand Pocket dam), but the river is subject to high turbidity during the wet season (turbidity >1000NTU). No data was found on the evaluation of the sediment on the holding capacity of Billi-Bili dam. The Mount Bawakaraeng area is also at risk of future land slide events.

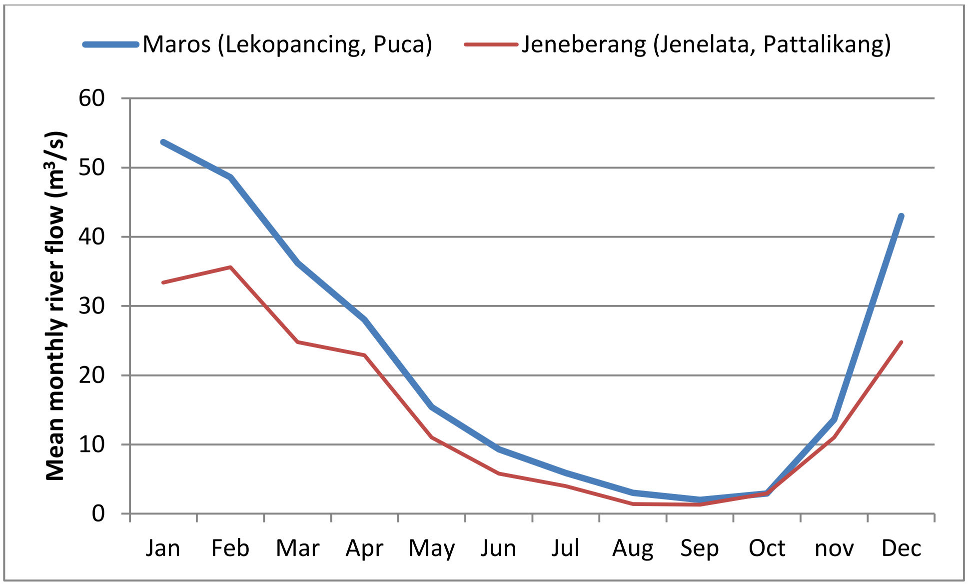


Figure 8 Long term (1980-1999) mean river flows at Pattalikang station (Jenelata river tributary of Jeneberang river) and Puca station (Lekopancing river tributary of Maros river)

2.1.3 Maros river

The Maros River is 82 km long and has a catchment area of 645 km^2. The river originates from the mountain range in the northeast of the Mamminasata region. It flows through the district of Maros after meeting its major tributary, the Bantimurung River, and empties into the Makassar Strait (CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants. Co Ltd., 2001). Similar to the Tallo river, river flow in the Maros shows high variability throughout the year (Figure 8). The Maros River is one of the main water resources for the drinking water supply for Makassar city. Raw water is abstracted, by the Makassar municipal water company (*PDAM*), from the Maros river at the Lekopancing weir, located at around 29.6 km inland from Makassar City (Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011).

2.2 Groundwater

Groundwater is another major source of water for the population and for economic activity in Makassar and the Mamminasata area. However, information about groundwater is sparse compared to the surface water.

Industry and large hotels often rely on deep wells to secure continuous water supply, whilst households often access shallow water wells for supplementing mains water (CTI Engineerring Co Ltd, 2001). Groundwater is the major water source for the 30% of the Makassar population without access to the mains water supply coverage and in districts subject to mains water shortage.

The use of shallow ground water in Makassar is unregulated , hence there is a lack of detailed information about how much groundwater is used by the population from shallow wells. A survey conducted in four districts (Ujung Tanah, Tallo, Mamajang, Makassar) verified that that the percentage of households with shallow wells varied widely, from 25% to 76% (*Selintung et al*,.2010) .

Shallow groundwater reserves are located at depths ranging from 0 to 22 m from sea level (Table 1). Ground water aquifers are made up of fine sand and clay and porosity ranges from 30% to

55%. The groundwater table height varies across the region, especially during the rainy season. Characteristics of groundwater in Makassar differ depending on location.

Changes in land use due to population growth are impacting surface water supply and groundwater reserves (Alexander *et al*, 2011). As centralised water supply has not been able to cope with the water demand, abstraction of ground water has increased significantly. The increase in groundwater abstraction is impacting groundwater level and causes periodical drying of the local wells (UNHAS, 2011). In coastal areas this is accompanied by seawater intrusion, which increases the salinity of the groundwater. Rapid depletion could also impact soil stability among others effects into the future.

The availability of groundwater has been declining over time and is expected to decrease further with population growth and further economic development of the area (UNHAS, 2011).

Table 1 Groundwater deposits in Makassar (Source: BPS, 2010)

District	SeaWater Level (m)	Ground water depth (m)	Porosity (%)	Spf yield (%)
Mariso	0-2.70	0.45-1.2	30-45	15
Mamajang	0.5-2.86	0.3-3.2	30-45	15
Tamalate	0-2.69	0.15-2.61	30-55	10
Makassar	2.1-2.3	0.43-2.4	30-35	15
Ujung Padang	1.75-3.9	0.25-1.6	30-35	20
Wajo	1.7-3.8	0.2-2.1	35-50	15
Bontoala	1.6-3	0.15-1.1	35-55	10
Ujung Tanah	0-2.9	0.25-0.75	35-55	10
Tallo	0.8-20.9	0.17-2.5	30-45	8
Panakkukang	0-4.01	0.11-0.4	30-35	15
Biringkanaya	0-22	0.5-15	35-45	8

2.3 Other water sources

Other potential water sources in Makassar include:

(i) Antang Lake (Lake Balang Tonjong) located in District of Manggala has a 20ha water catchment area in the Region of Makassar.
(ii) Lakes Tanjung Bunga in Tanjung Bunga,
(iii) Sultan Hasannudin Airport Lake in the Airport, and
(iv) Unhas Lake at Hasannudin University.

These water bodies offer additional water storage and are used mostly for stormwater collection and recreation (fishing and water sports) (UNHAS, 2011). In the future an 80 ha reservoir is planned to be built in Tamangapa. This will be used by the PDAM to take the raw water at 1000L /s, particularly during the dry season (UNHAS, 2011).

3. WATER RESOURCE MANAGEMENT

3.1 Legislative framework

The Legislative framework for water resources in Indonesia began with the enactment of the Act. No. 11/1974 on Irrigation (UNHAS, 2011). The Act stipulates that the State is the holder of tenure and authority for water management, for planning, development, exploitation, and protection of water resources. Prior to this, the regulatory framework, i.e. the Algemeen Waterreglement 1936, had been established in the Dutch colonization era. Until the early era of reform, water resource management in Indonesia was based on the Law No.11/1974. During this period, various water management policies have been applied including:

1. PP. No. 06/1981 on the Financial Fee of Exploitation and Maintenance of Water Infrastructure;
2. PP. No. 22/1982 on the Procedure of Setting Water;
3. PP. No. 23/1982 on Irrigation;
4. PP. No. 20/1990 on Water Pollution Control;
5. PP. No. 27/1991 on Swamps;
6. PP. No.35/1991 on Rivers;
7. Presidential Instruction No. 2 / 1984 on the Development of Farmers Water User Associations;
8. Presidential Decree No. 9 / 1999 on Coordination Team for River Usage Policy and Watershed Preservation;
9. Presidential Decree No. 123/2001 on Coordination Team for Water Resource Management.

In 2004 the Law No.7/2004 on Water Resources was formed. This was because of the realisation that the Law No.11/1974 became insufficient for dealing with water resource issues – which became increasingly complex. The creation of this Act was preceded by the formation of the Water Resource Management Coordination Team (*TKPSA*) whose task was to assist the President in formulating policies on water resources, including preparing Law No.7/2004 on Water Resources.

Law No.7/2004 largely regulates the principles for water use rights; the right to use water and permissions; authority and responsibilities of the national, provincial and city/regency (*Kota/Kabupaten*) governments in managing water resources; the principles of conservation of water resources; the principles of efficient use of water resources; the principles of controlling the destructive force of water; planning; construction and operation and maintenance of water resources; water resources information systems; empowerment and control of water resources; financing of water resource management; and the rights and obligations in society water resource management.

The Act. No. 7 / 2004 recognises the new paradigm of regional autonomy, decentralization and state revenue sharing. The Act states that regulation of water resources management is not only developed at the legislative level of national government/ministry but also at the provincial and city/regency level. Each region is authorized to establish regional regulations (*perda*), governor regulations (*pergub*) and mayor (municipal) regulations (*perbup*) for water resource management according to the authority of each level of government. Thus water management is controlled by all three levels of government, where applicable.

As an illustration, the Act states that the management of surface water is based on river basin while that of groundwater is based on the groundwater basin (Article 12). The national government has authority on the management of river basins which are cross-provincial and cross-nation as well as those which are defined as the national strategic river basin (Article 14) (Jeneberang river basin is one of the national strategic river basins). Meanwhile, the provincial government has a mandate for managing river basins which are cross-city/regency (Article 15). The city/regency government has authority for those located within the city/regency (Article 16) (UNHAS, 2011).

3.2 Institutional context

As described previously, water management is a shared responsibility among three levels of government organisations: national, provincial and city/regency level. According to Ageng (2005), water resources agencies in relation to the Indonesian water resources and Jeneberang river basin management are as follows.

At the national level, some agencies have the role of supporting river basin management in Indonesia. These include:

(i) the Directorate General of Water Resources (*Direktorat Jenderal Sumber Daya Air*), under the Ministry of Public Work, is responsible for supporting the Regional Governments through various Directorate General (for example, the control of irrigation service fees under the Ministry of Home Affair);

(ii) the Ministry of Agriculture is responsible for managing watershed and soils in un-forested regions and for supporting irrigation services for the farmers;

(iii) the Regional Office of Watershed Management which reports to the Directorate General of Land Rehabilitation and Social Forestry Affairs (*Direktorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial*) within the Ministry of Forestry and Plantations; the Ministry of Stated-Owned Enterprises, originally part of the Ministry of Finance, is responsible for all matters concerning the establishment, operation, performance and funding. The Ministry of Finance is managing the classification and evaluation program for tax of land and property (which is then partly redistributed to the regional Government, for example, for operation and maintenance funding of irrigation).

At the regional level, the relevant agencies include:

(i) the Technical Implementation Unit, known as Water Resource Management Agency (*Balai PSDA),* who is responsible to the Provincial Water Resources Management Service (*Dinas PSDA*); the Coordination Committee for Water Resources (*Panitia Tata Pengaturan Air, PTPA*)

At provincial level:

(i) the Committee for River Basin Water Resources Management (*Panitia Tata Pengaturan Air, PTPA*) which acts at Jeneberang river basin level;

(ii) Water Resources Service at the city/regency level;

(iii) the Water Users or farmer level, who is responsible for operation and management of tertiary irrigation system, P3A (Water User Association) and higher level farmers;

(iv) the Basin level management agencies such as Provincial Technical Implementation Units (*Unit Pelaksana Teknis Dinas, UPTD*);

(v) the Regional Development Planning Agency (*Badan Perencanaan Pembangunan Daerah, BAPPEDA*) ; and

(vi) the Provincial Environmental Agency (BAPEDALDA) who is responsible for controlling and managing the general state of the environment.

Based on the formal institutional context for water and wastewater management in South Sulawesi and Makassar city, the roles and responsibilities for the various governmental entities can be summarised as follows:

(a) Development of the network distribution system from intake to distribution pipes is the responsibility of central government through the Ministry of Public Works.
(b) Development of distribution pipes to the connection network units is the responsibility of provincial governments and the City of Makassar through the Department of Public Works -the Spatial and Settlement Agency (*Dinas Tata Ruang or Dinas tarkim*).
(c) Watershed management is the responsibility of the provincial government through the Provincial Forestry Office.
(d) Determination and utilization of groundwater is through the recommendation of the Office of Mines and Energy, which is also responsible for the survey of the ground water basins.
(e) Permits for the use of raw groundwater for industrial activities and hospitality services are granted through the Department of Environment of Makassar and through recommendation from the Department of Mines and Energy of South Sulawesi Province.
(f) Permit for the use of raw water for the needs of the urban settlements is through PDAM Makassar.
(g) Construction of urban drainage systems is the shared responsibility of the Department of Public Works, the Provincial Office and the Ministry of Public Works (Dinas Tarkim) which is responsible for financing of infrastructure.
(h) Large scale Drainage Development involves Balai Pompengan Jeneberang.

3.3 Key stakeholder identification and mapping

3.3.1 Data collection and stakeholder network analysis

To gain further understanding of the formal and informal functioning of institutional set-up for water resources in Makassar stakeholder analysis and social network analysis (SNA) were conducted. Stakeholders were identified using the methodology outlined in Larson *et al* (2012).Stakeholder analysis is an approach or a tool to obtain knowledge and information about stakeholders, their interests, importance, influence, resources and so on. The methodology and outcomes of the process are described in detail Larson *et al* (2011). In summary experts from nine different organisations took part in this activity and identified key stakeholders, or those who "can significantly influence, or are important for the successful functioning" of the water system (Larson *et al* 2011):

- Municipal Water Company (*Perusahaan Daerah Air Minum or – PDAM*)
- Municipal Sanitary and Landscape Office (*Dinas Kebersihan dan Keindahan Kota–DKK*)
- Municipal Public Works (*Dinas Pekerjaan Umum or DPU)*
- Environmental Agency –province level (*Badan Lingkungan Hidup– BLH*)
- Department of Health, at municipal and provincial level, (*Dinas Kesehatan–or DINKES)*
- Water Resources Development Office (*Dinas Pengelolaan Sumber Daya Air–or PSDA*)

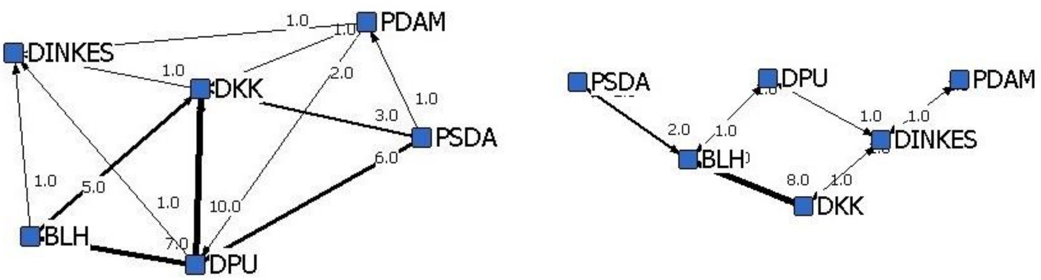
The Social Network Analysis shed light on the patterns of formal and informal interactions between different actors.We explored three different types of social networks (SNs) among the key stakeholders: formal, informal or shadow, and "ideal" SNs.

Formal SNs comprise networking that is required in current legal, management and other formal institutional arrangements. Formal networks were developed based on formal documents of each key stakeholder analysed. Two types of formal networking were assessed: shared roles and responsibilities in relation to legislations; and shared jurisdiction in relation to different aspects of water.

Informal or shadow SNs on the other hand are existing linkages between various actors in the network that are based on informal arrangements or personal contacts. Respondents were asked to identify their informal and also their ideal networks. Respondents were instructed to include all types of collaborations, from financing and consulting, to international collaborations and collaborations with industry and science providers (Larson *et al*, 2012).

3.3.2 Networks among key stakeholders

Results of the formal social networks analysis (among the group of six key stakeholders) based on the formal network of shared roles and responsibilities indicatestrong linkages between the DPU (Municipal Public Works), DKK (Municipal Sanitary and Landscape Office), BLH (Dept of Environment) and PSDA (Water Resources Development Office) (Figure 10a) (Larson *et al*, 2012). On the other hand, DINKES (Dept of Health) and PDAM (Municipal Water Company) had limited linkages to other actors in the system, indicating that their operational portfolios are much more specific. Figure 9b shows the formal network based on the shared jurisdiction in relation to different aspects of water (such as pollution prevention, provision of clean water, water born diseases, sanitation, maintenance of infrastructure, and watershed protection). Interestingly, BLH (Dept of Environment) and DKK (Municipal Sanitary and Landscape Office) emerged as having most shared responsibilities, followed by DPU and DINKES, with other agencies receiving a lesser share.

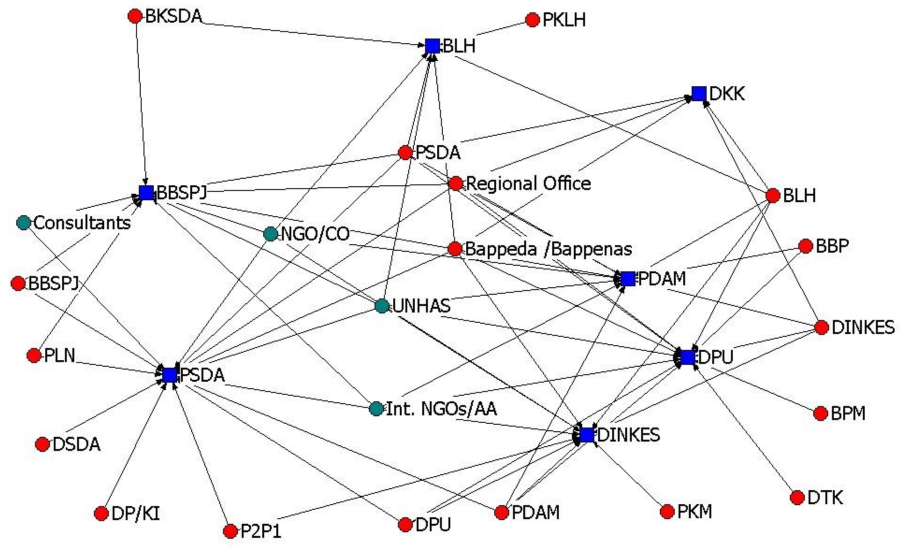


(a) (b)

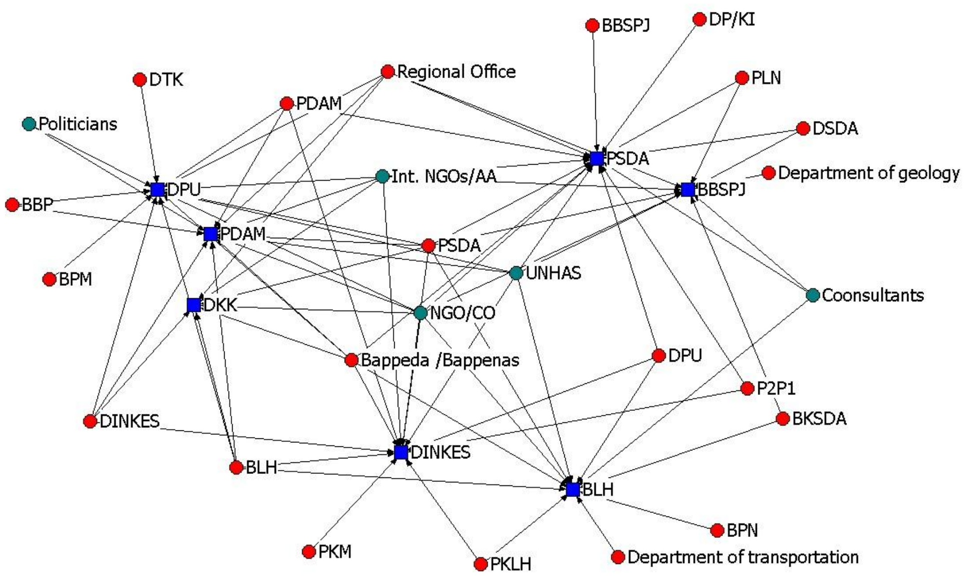
Figure 9 Net-maps of (a) formal legislative requirements for collaboration between agencies and (b) aspects for water under shared jurisdiction, key stakeholders in Makassar urban water system (Arrows indicate adjacency and numbers indicate density) (Larson *et a,l* 2011)

3.3.3 Informal networks beyond key stakeholders

Directors or equivalent management position holders in our six key stakeholder organisations were also asked to revile their organisations' actual informal networks over the last 3 years, as well as their visions of stakeholder network that would allow for "ideal" functioning of the water system in the city.



(a)



(b)

Figure 10 Net-map of organisations that (a) have collaborated on some aspect of water in the last three years, or (b) should collaborate together for the optimal operation Makassar urban water system ("ideal network"); blue square = key stakeholder; circle = collaborator: red = government; green = other.

Legend: BBSPJ (Watershed Management Office for Jeneberang River) , DP/KI (Dept. of Agriculture Irrigation office), PLN (State Electricity Department),DSDA (Water Resources Council),PSDA (Planning Department South Sulawesi Province –Regional Office), DPU (Municipal Public Works), BKSDA (Dept. of Forestry Natural Resources Conservation Unit / Watershed Area Management Office),PKLH (Ministry of Environment Regional Centre), DINKES (Dept of Health),BBP (Technological Study and Application Institute), BLH (Dept of Environment), DKK (Municipal Sanitary and Landscape Office),PDAM (Municipal Water Company), DPU(Municipal Public Works),NGO(Local non-government and community organisations), DTK(Land use and urban planning department),UNHAS (Hassanudin University) (Larson *et al,* 2012)

The exercise revealed that the actual network of past collaborations is much more complex than what could be expected based on formal requirements as shown in Figure 10a. Key stakeholders reported a total of 67 collaborations (ties) over the last 3 years, resulting in the network density of 0.4379. A number of non-government agencies were also included in the network and some of them, in particular Hasannudin University (UNHAS) and International NGOs and aid agencies (Int NGOs/AA), are rather central to the network with connections to majority of the key stakeholders (blue squares).

Key stakeholder representatives were also asked to express their opinions about a network that would produced an environment for ideal – optimal - functioning of the Makassar urban water system in the future (Figure 10b). As a result, a total of 78 ties were recorded for ideal links. Departments of Transport, Geology and BPN were added to the network, as well as political actors (elected representatives). However, the amount of shared nodes (connection) between existing actors did not increase, creating a lower network density of 0.3628 (Larson *et al* 2012b).

In conclusion, the institutional set-up for water resource management in Makassar is a complex environment with multiple stakeholders. Formal networks show a limited number of stakeholders. However, the informal networks among stakeholders are much more complex than the formal networks, and need to be considered in addition to the formal channels. UNHAS whilst not a formal stakeholder is heavily linked to other stakeholders via the informal network.

4. WATER SUPPLY CAPACITY IN MAKASSAR CITY

The *Perusahaan Daerah Air Minum* (PDAM) is the regional water utility responsible for treatment, distribution and billing of water to a regency. The water utilities in the Mamminasata area are PDAM Makassar, PDAM Takalar, PDAM Gowa and PDAM Maros. In 2010, their combined water supply infrastructure capacity was 2908 L/s (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011), of which 81% of the supply capacity belonged to PDAM Makassar and the remainder 29% was operated by the other PDAMs, as shown in Figure 11 . Thus in this section we will focus mainly on Makassar's water supply.

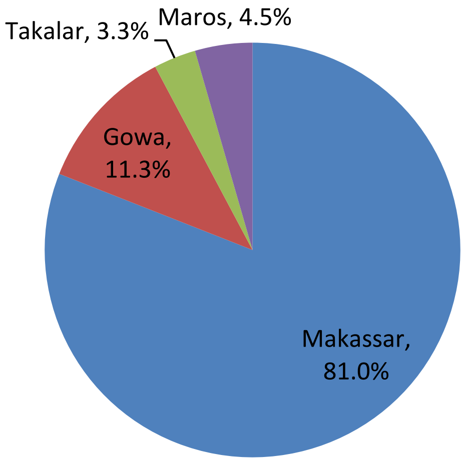


Figure 11 ;Existing water supply capacity in Mamminasata region (2010) (Adapted from Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011)

4.1 Makassar water supply

Makassar's water supply infrastructure has a design capacity of 2,375 L/s, however the actual production is 2,354 L/s due to technical difficulties (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011). PDAM Makassar operates 5 water treatment plants (WTPs): (i) Antang, (ii) Ratulangi, (iii) Maccini Sombala, (iv) Panaikang and (v) Somba Opu, which service 44 zones. Their supply capacity and service area details are shown in Table 2 and Figure 12

The two largest WTPs, Panaikang and Somba Opu, have each a supply capacity of 1,000 L/s (equivalent to 85% of PDAM water supply). WTP Pannaikang services the north and east of Makassar, whilst WTP Somba Opu supplies most of the south of Makassar. The other three plants have more limited production capacities and smaller service areas.

Bulk water for the WTPs is sourced from the Lekopancing canal (Maros river) or the Jeneberang river.

Although the combined water treatment plant capacity is theoretically sufficient to cover Makassar's water demand, water supply shortages occur due to losses in the distribution system and due to seasonality of raw water supplies, particularly for wtp Pannaikang, which extracts water from the Lekopancing canal and the Jeneberang river.

WTP Panaikang extracts water from Dam Lekopancing at a rate of 550 L/s, and from the Mallengkeri intake (Jeneberang river) at 500 L/s. But in the dry season, flow in the Lekopancing dam can decline to 85% capacity (October-November) and water has to be extracted mainly from the Mallengkeri inlet, at the Jeneberang river (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011).

The reduction in capacity of the Maros river is caused by a range of factors: low conservation at the upstream catchment, evaporation from the Lekopancing open canal, and upstream abstraction by farmers for irrigation needs.

WTP Somba Opu is able to maintain the same rate of water supply production throughout the year, because seasonality of flows in the Jeneberang river is mitigated by the Bili-Bili dam.

Water losses at the treatment plant are estimated as 10% due to the need for frequent backwash caused by high water turbidity (Nihon Suido, Nippon Koei Co. Ltd and KRI international, 2011).

Future capacity upgrade for WTPs Somba Opu and Panaikang is planned after 2014, including the installation of additional extraction pipes to draw water, subject to international funding (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011). After the upgrade, the service coverage from Somba Opu, will include the north of the city and is expected to guarantee security of supply (Figure 12).

Table 2 Water treatment plants in Makassar (PDAM Makassar, 2010)

	Water treatment plant	**Production Capacity in 2010 (L/s)**		**Intake**	**Service coverage**
		Wet season	**Dry season**		
1	Antang	90		Lekopancing (Maros river)	Mangala (zone 34)
2	Ratulangi	50		Jeneberang river	Ujung Padang (zones 4 and 6)
3	Maccini Sombala	200		Long storage dam, Jeneberang	Tamalate (zone 16), Mariso (zone 10)
4	Pannaikang	1000	350-400	Lekopancing (150L/s) Jeneberang river (200L/s)	Wajo, Bontoala, Tamalanrea, Kima, Biringkanaya
5	Somba Opu	1000	1000	Jeneberang river	Ujung Padang (zone 3a, 3b and 5), Mariso (zone 8, 9), Tamalate (zone21), Mamajang , Rappocini, Panakukang,Manggala
	Total	2340 L/s (202.2ML/d or 73.8GL/yr)			

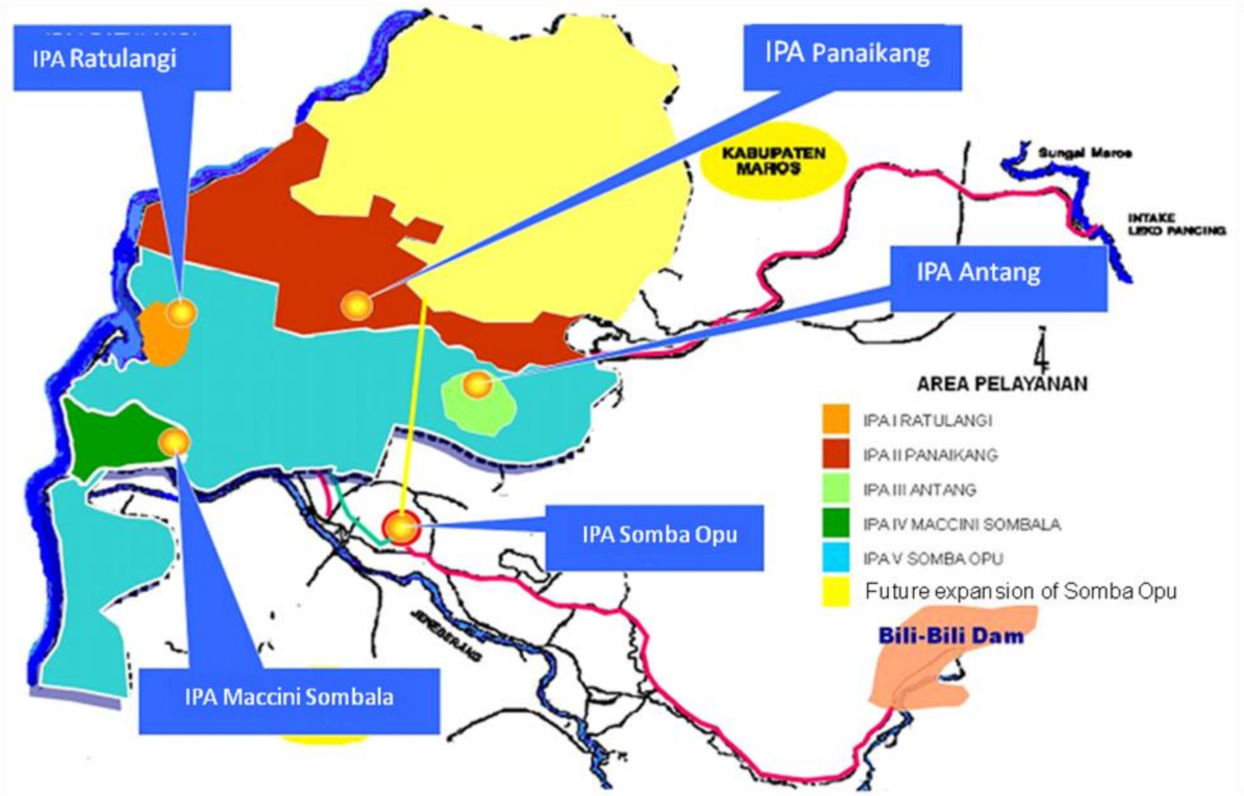


Figure 12 Service coverage areas for water supply plants in Makassar (Source: PDAM, 2010)

4.2 Water distribution

In 2010, the water distribution network in Makassar city covered an area of 11,250 ha and was comprised of 3,018 km of pipe assets, with an average asset pipe age of 80 years. The distribution system is a closed system with pipes of diameters ranging from 50 mm to 1,000 mm. In the old city centre, 54.67 km (1.8% of network) is comprised of metallic pipes installed in the colonial period. In 2010, expansion of water mains infrastructure was initiated to serve the northern and eastern regions of the city, to increase access to service taps in slum areas. Extension of the distribution infrastructure from WTP Maccini Sombala to the districts of Tallo and Ujung Tanah is also planned for the future (PDAM 2010). The total area of water distribution is expected to cover 97% of Makassar's population in the future.

The non-revenue water (NRW) in Makassar's water distribution is high (45%) (Table 3). This is caused by a number of factors (i) Leaks in real transmission and service pipelines, because of ageing pipes, (ii) Illegal water connections, (iii) errors in water meter accuracy, recording errors by officers in the field, and (iv) water use for social needs (which is not billed). It was estimated that real water losses account for 30 to 39% of total NRW (Table 3). Leakage rates are particularly high in the network section installed during the colonial times (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011).

Currently PDAM and JICA are running a leak reduction program to reduce non-revenue water losses by improving metering. Non-revenue water was reduced by five percent from 2009 to 2010 (PDAM, 2010).

In addition PDAM plans the gradual rehabilitation and replacement of old pipes to reduce real water losses in the future (PDAM 2010, Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011).

Table 3 Non-revenue water (NRW) estimates

Distribution	Real losses (%)	NRW	Reference
JICA	30	44.7	Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011
PDAM	39.37		PDAM 2010

4.3 Quality of PDAM water

The quality of treated mains water produced by the treatment plants meets the drinking water health standards of the Ministry of Health in Indonesia (PDAM 2011, pers.comm). However, water quality deteriorates due to contamination during travel within the distribution infrastructure, requiring water to be boiled or treated at home for drinking and cooking· Infiltration of groundwater caused by irregular mains supply pressure is likely to contribute to the quality deterioration·

5. WATER DEMAND IN MAKASSAR

Water demand in Makassar is driven by residential, industrial and commercial needs, such as aquaculture.

Consumption of mains water in the city of Makassar has increased rapidly, growing by 3.4% since 2006 (Figure 13). In 2010, PDAM Makassar had 150,924 customers (PDAM 2011a) and provided water to 692,308 people or 62.2% of the total population of Makassar (Nihon Suido, Nippon Koei Co. Ltd and KRI international, 2011). Of these 59.42% were served by pipeline to tap, the remaining 2.8% were served through hydrants (communal water outlets).

Segmentation of PDAM's customers was conducted using 2008 records. This revealed that majority of customers were residential customers, consuming 81% of the water supplied, whilst other customer categories (business, government, social and manufacture) used respectively 9%, 5%, 4% and 1%, of the water supplied (UNHAS 2010).

Evidence from interviews and the workshops indicates that seasonality impacts the water demand patterns in Makassar (Larson *et al*, 2011, Alexander *et al*, 2011). PDAM has reported more sales of carted water in the dry season (PDAM, 2010). Drying of shallow wells has also been reported (Alexander *et al* 2011) and is a likely cause for the higher demand in the dry season.

Analysis of PDAM supply data from 2008 to 2011, in Figure 14, indicates a strong increase in water demand for the dry season 2009 and 2011. However, further verification is required to evaluate why the effect is stronger in those years compared to 2008 and 2010 .

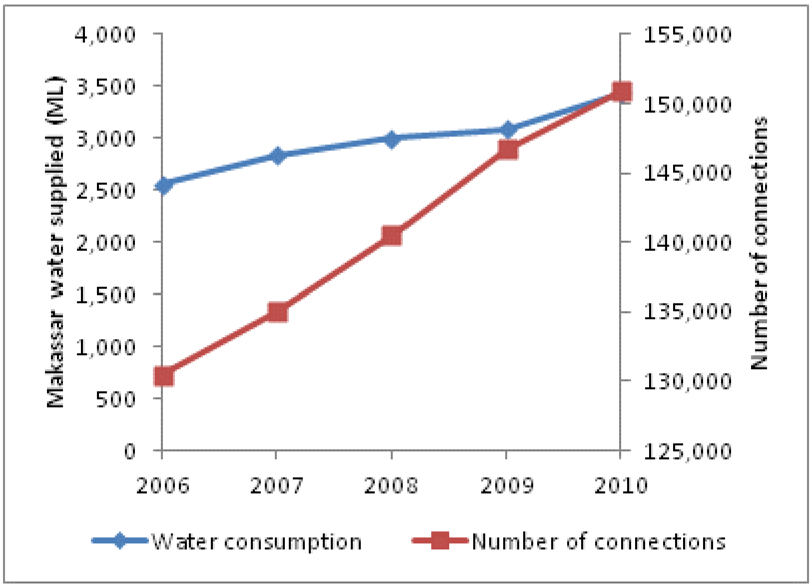


Figure 13 Water consumption and customer numbers from PDAM Makassar from 2006 to 2010 (Adapted from PDAM, 2011)

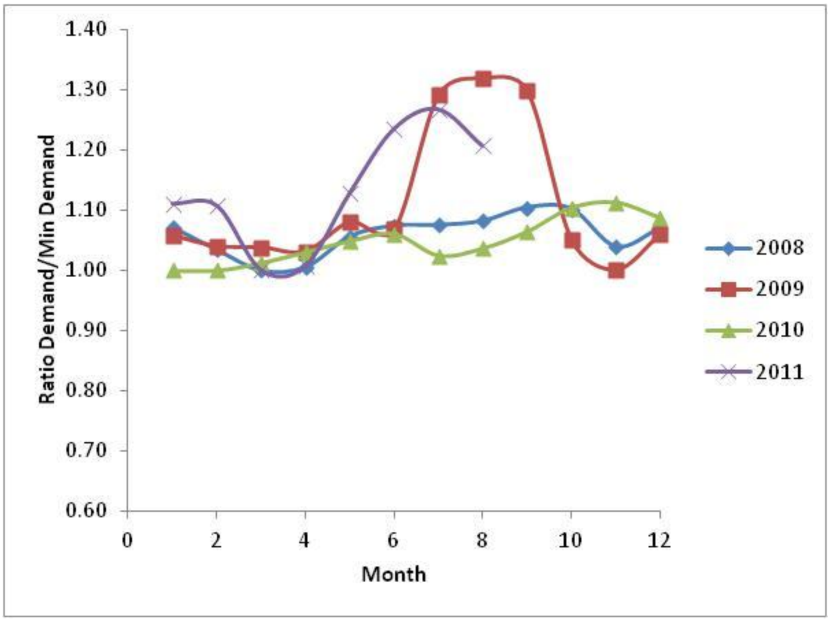


Figure 14 Historical seasonality of water demand from 2008 to 2011 (Adapted from PDAM, 2011)

5.1 Domestic consumption

The mean water demand based on the total actual water supply by PDAM across Makassar is estimated at 117L/cap/d (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011). By comparison, the daily per capita water consumption (q) adopted for water planning across Indonesia is 190L/cap/d (Table 4).

The average metered water consumption per connection varies significantly across water supply zones, ranging from 24L/connection/day to 206L/connection/day for zones 1 to 42, whilst being the highest at 2271 L/connection/d in zone 44 (industrial area) (Figure 15).

The water supply zones 11, 13, 17, 18, 23 and 28 consumed the largest volume of water in 2010 (over 100ML/yr) as shown in Figure 16.

Table 4 Water consumption per capita

Source	q(L/cap/d)	Reference
Indonesia	190	Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011
Makassar actual	117	Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011
PDAM suburban use	125	PDAM (pers.comm)
PDAM urban use	150	PDAM (pers.comm)

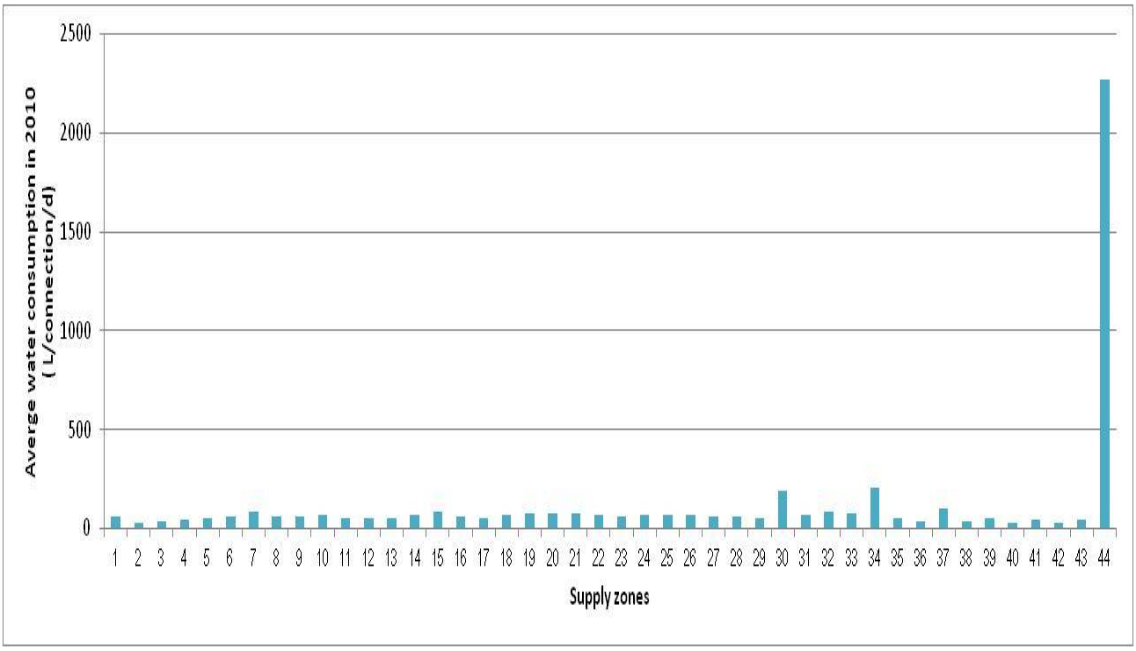


Figure 15 Average water consumption (L/connection/day) across supply zones in Makassar (Adapted from PDAM 2011)

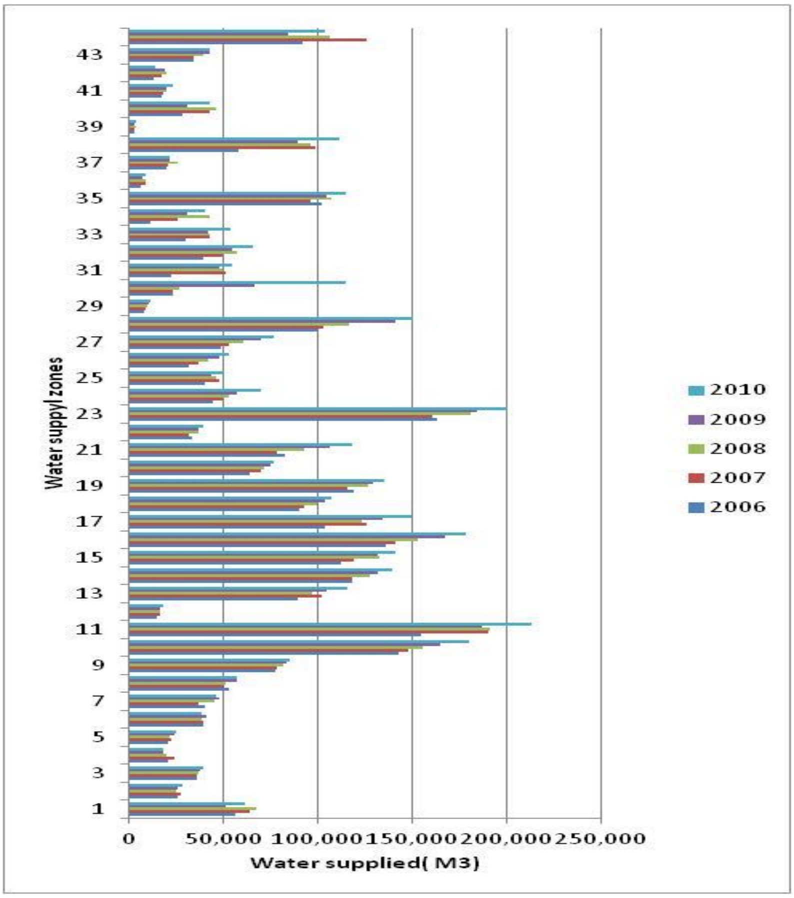


Figure 16 Distribution of mains water usage in Makassar based on water distribution zones (Adapted from PDAM 2011)

The low daily per capita consumption for Makassar can be attributed to the use of other water sources by the population, as access to and continuity of mains water supply varies across the city. A survey water of sources adopted by 379 households within the water supply service area in Makassar has shown that a large percentage of the population adopts both mains water and well water for water supply (Figure 17) (Selintung *et al*, 2010). Whilst PDAM and well water were adopted in households of all economic segments, the proportion of households dependent on well water was inversely proportional to income.

Mains water from PDAM was the water source of first recourse when available to residential users. Well water was adopted more widely in areas with limited access to mains water and in households of lower income (Figure 17). In low income households mains water is adopted preferentially for drinking and washing whilst well water is adopted for cleaning and bathing (Selintung *et al*, 2010). Unfortunately, there are currently no estimates of the actual amount of groundwater used per household.

Thus, the actual mains water consumption does not reflect the total water usage of the population in Makassar, due to the adoption of alternative water sources (mainly well water) by the population and the discontinuity of supply. Hence, if well recharge and supplies are vulnerable to climate change impacts, demand on mains water supply could increase.

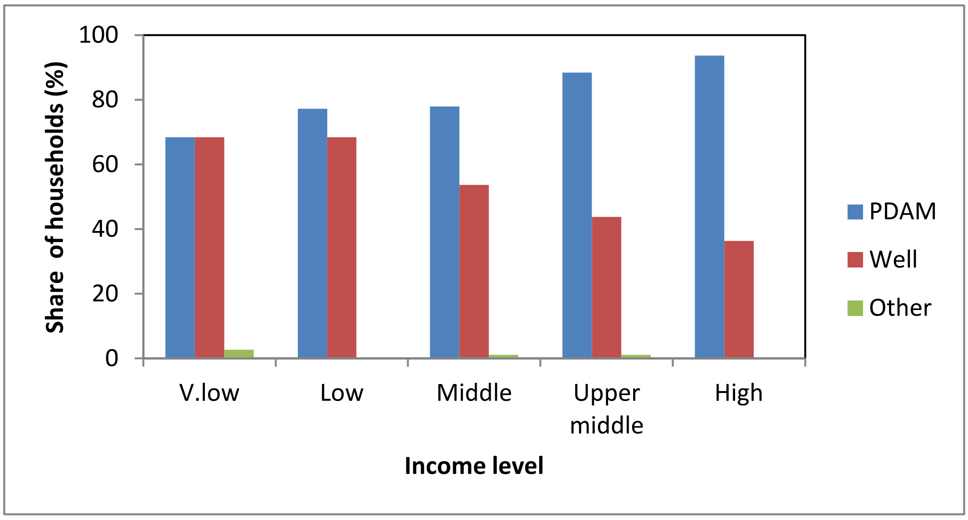


Figure 17 Water sources adopted by households in Mamajang, Tallo, Ujung Tanah and Makassar (Source: data from Selintung *et al*. Undated).

5.2 Industrial and commercial water consumption

Large industrial and commercial enterprises in Makassar adopt both bore water and mains water for supply of their water needs (PDAM 2010). The rate of industrial and business activity has grown rapidly in Makassar, resulting in an associated increase in demand for water resources for non-residential activities, which has not been matched by the water cycle which is relatively fixed. However, data was not available on the current overall industrial water consumption. Anecdotal evidence suggests that large manufacturers adopt bore water as primary supply (Larson *et al* 2011).

In 2001, groundwater use by industry was estimated at 1.59 GL/yr, this included 0.9 GL/yr for companies in the KIMA industrial district, and 0.62 GL/yr for industries outside the area KIMA (Directorate of Water Resources, 2001).

According to 2010 billing data, 7.5GL/yr or 16% of water supplied by PDAM was destined to commercial and industrial customers (Selintung *et al* ,2010). Whilst according to BPS (2009) only 10% of the water supplied by PDAM goes to industry and business.

During the dry season PDAM also experiences an increase in sales of trucked water to industrial customers due to drying of bores (PDAM pers.comm 2010).

The water demand for Makassar in 2010 is thus be summarised in Table 5. We estimated that the ratio of PDAM water to groundwater use may range from 1.4 to 4.8 for industry, but this figure cannot be verified.

Table 5 Water demand for Makassar (2010)

Customer type	**Water demand (GL/yr)**			
	PDAM*	**Groundwater**	**Total**	**Ratio PDAM/GW**
Residential	39.70	n.d.	n.d	
Industrial/Business	7.55	1.59 (2001) 5.4(2010 estimate)	9.14	4.75(2001) 1.4(2010 estimate)

*Includes distribution losses of 30%

Note: n.d. – not determined

5.3 Future water demand

Projections of water demand for Makassar and for other provinces in Mamminasata have been developed by PDAM, JICA and Dinas Tarkim MP (Nihon Suido, Nippon Koei Co. Ltd and KRI International, 2011). Estimation of future water demand is based on a number of water use scenarios.

5.3.1 Methodology

In this report we present the future water demand estimates adopted for the proposed infrastructure plans developed by PDAM and JICA (Nihon Suido, Nippon Koei Co. Ltd and KRI International 2011). The estimates of water demand for Makassar consider both residential and non-residential water mains consumption and are based on total population projections, service coverage, leakage reduction and changing water demand based on the JICA data (Nihon Suido, Nippon Koei Co. Ltd and KRI International 2011).

Residential water demand estimates for Makassar are determined based on population size projections and service coverage using the formula (Nihon Suido, Nippon Koei Co. Ltd and KRI International 2011):

$$D = f\ (P \times q), \qquad \text{Equation 1}$$

Where: D= water requirements (L/d)

q= daily consumption (L/cap/d)
P= number of people served = Pt x S
f = safety factor between (1.05-1.15)
Pt= Total population (inhabitants)
S=service ratio (%)

Alternative values for q were previously shown in Table 4. The water utility, PDAM, adopts 150L/cap/d for its water estimations for the urban communities and 125 L / cap/d for peri-urban communities. Based on such assumptions, the 2010 estimated mains water demand for Makassar ranges from 139.1ML/d to 166. 9 ML/d, depending on the population size assumed.

Estimates for supply by the WTPs are determined by incorporating correction factors to account for industry use and for losses in distribution (2011):

$S = D/[(0.01*RC)*Lk]$, Equation 2

Where: RC= domestic consumption (%Total supply)
Lk= correction factor for water loss during distribution = (1-L/100)
L = water loss in distribution (% total supply)

Figure 18 shows water demand per capita for the various districts in Makassar, which ranged from 118 to 208 L/cap/d in 2010. The figures were developed using population estimates and water billing data for 2010 (Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011). The current demand is higher in districts with full service coverage (old part of the city).

However in the future, PDAM demand projections estimate that districts to the north of Makassar (Tamalate, Tallo, Biringkanaya and Rappocini), which currently have the lowest demand, will experience the largest increase in demand as they become more urbanised, whilst well developed areas will experience slower growth (Figure 19).

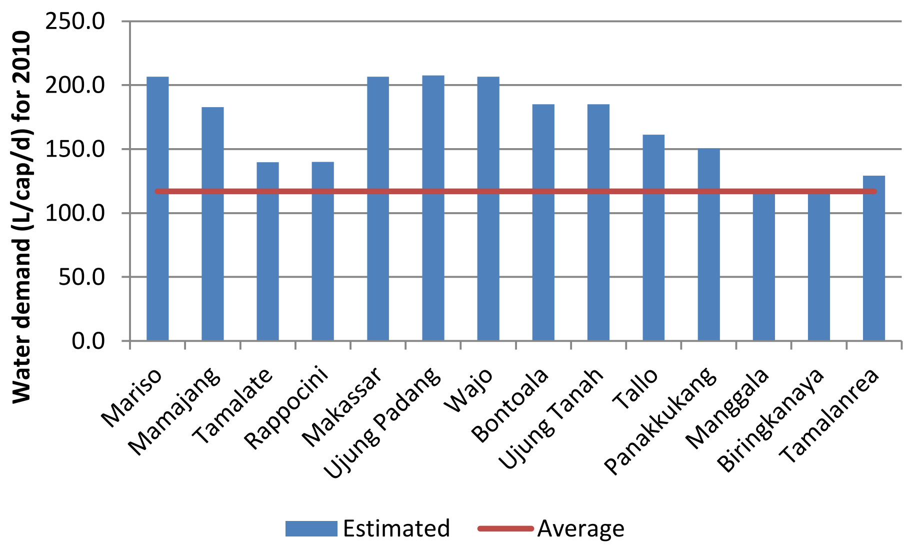


Figure 18 Estimated water demand for districts (*Kecamatan*) in Makassar in 2010 (Adapted from Nihon Suido, Nippon Koei Co. Ltd and KRI International 2011)

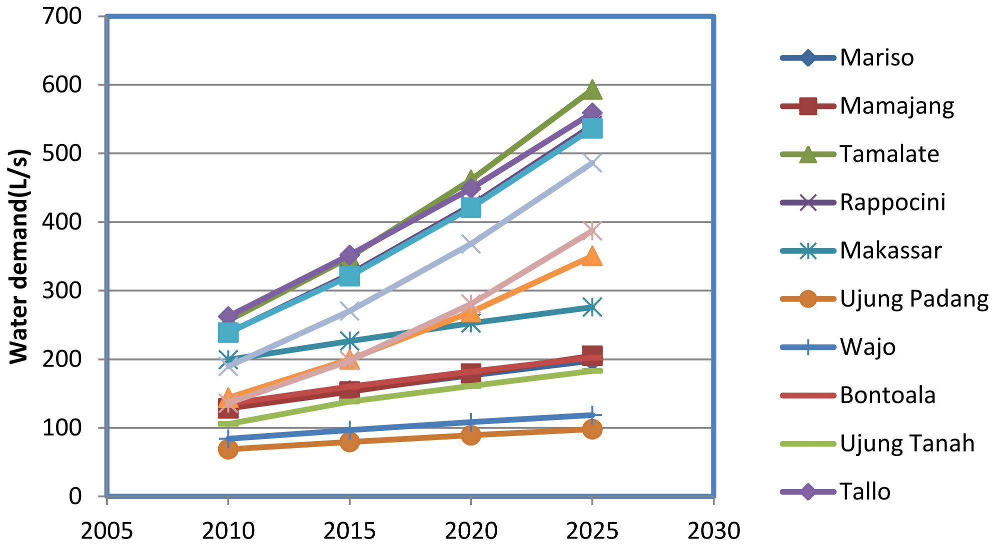


Figure 19 PDAM water demand for Makassar (Adapted from PDAM projections in Nihon Suido, Nippon Koei Co. Ltd and KRI International 2011)

We extrapolated the water demands for Makassar to 2050. The future maximum and average daily water demands for 2050 are 629 ML/d and 408 ML/d. Assumptions and parameters used for such estimation are shown in Table 6. The estimates assumed that the same ratio of domestic to non-domestic consumption in 2010 will apply to the future.

These estimates do not account for the demand supplied through use of groundwater (as mentioned in the previous chapter).

The Masterplan for Mamminasata plans to augment supply in part by reduction of leakage in distribution and also by construction of additional infrastructure, such as Bonto Sunggu dam and future expansion of WTPs' capacity (Nihon Suido, Nippon Koei Co. Ltd and KRI international 2011).

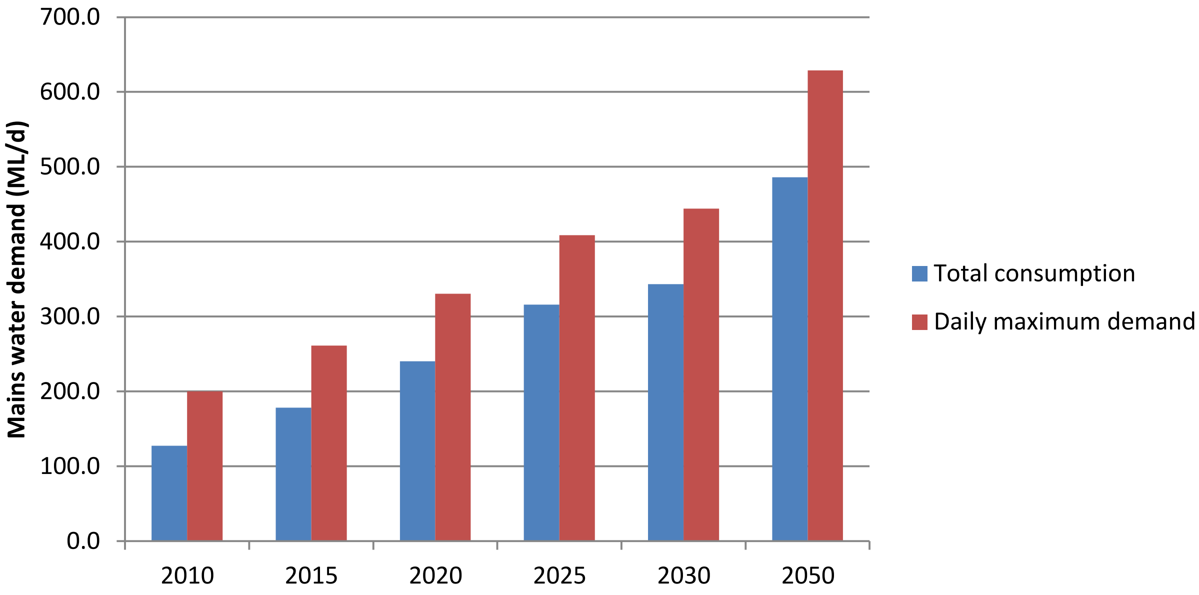


Figure 20 Mains water demand projections for Makassar to 2050

Table 6 Parameters used for water demand estimation for Makassar to 2050

Year	2010	2015	2020	2025	2030	2050
Population (x1000 people)	1,293	1,403	1,517	1,643	1,785	2,528
Service ratio (%)	72	76.3	80.7	85	85	85
Consumption (L/cap/d)	115	140	165	190	190	190
Service ratio (%)	72	76.3	80.7	85	85	85
Physical water loss in distribution (%)	30	25	20	15	15	15
Non-domestic consumption	16	16	16	16	16	16

6. WASTEWATER MANAGEMENT

Wastewater management in Makassar is based on the principles of decentralised on-site sanitation.

6.1 Residential wastewater

Access to sanitation systems is not universal in Makassar. Residential developments in Makassar are classified as per Table 7, and as shown their respective sanitation systems, vary according to built environment conditions, open space availability, age of infrastructure and household income (McDonald, 2011).

It is estimated that 85% of households have access to septic tanks or communal latrines, but in areas with no sanitation infrastructure, such as low income illegal settlements, open defecation is practised (McDonald, 2011).

In dwellings with on-site systems, the greywater and blackwater are separated at source. Blackwater is discharged to a septic tank and the effluent to a leach pit. Whilst greywater (from the bathroom, kitchen and laundry) is discharged to stormwater open drains located on the street.

Lack of maintenance of septic tanks or saturation of the soil can result in contamination of soil and groundwater. Building standards, require a minimum distance of 10m between a septic tank and a water well, but if the land size is limited this is not always complied with (MacDonald, 2011).

Regulations for Septic Tanks (SNI 03-2398-2003 Regulations) also require a minimum distance of 1.5 m above water level for the bottom of the pit or cistern. Septage removal is required and can be conducted by a Regional Enterprise on customer demand. The septage is transported to a treatment facility located in the eastern part of Makassar. However, the plant currently only stockpiles the septage, as it lacks funding for repairs and operation (PU 2010, pers.comm).

As urban densification increases, the ability of existing septic systems to safely diffuse the effluent into the environment decreases, due to limited block sizes and difficulty to access the septic tanks.

The municipal authority (PU) is conducting pilot trials of communal wastewater treatment with funding from the World Bank at 4 selected sites (PU 2011,personal comm.). The communal systems collect the wastewater from a number of households for treatment via a series of biofilters with various media sizes, before disposal of the effluent to the stormwater drain. Trials are currently in the evaluation stage.

Stormwater drainage channels are often blocked due to rubbish and sediment accumulation, which causes pounding of the greywater and spillage which could impact public health (UNHAS 2011). Drainage ways discharge into three major canals, Panampu, Sinrijala and Jongaya. These flow into the Tallo river.

Table 7 Typical development characteristics in Makassar (McDonald, 2011)

Development type	Development characteristics	Sanitation system	Key issues
Housing estate	Medium density allotments with some open space around houses	Blackwater discharged to leaching pit or septic tank, sometimes with an infiltration pit. Greywater (bathroom, kitchen and laundry) discharged to stormwater drain.	Few septic tanks, majority are leaching pits/cesspools (cubluk). Poor maintenance and effluent discharged to stormwater drains. Blockage of stormwater drains. Demand of water for garden irrigation
Residential area	Unplanned development with medium to high density housing and small plots. Houses may be multi-storey. Residents may lack tenure.	Some households have no private facility. Existing leach pits and septic tanks discharge to stormwater drains Community or public toilets maybe available Greywater separated from blackwater Inadequate drainage and water supply	Septic tanks and leach pits poorly maintained. Community toilets often poorly maintained. Pounding of wastewater. Greywater accumulation in stormwater drains due to blockage.
Slum area	High density, low income population, housing of poor construction narrow access and poor services. Lack of land tenure.	Some household have their own toilet Many use shared/communal toilets or defecate in the open.	Lack of space to build toilets in households. Lack of land tenure discourages improvements to houses. Toilets may discharge to stormwater drains.
Commercial area/CBD	Large buildings with limited open space surrounding buildings	Large septic tanks or Rotating Biological Contactor with soak ways.	Poor maintenance, unregulated septage removal and inadequate treatment.
Institutional buildings	Large areas of open space surrounding buildings	Large septic tanks with soak ways.	Poor maintenance, unregulated septage removal and inadequate treatment.

6.2 Non-residential wastewater

Commercial and industrial facilities in Makassar are required to have mandatory on-site wastewater treatment and to comply with discharge regulations. This applies to industry, supermarkets, shopping malls, hospitals, restaurants and hotels in the city of Makassar. The treatment type varies and can range from simple grease traps to more advanced separation such as aerated septic tanks. A number of large commercial enterprises, such as hotels reuse the effluent generated by their on-site treatment systems for irrigation (UNHAS, 2010 pers. communication). Small artisanal home –based manufacturing, such as small scale production of "*tofu*" or "*tempeh"* are not classified as trade waste and not subject to same requirements (PU 2011, personal communication).

6.2.1 KIMA industrial estate

A number of larger industrial dischargers are located within the Kawasan Industri Makassar (KIMA) industrial complex. The wastewater produced in KIMA is treated in a designated wastewater treatment plant (WWTP) before discharge to the Tallo river. The treatment train is described in Figure 21. The KIMA WWTP has a treatment capacity of 3000 m^3/day and the effluent quality produced is within the specifications required by Regulation no.14/2003 (Table 9). Industries located outside of the KIMA are required to conduct on-site treatment of wastewater. According to a survey in CTI Engineering Co Ltd, PT Virama Karya and PT DCC Consultants Co Ltd (2001), industries in KIMA were responsible for 61% of the industrial water demand and industries outside of KIMA accounted for the remainder 39%, hence it can be concluded that KIMA captures at least 60% of the industrial wastewater generated in Makassar.

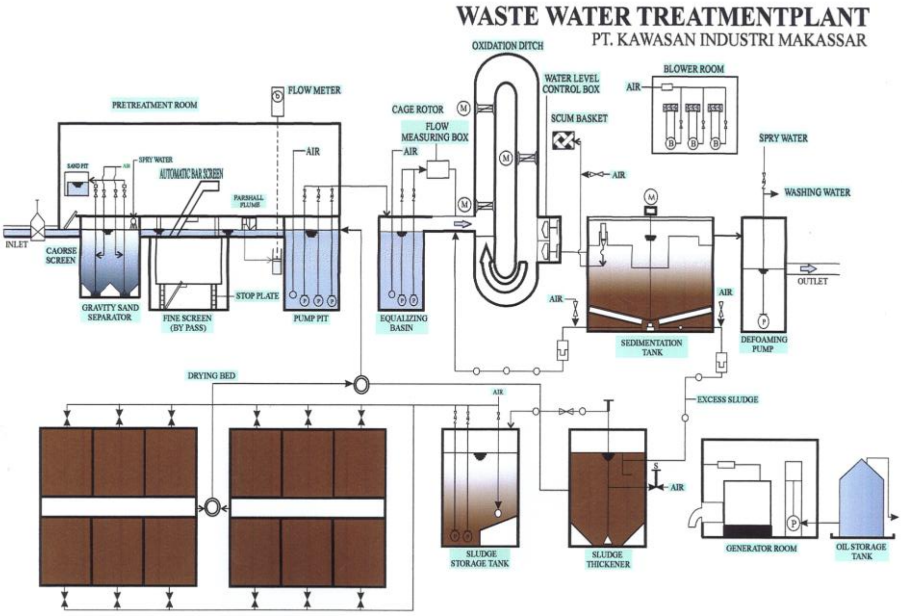


Figure 21 Wastewater treatment process at KIMA WWTP (Source: KIMA 2011).

6.2.2 Effluent quality

To gain an understanding of the quality of the effluent produced by trade waste dischargers across Makassar, we examined trade waste compliance reports from a sample of trade waste dischargers located at various locations across Makassar and compared them to Indonesian wastewater standards (Regulation no.14/2003). Groundwater quality reports were also examined to investigate for contamination from effluent.

Methodology

A total of 19 locations were examined, of which 14 locations (73.6%) had groundwater wells. Groundwater and wastewater effluent data were evaluated for respectively 12 and 10 trade waste dischargers in Makassar city. The type of traders examined is shown in Table 8 and included commercial food enterprises (restaurants and bakeries), hotels, car dealers, wood processors, hospital, supermarkets and other light industry.

Samples had been collected as grab samples during the period from 2010 to 2011. Majority of the readings were derived from single grab samples.

Table 8 Classification of water quality sampling locations

Classification	Total number of establishments	Groundwater locations	Wastewater locations
Industry (Trade waste)	7	6	4
Residential	1	1	
Port	1		
Hotel	3	3	2
Gas station	1		1
Hospital	1	1	1
Restaurant	1	1	1
Shop	2		1
Total	19	12	10

Effluent analysis

Table 9 shows the summary of water quality parameters evaluated for each water type and the allowable effluent quality requirements stipulated in the South Sulawesi Regulation no.14/2003 for a range of activities (Hospital, Hotel, domestic activities such as restaurants, class I and class II industrial discharge and KIMA).

The parameters analysed in the water quality reports varied between reports. For example, whilst Class I and II effluent requirements list 30 parameters, typically fewer parameters were analysed in the reports and these typically included temperature, pH, TDS or TSS, pH, COD, BOD, Fe, Cr, Cu and Cl_2.

BOD, COD, TSS and pH were the common parameters recorded at all sites' reports, followed by ammonia and pH which were reported in 70% of the reports.

Chromium, as Cr(VI) or as total Cr , was the only heavy metal recorded. They were measured in respectively 60% and 40% of reports respectively. Other heavy metals were not customarily disclosed in the reports.

The concentration of phosphorus or phosphates was seldom analysed in wastewater reports, having been recorded only at 2 sites. For those sites the concentrations were less than 0.12mg/L. Trade waste discharge from the port had not been reported, instead the quality of sea water samples collected from 3 locations near the port were shown in Table 9. The BOD concentrations were within the specifications for *Daftar persyaratan kualitas air laut sesuai kepmen LH No.51 2004 Lamp II* (max. 10mh/L), but the phosphate concentrations were higher than the maximum environmental limit of 0.015mg/L.

Overall, for the parameters measured the trade waste discharged by the sample of dischargers was mostly within the wastewater specifications established by the Indonesian standards for class I or II trade waste and also within the range expected for untreated domestic wastewater (Crites, 1998). The few exceptions mainly COD and ammonia for selected dischargers:

- The temperature and the pH were within the compliance range, with temperature at 30°C and pH being most commonly in the neutral range (mean pH 7.03$\pm$0.46).

- The TDS and TSS concentrations were respectively less than 70% and 30% of the maximum limit set for Class I discharge. Other parameters measured such as free chlorine, and chromium were within the limits stipulated for class I. For Ammonia 83% of the samples were within the class I limits and 8% complied with class II .

- However, BOD and COD were the parameters that most commonly approached the maximum limits of regulation form water quality. COD, TDS and TSS had shown high variability across dischargers as expressed in the respective mean and high standard deviation values 122.7+119.3, 352+530 and 28.0+22.7 mg/L.

- Microorganisms expressed as total coliforms were only recorded for the wastewater from the hospital outlet, this had a concentration of 14,000 MPN/100mL, which exceeded the allowable limit of 10,000MPN/100mL..

The sample of trade waste dischargers indicates production of low strength wastewater effluent as shown in Table 9. Based on the small sample size the on-site systems appear to provide adequate treatment to achieve the trade waste effluent standards required. However, given the limited range of pollutants measured it cannot be ascertained what environmental risk is posed by other parameters not monitored.

Table 9 Typical water and wastewater characteristics reported in trade waste analysis reports

Parameter	Units	South Sulawesi regulation No.14/2003					Water type					
		Maximum allowable concentrations per effluent type					Groundwater (air tanah/sumur)		Trade waste wastewater after on-site treatment (air limbah)		Sea water at port (air laut)	
		Class I	Class II	Hotel	Domestic (A,B,C)	KIMA	Mean	Median	Mean	Median	Mean	Median
BOD	mg/L	50 30[5]	150	30	25,40,75	50	1.19 ±1.31	0.99	41.9±37.3	35.84	3.98±0.21	4.02
COD	mg/L	100 80[5]	300	50	80,100, 125	100	7.3±2.9	8.3	122.7±119.3	100.0	19.61±0.35	19.45
TDS	mg/L	2000	3000				201.8±143.7	144	352.0±530	159.0	35482+3014	35879
TSS	mg/L	200 30[5]	400	50	20,35,50	200	14.9±10.1	11.6	28.04±22.72	16.4	6.83±1.29	7
pH		6-9	6-9	6-9	6-9	6-9	7.4±0.6	7.1	7.03±0.46	6.90	7.81±0.27	7.67
NO4 as N	mg/L	15	30			15	0.2±0.0	0.2	n.d.		0.13±0.01	0.12
NO2 as N	mg/L	1	3			2	n.d.	n.d.	n.d.		0.016±0.004	0.017
NH4	mg/L	1 0.1[5]	5			3	0.2±0.2[1]	0.1	1.04±1.75	0.30	0.014±0.002	0.014
PO4	mg/L	2[5]					n.d		0.06±0.05[1]	0.06	0.38±0.04	0.37
DO	mg/L						6.3±0.6	6.3	n.d.		7.71±0.27	7.57
O&G	mg/L				5,8,10	7	3.1±3.4	1.3[2]	2.4[3]		0.003±0.002	
Cr (total and VI)	mg/L	0.5 0.1(VI)	1 0.5 (VI)			0.3	0.01±0.01	0.007[2]	0.02±0.01(t)[4] 0.04±0.03(VI)(n=6)	0.02(t) 0.03(VI)	n.d.	
Fe	mg/L						0.029±0.025	0.015	0.04±0.04	0.03	0.15±0.02	0.16
Cu	mg/L	1.5	2			2	n.d.		n.d.[3]		n.d	
Cd	mg/L	0.05	0.1				n.d.		n.d.		n.d	
Pb	mg/L	0.1	0.8				n.d.		0.02[3]		0.002±0.001	0.002
Zn	mg/L	4	8			6	n.d.		n.d. [3]		n.d.	
Hg	mg/L	0.002	0.005				n.d.		n.d.		n.d.	
Cl^{-1}	mg/L						11.4±19	4.2			n.d	
SO4	mg/L						10.5±29.4	1.5			143.4±1.42	143.2
Free Cl_2	mg/L	1	2				0.02±0.04	0.0	0.14±0.08	0.16	n.d	
CN	mg/L	0.05	0.1			0.3	n.d.		n.d.		n.d	

H_2S	mg/L	0.05	0.1			0.03	n.d.		n.d.	n.d.	
T.coliforms	MPN/100 mL	10,000[5]		10,000	2500, 5000,-		10.5±8.8	10.0	14000[3]	400+234	280
F.coliforms	MPN/100 mL						n.d.		n.d.	29.3±10.2	25

n.d –not determined, [1] Only measured at 2 sites.[2]Only measured at 5 sites. [3]Only measured at 1 site.[4]Only measured at 4 sites.
[5] Requirement for hospitals only.

Groundwater analysis

As shown in Table 10, the groundwater characteristics of the samples examined were within the limits set by "*Standar Berdasarkan Keputusan Gubemur Sulawesi Selatan No.14 Tahum 2003 Tentang Pengololaan class I*". In particular, *t.coliforms* concentrations were within the limits stipulated by the standards, thus there was no indication of cross-contamination from wastewater effluent in the groundwater sources analysed .

Table 10 Groundwater quality at 14 commercial and industrial locations in Makassar

Parameter Units	BOD mg/L	COD mg/L	TDS mg/L	TSS mg/L	pH	Cl- mg/L	SO4 mg/L	*T.coliforms* MPN/100mL
Std max. limit[1]	2	10	800	50		600	400	1000
Mean	1.19	7.3	201.8	14.9	7.4	11.4	10.5	10.5
Standard Dev	1.32	2.9	143.7	10.1	0.6	19.0	29.4	8.8
Median	0.99	8.3	144.0	11.6	7.1	4.2	1.5	10.0
Min	0.2	1.42	36	5.6	6.6	0.32	0.004	0
Max	5.5	10.28	558	35.2	8.8	65.07	98.88	23
Sample size	14	14	15	13	14	13	11	13

[1] Standar Berdasarkan Keputusan Gubemur Sulawesi Selatan No.14 Tahum 2003 Tentang Pengololaan class I

6.2.3 Summary

The trade waste dischargers whose wastewater quality reports were provided were typically producers of low strength wastewater and included commercial food enterprises, car dealers, wood processors, supermarkets and other light industry. Effluent discharged from the KIMA complex was also within specifications and tended to display effluent quality compliant with class I or better.

However, the range of parameters measured in trade waste was limited – for instance heavy metals, phosphorus and organics were often not measured. Whilst it is not necessarily required for the range of parameters to be extended, it would be useful to clarify if the reported parameter selection were based on a risk assessment of the wastewater for each establishment.

Based on the limited number of samples, the indication is that the wastewater generated at those sites tends to be within the standard trade waste license requirements for the parameters analysed (pH, BOD, COD, TSS, TDS), however the *t. coliforms* concentration measured at the hospital exceeded the allowed guidelines.

Trade waste from businesses such as dental clinics, car mechanics and metal production can produce large loads of heavy metals and salts and but have not been evaluated in the limited sample reports obtained.

In summary, the small sample of effluent quality reports indicate that the on-site systems appear to provide adequate treatment for the range of contaminants monitored and is likely to result in low strength effluent . But given the limited range of pollutants measured it cannot be ascertained if other parameters not recorded would pose additional environmental risks.

7. STORMWATER

The city of Makassar has three primary drainage channels, Panampu, Sinrijala and Jongaya. These three drainage canals were designed to cope with the 20-year return design flood year . Secondary and tertiary channels were designed for the design flood year of 2 to 5-year return period (UNHAS 2010). Their drainage capacity has been reduced due to sedimentation and debris accumulation. But the current flow capacity of the canals has not been measured (Selintung 2010, pers. comm).

Selintung *et al* (2011) conducted a visual survey of the condition of the drainage systems in Makassar, including the Jongaya, Sinrijala and Pampang canals. The study recorded evidence of high sedimentation, poor stream aesthetics and the presence of solid waste (including plastic containers, wood refuse) and debris at multiple locations along the canals (Figure 22). Solid waste disposal at the banks and in the canals were common practices evidenced in the study, particularly in areas with poor roadside infrastructure. Stormwater quality was not evaluated.

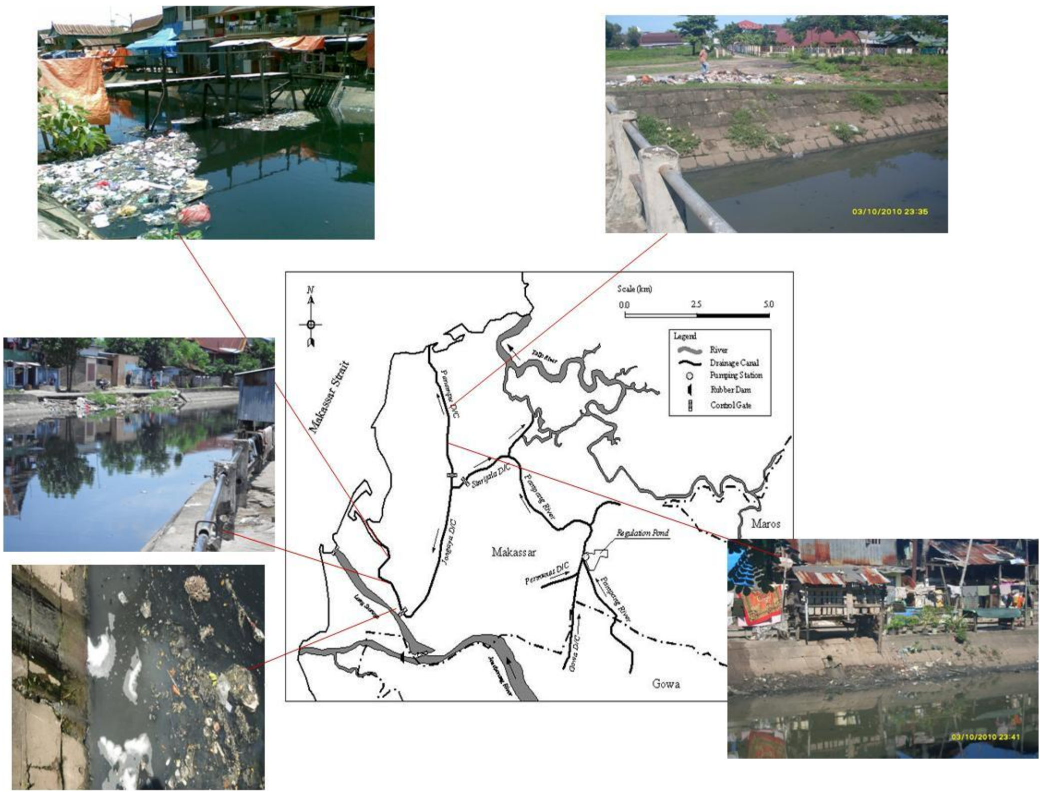


Figure 22 Drainage facilities in the city of Makassar (Adapted from Selitung 2010, Gambar drainase 1, 2 and UNHAS, 2011)

7.1 Flooding

Makassar is located on low lying terrain between the deltas of the Jeneberang and Tallo rivers. Hence, flooding is a common occurrence during the wet season, from December to April. Severe flooding typically occurs once a year for approximately 2-3 days (UNHAS 2011, UNHAS 2008). Figure 23 shows the typical prone flood areas in Makassar.

Flooding occurs in regions with low absorption soils, along river estuaries, such as along the banks of the Tallo river, in the districts of Tallo, Biringkanaya, and Tamalanrea, and at the estuary of the Jeneberang and Pampang rivers.

Flooding is also frequent in residential developments constructed on former ponds, marshes, paddy fields and swamp areas which have been redeveloped into residential areas. The redevelopment of such areas also increases the run-off to lower slope areas, which contributes to localised flooding in low lying areas, such as Antang, Minasa Upa, the seaport and the Toll Road (UNHAS 2010).

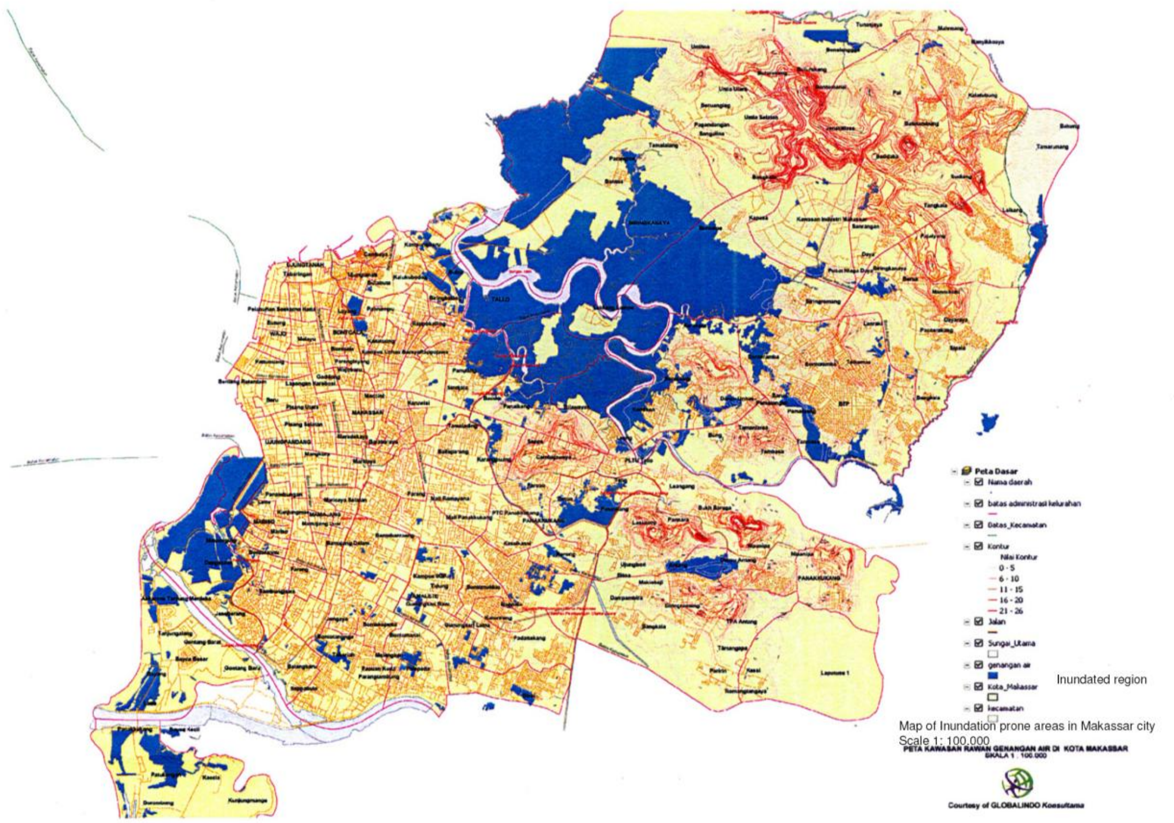


Figure 23 Flood prone areas (Source: UNHAS 2011).

7.2 **Characteristics of stormwater and surface waters**

Water quality in the city of Makassar, both surface water and ground water, varies with location. Examples of the water characteristics are given in the Appendices .

Limited water quality monitoring is conducted on raw water sources due to financial constraints. Water quality, especially organic content along the main rivers are often not within standard specifications, exceeding the threshold specified by environmental standard PP 82/ 2001 (UNHAS 2011).

An indication of the water quality in the Tallo river and groundwater wells around Makassar is provided in Table 12 in the Appendix B. Biological oxygen demand (BOD), chemical oxygen demand (COD) and iron content (2) in the Tallo river often exceed the standard (PP 82/2001). Water in the Sinrijala and Panampu canals in the city of Makassar is also polluted, with high concentrations of Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Iron (Fe) BOD and COD.

Solid waste disposed into canals is a key contributor poor water quality and also to sediment accumulation in the canals (Selintung, 2011).

As previously shown in Table 9, the quality of sea water samples collected from 3 locations near the port .. BOD concentration were within the specifications for *Daftar persyaratan kualitas air laut sesuai kepmen LH No.51 2004 Lamp II (max. 10mh/L)*, but phosphate concentration were higher than the maximum limit of 0.015mg/L.

8. SOLID WASTE MANAGEMENT

Solid waste is a major source of diffuse pollution in Makassar, with increasing amounts discarded along the coast, rivers, drainage channels and roadside and negatively impacting public amenity, public health and the environment.

Selitung *et al* estimated that 1676 m^3/d (771 tonnes) of waste were generated in Makassar in 2009 alone. The majority is household waste (76% v/v), the reminder of the waste is commercial, industrial and office waste, respectively 11, 10 and 4% v/v (Selitung *et al* 2009). Market and household waste are 70% organic matter (70%).

Garbage collection services cover 87% of Makassar. However, only about 70% of the total daily production of waste is processed, according to data collected by UNHAS (Selitung *et al* 2009).

Householders are required to take their waste to designated collection points, where the waste is collected by the garbage collection service. Collection points are concrete holding pens typically shared by multiple users within a designated area. However, overfilling of pens can lead to rubbish spillage into stormwater drains or onto the street, and heavy rainfall in the wet season often disperses solid waste if collection is not frequent enough (UNHAS 2010).

In areas with insufficient waste collection, rubbish is either burned or stacked along the side of the road or waterways and often ends in stormwater drainage ways and canals.

The collected waste is disposed at the Tamangapa landfill (*Tempat Pembuangan Akhir, TPA*), in Manggala District or into illegal landfills. The Tamangapa landfill is an open landfill that has been in operation since 1993. It covers 14.3 ha and has 810 m^3 the capacity. Soil cover is placed on the waste irregularly. The landfill is currently close to maximum capacity and operates in conditions considered unhealthy. The landfill leachate pool is not operational. Underground water contaminated by landfill leachate and odours are serious problems in the areas surrounding the landfill (UNHAS 2010, Alexander *et al* 2011).

Solid waste recycling is conducted by small-scale operators, who sell the recycled material to larger collectors. There are several recycling plants for plastic materials (Luhur Plastics), aluminium (CV. Andalas Jaya), metal (PT. Barawaja), wood chips (PT. Batatex), and organic waste (PT. Orgi). Most of the material that can be recycled are transported outside the island, to Surabaya, East Java, for recycling (UNHAS 2011).

9. OTHER ENVIRONMENTAL ISSUES

The environmental status in the city of Makassar is poor, particularly in settlements along many of the water catchment areas. The city faces various environmental issues ranging from littering to water, air and soil pollution.

Further urban development and the increase of population in the city of Makassar could have a significant influence on environmental quality. Unregulated discharge of residential wastewater into channels and rivers is a major source of pollution.

- ## Human health

Environmental conditions and community practices such as garbage disposal into waterways, can also contribute to the development of environmental conditions that harbour infectious diseases, such as diarrhoea, respiratory infections, dengue, and malaria occurs in massive (Astaqanliyah, 2008).

- ## Sedimentation

Makassar’s low-lying, coastal plains and small islands, are susceptible to sedimentation in the region around Losari beach. Satellite imagery shows that the distance between the beach and Losari has shrunk from 600 meters (in 1989) to 374 meters (in 2004). In 2015 this will be narrowed because of sedimentation at mouth of the Jeneberang river, i.e. 100 meters. The high sedimentation rate is caused by a lack of vegetation buffering on the river. Sedimentation has even reached the Port of Soekarno-Hatta, and causes silting in the harbor area. Engineering drainage is planned to tackle the problem in the RTRW plan (UNHAS 2011).

- ## Abrasion

Sea abrasion can impact Makassar’s Water Front City. The rate of abrasion occurring on coastal areas can threaten coastal buildings. A holistic and comprehensive solutions need to be initiated as a joint action to inhibit the rate of abrasion along the coast of Makassar.

- ## Sea Level Rise

Mean sea level rise occurs as a result of two main processes – melting of land-based ice and thermal expansion of the ocean. Global sea level rise is projected by the IPCC to be 18 to 59 cm by 2090-2100, with a possible additional contribution from ice sheets of 10 to 20 cm to the upper end. By 2020, the 5th to 95th percentile range is 3.2 to 10.0 cm and by 2050 the range is 8.9 to 27.8 cm (CSIRO 2010; Hunter 2010). However, the projected sea level change is not spatially uniform (IPCC, 2007). An ensemble mean over 17 GCMs shows that the projected sea level rise over the South Sulawesi region is 0 to 1 cm less than the global-average (O'Farrel, *personal communication* in UNHAS 2011). These estimates do not include land movement. It also must be noted that these estimates are from coarse spatial resolution global climate model, therefore, they should be considered indicative only.

Sea level rise will bring changes to the geographical map of the coast and threaten the existence of infrastructure in coastal areas and coastal groundwater reserves. The study results from PPLH Regional Sumapapua (2009) on vulnerability assessment and adaptation to climate change in the Territory Mamminasata show that the sea in 2050 will rise by 56 cm from the current sea level, and cover 3214 ha. In the year 2100, sea level rise will reach 110 cm, and cause increased inundation of an area of 4611 ha. Makassar itself will be inundated over an area of 2910 ha, with underwater areas of 908 ha in 2050, and 2010 ha in 2100 (Tamin, 2010).

10. STAKEHOLDER PERCEPTION OF KEY WATER ISSUES

To guide the research for this project and gain a greater understanding of the priorities and issues facing Makassar, institutional stakeholders were consulted through two workshops conducted in November 2010 and January 2011, as previously mentioned in section 3.

10.1 Methodology

To inform the research process and ensure its relevance to Makassar, representatives from key stakeholder groups (government at municipal, regency and provincial levels; academia; NGOs; and water utilities) were invited to take part in two workshops. Through the workshops participants were asked to identify: (i) the study boundaries, (ii) priorities and challenges that they perceived for the current and future Makassar water and wastewater system (workshop 1), and (iii) the major challenges and issues for the water catchments and urban Makassar using the Water needs index, (iv) to identify hotspots and the availability of data. A detailed description of the workshops' methodology and outcomes can be found in Larson *et al* (2012) and Alexander *et al* (2011).

10.2 Priorities

In total 21 individuals belonging to Makassar stakeholder groups took part in the objective identification and selection process. Stakeholders identified as the most pressing objectives:

- Current: the conservation of the water catchment and management of water resources. The need to reduce discharges to the environment and the reduction of leakage were also highlighted as important objectives.
- In 15 years time: the focus on the conservation of the water catchment continues (agreement among participants 57%), and increasing concern for the management of wastewater discharges with emphasis on reducing domestic and industrial discharges and

operation of the wastewater treatment plant. The third theme highlighted was the consideration of alternative water sources (greywater and stormwater).

- In 30 years: management of wastewater becomes the major concern, particularly for domestic wastewater.

10.3 Challenges to water security

Challenges to water security in Makassar are described in this chapter. Stakeholders identificed a range of environmental challenges impacting water catchments and the city of Makassar. Key issues were also identified by stakeholders and are shown in the Table 11 and Table 14 (in appendix).

The range of environmental threats identified was extensive and they were often associated with a specific geographical location within Mamminasata or Makassar. Their detailed location is shown the maps in the Appendices 3 (for catchments) and 4 (Makassar).

10.3.1 Water Catchments

For the 3 water catchments (Maros, Tallo and Jeneberang), the participants were asked to identify challenges within the categories: (i) water availability; (ii) infrastructure; (iii) land use; (iv) aquatic ecosystems; and (v) institutional collaboration.

A multitude of localised issues and concerns were identified. At catchment level, the key issues were:

- Lack of information on the environmental health of the rivers in the catchments for the Jeneberang river and particularly for the Tallo river. The threat of pollution to the Jeneberang river was identified to come from the upper catchments, by agriculture and sedimentation, and thus likely to be linked to the need for catchment preservation. For the Tallo and the Maros rivers the pollution came in the lower sections of the river– pollution and was attributed to residential and industrial discharges. In addition, sedimentation was also an issue for the last two rivers basins.

- Control of land use and development. Urbanisation and deforestation were identified as risks to the integrity of the catchments, and also to ecosystems and groundwater sensitive areas (such as mangrove, karst, swamps, floodplains). As the catchments pass via multiple regencies (Makassar, Maros, and Gowa) within Mamminasata, institutional collaboration was deemed essential, but was not fully effective among the agencies operating within the three catchments.

- Water availability at the catchment level was not discussed in depth, but its availability was linked by participants to the availability of infrastructure, such as dams and retention basins, to allow security of supply and to reduce seasonality impacts.

Table 11 Key catchment issues identified by stakeholders (adapted from Alexander *et al* , 2011)

	Catchment challenges		
Category	**Jeneberang**	**Maros**	**Tallo**
Infrastructure	Sedimentation	n.a	Need to increase water supply

Land use	Deforestation at river source	Need to control land use/development in Karst area. Mangrove: abrasion of seashore and seawater intrusion	High urbanisation and multiple land uses. High population density.
Aquatic ecosystem water quality	Bioindicator status unknown. Pollution from agriculture and sedimentation from Bawakaerang wall collapse.	Water quality estimated using bioindicator: Upstream medium pollution, downstream high pollution, high sedimentation.	Bioindicator status unknown. High pollution from domestic + industrial wastewater, sedimentation high,
Institutional collaboration	Land tenure conflict, sectoral egoism at source of Jeneberang, NGO and stakeholder forum, sectoral agency conflict downstream.	Land tenure conflict, sectoral agency conflict, sectoral egoism, ngo and stakeholder forum, roles of national and local government.	Land tenure conflict, sectoral egoism around Makassar, sectoral agency conflict.
Water availability	Not determined	Not determined	Not determined

10.3.2 Urban Makassar

For urban Makassar, the categories discussed were: (i) water use and needs; (ii) infrastructure; (iii) groundwater; (iv), sources of waste and wastewater (v) environment; and (vi) institutional collaboration.

In urban Makassar, multiple issues, geographically specific and localised were identified by stakeholders. These are summarised in Figure 24:

- Water needs: Makassar has diverse range of water needs (industrial, residential, recreational) and predominant needs can be geographically mapped. In the north the main need is water for industrial use given the high concentration of industry, manufacture and also the airport. In the south water is required mainly for residential consumption and also for recreation, whilst at the coast the major uses are for the port, aquaculture and mangroves.

- Water supply infrastructure is a severe challenge in the city: water supply pipes do not yet cover large sections in the north part of the city; in coastal Makassar infrastructure is ageing and in need of replacement and the south was in need of improved water supply. Drainage was an issue in the north and south of the city, and was linked to flooding.

- Groundwater in the south and coastal Makassar was under the threat of seawater intrusion and salinisation. Whilst in the north the lack of supply by PDAM meant a greater dependency and extraction of groundwater, with concerns of unsustainable extraction and insufficient groundwater recharge. In addition, to the north east of the city much of the groundwater is of poor quality (hard water) due to soil geology.

- Lack of wastewater infrastructure for the small islands and also for industry outside of the KIMA area were also challenges. In the north the major source of pollution was identified as industrial wastewater – particularly outside of the KIMA area, in the city centre and south the major sources of pollution were residential wastewater and solid waste, in coastal Makassar surface run-off and sea water intrusion also took place, and in the south- east agricultural pollution was the major threat..

- Similarly, as with catchments the need for dialog and cooperation between stakeholders (community, government, aquaculture, etc) was perceived as a challenge, but essential for the management of the problems. The nature of conflicts in urban Makassar was diverse and often localised (see maps in appendix for the geographical location of the issues).

- Overall, the workshop endorsed and provided further details on the issues highlighted in the literature review, indicating the development of a clear consensus and common awareness of the problems facing the region and the city by institutional stakeholders.

- However, the consultation with stakeholders on data sources that could be used to quantify the issues indicated that there are a range of gaps in the monitoring data availability, especially in environmental monitoring data (Alexander *et al*, 2011).

Figure 24 Key challenges to water security and environment identified by stakeholders in Makassar.

11. MAMMINASATA MASTERPLAN

The master plan 2010-2030 for Makassar city outlines the planned development of water resources for transport, urban development, and infrastructure for clean water and sanitation (KRI International Corp, Nippon Koei Co. Ltd.,.2006). The water supply masterplan is being developed by the various water related agencies in Mamminasata with the technical support of the Japanese International Cooperation Agency (JICA).

It is briefly summarised below.

11.1 Development of Water Resources and Water Supply

The Water supply masterplan focuses on the development of infrastructure to address a number of challenges identified previously including:

- To reduce water usage and maintain ground water resources on land and surface water as raw water;
- To implement clean water distribution to all layers of society;
- To implement groundwater conservation to control land subsidence, reduction in ground water level, and damage to soil structure.

The Masterplan recognises that water demand will outstrip supply capacity in the future. This was determined by analysis of water supply and demand based on a range of scenarios developed using historical data from the dry season river stream flows from 20 years ago. It identified the need for additional water resources to fulfil the demand needs into the future. Climate change effects have not been included in the assessment.

To address the deficit in water supply, the Masterplan proposes on a range of initiatives including:

- The construction of large scale infrastructure, including additional dams and water treatment plants, capacity expansion for existing water treatment plants, planning of zones of water service priority, upgrade of raw water drainage network, and new locations for water distribution centres across the Maminnasata region.
- Leakage reduction programs for existing infrastructure through pipe rehabilitation.

Urban infrastructure development is based on space availability and on strategic objectives, both guide the direction of the implementation. The objectives proposed include:

- Restriction of shallow ground water sampling in the area of housing and settlements.
- Expansion of water catchment areas through the addition of green open space in each integrated area, reservoir, lake, riverine and coastal border.
- Prevention of seepage of waste into the soil and pollution of water resources especially around the critical zones, such as in the area around the Jongaya and Pampang canals.
- Development of a waste and wastewater infrastructure network in the area around Terong market, Pakbaeng-Baeng Market, Butung Market and other traditional markets,

11.2 Wastewater Infrastructure Development

Wastewater generated in the city of Makassar is expected to rise sharply in line with the improvement of water supply services. Assuming a BOD content of household laundry water at 168 mg/L, commercial waste water services 250 mg/l, and industrial waste water 1152 mg/l, then the pollution load will reach 78,600 kg BOD/day in Makassar.

The Interim masterplan (McDonald 2011) aims to reduce the pollution load by improving drainage of wastewater, by construction of a wastewater treatment plant and by increasing access to toilet facilities and sewerage to all citizens. The plan aims to start infrastructure construction in 2012 ~ 2015 and to be completed by 2020.

The Masterplan's sanitation targets aim to initially achieve greywater quality of less than 30 mg BOD/L, and in the long term to further reduce the BOD content to less than 10 mg /L for treated wastewater from toilet amenities and coastal areas discharges (MacDonald, 2011).

In the master plan 2010-2030 for Makassar city, wastewater will be managed using a range of on-site and off-site sanitation options:

- On-site systems in areas with a population density of less than 100 persons / ha.
- Floating septic tanks (*Hole pelumeran)* in areas with ground water depth greater than 4 m.
- Communal systems in areas of medium density for collective treatment of wastewater from 10-15 families.
- Sewered (off-site systems) with treatment at a centralised plant, in areas of high density population density of more than 100 persons / ha, such as high density settlements, business centres, industrial estates and the port.

Further details of these systems are described in the literature review by UNHAS (2011) and in MacDonald (2011).

Sanitation coverage will vary for each subdistrict and will be managed by the Municipal Public Works Agency (PU, 2011).

By the year 2030, septic tank and absorption facilities are expected to be accessible to 80% of the total population in inland low density areas.

For coastal residential areas above the water level, a floating septic tank system with tidal removal will be adopted is proposed. By the year 2030 the use of floating septic tanks is expected to reach 90% of the total population in areas of low density houses on the water.

Off-site sanitation will be applied to urban residential areas and areas of medium population density using communal septic tanks and a sewerage system will be constructed for off-site treatment in the city centre and areas of high population density and high built density.

11.3 Drainage

The Masterplan 2010-2030 for Makassar aims to improve the condition of the canals, control inundation and manage flooding by:

- Turning basins or major river corridor into destination areas within the city;
- Optimizing and integrating the functions of macro-channel networks, sub-macro, micro, and location of water storage (reservoirs) in the system

- Construction of flood control facilities to enhance the capacity of infrastructure to handle the 100 year flood, while maintaining minimal discharge and its steady flow of quality;
- Normalization of flow from the three rivers (Jeneberang, Tallo, and Maros) and completion of the city channel flow system.
- The restructure of the river banks in line with river function, namely as flood control, drainage, and amenity.
- Development and improvement of infrastructure for water reservoirs, especially upstream of the basin where land is limited.

11.4 Solid waste management

The Mamminasata Masterplan (KRI International Corp and Nippon Koei Co. Ltd. 2006), proposes a number of strategies to improve the problem of solid waste management in the city of Makassar, including:

- Improvement of waste collection services, especially in low-income areas where streets are too narrow for trucks to pass. Trial of a waste segregation system will be tested to determine whether it can be applied in selected residential areas.
- New landfill Disposal, as TPA Tamangapa reaching capacity and is a source of pollution in and around the landfill, Makassar city has prepared a feasibility study to obtain l funding for construction of a new landfill in Gowa. However, there are public objections by residents from Gowa who do not want the landfill to built near their settlements.
- Disposal of Hazardous and Toxic Waste
  Hazardous waste and toxic (*Bahan Berhaya dan Beracun, B3*) must be handled separately from household waste and non-hazardous waste. The licensing and its management are strictly controlled under the Government Regulation No. 85 of 1999 and No. 74 of 2001.
- Education and awareness campaigns directed at the public and dischargers to increase awareness of waste reduction, reuse and recycling. Proposed initiatives include: (i) Implementation of environmental plans in primary schools, (ii) Promotion of 3R (Reduce, Reuse and Recycle) aimed at effective garbage collection and transportation services and community involvement to reduce solid waste, (iii) Establishment of waste sorting system.
- Gradual introduction of Recycling-Oriented Society, a system for waste disposal is planned to start for industrial and commercial sectors in urban areas.

Overall, there are many and diverse needs in Makassar. The masterplan recognises the range of challenges Makassar faces, including: access to water supply and sanitation, wastewater management, drainage, solid waste, transport, urban planning, etc. However, improving the condition of infrastructure in each of those realms requires investment in many areas in an integrated manner.

For water supply, the masterplan recommends the construction of large scale centralized infrastructure to reduce flow seasonality. Concurrently, a range of initiatives aimed at improving the condition of the distribution assets, extending water intake capacity and distribution infrastructure and improving the financial viability of PDAM are being proposed. Capacity wise these projects are being technically supported by JICA.

For wastewater, trade waste management practices are in principle sustainable, particularly the model of cluster treatment in KIMA, and the source management for commercial dischargers. However, ensuring that dischargers comply with discharge standards requires verification and monitoring. Pollution from residential wastewater and access to sanitation are more urgent problems for Makassar and the mix of centralised and decentralized approaches proposed to manage domestic wastewater is a good example of the integration of fit-for-purpose centralized and decentralised management strategy. However, as with all such strategies operation and maintenance long-term are the greatest challenges which will require on-going support.

For waste management the solutions proposed adopt a mix of social intervention and engineering solutions. Drainage of the canals and removal of rubbish can temporarily improve flows. But the major challenge regarding waste management appears to be public behaviour and the lack of understanding of the impact of the current indiscriminate disposal practices on the environment, infrastructure and public health. Thus solutions are aimed to change behaviour and increase awareness would be more effective on the long term.

Extensive funding will be required to fund the programs and the proposed infrastructure and these are likely to be coming from central government and donors. What alternatives and what priority of implementation will Makassar adopt if not all projects and programs can be funded?

Another challenge will lie on the long-term viability of large infrastructure projects, are the projects self-sustainable financially, environmentally, capacity wise are they able to cater for improving social and living conditions? Partnerships between capacity building institutions for technical aspects and also between key stakeholders, such as the community are important for the on-going viability of such systems.

12. DISCUSSION AND RECOMMENDATIONS

12.1 Priorities

As with many developing economies, there are multiple challenges that need to be addressed in Makassar and Mamminasata. Many of which are inter-related, such as access to basic services, financial constraints and social equity, urban planning and the state-of the-environment and public amenity. In addition, the social, economic and institutional context in Makassar and the Mamminasata area is complex, as with any developing country. Whilst regulations and standards are available, their enforcement or implementation is often marred by economic and institutional constraints.

The major priority for stakeholders at present is ensuring access and security of water supply. Stakeholders also recognise growing concerns over pollution and expect that risks associated with wastewater disposal and the pollution will become key priorities more significant in the next 15 years and into the future.

12.2 Monitoring and scientific data

Data access is complex with fragmented repositories located across various government agencies and departments. Identification of data sources has been challenging, in addition there are also significant data gaps and integrity issues in many cases particularly for environmental data. An inventory of wastewater discharge and further understanding of the groundwater context could assist in gaining further insight into the future supply and demand context.

12.3 Bulk water supplies

The Mamminasata area relies on river and groundwater for its bulk water supplies. River supplies are shared by the 4 regencies in the region and are the major water resource for mains supply by PDAMs, agriculture, aquaculture and electricity generation. Deforestation of catchments, leading to increased soil instability and pollution due to land use activities were identified as the major threats to the bulk water supplies, with evidence of river bank collapse and sedimentation impacting supply, e.g. 1994 Mount Bawakaerang collapse. Evidence of river pollution is available in two of the catchments and is still to be evaluated in the third.
Changes in precipitation could aggravate some of the risks to the catchment and hence it would be useful to determine if climate change may pose a threat.

12.4 Urban water needs

Makassar, which is located to the east of Mamminasata, houses the largest population and also represents the largest piped water demand. Mains (piped) water demand currently outstrips supply capacity in Makassar City. The supply deficit is the most severe to the north of the city, which houses the industrial area and is earmarked for urban development.

All over the city, the deficit in mains water is mitigated by use of groundwater, either from shallow wells by the general population or from deep bores (by industry and other users that can afford it). Information on groundwater rate of abstraction and recharge is poor at present.
However, concerns exist of over extraction of groundwater, with reports of drying out of wells in the dry season and of sea water ingress into groundwater reserves at coastal areas – which are indicators of unsustainable yields.

Mains water shortage is caused mostly by distribution issues: lack of distribution infrastructure coverage to the north, 30% water losses during distribution (which also contributes to intermittent water supply) and the need for infrastructure upgrade to reduce leakage. Ageing infrastructure and poor condition also has a detrimental impact on water quality causing recontamination due to infiltration from low pressure. Seasonality of bulk supply requires water transfer from the south to the north of the city during the dry season, however current pumping infrastructure capacity limits the amount of bulk water that can be transferred.

12.5 Wastewater context

The sanitation model adopted in Makassar relies on on-site septic systems and leach pits for blackwater and covers 60% of the city. Greywater from households, which encompasses bathroom, laundry and bath water is discharged to open stormwater drains located at the front of houses along streets. These also collect stormwater run-off and the combined greywater and stormwater are discharged untreated into drainage canals and finally to the sea. Greywater whilst not having as high pathogen levels as blackwater, also harbours contaminants and needs to be evaluated for environmental impact (Diaper 2007).

In some areas there is no access to sanitation or tap water. The municipality is trying to address access to tap water by installation of communal hydrants.

Septic systems become less efficient in high density areas, where land block size may restrict effluent dispersion. In addition, it becomes increasingly difficult to access the septic tank sludge removal –as they are often located to the back of the property. As a result, the risk of cross-contamination also increases with the proximity between wells and septic tanks. This risk is recognised in the wastewater Masterplan.

Septic tank sludge is supposed to be treated before disposal in a dedicated treatment plant (IPA). However, the Makassar's plant is currently non-operational due to lack of funds for maintenance of the digestion equipment. As a result the plant currently only stockpiles the sludge.

Trade waste dischargers are required to provide on-site treatment before discharge to stormwater or river outlets. In addition, wastewater discharged by industries in the KIMA industrial complex is treated in a dedicated plant managed by the municipality, which complies with environmental discharge standards.

However, the level of on-site treatment and compliance from industrial dischargers outside of KIMA, is not as well documented. And the municipality also suffers from financial constraints which limits their capacity of monitoring and enforcement (PU 2010,personal comm.).

Overall, the decentralised model adopted places a large emphasis on the treatment of industrial wastewater at source and based on a sample of the effluent discharges it appears that compliance regarding BOD and SS is achieved. The existence of the KIMA treatment complex also contributes to reduce pollution load from industry and these are good examples of segregation at source for pollution control – which offer potential for sustainable trade waste management into the future. Reuse of effluent for irrigation by some of the private enterprises is also an example of good resource maximisation practices. These can be further enhanced to lead to “cleaner production” and source control practices which are aimed worldwide for reducing pollution by industrial wastewater discharges.

In contrast, the biggest pollution load in Makassar appears to be derived from the residential wastewater/stormwater generation.

However, it is also noted that the range of trade waste parameters evaluated is limited and that data on the state of the environment and waterways is also scarce.

12.6 Stormwater and municipal waste

The stormwater drainage system is gravity based and was originally designed to operate with simple maintenance, where community groups or householders are responsible for removal and cleaning of debris or sediment trapped in the stormwater sections in front of their households. However, literature and anecdotal evidence gathered suggests that stormwater drains have reduced capacity due to sediment accumulation and disposal of litter. Maintenance (removal of sediment) may occur prior to the wet season, but is not believed to occur as frequently as needed.

More concerning is the widespread disposal of litter onto roadsides, stormways and canals, which occurs criminally (e.g. illegal dumping) and also as common practice by the population. Plastic bags, plastic bottles and debris were clearly visible in major canals, accumulated on their banks and by the roadside.

Such practices can lead to public health and environmental health deterioration. They also limit the drainage capacity of the system and exacerbate flooding. Considering that stormways also serve as drainage for greywater – infrastructure capacity is reduced and can also lead to public health issues.

Municipal waste disposal is recognised as an important issue, which is closely linked to stormwater health. The existing solid waste disposal landfill is reaching capacity and constitutes a point source of pollution to groundwater.

12.7 Environmental health

Information on the status of environmental health of water ways was limited. Information on wastewater and groundwater supplies is scarce and often limited. This applies both to loads and volumes discharged/extracted. In particular there is limited data on nutrient loads and toxicity of the waters, however anecdotal evidence indicates that residents do not swim in the sea waters due to pollution.

Finding data on the state of environment proved to be a difficult task, as identification of data silos was often difficult. However, based on the knowledge of stakeholders it was possible to identify a range of environmental challenges in the Makassar.

Other environmental issues reported include sedimentation at the mouth of rivers, abrasion of the coastline, salinisation of groundwater at coastal area, point source and diffuse pollution from urban activity (markets, waste disposal tips, stormwater run-off, illegal wastewater disposal).

Many of the environmental and water cycle issues are exacerbated by indiscriminate development either at city or catchment level. Examples include the redevelopment of flood plains, marshes and river banks into residential areas, without proper consideration of an environmental impact assessment.

The environmental awareness by the general population appears to be low, in particular their understanding of the links between day-to-day practices and environmental consequences. The lack of understanding/awareness by the general community of the environmental implications of actions such as littering or other practices and their link to public health, environmental health and resource use is also a major contributor to the poor condition of water ways and infrastructure.

12.8 The future

Whilst a number of the practices adopted in the management of water and wastewater by the city/population would at one time been adequate, population growth and urban development are overwhelming the long-term sustainability of urban growth.

Population projections for 2035 estimate population growth rates will bring the population up to 3.4 million people in metropolitan Mamminasata (Dinas Tarkim in CTI Engineering 2010). Makassar alone will house approximately 54% of the population of the area. Under such conditions, the problems which currently plague Makassar and the region will worsen if not acted upon. Water demand and pollution loads will increase and overwhelm the ability of the natural environment to cope with them.

Multiple governmental agencies operate in the water resources and sanitation context in Makassar. Municipal and regency authorities are well aware of the challenges that they face in providing basic access to mains water to the overall population. However, they are also constrained by economic resources and capacity.

The masterplan for the Mamminasata region aims to improve water, wastewater and municipal solid waste management services in the area. It is being developed with the input from key agencies including the PDAMs, technical assistance from JICA, municipal and regency authorities. To ensure water security for the region, the masterplan suggests the development of additional large scale infrastructure (e.g. Botto Sunggu dam, new landfill) and upgrade of existing distribution and water supply infrastructure using donor funding. Plans were developed through extensive assessment of population projections, urban development objectives and technical and engineering assessments based on best available historical data.

There is a strong interdependency between water supply, wastewater management, solid waste management and urban development in Makassar. At the same time, the influence of climate change on water resources is being increasingly acknowledged in policy making and future planning around the world (Huntjens *et al*, 2012).

Whilst there is recognition by stakeholders that climate change is happening, the impact of climate change on water resources has not been fully examined to date in Makassar. There are still a number of unknowns:

- What impact climate change will have on precipitation, temperature and overall water resources and water demand has not yet been quantified. Groundwater supplies are likely to become more strained due to population growth and pollution. However, could rainfall frequency and reduced intensity further reduce groundwater recharge? Could this lead to the need for increased reliance on mains water supply? Could climate change also increase the vulnerability of catchment areas to further landslides? It also has to be recognised that there is limited understanding of the groundwater status in Makassar regarding reserve sizes and sustainable yields.
- Could river flows and frequency of extreme events change into the future? What implications could this have on Makassar's urban planning or drainage capacity?
- Could this lead to further competition for water resources among rural, industrial and residential sectors?

These and other questions need to be addressed in the research that will be conducted in the Ausaid-CSIRO- Indonesia alliance and hopefully will enhance the understanding of climate change vulnerability in Makassar.

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APPENDIX 1- WATER QUALITY

Table 12 Water quality of river Tallo (adapted from UNHAS 2010)

No.	Parameter	Units	Tallo[1]		Jeneberang[2]		Maros[3]	Canal[4]		Marine[4]		Standard (PP 82/ 2001)
			Upper catchment	Lower catchment	S-Minasa bridge	Benteng S-Opu	Bantimurung	Panampu	Urip Sumoharjo	Estuary Tallo	Losari	
Physical												
1	Temperature	°C	29.8	29,7	123	214	28					Deviation 3
2	Total Dissolved Solid (TDS)	mg/L	609.2	1042,6	454	111	70	1.64	13.40	43.80	846.3	1000
3	Total Suspended Solid (TSS)	mg/L	19,3	17.4	-	-	26,4	-	-	333	370	50
4	Turbidity	NTU	14.2	12,8	-	-	12					25
5	Electric conductance	usms	1.218	2,085	-	-	-					-
6	Colour	TCU	42.9	38,6			18					-
Chemical												
7	pH		7.16	7.05	2.04	7.45	7	7.13	7.38	8.16	8.27	6-9
8	Iron (Fe)	mg/L	0.696	0.685	-	1.87	0.03	0.728	0.099	1.03	0.74	0.3
9	Calcium (Ca)	mg/L	78.6	97.9	-	-	-	600.5	3823.0	-	-	(-)
10	Magnesium (Mg)	mg/L	57.3	72.6	0.258	0.139	-					(-)
11	Calcium carbonate (CaCO3)	mg/L										
12	Cadmium (Cd)	mg/L						tt	0.062	0.006	tt	
13	Copper (Cu)	mg/L						-	-	0,191	0.183	
14	Chromium (Cr)	mg/L						-	-	tt	tt	
15	Zinc (Zn)	mg/L						tt	tt	0,184	tt	
16	Lead (Pb)	mg/L	0.016	0.19	3.88	50.44	-	0.017	0,009	-	-	0.03
17	Manganese (Mn)	mg/L						1,217	0.239	Tt	tt	
18	Chloride (Cl)	mg/L	384,15	546.23	0.11	0.13	-	1616	9146	-	-	(-)
19	Nitrogen Ammonia (N-NH3)	mg/L	0.027	0.024	0.144	0.065	0.003	-	-	-	-	1.0
20	Nitrogen Nitrite (N-NO2)	mg/L	0.012	0.014	1.007	0.715	-	0.026	0.059	0.004	0.003	0.06
21	Nitrogen Nitrate (N-NO3)	mg/L	0.087	0.092	-	-	ttd	3.4	2.5	0.4	0.3	10
22	Phosphate (PO4)	mg/L	0.031	0.030	17	20	0.2					0.2
23	Sulfate (SO4)	mg/L	11.87	16.37			(-)	71.3	236	-	-	(-)
24	Dissolved oxygen (DO)	mg/L	6.46	6.53	1.44	3.06	>4	0	1.5	6.2	6.6	>4

25	Biological oxygen demand (BOD)	mg/L	6.89	6.94	4.0	6.3	<3	620.0	43.7	23.0	29.9	<3
26	Chemical oxygen demand (COD)	mg/L	11.08	12.46	-	-	<10	1.702	126	52.0	59.0	<10
27	Minyak/Oil	mg/L	0.0	0.0			1					1
28	Detergent							1.02	1.95	-	-	
29	Organic matter ($KmnO_4$)	mg/L						158	50.56	-	-	
Microbiology												
30	Total Coliform (TC)	Sel/100 ml	340	370	1700	1100	5000	-	-	-	-	5000
31	Fecal Coliform (FC)	Sel/100 ml	21	23	123	214	1000	-	-	-	-	1000

Note: [1]Source : Amdal pengendalian banjir Kota Makassar dan sekitarnya
[2]Source : Rencana Tata Ruang Terpadu Untuk Wilayah Metropolitan Mamminasata
[3]Source : ANDAL Pabrik Semen Bosowa Maros
[4]Source : Studi Rencana Induk pengelolaan Sumberdaya Air Untuk Wilayah Sungai Maros-Jenneponto

Table 13 Groundwater quality in Makassar (UNHAS 2011)

14. **No.**	**Parameter**	**Units**	**Location** Deep well Baruga	Well Monc. Leppara	Well in front of UVRI	**Standard (PP 82/ 2001)**
Physical						
1.	Temperature	OC	29,7	29,9	30,0	Deviation 3
2.	TDS	mg/L	1160,4	381,8	172,9	1000
3.	TSS	mg/L	4,3	1,2	0,9	50
4.	Turbidity	NTU	2,6	0,9	0,5	25
5.	Electric conductance	ma/cm	2,321	0,764	0,346	-
6.	Color	TCU	5,8	3,4	2,1	-
Chemical						
1.	pH		6,97	6,16	6,42	6-9
2.	Besi (Fe)	mg/L	0,065	0,077	0,059	0,3
3.	Kalsium (Ca)	mg/L	36,84	26,82	35,24	(-)
4.	Magnesium (Mg)	mg/L	42,13	31,73	32,23	(-)
5.	Timbal (Pb)	mg/L	0,010	0,009	0,011	0,03
6.	Klorida (Cl)	mg/L	910,30	273,42	182,73	(-)
7.	Nitrogen Ammonia (N-NH3)	mg/L	0,011	0,026	0,019	1,0
8.	Nitrogen Nitrit (N-NO2)	mg/L	0,008	0,011	0,010	0,06
9.	Nitrogen Nitrat (N-NO3)	mg/L	0,083	0,079	0,091	10
10.	Fosfat (PO4)	mg/L	0,026	0,035	0,068	0,2
11.	Sulfat (SO4)	mg/L	48,66	4,97	7,89	(-)
12.	Oksigen terlarut (DO)	mg/L	6,54	6,29	6,47	>4
13.	Kebutuhan Oksigen Biokimia (BOD)	mg/L	3,96	4,93	5,25	<3
14.	Kebutuhan Oksigen Kimia (COD)	mg/L	8,23	9,87	11,36	<10
15.	Minyak/Oil	mg/L	0,00	0,00	0,00	1
Microbiology						
1.	Total Coliform (TC)	Sel/100 ml	90	310	170	5000
2.	Fecal Colifrom (FC)	Sel/100 ml	6	19	11	1000

Source : Amdal Pengendalian Banjir Kota Makassar dan Sekitarnya

APPENDIX 2 – CATCHMENT ISSUES IDENTIFIED BY STAKEHOLDERS IN WORKSHOP

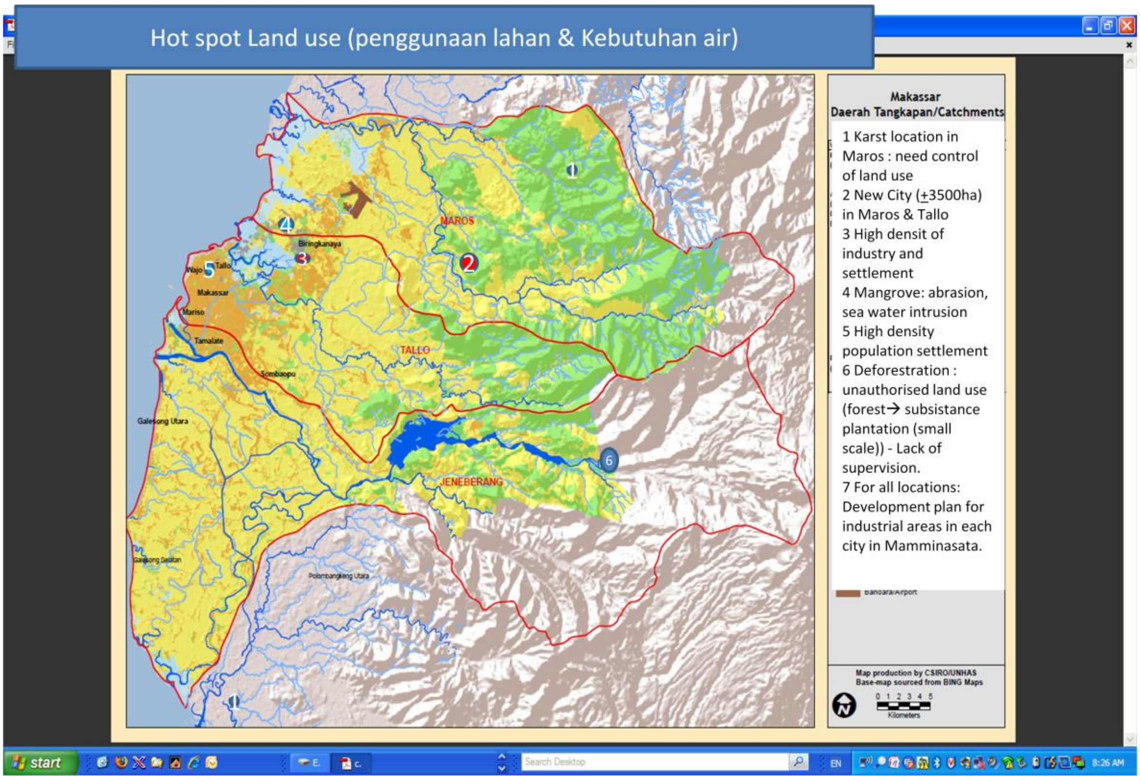


Figure 25 Land use conflict impacting catchments

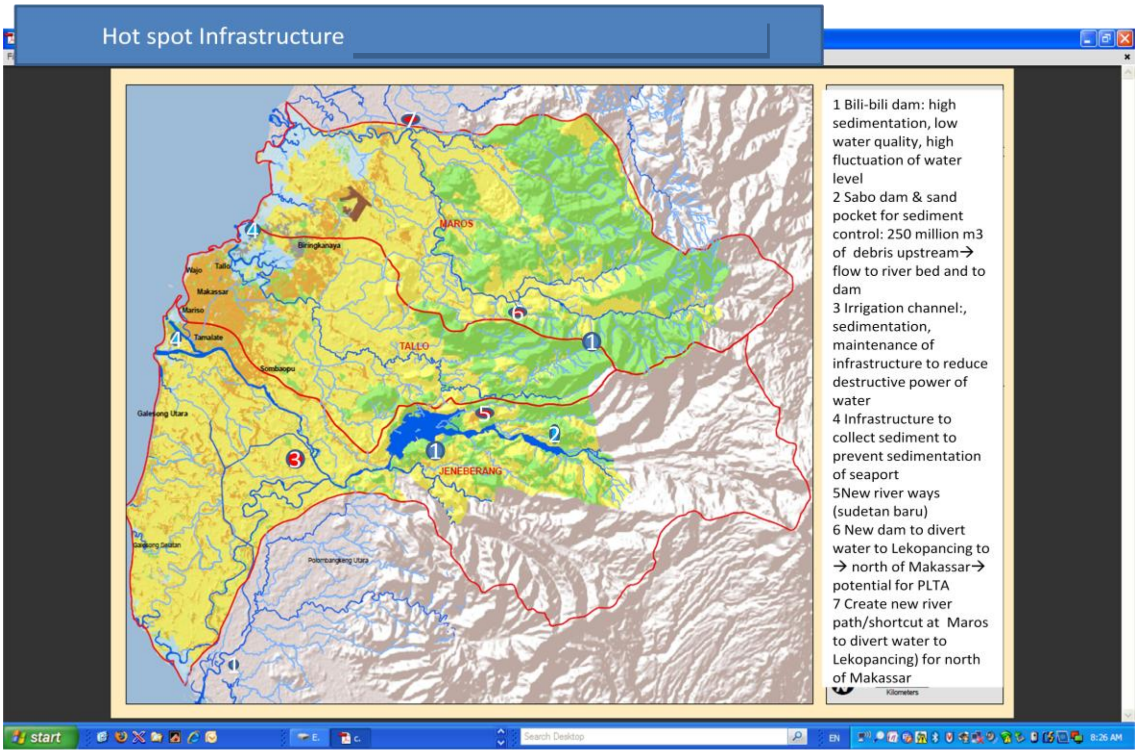


Figure 26 Infrastructure issues in catchments

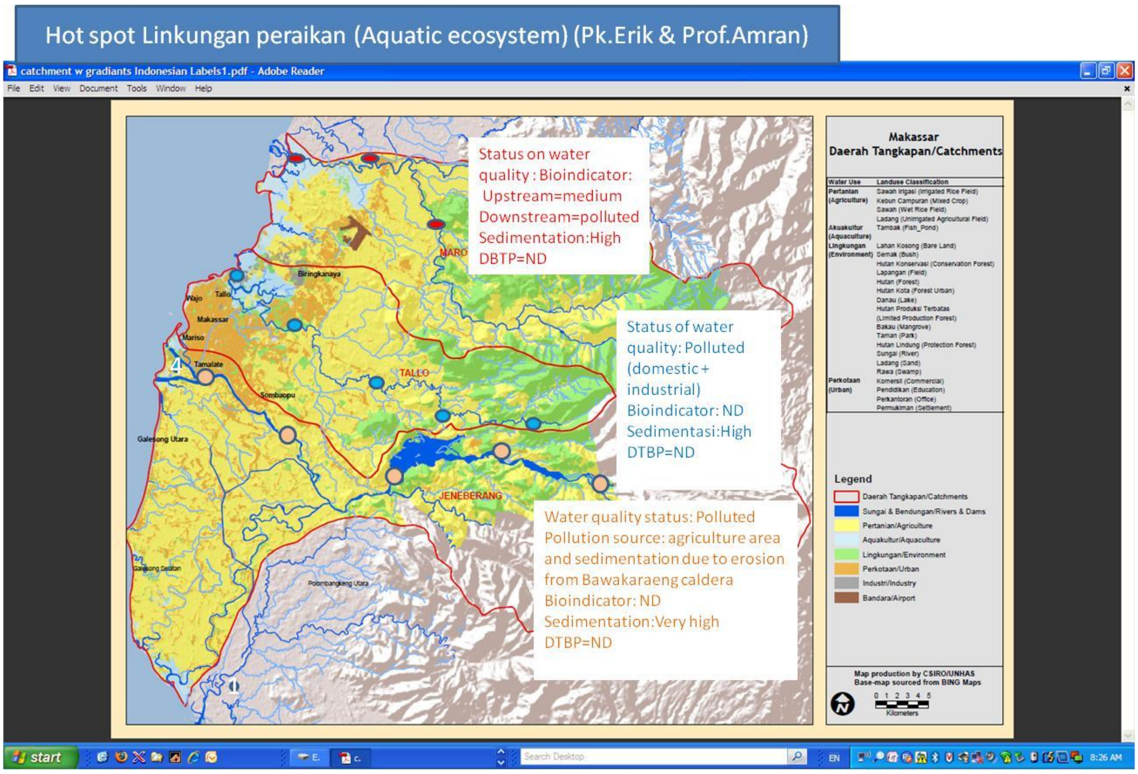


Figure 27 Aquatic ecosystem issues in catchments

APPENDIX 3- URBAN WATER HOTSPOTS IDENTIFIED BY STAKEHOLDERS IN WORKSHOP

Table 14 Key urban issues identified by stakeholders (adapted from Alexander *et al*, 2011)

	Makassar challenges		
Category	**North**	**South**	**Coastal**
Water use and needs	Water for airport, industry and manufacture. Water use for transportation at rivers Tallo-Pampang	Water use for households, for recreation and rowing.	Fresh water supply to mangrove and fish farms Water use for port logistics
Infrastructure	Poor drainage (incl.Tamalanrea and Biringkanaya districts). PDAM supply is not available to the north-east and north-west areas. Growth and optimisation of water hydrant network for low income areas	Lack of clean water supply infrastructure, need for normalisation of drainage in (Ujung Tanah flood area), plan for new WTP. Blackwater treatment plant.	Pipe network is from colonial times, wastewater collection and treatment plant planned (cover 6 districts) Lack of water and wastewater infrastructure in islands. Need WWTP for industry outside of KIMA.
Waste and wastewater sources	Industrial wastewater (large and secondary effluent) in Tamalanrea and Birikanya)	Wastewater in south-east	Municipal solid waste (garbage discharge) in city centre.
Groundwater	Water shortage in all of Birikanaya. No PDAM supply to North west (covers industrial area to east of KIMA at coast) thus heavy use of groundwater. Flood-prone at Tallo river in eastern area. Need for coordination between industry and government for groundwater use.	Flood prone area. Sea water intrusion (coastal)	Water shortage at Tallo Drainage problem in old city area. Sea water intrusion
Environmental	Hard water (due to rocks)	Riverbank areas at risk of residential development	Pollution from shallow brackish water in alluvial soil, pollution and waste

			from heavy traffic(lead and CO_2)
Institutional collaboration	Industry and government land use, need for cooperation between fish farmers and PSDA, area of mangrove swamp (+/- 5% local administration)	Need for coordination between government and community to manage public hydrant and waste, pollution around TPA (waste treatment plant) waste tip.	

Figure 28 Urban infrastructure hotspots in Makassar

Waste and wastewater sources (sampah + air limbah)

Figure 29 Sources of waste and wastewater

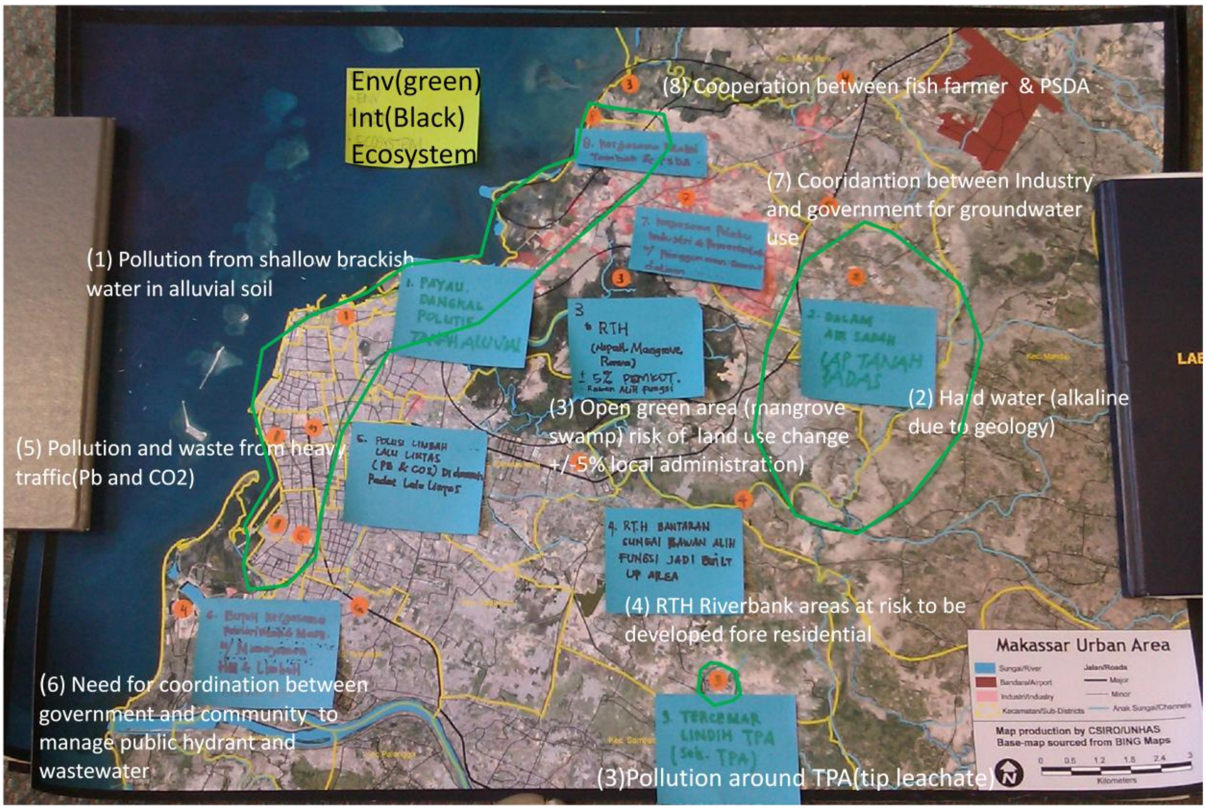
Water use and needs

Figure 30 Water use and needs in Makassar

Groundwater (air tanah)

Figure 31 Groundwater hot spots

Environment, institutional collaboration and ecosystem



RTH=open green area (worry that they will be converted into built area)

Figure 32 Environmental issues and institutional collaboration hot spots in Makassar.

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