Planning for an Uncertain Future: Strengthening the Resilience of Indonesian Water Utilities

Technical Report
February 2021

RESILIENT Water Supply and Sanitation COMMUNITY OF PRACTICE
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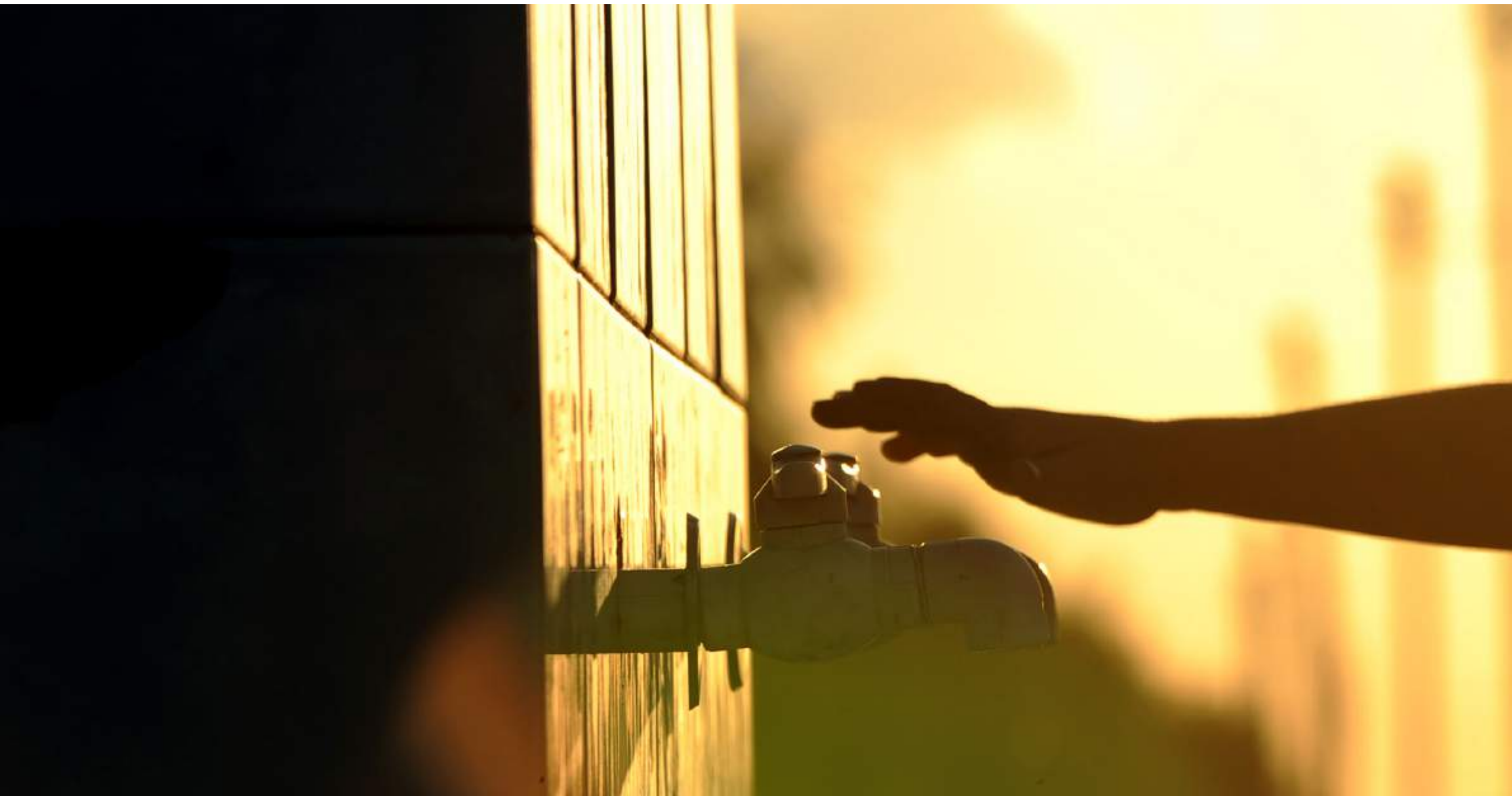

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Abbreviations

ADB	Asian Development Bank
AKATIRTA	*Akademi Teknik Tirta Wiyata*[1]
BAPPENAS	*Badan Perencanaan Pembangunan Nasional*[2]
BCP	Business continuity plan
BMKG	*Badan Meteorologi, Klimatologi, dan Geofisika*[3]
BNPB	*Badan Nasional Penanggulangan Bencana*[4]
BPBD	*Badan Penanggulangan Bencana Daerah*[5]
BPPSPAM	*Badan Peringkatan Perselanggaran Sistem Persediaan Air Minum*[6]
BPKP	*Badan Pengawasan Keuangan dan Pembangunan*[7]
CBDRRM	Community-Based Disaster Risk Reduction and Management
CC/DR	Climate change and disaster risk
DEM	Digital elevation model
DRFI	Disaster risk financing and insurance
DRM	Disaster risk management
DRR	Disaster risk reduction
EWS	Early warning system
EPA	US Environmental Protection Agency
EVA	Extreme value analysis
FEMA	US Federal Emergency Management Agency
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic information system
HDPE	High-density polyethylene
ICS	Incident Command System
IFD	Intensity–frequency–duration
InaTEWS	Indonesia Tsunami Early Warning System
LAPAN	*Lembaga Penerbangan dan Antariksa Nasional*[8]
LG	Local government
MOF	Ministry of Finance
MOH	Ministry of Health
MoHA	Ministry of Home Affairs
MPWH	Ministry of Public Works and Housing
NASA	US National Aeronautics and Space Administration
NGO	Non-governmental organization
NOAA	US National Oceanic and Atmospheric Administration
NRW	Non-revenue water
NUWAS	National urban water supply
NUWSP	National Urban Water Supply Project
O&M	Operation and maintenance
PDAM	*Perusahaan Daerah Air Minum*[9]
PERPAMSI	*Persatuan Perusahaan Air Minum Indonesia*[10]
PGA	Peak ground acceleration
PGD	Permanent ground deformation
PGV	Peak ground velocity
PPP	Public–private partnerships
PUPR	*Kementerian Pekerjaan Umum dan Perumahan Rakyat*[11]
PVC	Polyvinyl chloride
QA	Quality assurance
RBO	River basin organization
RCP	Representative concentration pathway

1 Technical training academy for drinking water supply services based in Magelang City in Central Java.

2 Indonesian Ministry of National Development Planning

3 Agency for Meteorology, Climatology and Geophysics.

4 Indonesian National Disaster Management Authority

5 Subnational disaster management agency.

6 Body tasked with enhancing the reliable availability of the drinking water supply, chaired by the Minister of Public Works and Housing.

7 National Government Internal Auditor.

8 National Institute of Aeronautics and Space.

9 Local drinking water supply enterprise.

10 Association of PDAMs.

11 Ministry of Public Works and Housing.

RISPAM	*Rencana Induk Sistem Penyediaan Air Minum* [12]
RPAM	*Rencana Pengamanan Air Minum* [13]
RPJMN	*Rencana Pembangunan Jangka Menengah Nasional* [14]
SFWRM	Service fee for water resource management
SNI	*Standar Nasional Indonesia*[15]
SRTM	Shuttle Radar Topography Mission
T&D	Electrical transmission and distribution
TNI	*Tentara Nasional Indonesia* [16]
TOR	Terms of reference
TWG	Technical working group
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USGS	US Geological Survey
WHO	World Health Organization
WSP	Water safety plan
WTP	Water treatment plant

12 Water Supply System Master Plan.

13 Water Safety Plan.

14 National Medium-Term Development Plan.

15 Indonesian National Standard.

16 Indonesian national armed forces.

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Executive Summary

Indonesia's location in a very active seismic zone naturally exposes it to significant geophysical hazards (earthquakes, volcanic eruptions, tsunamis). In addition to these geophysical hazards, climate models project an increase in the frequency of heavy rainfall in the region, which is worrisome because flooding and landslides are the two most frequent and widespread natural disasters experienced in Indonesia. Indeed, climate change will not only increase flooding hazards; it will also worsen weather variability, resulting in recurrent cycles of too much water and then too little. (For example, the very strong El Niño of 2015–2016, which caused severe drought in Southeast Asia, was followed by a La Niña, which caused higher-than-average rainfall in the latter part of 2016, resulting in flash floods in many areas.)

Marginalized communities and the poor tend to live in high-risk areas that are vulnerable to natural disasters. The poor often migrate to urban areas and settle on marginal lands there (e.g., riverbanks and flood-prone areas) while they search for jobs and livelihood opportunities. As the vulnerability of urban areas to natural hazards (notably flooding) increases, so does the risk to poor communities living there.

Marginalized groups are thus more likely to suffer disproportionately from the effects of climate change and natural disasters. They suffer from generally poor living conditions, lack of access to adequate infrastructure and basic services (especially water and sanitation), a lack of resources, and low levels of education – all of which not only drive them to unsafe areas, but also limit their capacity to adapt.

The Government of Indonesia recognizes these risks and is committed to enhanced efforts to identify specific vulnerabilities, strengthen policies and regulations, and build institutional capacity for resilience (including through knowledge-building, local capacity strengthening, and the application of technology).

Photo: Pexels

Managing disaster and climate risks is vital for achieving and sustaining water supply development targets, inasmuch as the sector is naturally vulnerable to both geophysical and climate change hazards. This report aims to help strengthen the capacity of Indonesia's government and local water utilities (PDAMs) to provide resilient water supply services. As one of several outputs under a World Bank–executed technical assistance program, this report supports Akademi Teknik Tirta Wiyata (AKATIRTA), a higher education institution that develops environmental engineering professionals specializing in water supply and sanitation. Along with government partners and PDAMs, AKATIRTA also provided feedback on the practicality of the recommendations discussed here through a series of capacity-building and verification workshops. The resulting guidance will inform the development of comprehensive training modules to enhance AKATIRTA's academic curriculum on disaster risk management and climate adaptation of water supply infrastructure. The report explores global good practices of urban water supply planning and management that enhance resilience to geophysical and climate-related hazards, in particular through systematic procedures for risk-based system planning and appropriate engineering measures.

Even though the report principally addresses *technical* capacity building among water supply planners (i.e., PDAM staff and local government planners), it also addresses the need to enable their *action capacity.* The latter involves guidance and vital support roles from other institutional players (e.g., BAPPENAS, Ministry of Public Works and Housing, Ministry of Home Affairs). As such, this report starts with a background review of policy, institutional context, operational management, and financing aspects of urban water supply services in Indonesia, with a view to identifying gaps or weaknesses that could curtail the sector's ability to deal with climate and natural disaster risks.

Overall, Indonesia's water supply infrastructure has not been able to keep pace with the country's rapid urban growth, as evidenced by the prevailing low service coverage of local water utilities (PDAMs) in urban areas. There remains a large discrepancy between the available capacity of PDAMs and the demand for clean water in urban areas, with future demand bound to grow even more. This paper reviews the sector's underlying institutional limitations, among which are:

- the fragmentation of water supply services into numerous small providers that have limited technical and financial viability;
- governance weaknesses, precipitated by a legal vacuum created by the Constitutional Court's reversal of the 2004 Water Law;[17]
- the consequent inadequate regulatory framework and an inability to attract investments; and
- the limited autonomy of PDAMs from their subnational government owners, with the latter preferring to keep tariffs artificially low, resulting in inadequate funds for water system maintenance and upgrading.

The perception created by past assessments of Indonesia's water supply sector (e.g., by the World Bank and the Asian Development Bank) is that its challenges are principally issues of governance and utility management (e.g., non-revenue water,

[17] Although Indonesia has recently issued a new Water Law (Law No. 17/2019) to replace the reversed 2004 law, implementing regulations have yet to be developed. Until these regulations have been enacted, the country's legal framework will remain a challenge for Indonesia's water sector.

inadequate system coverage, operational weaknesses, financial difficulties) and not always a result of water resource constraints or insufficient technologies. However, rapid urbanization, land-use changes, deforestation, pollution, and excessive groundwater extraction have left many more areas susceptible to recurrent cycles of flooding and drought – even without factoring in climate change and disaster impacts – making it more difficult to provide adequate and reliable water supply services.

On top of existing management concerns, the impacts of climate change and natural disaster events pose fundamental threats to water supply security – that is, to the sustainability of water resources already suffering from degradation, overuse, and pollution. In the coming years, PDAMs will have to face the challenge of addressing climate and natural disaster threats while putting their internal management systems in order.

The observations above, derived from a sector review, are borne out by findings from three PDAM case studies conducted as the basis for this Technical Report. The case studies examined the ongoing management concerns of the PDAMs and the level of attention that they are able to devote to climate change and disaster risk (CC/DR) concerns. The case studies looked into each PDAM's perception of risks posed by climate change and natural disasters, as well as the coping measures they applied, gaps and constraints, and the fundamental needs for capacity building and technical support.

In this report, resilience is defined as the ability of a system to withstand or accommodate stresses and shocks while still maintaining its function. The resilience framework described in this report covers two main aspects: (a) enhancing a system's resilience to maximize its capacity to withstand adverse climatic impacts, through a combination of better planning, improved systems operations, and "hardening" of physical assets; and (b) being better prepared to rapidly respond when damages are sustained, and to efficiently and quickly recover from such events.

Consistent with the government's existing need-based and performance-based approach to PDAM improvement and expansion (under the National Urban Water Supply Project, or NUWSP), the resilience framework discussed in this report also adopts a differentiated approach – that is, one in which resilience measures are not necessarily uniform or standardized, but are instead fitted to the risks faced by each PDAM, based on area-specific vulnerabilities and the evaluation of those risks.

The report proposes two "minimum standards" to be institutionalized in PDAM water system planning and management. The first is *procedural* (risk-based water supply planning), and the second concerns *engineering design*. These two aspects are described in detail.

The report clarifies that there is no pre-defined climate or disaster risk threshold. Resilience needs to start from mainstreaming risk assessment into the planning and design of water supply infrastructure. The previous World Bank–GFDRR program in Indonesia, as well as the lessons from other countries described below, have emphasized the need to institutionalize risk assessment in planning and managing water supply systems. The climate and disaster risk assessment procedure prescribed in this report can be implemented within the existing urban water master planning process (RISPAM) that is required by subnational governments, and in water safety planning (RPAM), which is an adoption of the World Health Organization's water security planning concept for securing drinking water safety through a risk-management approach.

In order to pave the way for *action* to tackle CC/DR risks, and to enable risk assessments to become an integral part of the PDAM business process, the risk assessments' findings and measures must be incorporated into business continuity plans (BCPs). Through a BCP, PDAMs can specify in detail, rehearse, and regularly update emergency preparedness and response actions that will be taken to prevent potential hazards (if prevention is feasible), accommodate or mitigate hazards (if they cannot be prevented outright), and in any case prepare for contingent disruptions (should risk mitigation measures prove inadequate, or when it is economically wiser to opt for post-disaster restoration rather than high-cost prevention). Such a plan outlines practical steps for PDAM personnel to respond quickly in an emergency and provides measures for critical assets (including back-up facilities) to continue functioning in the event of a disruption. In addition, the plan must provide contingencies in the event of major disasters that do not just disrupt but totally disable the water supply.

The BCP elements described in this report can be incorporated in the existing business planning procedure that USAID's IUWASH project has developed and tested for PDAMs. This existing PDAM business planning procedure is, for now, oriented toward investment planning, but can be adapted to include CC/DR resilience activities and risk assessments.

Risk assessment is a three-step process of hazard identification, risk analysis, and risk evaluation. Hazard identification is the process of situating and screening hazards. Risk analysis examines the nature of the hazards to ascertain their likelihood and the severity of their consequences. Lastly, risk evaluation compares these outputs against stakeholder-prescribed risk criteria to determine the acceptability or unacceptability of the risk, based on which risk-control investment decisions can be made.

Although risk assessment is a well-established field in general, its application to water supply planning in the context of natural disaster and climate risks needs to be situation-driven. For such planning, the procedure translates specifically to hazard identification (with an emphasis on climate change impact modeling and risk mapping); vulnerability assessment, based on exposure, sensitivity, and capacity; and evaluation of adaptation and other risk-management options. The steps are described in this report, along with various tools (databases, mapping, online resources) useful for expediting the procedure.

The report also clarifies the differences and commonalities between climate change adaptation and disaster risk management, which have evolved as separate communities of practices. The difference lies mainly in the kind and magnitude of the hazards addressed and the management measures applied, but they are united in applying a common risk-assessment approach.

The range of resilience-building engineering options is diverse, but the viable choices are dependent on unique combinations of site-specific characteristics and the stakeholder's risk preferences (including their degree of risk aversion). As such, a one-size-fits-all approach to the engineering design of resilience measures is not feasible. Deciding on appropriate engineering approaches for water supply resilience requires a multi-step process to integrate considerations of hazard exposure, site vulnerability, appropriate design for risk reduction, available technology, and cost. This report describes guidelines for various engineering measures, drawing from international best practices and examples.

Recent World Bank publications demonstrate that investment in infrastructure resilience pays off (Hallegatte, Rentschler, and Rozenberg 2019; Miyamoto International, Inc. 2019). If infrastructure is to be resilient to natural shocks, countries first need to get the basics right – providing enabling regulations, incorporating resilience in the earliest stages of planning, and ensuring proper operation and maintenance of assets. Doing so can increase resilience as well as save costs.

To that end, this report discusses the incentive and support systems needed to implement the risk-based planning and engineering options described – in particular, financing. Depending on an event's frequency and severity, it might represent one of four layers of risk: reducible, retainable, transferrable, and residual risk. The probability of a disaster event is inversely proportional to the magnitude of damage or loss (i.e., more-frequent events are less intense therefore generate a lower volume of losses, and vice versa). Each risk layer warrants the use of different financing instruments to mitigate the risk, including insurance, reinsurance, pooling funds, contingency funds, and other instruments.

The first risk layer (reducible risk) could be supported as part of the national urban water supply framework. For the second layer, retainable risk, budgetary reserves or contingency provisions would be more appropriate. Transferable risk is related to low-probability events with relatively high impacts, and calls for risk-transfer instruments such as insurance or reinsurance. Residual risk – what remains after all risk control and mitigation actions – can only be managed through disaster preparedness.

This report also discusses other financing instruments, such as Cat-DDOs (Catastrophe Deferred Drawdown Options) and climate change adaptation funds.

Photo: **World Bank** / Flickr

I.

I. Introduction

This chapter introduces the importance of integrating climate change adaptation and disaster risk management principles in the water supply sector. It demonstrates why technical capacity and funding resources in this area should be enhanced to reduce risk.

A. Indonesia's Climate Change and Disaster Risk Context

A global risk analysis conducted by the World Bank (2006; see also GFDRR and CIF 2011) ranks Indonesia 12th out of 35 countries facing a relatively high risk from multiple hazards, with an average of 290 *significant* natural disasters experienced annually over the last 30 years (Taylor 2018). Because of its location along the Pacific Ring of Fire, Indonesia is naturally exposed to volcanic eruptions, earthquakes, and tsunamis.

The series of earthquakes in Lombok Island during July and August 2018, the earthquake-caused tsunami in Central Sulawesi in September 2018, and the tsunami triggered by volcanic activity on the island of Anak Krakatoa, which caused an undersea landslide in December 2018 – all these disrupted water supply services for weeks, destroyed pipe infrastructure and water treatment facilities, and reduced the quality of drinking water.

Further back, the 2006 earthquake in Yogyakarta destroyed major basic services infrastructure, including that of the water sector, whilst the eruption at Mount Merapi just prior to that event caused lava and volcanic ash to infiltrate the city's water supply.

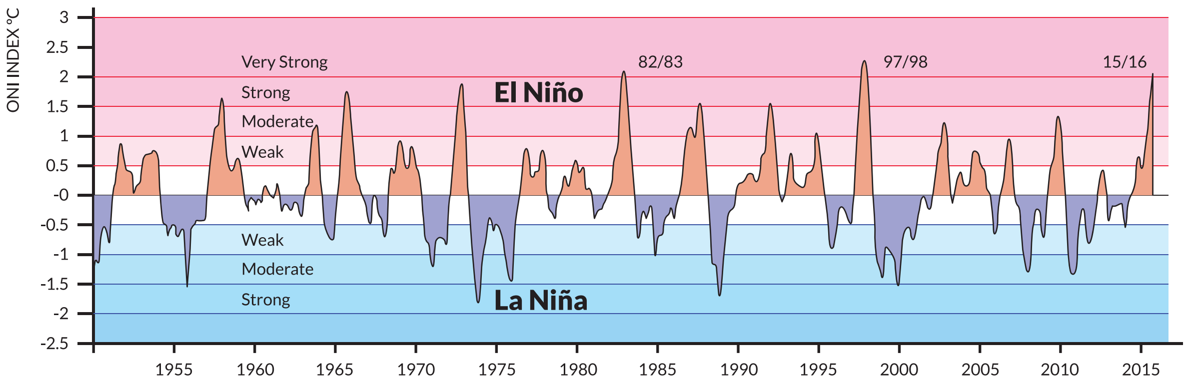
Frequent flooding events in Jakarta (including in 2007 and 2013), attributed in part to land subsidence due to excessive groundwater pumping, disrupt access to clean drinking water and damage water supply infrastructure.

On top of these hazards, climate models project an increase in the frequency of intense precipitation in the region. Progressively heavier rainfall will have important consequences for Indonesia because flooding and landslides are the two most frequent and widespread natural disasters experienced in the country. In vulnerable areas, flooding disruptions gradually weaken capacity to deal with other disasters.

Climate change will not only increase rainfall intensities but will also worsen extremes of flooding and drought, creating a recurrent cycle of too much water and then too little. Climate variability is a natural effect of the El Niño Southern Oscillation phenomenon (figure 1), but climate change is causing wet and dry weather extremes and variability to become more pronounced.[18]

[18] In the past 65 years, there have been 20 El Niño events or episodes, 3 of them very strong, 5 strong, 5 moderate, and 7 weak. There have been 18 La Niña events, 5 of them strong and 5 moderate. Even just 1–1.5˚C warming in the Pacific is enough to cause a strong El Niño.

Figure 1. El Niño Southern Oscillation (ENSO) Events



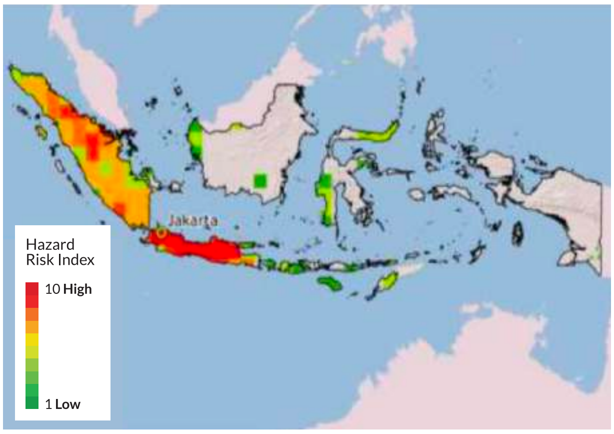
Note: ONI refers to the Oceanic Niño Index, a measure of sea temperature anomaly. *Source:* UK Met Office.

For instance, the very strong El Niño of 2015 and the first half of 2016 (indicated by the rightmost red spike in figure 1) caused severe drought and heat waves in much of Southeast Asia, including Indonesia. It was then followed by a La Niña that caused higher-than-average precipitation in the latter part of 2016.

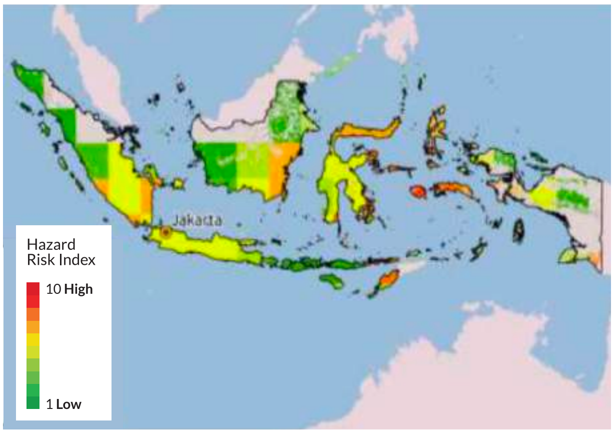
The frequency and distribution of floods and droughts across Indonesia are shown in figure 2 (GFDRR and CIF 2011).

Figure 2. Flood Frequency and Drought Across Indonesia

Flood Hazard
(higher in west)



Drought Hazard
(higher in east)[19]



Source: World Bank - GFDRR (2011).

19 Large parts of Indonesia normally experience long dry periods, particularly in Nusa Tenggara Barat and Nusa Tenggara Timor. During El Niño events, these dry periods cause significant impacts. Many parts of eastern Indonesia faced drought conditions beginning in December 2015 and lasting through 2017.

B. Strategic Government Directions

The government recognizes that climate change will especially increase the risk of hydrometeorological disasters, which make up 80 percent of disaster occurrences in Indonesia. To address the negative impacts of climate change and related disaster risks, the government is committed to enhanced efforts to identify regional vulnerabilities, strengthen policies and regulations, and build institutional capacity for climate resilience. The medium-term goal of the government's adaptation strategy is to reduce such risks through local capacity building, undertaken along with improved knowledge management, supportive policies, and the application of technology.[20]

Indonesia's National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional* – RPJMN) for the period 2015–2019 set a target of universal access to water supply and sanitation by the end of 2019. To achieve this target, the Ministry of Public Works and Housing (MPWH) launched the 100-0-100 program – that is, 100 percent access to water supply, zero urban slums, and 100 percent access to sanitation. This ambitious target was not achieved and was carried over and included in the RPJM 2020–2024.

The MPWH program set targets for water supply service levels that were to be met by the end of 2019: piped water accessible to 40 percent of the total population and non-piped water to 60 percent. For urban areas, the target was 60 percent piped and 40 percent non-piped water supply, with 85 percent of urban areas receiving at least 100 liters per capita per day and the remaining 15 percent receiving the minimum level of 60 liters per capita per day. Water supply services were to meet standards for quality, quantity, continuity, and affordability.

In support of the program, the government initiated programs to expedite financing support to the water supply sector, leveraged with resources available from related government programs, donor financing, and partnerships with the private sector.


Photo: World Bank (Flickr)

20 Indonesia's First Nationally Determined Contribution, November 2016.

C.
Critical Factors for Building Resilience Capacity

This report focuses on aspects of water supply planning and operation that are the responsibility of PDAM staff, who are the project's main target for capacity building through AKATIRTA. Specifically targeted are PDAM planners and engineers, in order to help them develop increased awareness and acquire technical and practical knowledge of planning and managing water service delivery systems in a manner that enhances CC/DR resilience.

To build the technical capacity of PDAM staff, this report draws lessons from international good practices, available knowledge resources and tools (particularly for CC/DR vulnerability assessment and resilience planning), and case studies to more fully contextualize the challenges in specific PDAM settings and for specific CC/DR hazards. The guidelines and procedures will subsequently be converted into a set of academic training modules that, through AKATIRTA, can be imparted to PDAM staff.

In developing the technical sections, however, the report applies a resilience framework that speaks not only to the need to build the technical capacity of PDAM staff, but also the need to *enable their action capacity.* Enabling the action capacity of PDAM staff will involve other institutional players – specifically, the coordinating and line agencies responsible for managing water supply policy and investment coordination (BAPPENAS), setting service standards and conducting performance evaluation (Ministry of Health, Ministry of Public Works and Housing), and providing capital financing (Ministry of Finance). While the technical assistance will not directly build the capacity of these action-enabling players, it will raise their awareness about the kind of motivational and material support needed by PDAMs to move toward enhanced CC/DR resilience in water supply system planning and operation. Hence, this report also provides a background assessment that discusses policy, institutional, operational management, and financing aspects of water supply services in Indonesia.

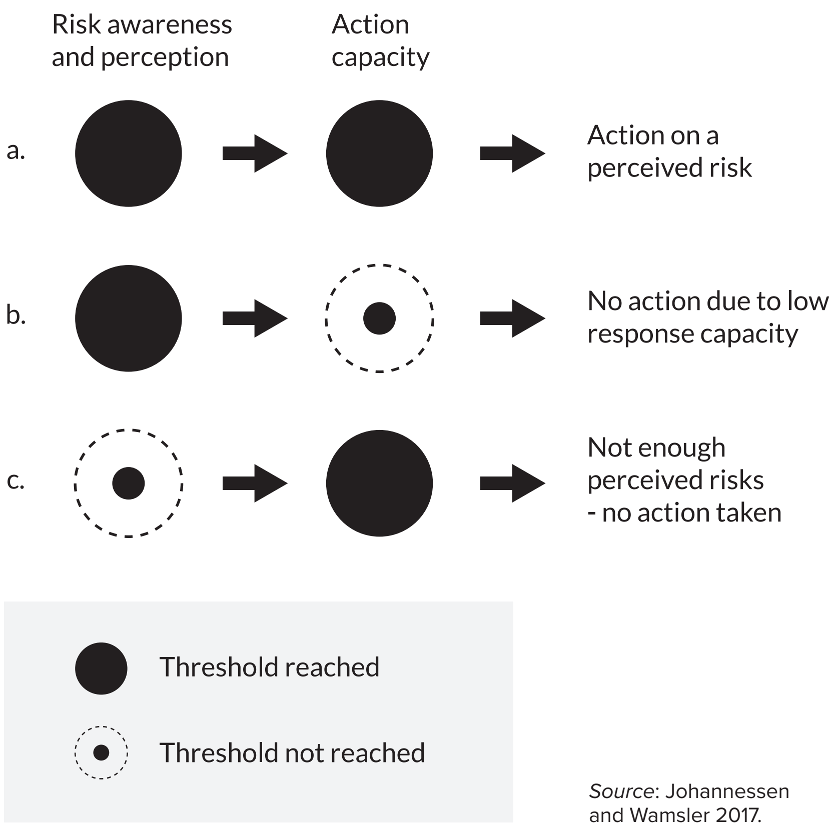
A useful framework for understanding resilience is described in Johannessen and Wamsler (2017), which defines resilience in the context of disaster risk management (DRM) as "the degree to which the system can build capacity for learning and adaptation." This framework postulates that resilience in urban water services is enabled (or disabled) by two key factors:

- Stakeholders' capacity to drive development by applying improved technical knowledge, which is seen as crucial; and

- The level of good governance (including policy integration and financial support).

Planners often have difficulty grasping the applicable risks, particularly in the context of hazard resilience. At the same time, the high value placed on cost-effectiveness in water service delivery conflicts with the need for increased redundancy (e.g., through backup systems and robustness of materials used) for increased resilience. Therefore, this report, in its framework for resilience capacity building, identifies two thresholds to achieve disaster risk resilience. The first is risk awareness, which requires overcoming the lack of capacity (primarily know-how) to identify and assess risks so that appropriate reduction measures and emergency response and recovery mechanisms can be designed into the system. The second threshold is action capacity, primarily the provision of financial resources, which is essential for the actual shift to more disaster-resilient water services. The combined effect of these two thresholds are illustrated in figure 3.

Figure 3. Thresholds for Achieving Disaster Risk Resilience



Source: Johannessen and Wamsler 2017.

Photo: Freepik

II.

II. Background Institutional Context

This chapter provides an overview of the institutional context (regulatory, legal, and policy) related to water supply services and disaster risk management in Indonesia. It sets the scene for the sectoral assessments in the next chapter.

A. State of Water Supply Services in Indonesia

WHO–UNICEF defines an "improved" drinking-water source as one that, by the nature of its construction, and when properly used, adequately protects the source from outside contamination, particularly fecal matter. According to a WHO–UNICEF Joint Monitoring Program for Water Supply and Sanitation, access to an "improved water source" in Indonesia was at 82 percent in 2010. A 2013 report from the Indonesian National Institute of Health Research and Development put the proportion of Indonesian households with "access to [an] improved drinking water source" at 66.8 percent (urban, 64.3%; rural, 69.4%).

The improved water sources most commonly used by Indonesian households in urban areas are bored wells and PDAM piped water connections. In rural areas, protected dug wells are still common. The source of raw water for PDAMs is mainly surface water (rivers and canals). In areas where groundwater can be tapped, water is also sourced from deep wells, but this entails the additional cost of pumping.

There are around 380 PDAMs in Indonesia. Two of these operate at a provincial level (in Jakarta and North Sumatra) while the rest operate at the district-government or city level. Most PDAMs are small (due in part to the splitting of districts following decentralization), with less than 10,000 connections. Only a small number (4%) have more than 50,000 connections. Such fragmentation and generally small system coverage limits economies of scale and constrains both the technical and financial viability of many PDAMs.

A national association of PDAMs, the PERPAMSI, was established in 1972. Its member companies serve about a quarter of the population. PDAM members support each other through technical advice and direct assistance, including during natural calamities that damage water supply facilities or disrupt services.[21]

Public-private partnerships (PPPs) have been initiated since the late 1990s. Some local governments have also signed contracts with private companies to operate (and in some cases finance) water supply infrastructure. Except for two concession contracts in Jakarta, most PPP contracts are management-type contracts, or fall under Build Operate Transfer contracts (mainly for water treatment plants).

Estimates of piped water coverage vary, but, in general, PDAMs serve up to about half of urban residents. The rest get water from individuals' wells, and others through a combination of PDAM piped water and pumped well water.

The government's goal in the previous RPJMN 2015–2019 was to provide universal access to clean water for the entire urban population by the end of 2019. This goal has not been achieved, and the government has included this target in the current RPJMN 2020–2024. Moreover, urban water supply services will need to continue expanding to keep pace with population growth. Over the next 20 years, Indonesia's urban population is projected to grow by about 90 million.

According to a 2015 water sector assessment for Indonesia by the Asian Development Bank (ADB),

21 See https://gwopa.org/en/gwopa-news/mobilizing-resources-to-help-water-utilities-in-the-case-of-natural-disasters-perpamsi-and-the-palu-earthquake

PDAMs covered only 30 to 40 percent of their designated service areas in 2011. In terms of population coverage, in 2012, another ADB report on the state of Indonesia's water supply and sanitation noted that only 18 percent of the country's total population was connected to piped water supplied by PDAMs. Even in urban areas, only about a third of the population receive piped water. The 2012 ADB assessment report added that this percentage was even declining, as service coverage has failed to keep pace with the rising urban population. Urban households not served by PDAMs depend on individual wells, small-scale piped water providers, and private water vendors – often at high cost.

In rural areas, about 12 percent of households get drinking water from piped supplies. Most rural households rely on shallow wells, collect rainwater, or use water from nearby rivers or springs.

As evidenced by the prevailing low service coverage of the water supply system, PDAMs have not been able to keep up with the pace of urban growth. There remains a large discrepancy between the available supply capacity of the PDAMs and the demand for clean water in urban areas. Additionally, natural hazards can cause significant disruptions and damage to a city's water supply system, and Indonesia's growing urban areas, where people and assets are concentrated, are particularly vulnerable. For example, when a landslide struck Magelang City in 2008, the city's water pipes were damaged and leaked 70 liters of water per second for 10 continuous hours. Climate change will further exacerbate the frequency and intensity of hydrometeorological disasters, reducing water quality and disrupting water services.

The 2012 sector assessment by ADB identified core issues that continue to challenge Indonesia's water supply sector: "inadequate regulatory framework, inadequate cross sector policy coordination (too many institutions involved), decline in quality and quantity of water supply in urban areas, rapid population growth, low community awareness, limited provision of water supply by PDAMs and privately owned water companies, limited capacity of subnational governments to ensure that improved drinking water and sanitation are in place or operating properly."

B.
Legal and Regulatory Framework[22]

Within a decentralization context, Law 7/2004 on water resources aimed for integrated water resources management and clarified the responsibilities of the central and subnational governments. Law 32/2004 on regional governance devolved greater authority and responsibility to the subnational governments for planning, financing, implementing, and managing regional or local infrastructure services, including water supply and sanitation.

During 2006 and 2007, the MPWH issued two decrees establishing a National Water Board (BPPSPAM) mainly aimed at expanding piped water supplies. BPPSPAM promotes public-private partnerships and conducts performance monitoring of PDAMs. MPWH Regulation 21/2009 guided investments in piped water systems, and Regulation 12/2010 provided guidance on joint ventures.

MoHA Decree 23/2006 provided guidelines for water tariff setting.[23] Presidential Regulation 29/2009 provided for the central government to offer loan guarantees and interest subsidies for commercial borrowing by PDAMs.[24]

22 This section accurately represented the state of Indonesia's legal and regulatory environment when the World Bank–executed technical assistance program began. Since that time, however, there have been updates to relevant laws and regulations, and developments in the legal and policy framework. In addition to the new Water Law (Law No. 17/2019), the government of Indonesia has updated several regulations under the Ministry of Public Works and Housing (MPWH) and the Ministry of Home Affairs (MoHA).

23 This regulation stipulated that tariffs fully recover costs, and it capped the rate of return on investments at 10%.

24 40% of the commercial loan is to be guaranteed by the central government; subnational governments are to guarantee 30%, with the lending bank taking the risk on the remaining 30%.

MOF Regulation 120/2008 provided for PDAM debt restructuring.[25] MOF Regulations 168 and 169/2008 clarified the fiscal transfer mechanism from the central government to local governments, either by means of loans or through grants. The national government subsequently issued Government Regulation No. 2/2012 specifically for Grants to Local Governments, which was followed by the MOF's issuance of implementing regulations through MOF Regulation 188/PMK.07/2012.

Law 7/2004 on water was meant to serve as a *framework law,* meaning that it was to be further elaborated through follow-on regulations covering specific aspects of water resource management and services. Supporting regulations had been promulgated and were in force by end of 2014, and a few more were under preparation.

However, in February 2015, Indonesia's constitutional court, based on its Decision No. 85/PUU-XI/2013, officially repealed the 2004 Water Law. The court ruled that said law was contrary to the intent of the 1945 Constitution.[26] To address the legal vacuum created by this court ruling, and to pave the way for drafting a new water law, the court reinstated the old Water Law No. 11, which dates back to 1974. The repeal of the 2004 landmark water law created gaps between the regulations already promulgated under that law and their legal basis under the re-instated old water law. As a result, existing water governance regulations are vulnerable to legal challenges and cannot not be effectively enforced.[27]

C.
Agencies Managing the Sector

Various line agencies and special bodies are involved in water resource and water supply management in Indonesia: the Ministry of Public Works and Housing (MPWH), the Ministry of Health (MOH), the Ministry of Home Affairs (MoHA), and the Ministry of Finance (MOF), with BAPPENAS providing a coordinating role in development planning.

The MPWH is responsible for developing raw water resources (e.g., large dams and reservoirs) and for supporting local governments in developing water supply infrastructure (e.g., water treatment plants); it also promotes coordinated drinking water supply management through BPPSPAM. Although local governments are responsible for ensuring water service provision, the MPWH continues to invest more in the water sector than local governments do, primarily through mandated investment in bulk water supply in regional systems and remote areas. Only around 0.3 percent of sector expenditure for water supply comes from local governments.

The MOH is responsible for setting standards of water quality and service performance, with the MOF providing loans to local governments for on-lending to PDAMs. The MoHA is responsible for governance decentralization, maintenance of public order, and community empowerment for disaster preparedness.

25 PDAM debts are re-structured through a partial or full write-off of accumulated interest/arrears on sub-loans through the local governments. Under debt restructuring, PDAMs agree to conditions including full cost–recovery tariffs and authorization of "intercepts" on fund allocations from central to local governments in the event of non-compliance with debt servicing. PDAMs must be rated "healthy" by the MOF to qualify for debt restructuring.

26 The Court reasoned that the law's provisions allowing private companies to be given rights to water resources was unconstitutional and that control of water resources is a government mandate.

27 Since 2015, the Government has issued two new implementing regulations (Government Regulation 121/2015 on Water Resources Management and Government Regulation 122/2015 on Water Supply Provision) providing adjustments to the Waterworks Law in order to be consistent and aligned with the decentralization law. Until the newly enacted water law can be implemented, these regulations will continue providing the overall legal framework for the sector.

D.
Water Resource Management System

The 1990s saw new efforts to set up various river basin organizations (RBOs) in Indonesia. The institutional reforms focused on fostering basin-wide operations with integrated water resources management as the model. These efforts resulted in the establishment of river-basin management authorities (Balai PSDA43) in Java by around 1998, followed later by organizations in major basins elsewhere in the country.

In each river basin, management activities are coordinated through a council composed of government and non-government representatives (stakeholders). A water allocation plan is prepared each year by the RBO. To date, however, the guidelines for preparing water allocation plans have not been approved by the relevant authorities (nominally the MPWH). The repeal of the 2004 Water Law has complicated the promulgation of the guidelines.

The RBOs are tasked with collecting data on water resources, including rainfall, river flow, and water levels throughout each basin.[28] Data on water balance (supply and demand) are collected by the Research Centre for Water Resources (*Puslitbang Sumber Daya Air*, or PusAir), based in Bandung.

In addition to the RBOs, the government also established state-owned enterprises (*Perum Jasa Tirta*, or PJTs) to operate river-based water infrastructure. PJTs undertake riverbank protection works, control sand and gravel mining, and manage irrigation systems. Fees to cover operation and management are collected from users (e.g., hydropower operators, urban water supply enterprises).

Indonesia has two systems for pricing water: a service fee for water resources management (SFWRM), and a fee for the processed drinking water supplied by PDAMs. The SFWRM is applied when efforts to conserve water resources are underway, and is intended to facilitate development of raw or bulk water source infrastructure, such as dams and water conveyances. Bulk water users include irrigation associations, PDAMs, industries, and electricity generators (for hydropower dams). The fee is calculated by dividing the total operating cost of the bulk water infrastructure by the volume of water produced. Revenue from SFWRM fees can be tapped to build and operate new water infrastructure, for which a special purpose PT/Limited Company is usually formed.

After PDAMs process raw water for the drinking-water supply, customers are charged a fee for its use; fees are regulated under MoHA Regulation (*Permendagri*) 23/2006. However, only about a third of PDAMs are operating at cost-recovery tariff levels for water supply services, according to findings by the MPWH in 2013. Although guidelines on tariff levels have been issued by the MoHA, local governments are reluctant to raise tariffs for political reasons.

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28 The water resources management strategy (*Pola*) and operational plan (*Rencana*) of each managed river basin provide an overview of the data available at the river-basin level.

E.
Disaster Risk Management System

Disaster risk management in Indonesia is a shared responsibility, cutting across sectors and agencies, and designed to be participatory and collaborative. Since the 2004 Indian Ocean Tsunami, the government has reformed its laws, policies, and institutions to better manage disaster risk. In 2007, the government passed a law on disaster management, which is notable for its emphasis not just on emergency response but also on disaster risk reduction (DRR). In 2008, the National Disaster Management Authority was created (*Badan Nasional Penanggulangan Bencana*, or BNPB).

The country's disaster management system is embodied in the following laws and regulations:

- Law of the Republic of Indonesia, Number 24 of 2007 Concerning Disaster Management
- Regulation of the National Disaster Management Agency (Perka BNPB No. 3/2008) Concerning Guidelines for Establishment of Regional Disaster Management Bodies
- Ministry of Home Affairs Regulation (*Permendagri* No. 46/2008) Concerning Organization Guidelines and Work Procedures of the Regional Disaster Management Agency
- Government Regulation Number 23 of 2008 Concerning Participation of International Institutions and Foreign Non-Governmental Organizations in Disaster Management
- Disaster Management Strategic Policy (2015–2019)
- National Disaster Management Plan (2010–2014)
- BNPB Guideline Number 22 of 2010 on the Role of International Organizations and Foreign Non-Government Organizations during Emergency Response
- Law of the Republic of Indonesia Number 3 of 2002 on National Defense
- Law of the Republic of Indonesia Number 34 of 2004 Concerning the National Armed Forces

Under Indonesia's 2007 Disaster Management Law, provincial and district administrations are mandated to take the lead on disaster management during a crisis. When requested, the BNPB and the military (TNI) are expected to step in and provide support.

The National Disaster Management Plan (2010–2014) outlines key disaster management planning priorities and activities, including guidelines for developing strategic plans for government agencies and ministries. It stipulates that the BNPB and the TNI work closely on disaster management.

Although the government has reformed laws, policies, and institutions to better manage disaster risk, work continues to integrate DRR into critical public services, including drinking water supply. Frequent disaster events underscore the need to design and maintain water supply infrastructure with resilience, continuity, and recovery as key considerations.

The BNPB is the primary national agency responsible for coordinating disaster risk mitigation, preparedness, and response, as well as recovery. The BNPB is responsible for preparing, directing, and handling all aspects of disaster management efforts. The BNPB head reports directly to the President.

Subnational disaster management agencies (Badan Penanggulangan Bencana Daerah, or BPBD) have been set up to cover each province and district, and they coordinate closely with the BNPB and the MoHA. Together, the BNPB and BPBDs work to consolidate risk information related to major hazards; communicate risk in meaningful ways to government officials and the public; identify appropriate legal and institutional arrangements, including administrative structures and resource needs; engage in a participatory planning process to develop consensus and a sense of ownership among stakeholders on priority actions as well as promote a commitment to act; and establish implementation structures and procedures for monitoring and continually improving DRM plans.

Although the BNPB and BPBDs act, respectively, as the central and local *coordinating* agencies during disaster events, it is the Indonesian Armed Forces (TNI) that acts as the primary responder in coordination with local governments. The TNI has been deployed regularly during disaster emergencies. The vital role of the TNI is underscored in Indonesia's disaster-related laws and policies and is embedded in the country's military doctrine and personnel training.

The TNI also helps communities strengthen their capacity to reduce exposure to disaster risks, and to cope with disaster impacts.

During disaster response, Indonesia uses an Incident Command System (ICS). ICS is a standardized, on-scene, all-hazard, incident-management concept. It facilitates interoperability among disaster-response personnel and other agencies in different jurisdictions. Traditionally, the ICS commander is a TNI officer or representative.

Various other agencies have specified DRM roles. The Indonesia Tsunami Early Warning System (InaTEWS) is disseminated by the Agency for Meteorology, Climatology and Geophysics (BMKG). The Ministry of Public Works and Housing (*Kemen Pu Pera*) is the primary agency responsible for implementing flood early warning systems in vulnerable areas.[29] The MoHA oversees DRM policy and operational decentralization, maintenance of public order in times of disaster, and community empowerment for disaster preparedness and response.

To deal with potential flooding during the rainy season, in October 2017, the BNPB launched a free, open-source platform in collaboration with the Massachusetts Institute of Technology (MIT) Urban Risk Lab called PetaBencana.id. The project is part of the InAWARE Disaster Management Early Warning and Decision Support Capacity Enhancement within Indonesia's Subnational Disaster Management Agencies (BNPB and BPBDs).[30]

> "Disaster risk management in Indonesia is a shared responsibility, cutting across sectors and agencies, and designed to be participatory and collaborative."

29 Flood warnings cover both inundation flooding and flash flooding. The BNPB, LAPAN (Indonesia's National Institute of Aeronautics and Space), and BMKG are designated as secondary agencies supporting *Kemen Pu Pera* on flood warning.

30 Users can visit the website to access the latest information on flooding in areas of Indonesia including Greater Jakarta, Surabaya, and Bandung. Users can also actively provide maps and real-time reports on the flood situation using social media and instant messaging applications (crowdsourcing).

to: Pixabay

III.

III. Challenges and Gaps in the Context of Climate and Disaster Risks

This chapter provides a high-level assessment of the key issues facing PDAMs in Indonesia, particularly in relation to CC/DR and social inclusion.

A. Traditional Assessments of Management Concerns Facing PDAMs

Considering the country's natural endowment of water resources and the fact that drinking water receives the highest priority in water resource allocation, most assessments of Indonesia's water supply sector do not see water availability and system technology as the main issue facing PDAMs (except on the small islands).

Rather, the main issues that assessments routinely point to are management difficulties, compounded by financial challenges and an inability to attract investments. Until recently, many PDAMs (about two-thirds) were heavily indebted, with MOF loans (on-lent to the PDAMs through the local governments) that needed to be restructured. To provide relief, a debt restructuring program has been initiated by the Government of Indonesia, under which PDAMs may partially or fully write off accrued interests and penalties, and which provides options for debt-to-equity conversion. Still, most PDAMs are not considered creditworthy on their own, and the government has had to provide a program of guarantees and interest subsidies for commercial loans to them.

The lack of funding constrains preventive maintenance and upgrading of assets. Additionally, PDAMs generally function with little autonomy from subnational governments, which prefer to keep tariffs artificially low (and still demand dividends), thereby limiting funds for maintenance and investments.

Levels of non-revenue water (NRW) are more than twice what might be considered acceptable. For PDAMs operating in large cities, reduction of NRW is seen as a priority to improve water supply, though it is also recognized as only a short-term solution.

B. Management Concerns Typically Faced by PDAMs

The Kendari City PDAM illustrates typical management issues faced by PDAMs.[31] It was set up in 2010 as a local government enterprise. Water for the city comes from three river and spring sources, diverted through pipes to a water treatment plant (WTP) by means of a gravity system. The main river source is quite far – 16 kilometers from the WTP. Although the sources can provide more than adequate water volume, the PDAM system is constrained by the size of its transmission pipe, which it plans to upgrade. The PDAM also wants to build a new intake farther downstream of the source river to shorten the distance to the WTP. But this means that the intake will be closer to the city suburbs, raising the risk of future water contamination.

The water catchment areas have poor vegetation cover (mostly grass and shrubs); because of this, erosion rates are high. Conversion of the catchment areas to plantations is worsening the problem. Consequently, water quality and turbidity has deteriorated. High water turbidity raises the cost of treatment by up to three times during the rainy season.

Water system losses are also high. As of 2015, non-revenue water had remained at about 50 percent. Kendari's non-revenue water is attributed to physical losses, mainly due to pipe leakage (in particular, from the 16-kilometer transmission pipe), and to non-physical losses associated with illegal connections and water meters that are malfunctioning or have been tampered with.

The PDAM is taking steps to improve performance and envisions cutting NRW by half, to roughly match what other cities in Indonesia (e.g., Palembang) have achieved. It has identified 6,000 damaged meters that need to be replaced.

In 2012, the annual water volume delivered to consumers (revenue water) was recorded at 4,283,063 cubic meters, corresponding to 20,202 connections in a city with a population of 304,862. In 2014, revenue water went down to 2,939,655 cubic meters, with fewer connections (18,789), though it served an increased city population (322,607). The PDAM attributed the reduced water volume delivered to frequent power outages and the poor condition of its water distribution system. The reduced number of connections was attributed to disconnections arising from unpaid water bills.

PDAM water service is intermittent. In some areas, piped water is reportedly only available for three days a week. Consumers supplement their water supply through individual wells or with water bought from private vendors. But groundwater is of poor quality (it has a high concentration of calcium and magnesium, or "hardness") and is used only for washing and cleaning. And whereas the basic water tariff is only 6,500 rupiah per cubic meter, water supplied by private vendors costs up to 50,000 rupiah per cubic meter.

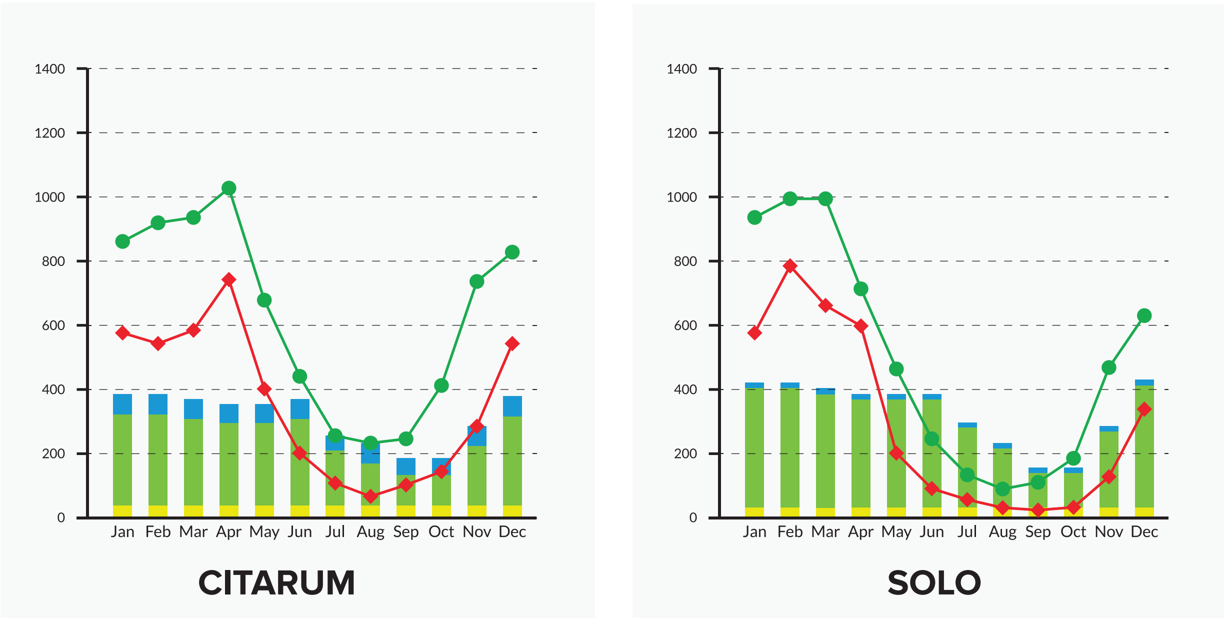
Water tariff collection efficiency is at 70 percent. The PDAM has taken steps to replace damaged water meters (with a plan to procure 1,000 new units) and to stop collusion practices between households and meter readers. Simple and inexpensive solutions are being tested, including the use of cameras to photograph water meter readings and transmit the images to a central server by cellphone. Such simple solutions have been proven successful elsewhere in Indonesia, notably in Palembang, which reduced its NRW from 60 to 27 percent, and which now serves as a model for other cities.

[31] References for this illustrative case were taken from ADB TA-8518 INO, *Green Cities: A Sustainable Urban Future in Indonesia,* 2015.

C.
Existing Challenges Due to Water Resource Degradation

Indonesia has abundant rainfall (and total surface water), but the distribution is skewed and highly seasonal. Figure 4 shows the yearly flow variation in two representative basins in Java (Citarum at left, and Solo at right) (Radhika et al. 2013).

Figure 4. Yearly Flow Variation in Two Representative River Basins in Indonesia (m³/sec)



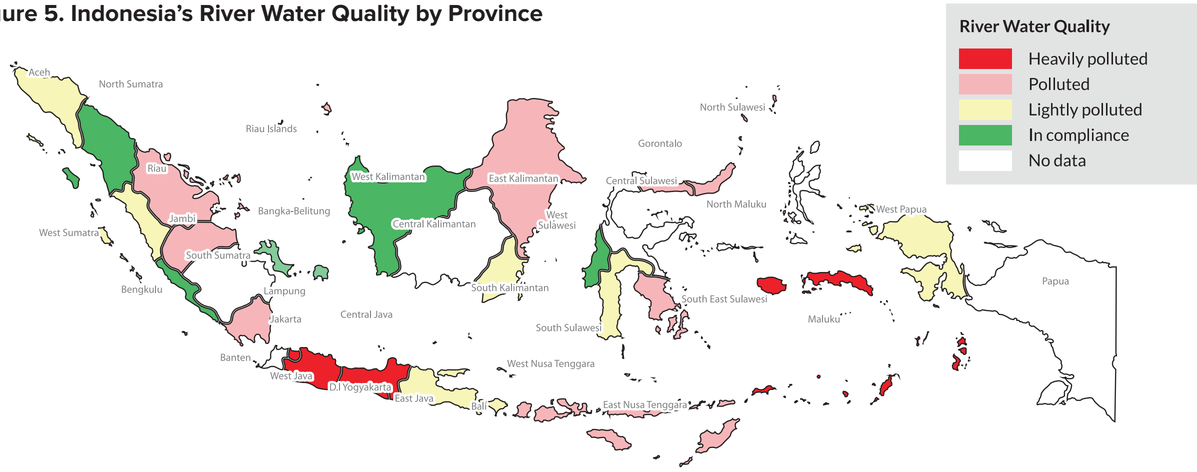
Note: For the dotted lines, green indicates the average flow; red indicates the average flow that is exceeded 80% of the time. For the columns, blue indicates maintenance flow, green indicates irrigation demand, and yellow indicates municipal and industrial water demand. *Source:* Radhika et al. 2013.

Surface water quality has become degraded, and the water quality of rivers and lakes in Indonesia is poor. Monitoring results show that over 50 percent of the parameters, including biological oxygen demand, chemical oxygen demand, fecal coli, and total coliform, do not meet the norms set for water quality Class I. Figure 5 shows river water quality by province.

Groundwater basins in Indonesia have about 520 billion cubic meters per year of potential storage, with a safe yield of about 155 billion cubic meters per year (30%). The most productive basins (deep sandy aquifers) are found along the northern side of Java and Sumatra, and in the southern parts of Kalimantan and Sulawesi.

Deep groundwater is overexploited in most urban areas of Indonesia. As a result of low coverage or poor service by water supply companies, combined with minimal groundwater permit enforcement, many industries and housing estates have pumped deep pressurized aquifers. These aquifers have become overexploited (not replenished) and gradually depleted. An accompanying result is land subsidence, which worsens flooding. Serious impacts are evident in North Jakarta, Bandung, and Semarang.

Figure 5. Indonesia's River Water Quality by Province



Source: Ministry of Environment and Forestry, Status of Environment, Indonesia 2012.

Shallow groundwater sources are prone to contamination, which is the case in all large cities of Java. In Jakarta, 45 percent of groundwater has been contaminated by fecal coliform, and 80 percent by Escherichia coli. Major sources of groundwater pollution are leakage from septic tanks, discharges of untreated domestic wastewater, leachate from landfills, and industrial effluents.

Overall, land-use changes, deforestation, pollution, and excessive groundwater extraction have left many more areas susceptible to recurrent cycles of flooding and drought, making it more difficult to provide adequate and reliable water supply services. Climate change will worsen these existing resource management problems.

D. Added Challenges Posed by Climate Change and Natural Disasters

Against this existing background of resource degradation and management and operational challenges facing the PDAMs are superimposed two looming threats: (i) imminent climate change and its adverse impacts on water resource availability and distribution, and (ii) natural disaster events to which the country is regularly exposed, some of which are climate-related (e.g., floods, landslides, and droughts). These will worsen the effects of existing water resource management problems, as well as create new problems for water supply infrastructure resilience.

Previous assessments of Indonesia's water supply sector have produced the perception that the sector's challenges are principally management-oriented, and not based on water resource availability or a lack of appropriate technologies. However, while it is true that ongoing internal management problems (from standpoint of the PDAM and its local-government or private-sector owners) are serious, so also are the threats of climate change and the increased risks of natural disasters.

On top of existing internal management concerns, the imminent impacts of climate change and natural disaster events pose fundamental threats to water supply security – that is, to the availability and reliability of water resources already suffering from watershed degradation, overuse, and pollution, which will be aggravated by the effects of climate change. In the coming years, PDAMs will have to face the challenge of addressing these threats while putting their internal management systems in order.

E. Need for Social Inclusion and Gender Sensitivity

In Indonesia, as in most other developing countries, marginalized communities and the poor tend to live in high-risk areas that are vulnerable to natural disasters. The poor often migrate to urban areas and settle on marginal lands there (e.g., riverbanks and flood-prone areas) while they search for jobs and livelihood opportunities. As the vulnerability of urban areas to natural hazards (notably flooding) increases, so does the risk to poor communities living there (Lovell and Masson 2014; see also Rashid and Shafie 2009).

Marginalized groups are thus more likely to suffer disproportionately from the effects of climate change and natural disasters. They suffer from generally poor living conditions, lack of access to adequate infrastructure and basic services (especially water and sanitation), a lack of resources, and low levels of education – all of which not only drive them to unsafe areas, but also limit their capacity to adapt.

While this report is focused on making water supply infrastructure and services more resilient, it is also important to raise the awareness and capacity of urban water *users* to become resilient to climate hazards and natural disasters.

1. Social Inclusion

The participation of communities and other urban stakeholders is critical in building resilient cities. Experiences have shown that community-driven programming is essential to the success of urban planning and infrastructure development.

It is also vital to ensure that the most vulnerable and marginalized populations have access to full and meaningful participation in all processes related to urban development, including the assessment of risks. Since local governments have limited capacity to address disaster risk reduction and climate change adaptation, all levels of urban society should support resilience actions, particularly those directed at urgent and significant risks. There are several examples of socially inclusive disaster management initiatives in Indonesia:

- To accelerate trauma healing after the 2004 tsunami, rebuilding in Aceh was conducted with an eye to maximizing the engagement of community members. BAPPENAS and the Agency for the Rehabilitation and Reconstruction of Aceh agreed to use a community-based approach that ultimately led to the establishment of the *Rekompak* program (Community-based Rehabilitation and Reconstruction of Communities and Housing).[32]

- The government also used a community-based approach through the *Rekompak* program for the post-2010 Mount Merapi eruption recovery. In this case, the program gave disaster-affected communities the opportunity to rebuild their public infrastructure through funding provided by direct grants from the government to the community.

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32 *Rekompak* stands for Rehabilitasi dan Rekonstruksi Masyarakat dan Permukiman Berbasis Komunitas.

Communities play a vital role in the successful and sustainable implementation of urban resilience initiatives. The main features of a Community-Based Disaster Risk Reduction and Management (CBDRRM) approach are summarized in table 1. There are a host of benefits:

- A community-based approach can identify and implement a wide range of innovative and feasible structural and non-structural preparedness and mitigation measures to reduce vulnerabilities by building on and strengthening local coping strategies and capacities.
- Community members are involved throughout the process, from risk assessment (hazard vulnerability capacity assessment) to disaster action planning (counter-disaster planning), which leads to ownership, commitment, and individual and collective actions for disaster preparedness and mitigation.
- Community members mobilize resources from within (mostly labor) and outside the community, so community disaster preparedness and mitigation is cost-effective.
- Use of CBDRRM creates a virtuous cycle: case stories that show its success lead to replication and increased demand for CBDRRM.
- CBDRRM strengthens social cohesion and cooperation within the community and society.
- Community disaster preparedness and mitigation provides opportunities to integrate disaster management into local development planning processes and systems.
- CBDRRM builds confidence among individuals, households, and communities when it comes to undertaking disaster preparedness and mitigation, as well other development-related endeavors. This leads to self- and community empowerment.

Table 1. Key Elements of Community-Based Disaster Risk Reduction and Management

Community ownership	The community manages the implementation of disaster risk reduction measures through CBDRRM processes that could be undertaken by outside facilitators from NGOs or government agencies. The community solves a disaster risk problem and decides on the risk reduction project or program. The community also takes control of plans and actions in risk reduction and disaster management.
Use of local knowledge about hazards	Disaster risk reduction plans and strategies are informed by and rely on the recognition of existing coping mechanisms and capacities of the community, as well as local know-how and resources.
Communities as ultimate beneficiaries	In the process of sustaining CBDRRM efforts, the community directly shares in the benefits of disaster preparedness, mitigation, and development. Priority is given to the most vulnerable groups, families, and people in the community.

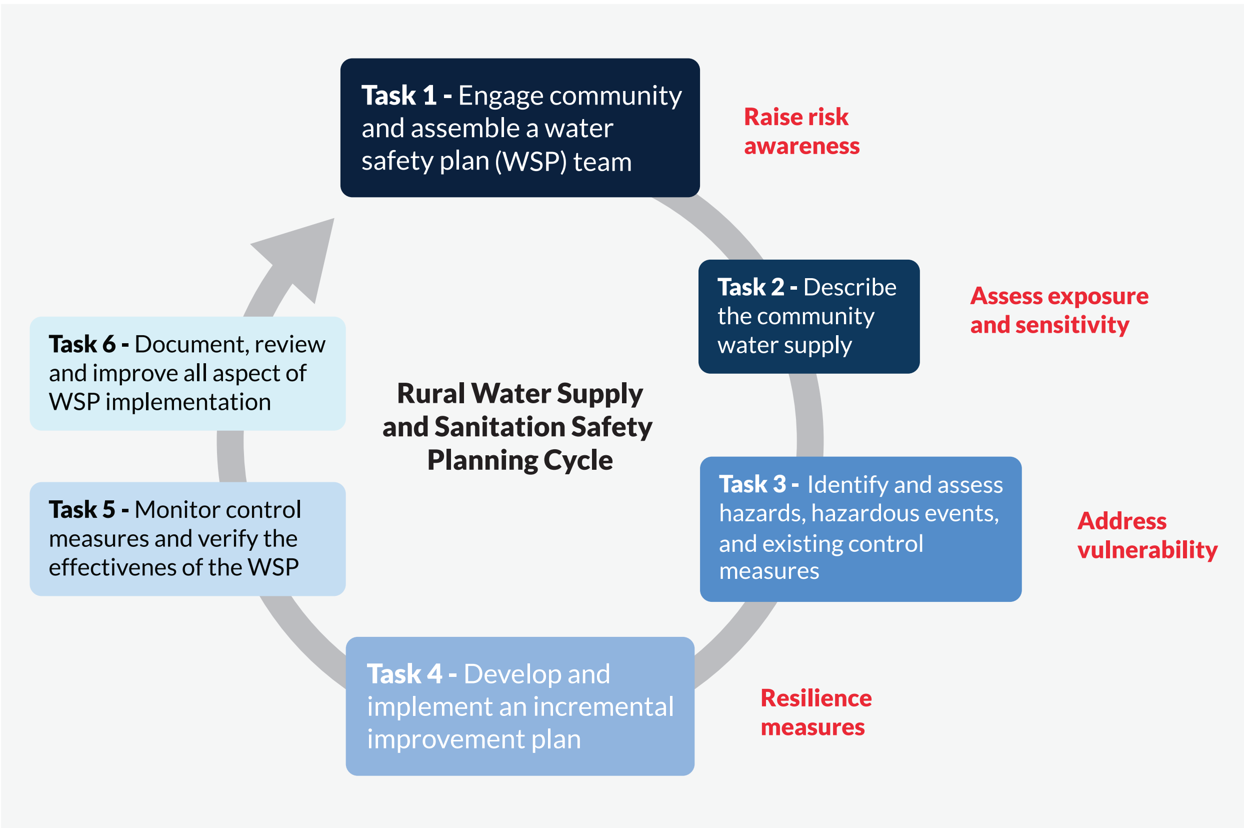
Multi-stakeholder participation	The community is considered to be the key resource and frontline actor in CBDRRM implementation. Local people are the main actors and prime movers in reducing disaster risks in their community through multi-stakeholder participation and involvement in the entire process – from vulnerability assessment and planning to implementation, including the identification of disaster mitigation and preparedness measures, decision-making, response, rehabilitation, and monitoring and evaluation.
Education and capacity-building initiatives	Capacity-building activities that increase the community's skills, resources, and readiness are a key component of any CBDRRM intervention. These skills enable the community to assess the risk, identify risk-reduction measures, and plan and implement those measures, including activities that will prevent disasters and mitigate hazards. These are aimed at preparing the community to respond to crises and emergencies.
Gender sensitivity	Gender sensitivity in intervention recognizes that men and women have different needs, activities, perception of risks, and priorities in the face of natural disasters. Both men and women must be part of the CBDRRM process.
Cultural sensitivity	Community cultures, traditions, and customs are recognized and respected.
Sensitivity to local structures	Planning involves a conscious recognition of community organizations, resources, and coping strategies.
Harmonization of indigenous and scientific knowledge	The process integrates local and indigenous knowledge with scientific knowledge, and incorporates both in risk assessment and disaster management.
Combination of bottom-up and top-down approaches	While community participation and empowerment is the fundamental principle in CBDRRM, the involvement and full support of the national government, local governments, and civil society groups is also vital. Formal directions from government decision-makers may be necessary to enforce laws and regulations.
Building economic resilience	CBDRRM initiatives are primarily geared toward strengthening the community's coping mechanisms.
Commitment and accountability of stakeholders	Accountability to the people and community is crucial. Initiatives must demonstrate that individual and collective actions for disaster preparedness and mitigation are called for to address a disaster's consequences both before and after it occurs.

Use of public communication	CBDRRM initiatives should demonstrate observable capacity in using early warning information, and should disseminate such information to the community. They should promote self-help actions for prevention, mitigation, emergency response, and recovery, and contribute to sustained public awareness.
Sustainable mechanisms	CBDRRM initiatives can be sustained even beyond the project's termination, with mechanisms for sustaining gains already in place at the start of the intervention.

Source: Monitoring and Reporting Progress on Community–Based Disaster Risk Management in the Philippines, Partnerships for Disaster Reduction-South East Asia Phase 4, April 2008.

PDAM staff can help facilitate the preparation of community water supply safety plans that incorporate climate change adaptation measures (e.g., rainwater harvesting) and preparedness for potential disaster events (e.g., extreme flooding that may damage or contaminate village wells). The basic risk-management concepts described in this report apply in community planning contexts as well.

Figure 6. Steps in Community Water Supply and Sanitation Safety Planning



Source: UNICEF and GWP 2014b.

2. Gender Considerations

The UN International Strategy for Disaster Reduction identifies gender as a cross-cutting principle in disaster risk reduction. Gender is a core factor in disaster risk and in the implementation of disaster risk reduction. Gender shapes the capacities and resources of individuals to adapt to hazards and respond to disasters. It is therefore necessary to identify and use gender-differentiated information to ensure that risk reduction strategies are correctly targeted at the most vulnerable groups and are effectively implemented through the roles of both women and men (USAID 2011).

Part of the reason for the weak governance of disaster risk reduction institutions is that disaster policies and programs have low levels of gender sensitivity. When disaster risk managers strive to use all the tools at hand to reduce risk and respond effectively to disasters, they often learn of multiple entry points for mainstreaming gender at every step in the process. Effective gender mainstreaming cuts across every sector and level of disaster risk management, and engages men as well as women.

When disasters do occur, researchers have found that, on balance, women are more significantly affected, including through higher fatality rates, greatly increased domestic labor, slower recovery, higher reported post-disaster stress rates, and increased exposure to gender violence. It is thus still necessary to focus on women to identify these risk factors and plan to minimize them.

At the same time, the grassroots efforts of women to reduce risk are evident. They harvest rainwater, adopt new farming techniques, and plant trees; raise awareness through community radio and drama; educate children about environmental stewardship and emergency preparedness; and provide essential local leadership when communities must act. In particular, women have been found to be more aware of risks, readier to engage in risk-reduction activities such as risk mapping, and more responsive, when feasible, to warnings and preparedness guidance.

IV.

to: Nitin Sharma / Pexels

IV. PDAM Case Studies

This chapter outlines findings from three PDAM case studies (in Magelang City, Bantul District, and Makassar City) that informed the above sector review and other recommendations in this report. The case studies examined the ongoing management concerns of the PDAMs and the level of attention that they are able to devote to to climate change and disaster risk (CC/DR) concerns. The studies looked into each PDAM's perception of the risks posed by climate change and natural disasters, as well as the coping measures they applied, gaps and constraints, and the fundamental needs for capacity building and technical support.

A summary of findings for each case study is given below. Additional information can be found in Annexes 1 and 2.

A. Magelang City

Figure 7. Location Map of Kota Magelang

Situated in a narrow valley surrounded by rivers, Magelang City faces flood hazards classified as high based on the modeled flood information currently available through a hazard assessment tool created by the Global Facility for Disaster Reduction and Recovery (GFDRR).[33] This means that potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years (10-year return period). With medium confidence, models predict more frequent and intense rainfall days and increased numbers of extreme rainfall events. Within the city boundaries, the terrain slope, geology, soil, and land cover make localized landslides rare. However, in the steeper mountain slopes outside the city, where the city's spring water sources are sourced, landslide risk is high. Cyclone hazard is low, meaning that there is a 1 percent chance of potentially damaging wind speeds in this area in the next 10 years.

Water scarcity is classified as medium, according to the information currently available to the GFDRR hazard tool. This means that there is up to a 20 percent chance that droughts will occur in the coming 10 years. This present hazard level may increase in the future due to the effects of climate change. In this area, the temperature increase in the next 50 years will be much lower than the worldwide average, but still significant.

33 World Bank group Global Facility for Disaster Reduction and Recovery (GFDRR) Innovation Lab GeoNode (https://geonode-gfdrrlab.org and http://thinkhazard.org).

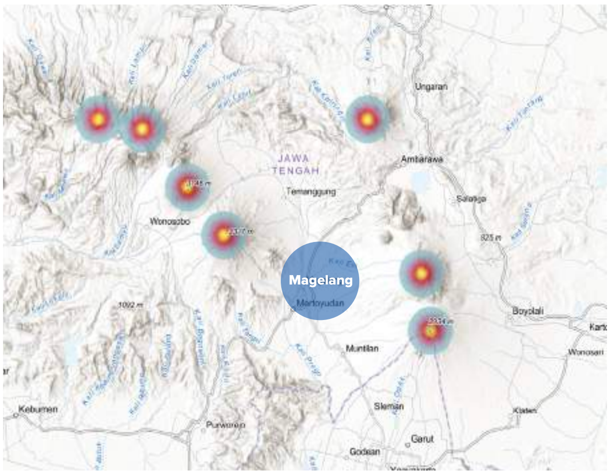
Extreme heat hazard is classified as medium based on the modeled heat information currently available to the GFDRR tool. This means that there is more than a 25 percent chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years. Wildfire hazard is classified as high: in any given year, there is a greater than 50 percent chance of weather that could support a significant wildfire.

Geophysical hazard drivers for the central Java area are shown in figure 8. Earthquake hazard is classified as medium, meaning that there is a 10 percent chance of potentially damaging earthquake shaking in this area in the next 50 years. The city is located less than 50 kilometers from a volcano for which a potentially damaging eruption has been recorded and from which future damaging eruptions are possible. Volcanic hazard is thus classified as medium for this area.

Figure 8. Geophysical Hazard Drivers in Magelang City

Convergent plate boundaries (green)[34]

Volcanoes



Source: ArcGIS.

Natural disasters that affected the PDAM's assets and operations within the last 15 years include:

- 2006 earthquake, Bantul District, Yogyakarta Special Region Province. The earthquake shifted some springs and decreased production capacity.
- 2007 drought. Because of the long dry season, the water debit of some springs decreased.
- 2008 landslide, Tuk Udel area (between Pressure Reducer Chambers in Putihan dan Kiringan). The landslide damaged PDAM transmission pipes (10-inch PVC) resulting in water production leakage of as much as 2,520 cubic meters (70 liters per second for 10 hours).
- 2009 flooding, Tuk Pecah source area. The Elo River overflow forced the PDAM to stop the operation of its submersible pump in order to avoid equipment damage and degradation of water production quality.
- 2006 and 2010 Merapi volcano eruptions. To maintain water production quality and protect the supply from volcanic ash, all "ground capturing" sources had been encased permanently in concrete structures. Therefore, during the Merapi eruptions, water from all five of the city's sources succeeded in meeting water production quality standards.
- 2018 flooding, Tuk Pecah source area. Due to overflow of the Elo River, the PDAM stopped the operation of the submersible pump to avoid equipment damage; the overflow also reduced the water production quality.

34 A convergent plate boundary is where two tectonic plates are moving toward each other. In the Java trench (south) extending to Sumatra, one plate is sinking beneath the other in a subduction zone.

The PDAM does not have a specific department, division, or officer to assess the vulnerability of its assets to natural disasters and climate change, although each relevant division conducts asset monitoring in regard to natural disasters and climate change. Additionally, there is no disaster regulation related to PDAM assignments; however, during disaster events, Basarnas (National Search and Rescue Body) and the BPBD are mandated to coordinate with the PDAM with regard to distribution of water to disaster-affected areas.

The PDAM currently has no water reserve facilities to store or reserve water for mitigating water-supply emergencies. The current water reservoirs are primarily functioning as a "balancing system."

The PDAM has built a flood-reinforcement embankment around the spring at the Tuk Pecah source to reduce the effect of flash flooding. However, if river water overflows (as it does during big floods), the PDAM's operations and production system will be halted to prevent damage to equipment and avoid low water production quality.

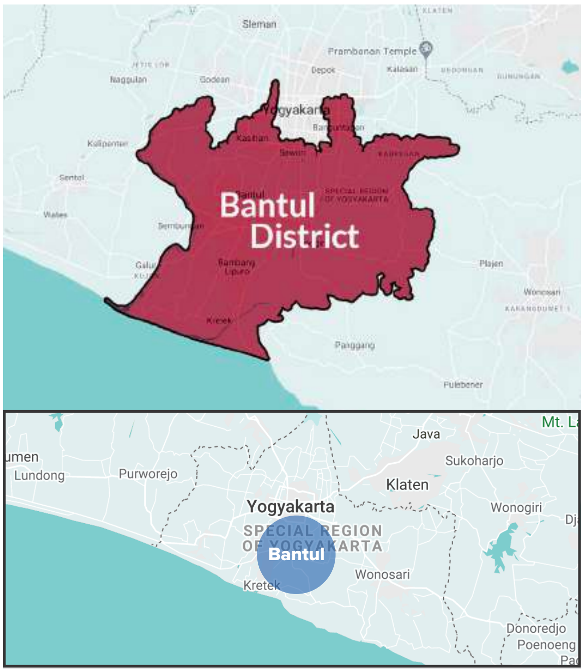
The PDAM has planted trees and constructed gabion walls at vulnerable slopes around the spring source areas located at Wulung, Kalegen, Kanoman, and Tuk Pecah. These are intended to protect the spring sources and pipes against landslide risk.

The PDAM has also encased the spring water sources with reinforced concrete structures to protect them from volcanic dust contamination during Merapi volcanic eruptions.

> " High-probability events (more frequently recurring) are less intense and generate less damage and loss, while the low-probability events are more intense and generate greater damage."

B.
Bantul District

Figure 9. Location Map of Bantul District



In this area, river-flood hazard is classified as high based on the modeled flood information currently available to the GFDRR hazard assessment tool.[35] This means that potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years. The present hazard level may increase in the future due to the effects of climate change. With medium confidence, models predict more frequent and intense heavy precipitation days and increased numbers of extreme rainfall events. There is a 10 percent chance of potentially damaging wind speeds in this area in the next 10 years.

Water scarcity is classified as medium according to the GFDRR hazard tool; this means that there is up to a 20 percent chance that a drought will occur in the coming 10 years. Extreme heat hazard is classified as medium based on the modeled heat information currently available to the GFDRR tool. This means that there is a greater than 25 percent chance of at least one period of prolonged exposure to extreme heat, resulting in heat stress, occurring in the next five years. Wildfire hazard is classified as high, meaning that, in any given year, there is a greater than 50 percent chance of encountering weather that could support a significant wildfire.

The district's terrain slope, geology, soil, and land cover make localized landslides rare. However, climate change is likely to alter slope and bedrock stability through changes in precipitation and temperature.

Coastal flood hazard is classified as medium, meaning that there is more than a 20 percent chance of potentially damaging coastal flood waves occurring in the next 10 years. Even though there is high confidence that extremes in sea level will increase with expected sea level rise, region-specific projections for storm surges cannot be made with high confidence.

Earthquake hazard is classified as medium, with a 10 percent chance of a potentially damaging earthquake occurring in this area in the next 50 years. Due to the area's proximity to the Java trench (a subduction fault line), tsunami hazard is classified as high, meaning that there is more than a 20 percent chance of a potentially damaging tsunami occurring in the next 50 years.

Volcanic hazard is classified as medium because the area is located less than 50 kilometers from a volcano for which a potentially damaging eruption has been recorded in the past; future damaging eruptions are possible. Geophysical hazard drivers for the central Java area are shown in figure 10.

35
GFDRR Innovation Lab GeoNode (https://geonode-gfdrrlab.org and http://thinkhazard.org).

Figure 10. Geophysical Hazard Drivers in Bantul District

Plate boundary and tsunami observations Volcanoes

Note: The Java trench (tectonic plate boundary) is shown as the green line south of Java island, and tsunami observations are shown as vertical bars.
Source: ArcGIS, NOAA National Centers for Environmental Information.

Natural disasters that affected the PDAM's assets and operations within the last 15 years include:

- 2006 earthquake and drought.
- 2010 Mount Merapi eruption. The event affected the Nephelometric Turbidity Unit (NTU) value of the raw water in the water treatment plant (WTP) system. It also impacted the performance of intake buildings, affecting the pumping of raw water. The process of sedimentation in each WTP requires extra care.
- 2017–2018 Imogiri and Pundong floods.
- 2017 Cempaka cyclone disaster.
- 2018–2019 flash flood, Bantul. Flash flooding came from Gunung Kidul. The impact of the Dlingo floods resulted in secondary flooding in the direction of the Dodokan Jatimulyo WTP; the Parangtritis WTP was also affected.

The Bantul District PDAM does not have a specific department, division, or officer to assess the vulnerability of PDAM assets to natural disasters and climate change. However, each relevant division conducts asset monitoring in regard to natural disasters and climate change.

Thus far, the PDAM has no water reservation system to store or reserve water in response to water source emergencies. The current water reservoirs are mainly functioning as a "balancing system."

Siltation at the Pajangan WTP and flash flood risk at Jatimulyo (Dlingo) – both of which are related to climate change and natural disaster occurrences – have been identified as significant risks to water supply assets. In this case, the water source is located in the path of the flash flood. The PDAM water treatment plant, which is located on the riverbank, has already been affected by flooding. Considering the siltation of rivers in the water intake area, the PDAM plans to make greater use of infiltration galleries.

The PDAM has an "Integrated System," in which the water supply system serves to mitigate the installation damage caused by flooding. There is no specific unit assigned to CC/DR concerns. However, during the overflow of water from upstream rivers in the Gunung Kidul area, monitoring from WTP operators is routinely carried out as a preventive measure in anticipation of asset damage.

To address the flash flood risk at the Trimulyo Sub-Unit, the PDAM sought assistance in reinforcing the distribution transmission pipe bridges. The work was carried out by SATKER PSPAM DIY with disaster management funds from the central government.

C. Makassar City

Figure 11. Location Map of Makassar City[36]

Makassar City is crisscrossed by waterways. Based on the modeled flood information currently available to the GFDRR hazard assessment tool,[37] there is a greater than 20 percent chance that potentially damaging and life-threatening urban floods will occur in the coming 10 years. With medium confidence, models predict more frequent and intense heavy precipitation days, which could exacerbate flooding risk. On the other hand, cyclone hazard is classified as low, meaning that there is only a 1 percent chance of potentially damaging wind speeds in this area in the next 10 years.

Coastal flood hazard is classified as medium according to the GFDRR tool, which means that there is more than a 20 percent chance of potentially damaging coastal flood waves occurring in the next 10 years. According to the IPCC (2013), there is high confidence that extremes in sea level will increase, even though region-specific projections in storm surges cannot be accurately predicted. The interaction of increasing tide levels and bigger run-off volumes during intense rain events is already creating coastal flooding problems for the area.

Existing model projections are generally inconsistent in their estimates of how drought hazard will change. Even though the present drought hazard level for this area is classified as low (along with wildfire hazard), it may increase in the future due to the effects of climate change. Extreme heat hazard is classified as medium based on the modeled heat information currently available. This means that there is more than a 25 percent chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years. It would be prudent to design the city's water supply to be robust enough to withstand increased drought hazard and extreme heat in the long term.

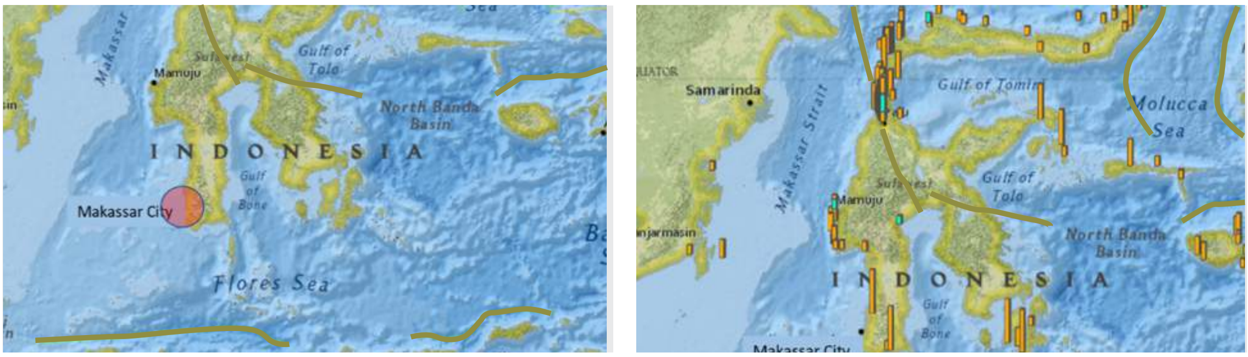
Earthquake hazard is classified as medium based on the information that is currently available. This means that there is a 10 percent chance of a potentially damaging earthquake this area in the next 50 years. Tsunami hazard is classified as medium, with more than a 10 percent chance of a potentially damaging tsunami occurring in the next 50 years. The area at risk from tsunami will increase as the global mean sea level rises. There are no volcanoes within 50 kilometers of the city. Geophysical hazard drivers for this area are shown in figure 12.

36 Also referred to as Ujung Pandang.

37 GFDRR Innovation Lab GeoNode (https://geonode-gfdrrlab.org and http://thinkhazard.org).

Figure 12. Geophysical Hazard Drivers in Makassar City

Tectonic plate boundaries | Tsunami observations



Note: Tectonic plate boundaries are shown are shown as colored lines: green for convergent plate boundaries, and yellow for transform plate boundaries. Tsunami observations are shown as vertical bars based on eyewitness observations and post-tsunami surveys. Water heights range from 1 to 10 meters.
Source: NOAA National Centers for Environmental Information.

Recent natural disasters that affected the PDAM's assets and operations include:

- 2018 flash flood, South Sulawesi. Floodwater came from the Bili-Bili Dam, one of the main water sources for the city. The flash flood cut off several roads and bridges and flooded some areas of Makassar, interrupting the PDAM's systems for several days.
- 2018 drought, Lekopancing Dam. This rain-fed dam only had 20–30 percent of its normal debit water left during the dry season. The PDAM made an effort to mitigate this drought in the water source by paralleling the water supply to IPA-2 and IPA-3 from the Jeneberang River.
- 2019 Sungai Jeneberang River inundation, which hit the city's bridges. The inundation was the result of a flood from Malino that caused the Bili-Bili Dam channels to be opened.

The PDAM does not have a specific department, division, or officer to assess the vulnerability of PDAM assets to natural disasters and climate change. However, each relevant division conducts asset monitoring in regard to natural disasters and climate change.

Like the two PDAMs reviewed above, Makassar City currently has no water reserve system to supply water during emergency situations. The existing water reservoirs are functioning primarily for pressure balancing in the system.

Makassar's PDAM is aware of the risks that climate change and natural disaster events pose to its critical assets, but it recognizes that these are unpredictable and difficult to plan for. Moreover, the raw water is obtained from a dam and reservoir that is located outside the city's boundaries[38] and that is thus largely outside the local government's direct control. Seawater intrusion during tides is also a concern.

The PDAM conducts regular installation leakage repair in an effort to reduce water losses (NRW). To improve services and control water loss due to leakage, the PDAM has an application called "SIPPAM," which is available on iOS and Android. In this application, customers can update information related to PDAM facilities, damage, complaints, and reports on water leakage anywhere within the Makassar City area. Moreover, the PDAM has received a grant from JICA that provides a pipe leakage detector and is supported by a training program on equipment usage and maintenance.

38 The dam water source is used by the PDAM of Makassar City and the PDAM of Maros District. However, there appears to be no sharing mechanism in place for managing this common water source.

to: Pixabay

V.

V. A Framework for Water Supply Infrastructure and System Resilience

Resilience can be defined as the ability of a system to withstand or accommodate stresses and shocks, such as climate impacts, while still maintaining its core functions. Based on that definition, this chapter proposes a framework for resilient water supply infrastructure. It integrates the World Bank's approach to infrastructure resilience – as described in *Lifelines* (Hallegatte, Rentschler, and Rozenberg 2019) – with Indonesia's ongoing framework for the development of national urban water supply (NUWAS) as supported by the National Urban Water Supply Project (NUWSP).

Consistent with the NUWAS framework's need-based and performance-based approach to PDAM improvement and expansion, this water supply resilience framework adopts a *differentiated* approach – that is, one in which resilience measures are not necessarily uniform or standardized. Instead, they are fitted to the risks faced by each PDAM based on area-specific vulnerabilities and the local government (or other) owner's evaluation of whether those risks are acceptable or not, using criteria agreed upon under the program.

Higher-intensity, lower-frequency catastrophic events (significant natural disaster shocks) require different approaches than lower-intensity, often higher-frequency events (such as recurrent flooding, landslides, and drought – which are often exacerbated by climate related risks). More infrequent catastrophic events commonly require significant resources from the central government, as well as multi-agency cooperation for emergency response and longer-term recovery (rehabilitation and reconstruction). But water supply services and infrastructure should be designed to withstand frequent and small-scale shocks so that core functions can be maintained without disruption. There are two "minimum standards" that should be institutionalized in water system planning and management: the first is *procedural* (risk-based water supply planning by local governments and PDAMs), and the second concerns *design and engineering*. These "standards" are not intended to be regulatory instruments; rather, they may be adopted as prerequisites for PDAM participation in the NUWAS program.

Whereas risk-based planning procedures can be standardized, it is not advisable to standardize engineering measures for resilience. There is no one-size-fits-all engineering solution for CC/DR risks: every location will have different risks and severity of impacts, and measures must therefore be case-specific and based on risk assessments. Additionally, the costs associated with resilience measures will need to be estimated at the project level and will depend on the project scale and the risk level.[39]

In the resilience framework above, local governments (LGs) and PDAMs are to conduct risk assessments of their water supply systems. We assume that NUWSP's capacity-building component (component B) would support or facilitate these assessments, enabling them to be completed quickly (yet rigorously, especially the vulnerability analysis) so as not to delay project development. As system owners, the LGs decide on the acceptable and unacceptable risks, and determine the risk-reduction measures they will commit to implementing. The latter should be driven by incentives under NUWAS (e.g., as part of the seed/matching/performance-based grant mechanism, and access to commercial financing or to climate adaptation funds if those become available), and included as part of the PDAM performance evaluation system.

CC/DR risk reduction measures need not entail additional costs. Simply planning and constructing systems properly by following existing standards, plus practicing good maintenance, produces durable and more resilient systems. Infrastructure can be protected best at the planning stage, when climate change risk management measures are easy to implement and will reduce long-term costs. Although additional investments may become necessary for certain design and engineering measures, the long-term (life-of-system) savings from avoided disruption, refitting, and repair outweigh the costs. Incentives and support may be further developed or offered under the NUWAS program.

The resilience framework above integrates disaster risk management (DRM), with the caveat that risks posed by catastrophic events (e.g., the Central Sulawesi disaster in 2018) that destroy or heavily damage water supply infrastructure should be borne by the central government, not by the LGs or PDAMs. Addressing such major disaster events – in particular, the resultant reconstruction needs – will likely require financing mechanisms beyond what NUWAS provides (e.g., region-wide parametric natural catastrophe insurance through the central government). However, the risk assessment procedure and technical guidelines laid out in the resilience framework also apply to recovery activities, such as the rehabilitation or reconstruction of water supply infrastructure.

“ Simply planning and constructing systems properly by following existing standards, plus practicing good maintenance, produces durable and more resilient systems.”

39 In terms of engineering measures, therefore, this report mainly provides technical guidelines and examples drawn from the PDAM case studies and international best practices.

to: Pixabay

VI.

VI. Proposed Standard Procedure for Resilience Planning and Management

The Ministry of Public Works and Housing's Ministerial Decree No. 23 of 2014 provided standard operating procedures for PDAMs to follow, but these procedures mainly addressed day-to-day operations; they did not specify the steps or precautions that should be taken to assess, mitigate, and respond to hydrometeorological and geophysical hazards. This chapter outlines a proposed risk assessment framework that integrates principles from climate change adaptation and disaster risk management.

A. Review of Lessons on Strengthening Water Supply Resilience

The World Bank's program on mainstreaming disaster risk management in Indonesia, which was supported by the Global Facility for Disaster Reduction and Recovery (GFDRR), adopted five "pillars of action." The first is risk assessment, which provides the basis for decision-making on the others: risk reduction or mitigation, preparedness, financial protection, and resilient recovery.

In Indonesia, the main hazards identified by the program will be exacerbated by climate change impacts (e.g., more severe rainfall), or result from Indonesia's geographical position along the Pacific "Ring of Fire," which contributes to high seismicity and volcanism. The World Bank–GFDRR program estimated that 80 to 90 percent of Indonesia's population is exposed to the two most common hazards: *flooding* and *landslides*. These cause frequent widespread damage during the rainy season. On the other hand, earthquakes and tsunami, although rarer and more localized, cause much more severe damage, larger shocks to government budgets, and longer-term disruption.

The World Bank–GFDRR program concluded that *risk identification and assessment tools are essential* so that project owners (in this case, PDAMs) can incorporate disaster and climate risks in their infrastructure design process. Such tools include risk maps and area risk profiles.

Studies and programs specifically concerned with the water supply system – both within Indonesia and elsewhere in the East Asia and the Pacific region – have gleaned additional valuable lessons. A case study on flood disasters in Metro-Jakarta and its impact on water supply and sanitation is described in Hartono et al. (2010). The study reported that booster pumps for water mains located in flooded areas could not function because power had to be cut off for public safety reasons. For those customers who relied on groundwater, the power outage also cut the water supply. Moreover, floodwater contaminated the groundwater, which became unsuitable for drinking. The only recourse was bottled water, which had to be distributed to evacuation centers by relief organizations (often with difficulty due to the flooding itself). The study's main recommendation was to ensure that water storage tanks be made available at every emergency evacuation center. Given that this case study was written in 2010, the recommendations focused on emergency response rather than on the need for resilience to be built into the water supply system itself.

In the Philippines, USAID implemented a project that aimed to strengthen water infrastructure resilience (AECOM 2017). The project concluded that the traditional water infrastructure design data, methods, and construction materials that used to work in the past need to be modified in order for infrastructure to withstand the weather extremes that climate change is expected to cause (specifically, more frequent severe storms and more prolonged droughts). This means, for example, that the design of water infrastructure cannot continue to rely on historical data to set design parameters.[40]

The project noted that two aspects of resilience need to be considered: the water supply side and the behavioral side (that is, the behavior of water end-users). The main vulnerability points identified in this USAID project are:

- Integrity of the water source, conveyance network, storage tanks, and treatment facility;
- Ability to secure the materials required to operate and maintain the water supply system (i.e., having storage locations for treatment chemicals so that they are not left vulnerable to flooding or building collapse);
- Possibility of physical damage to power lines or fuel supplies that support water pumps and treatment facilities, which can bring water service delivery to a halt;
- Safety of the personnel responsible for water service provision during natural disasters or other crises;
- Changes in people's behavior following a natural disaster or other climate-related disruption in water supply, such as hoarding water to cope with the crisis.

The project concluded that there is no pre-defined risk threshold. After the above-mentioned risks have been assessed, the water service provider must next determine the acceptable level of risk. Some impacts may be insurmountable (for instance, an earthquake or tsunami event), while others can be more manageable (for example, a landslide burying a pipeline, or a dry spell). Final decision-making on the appropriate level of infrastructure hardening will be informed by the risks that stakeholders (including authorities and end-users) have identified as unacceptable. This framework of risk-based decision-making needs to be instilled among water supply planners.

The engineering resilience measures that the USAID Philippines Project implemented were relatively straightforward and not too capital-intensive. They included encasing springs with reinforced concrete structures to prevent contamination; constructing spring boxes to capture excess water; re-aligning pipes; securing exposed ground-level or hillside pipes in trenches (with some sections encased in concrete); securing hanging pipes with steel cables; raising the elevation of transmission pipes that cross streams above the projected flood level; installing reinforced concrete roof decks to house vulnerable pumps, generators, and chemical sheds; and strengthening structures that hold elevated tanks to resist seismic and wind forces.

In Japan, the World Bank, through GFDRR, also conducted city-level case studies on how the country has built resilience into its water supply and sanitation services by applying an "adaptive" management approach based on its experience with natural disasters. Even though the development context in Japan differs from that of Indonesia (and the Philippine case described above), the Japan case studies nevertheless provide useful insights. The Japanese approach is more comprehensive (system-oriented), as it includes policy, legal, and institutional measures in addition to engineering solutions.

40 Examples of data that need to be reconsidered include estimates of future rainfall intensity with a 50-year average frequency (return period), which is used to assess flooding and landslide risks, and the dependable dry season rainfall, used to calculate water-storage requirements.

B.
The Fundamental Role of Risk Assessment in Climate Change Adaptation and DRM

The GFDRR program in Indonesia and the experiences of other countries described above all emphasize the *need to institutionalize risk assessment in planning and managing water supply systems* in order to build resilience.[41]

The USAID Project in the Philippines, for example, used multi-criteria analysis to determine the acceptable level of risk and the need for adaptation measures. Such an evaluation uses an array of specific criteria, which depend upon stakeholder values and needs and will therefore vary from one context and location to another. The project noted that the range of resilience-building options is diverse but, in each case, the viable options depend on unique combinations of site-specific characteristics and stakeholders' needs (including their degree of risk aversion). As such, a one-size-fits-all approach to designing resilience measures is not feasible.

Instead, a multi-step process is needed to decide on appropriate engineering and management approaches for water supply resilience. Only such a process will enable PDAMs to integrate various considerations of hazard exposure, site vulnerability, appropriate design for risk reduction, available technology, and cost considerations. As such, a water service provider must first carry out a risk assessment to determine the likely hazards and consequent impacts.

Risk assessment is a three-step process comprising hazard identification, risk analysis, and risk evaluation. Hazard identification is the process of situating and characterizing hazards. Risk analysis then examines the nature of the hazards and risk levels to ascertain their likelihood and the severity of their consequences. Finally, risk evaluation compares the estimated risk against stakeholder-prescribed criteria to determine the significance and acceptability of the risk, based on which risk-control investment decisions can be made.

Risk assessment is a well-established field in general, but its application to water supply planning in the context of natural disaster and climate risks needs to be situation-driven. For water supply planning, risk identification and assessment translate specifically to hazard identification, vulnerability assessment, and the evaluation of risk-management options. The guidelines and procedures developed below emphasize hazard and vulnerability assessment.

Below, we review the general risk assessment framework and reframe it for systematic application to climate change adaptation (CCA) and disaster risk management (DRM) in the context of building water supply resilience.

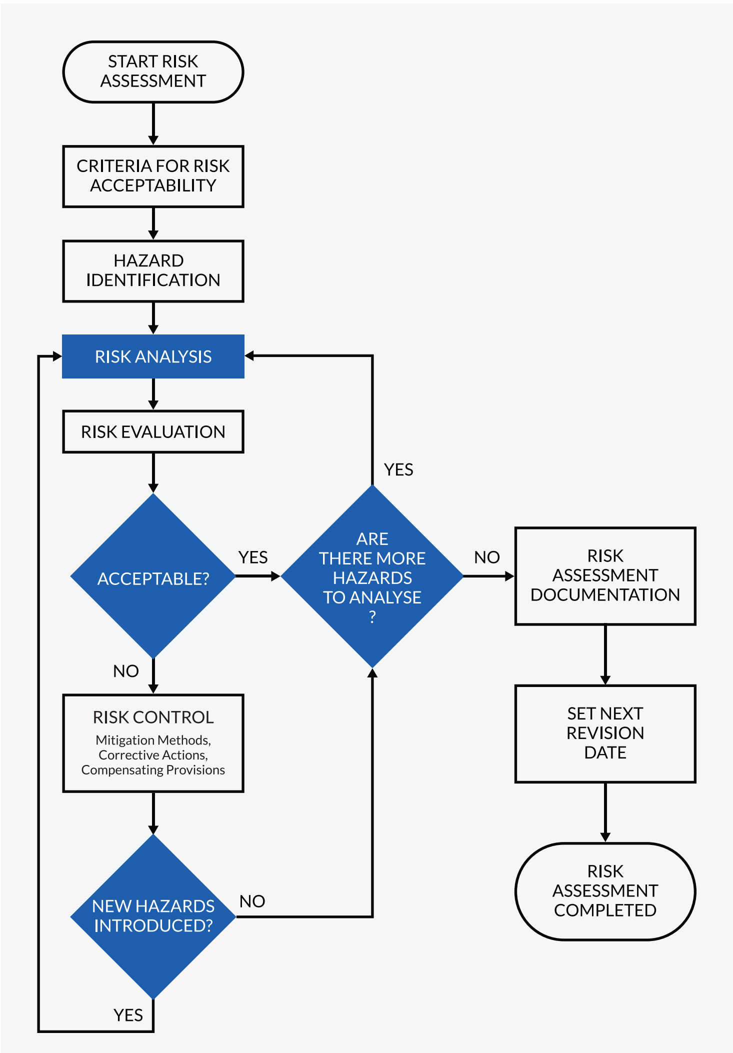
41
"Resilient" means better able to deliver water supply services during and after natural shocks, which involves improving business continuity planning, asset management, and contingency programming.

C. Standard Risk-Assessment Framework and Steps

Risk assessment is an essential component in both disaster risk management and climate change adaptation approaches (figure 13). This applies not only for water infrastructure, of course, but also for a wide range of other essential urban services (e.g., energy, transportation, communication) and their underlying infrastructure (see Dickson et al. 2012 and Herron et al. 2015).

The purpose of a risk assessment is to define the risk, answer questions about characteristics of potential hazards (as to frequency of occurrence and severity of consequences), and assess specific vulnerabilities of infrastructure systems (and communities) based on their exposure to the hazards and their existing capacity to manage them.

Figure 13. Standard Risk-Assessment Framework



BASIC STEPS

Step 1:
Screen for risk. Review the activity or project to determine whether a more detailed assessment is warranted by the nature of the risk and its potential consequences.

Step 2:
Define the assessment parameters. This includes setting the criteria that will be used to decide on risk acceptability, defining the area and planning horizons, and identifying and gathering relevant data to better understand what vulnerabilities must be examined more closely.

Step 3:
Assess risk and identify risk-management strategies (i.e., accept or accommodate the risk, prevent it if possible, or else transfer the risk through insurance instruments or implement mitigation measures to reduce it).

Step 4:
Implement, monitor, report. Implement the risk-management strategies. Evaluate the effectiveness and efficiency of the measures implemented.

Risk evaluation, which is a key step in risk assessment, helps prioritize measures for risk management, taking into account the assessed likelihood and impact of potential hazards, the cost-effectiveness of alternative mitigation measures, the social and political acceptability of possible solutions, and resource availability.

Risk assessment should not be a one-off activity. It should ideally be undertaken at regular intervals so that risk managers can evaluate progress toward reducing vulnerability and continually improve the mitigation measures employed.

The conventional process of a risk assessment (applied to any relevant context) is shown in figure 13. Note the key steps of criteria-setting, hazard identification and screening, risk analysis, and evaluation of options (i.e., accept the risk, or decide to manage it through prevention or risk-reduction measures, if feasible).

Once project planners have identified risk-management options, the next step is to evaluate various criteria against project-specific considerations. By doing so, they can evaluate the feasibility of implementing any given risk-management strategy. This can be thought of as the probability that the option will be implemented. As described in Coppola (2015), these criteria could include:

Political support:

Would political support be necessary for implementation of the proposed option? Could lack of political support decrease the possibility of implementation?

Public support:

Is the proposed option socially acceptable in the community? Would implementation of the proposed option cause adverse impacts to the population or to segments of the population?

Cost and benefits:

Is the proposed option economically efficient or cost-effective?[42] Are there funds in place to support the option? Would implementation impose a financial burden or negatively affect the income generation of the system or project?

Technical viability:

Is the proposed option technically feasible? Might there be ancillary impacts?

Capacity:

Does the project proponent have the capacity to implement the proposed option with respect to staffing, funding, and maintenance requirements?

Regulatory or legal aspects:

What are the regulatory requirements and legal authorities needed to implement the proposed action?

Environmental impact:

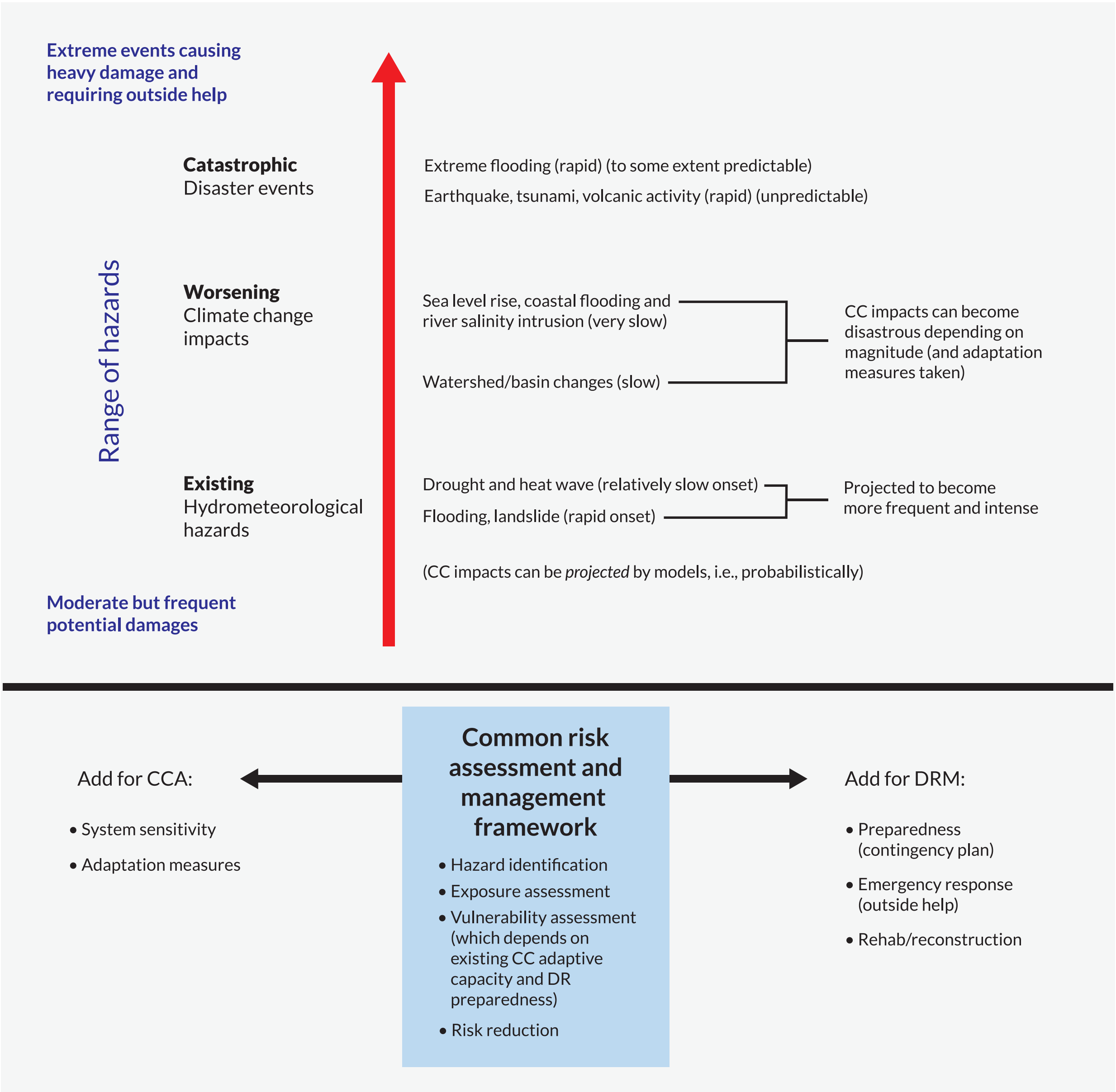
Would the proposed option negatively affect the environment?

42 Economic-efficiency analysis or cost–benefit analysis compares the costs and benefits of undertaking a risk-management option. Alternatively, cost-effectiveness analysis is used when benefits cannot be measured in a reliable manner. This latter method involves costing the different options that achieve the same result or outcome and then comparing the options to determine how the result can be obtained in a least-cost way.

D.
Integrating CCA and DRM within a Common Methodology for Risk Assessment

Figure 14 supplements the infrastructure resilience framework described above. It integrates CCA and DRM in the context of water supply infrastructure resilience and capacity building, and it shows the kinds of hazards each approach addresses and the common risk assessment methodology they apply.

Figure 14. Integrating Climate Change Adaptation and Disaster Risk Management



This method-integration framework is useful because CCA and DRM have developed as somewhat distinct communities of practice, with their own methods, terminologies, and even institutional arrangements.

- Climate change risk management is often discussed together with adaptation. The latter is the process of adjusting to ongoing or projected climate change and its impacts (considering the unavoidable uncertainty – hence, risk).

- Disaster, on the other hand, is the occurrence of an extreme hazard event of a contingent nature – subject to chance, and generally unpredictable – which impacts vulnerable systems or communities, causing substantial damage and disruption and leaving them unable to function normally without external emergency assistance.

The reason these fields have developed separately is that there is a big difference in their scope (as to the types and the severity or manageability of hazards addressed), and the response and management methods they apply. However, they are united in applying a common risk assessment approach, and for the purpose of developing resilient water supply systems, this common approach is recommended. The common elements of the risk assessment and management approach used in both CCA and DRM include hazard identification, exposure and vulnerability assessment, and risk reduction.

When considering differences between DRM and CCA, it should be noted that DRM is not just concerned with low-frequency, high-impact (catastrophic) events but also high-frequency, low-impact disasters. One key difference between CCA and DRM is related to the timing of hazards addressed by each. CCA generally applies to slow-onset hydrometeorological disasters, whereas DRM is usually more concerned with specific events caused by natural hazards. The latter can be either geophysical or hydrometeorological in nature, and can encompass a range of magnitudes.

VII.

Photo: World Bank / Flickr

VII. Risk Assessment Applied to Climate Change Adaptation and DRM

This chapter provides detailed guidance on procedures and tools for risk screening and assessment, including decision-making under deep uncertainty. It outlines the principles and benefits of the various approaches.

The scheme presented below, which draws from the generally accepted risk-assessment procedures described above, follows a methodology endorsed originally by the UN Inter-governmental Panel on Climate Change (IPCC), which applies three considerations in climate risk and vulnerability (UNFCCC 2007):

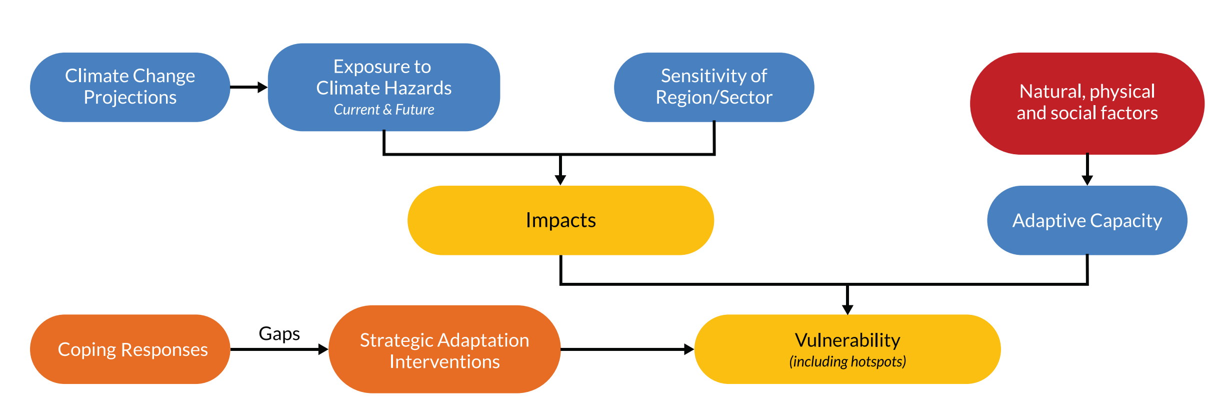
Exposure to climate change hazards;

Sensitivity of natural environments and human populations exposed to these hazards;

Capacity of communities and institutions to adapt to climate change.

Exposure to climate hazards is influenced mainly by geographical location. Sensitivity and adaptive capacity, on the other hand, are context dependent. For instance, a segment of a country's population may be considered more sensitive because their livelihood depends on rain-fed agriculture. Adaptive capacity in turn depends on access to the resources and support systems that enable communities to respond to climate threats. The framework is summarized in figure 15.

Figure 15. Scheme for CC/DR Risk Assessment



Climate-change exposure in this framework is derived from regional climate modeling data, the sensitivity of affected areas, and adaptive capacity, and informed by geospatial information. Integrated analysis is done through a geographic information system (GIS) via overlay mapping, which is used to assess spatial patterns and to identify "hotspots" – that is, sensitive areas with significant exposure to climate hazards and low adaptive capacity.

A.
Initial Risk Screening

Climate change will bring about two main outcomes affecting water supply planning: a projected increase in rainfall variability and extremes, and the attendant hydrological impacts (flooding and drought) – in a context where hydrometeorological impacts already make up 80 percent of disaster occurrences in Indonesia.

Infrastructure resilience is fundamentally about managing risk. The IPCC defines climate change risk as a function of the *likelihood* and *consequences* of a climate change hazard. Likelihood and consequences are in turn determined by the nature of the *hazard* and its projected future frequency as indicated by climate models, and the *vulnerability* of the area or system affected.

The first step in assessing climate risk is a climate change risk screening, in which risk managers determine whether the available information on hazards and vulnerability warrants a more detailed assessment. A quick way to undertake such a screening is by using a GIS database that provides information on the probability profiles (percentile values and return periods) of rainfall-related climate parameters derived from climate models. By using the data in combination with vulnerability mapping (overlay of climate change exposure, sensitivity, and adaptive capacity), users can identify locations exposed to hazards (e.g., flood-prone or drought-prone areas).

Various tools for climate change risk screening and analysis are available. Their applicability varies according to whether the risk assessment is being applied to an area, a project, a program, or a sector. These tools, all open source, are summarized in table 2.

Table 2. Sample Tools for CC/DR Risk Screening and Assessment

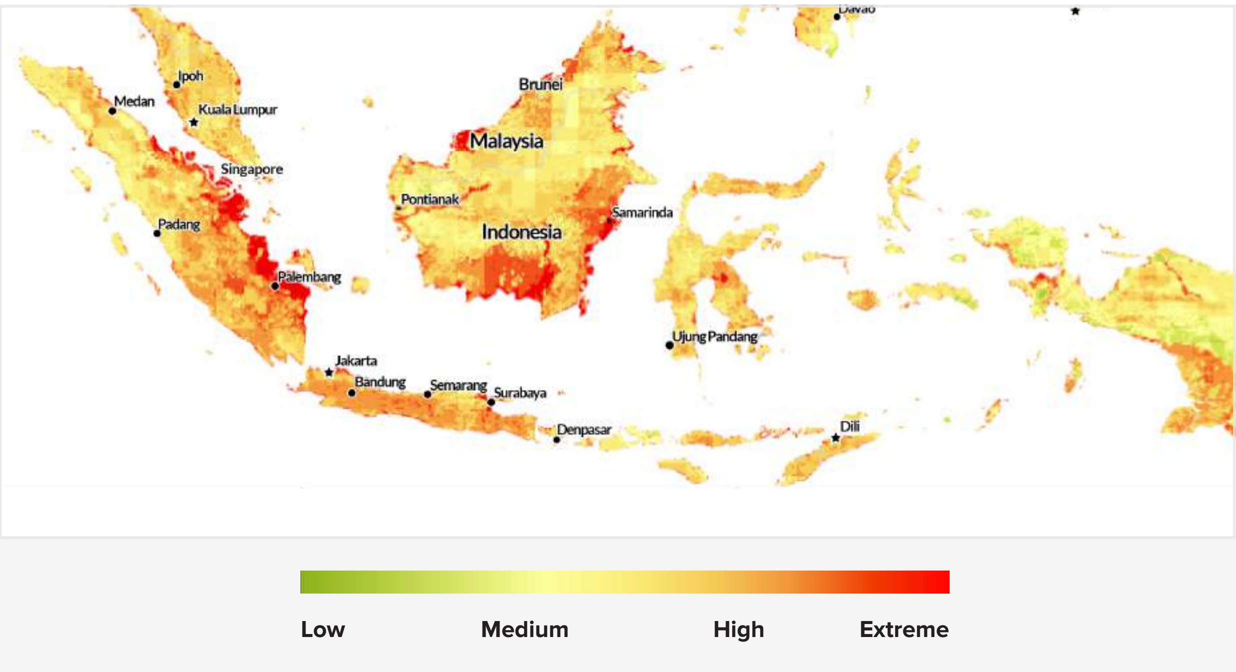
Tools	Application level	Developer	Summary	Links (and examples)
Assessment and Design for Adaptation to Climate Change (ADAPT)	Project	World Bank	Carries out risk analysis during project planning and design stage through a five-level flag classification	http://sdwebx.worldbank.org/climateportal/
Adaptation Wizard	Organization (e.g., RBO)	UK Climate Impacts Program	Five-step process to assess vulnerability and identify options to address key risks	http://www.ukcip.org.uk/
Climate Risk Impacts on Sectors and Programs (CRISP)	Program and sector	UK Department of International Development (DFID)	Structuring framework developed for portfolio screening of DFID projects, originally applied in Kenya	http://www.dewpoint.org.uk/
Community-based Risk Screening Tool for Adaptation and Livelihoods (CRiSTAL)	Project	IISD, IUCN, SEI cooperation	Participatory approach based on vulnerability assessment; features computer-assisted step-by-step procedure	http://www.iisd.org/cristaltool/
Climate Vulnerability and Capacity Analysis (CVCA)	Project and program	CARE	Features a participatory process for multi-stakeholder analysis of vulnerability and adaptive capacity, with focus on the community level	http://www.careclimatechange.org
Designing Climate Change Adaptation Initiatives: A Toolkit for Practitioners	National, subnational, sectoral, local	UNDP	Step-by-step generic guidance for analyzing vulnerability and capacity to adapt to climate change, with emphasis on the community level	http://www.undp-adaptation.org/

An example of climate change exposure mapping for risk screening is shown in figure 16, which is taken from Maplecroft's risk analysis data portal.[43] The degree of exposure is color-coded for each point on the map and captures the level of potential exposure to extreme climate-related events (drought, cyclones, storm surges, wildfires, severe local storms, landslides, flooding, and sea-level rise), incorporating predicted changes to baseline climate parameters, notably precipitation. The map combines climate change modeling data with information on past extreme events.

If the screening indicates that a more detailed risk assessment is warranted, risk managers examine the technical characteristics of the hazard. These include the hazard's location or geographic coverage, its intensity or magnitude, its projected frequency or probability of occurrence (e.g., return period), and the degree of vulnerability of the system exposed to the hazard – the latter with regard to physical, socio-economic, and environmental consequences. These steps are further described below.

Risk managers can then identify and analyze anticipatory adaptation options and measures, and compare their technical feasibility and their costs and benefits (i.e., benefits estimated as the damages, repair costs, or retrofitting costs avoided as a result of implementing adaptation measures).

Figure 16. Exposure to Climate Change Hazards



Source: Maplecroft.

43 Maplecroft (www.maplecroft.com) is a web portal that provides a quantitative assessment of different regions' vulnerability to changes in major climate parameters over the next 30 years. Maplecroft's climate change vulnerability index is obtained for each point on the map (at 22-km spatial resolution) through weighted overlaying of three component indices or sub-indices: an exposure index, which is assigned a 50% weighting, and a sensitivity index and adaptive capacity index, each assigned a 25% weighting.

B. Detailed Climate and Disaster Risk Assessment

1. Understanding Climate Change Modeling Projections and Handling Uncertainties

Assessing climate change risk means predicting the magnitude of climate change and the direction and intensity of its impacts (on flood levels, for example). Climate projections are based on plausible scenarios of future greenhouse gas emissions, as driven by population, technology, and economic factors. Climate modeling combines fundamental physics, approximations, and empirical estimates. More than 30 climate research institutions worldwide develop and run these models. Each group makes different assumptions about their estimates and therefore generates different projections.

Unlike short-term weather forecasts, projections derived from climate models are not predictions of actual future climate. The sequencing of events as simulated in climate models (e.g., occurrences of the El Niño Southern Oscillation) will not correspond to actual observations, since the models are not constrained to reproduce the timing of natural climate variations. The models only provide simulations of the future climate under various plausible assumptions, called *scenarios*. These scenarios capture a range of hypothetical development contexts and greenhouse gas emission levels, as well as (more recently, through the "representative concentration pathways," or RCPs) alternative global policy choices.

Even though climate models have become very sophisticated, the data fed to them are based on assumptions – notably, about global policies limiting greenhouse gas emissions – and these assumptions are uncertain. Hence, despite significant advances in scientific understanding and climate modeling techniques, climate projections cannot remove uncertainty. The uncertainty is managed by using climate models that thoroughly capture a region's dominant climate drivers (through "downscaling"), and by not relying on only one model.

Another aim of climate modeling is to facilitate planning and decision-making by characterizing the uncertainty so that the range of probable outcomes can be examined statistically. This is done by using an ensemble of models. In this case, the ensemble's *range* of projections is used as a surrogate for the probability distribution of the future climate (even though, strictly speaking, model data spreads are not equivalent to probability statements). The average of data from multiple models is frequently closer to observations than data from any single model – as demonstrated by short-term weather forecasting models. Thus, agreement across multiple models implies a reliable projection.

Nevertheless, model projections are still driven by assumptions and should be interpreted properly and with caution, considering the unavoidable uncertainty. Despite continuing advances in climate change science, uncertainty about impacts and outcomes will remain. Models cannot pinpoint the occurrence of any discrete climate change event; they can only estimate its likelihood through the use of probabilities. And it is not possible to precisely predict the size and form of climate change impacts, particularly at the local level, where water infrastructure resilience measures have to be implemented.

Nevertheless, there is scientific consensus that climate change will alter the hydrologic cycle in important ways. The difficulty is that the science community and its terminology uses terms like "risk," "likelihood," and "uncertainty" that policy makers and the public, including engineers, mistake for a lack of the information needed to act, encouraging either skepticism or a wait-and-see attitude.

But water planners and decision makers cannot wait for climate change uncertainty to somehow be cleared up by science or more evidence before acting, for such uncertainty is unavoidable and will not disappear. Given this, risk managers and governments should employ robust measures for resilience that can address both present and future vulnerability concerns in the face of uncertainty. This precept is reflected in the resilience principles described earlier, which suggest that risk managers should prefer diversity in adaptation solutions and contingencies, adjust to changing circumstances and prepare for extreme events, and continuously learn from experience with an adaptive mindset that can cope with unavoidable uncertainty.

Indeed, planning and decision-making strategies must fundamentally change. The old planning paradigm that shuns uncertainty is no longer appropriate. Urban planners and engineers who design urban infrastructure must become accustomed to dealing with climate uncertainty. Water resources development should adopt an adaptive approach, one that confronts uncertainty directly and proactively manages its implications. Going forward, capacity-building programs must emphasize such mind-set changes, and develop a stronger culture of ex-ante preparedness and planning for resilience.

However, it can often be challenging to integrate climate change projection data and models into day-to-day decision-making for infrastructure investment and management. To manage these difficulties, Decision-Making Under Deep Uncertainty (DMDU)[44] approaches have been applied in a variety of projects and by a range of stakeholders, including water supply providers. Using DMDU approaches, PDAMs can become more resilient by changing the way they design infrastructure, shifting the focus from the use of highly precise predictions that rely on (unadjusted) historical data (e.g., rainfall intensity) to the exploration of future scenarios.

The multiple scenarios considered under DMDU will present different degrees of challenges and require that PDAMs make decisions about trade-offs and priorities. Each water utility is unique, with different needs and capacity; each must prioritize investments specific to its own context. To achieve consensus on priorities, all stakeholders must explore the consequences of each scenario or each relevant project performance indicator (e.g., whether to prioritize cost, equity, reliability, etc.) in a participatory process. Every stakeholder should be part of an informed and transparent dialogue that considers all resilience measures and associated trade-offs.

For example, if a PDAM is exploring the potential expansion of its distribution network with a 10-year design horizon, it would need to identify the relevant natural hazards and risk exposure, and assess the different types of pipe materials suitable for this risk profile. The PDAM would then need to make decisions such as whether to use polyvinyl chloride (PVC) or high-density polyethylene (HDPE) in areas that have high earthquake risk or that are exposed to land subsidence. Whilst HDPE pipes may be more expensive, they are more flexible, do not require many pipe accessories, and are more efficient to install; thus, investment costs and operation and maintenance costs could be lower. On the other hand, PVC pipes are cheaper, but come in 6-meter bars, are less flexible, and require accessories for connections. Therefore, even if there is low risk of earthquakes in the city, it may still be more cost-efficient to use HDPE pipes.

Similarly, if a PDAM were planning new water intakes, it would need to identify the types of intake systems (e.g., the locations and types of structures and pumps), with a balanced consideration of the water levels in the river (average, minimum, and maximum level) so that water could be drawn throughout the year, even when water levels were at their lowest, whilst still allowing for the system to be operational during a flood event.

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44 More detailed information on these approaches can be found in a World Bank guidance note, the Decision Tree Framework (Ray and Brown 2015). This note illustrates practical applications of DMDU to water utilities and water resource management.

2. Expanded Framework for Climate Change and Vulnerability Assessment

Climate change and its disaster-related impacts will manifest at different times and on different spatial scales, and it is useful to conduct analyses with those differences in mind. Presented below is a framework that organizes climate change risk assessment in terms of large-scale (global or regional) climate change risk on the one hand, and local (site-specific) vulnerabilities on the other.

Risk in this context is defined as the likelihood of exposure to a climate-related *hazard* (such as extreme rainfall) and its harmful consequences (such as flooding and landslides). Vulnerability is the degree to which an area or a system (e.g., a water supply network for an urban area) is *exposed* and *sensitive* to the hazard because of its terrain, land use, and drainage infrastructure deficit, as well as the *capacity* of its residents and institutions to adjust and for its infrastructure to be *resilient* to adverse effects.

A system's *exposure* to climate hazards is influenced mainly by its location in relation to hydro-geographical characteristics (e.g., riverbank, flood plain, natural depressions). *Sensitivity* is context dependent. For instance, a surface water supply source would be highly sensitive to increasing rainfall intensity and to the resulting floods, which carry high sediment loads that increase the cost of water treatment and can damage pumps. *Adaptive capacity* depends on *non-climate* factors that mitigate the effects of climate change and related disaster risks. Adaptive capacity reflects natural, physical, socio-economic, and institutional factors that include, for example, awareness of risks and the extent to which infrastructure is designed to be resilient to shocks.

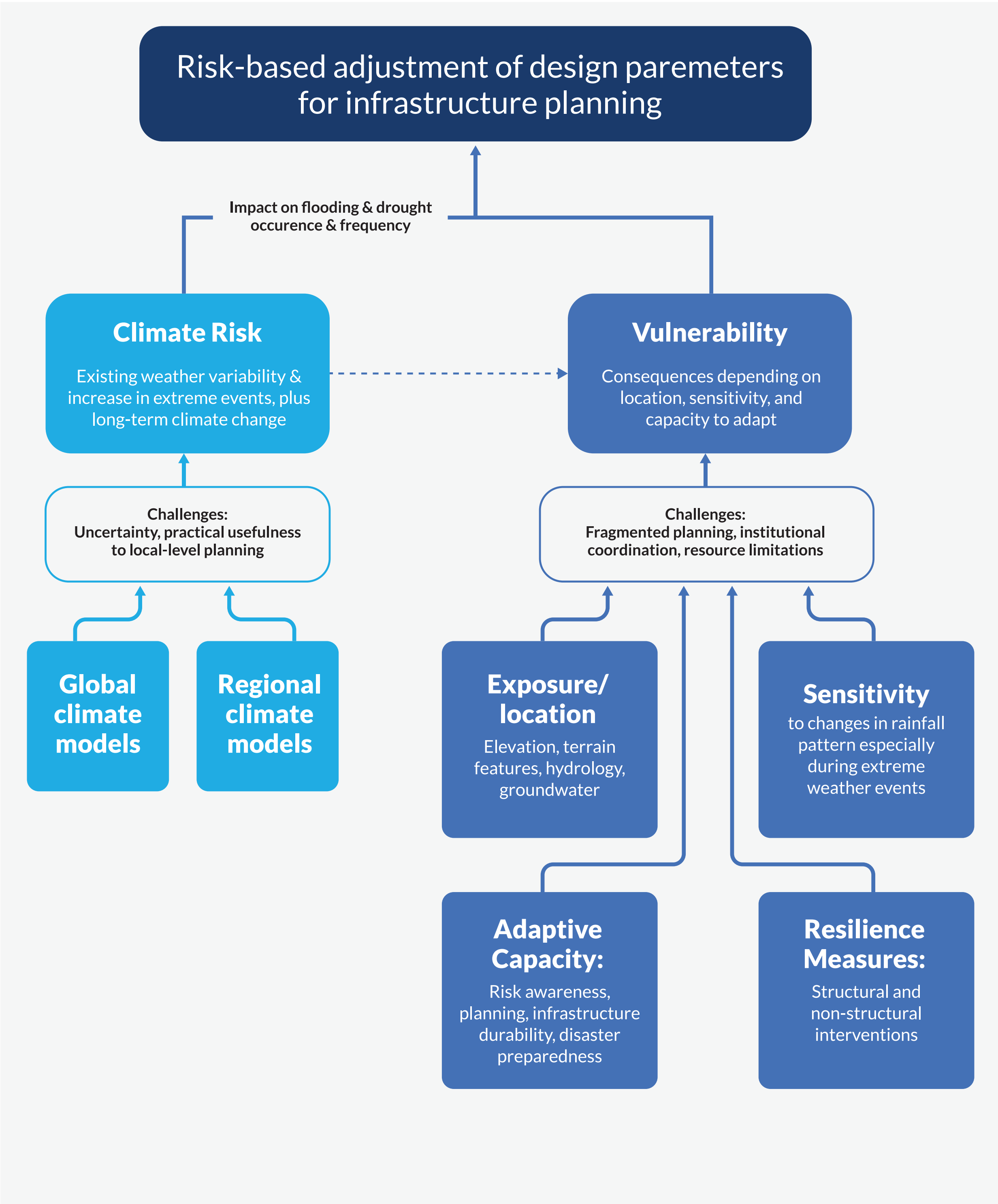
Urban systems are complex and interdependent, so, from a planning standpoint, the emphasis is not just on the climate change vulnerability of civil works but also on coordination across sectors (i.e., other infrastructure on which water supply depends, such as electricity supply and transport routes used as pipeline right-of-way).[45] Another guiding principle is to first address the immediate challenges, while drawing lessons and building capacity to tackle future problems in more innovative ways – in other words, continuously learning from experience with an adaptive mindset.

Underpinning these principles is a systematic assessment of *climate risk* using indicators that are relevant and comprehensible to stakeholders (engineers and decision-makers), combined with an assessment of site-specific vulnerabilities that enable risk managers to identify appropriate and actionable measures.

The Climate Change and Vulnerability Assessment (CRVA) framework and its steps are summarized in figure 17.

45 For instance, while raising road-top elevations in a flood-prone area is an important resilience measure for maintaining access and connectivity during extreme weather events – as well as for preventing prolonged water saturation of road structures, which undermines durability – road-raising cannot be done in isolation from area-wide water supply network planning that uses the roads as pipe routes, or without considering drainage and sewerage concerns.

Figure 17. Climate Risk and Vulnerability Assessment



VIII.

to: Pixabay

VIII. Data and Tools for Climate Change and Disaster Risk Assessment

This section outlines several common tools that are used for performing vulnerability assessments.

Carrying out the risk assessment procedure described above requires not only that stakeholders understand the technical concepts, but also that they have access to the data needed to apply the procedure properly.[46] Although plentiful data on modeling-based climate change projections are available online, in their raw form they are not useful to local governments (LGs) and PDAM planners. There are, however, data portals, such as those set up by the World Bank, that provide processed climate data that are more readily useful for climate risk assessments. Similarly, vulnerability assessments require information in a spatial format concerning asset locations, landforms, and geophysical features relevant to assessing an area's vulnerability to specific hazards. These, too, need to be made accessible in ways that allow PDAM planners to use them easily.

A. Obtaining Processed Climate Change Data and Projections

Indonesia's climate change risk profile is described in a country assessment prepared by the Global Facility for Disaster Reduction and Recovery (GFDRR).[47]

An online tool[48] developed by the World Bank provides quick access to site-level climate change projections using the latest climate change scenarios or RCPs;[49] users can just point and click on a desired location on the interactive map. This tool uses all four RCP scenarios and an ensemble of 35 global climate models. Data is presented at 1-by-1-degree grid spacing (approximately 100 by 100 kilometers).[50] In the sample output shown in figure 18, Central Java is selected, along with a specified climate model (developed by CSIRO) and scenario (RCP 8.5). The chart produced shows the projected change over four time periods from 2020 to end-century for the annual maximum five-day rainfall at a 25-year return period.

46 This sentiment was raised and repeated during the technical working group (TWG) meeting that took place on July 9, 2019, and it is central to the development of the AKATIRTA training module that will follow from this Technical Report.

47 https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_IDN.pdf

48 https://climateknowledgeportal.worldbank.org/country/indonesia

49 RCP scenarios refer to the "representative concentration pathways" for greenhouse gases that were used in the IPCC's 2013 Fifth Assessment Report. The scenarios were run using the CMIP5 family of global climate models.

50 Climate change projections based on higher-resolution (downscaled) climate modeling are available from this link: https://climatewizard.ciat.cgiar.org/. The projections in this GIS database are statistically downscaled results from nine global climate models, which were run under three SRES (Special Report on Emission Scenarios) at 50 x 50-m resolution: low (B1), moderate (A1B), and high (A2). The SRES were used in the 2007 Fourth Assessment Report (AR4) of the IPCC.

Figure 18. Online Tool for Climate Projections Based on RCP Scenarios and CMIP5 Models

(Sample output for projected change in annual maximum five-day rainfall)

Source: World Bank Climate Knowledge Portal.

The World Bank data portal is useful as it provides indicators of climate change that are relevant to specific concerns (e.g., water supply, urban development, agriculture, human health, energy use). It offers a large set of climate change and impact indicators. Table 3 lists a subset of indicators relevant to water supply planning and engineering design. Values obtained are averages or changes with respect to the baseline period 1986–2005. Using these data, each location's climate change and impact profile can be produced.[51]

Table 3. Indicators of Climate Change and Its Impacts on Drainage using RCP Scenarios

Variable	Unit	Description
Number of Days with Rainfall > 20mm	Days	Average count of days per month or year with at least 20mm of daily rainfall.
Number of Days with Rainfall > 50mm	Days	Average count of days per month or year with at least 50mm of daily rainfall.
Rainfall Amount from Very Wet Days	Percentage	Monthly or annual sum of rainfall when the daily precipitation rate exceeds the local 95th percentile of daily precipitation intensity.
Largest Single-Day Rainfall	mm	Monthly or annual average of the largest daily rainfall amount.
Largest 5-day Cumulative Rainfall	mm	Monthly or annual average of the largest 5-day consecutive rainfall amount.
Expected Daily Rainfall Maximum in 10 Years (10-yr Return Level)	mm	Statistical 10-yr return level of the largest daily rainfall event.
Expected 5-day Cumulative Rainfall Maximum in 10 Years (10-yr Return Level)	mm	Statistical 10-yr return level of the largest 5-day consecutive rainfall sum.
Expected Daily Rainfall Maximum in 25 Years (25-yr Return Level)	mm	Statistical 25-yr return level of the largest daily rainfall event.
Expected 5-day Cumulative Rainfall Maximum in 25 Years (25-yr Return Level)	mm	Statistical 25-yr return level of the largest 5-day consecutive rainfall sum.
Expected 5-day Cumulative Rainfall Maximum in 25 Years (25-yr Return Level)	mm	Statistical 25-yr return level of the largest 5-day consecutive rainfall sum.
Expected Largest Monthly Rainfall Amount in 10 Years (10-yr Return Level)	mm	Statistical 10-yr return level of the largest monthly rainfall sum.
Expected Largest Monthly Rainfall Amount in 25 Years (25-yr Return Level)	mm	Statistical 25-yr return level of the largest monthly rainfall sum.
Maximum Length of Consecutive Wet Spell	Days	Number of days in the longest period with continuous significant rainfall of 1mm or more.
Rainfall Seasonality	Standard Deviation	Standard deviation of monthly rainfall against the mean monthly rainfall across the year.

51 A current limitation of this database is that it does not provide the modeled baseline values for the indicators, so users cannot fully assess the significance of projected changes (e.g., to calculate percentage change). A historical baseline is provided but not expressed in the same parameters. Users may need to collect data from a nearby meteorological station to establish the baseline.

B.
Obtaining Raw Climate Modeling Data

Raw climate modeling data can be downloaded from other internet sources when an analysis requires it. One might, for example, perform a statistical analysis of daily rainfall data for both the modeled baseline period and a future period to compare intensity–duration–frequency charts. For large drainage areas requiring basin-wide modeling, projections of daily rainfall and relevant atmospheric conditions (e.g., temperature, relative humidity) obtained from climate models can be used as climatic time-series inputs to hydrologic models (e.g., SWAT, HEC-HMS) to assess future change in flood volumes. That is, one can compare the results of hydrologic modeling from simulations using baseline rainfall data with results from those using projected climate data.[53]

Baseline and projected rainfall in gridded format (tiles) generated from various climate models and under the 2013 RCP or 2007 SRES scenarios can be downloaded from:

- NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP)[53]
- CGIAR Global Climate Model (GCM) downscaled data portal[54]
- WorldClim global climate data[55]
- World Climate Research Program Coordinated Regional Climate Downscaling Experiment (CORDEX)[56]

Downloaded climate data sets are usually in NetCDF format, which can be processed in Excel using a plug-in program.[57] On some sites, the data is available in CSV format, which is Excel-ready.

C.
Graphical Representations of Climate Change Risk Profiles for Point Locations

For rapid climate profiling of a province, district, or city, plotting key parameters (e.g., monthly temperature and rainfall) for the baseline and future period, analysts can use the MarkSim DSSAT weather file generator.[58]

This online tool is easy to use. The output is a graphic comparison of the baseline climate versus the projected climate for any specified future year, which is straightforward to interpret and can be easily saved, copied, or pasted onto display boards, reports, or presentations. The tool uses ensemble climate modeling (multiple GCMs) under various RCP scenarios. A sample output of this rapid climate change profiling tool applied to Magelang is shown in figure 19.

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52 Hydrologic models simulate the complete hydrologic processes of watershed systems. Data inputs cover topography, land use, soil, land-use management, and climate. In very flat areas (i.e., braided river networks), such modeling is not straightforward. Fortunately, it may not be necessary for small drainage areas, as simpler empirical approaches and formulas can be used.

53 https://cds.nccs.nasa.gov/nex-gddp/

54 http://ccafs-climate.org/data_spatial_downscaling/

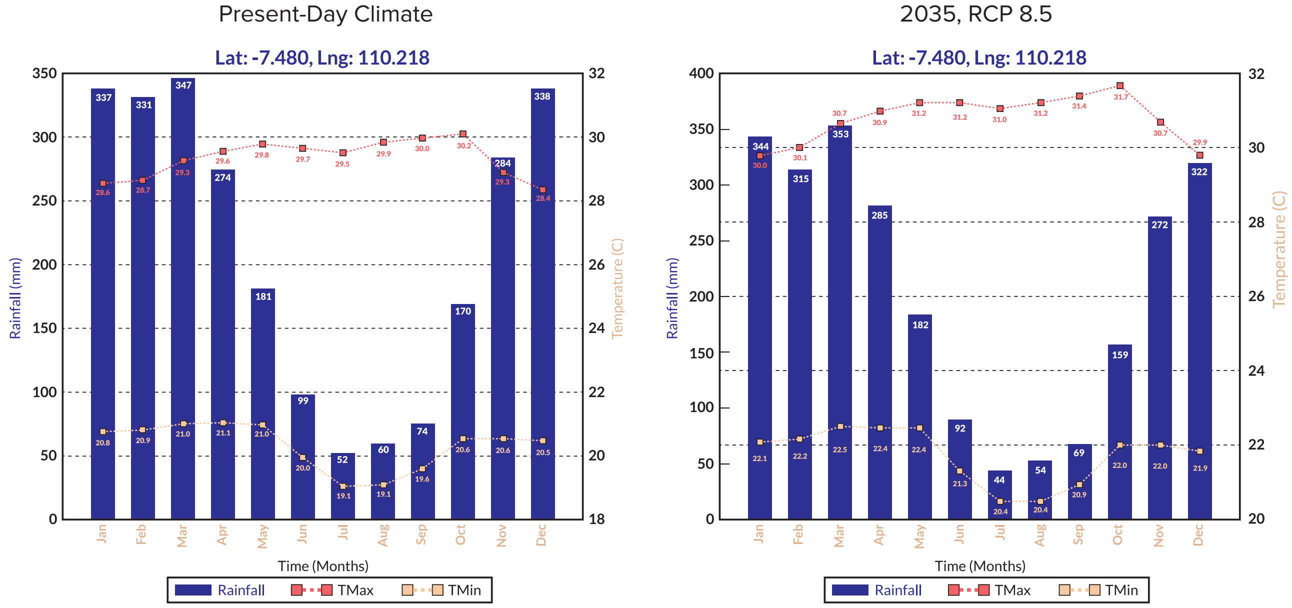
55 http://worldclim.com/version1 – CMIP5 projections are available in a set of global climate layers (climate grids) with a spatial resolution of about 1 km^2.

56 http://www.cordex.org/

57 Plug-in available at http://netcdf4excel.github.io/.

58 http://gismap.ciat.cgiar.org/MarksimGCM/

Figure 19. Climate Change Profile of Magelang, Central Java[59]



Source: MarkSim DSSAT weather file generator.

Described below is a geographic information system (GIS) tool that can also generate baseline-versus-future climate graphs like the one above, with the additional capability of showing a gridded map of the climate projections across the region (which helps when comparing geographical areas). However, this tool only uses one climate model (under an RCP 6.0 equivalent scenario) and is best used for initial area profiling and risk screening.

D.
Tools for Assessing Vulnerability

For water planners to be able to assess risks systematically, they need to be supported by appropriate and easy-to-use tools and knowledge resources. The tools described below can be set up for two purposes: (i) to facilitate climate change risk and vulnerability assessment, and (ii) to serve as knowledge products that can be used for subsequent capacity-building activities for urban water planners (through AKATIRTA).

The web-based tools described below could be assembled in a website specifically set up to support water supply planning for climate and disaster resilience. The website, perhaps maintained at AKATIRTA, would mainly serve as a repository of links to the various online tools made available by international climate and geophysical research organizations, such as the National Oceanic and Atmospheric Administration (NOAA), the World Bank and GFDRR, the European Union's Copernicus program, NASA, and the US Geological Survey (USGS), as well as the BNPB and Indonesia-based academic and research institutes working on climate- and disaster-related concerns.

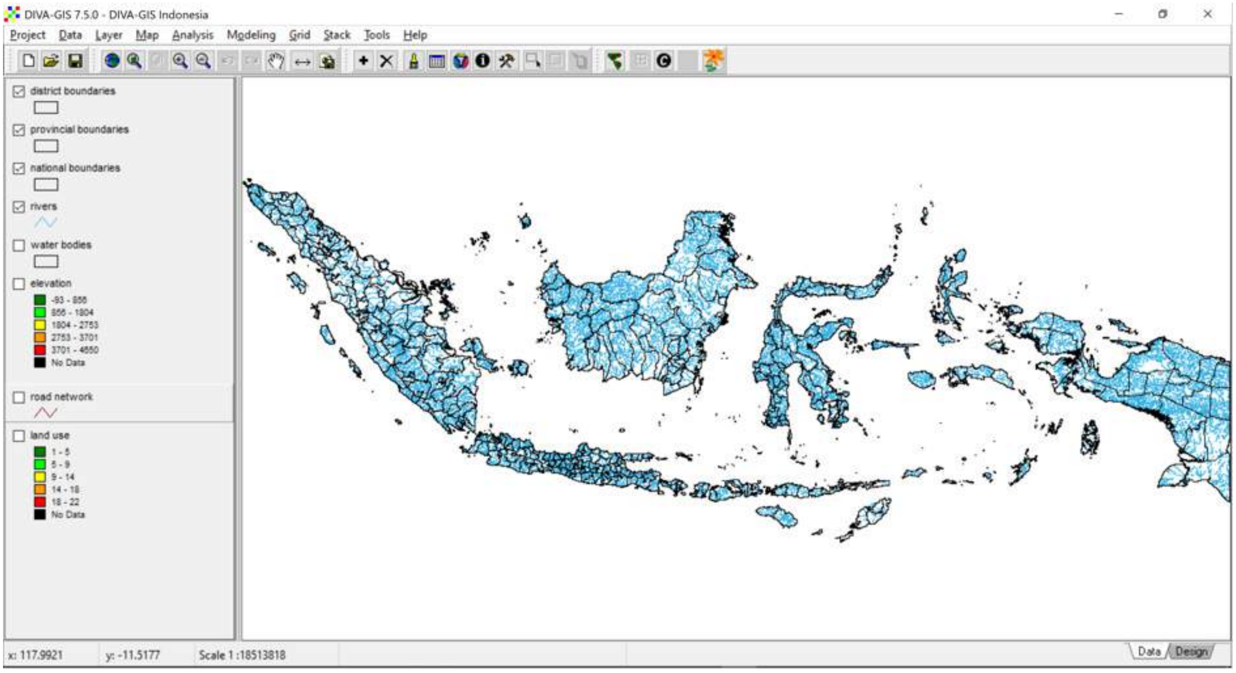
59
The 2035 projections shown in the graph are based on the average of four climate models: (i) csiro_mk3 model, developed by the Australia-based Commonwealth Scientific and Industrial Research Organization, (ii) hadgem2, developed by the UK-based Hadley Center of the Met Office, (iii) ipsl-c5ma, developed by the Institute Pierre Simon Laplace of France, and (iv) mri_cgcm3, developed by Japan's Meteorological Research Institute.

1. Geographic Information Systems

Since vulnerability is strongly influenced by location and geographic characteristics, a geographic information system (GIS) is vital for rapidly assessing hydro-geographic factors that determine exposure to climate change impacts (e.g., land use, elevations, topography, wetlands, river networks, and watersheds, which all affect vulnerability to flooding). Visualizing and manipulating information on digital maps is very helpful for performing vulnerability risk assessments. An open-source and easy-to-use GIS application can be readily set up and loaded with base maps on hydro-geography and land use, including gridded maps of baseline and projected climate change parameters.

A convenient open-source mapping software is DIVA-GIS,[60] which does not require specialized GIS know-how. The application can be zipped, copied, and distributed with no need for software licensing. The program can be installed with accompanying data on administrative boundaries and geographic features (e.g., water bodies, land use), as well as a built-in climate change model (figure 20).

Figure 20. DIVA-GIS Database for Indonesia



As more data becomes available, AKATIRTA can expand this easy-to-use GIS database. Users can zoom in easily to a zone within any province or district, or zoom down to a water supply service area or project location. Location coordinates (as a KMZ file) can also be readily extracted from the GIS and used in Google Earth to view satellite imagery, enabling planners to examine built-up areas, related infrastructure (e.g., bridges, roads, drainage systems), inland topography, bodies of water, and other geographic features. Available risk-ranking maps (shapefiles) from the BNPB can be added to the GIS.[61]

60

The DIVA-GIS installation program can be downloaded at http://www.diva-gis.org/download. The technical manual can be downloaded from http://www.diva-gis.org/documentation.

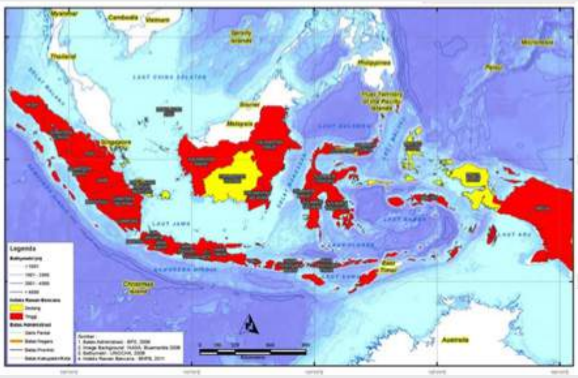
61

The World Bank–GFDRR Indonesia program facilitated an earlier disaster risk identification and assessment through the development of risk maps. The national-scale maps developed by the program show the spatial distribution of risk (as a function of hazard, vulnerability, and capacity) using the district as the smallest unit. The Indonesian National Board for Disaster Management (BNPB) further downscaled the risk mapping to the sub-district level, thus providing guidance for sub-national governments to prioritize their risk reduction efforts in areas that have higher relative risk levels.

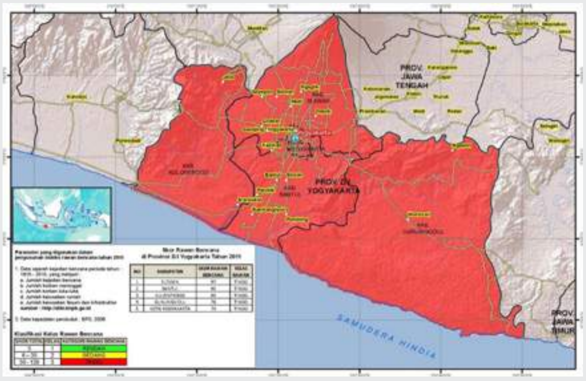
Figure 21. BNPB Disaster Risk Mapping of Indonesia

To identify disaster risk–prone areas in Indonesia, the *Badan Nasional Penanggulangan Bencana* (BNPB) has developed vulnerability indexing, in which areas (defined by administrative boundaries) are ranked by their degree of susceptibility to disaster risk. The ranking is based on their history of natural disaster occurrences and the damages suffered. A risk mapping for the whole country and a sample for Yogyakarta Province is shown below. The risk indexing is updated every two years.

Indonesia-wide



Yogyakarta Province



Source: BNPB 2011.

Thematic maps can also be readily uploaded in the GIS. These include maps of administrative boundaries (from national to provincial and district levels), locations of water supply project sites (e.g., raw water sources, transmission lines), elevation, land use, transport networks, river networks, and climate change projections. The climate change projections embedded in a GIS can also be shown in gridded format (e.g., at 20-by-20-kilometer resolution) useful for rapid climate risk assessment.

The climate projections are derived from climate models. For instance, one of the built-in climate models incorporated in DIVA-GIS is the CCSM model, developed by the US National Center for Atmospheric Research based on a scenario in which atmospheric CO_2 concentration doubles by end-century relative to pre-industrial times (i.e., roughly equivalent to RCP 6.0 scenario).

A GIS tool such as this one can be passed on to AKATIRTA students and trainees and other interested parties without the need for licenses or intensive training. As users acquire more experience, the map files can be reloaded to a full-featured GIS, like the open-source Quantum GIS (QGIS) or the proprietary ArcGIS.[62]

2. Mapping the Extent of Observed Flooding

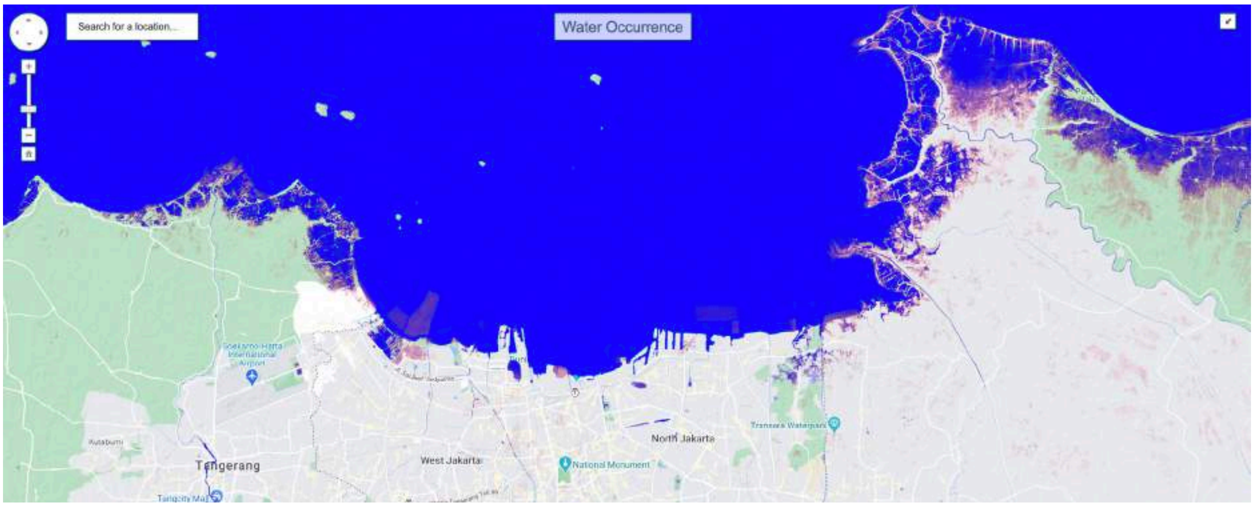
Given the predominance of flooding and landslides in Indonesia, and with the likelihood of more intense rainfall in the future, a tool for flood vulnerability mapping would be useful for risk assessment. One available online tool[63] uses an interactive, high-resolution database of surface-water occurrence. The outputted charts are useful for assessing the current situation and the need for flood-resilience measures.[64] A map showing the maximum extent of flooding in Jakarta and Bekasi is shown in figure 22.

62
The shapefiles used in DIVA are in the same format as those readable by QGIS and ArcGIS. However, grid/raster files need to be converted (using a module within DIVA).

63
https://global-surface-water.appspot.com/

64
In addition to this online flood-occurrence mapper, an online weather generator for baseline and projected climate (rainfall, temperature) is available at http://gisweb.ciat.cgiar.org/MarkSimGCM/.

Figure 22. North Jakarta Maximum Flood Extent (Zoomable at 30-m Resolution)



Source: European Commission, Global Surface Water Explorer.

The flood mapping tool above shows the frequency of water occurrence on a monthly basis, derived from 32 years of satellite imagery (1984 to 2015); the maximum extent of water cover in the area over the satellite observation period can also be mapped with this tool, which can be used to identify areas at risk from extreme rainfall events that result in flooding and landslides.

Surface Water Occurrence is the measure most relevant to water supply planning. It shows the frequency of flooding on a monthly basis. Some locations may be underwater during a given month (say, during monsoon months) every year throughout the observation period (100% recurrence), others may be underwater only a certain number of times during certain months (X% recurrence), and some never underwater (0% recurrence). For example, the output for a village location might show that, in June, there is a 25 percent chance that it will be flooded.

Surface Water Occurrence Change Intensity can be used to assess possible effects of climate change and/or land-use change. Two 15-year periods (1984–1999 and 2000–2015) are used to build a map that shows the change in the intensity of surface-water occurrence. The map shows where surface-water occurrence increased, decreased, or remained the same across the 32-year period. Both the direction (i.e., increase or decrease) and intensity of the changes are documented. Areas where water has been detected with equal occurrence in both periods (considering a tolerance of plus or minus 15%) are shown in black on the map (i.e., water presence, with no change). Locations where surface water occurrence decreased across the 32-year period are mapped in red; locations where the water occurrence increased are mapped in green; in both cases, brighter tones indicate greater changes in intensity.

Water Recurrence is also useful for water supply planning. It measures the degree of variability in the presence of water from year to year. The output describes the frequency with which water was observed in a location from one year to another, expressed as a percentage.

Using this tool, planners can select a specific location, then activate any of the mapping options available – for example, they can zoom in on a PDAM service area to check for occurrence and frequency of water occurrence there, which can then be verified in Google Earth (and in the field for validation). The output charts are useful for site assessment of flooding and landslide vulnerability.

3. Mapping Elevation, Contour Lines, and Slope

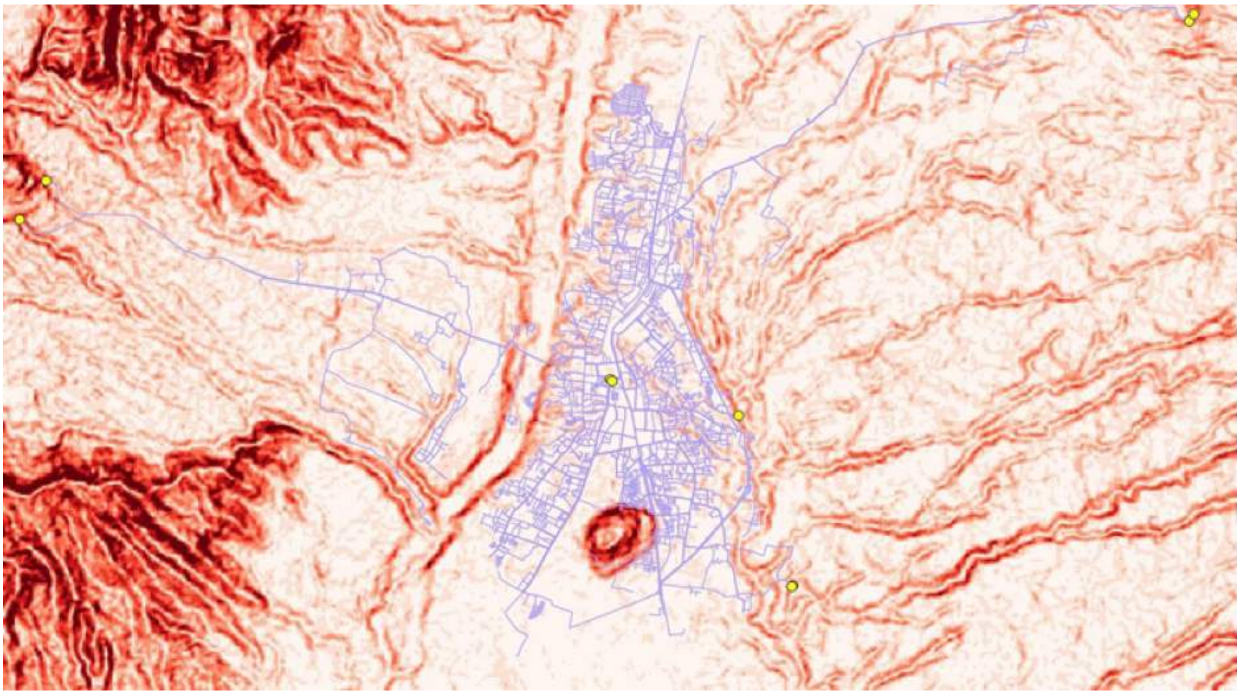
Elevation maps and contour or slope maps are important in the (master) planning of area drainage and in the engineering design of infrastructure components. These maps can be obtained from internet portals that provide *digital elevation models* (DEM). A digital elevation model is a three-dimensional representation of an area's surface (relief image) that is created from the terrain's elevation data, which is obtained by remote sensing.[65]

One quick source of terrain elevation data is the SRTM database. The acronym stands for *Shuttle Radar Topography Mission*, an international research effort that obtained digital elevation data on a near-global scale. It flew on NASA's Space Shuttle and used a radar system to acquire topographic data. SRTM's output images are arranged into tiles, each covering one degree of latitude and one degree of longitude. For tiles covering Indonesia, the available resolution of the raw data is three arc-seconds (90 meters).

SRTM images can be downloaded for free over the internet, including from the US Geological Survey (USGS) Earth Explorer.[66]

Using GIS, users can generate contour and slope maps from the DEM, which is useful for performing flooding and landslide risk assessments. Detailed steps on how to do this will be provided in the AKATIRTA training modules to be developed. In the example in figure 23, slope steepness is mapped alongside Magelang City's water supply transmission and distribution network.

Figure 23. High-Resolution Slope Map of Magelang Vis-à-Vis Its Water Supply Network



Note: The darker areas show where the steep slopes are located, including riverbanks. The yellow dots show the spring raw water sources.

65
There is no universally agreed usage of the terms digital elevation model (DEM), digital terrain model (DTM), and digital surface model (DSM). Digital surface models include buildings and other objects. Digital terrain models represent the bare ground. DEM is often used as a generic term for DSMs and DTMs. A DEM only presents height information, without any further detail about the surface.

66
https://earthexplorer.usgs.gov/. Another source of SRTM images is NASA's Earth Observing System Data and Information System (EOSDIS), hosted at http://sedac.ciesin.columbia.edu/data/.

4. Satellite Imagery and Analysis

Satellite imagery is very useful for inspecting areas at close range, which could be called for if, for instance, an analysis using the elevation and contour mapping tool above reveals that an area is located on vulnerable terrain, or if the water coverage mapping tool described earlier shows that the area is frequently underwater. Of course, satellite imagery does not replace a first-hand check of the area in the field, but it is helpful in rapidly identifying and assessing the location of vulnerability "hotspots" that require attention during planning.

Satellite imagery is best used in combination with GIS. It is useful in checking point locations at close range when the GIS analysis indicates that the location may be vulnerable (e.g., steep slopes indicated in the DEM; weak soils; or frequent inundations in previous years, as revealed by satellite images).

5. Statistical Analysis and Adjustment of Design Rainfall Intensity

Since an increase in rainfall intensity is the climate change impact most relevant to flooding and landslide occurrences in Indonesia, planners assessing risk need a method to analyze changes in the frequency of *extreme* rainfall events between a baseline or historical period and some future period. In short, the critical information is:

- How the return period of a given extreme rainfall event (say, a one-day rainfall that dumps 250 millimeters) would change in the future because of climate change; or, conversely,
- How the magnitude associated with a specified return period (data that might be used, for instance, in designing a drainage structure to accommodate a 25-year flood) would change in the future due to climate change.

Currently, rainfall intensity–frequency–duration (IFD) relationships are derived from historical rainfall records with the assumption that future rainfall will mirror the statistical characteristics of the historical rainfall record. Climate modeling projections clearly invalidate this assumption. As such, historical rainfall IFD relationships are likely to be increasingly unreliable predictors of future flood levels and drainage requirements.

Extreme value analysis (EVA) is a branch of statistics dealing with analysis of rare events that lie in the tails of probability distributions. EVA seeks to estimate the probability of events that are more extreme than those that may previously have been observed. For IFD, the random variable commonly used for the extreme value analysis is the annual one-day maximum rainfall, which is extracted from a rainfall gauging station. For any specified frequency or return period, values corresponding to the maximum one-day rainfall in the historical period being modeled are adjusted upward using the increase projected for that return period in climate models. The analyst then derives the percentage adjustments, which can be used as guide for climate-adapted designs.

For small urban drainage catchments, empirical equations (e.g., the so-called rational equation) are used to estimate peak flow based on the rainfall intensity. In these equations, the peak flow is proportional to the rainfall intensity, assuming a constant run-off coefficient.[67]

67 Where the size of the drainage basin is large, water balance modeling, which requires input of rainfall time series, is usually used.

The most common EVA approach involves fitting a statistical model to the annual extreme values in the time series data.[68] This requires putting together a sample of extreme values, which is obtained by selecting the maximum value observed in each time block (in this case, each year). This analysis procedure can be applied to both modeled climate data and actual historical data on selected climate parameters (in this case, rainfall).

Although very long period return values (say, 100 years) can be calculated from the fitted probability distribution, if the length of the return period is substantially greater than the period covered by the sample of extremes (in our case, 20 years), little confidence can be placed in the results. Estimating return levels for very long return periods is prone to large sampling errors and potentially large biases due to uncertainty about of the actual shape of the tails of the probability distribution. Generally, confidence in return levels decreases rapidly when the period is more than about two times the length of the time series data (WMO 2009).

Statistical extreme value analysis comes with uncertainty – in this case, associated with the estimation of the statistical model parameters.[69] Thus, on top of the inherent climate modeling uncertainty described earlier, statistical modeling of extreme events creates an additional layer of uncertainty. When interpreting findings, it is important to recognize this propagation of uncertainty throughout the modeling process.

6. Web-Based Tools for Rapid Disaster Risk Appraisal

A web-based tool called ThinkHazard,[70] developed by the World Bank and GFDRR, enables non-specialists to consider the impacts of disasters on new development projects. Users can quickly assess the risk level of river flood, earthquake, drought, cyclone, coastal flood, tsunami, volcano, and landslide hazards within their specified area to assist with project planning and design.

ThinkHazard uses a simple flagging system to highlight the hazards present in a project area. Based on the location specified by the user (at the national, provincial, or district level), the tool indicates whether the risk of the hazard is low, medium, or high. It also highlights how each hazard may change in the future as a result of climate change.

The tool provides recommendations and guidance on how to reduce the risk from each hazard within the specified area, and it provides links to additional resources, such as country risk assessments and best-practice guidance. The tool is intended to become increasingly comprehensive over time as users contribute new data and information.[71]

The NOAA National Centers for Environmental Information archives and disseminates tsunami, earthquake, and volcano data to support research, mitigation planning, and disaster risk management.[72] Long-term data, including photographs, can be used to establish the history of natural hazard occurrences and help mitigate against future events.

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68 When using projected climate data that cover several periods (e.g., early century, mid-century) it is assumed that the time series is stationary within any one period. Time periods must be sufficiently spaced apart for the analysis to be able to detect changes in statistical parameters between the periods.

69 Uncertainty may be related to the statistical techniques, but for extremes analysis it depends particularly on the sample series length. The fitted probability distribution is also sensitive to the inclusion or exclusion of outlier values.

70 http://thinkhazard.org/en/report/116-indonesia

71 More detailed impact analysis can be conducted on data stored at the GFDRR Innovation Lab GeoNode using the GeoSafe impact analysis tool (https://geonode-gfdrrlab.org).

72 The web portal can be accessed at https://ngdc.noaa.gov/hazard/hazards.shtml.

to: World Bank/Flickr

IX.

IX. Risk-Based Business Continuity Planning

This section provides information on the key elements of a business continuity plan and discusses various models that PDAMs could adopt.

A. Key Elements

To pave the way for action to tackle risks, and to make risk assessment an integral part of the PDAM business process, the CC/DR risk assessment procedure described earlier is best carried out within the context of *business continuity planning*.[73] Through a business continuity plan (BCP), PDAMs can specify in detail, rehearse, and regularly update actions that will be taken to prevent potential hazards (if prevention is feasible), accommodate or mitigate hazards (if they cannot be prevented outright), and in any case prepare for contingent disruptions (should risk mitigation measures provide inadequate). A BCP ensures that PDAM personnel can respond quickly in an emergency and that critical assets (including back-up facilities) continue to function in the event of a disruption. In addition, the plan must provide for *contingencies* in the event of major disasters that do not just disrupt but totally disable the water supply.

A BCP must be comprehensive. Although a BCP seems fundamentally different from an emergency preparedness and response program, the two plans must be integrated. Therefore, it is more efficient to develop a BCP from an existing emergency preparedness and response program than to build a BCP from scratch.

Detailed protocols should be prepared in advance so that the plan can be implemented properly when a disaster occurs. In an emergency, having preexisting mutual agreements with external parties (e.g., the local disaster management agency, local public works agencies, etc.) is often of critical importance. Typical emergency support includes providing heavy equipment, dispatching emergency response teams, or setting up temporary sanitary facilities. In addition, the BCP should outline if and how external parties will support the PDAM by providing continued services during the transition period after the emergency and during the longer-term recovery phase.

In Japan, utilities companies have recognized the limited resources available for restoring operations and continuing normal services following major disaster events. To address the problem, they have built mutual support networks among themselves and with the private sector as part of their business continuity management systems. For example, Kobo City has established a mutual support agreement with water supply utilities in other cities. The partner utilities agree to provide typical emergency support services, including dispatch of field engineers, provision of emergency supplies and equipment (e.g., water tanker trucks), assessment of damaged infrastructure, and critical repair work. The cooperating utilities conduct annual trainings and drills together to sustain an efficient arrangement (World Bank 2018).

[73] Business continuity management is an alternative term that emphasizes the need to continually adapt and improve the plan based on experience and lessons learned (i.e., plan, do, check, act). This approach is exemplified by the Japanese model described later in this section.

A BCP for CC/DR is a proactive planning *process*. It involves creating a *system* for managing climate and disaster risks (applying the risk assessment procedure discussed above), and instituting measures for both timely response and recovery from potential disruptions so as to secure operational continuity, particularly of the critical system components identified in the risk assessment. The plan must also provide for *disaster response and recovery* steps in case of a major disaster that causes not just a disruption of normal operations but major damage to the system, necessitating outside assistance and coordination with emergency response organizations. The disaster recovery plan should be part of the BCP.

This planning exercise has two objectives: (i) identifying low-cost options that can reduce the vulnerability of the business operation and its assets to the range of hazards assessed as significant, and (ii) preparing for contingent disaster events by managing systems and planning appropriately, such as considering in advance how to recover from a major failure. Running scenarios of failures is an important step in defining contingency plans.

In general, then, a PDAM business continuity plan (or business continuity management plan) must incorporate:

- Specific actions and measures that will ensure the continuous delivery of critical water supply services during extreme hydrometeorological events (relatively frequent but not severe), and will enable the PDAM to safeguard its assets from damage;

- Specific plans for the PDAM to provide an emergency supply of safe water during a major natural disaster or crisis, communicate and coordinate with disaster response organizations, and implement contingencies for restoring or rebuilding the system with enhanced resilience features; and

- The resources required to support business continuity and disaster contingency preparedness, including training of personnel, communications, financial reserves, and emergency response equipment and tools.

The specific contents of the BCP will depend on the identified hazards, the degree of exposure, and the location and system vulnerabilities identified during the risk assessment. It will be informed by which risks the PDAM (and its LG owners) evaluate as manageable, and which are considered to be disaster-level risks that cannot be prevented or mitigated but should instead be tackled through disaster recovery planning. In other words, when preparing the BCP, PDAMs and stakeholders must take into account their limited resources.

For the purpose of this report, the BCP is focused on risk-based planning for natural disasters ranging from hazards with low-to-moderate intensity but high frequency (notably, hydrometeorological hazards) to major but rare events (e.g., geophysical disasters). However, the BCP can also cover a wider range of threats, including power outages (those not due to natural events), sabotage, and environmental disasters caused by pollution or hazardous material contamination of water sources.

A BCP should not just be maintained as a planning document. It needs to be tested to ascertain its practicability and its ability to meet a variety of credible natural disaster scenarios. The BCP test team is normally composed of staff from each functional business unit, the emergency response officer, the security officer, and the operations supervisor. Common tests of BCPs include table-top scenario exercises, structured walk-throughs of critical facilities, and disaster simulations. Table-top disaster simulations – for instance, those performed during review of the risk assessment and management system – are easier to do regularly. Such simulations can be conducted in a workshop setting with the representatives of the various business units comparing (updated) risk maps to critical facility locations, playing out scenarios, evaluating the effectiveness of resilience measures already taken, and identifying potential gaps or weaknesses in the plan.

B.
Models for Business Continuity Planning

The BCP elements described above can be incorporated in the existing business planning model that USAID's IUWASH[74] project has developed and tested for PDAMs. This existing PDAM business planning model is currently oriented toward the technical and financial aspects of PDAM operations in support of investment planning. It need not stop there. The existing procedure can be extended to also cover the management of risks associated with climate change and natural disasters. Indeed, the financial-risk orientation of the IUWASH business planning procedure will facilitate the assessment of CC/DR risks with a view to the financial implications that are central to making decisions about resilience investments.[75]

Japan's experience also serves as a good model for how to prepare water utility BCPs that are comprehensive and regularly updated. The technical and engineering resilience measures adopted there have been more system-oriented and procedural, with an emphasis on adaptive learning and *continual improvement* of systems (a hallmark of Japanese business management). As with the lessons drawn above from the World Bank–GFDRR program in Indonesia and the USAID project in the Philippines, the Japanese experience underscores the importance of risk assessment.

The Japanese approach is built on identifying critical components of the water supply infrastructure, optimizing stormwater drainage capacity, regularly maintaining assets, adopting topography-oriented design of pipe networks so that they continue to function even when pump stations are damaged, using GIS databases to facilitate risk assessment and construction planning, and continually improving the efficiency of water distribution to control water supply quantity, quality, and leakage. These measures then become part of an integrated asset-management system that allows water utilities to continuously review and re-evaluate performance, plan and prioritize resilience investments, and make maintenance decisions.

Japan's water utilities plan and implement business continuity and contingency measures that are then iteratively improved through experience. Business continuity management and resilience in Japan entails continuously improving asset-management practices to enhance system resilience and extend the lifetime of assets. Water utilities are incentivized to upgrade and increase the resilience of their facilities by the central government, which provides a range of subsidy programs and contingency funding, especially to support capital-intensive measures.

For Japanese water utilities, disaster contingency planning covers a range of activities, including: emergency operations for water treatment plants, storage of critical materials and equipment, establishment of mutual assistance agreements for emergency response and recovery, the provision of emergency water storage systems to sustain water distribution via pipelines and water tanker trucks during emergencies, and the creation of an emergency communications system (using mass media and hotlines) to inform the public during natural disasters.

Aside from the Japanese business continuity model above, there is an International Organization for Standardization (ISO) standard that PDAMs can refer to as they set up an effective BCP model. ISO 22301 sets out requirements for a business continuity management system that is applicable to organizations of various sizes and types. By aligning their business operations with this international standard, PDAMs can obtain independently audited certification that their measures for disaster preparedness and response are adequate; these certifications enhance business reputation and creditworthiness (when applying for, say, government incentives or non-public financing).

74
The USAID Indonesia Urban Water, Sanitation and Hygiene, *Penyehatan Lingkungan Untuk Semua* (IUWASH PLUS) program is a five-year initiative designed to assist the Government of Indonesia in increasing access to water supply and sanitation services as well as improving key hygiene behaviors among the urban poor and vulnerable populations.

75
A weakness of the PDAM business plans developed under IUWASH is that, even though the risks assessed include aspects related to climate change hazards, there is no budget allotted for risk mitigation by the PDAMs. This observation was raised during the 9 July 2019 TWG discussion attended by IUWASH consultants.

to: World Bank/Flickr

X.

X. Technical And Engineering Aspects

This chapter outlines key technical design principles and standards relevant to resilient water supply systems. It recommends infrastructure improvements for reservoirs, water storage tanks, water treatment plants, water distribution pipes, water conveyance systems, drainage systems, and electrical transmission and distribution systems. It is intended to be a reference for PDAMs as they design and plan upgrades to existing infrastructure or the construction of new infrastructure. However, it is not intended to replace existing engineering standards and other comprehensive technical guidelines.

A. Existing Guidelines and Standards

Indonesia's *Engineering procedure for distribution, planning and service network units of the water supply system* (SNI 7509:2011) is a new standard that has been prepared as a reference for distribution network engineering planning and service units in the field. It aims to ensure sufficient quality of construction.[76]

The procedure covers the layout and type of the distribution system; its provisions apply to the reservoir, pumping system, water hammer, transmission pipeline, distribution pipes, service units, the results of planning, and workmanship. Its technical substance is taken from several sources, including reference books, Indonesian standards, and other countries' standards.

The complete document is available online.[77] Several sections are particularly relevant to resilient water supply systems, such as the section on reservoirs below.

[76] This standard was prepared in order to carry out the mandate of the Minister of Public Works Regulation (Permen PU) Number 16 of 2005 concerning the Development of Drinking Water Supply Systems (namely, Part Two: Authority and Responsibility of the Government, Article 38 (B) – "Establish norms, standards, guidelines, and manuals").

[77] http://sni.litbang.pu.go.id/image/sni/isi/sni-7509--2011.pdf

1. Reservoir Standards under SNI 7509:2011

The main function of a reservoir is to balance the production flow and the fluctuating discharge of water usage for 24 hours. When the amount of clean water production is greater than the amount of water used, excess water is stored in the reservoir, where it serves as a source of reserve water to cover shortages during times when water production is less than demand. Based on their function, reservoirs in the distribution system are divided into two categories: service reservoirs and balancing reservoirs.

A *balancing reservoir* serves as a source of clean water that is pumped and distributed to multiple service reservoirs. During this process, evenly distributed pumping can reduce electricity consumption since service reservoirs are filled only when needed, with an adjustable pump capacity that avoids continuous and excessive pumping. The reservoir's filling system can be either a pump system or a gravity system. Similarly, water supply to consumers is carried out by either gravity or pumping.

A *service reservoir* has several functions:

- It supplies most distribution pipelines; increases water pressure in distribution pipelines; and helps maintain a relatively stable water pressure in the distribution pipeline.
- It serves as a water supply in an emergency (e.g., when a fire occurs or when a transmission pipe is being repaired) as well for other public purposes.
- It provides a place for water to be mixed with disinfectants, ensuring more even distribution and reducing residual chlorine (an expected result of longer mixing).
- It allows for the deposition of sand or other impurities, which may be carried by water from the treatment plant or from deep wells.

The effective volume of any reservoir can be calculated via several methods:

- Tabulation: the reservoir's effective volume is the largest positive difference (in cubic meters) plus the largest negative difference (in cubic meters) between the fluctuations in water use and water supply to the reservoir. The results of the cumulative value calculation are made in table form.
- Mass curve: the effective volume is obtained from calculating the largest accumulation of surplus water plus the largest deficit from water use, then determining what that sum represents as a percentage of total water flow to the reservoir (if water were to be drained to the reservoir for 24 hours).

  Percentage terms: the effective volume is a minimum of 15 percent of the maximum water requirement per day.

For a balancing reservoir, the ideal effective volume is determined based on the balance of outflow and inflow during water usage in the service area. The effective volume required for a service reservoir is determined based on multiple factors:

- the maximum volume of water that must be accommodated at the time of minimum water use, plus the volume of water that must be provided during peak hour flow due to water use fluctuations in the service area and the reservoir filling period;
- water reserves required for city firefighters in accordance with applicable regulations from the fire service for the local area;
- special water needs (flushing, parks, and special events); and
- water requirements for backwash.

2. Green Infrastructure Design Standards under BSNI 8456:2017

BSNI 8456:2017 [78] specifies standards of design methodology for rainwater catchment wells and sub-reservoirs for eco-drainage. Included here are the design standards and guidance for engineering calculations.

Urban green open space that is sufficiently equipped with retention ponds can provide nature-based water control or eco-drainage. Water retention ponds are useful for maintaining groundwater levels, but the drawbacks are that sufficient land area is required and that land on top of the pool cannot be used for parking lots or buildings.

Technical specifications for sub-reservoir eco-drainage under the BSNI are as follows:[79]

1. Sub-reservoir material: fiber-reinforced plastic (FRP), or precast or cast concrete in situ, K350. Local materials and local products preferred.

2. Sub-reservoir construction: (1) depth of excavation above the sub-reservoir at least 100 centimeters from the ground surface; (2) thick sand work floor (10–15 centimeters); (3) concrete foundation 1:3 (one part cement to three parts sand), with steel plate or sub-reservoir belt ties FRP attached to the foundation or workshop floor; (5) sub-reservoir consisting of at least tidal sand on the bottom half and fine soil on the top half, with the topmost layer closed with a K350 concrete plate to allow for parking or the growth of grass and shrubs in gardens or landscaping above the sub-reservoir.

B. BNPB Guidelines for Disaster Risk Assessment

The Chief of BNPB Regulation Number 2 of 2012 regarding general guidelines for disaster risk assessment calls for hazards in the area to be identified. Disaster risk assessment aims to: (i) provide adequate guidance for each region in assessing risk disasters in the area; (ii) optimize the implementation of disaster management in an area by focusing on the treatment of several risk parameters with a clear and measurable basis; and (iii) harmonize the direction of the policy for implementing disaster management coordination between the central, provincial, and district or city governments with unified objectives.[80]

For example, BPBD D.I.Yogyakarta contributes to the disaster risk mapping for five districts and one city (Gunung Kidul, Kulon Progo, Sleman, Bantul, Klaten, and Yogyakarta City). A disaster risk map identifying a potential hazard that threatens the Bantul District is shown above in the section on GIS mapping.

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78 SNI 8456:2017: http://sni.litbang.pu.go.id/image/sni/isi/sni-8456-2017.pdf

79 BSNI Jurnal: http://js.bsn.go.id/index.php/standardisasi/article/view/169

80 BNPB Chief Regulation (Peraturan Kepala BNPB) No. 02 Tahun 2012 – General guideline for disaster risk assessment (Pedoman Umum Pengkajian Risiko Bencana): https://bnpb.go.id/uploads/24/peraturan-kepala/2012/perka-2-tahun-2012-tentang-pedoman-umum-pengkajian-resiko-bencana.pdf

C.
Water Safety Planning

Indonesia's Water Security Plan (*Rencana Pengamanan Air Minum*, or RPAM) is an effort to protect and control drinking water supplies for the people of Indonesia.[81] RPAM is an adoption of the World Health Organization's Water Security Plan concept, which secures drinking water through a risk-management approach. This concept is carried out with a dynamic system that begins with identifying the risks – from upstream through to the consumers – and then determines appropriate control measures. In general, RPAM is expected to strengthen water services throughout Indonesia and improve community welfare.

RPAM aims to fulfill the principle of 4K (Quality, Quantity, Continuity, and Affordability) in the provision of drinking water, as described in figure 24.

Figure 24. Water Safety Planning under RPAM

Source: Adapted from the Directorate-General of Human Settlements, Indonesia Ministry of Public Works and Housing.

RPAM is implemented under three components:

- *Component Sumber,* which aims to increase drinking water security via improvements to water sources, including springs, rivers, lakes, seas, shallow ground water, and deep ground water. RPAM-Sumber aims to control pollution and improve the quality of raw water sources for drinking water operators and consumers who use water directly from raw water sources.

- *Component Operator,* which is carried out on drinking water treatment systems, including facilities for the intake, processing, and distribution of drinking water. RPAM-Operator aims to streamline processing costs and improve drinking water service provision by the government, PDAMs, and the private sector. RPAM Operators include institutional-based operators such as regional water companies (PDAMs) and regional public service agencies (BLUD); regional technical implementation units (UPTD) that manage regional drinking water; and community-based operators such as water supply system management bodies (BP-SPAM), the Drinking Water Users' Association (HIPPAM), and village-level management bodies or communities that manage drinking water.

- *Component Konsumen*, which is a drinking water safety program at the user or consumer level. It aims to improve safe water storage methods at the household level by increasing public awareness and promoting "Clean and Healthy Life Behavior." RPAM-Consumer is intended to prevent recontamination of drinking water after it reaches consumers. The goal of RPAM-Consumer is to guarantee that the community always gets drinking water that is of high quality and meets health standards.

[81] Source: Konsep rencana pengamanan air minum (RPAM), 9 November 2014, DIRJEN Cipta Karya and POKJA AMPL in regard to RPAM.

D. Green Infrastructure Options

Green infrastructure is a cost-effective, resilient approach to managing wet-weather impacts that provides many community benefits. While single-purpose *gray* stormwater infrastructure – such as conventional piped drainage and water treatment systems – is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.[82]
Some examples (lightly edited from EPA 2020):

- *Downspout disconnection* is a simple practice that reroutes rooftop drainage pipes; instead of draining into the storm sewer, rainwater drains into rain barrels, cisterns, or permeable areas.
- *Rainwater harvesting* systems collect and store rainfall for later use.
- *Rain gardens* are versatile features that can be installed in almost any unpaved space. Also known as bio-retention or bio-infiltration cells, they are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets.
- *Planter boxes* are urban rain gardens with vertical walls and either open or closed bottoms. They collect and absorb runoff from sidewalks, parking lots, and streets, and are ideal for space-limited sites in dense urban areas and as a streetscaping element.
- *Bioswales* are vegetated, mulched, or *xeriscaped*[83] channels that provide water treatment and retention as they move stormwater from one place to another. Vegetated swales slow, infiltrate, and filter stormwater flows.
- *Permeable pavements* infiltrate, treat, and/or store rainwater where it falls. They can be made of pervious concrete, porous asphalt, or permeable interlocking pavers. This practice could be particularly cost-effective where land values are high and flooding is a problem.
- *Green streets* and *alleys* are created by integrating green infrastructure elements to store, infiltrate, and evaporate stormwater. Permeable pavement, bioswales, planter boxes, and trees are among the elements that can be woven into street or alley design.
- *Green parking.* Many green infrastructure elements can be seamlessly integrated into parking lot designs. Permeable pavements can be installed in sections of a lot, and rain gardens and bioswales can be included in medians and along the parking lot perimeter. Benefits include mitigating the urban heat island and producing a more walkable built environment.
- *Green roofs* are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water. They are particularly cost-effective in dense urban areas where land values are high, and on large industrial or office buildings where stormwater management costs are likely to be high.
- *Urban tree canopy.* Trees reduce and slow stormwater by intercepting precipitation in their leaves and branches.
- *Land conservation.* The impacts of urban stormwater on water quality and flooding can be addressed by protecting open spaces and sensitive natural areas within and adjacent to a city, which also provides recreational spaces for city residents. Natural areas that should be a focus of this effort include riparian areas, wetlands, and steep hillsides.

82
Gray infrastructure NGICP: https://ngicp.org/glossary/gray-infrastructure/.

83
Xeriscaping is a landscaping philosophy that uses as many native, drought-resistant plants as possible and arranges them in efficient, water-saving ways.

E. Engineering Options for Increased Infrastructure Resilience

A 2009 report by Miyamoto International, Inc., published by the Global Facility for Disaster Reduction and Recovery (GFDRR), included engineering options for enhancing the resilience of water supply infrastructure. The remainder of this section (Chapter X, Section E: "Engineering Options for Increased Infrastructure Resilience"), which represents the hazards, engineering options, and recommended infrastructure improvements relevant to PDAMs in Indonesia, is drawn almost verbatim from the Miyamoto International report. The original language – including descriptions of types of water supply infrastructure, vulnerability to hazards, and recommended resilience improvements – has been lightly edited for clarity and relevance.[84]

Engineering options should be selected through a comprehensive cost–benefit analysis. By allowing risk to remain unmitigated or by using certain solutions, PDAMs may accrue economic benefits or see some positive outcomes; the analysis must demonstrate that these benefits or outcomes can be appropriately traded off against the cost of a disaster's negative consequences. Planners and engineers must be able to carefully evaluate impacts that a disaster event can impose on infrastructure, the economy, health, and the environment. A detailed cost–benefit analysis will help PDAMs and local governments prioritize and choose the most economically viable solution.

In addition to the recommended infrastructure improvements below, the Miyamoto International report recommends conducting a "higher-level quality assurance (QA) protocol" – for instance, regular "testing and continual and detailed field inspections" (Miyamoto International, Inc. 2009, 119). By regularly resting and inspecting their systems, PDAMs can promptly detect and identify any retrofitting needs (e.g., for dams or water towers subject to seismic hazards) or structural issues (e.g., with pipe joints and sections in a water distribution system that has been affected by an earthquake).

In some cases, the higher QA protocols may involve installing remote sensing and early warning systems. In particular, such systems can help mitigate flood hazards for dams and water treatment plants. PDAMs whose water treatment plants face risks from flood hazards should also develop mechanisms and protocols to be used in the event of a flood (e.g., how and when to shut down the treatment plant operation) and after the flood is over (e.g., clean-up protocols, and how and when to resume operation).

[84] Some technical details and specifications included in the Miyamoto International report have been left out of this summary. The original report also included cost–benefit considerations, which have not been reproduced here. The remaining language has been lightly edited, compressed, and occasionally reordered. Clarifying footnotes have been added where appropriate.

1. Water Impounding Reservoirs

Figure 25. A Typical Reservoir (Bili-Bili Dam in South Sulawesi)

Source: Finnish Consulting Group.

Flood hazard:

- Water reservoirs can provide flood protection for areas downstream.[85] However, the reservoirs themselves can be subject to flooding.
- The key consideration is to avoid overtopping of the dam during extreme flooding, which can occur when flooding causes upstream tributaries to discharge into the dam.

Infrastructure improvement:

For water reservoirs, flood performance can be improved by several methods:

- Ensure that the reservoir is properly drenched[86] regularly to remove excess sediment and to reduce the chance of overtopping
- Ensure that the dam has adequate spillway capacity and that there is remote access to operate the spillways
- Increase the freeboard (the difference in elevation between the dam crest and the water surface in the reservoir)

85
For seismic considerations, open-cut reservoirs (*waduk*) are considered embankment dams.

86
Proper drenching can achieve the same reduction in overtopping failure risk as adding 1 m of freeboard.

Earthquake hazard:

Dams are susceptible to damage from earthquakes. Modes of failure include:

- Sliding and cracking
- Liquefaction of foundation[87]
- Embankment deformation and loss of freeboard
- Cracking of the embankment, leading to piping
- Fault displacement of a dam foundation
- Overtopping from landslides into the reservoir

Infrastructure improvement:

Earthquake performance of dams can be improved by several methods:

- Consider higher operational design standards and basic safety earthquake return intervals (i.e., larger earthquakes)
- Implement drenching
- Perform routine periodic maintenance of the reservoir
- For new infrastructure, use geophysical design provisions; for existing assets, perform geophysical (especially seismic) retrofitting

Liquefaction hazard:

Earth dams are typically constructed in areas that are susceptible to liquefaction. The increase in pore water pressure due to liquefaction reduces the soil's shear strength.[88] Reservoir loading exceeds the shearing resistance that remains in the layer, and the entire embankment slides downstream. The depth and velocity of water that flows through the gap can erode the materials along the sides and across the bottom of the gap. One type of erosion, known as "head cutting," carves channels across the crest. The channels can widen and deepen to a point at which the embankment is breached and water in the dam is released.

The first item to evaluate is the likelihood that a continuous layer or zone of potentially liquefiable material exists within the dam or the foundation. Soil property data from site testing can provide insights into the potential for such a continuous liquefiable layer. Data from a cone penetration test,[89] which is readily available, can be correlated to the cyclic stresses and to the plasticity index to help develop the likelihood of liquefaction.

Infrastructure improvement:

- Drive pre-stressed concrete piles below the liquefiable layer to stabilize the foundation and the abutments
- Place a buttress on the downstream slope of the dam and strengthen the foundation beneath the buttress with stone columns
- Ensure that the freeboard allows crest settlement, and that drains and filters can accommodate the expected shear deformations

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87

Soil liquefaction – when material that is usually a solid behaves like a liquid – occurs when a saturated soil substantially loses strength and stiffness response, as a result of, for instance, shaking during an earthquake or a sudden change in stress condition.

88

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and the interlocking of particles, and possibly cementation or bonding at particle contacts.

89

The cone penetration test is used to determine the geotechnical engineering properties of soils and for delineating soil stratigraphy.

2. Clean Water Storage Tanks

Tanks (elevated or ground supported) can be constructed of steel, wood, or concrete.

Figure 26. Water Tower in Makassar (left) and Water Tower in Magelang (right)

Source: FCG.

Flood hazard:

Elevated water storage tanks are not vulnerable to flooding. However, ground-level water tanks can be damaged and lose capacity if the water level in the tank is below the floodwater level.

Infrastructure improvement:

The key consideration is to avoid low water levels for at-grade tanks and to ensure that the foundation is anchored for elevated tanks.

Wind hazard:

Because their design is governed by seismic forces, ground-level tanks typically are not affected by wind loading except during large hurricanes. However, elevated water tanks could fail due to wind forces. The areas of vulnerability for elevated tanks include:

- High stress induced in the tank itself
- The load on the members and the structural connections (joints) of the supporting tower
- Damage from wind forces, especially in steel tanks, which are more vulnerable because of their lighter weight

Infrastructure improvement:

Water storage tanks can be improved by following the National Fire Protection Association (NFPA) guidelines (2018):

"Anchor bolts shall be arranged to securely engage a weight at least equal to the net uplift when the tank is empty, and the wind is blowing from any direction. Lightweight tanks need to be anchored against high winds in areas that experience them, and elevated water tanks should have their windage rods inspected and tightened regularly to maintain winds of 150 mph, blowing from any direction. Concrete tanks are more resistant to wind loading, so they can be considered as an effective option."

Earthquake hazard:

Water storage tanks are susceptible to damage from peak ground acceleration (PGA).[90] Modes of failure include:

- Cracking and spalling[91] of concrete tanks
- "Elephant foot" buckling of ground-level steel tanks
- Shear failure of concrete tanks
- Failure of support members and connections for elevated tanks
- Anchorage failure

Infrastructure improvement:

For water storage tanks, earthquake performance can be improved by several methods:

- Use a larger design earthquake for critical facilities
- Ensure that the tank is seismically designed and that all members and connections are designed for seismic forces
- For ground-level steel tanks, use stiffeners to delay the onset of local buckling[92]
- For concrete tanks, ensure that the walls are sufficiently reinforced to prevent shear failure
- For elevated towers, design the members and connections to remain elastic under seismic loading
- Ensure that proper types of foundation anchorage are used and that they have adequate embedment

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90
Peak ground acceleration (PGA) is the maximum ground acceleration that occurs during earthquake shaking at a given location. PGA is equal to the amplitude of the largest absolute acceleration recorded on an "*accelerogram*" at a site during a particular earthquake. Since earthquake shaking generally occurs on all three axes, PGA is often split into horizontal and vertical components. Horizontal PGAs are generally larger than those in the vertical direction, but this is not always true, especially close to the epicenter of large earthquakes. PGA is an important parameter (also known as an intensity measure) for earthquake engineering. The design basis earthquake ground motion (DBEGM) is often defined in terms of PGA.

91
"Spalling" is a break in a concrete surface that often extends to the top layers of reinforcing steel.

92
Buckling is an instability that leads to structural failure.

Liquefaction hazard:

Elevated water tanks are not constructed in liquefaction zones. Liquefaction can affect ground-level water storage tanks, however. Ground displacement due to liquefaction is a key concern, as it can result in tilting or damage to storage tanks.

Infrastructure improvement:

Yoshizawa et al. (2000) studied the performance of three tanks in the aftermath of the 1995 Kobe Earthquake. The study concluded that soil compaction to a greater depth is more effective than enlarging the width of the compaction area that is outside the tank footprint. For new tanks in liquefiable zones, the use of concrete piles is recommended. To strengthen existing tanks that are in a liquefiable zone, secant piles can be used. Secant piles[93] tend to homogenize settlement under a tank (Saez and Ledezma 2014), and by reducing the differential settlement, they also reduce damage from ground liquefaction.

3. Water Treatment Plants

Water treatment plants (WTPs) improve the quality of water to make it more acceptable for a specific end use. The end use might be consumption, industrial water supply, irrigation, river flow maintenance, water recreation, etc., or it might be a safe return to the environment. WTPs remove contaminants and undesirable components, or they reduce the concentration of these elements enough to make the water satisfactory for its intended end use.

Figure 27. WTP Panaikang – PDAM Makassar City, South Sulawesi

Source: FCG.

93 Secant pile walls are used when the shoring systems have to cut off water flow. Retain soils underneath adjacent structures or in excavations where you are unable to install lagging effectively. See https://www.kellerfoundations.ca/solutions/techniques/secant-or-tangent-piles.

Flood hazard:

WTPs are susceptible to damage from flooding. Modes of failure can include:

- Loss of electric power and loss of backup power
- Pump failure
- Flooding of sedimentation basins and subsequent contamination
- Damage to chlorination tanks
- Damage to chemical tanks
- Failure of electrical or mechanical equipment

Infrastructure improvement:

There are two main recommended techniques for reducing flood-related damage to essential water treatment systems and equipment (FEMA 2013b):

- ***Elevate equipment.*** The most effective mitigation method for flood-related damage is to raise all essential equipment to a location that is above the highest anticipated flood elevation, or to the elevation of the 0.2-percent-annual-chance flood that FEMA recommends, whichever is higher. When essential equipment is below grade, elevating typically requires relocating the equipment to higher floors in the building.

- ***Implement dry floodproofing.*** When elevating equipment is not practicable, essential equipment can be protected with dry floodproofing methods. Dry floodproofing involves constructing flood barriers or shields around individual pieces of equipment, or around areas that contain essential equipment, to prevent floodwaters from coming into contact with critical equipment. For dry floodproofing to be effective, the barrier must be high enough to protect equipment from floodwaters, strong enough to resist flood forces, and sealed well enough to control leakage and infiltration. Dry floodproofing measures must also satisfy applicable codes and standards – specifically, it should meet ASCE 24 criteria (ASCE 2015) in all locations.

  Construction of flood barriers or shields around critical equipment or elevation of critical equipment from the ground level is an inexpensive improvement that can completely prevent failure of the equipment. Building flood barriers around basins represents a much more expensive option that requires more detailed analysis to produce reliable cost–benefit recommendations, which also must be plant-specific.

Earthquake hazard:

WTPs are susceptible to damage from peak ground acceleration (PGA) caused by an earthquake. Modes of failure can include:

- Loss of electric power and loss of backup power
- Pump failure
- Damage to sedimentation basins
- Damage to chlorination tanks
- Damage to chemical tanks
- Failure of electrical or mechanical equipment or its anchorage
- Failure of piping systems

Because WTPs represent a complex system that consists of many components, failure of one component can lead to the failure of another or to failure of the whole system, also known as a “cascading effect.” Cascading effect refers to damage not only to a piece of infrastructure itself but also to the resulting distributions downline.

Infrastructure improvement:

For WTPs, several methods can improve performance during an earthquake:

- Increase the redundancy of WTP components through the addition of backup components
- Minimize the possibility and the effect of cascading failure by introducing emergency shutdown procedures for different failure scenarios
- Ensure that the buildings and mechanical equipment of WTPs can tolerate geophysical forces
- Ensure that components of treatment plants cannot be so severely damaged that they then affect the function of an undamaged component
- Improve the seismic capacity of other infrastructure facilities, especially the power network, which can adversely affect the function of a WTP
- Avoid placing pumping systems in loose sandy soil with a high groundwater table (such as the soil found near rivers). Power outages are less likely to severely affect pumping systems or to cause them to fail if such systems are not in these areas
- Ensure that water pipelines cannot fail (leak or break) under a design PGA and the anticipated permanent ground displacement (i.e., liquefaction) by making flexible pipes and adequate joint types a top priority for water supply to populated cities in earthquake-prone regions
- If an earthquake occurs, conduct an intensive post-earthquake inspection to detect all damage in water pipelines within the affected zones. Post-earthquake inspections should include various methods to detect all types of earthquake-induced defects in pipelines
- Ensure that all electrical and mechanical components are designed and installed per geophysical requirements
- Ensure that a seismic switch is installed to allow safe shutdown and safe restart
- Perform routine and regular maintenance for the facility and promptly fix any observed problems

Liquefaction hazard:

A key consideration for WTPs is the amount of time that it takes to restore operations. As with flooding damage, the timeline of restoration for liquefaction-related damage is similar to the timeline for earthquake-related damage.

Infrastructure improvement:

The primary recommendation is to build WTPs away from areas susceptible to liquefaction. The following countermeasures against liquefaction-related damage in WTPs and in pumping stations should also be considered (Matsuhashi et al. 2014):

- Install equipment at a higher elevation
- Ensure that the water resistance of the building is adequate, and install water-resistant equipment, doors, and windows
- Increase the redundancy of critical equipment

Because WTPs represent complex systems with many components, the nature of the improvement that will provide the greatest benefit depends on the plant. To address this issue, the plant should be analyzed as a system, the critical components identified, and possible failure scenarios developed. For example, if the analysis identifies a critical equipment failure that will cause cascading failure of the system, one solution is to move the plant to an area that is less susceptible to liquefaction; this solution can eliminate this mode of failure completely.

4. Water Distribution Pipes

Water distribution pipes are typically large pipes (more than 20 inches in diameter) or channels (canals) that convey water from its source (reservoirs, lakes, rivers) to a treatment plant. Transmission water aqueducts are commonly made of concrete, ductile iron, cast iron, or steel, and they can be elevated, at grade, or buried. Elevated or at-grade pipes are typically made of steel (welded or riveted), and they can run in single or multiple lines.

Figure 28. PDAM Magelang's Distribution 10-Inch Pipe (left) and PDAM Makassar's Intake Pipe (right)

Source: FCG.

Flood hazard:

Water pipelines can experience large displacements due to buoyancy effects only if the pipelines are empty (e.g., during maintenance or repair).

Infrastructure improvement:

In zones that are subject to flooding, the recommendation is to minimize maintenance or repair time. Because of the similarities in potential failure modes, infrastructure improvements in the liquefaction section also apply to flood hazards.

Earthquake hazard:

Water pipelines are susceptible to damage from both peak ground acceleration/peak ground velocity (PGA/PGV) and permanent ground deformation (PGD). Modes of failure can include:

- Excessive differential movement between the sections
- Failure of joints
- Failure of pipe sections
- Failure at manholes

For pipelines, two damage states are considered (leaks and breaks). Generally, when a pipe is damaged by ground failure (PGD), the damage is likely to be a break. When a pipe is damaged by seismic wave propagation (PGV), the damage is likely to be joint pull-out or crushing at the bell (FEMA 2013a). The loss-assessment methodology assumes that damage due to seismic waves consists of 80% leaks and 20% breaks, and damage due to ground failure consists of 20% leaks and 80% breaks.

The post-disaster restoration time depends on the availability of labor and on the number of breaks and leaks in pipes that are within a certain diameter range. Pipes with a diameter between 60 and 300 inches are assigned the highest priority in restoration. The priority level goes down as the pipe diameter decreases.

Infrastructure improvement:

For water pipelines, earthquake performance can be improved by several methods:

- Replace pipelines that are especially vulnerable to failure from PGD (resulting from liquefaction and landslides)
- Replace pipelines that are made from non-ductile (inflexible) materials, such as concrete and cast-iron pipe, which tend to fail during strong ground motion
- Create a geophysically resilient pipe network
- Introduce flexible joints

Additionally, Eidinger and Davis (2012) provided the following recommendations for improving pipelines to withstand earthquake forces. For seismic mitigation, the long-term strategy is to replace all seismically weak pipes that cross zones that are subject to permanent ground deformation (PGD), such as zones that are subject to liquefaction, landslide, or fault offset. The replacement pipes should be designed to withstand settlement from PGD (such as by using ductile iron pipe[94] with chained joints, butt fusion–welded[95] or clamped electric-resistance-welded high-density polyethylene pipe, or heavy-walled butt-welded steel pipe).

94 Ductile iron pipe product samples and specifications can be found at https://uspipe.com/products/ductile-iron-pipe.

95 Butt fusion is a thermo-fusion process. Butt fusion involves the simultaneous heating of the ends of two pipe/fitting components which are to be joined, until a molten state is attained on each contact surface.

Liquefaction hazard:

Strong ground motion can cause the development of large pore pressures with an accompanying strength loss that results in liquefaction. Based on the site geometry, the strength loss might induce lateral slope movement, ranging from a few inches to many feet, commonly referred to as a “flow failure.” Liquefaction-induced slope movement often occurs in ground that slopes gently toward a free face, such as a creek or a channel. Increases in pore water pressure can impose buoyant force on buried pipelines, which if not properly accounted for might lead to pipe flotation and possible damage. Liquefaction can also induce pipe flotation, especially for empty pipes.

Liquefaction can cause large lateral permanent deformations of soil, or soil settlement in a vertical direction. In these cases, the following failures of buried pipelines can occur:

- Failure of pipe sections: collapse of steel pipes, failure of concrete and asbestos pipes (break-type failures)
- Loss of continuity between pipe sections due to large differential rotations of the sections (leak-type failures)
- Loss of continuity between pipe sections due to large differential lateral movements of the sections (leak-type failures)

A key consideration for distribution pipelines is the time that it takes to restore operations after liquefaction damage. The timeline of restoration for liquefaction-related damage is similar to the timeline for earthquake-related damage.

Infrastructure improvement:

For water pipelines, liquefaction performance can be improved by several methods:

- Replace pipelines that are especially vulnerable to failure from permanent ground deformation (resulting from liquefaction and landslides)
- Replace pipelines that are made from non-ductile (inflexible) materials, such as concrete and cast-iron pipe
- Introduce flexible joints that can accommodate large rotations and lateral movements
- Improve the properties of backfilling soil for buried pipelines to decrease the pipelines’ susceptibility to liquefaction

5. Water Conveyance Systems

Canals, artificial channels, and waterways are used to convey water from its source, such as a reservoir. Open canals usually follow the slope of the terrain and have trapezoidal or rectangular cross-sections. Canals are typically lined with concrete to reduce water loss and seepage. Culverts are buried pipes that provide transitions for water flow underneath obstacles such as roadways. The design, vulnerability, and recommended improvements for culverts are similar to those for pipeline networks. Where metal pipes convey water, expansion joints are used to allow for movement from thermal expansion and shrinkage.

Figure 29. Intake Canal Wall at Jatimulyo, Dlingo, which was Damaged by Flood (left), and Riverbank at Tuk Pecah Magelang (right)

Source: FCG.

Flood hazard:

Canals are highly vulnerable to flooding.

Infrastructure improvement:

The following improvements can be made to reduce damage to canals from flooding:

- Provide reinforced concrete liners
- Provide sufficient freeboard to accommodate added water
- Perform regular maintenance, keep the canal clean, and remove all debris and obstructions
- Provide floodgates, flume gates, and weirs to allow water discharge during storm surges or during heavy water flow
- Next to canals, provide emergency water storage or dry canals that can be used in case of flooding

Earthquake hazard:

Canals are susceptible to damage from peak ground velocity (PGV) and permanent ground displacement (PGD) from wave propagation and permanent deformation. The hydraulic performance of a canal is the key metric to consider. The repair rate per kilometer depends on the level of damage.

Infrastructure improvement:

For water canals, earthquake performance can be improved by several methods:

- Account for larger earthquake velocities and displacements
- Use reinforced concrete lining

Liquefaction hazard:

Water canals are constructed over long stretches, and portions of them can be on liquefiable soil. Damage can include loss of bearing strength, differential settlement, and soil spreading. The key metrics to consider are the structural integrity of the canal and the canal's ability to transport water to full capacity.

Infrastructure improvement:

It is anticipated that most of the canal will be constructed away from liquefiable zones, and that liquefaction will mainly be localized. Localized ground failures are smaller-scale displacements that often can be mitigated by treating the site with soil improvement methods:

- Excavate and remove or re-compact potentially liquefiable soils
- Perform soil densification or other types of in-situ ground modifications
- Reinforce shallow foundations and improve the structural design to withstand the predicted vertical and lateral ground displacements
- Use ductile channel liners to allow for differential movement

6. Drainage Systems

A drainage system is a water infrastructure network for discharging water that has accumulated in buildings, facilities, soil, etc. The discharged water is generally called "drainage." Typically, the system is spread widely, and it generally consists of three fundamental below-ground components: the catch basin, the drain channel, and the drainpipe. For this kind of expansive infrastructure system, a multi-hazard analysis is necessary; serious hazards are governed by the natural environment at each infrastructure component location, and each system component has a different vulnerability and robustness to each hazard.

Earthquake and Liquefaction hazards:

The level of seismic damage to drainpipes is greatly affected by peak ground acceleration (PGA) and peak ground velocity (PGV) from earthquake shaking. FEMA (2013a) defines the damage states of drainpipes as follows: "For pipelines, two damage states are considered. These are leaks and breaks. Generally, when a pipe is damaged due to ground failure, the damage is likely to be a break, while when a pipe is damaged due to seismic wave propagation, the damage is likely to be joint pull-out or crushing at the bell."

Underground drainpipes can also be damaged by large permanent ground deformation (PGD) such as horizontally forced displacement and lateral spreading of soil due to earthquake-induced liquefaction (FEMA 2013a). Drainpipe networks that are buried in liquefiable and weak soils in high-seismicity areas are particularly vulnerable to such liquefaction damage.

Infrastructure improvement:

For the most critical component of a drainage system, drainpipes, replacing pipes and joints can improve deformability and sustainability during earthquakes, and is a fundamental and effective engineering improvement for existing drainpipes (EPA 2018 & FEMA/NIBS 2005). Soil improvement greatly raises the capacity of buried piping to resist liquefaction, and it is an effective engineering improvement for existing buried drainpipes (EPA 2018 & Andrus and Chung 1995). Soil improvement by permeation grouting[96] or by jet grouting[97] strengthens weak soils.

Other recommendations to increase the earthquake resistance and liquefaction resistance of drainage systems include:

- Replace existing brittle pipes with ductile pipes
- Upgrade existing nonflexible joints to flexible/expandable joints
- Assess geotechnical components and strengthen them if they are seismically deficient
- Apply soil improvements and densification via several measures (e.g., cement mixing and soil compaction)
- Move the pipe network into non-liquefiable areas
- Perform routine and regular maintenance for all components and fix any observed problems

96 Permeation grouting is a more precise term for what is commonly referred to as pressure grouting. Permeation grouting is the direct pressure injection of a fluid grout into the ground to fill the spaces between particles.

97 Jet grouting sample system and specifications are available at https://www.haywardbaker.com/solutions/techniques/jet-grouting.

7. Electrical Transmission and Distribution Systems

The purpose of an electrical transmission and distribution (T&D) system is to transfer electrical energy from generating units at various locations to the customers who need the power. T&D systems comprise a high-voltage distribution system that spans long distances and a medium-to-low voltage local distribution system. The distribution systems can be either overhead or underground. Most high-voltage systems are overhead, and this section focuses on those systems. Underground T&D systems perform similarly to underground water distribution systems.

Wind hazard:

Tall and slender (and low-damped) T&D towers are susceptible to damage from wind. Such damage can result in loss of power.

Infrastructure improvement:

For T&D systems, wind performance can be improved by several methods:

- Design the T&D system components to withstand a higher wind speed
- For distribution systems, upgrade wooden poles to concrete, steel, or a composite material, and install support wires and other structural supports
- For transmission systems, upgrade aluminum structures to galvanized steel lattice or concrete
- Add more transmission lines to increase power flow capacity and to provide greater control over energy flows

Earthquake hazard:

T&D systems are not particularly susceptible to damage from peak ground acceleration (PGA).

Infrastructure improvement:

For T&D systems, earthquake performance can be improved by using seismic components.

Wind hazard:

T&D lines that are anchored in liquefiable soil in earthquake zones are vulnerable to damage. For T&D towers that are constructed on a shallow foundation, liquefaction can result in damage and loss of operation and power for an extended period. Power restoration could be costly and long delayed.

Structural damage is used to assess the vulnerability of T&D systems. Liquefaction can damage T&D systems and cause loss of continuity, which can have a cascading effect and lead to failure of adjacent towers.

Infrastructure improvement:

For T&D systems, liquefaction is mitigated by using deep foundations (Doohyun et al. 2015). Towers that are constructed using deep foundations (piles) driven past the liquefiable layers would be immune to as extensive damage.

XI.

to: World Bank/Flickr

XI. Moving Forward

This section outlines some gaps that could be addressed in more detailed technical guidelines and standards, and suggests potential financing options that could be used to implement the technical recommendations outlined in this report.

A. Gaps that Should be Addressed in Technical Guidelines and Standards

Indonesia has put in place a collection of guidelines and regulations relevant to enhancing water supply resilience. However, the current patchwork of standards offers several key opportunities for improving the strength and comprehensiveness of regulations, particularly in the following areas:

- **Disaster risk maps.** Risk maps have not been mandated for all city or district regional disaster management agencies (BPBDs), so not every BPBD has one. Additionally, there is no mechanism for integrating disaster risk maps with PDAMs' working service maps.
- **Early warning system (EWS) for CC/DR.** Currently there is no EWS mechanism for vital components of water supply systems. PDAMs should be part of an end-to-end multi-hazard early warning system as downstream users of early warning services so that their operations can take prompt action to protect assets and services.
- **Water Safety Plan ("Rencana Pengamanan Air Minum," or RPAM)**. SNI 7509:2011 has not addressed the need for water reserves to serve as emergency water sources. As written, the emergency mechanism assigns responsibility for emergency response to the PDAM when a disaster (such as a fire) occurs. The same is true of the disaster mechanism of Perka BNPB No. 2/2012, which confirms the responsibility of PDAMs to, for example, deliver water in disaster-affected areas. Furthermore, the Safety Induction Standard for water treatment plants should be mandatory.
- **PDAM business contingency plans.** PDAMs are currently not required to mitigate the risk of CC/DR to their infrastructure assets. In addition, the current PDAM business contingency plan document does not specifically address CC/DR risk mitigation programs.
- **Neutralization of the impact of chlorine gas leakage.** There is no mechanism to mitigate the impact of chlorine gas leaks due to soil and water pollution in PDAM water treatment plants that do not have a chlorine neutralization system.

B.
Financing and Other Support Programs

Currently, PDAMs rely heavily on central government funding for local water supply development. The Government of Indonesia is working to reverse this over-reliance and to overcome the challenges of political influence in the proper pricing of water supply services.

There are various ongoing sector initiatives related to financing of water supply services in Indonesia, including:

- guidelines for setting water tariffs stipulating that tariffs must fully recover costs and generate a 10-percent rate of return on investments;[98]
- a debt restructuring program for PDAMs that includes partial or full write-off of accrued interests and penalties, and debt-to-equity conversion;
- a program of central-government guarantees and interest subsidies for commercial loans;
- output-based grants through the water *hibah*[99] program, which is the central government's primary mechanism for increasing piped water access for poor urban households; and
- special allocation funds and grants from the Ministry of Finance for water supply and sanitation through the *Dana Alokasi Khusus.*

Previous donor-assisted programs that have supported Indonesia's water supply sector include: (i) the World Bank–managed Dutch Trust Fund, which supported the *Water and Sanitation Program* (WASAP) implemented from 2005 to 2011; (ii) the Australian Aid Trust Fund, which supported the *Water Supply and Sanitation Policy Formulation and Action Planning Project* (WASPOLA) and the *Indonesia Infrastructure Support Project* (INIS); (iii) the USAID-funded *Environmental Services Program* (ESP) in 2005–2011, and *Indonesia Urban Water Sanitation and Hygiene* (IUWASH) in 2011–2016 and its follow-up IUWASH Plus, which began in 2016; and (iv) the Australian Aid/Department of Foreign Affairs and Trade (DFAT) through its *Indonesia Infrastructure Initiative* (IndII) in 2011–2017.

The Government of Indonesia has recognized the need for more integrated support and targeted financial assistance to PDAMs. To address these needs, the government recently developed the NUWAS framework for urban water supply development with support from the World Bank, including from several Australian Aid trust funds.[100]

Various existing government programs are being integrated in the NUWAS framework. The aim is to provide comprehensive technical assistance, capacity building, and investment financing targeted to local governments and PDAMs to support them in achieving specific improvement objectives.

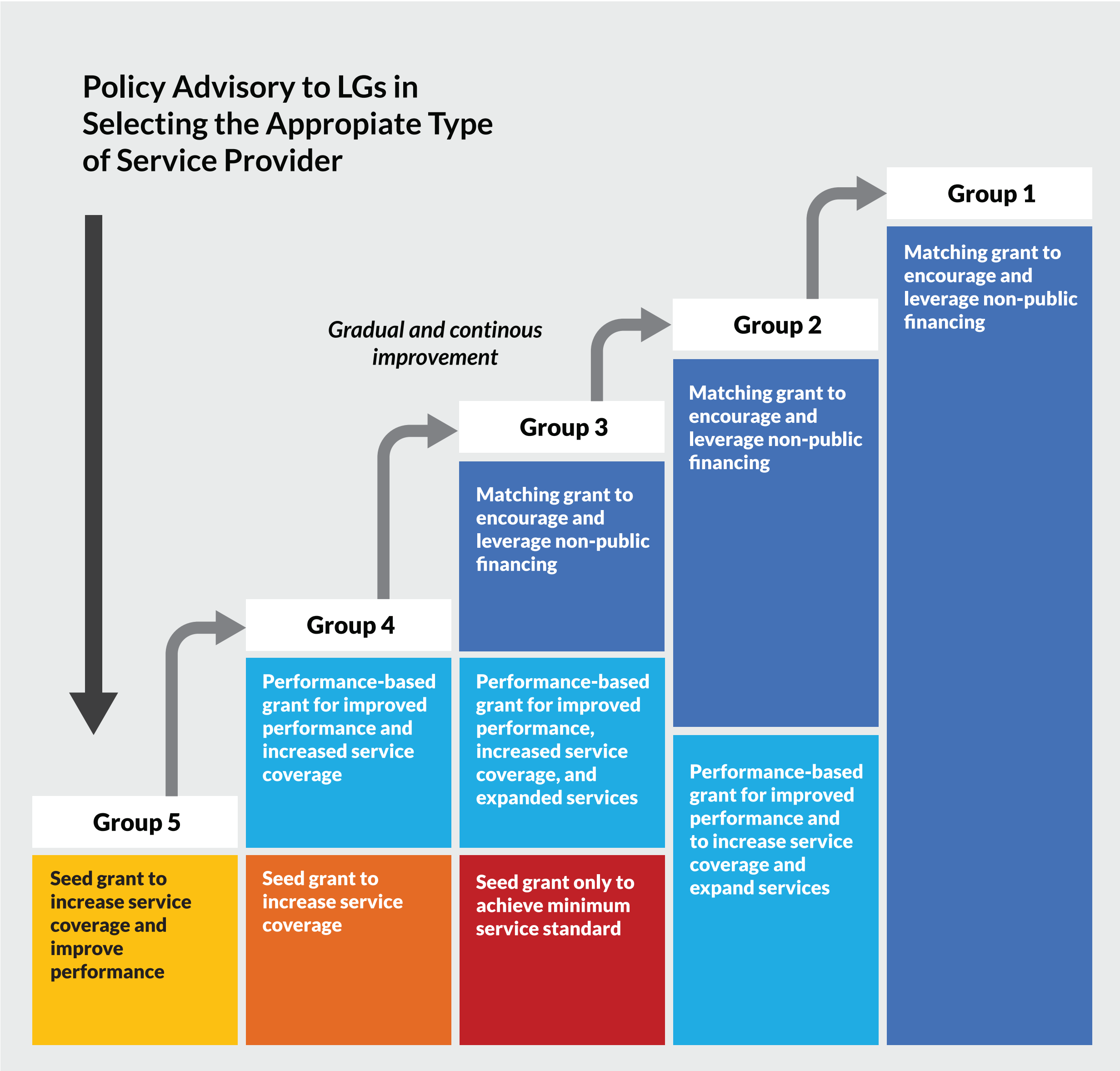
Differentiated packages of support under the program are tailored to the specific needs, capacities, and circumstances of each PDAM. Each support package is designed to integrate central and local government resources with PDAM financing, as well as to tap non-public sources of financing. The strategy is to progressively raise the performance of the PDAM so that it becomes eligible for succeeding rounds of support packages, leading to gradual and continuous improvement of overall performance.

98
The guidelines for water-tariff setting issued by the MoHA have not been accompanied by strong enforcement and monitoring and evaluation schemes, which may explain why compliance is still low.

99
The water *hibah* program started as a project to provide piped water supply services to the urban poor in Surabaya and Jakarta. It was then scaled up to a national program with funding support from Australian Aid and USAID. Since then, the program has been run using the Government's own funds.

100
The Indonesia Infrastructure Support (INIS Trust Fund) and the East Asia Australia Infrastructure Growth (EAAIG Trust Fund).

Figure 30. NUWAS Framework Incentive-Based Structure



Source: IBRD 2018.

The NUWAS framework is currently being operationalized by the MPWH Directorate of Drinking Water Supply Development of the Directorate General of Human Settlements. With support from the World Bank, the government is initiating a National Urban Water Supply Project (NUWSP) to expedite operationalization of the NUWAS framework. The NUWSP includes capacity-building support to enhance water supply infrastructure resilience (IBRD 2018).

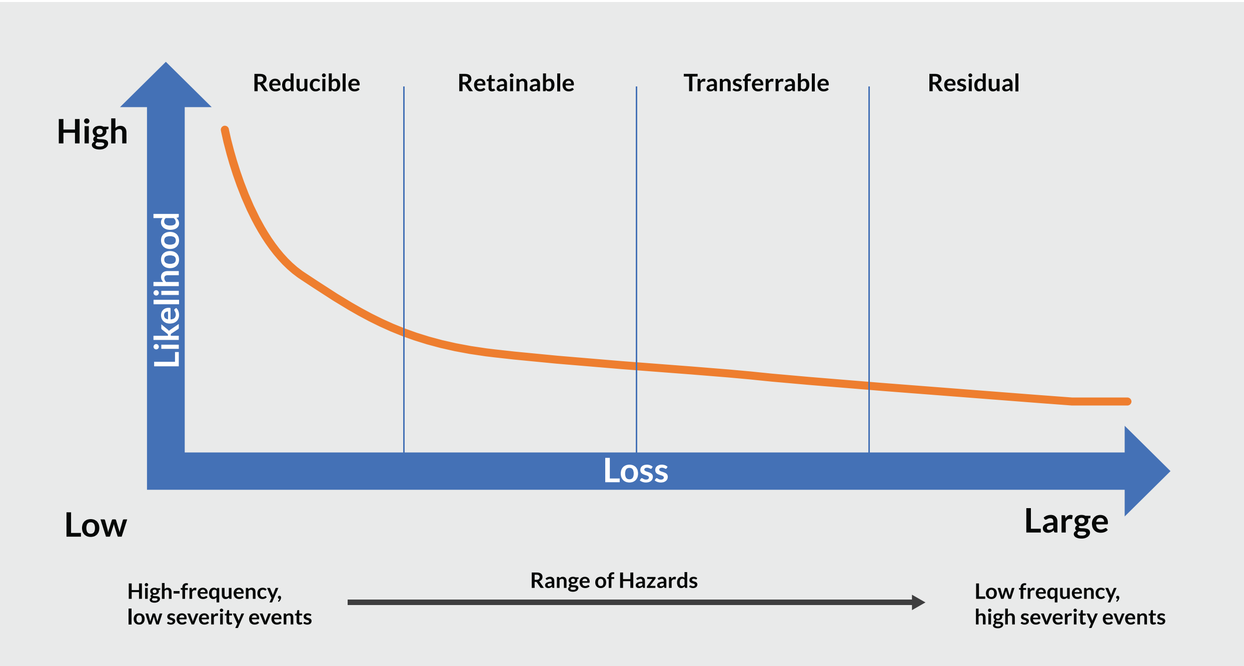
The World Bank has recently published a global study showing that every dollar invested in infrastructure resilience returns four dollars in benefits. It concludes that if infrastructure is to be resilient to natural shocks, countries first need to get the basics right: providing enabling regulations, incorporating resilience in the earliest stages of planning, and ensuring proper operation and maintenance of assets. Doing so can increase resilience as well as save costs (Hallegatte, Rentschler, and Rozenberg 2019).

C.
Alternative Financing Mechanisms for Natural Disasters

As shown in figure 31, there is an inverse relationship between the probability of an event and the magnitude of losses. High-probability events occur more frequently but are less intense and generate less damage and fewer losses, while low-probability events are more intense and generate greater damage.

- The most efficient method of managing high-probability events is to build risk prevention and risk reduction into the system. This first risk layer (Layer 1) is the **reducible** risk, for which prevention or hazard mitigation is feasible. Mitigating this risk will require investments in disaster risk reduction and climate resilience.
- The next layer of risk (Layer 2) is the **retainable** risk, which comes into play in the event that measures taken to mitigate a hazard prove inadequate, or when such measures are not technically or financially feasible to undertake. This layer requires budgetary reserves or contingency provisions as specified in, say, the business continuity plan of the organization.
- The third layer corresponds to low-probability events and is referred to as **transferable** risk, i.e., risk that can be transferred efficiently through insurance, reinsurance, or other capital market instruments.
- Finally, there is a layer of very low–probability but very high–impact **residual** risk that can only be managed though disaster preparedness and central government intervention.

Figure 31. Range of Hazard Risks and Magnitude of Damage and Losses



Source: TA Team.

Traditionally, the Government of Indonesia relied heavily on the state budget to deal with disasters, specifically a contingency fund of around 3.1 trillion rupiah annually (from 2005 to 2017), which has proven inadequate.

This report is not intended to discuss the full range of risk-financing instruments indicated in the framework above. However, it is important to note the mechanisms that are already available to finance measures for reducing natural hazard risks. These mechanisms are particularly appropriate for efforts to boost resilience by improving standards of practice and applying the resilient engineering measures described earlier – in other words, for Layer 1 risk in the framework above. The most suitable instrument for that purpose – with the added advantages of being already available – is NUWAS. NUWAS can provide financing for managing reducible hazard risks (Layer 1 above), but additional quick-disbursing financing mechanisms are needed to address the other types of hazard risks (i.e., contingency financing and insurance strategies).

In October 2018, Indonesia's Ministry of Finance launched the Disaster Risk Financing and Insurance (DRFI) Strategy, which established a pooling fund and insurance scheme for disaster financing. The DRFI strategy is suitable for flexibly addressing the financing needs of Layers 2 and 3 in the loss framework described above. Under the DRFI strategy, the government will establish a disaster risk financing instrument that will be managed in an insurance-type process. Local governments can draw on the instrument in the event that their budgets are wiped out because of a natural catastrophe. The central government may opt to reinsure the risks with either global or local insurance providers.

Examples of other financial tools include ex-ante contingent financing instruments – such as Catastrophe Deferred Drawdown Options (Cat-DDOs) and Contingent Emergency Response Components (CERCs) – and risk-transfer and insurance solutions.[101] The World Bank's *Cat-DDO* instrument provides immediate liquidity to address natural catastrophes, ensuring prompt release of funds in the aftermath of natural disasters. Specifically, it is intended to provide a quick and flexible source of funds for disaster response. It also incentivizes disaster preparedness and prevention: to qualify, countries need to have an adequate macroeconomic policy framework as well as a satisfactory disaster risk management program in place or under preparation. Under the Cat-DDO, once financing is approved for a country, the facility remains active until disaster strikes. The country can then quickly access the funding, helping relieve fiscal constraints on urgent relief and recovery efforts while avoiding disruptive reallocations from priority budget programs.[102]

Other alternatives for natural disaster financing include the Southeast Asia Disaster Risk Insurance Facility, which was launched by the World Bank Group in 2018 in collaboration with the Government of Japan. The World Bank Group also maintains a pool of funds that is available for countries affected by a disaster, including a US$2.5 billion contingent credit facility.

101
These instruments are described in World Bank Group 2018.

102
A similar example of quick-disbursing financing mechanism for natural disasters is the Asian Development Bank's Contingency Disaster Financing (CDF), launched recently.

D.
Accessing Resilience Finance through Climate Funds

An ancillary aim of this report is to better position LGs and PDAMs to absorb and allocate discrete adaptation funds, should they be available. To access these funds, projects must adhere to the planning procedure described below.

- In order to access financing through adaptation funds, LGs and PDAMs should formulate and justify their resilience initiatives based on the basic principle of *additionality.* The aim is to ensure that "additional" resources from such funds are indeed used for worthy adaptation measures, and not for business-as-usual activities. On the basis of this principle, project planners are required to justify attributions of cost for adaptation purposes. To operationalize this additionality principle, planners must follow a three-step planning procedure:

- The first step establishes a baseline planning scenario. This is defined as "business-as-usual" water resources development, with no consideration of the likely implications of long-term climate change. It uses data derived from historical records.In the second step, an alternative scenario is defined as the basis for planning. The alternative scenario(s) is based on climate change projections; planners must use climate modeling data in order to examine climate change hazard exposure. The scenario includes outcomes that are to be achieved by a set of adaptation measures that *explicitly* address climate change risk. In short, this is an altered plan that includes measures for climate resilience.

- Then planners can use the findings from the first and second steps to determine and justify the *incremental* cost of adaptation.

This three-step procedure enables decision-makers to better assess the risk that climate change poses to water infrastructure development plans, and to quantify the costs of measures for climate adaptation and resilience. This procedure is not routinely done in water planning unless the projects in question are being co-financed by climate adaptation funds that mandate it (i.e., so that the basis for justifying the adaptation cost is easier to assess).

This three-step logic applies quite readily to climate-proofing the design or retrofitting of water infrastructure. For instance, one can assess the engineering design difference and compare the estimated cost of upgrading infrastructure to meet current service standards (the *baseline* scenario) with the cost of upgrading it to even higher standards to anticipate climate change effects (e.g., providing system redundancy or back-ups).

This risk-based planning framework involves determining the likelihood of causal events (e.g., a 25-year flood), then estimating the probabilistic damage consequences of those events. Such calculations are based on projections from climate and hydrologic models under different climate change scenarios. Impact modeling software that makes use of climate modeling projections to estimate risks and guide decisions are available on the market.[103]

103
An example is SimCLIM, a computer model for examining the effects of climate variability and change over time and space.

Planners must also calculate the benefits of an adaptation measure that addresses a climate change scenario. This measurement derives from the damages avoided with reference to the baseline scenario. In practice, such avoided damages are still difficult to estimate given the uncertainty inherent in the modeling tools used for climate change prediction. Climate models cannot pinpoint the occurrence of any discrete climate change event; they can only estimate its likelihood through the use of probabilities. And as only the frequency and severity of events over time can be projected, *damages can only be estimated in a probabilistic sense*. Nonetheless, using these models enables decision-makers to systematically account for risk and to assess the robustness of the adaptation plan.

In 2012, the multilateral development banks proposed a harmonized approach for adaptation financing, under which activities are required to fulfill three *design process criteria* in order to be recognized as adaptation initiatives:

- **Vulnerability context.** A purported adaptation initiative should explain the context of climate vulnerability (exposure, sensitivity, adaptive capacity), considering both the impacts from climate change and the risks related to climate variability.

- **Adaptation intent.** Projects should include a statement of purpose indicating their intent to enhance climate resilience. This helps differentiate between projects intended to improve adaptation to current and future climate change and those that are simply "good development."

- **Activity linkage.** Proposed initiatives should link project activities to the context of climate variability (e.g., socio-economic conditions and geographical location), reflecting only direct contributions to climate resilience. The activities should reflect at least one of the following adaptation categories:

    - *Addressing current drivers of vulnerability*, especially in poor areas or communities – e.g., investments in poverty reduction, income and livelihood diversification, or health programs, when specifically designed in response to climate risks.

    - *Building resilience to current and future climate risks* – e.g., reducing land degradation, establishing reforestation programs, introducing new varieties of crops or farming techniques better suited for increased droughts and shorter rainfall seasons, investing in adaptation products and services, supporting effective early warning systems.

    - *Incorporating climate risks into investments,* especially for infrastructure with a long lifespan (for example, water-storage infrastructure).

    - *Incorporating management of climate risk into plans, institutions, and policies* – e.g., in local and national planning, water allocation programs and policies, training programs, support for research including climate information, agriculture, etc.

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ANNEX 1. PDAM Case Studies

The three case studies below illustrate the climate and disaster risks facing PDAMs and their constraints in managing such risks. The PDAMs in these case studies were selected based on their experience facing natural disaster events such as earthquakes, volcanic eruptions, landslides, droughts, and flooding.[104] Additionally, as these case studies will be used to support the development of AKATIRTA's training program, one of the three sites also needed to be located near the AKATIRTA campus so that it could be reached more easily by students and trainees during field visits.

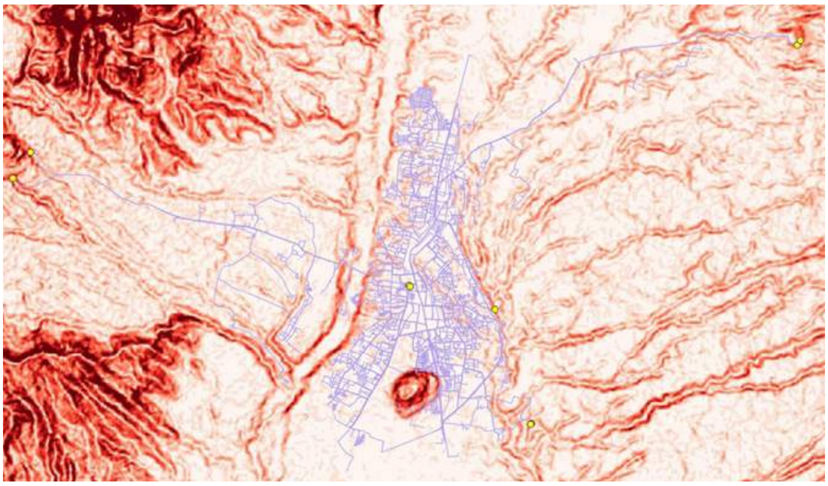
The case studies focus on the PDAMs' perception of climate change and natural disaster risks, the coping measures they have applied, and gaps and constraints, including fundamental needs for capacity building and support. The findings presented here are drawn from the detailed case study reports, which are available upon request.

Magelang City

Overview of PDAM service area and areas prone to flooding- or earthquake-induced landslides

A disaster risk map for Magelang is not available from the BPBD Central Java Office. Disaster response-related matters are handled by SatPol PP.

The image below presents an overview of the Magelang City PDAM's service area and pipe distribution network, superimposed on a slope map derived by the case study team using a satellite *digital elevation map* of the area. The darker areas show where the steep slopes, including riverbanks, are located.



104
Volcanic eruption in 2018 impacting Magelang: https://beritakompas.com/2018/05/11/gunung-merapi-kembali-erupsi/
Earthquake in 2006 in Bantul DIY: https://krjogja.com/web/news/read/61047/Gempa_Bantul_2006_Berpotensi_Kembali_Terjadi/
Flood and landslide in 2019 in Bantul: https://yogyakarta.kompas.com/read/2019/03/18/08033411/banjir-dan-longsor-terjang-bantul-2-warga-meninggal
Flash floods in 2019 in Makassar: https://www.youtube.com/watch?v=uCzghvQdm18
Drought in 2018–2019 in Makassar: http://news.rakyatku.com/read/112993/2018/08/04/air-bendungan-leko-pancing-surut-warga-makassar-terancam-krisis-air-bersih
Drought in 2017 in Magelang: https://krjogja.com/web/news/read/74360/Kekeringan_di_Magelang_Meluas_TNI_Polri_Bergerak

Characterization of the water production and distribution system

The data on water production, non-revenue water (NRW), and number of customers (based on the PDAM's annual reports for 2016, 2017, and 2018) are shown below.

	December 2016	**December 2017**	**December 2018**
Water production (m^3/yr)	15,553,161	15,261,401	15,111,762
Number of customers	28,876	30,198	31,381
Non-revenue water (NRW)	37.27%	35.30%	34.81%

Installed water production capacity

As the water resource owners, the central Government (under the MPWH Natural Resources Directorate General) and the regional government regulate efforts to increase installed water production capacity[105] with regard to the maximum level of "source production capacity"[106] that can be applied, taking into consideration the water needs for agriculture.

Based on interviews with relevant officers at PDAM Magelang City, and according to the BPKP audit report from 2017, the decrease in water production is caused by the following factors:

- Natural factors, such as occurrences of drought, flooding, earthquake, and landslides; and
- Technical factors (pipe installation damage, pump damage, and installation leakage due to material age and quality). This can be divided further into two causal factors: (i) physical factors, such as installation leakage, inaccuracy of PDAM meter equipment, and water theft or illegal connections; and (ii) non-physical factors, such as data input errors, human resource limitations, and customer payment delays.

Based on data from *Pusat Penelitian dan Pengabdian* Masyarakat (P3M)/Centre of Research and Community Service-AKATIRTA,[107] water loss can be broken down as follows: (i) legal consumption, with a revenue of 0.9%; (ii) non-physical or commercial water loss of 6.8%; and (iii) physical water loss of 34.9%.

The PDAM is facing challenges in system maintenance and in coordinating with the DPWH during road work, particularly work affecting transmission pipes laid under the roads. All the systems must be combined into one blueprint to ease and increase the effectiveness of system maintenance and repairs.

105 Installed water production capacity is the capacity or water debit that is allowed to be channeled through PDAM pipes and commercialized.

106 Source production capacity is the capacity or water debit produced by a spring source.

107 This data can be found in Bhaskoro and Aji 2018.

Natural disaster experiences that affected PDAM assets and operation in the last ten years

- *2006 earthquake.* Bantul District, Yogyakarta Special Region Province. The earthquake shifted some springs and decreased production capacity.
- *2007 long dry season (drought).* Because of the long dry season, some springs experienced decrease in their water debit.
- *2008 landslide at Tuk Udel* area (between Pressure Reducer Chambers in Putihan dan Kiringan). The landslide damaged PDAM transmission pipes (10-inch PVC), resulting in production water leakage of as much as 2,520 m^3 (70 liters per second for 10 hours).
- *2009 flooding at Tuk Pecah source area.* The Elo River overflow forced the PDAM to stop the operation of the submersible pump in order to avoid equipment damage and water quality degradation.
- *2006 and 2010 Merapi volcano eruption.* To maintain water production quality and protect the supply from volcanic ash, all “ground capturing” sources had been encased permanently. Therefore, during the Merapi eruptions, water quality from all five of the city’s sources succeeded in meeting water production quality standards.
- *2018 flooding at Tuk Pecah source area.* Due to overflow of the Elo River, the PDAM stopped the operation of the submersible pump to avoid equipment damage; the overflow reduced the quality of the water production supply.

Water supply and coordination during emergency situations

Under regular emergency conditions at the individual-customer scale, the PDAM conducts a field survey based on complaints from customers (e.g., regarding installation problems). The field survey result is processed by the PDAM as soon as possible so as to initiate a repair process (referred to in the PDAM service slogan as “one-day service”). Based on PDAM operational experiences, the longest water supply service interruption lasted for six to 24 hours. The PDAM disseminates announcements and advises the public of interruptions in water supply on local radio and social media (Twitter and Facebook). Announcements or information are usually broadcasted 24 hours before water supply service is stopped in order to give customers time to reserve water.

During water supply emergency situations at the city or district scale, the PDAM’s Supervisory Board discharges one of its main functions by acting as a bridge between the PDAM and the regional government. With regard to water supply emergencies, the PDAM coordinates with BUMD (Regional Government Business Unit). Both the Board of Supervisors and BUMD provide inputs to the regional government concerning the emergency situation and options to resolve the issue.

Under natural disaster or evacuation emergency conditions, DINSOS (Department of Social Affairs) and BASARNAS (National Search and Rescue Body) are to contact the PDAM requesting support for clean water distribution. The PDAM then distributes clean water using water tank vehicles. The PDAM has two units of these tankers, each with a 5,000-liter capacity.

Disaster risk reduction and climate change adaptation in PDAM operations	The PDAM does not have a specific department, division, or officer to assess the vulnerability of PDAM assets to natural disasters and climate change, although each relevant division conducts asset monitoring in regard to natural disasters and climate change. Additionally, there is no disaster regulation related to PDAM assignments; however, during disaster events, Basarnas (National Search and Rescue Body) and BPBD are mandated to coordinate with the PDAM regarding the distribution of water to disaster-affected areas. The PDAM currently has no water reserve facilities to store or reserve water for mitigating water supply emergencies. The current water reservoirs are primarily functioning as a "balancing system." The PDAM has built a flood-reinforcement embankment around the spring at the Tuk Pecah source to reduce the impact of flash flooding. However, if river water overflows (as it often does during big floods), the PDAM's operations and production system will be halted to prevent damage to equipment and avoid low water production quality. The PDAM has planted trees and constructed gabion walls at vulnerable slopes around the spring source areas located at Wulung, Kalegen, Kanoman, and Tuk Pecah. These are intended to protect the spring sources and pipes against landslide risk. The PDAM has encased the spring water sources with reinforced concrete structures to protect them from volcanic dust contamination during Merapi volcanic eruptions. Other risks pointed out by the PDAM are related to air and soil pollution: (i) the lack of a system to regulate chlorine usage and its effects, which, in large amounts, can pollute the air and soil;[108] and (ii) the poor sanitation system in the PDAM's service area, which indirectly contaminates the water supply.
PDAM financial overview	• High return on equity (11.12%) in 2017, so it may be concluded that the profit rate is good. • Cash ratio was 143.3%, showing that the PDAM had sufficient cash to fulfill its short-term liabilities, such as its debt at Magelang Bank, which for a three-year period was as much as Rp 1,500,000,000. • Billing effectiveness was at 93.1%, meaning that the PDAM was able to effectively manage its income from selling to customers (water receivables). • Solvability ratio was 1,085.3%, indicating that the PDAM had assets guaranteeing long-term liabilities.

108
This is also relevant for maintenance: it is important to consider using alternative materials for the chlorination process to reduce corrosion of equipment (i.e., transmission pipes and other assets).

- Cost of repairs to damaged PDAM assets: (i) The PDAM has a budget allocation for repairing damaged facilities. It does not use donations from other organizations or institutions. (ii) The strengthening of facilities and large-scale renovations are jointly funded by several institutions, including the PDAM, the regional government, and the central government.

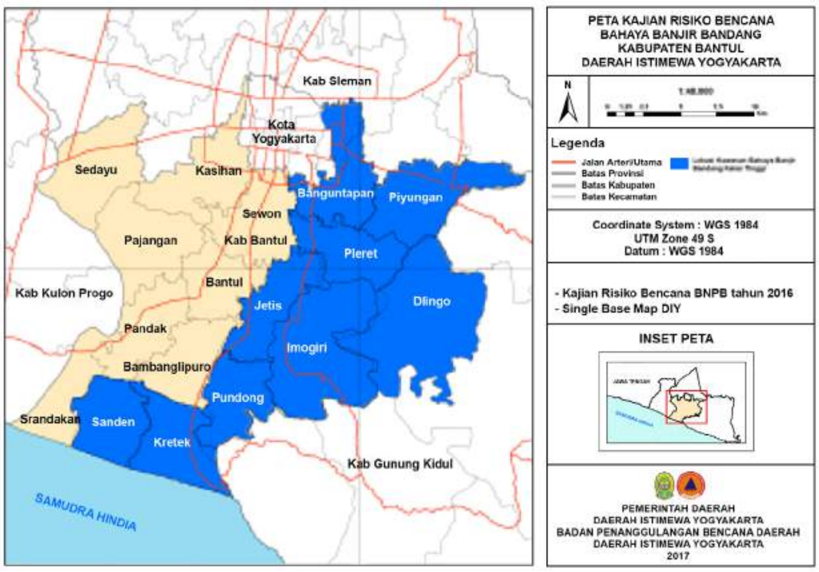
PDAM's business continuity plan

"PDAM of Magelang City Business Plan Report Year 2019 – 2023" was developed with assistance from USAID/Indonesia in Indonesia Urban Water, Sanitation and Hygiene. *Penyehatan Lingkungan untuk Semua*/Making a Healthy Environment for All (IUWASH PLUS) mentions that the business development program is grouped into several field programs. These programs are the (i) Technical and Operation Field Program; (ii) Service Field Program; (iii) Finance and Human Resources Field Program; and (iv) AMDK Business Field Program.

Bantul District

BPBD disaster risk map covering the service area of the Bantul District PDAM

The map below shows the portion of the disaster risk map for the Bantul District area, as prepared by the BPBP D.I. Yogyakarta Office, that covers the Bantul District PDAM's service area.



The blue areas are subject to high risk of flash flood. These areas include *Sanden, Kretek, Pundong, Jetis, Imogiri, Pleret, Dlingo, Banguntapan,* and *Piyungan,* which overlap with PDAM Bantul's water treatment plant locations.

Based on information provided by the PDAM Design Division *(Bagian Perencanaan)*, service development planning is initiated by the Design Division, which is supposed to use GIS to monitor the implementation and performance of the water supply distribution system based on the plan. However, the Design Division is facing difficulties in operating its GIS, including for the data-collection process. The division reportedly has not had any intensive training in operating the GIS system.

Characterization of water production and distribution system

According to the PDAM's annual reports for 2016, 2017, and 2018, there was an increase in water production volume and in the number of customers served, whereas water loss or non-revenue water (NRW) decreased.

	December 2016	**December 2017**	**December 2018**
Water production (m^3/yr)	7,489,910	7,761,419	8,759,585
Number of customers	26,079	28,737	31,058
Non-revenue water (NRW)	27.05%	26.29%	25.80%

The PDAM has prepared quick and ready installations all over Bantul District for people who do not have PDAM clean water access. However, not all community members want to be PDAM customers, particularly those who already have access to other water sources, such as traditional wells.

Installed water production capacity

Raw water sources used by the PDAM comprise springs, surface water, and deep wells. The available raw water source capacity is 613 liters per second, and to obtain raw water the PDAM uses both gravity systems and pumping systems, which are rated at a capacity of 293 liters per second.

In addition to the raw water sources above, PDAM Bantul can use the water obtained from a water treatment plant (*Instalasi Pengolahan Air* – IPA) built by the Directorate General of Cipta Karya and the Opak Progo River Regional Center, located in *Argosari Sedayu Bantul.* The Bantul District PDAM was allocated 100 liters per second from this water treatment plant.

Based on the information of the PDAM production division, additional (supplementary) water supply during times when PDAM Bantul's own production is deficient is provided through contracts[109] with Cipta Karya SPAM Regional MANTULKARTA Province or "Yogyakarta-Sleman-Bantul" (through the Balai PISAMP). Through these contracts, the PDAM obtains additional water ready for distribution. The additional water is sold at a price greater than the tariff usually applied by PDAM Bantul.

Bulk water from "Regional SPAM" is sold to PDAM Bantul at a price of Rp 2,250 per m^3 (out of the flow meter), while the distribution price of the PDAM (for its independent production) is Rp 3,000 per m^3 for water sold to PDAM customers.

109
The work contract for the Regional SPAM tariff is based on the applicable provisions, in accordance with the Cooperation Agreement for the supply of raw water No. 815/6203; No. 690/1565; No. 66/spks/pdam/slm/x/2017 and No. 690/147/pdam/btl/2017. *Dokumen perjanjian kerjasama antara Balai Pengelolaan Infrastruktur Sanitasi dan Air Minum Perkotaan (PISAMP) Dinas Pekerjaan Umum Perumahan dan Energi Sumber Saya Mineral DIY dan PDAM Tirta Marta Kota Yogyakarta dan PDAM Tirta Dharma Kabupaten Sleman dan PDAM Tirta Dharma Kabupaten Bantul (tentang pemanfaatan sistem penyediaan air minum regional di wilayah kota Yogyakarta, Kabupaten Sleman dan Kabupaten Bantul DIY)*, documented and available if needed for further study.

There is a difference of Rp 750 per m^3, which the PDAM must use to finance its operations (clean water distribution services, installation services, etc.), for activities related to reducing non-revenue water, and for PDAM company profits and taxes.

Non-revenue water (NRW)

Based on the BPKP audit report for 2017, the loss of water is caused by a combination of the low quality of raw water, the need to use water to remove sediments and wash filters, and the failure of water treatment.

The audit report recommended repairing the intake building by holding mud drains; monitoring changes in raw water from trash; monitoring changes in raw water and chemical settings to anticipate sudden differences in turbidity levels of raw water; optimizing maintenance and repair of production installations; and optimizing pump work in production installations in anticipation of overflow (wasted water).

NRW is caused by distribution networks that have been damaged and often leak due to network age factors, damaged or leaking customer water meters, and water theft or unregistered connections. To control NRW, the audit report recommended conducting a search of customers that use more than 10 m^3 of water in three consecutive months; improving distribution network systems and replacing damaged or leaky pipes; replacing damaged customer water meters; and implementing meter-reader rotation and controlling unauthorized connections.

As in Magelang, the PDAM in Bantul District is facing challenges in system maintenance and in coordinating with the DPWH during road work, particularly work affecting transmission pipes laid under the roads. All the systems must be combined in one blueprint to ease and increase the effectiveness of system maintenance and repairs.

Natural disaster experiences that affected PDAM assets and operations in the last ten years

- *2018–2019 flash flood in Bantul.*[110] Flash flooding came from Gunung Kidul. The impact of the Dlingo floods resulted in secondary flooding in the direction of the Dodokan Jatimulyo WTP; the Parangtritis WTP was also affected.
- *2017–2018 Imogiri and Pundong floods.*
- *2017 Cempaka cyclone disaster.*[111]
- *2010 Mount Merapi eruption.* The eruption affected the NTU (turbidity) of the raw water in the WTP performance system and impacted the performance of intake buildings, including the pumping of raw water. The process of sedimentation in each WTP requires extra care.
- *2006 earthquake and drought.*

110 Local headline news of Bantul flash flood (Dlingo) can be accessed through the following links: https://regional.kompas.com/read/2019/03/18/11434041/kabupaten-bantul-jadi-wilayah-terbanyak-terdampak-banjir-dan-longsor and https://news.detik.com/berita-jawa-tengah/d-4471925/sungai-meluap-puluhan-warga-imogiri-bantul-dievakuasi.

111 Local headline news of floods disaster impact (Cempaka cyclone) can be accessed through the following link: https://kabar24.bisnis.com/read/20171207/78/716065/javascript.

Water supply and coordination during emergency situations

Under normal emergency conditions at the customer scale, the PDAM conducts field surveys of complaints from customers (e.g., for installation disruptions). The results of the field survey are processed by the PDAM as soon as possible so that the repair process can proceed without delay.

Based on the PDAM's operational experience, water supply disruption is of one-day duration at most. PDAM Bantul's standard operating procedure requires that customers must be notified of disruptions in water distribution no later than 24 hours in advance. The PDAM has also deployed an Android application to alert customers to water supply disruptions ("PDAM Bantul application").[112] The longest disruption to water supply was three days. This was due to damage to the intake structures and interruption of the distribution transmission pipelines.

When flooding damages a bridge and the pipes that use it as a crossing, the PDAM must wait for the bridge repair work (performed by the PUPR Service) to be completed before they can repair the damaged PDAM pipeline. While waiting for the infrastructure repair process, the PDAM installs a temporary pipeline connection.

For disaster-related emergency water supply needs, the reporting system is as follows:

- Reporting mechanism 1: If a natural disaster occurs in the region, the disaster management team formed by the district (in this case, the BPBD) collects all disaster studies from related parties (of which the PDAM is one). All information related to the disaster is funneled through the BPBD. The BPBD reports to the *Bupati* (Head of District) and subsequently the Bupati reports to the provincial government, with copies sent to the national government.

- Reporting mechanism 2: The PDAM reports its assessment of the natural disaster to the Water Supply System Development Work Unit (SATKERSPAM); the report is then forwarded to the DIRJEN *Cipta Karya* and copied to the ministry.

Disaster risk reduction and climate change adaptation in PDAM operations

The Bantul District PDAM does not have a specific department, division, or officer to assess the vulnerability of PDAM assets to natural disasters and climate change. However, each relevant division conducts asset monitoring in regard to natural disasters and climate change.

The PDAM has no water reservation system thus far to store or reserve water in response to water-source emergencies. The current water reservoirs are mainly functioning as a "balancing system."

Siltation at the Pajangan WTP and flash flood risk at Jatimulyo (Dlingo) – both of which are related to climate change and natural disaster occurrences – have been identified as significant risks to water supply assets. The water source is located in the path of flash floods, and the PDAM water treatment plant, which is located on the riverbank, has already been affected before by flooding.

112
PDAM Bantul application can be downloaded through the Android Playstore.

Considering the siltation of rivers in the water intake area, the PDAM plans to make greater use of shallow wells.

The PDAM has an "Integrated System," in which the water supply system serves to mitigate the installation damage caused by flooding. There is no specific unit assigned to CC/DR concerns. However, during the overflow of water from upstream rivers in the Gunung Kidul area, reports from WTP operators are routinely carried out as preventive measures in anticipation of asset damage.

To address the flash flood risk at the Trimulyo Sub-Unit, the PDAM sought assistance in reinforcing the distribution transmission pipe bridges. The work was carried out by SATKER PSPAM DIY with disaster management funds from the central government. The PDAM submitted a proposal addressed to the central government through SATKER PSPAM DIY.[113]

Like in Magelang, other risks pointed out by the Bantul PDAM are related to pollution: (i) the lack of a system to regulate chlorine usage and its effects, which, in large amounts, can pollute the air and soil; and (ii) the poor sanitation system in the PDAM's service area, which indirectly contaminates the water supply.

PDAM financial overview

Based on BPKP Performance Audit, PDAM's financial performance in 2017 was scored at 0.865, a decrease of 0.055 from the score in 2016 (at 0.920).

Other indicators of the Bantul PDAM's financial performance are:

- Return of Equity (RoE) of 2.23%
- Operational ratio of 0.96

The PDAM Bantul financial report for 2017 has been audited by an independent auditor[114] and received a rating of "normal" in accordance with the independent auditor's report (number 34/LAI-GA/III/2018, dated 12 March 2018).

PDAM's business continuity plan

Based on PDAM Bantul's business plan report 2015–2019, the five-year work plan covers the following:

1. Service programs, which include expanding coverage of services and improving quality by building and perfecting WTPs;
2. Financial programs, which include financial restructuring and achieving full cost recovery;
3. Operational programs, which include reducing the level of water leakage, increasing production flow, and improving pipelines; and
4. Management and Human Resource programs, which include regulatory strengthening, human resource professionalism improvement, and an employee guidance system.

113 Proposal addressed by PDAM is for the five locations of distribution transmission pipe's bridge, however, until now it has only realized assistance for one bridge.

114 Public Accountant Office Drs. Soeroso Donosapoetra.

Makassar City

BPBD disaster risk map for areas covered by the services area of Makassar City PDAM

The figure below integrates Makassar City PDAM's service area and the disaster risk map of the area prepared by the BPBP Makassar Office.[115]

Characterization of water production and distribution system

Based on the PDAM's annual reports for 2016, 2017, and 2018, water production decreased even as the number of customers rose. The percentage of non-revenue water has been reduced.

	December 2016	December 2017	December 2018
Water production (m^3/yr)	92,023,315	90,909,098	88,004,292
Number of customers	168,454	169,413	172,447
Non-revenue water (NRW)	49.03%	48.09%	46.68%

The Makassar City PDAM has been offering expedited water supply installations for people who do not have piped water access. However, not all community members want to be PDAM customers, particularly those who already have access to other water sources, such as traditional wells.

[115] The BPBD office of Makassar City stated that they have no capacity to prepare a disaster risk map using GIS.

Installed water production capacity	The PDAM's water supply and distribution system consists of five distributed Water Treatment Plants that obtain water from two sources, as follows: *From the Jeneberang River raw water source:* • IPA-1 Ratulangi serves Marios, Mamajang, Makassar, Ujung Pandang, and Bantoala sub-districts with an operational capacity of 50 liters per second. • IPA-2 Panaikang serves Makassar, Wajo, Bontoala, Ujung Tanah, Tallo, Panakkukang, Manggala, Biringkanayya, and Tamalanrea sub-districts with an operational capacity of 1.3 liters per second. • IPA-3 Antang serves Manggala sub-district with an operational capacity of 95 liters per second. • IPA-4 Maccini Sombala serves Mariso, Majo, Bontoala, and Ujung Tanah sub-districts with an operational capacity of 300 liters per second. *From the Bili-Bili Dam raw water source:* • IPA-5 Somba Opu serves Mariso, Mamajang, Tamalate, Rappocini, Makassar, Ujung Pandang, Panakkukang, and Manggala sub-districts with an operational capacity of 1.55 liters per second.
Non-revenue water (NRW)	Based on interviews with relevant divisions of the Makassar City PDAM, the decrease in water production was caused by natural and technical factors. Natural factors include drought, flood, earthquake, and landslide occurrences. Technical factors are related to damages at distribution pipe installations. The latter can be divided further into two causal factors: (i) physical factors (such as installation leakage, inaccuracy of PDAM meter equipment, and water theft or illegal connections), and (ii) non-physical factors (such as data input errors, human resource constraints, and customer payment delays). Based on the 2016–2018 annual reports on NRW, there were several causes of the high non-revenue water in the PDAM's service area, including consumption without meter but with account; consumption with meter but without account; and consumption without meter and without account. The PDAM of Makassar City did not provide the case-study team with its BPKP audit report. As such, NRW review and BPKP recommendations cannot be presented in this report.
Natural disaster experiences that affected	• *2019 Sungai Jeneberang River Inundation*.[116] This river inundation hit the city's bridges. It resulted from a flood from Malino that caused the Bili-Bili Dam channels to be opened: "The Malino flood caused the water level in the Bili-Bili Dam to reach alert status, so the government had to open the water channel, causing the Jeneberang River inundation." • *2018 flash flood in South Sulawesi.*[117] Water came from the Bili-Bili Dam inundation, reaching over 100 meters in height. This flash flood cut off several roads and bridges and flooded some Makassar areas.[118]

116
Jeneberang River Inundation: https://regional.kompas.com/read/2019/01/22/16455041/sungai-jeneberang-meluap-jembatan-putus-ratusan-rumah-kebanjiran and https://regional.kompas.com/read/2019/01/22/16455041/sungai-jeneberang-meluap-jembatan-putus-ratusan-rumah-kebanjiran

117
The flash flood in South Sulawesi can be watched in this video link: https://www.youtube.com/watch?v=uCzghvQdm18

- *2018 drought at Lekopancing Dam.*[119] This rain-fed dam only had 20–30 percent of its normal water debit left during the dry season. The PDAM made an effort to mitigate this drought in the water source by paralleling the water supply to IPA-2 and IPA-3 from the Jeneberang River.

Water supply and coordination during emergency situations

The Climate Change Adaptation and Disaster Risk Reduction plan stipulates the disaster response mechanism to be used (on page 24, in chapter 3, concerning institutional and program coordination). It follows the POKJA-API structure, which designates the Vice-Mayor of Makassar City as the responsible officer, together with an advisory team.

The advisory team consists of the respective heads of the BPBD, DPU, Dikpora, DTRB, DKP3, BPS, PDAM, BLHD, Dinsos, BPM, and DKK.

Page 26 of the regional action plan outlines mitigation measures and clarifies that clean water supply is the responsibility of the PDAM. The document also establishes a coordination mechanism. However, it has not been able to effectively realize a monitoring and evaluation program.

Disaster risk reduction and climate change adaptation in PDAM operations

The PDAM does not have a specific department, division, or officer to assess the vulnerability of PDAM assets to natural disasters and climate change. However, each relevant division conducts asset monitoring in regard to natural disasters and climate change.

Like the other two PDAMs reviewed, the Makassar PDAM currently has no water reserve system to supply water during emergency situations. The existing water reservoirs are functioning primarily for pressure balancing in the system.

Makassar's PDAM is aware of the risks that climate change and natural disaster events pose to its critical assets, but it recognizes that these are unpredictable and difficult to plan for. Moreover, the raw water is obtained from a dam and reservoir that is located outside the city's boundaries[120] and is thus largely outside the local government's direct control. Seawater intrusion during tides is also a concern.

Risk mitigation steps that the PDAM has taken include:

- Identifying the vulnerability of the dam raw water source area to floods
- Identifying the vulnerability of the raw water source area to droughts
- Identifying the risk to raw water sources of sea water infiltration to rivers
- Identifying service expansion opportunities by planning the east city IPA construction, which takes raw water from the Das Tallo River with a capacity of 400 liters per second; the facility will maximize services in the east city area and provide around 1,000 new connections for future customers.

118 Impacts of the Bili-Bili Dam inundation flash flood: https://www.youtube.com/watch?v=cPcA4LdrS0c

119 Impacts of the drought at Lekopancing Dam: http://news.rakyatku.com/read/112993/2018/08/04/air-bendungan-leko-pancing-surut-warga-makassar-terancam-krisis-air-bersih

120 The dam water source is used by the PDAM of Makassar City and the PDAM of Maros District. However, there appears to be no sharing mechanism in place for managing this common water source.

- Identifying service expansion opportunities by planning to build IPA Barombong to maximize services and reach around 11,573 people.

The PDAM conducts regular installation leakage repair in an effort to reduce water losses (NRW). To improve services and control water loss due to leakage, the PDAM has an application called "SIPPAM," which is available on iOS and Android. In this application, customers can update information related to PDAM facilities, damages, complaints, and reports on water leakage anywhere within the Makassar City area. Moreover, the PDAM has received a grant from JICA that provides a pipe leakage detector and is supported by a training program on equipment usage and maintenance.

Like in Magelang and Bantul, other risks pointed out by the Makassar PDAM are related to pollution:

- The PDAM does not have system to normalize chlorine usage; in large amounts, the material could possibly pollute the air and soil.

- The poor sanitation system within the PDAM's service area indirectly contaminates the water supply.

ANNEX 2.
Critical Components And Hazard Threats from PDAM Case Studies

Raw water sources (surface water, river diversion, springs, and groundwater)

The cases below are taken from field studies of PDAM Makassar (flash flood at Bili-Bili Dam,[121] drought at Jeneberang), PDAM Bantul (river diversion, siltation), and PDAM Magelang (springs).

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
Surface water (i.e., dam, river)	Flash floods	Large event	All the facilities within the disaster area	Halt operations	N/A	• Open cut reservoir/flood hazard section • Other sections relevant to affected components
	Drought	Large event	Intake source	Alternative water source (ground water, springs)	N/A	RPAM regulation
River diversion	Floods	HWL +2,5 to 3m	Submersible pumps, electrical panel, voltage regulator, and water quality	Embankment protection using gabion walls to reduce the river's water pressure	Gabions do not protect soil erosion under the embankment	• Open cut reservoir/flood hazard section • WTP/ flood hazard section • SNI 7509:2011
	Siltation	SL +(50 to 60cm)	Intake source	Traditional well as water capture	N/A	RPAM regulation
Springs	Drought	Decrease in source water quantity up to 50%	Catchment reservoir	Planning to find alternative water source (i.e., surface water)	N/A	RPAM regulation
	Floods		Submersible pump, electrical panel, and water quality	Embankment protection	Embankment does not avoid soil erosion under the embankment	• Open cut reservoir/flood hazard section • Water conveyance system/flood hazard section • RPAM regulation
	Landslide	High intensity of rainwater	Springs' supporting facility	Slope stability (i.e., tree-planting)	Maintenance	• BNPB regulation • PUPR regulation on the embankment
	Earthquake motion	6.8SR (2006)	Shift in springs	KKMA Program	N/A	RPAM regulation
	Drought	Decrease in reserves of ground water quantity	N/A	N/A	N/A	RPAM regulation

121 Bili-Bili Dam flash flood footage can be viewed through this link: https://www.youtube.com/watch?v=uCzghvQdm18

Raw water transmission and distribution (by gravity and/or pumped)

The case below is taken from the field case study of PDAM Bantul and Magelang.

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
Raw water transmission	Earthquake	6.8SR (2006)	Transmission, distribution pipes, and water quality	Maintenance	Material replacement	• Distribution pipe/earthquake section • RPAM regulation
	Flash floods	Medium event		Halt operations	N/A	
	Drought	Medium event		Alternative water source (ground water, springs)	N/A	

Water treatment and clean water storage

The case below is taken from PDAM Bantul and Makassar.

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
WTP, clean water storage and appurtenances (Chemical storage and equipment)	Earthquake	6.8SR (2006)	Entire water treatment system and water quality	Halt operations	Material replacement	• WTP/earthquake section • WTP/flood hazard section • Storage tanks/earthquake section • Storage tanks/flood hazard section • RPAM regulation • SNI 7509:2011
	Flash floods	Medium		Halt operations	Material replacement	
	Drought	Medium		Alternative water source (ground water, springs)	N/A	

Emergency water reserves and delivery system

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
Water reserves	Drought	3 days	Storage tank and water quality	Alternative water source (ground water, springs)	N/A	• RPAM regulation • SNI 7509:2011 • BNPB regulation
Delivery system		N/A	Distribution pipes	Water delivery by water tank trucks	N/A	

Electricity/power supply (and backups)

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
Electricity	Power outage	1–1.5 hours	Pumps, WTP	Generator set	N/A	• T&D system

Site suitability (for siting above-listed assets)

This case is taken from studies of PDAM Bantul (WTP Dlingo).

Cases	Natural Hazard		Affected component	Critical system		Recommendation based on references
	Hazard	Intensity		PDAM's engineering improvement	PDAM's quality improvement	
Site suitability	Flash flood	HWL +2,5 to 3m	WTP	Halt operations	N/A	• WTP/flood hazard/flood barriers • RPAM regulation on the operator

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RESILIENT Water Supply and Sanitation COMMUNITY OF PRACTICE

GFDRR Global Facility for Disaster Reduction and Recovery

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