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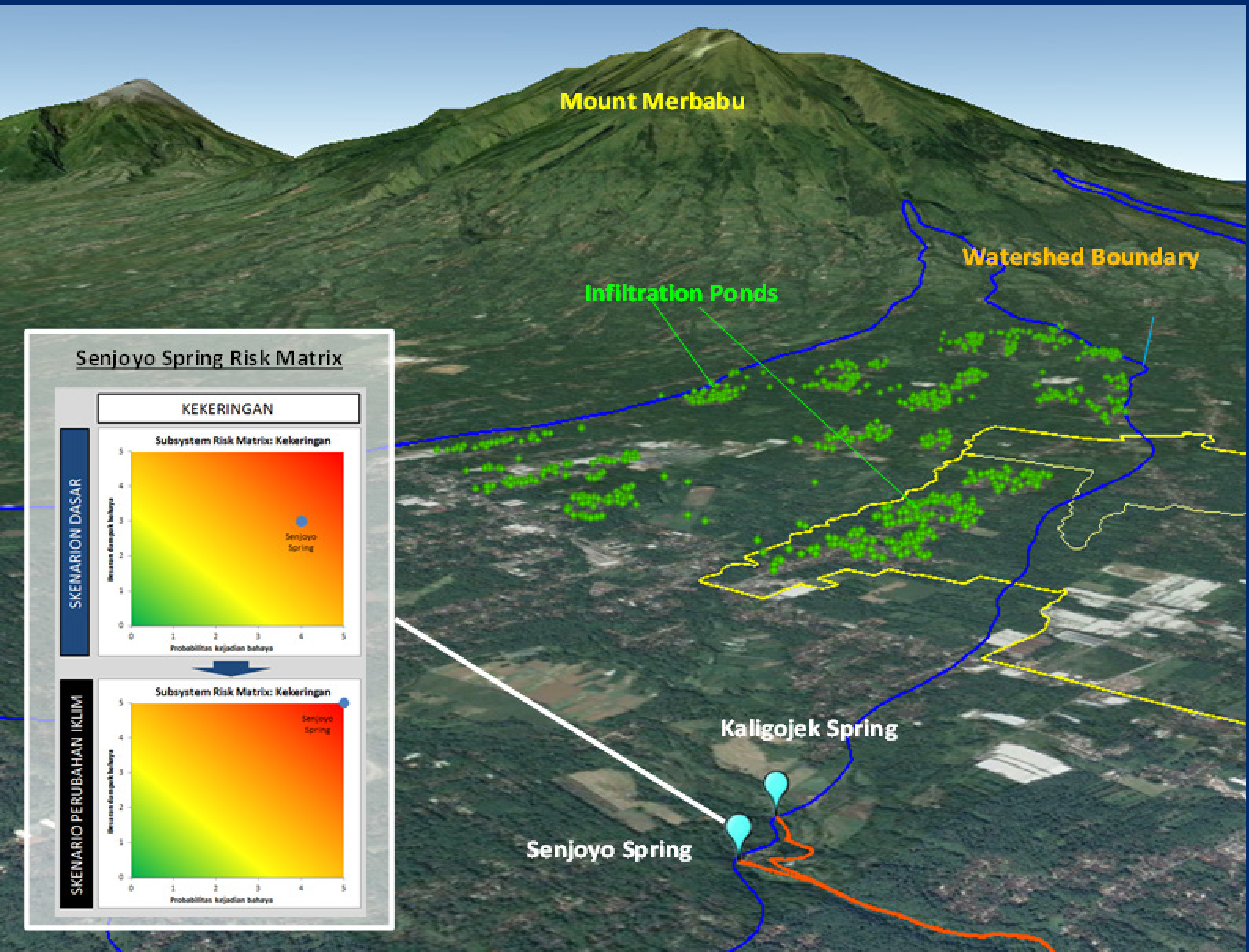
WATER SUPPLY VULNERABILITY ASSESSMENT AND ADAPTATION PLAN

PDAM SALATIGA CITY SUMMARY REPORT



MARCH 2015

This document was produced for review for USAID/Indonesia by the Indonesia Urban Water, Sanitation and Hygiene (IUWASH) project, implemented by DAI, in accordance with ADS Chapter 320.3.2.4 (e) 05/05/2009 Revision.

The Asset Risk Matrix (ARM) for Senjoyo spring shows an elevated risk associated with drought under the climate change scenario. Infiltration ponds are constructed upstream of the spring to help improve the recharge into the spring's aquifer. PDAM Salatiga City uses 140 liter/second of Senjoyo spring as its main raw water source. The ARM for Senjoyo spring was profiled through a stakeholder discussion process.

USAID INDONESIA URBAN WATER SANITATION AND HYGIENE

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PDAM SALATIGA CITY SUMMARY REPORT

Project:	**Indonesia Urban Water, Sanitation and Hygiene (IUWASH)**
DAI Project Number:	**1001457.**
Assistance Objective (AO):	**AO Improved Management of Natural Resources, under (IR) 3 – Increased Access to Water and Sanitation.**
Sponsoring USAID Office and	**USAID/Indonesia**
Contract Number:	**AID-497-C-11-00001**
Contractor's Name:	**Development Alternatives Inc.**
Date of publication:	**March 2015**

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Given the potential acceleration of recent climate trends presented by climate change, it is critical that PDAMs and their local government owners begin to assess how temperature fluctuations and shifts in precipitation patterns will impact their municipal water supply systems, and, further, include appropriate adaptation measures in local planning documents to help reduce future risks. Toward this end, USAID's Indonesia Urban Water, Sanitation, and Hygiene (IUWASH) Project supported PDAM Kota Salatiga and the Local Government to undertake a **Water Supply Vulnerability Assessment and Adaptation Planning Process**. The results of this process are summarized in the following report which seeks to: highlight the current risks facing the PDAM's natural and physical assets, consider how those risks may fluctuate due to climate change, propose a list of practical adaptation actions to reduce both the risks of today and in the future, and identify specific next steps to begin the implementation of the identified actions.

Importantly, the inputs and resulting conclusions do not represent a comprehensive assessment of climate change vulnerability for the PDAM, but are instead a first step towards achieving long-term resilience. Indeed, the underlying objective of the work described herein was to introduce the *process* of vulnerability assessment and adaptation planning to the PDAM, thereby stimulating a *dialogue* among stakeholders regarding existing vulnerabilities and how climate change may further impact the water utility in the years to come.

The content of the Water Supply Vulnerability Assessment and Adaptation Plan (VA&AP) was developed over a period of approximately 20 months with IUWASH technical assistance. Key steps in the process included the completion of a baseline water resources vulnerability study by PT Miranthi, a series of workshops, and focus group discussion with the PDAM and its stakeholders. Supporting technical tools that informed the VA&AP process included the completion of the Asset Risk Matrix (ARM), geospatial analysis, global and regional climate change models, and multi-criteria analysis.

Concerning the results of the vulnerability assessment process, the major "vulnerability hotspots" for PDAM Salatiga City are the deep well in the center of the city and the fresh water springs. More specifically, **Senjoyo Spring** has a high risk of adverse effect from drought under the baseline scenario and very high risk under the climate change scenario.Both **Deep well Sukowati** and **Kalitaman Spring** have a high risk of adverse effect due to drought in the climate change scenario. Recurring drought is a trend that is only predicted to be accelerated by climate change as fluctuations in precipitation patterns are likely to lead to less groundwater infiltration. Further, regarding the built assets under the climate change scenario, the intake for Kalitaman Spring faces a medium level of risk of drought, and the transmission system faces a medium level of risk of landslide. It is clear that baseline scenario risks will increase under the climate change scenario as flood and drought become more extreme.

Based on these results, local stakeholders identified a series of possible adaptation actions to reduce current risks and mitigate the longer term risks posed by climate change. The PDAM is facilitating the establishment of infiltration ponds in the aquifer recharge area and closer relations with local communities to ensure proper maintenance. Among the short list of options discussed by representatives from the PDAM and Local Government were: strengthened water withdrawal policies, better sanitation practices, increased storage capacity, and the reduction of non-revenue water. Building on the adaptation options identified by the PDAM and local government officials, IUWASH also recommended consideration of the following actions: strengthening and/or repositioning of key transmission lines in improved landslide areas, maintenance or replacement of old or broken meters, and investments in water resources decision support systems.

Looking ahead to immediate follow-up steps, the PDAM is expected to set aside funds for the maintenance of artificial infiltration wells in critical recharge areas and for continuing GIS mapping of its piping network for better management, especially of pipes that may be vulnerable to landslides. The PDAM has participated in initial discussions that are expected to lead to an institution for dialogue with users of the Senjoyo Spring, its main source of raw water. The PDAM has developed a Water Safety Plan to ensure that long-range water needs will be met, and it is cooperating with the neighboring Semarang District for management of raw water from Semarang District destined for use by Salatiga city. At present more than half of Salatiga City's raw water comes from sources in Semarang District.

Medium term steps that are under discussion with the PDAM include additional strengthening of hydrological and meteorological monitoring, the replacement of key aging infrastructure, and the fortification of above-ground pipelines in flood and landslide prone areas. In conjunction with the commencement of the implementation of immediate and short-term adaptation options, it is also important that the results of this assessment and planning exercise be integrated into the PDAM and local government's broader development planning.

1 INTRODUCTION

1.1 PURPOSE AND STRUCTURE OF THE REPORT

Perusahaan Daerah Air Minum (PDAMs) across Indonesia face many different types of risks as they seek to deliver clean water to their customers. These risks include land use change, rapid and unplanned urbanization, competition for scarce water resources, and natural disasters. Importantly, many of these risks have been exacerbated by the negative impacts of climate change, which is expected to modify the duration and intensity of rainfall patterns across the archipelago. If risks are accurately anticipated and monitored, PDAMs can manage their resources better for the benefit of consumers.

Given the potential complications presented by changes in precipitation patterns, it is critical the PDAMs and their local government owners begin to assess how climate change will impact their water supply systems, and include appropriate adaptation measures in local planning documents to help reduce future risks. **The Water Supply Vulnerability Assessment and Adaptation Plan for PDAM Salatiga City** represents an important milestone towards achieving these goals. The objectives of this report are to:

1. Summarize the current risks facing the PDAM's natural assets (i.e. sources of water and the surrounding watersheds) and physical assets (i.e. water supply infrastructure such as treatment plants and reservoirs) under existing climate conditions (Chapter 2);
2. Consider how these risks may be increased by climate change by midcentury (Chapter 2);
3. Propose a portfolio of practical adaption actions that the PDAM can take to redPTuce risk under both today's climate and the climate change scenario (Chapter 3); and
4. Identify next steps to begin the implementation of the proposed adaptation actions and integrate these actions into local planning documents (Chapter 4).

The content of the Water Supply Vulnerability Assessment and Adaptation Plan (VA&AP) was developed over a period of approximately 20 months with the support of USAID's Indonesia Urban Water, Sanitation, and Hygiene (IUWASH) Project. Key steps included the completion of a baseline water resources vulnerability study by PT Miranthi, a series of workshops and focus group discussion with the PDAM and its stakeholders, and meetings with local government officials. The results of these steps are discussed throughout the report as well as in the annexes.

It is important to note from the outset that the completion of this report in no way means that the process of identifying water supply vulnerabilities to climate change and associated adaptation actions is also "complete." Indeed, given limited time and resources, this report (and the related inputs) provides only a broad overview of climate change vulnerabilities and potential adaptation actions. It is, in other words, a first step down toward improving the resilience of water supply systems in Kota Salatiga.

The underlying objective of the work described herein, then, was not to undertake a comprehensive vulnerability assessment, but rather to introduce the *process* of vulnerability assessment and adaptation planning to the PDAM, thereby stimulating a *dialogue* among stakeholders regarding existing vulnerabilities and how climate change may further impact the water utility in the years to come.Ultimately, resilience can only be achieved through an iterative process of assessment, planning, action, and the deliberate monitoring of impact to better understand what works and what does not.

1.2 THE WATER SUPPLY VULNERABILITY ASSESSMENT AND ADAPTATION PLANNING FRAMEWORK

The methodology guiding the compilation of **The Water Supply Vulnerability Assessment and Adaptation Plan for PDAM Salatiga City** is based upon an IUWASH document entitled, "Climate Change Vulnerability Assessment and Adaptation Planning for Water Supply: Inception Report" (available for download at http://iuwash.or.id/category/download-publication/technical-report/). Based upon emerging best practices in climate change adaption in the water sector, this document presents vulnerability assessment and an adaptation planning framework built on the following principles:

a. Climate change is not an isolated issue or separate field of expertise, but a source of risk that is inextricably linked to the way utilities and the communities they serve use and manage water and land resources. It is thus is best approached in an **integrated manner**, building off of and contributing to the utility's and local government's broader planning efforts;

b. Given that "top-down" climate change models are both expensive to develop and require extensive data, a **"bottom-up" approach** that focuses on what is known about the current environment and how the water system may be sensitive to climate change is the more appropriate for the water sector in Indonesia;

c. To focus the vulnerability assessment and adaptation planning process, the IUWASH Water Supply VAAP Framework distinguishes between a utility's **natural assets** (in the form of water resources such as rivers, spring, and wells) and **constructed assets** (in the form of intakes, transmission lines, treatment facilities, and storage facilities). Further, the Framework considers the extent to which these assets are able to meet demand under both existing conditions as well as under climate change. Indeed, understanding the supply and demand balance is critical to future water security;

d. The vulnerability assessment and planning process itself is a means of **learning, collaboration, and capacity-building**. In other words, it is not just about "making another plan," but thinking and learning in a collaborative manner with PDAMs, local governments, and supporting stakeholders on how to better plan for a highly variable future; and

e. Vulnerability assessment and adaption planning must be conducted on an **iterative basis**. Given the degree to which climate change knowledge and research continues to evolve, PDAMs should revisit the vulnerability assessment and adaptation process with each new five year business plan, ensuring that plans fully reflect the latest scientific findings and local conditions.

Building off of the principles discussed above, Table 1 below summarizes the four phases and associated steps that make up the framework used in Kota Salatiga.

Table 1: IUWASH Vulnerability Assessment and Adaptation Planning Framework.

Phases		Steps	Tools/Methodologies
1.	**Evaluation of the Current Situation: The Baseline Scenario**	a. Stakeholder Engagement: Understanding the objectives and perspectives of the PDAM and Local Gov't; b. Data Collection and Analysis: Description of current system, types of water resources, historical hydro-met data, customer data, and supply/demand projections; c. Baseline Scenario Vulnerability Assessment: Identification of existing hazards and evaluation of associated risks.	• Stakeholder Kickoff Meeting • Key Informant Interviews • Geospatial Analysis • PDAM Asset Risk Matrix
2.	**Climate Change Vulnerability Assessment: The Climate Change-Driven Scenario**	a. Analysis and synthesis of localized climate change data using existing research, interviews, and models; b. Development of Climate Change-Driven Scenario: Using quantitative and qualitative information to envision future impacts; c. Climate Change-Driven Scenario Vulnerability Assessment: Considering how the hazards may change, altering the PDAM's risk profile.	• Geospatial Analysis • General Circulation Models • PDAM Asset Risk Matrix • Stakeholder Workshop
3.	**Adaptation Planning: A Portfolio of Prioritized Responses**	a. Develop Long-List of Adaptation Options for Natural and Constructed Assets; b. Develop a Short-List of Adaptation Options; c. Prioritize Actions within Portfolio	• Multi-Criteria Analysis • Cost-benefit analysis • Decision-Maker Workshop
4.	**Implementation, Integration, and Learning**	a. Implementation of balance portfolio of adaptation options b. Integrate prioritized adaptation responses into PDAM planning documents; c. Begin implementation and monitoring, emphasizing an iterative approach to regularly incorporate new knowledge and experiences (learning).	• PDAM Corporate Plan • Project Feasibility Studies • M&E systems

As noted in Phases 1 and 2, an important aspect of the vulnerability assessment and adaptation planning (VAAP) process is the identification of the types of hazards to which the PDAM's natural and constructed assets are currently exposed. To facilitate this analysis, these hazards are organized under the following four categories:

- **Drought (Water Scarcity):** Most water utilities face some degree of risk pertaining to shortages of raw water resources, whether it is due to prolonged periods of little to no precipitation or decreased recharge stemming from land use change. Climate change is only expected to worsen the risk of such hazards, particularly as dry seasons are predicted to lengthen over time and more intense, compacted rainy seasons will yield less recharge.

  Concerning constructed assets, one might normally anticipate that drought would not result in actual physical damages. While the infrastructure would not operate effectively with low levels of raw water, the plant itself would not be damaged meaning that it could return to operating when access to raw water is restored. The reality, however, is that the transmission systems are frequently exposed to damages during drought, as local communities break pipes in search of available water. This is especially true for above-ground pipes.

- **Flooding**. The elevated intensity of storms under climate change is expected to lead to more frequent flood events. Flooding poses an obvious risk to a PDAM's physical assets, particularly to intakes, treatment facilities, and storage facilities given that they tend to be located near rivers and other sources of surface water. Floods can also be detrimental to the water quality of natural assets, leading to spikes in turbidity that can make the raw water more difficult and costly to treat.

- **Landslides**. Also associated with increases in the intensity and duration of precipitation events, landslide hazards pose the greatest risk to physical infrastructure, particularly well and spring heads and surface water intakes given their tendency to be located in steeper, upstream topography. Landslides pose minimal threat, however, to the quality and quantity of natural assets, with the exception of an extreme event that alters the course of the river channel.
- **Sea Level Rise**. A final hazard that is commonly associated with climate change is sea level rise induced by warming oceanic temperatures. Sea level rise (SLR) generally presents the greatest risk to a PDAM's natural assets in the form of saltwater intrusion, which is already common in many of Indonesia's coastal cities due to the over-pumping of groundwater resources. SLR will only exacerbate this problem, and may also pose a threat to constructed assets located near the coast due to more frequent inundation of the shoreline.

On a final note, the implementation of the Framework is supported by several tools and methodologies (see the right-hand column of Table 1), including the PDAM Asset Risk Matrix, geospatial analysis, general circulation models, and multi-criteria analysis.Each of these tools played an important role in the vulnerability assessment and adaptation planning process with PDAM Kota Salatiga, and the results are presented in the following chapters.

2 WATER SUPPLY VULNERABILITY ASSESSMENT

Chapter 2 of the Salatiga City Water Supply VA & AP Report summarizes the current state of the piped water supply system in (Section 2.1) and then identifies the specific vulnerabilities of this system under current climate conditions (Section 2.2) as well as under a mid-century (2045 – 2055) climate change scenario (Section 2.3).

2.1 WATER SUPPLY CONTEXT

The following subsections provide an introduction to the water supply context for Salatiga City, including the general characteristics of the PDAM, the natural assets on which the PDAM relies for its raw water, and the built assets that the PDAM uses to clean, store, and deliver that water to its customers. These subsections are based upon the IUWASH-supported report by PT Miranthi entitled "Water Supply Vulnerability Assessment Scoping Study PDAM Kota Salatiga", while also drawing from stakeholder consultations and other secondary data sources where noted.

2.1.1 Overview of PDAM Salatiga City

PDAM Salatiga City provides piped water service to the citizens of Salatiga City, composed of 4 sub-districts and home to approximately 172,400 people in 2011. Encompassing only 56.78 square kilometers, the city is located on an upland plain enclosed by Semarang district per Figure 1, at right. During the period 2007 to 2011, the population increased at an average of 0.65% per year.In the period 2003 to 2011, the proportion of land devoted to settlements more than doubled, mainly replacing dry land agriculture. Development of settlements has raised the demand for piped water while increasing runoff and reducing the ability of the soil to absorb water. More than 90% of the PDAM's customers are households.

Established in 1981, PDAM Salatiga City is the official source of piped water throughout the city and the heir to a Dutch water enterprise that was founded in 1921. Table 2 summarizes the key characteristics of the PDAM and its service area for the past three years of audited data. In 2013, PDAM Salatiga City was awarded a commendation as the best PDAM in its category in Indonesia by PERPAMSI, the Indonesian Association of Water Enterprises.

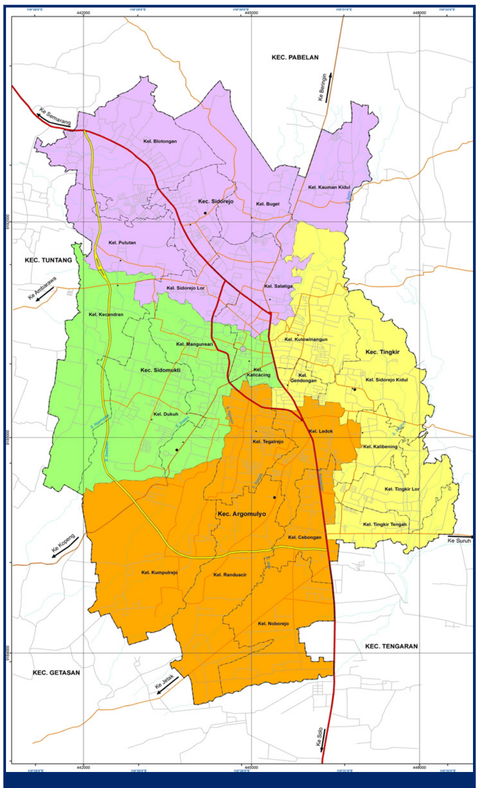


Figure 1: Salatiga City, Central Java.

Table 2: PDAM Salatiga City Characteristics.

	Characteristic	2013	2012	2011	2010
Customer	Number of Customers	27,878	26,950	25,567	24,393
	Coverage of Service Area	75.79%	25,131	24,176	23,400
Technical	Total Water Produced	8,735,472	8,388,719	8,011,721	7,731,969
	Total Water Sold	6,507,981	6,288,019	7,999,646	5,801,736
	Non-Revenue Water	24.36%	24.67%	24.93%	24.96%
	Total Staff	138	142	139	138
Financial	Average Tariff	2,760,55	2,588.19	2,146.87	2,179.29
	Cost recovery Tariff	2,520.26	2,423.64	2,211.85	2,180.12
	Total Asset Value	47,200,270,061	n/a	n/a	n/a

Source: PDAM Kota Salatiga

2.1.2 Natural Assets of the PDAM

The "natural assets" of a PDAM include all sources of raw water, including the aquifers and groundwater systems that feed into springs and wells as well as surface water sources such as streams, rivers, and lakes. Broadly speaking, the watershed in which these water resources exist can also be seen as part of the PDAM's natural assets given that the condition of the watershed directly impacts the supply and quality of water resources.

Raw Water Sources. PDAM Salatiga City derives its raw water solely from natural springs and deep wells, located both in Salatiga City and the surrounding Semarang District. Figure 2 at right accompanied by the map (Figure 3) on the following page highlight the principal sources of raw water for the PDAM and their locations.

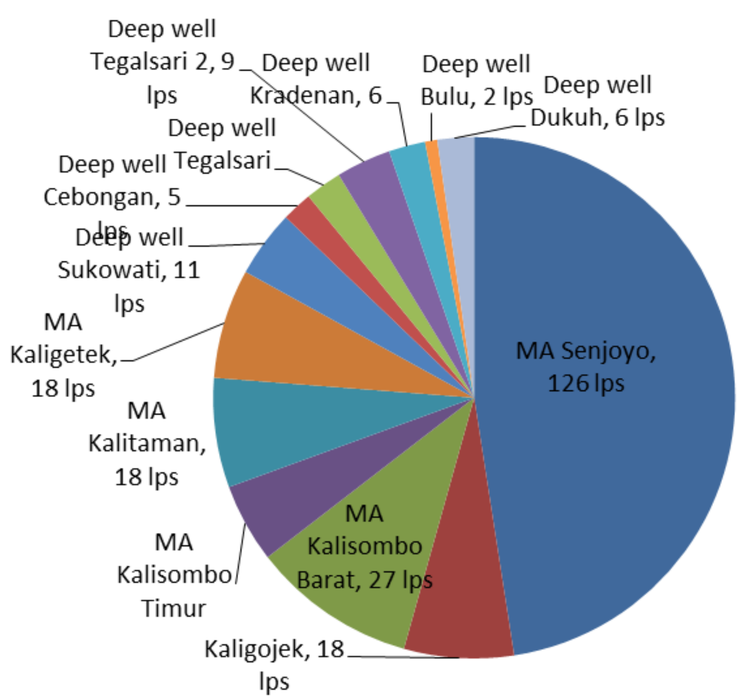


Figure 2: PDAM Salatiga City Raw Water Resources.

As shown in the pie chart, the PDAM uses a set of springs and deep wells to supply water to the residents of Salatiga City, including six fresh water springs and seven deep wells. It is important to note that the pie chart shows the connected capacity of each source, which does not necessarily reflect the total flow capacity of the spring or well. Thetotal connected capacity of these sources is about 328 liters per second (lps) while the total production capacity is approximately 296 lps.

Beginning with the fresh water springs, which in 2011 supplied 81% of Salatiga City's water, the key characteristics of these natural assets are as follows:

- **Mata Air Senjoyo** is the main source of PDAM Salatiga City's raw water, accounting for almost half of its total supply. The first bronkaptering on Mata Air Senjoyo was built in 1921, and the second in 1973.It is located outside the city limits of Salatiga in Semarang district.In 2006, PDAM Salatiga City withdrew about 190 liters per second from Mata Air Senjoyo, and PDAM Semarang district took about 30 l/s.About 67 l/s were withdrawn by the private sector and local communities, and 868 l/s was withdrawn for irrigation. The discharge from MA Senjoyo appears to have declined about 13% between 2000 and 2004. In 2008, a study by the Faculty of Economics, University of Diponegoro, found that Air Mata Senjoyo already was supplying less than what was needed for agriculture, households, and the PDAM. This steady downward trend has been of concern to the PDAM even though there are additional groundwater and surface water sources of raw water available to the PDAM.

- **Mata Air Kalitaman and Mata Air Kalisombo,** located close to each other within Salatiga City, are two additiona lkey sources of spring water for PDAM Salatiga. According to the Office of the Environment of Salatiga City, the total flow to all users from Mata Air Kalitaman is about 150 liters per second while the PDAM uses only 18 liters per second. The total flow to all users from Air Mata Kalisombo is about 50 liters per second. The PDAM and the press have reported a reduction over time in the discharge from MA Kalitaman since its construction in 2004.

Table 3: Use of water from SenjoyoSpring in 2006.

No	Water user	Discharge (L/sec)
A.	**Raw water for drinking, domestic:**	
1	PDAM Kota Salatiga	190,00
2	PDAM Kabupaten Semarang	30,00
3	PT Damatex dan Timatex	53,00
4	Desa Karang Gondang Kec. Pabelan	2,94
5	Yonif 411 Kota Salatiga	11,80
	Total for domestic use	287,74
B. Water for irrigation		868,26
	Total	**1,156,00**

Source: PDAM Semarang district, 2006

Mata Air Kaligojek, located in Semarang District near Senjoyo Spring, supplies about 7 per cent of PDAM Salatiga City's raw water, bringing the total amount of raw water originating from sources in Semarang District to more than 55% of PDAM Salatiga City's needs.

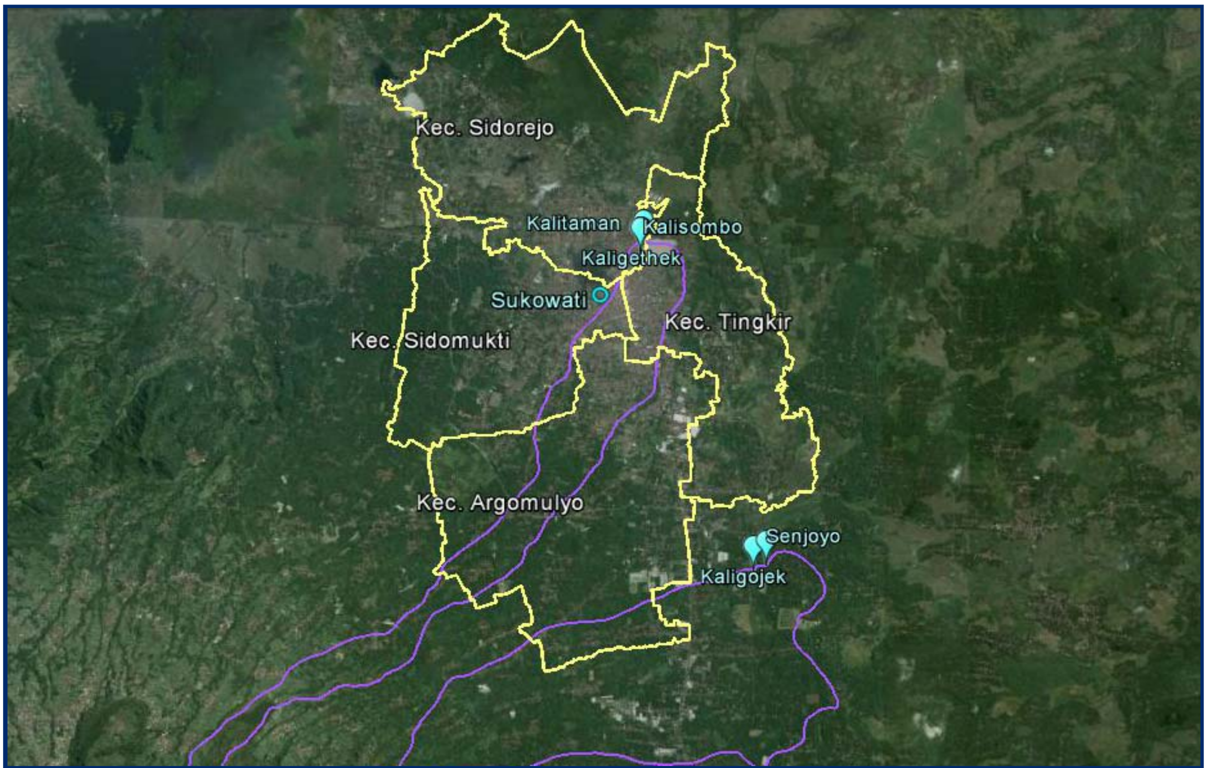


Figure 3: Main Springs and Deep Well Supplying Raw Water to PDAM Salatiga City.

The purple lines define the recharge area emanating from Mount Merbabu located outside the lower left corner of the map. Senjoyo (the PDAM's main source of water) and Kaligojek Springs are in Semarang District, just outside of the city boundaries, and Kalitaman, Kalisombo, and Kaligethek Springs are closer to the PDAM which is by deep well Sukowati. (Map View: Google Earth©)

Deep wells also represent an important source of raw water for the PDAM. Table 4 below lists the 6 springs and 7 deep wells that the PDAM utilizes to service the residents of Salatiga City. Generally speaking, the water pressure and water quality from deep wells supplying Salatiga City is quite good. Under the PT Miranthi baseline study, for example, the research team tested samples from a number of locations and found that all samples could be classified as "clean water" given that the parameters were found to be better than those set forth in Government RegulationNo.82 of 2001, except one sample that had excess manganese. In general, the quality of water was found to have met the standards of Ministry of Health Regulation No 492 of 2010.

Deep Well Sukowati, the PDAM's main source of deep well water, was developed in 2007 on PDAM Salatiga City property when the PDAM needed additional water besides that withdrawn from springs. During the same year, four sub-districts reported a lack of piped water due to a shortage of raw water supply.

Table 4: Springs and Deep Well Water Sources of Salatiga City.

No	Water Source	Capacity (L/Second)		Year constructed
		Designed	Production	
1	Senjoyo Spring	145	140	1925, 1957, 1989
2	Kaligojek Spring	20	20	2000
3	Kalisombo Barat Spring	35	30	1980, 1985
4	Kalisombo Timur Spring	15	15	2005
5	Kalitaman Spring	25	20	2004

No	Water Source	Capacity (L/Second)		Year constructed
		Designed	Production	
6	Kaligetek Spring	20	20	2003
7	Deep well Sukowati	15	12	2007
8	Deep wellCebongan	8	6	2008
9	Deep wellTegalsari 1	7	7	2009
10	Deep wellTegalsari 2	12	10	2009
11	Deep well Kradenan	7	7	2010
12	Deep wellBulu	5	2	2011
13	Deep wellDukuh	7	7	2012
	Total	**321**	**296**	

Source: PDAM Kota Salatiga, 2012

Surrounding Watershed. The productivity and sustainability of the PDAM's raw water resources is closely linked to the characteristics of the surrounding watershed. In this regard, the jurisdictions of both Salatiga city and Semarang district fall within the Jrantunseluna River Basin that runs more or less from east to west through the northern parts of East Java and Central Java.Two watersheds are found in the area of Salatiga City.The Tuntang watershed is the main watershed covering most of the city, and the second is the Serang-Lusi watershed, as shown in Annex 2. PDAM Salatiga City still relies heavily on sources of water that are within the Serang-Lusi watershed, Semarang district, and fortunately there is currently a cooperative working relationship between Salatiga City and Semarang District and their PDAMs.

In general, land use in Salatiga City (Annex 3) can be divided into three types: rice paddies, dry land farmlands, and settlements (including housing, commercial areas, and industrial areas).

2.1.3 Physical Assets of the PDAM

The physical or "constructed" assets of the PDAM include the intake, pumps, the transmission pipeline, water treatment facilities, and storage and distribution facilities. These built assets allow the PDAM to obtain raw water from its natural assets and then clean, store, and transport water to its customers. The following table summarizes the key built assets of the PDAM, highlighting those that deliver/store the greatest volume of water and have the highest replacement value:

Table 5: PDAM Salatiga's Constructed Assets.

No	Assets Category	Location	Technical Details	Value at Acquisition/ hand over (IDR 2012)	Accumulated Depreciation (IDR 2012)	Book value (IDR 2012)
I	Land	Office, intake locations, storage location,	Including for storage	1,673,495,000	0	1,673,495,000
II	Intakes	Salatiga	At spring	1,054,557,301	410,900,705	643,656,596
III	Pump & pumping station	Salatiga	Pumps and stations, chlorinator, electrical panel station	11,375,162,215	4,828,302,731	6,546,859,484

No	Assets Category	Location	Technical Details	Value at Acquisition/ hand over (IDR 2012)	Accumulated Depreciation (IDR 2012)	Book value (IDR 2012)
IV	Treatment plant/Aerator			1,111,994,078	4,828,302,731	6,546.859,484
V	Transmission / distribution	Across all service area of PDAM	Piping, valves, and piping accessories	13,425,042,774	11,833,206,708	1,588,477,568
VI	General assets	Across service area of PDAM	Automobiles, motorcycles, other assets	3,608,423,636	3,039,241,453	569,182,883
	Total			**32,248,675,133**	**20,445,249,821**	**11,800,067,515**

Source: PDAM Salatiga 2014

Several noteworthy characteristics of PDAM Salatiga City's constructed assets are as follows:

- Given the limited size of the city, the PDAM is able to maintain the network more easily than PDAMs serving districts, although the main source of raw water is a spring outside of the city limits. Still, the majority of the PDAM's built asset value—and thus the majority of the PDAM's risk—is contained within the transmission and distribution system.
- Since the PDAM uses only high quality raw water from springs and aquifers, minimal treatment infrastructure is necessary which represents a significant cost savings to the PDAM.
- The acquisition value of the PDAM's piping is very high, but the current book value is very low compared to the book value of pumps and pumping stations.Thus, any piping that might be vulnerable to landslides is likely to be older and thus of much lower value than its value at acquisition.

See **Annex 4** for a map depicting the layout of the PDAM's distribution network.

2.1.4 Asset Monitoring Systems

A critical aspect of providing water supply services is the regular monitoring of the utility's natural and constructed assets. On the natural assets side, it is extremely important to understand the condition of raw water resources and the hydrological characteristics of the surrounding watershed more broadly. As such, a water utility needs to have access to hydrological data such as precipitation data, ground water levels, spring flow volume, stream flow volume, as well as an awareness of the competing uses of raw water that may impact the available supply. Ideally, hydro-meteorological (hydro-met) data at key locations is recorded on a daily (if not hourly) basis, thereby allowing water utility managers to understand how the watershed responds to weather events.

Similarly, on the constructed assets side, it is necessary to understand the condition of each capital asset, its remaining useful life, and estimated replacement cost. In the absence of this data, these assets are more difficult to maintain, and utility managers cannot easily plan for capital asset replacement or rehabilitation costs.

Table 6 summarizes the availability of important natural asset monitoring data, including the relevant stations and systems that are in place to capture this data.

Table 6: Natural Asset Monitoring Systems, PDAM SalatigaCity.

Topic	System/Equipment	Type of Data	Historical Data
Precipitation	Meteorological Station in Getas,inSemarang District, operated by BMKG (Dept. Meteorology, Climate, and Geophysics)	Daily rainfall data manually recorded.	- Since 1983
Temperature	Station in Getas, Semarang District, operated by BMKG	Daily high, low, and average data recorded	- Since 2003
Spring Flow	Simple flow meters at some springs used by PDAM	Flow rate (liters per second) manually recorded once per day.	- Limited historical data available
Deep Well Flow (Aquifer)	No flow meter at Sukowati deep well	No hourly or daily data is recorded for the deep well.	- Not available. Well flow is only tested on an intermittent basis.

Source: PT Miranthi and PDAM Salatiga City

There is only limited hydrological and meteorological data available inSalatiga City, making it very difficult to develop accurate predictive models of how spring flows and recharge rates may change in the future based upon land use change, climate change, or, more likely, both factors occurring simultaneously. The PT Miranthi Team did construct hydrographs and calculate runoff coefficients based on empirical analysis that incorporated the topography, basin area, length of the main river channel, land use in each watershed, and actual rainfall data. The results are presented in Chapter 4 of the Baseline Study.

In terms of raw water quality, the PT Miranthi Team did not present evidence that resources are tested on a regular basis by the PDAM or local government. That said, the Team did conduct its own sampling and analysis, which is presented in Chapter 3.3 of the Baseline Report.

Regarding tracking systems for constructed assets, PDAM Salatiga City is beginning to establish a geographic information system (GIS) to plot the location of its assets and record key characteristics concerning these assets (such as recent maintenance, breakages, year constructed, etc.). Natural asset monitoring data should be included in this system.

2.2 WATER SUPPLY VULNERABILITY ASSESSMENT: BASELINE SCENARIO

Utilizing the historical and current hazards identified during the data collection, the final step under Phase 1 of the VA & AP Framework is the development of the vulnerability assessment for the baseline scenario which estimates the level of risk to the PDAM's natural and constructed assets *in the climate up to and including the present*. PDAM assets are already threatened by a broad spectrum of existing hazards, including flooding, drought/water-stress, landslides, and sea level rise. These hazards represent a critical point of reference for understanding how changes to the climate may alter the severity of these hazards in the years to come.

Key resources utilized in the development of the baseline scenario include: (1) the "Water Supply Vulnerability Assessment Scoping Study PDAM Kota Salatiga, Central Java" (also referred to as the "Baseline Study") as compiled by local partner PT Miranthi, (2) the Asset Risk Matrix compiled during a stakeholder workshop in September 2014, and (3) key information interviews and focus group discussions with PDAM and PEMDA representatives. Regarding the ARM compilation, the workshop participants assessed the vulnerabilities of four of the PDAM's subsystems during the two-day event, including the fresh water springs at Senjoyo, Kalisombo, and Kalitaman as well as the deep well at Sukowati.

2.2.1 Baseline Scenario: Natural Assets

The main risk to PDAM Salatiga City's natural assets is the quantity of raw water. The flow in current fresh water springs and deep wells has been seen to have declined from year to year, and the trend has been increased during the dry season.New springs and wells will have to be found in order to meet the growing demand for water.Based upon the baseline vulnerability study as well as the compilation of the Asset Risk Matrix with local stakeholders,the following levels of vulnerability of natural assets were identified under the current context for the water resources supplying the citizens of Salatiga City:

- **Drought/Water Scarcity**. The risk scores under the Asset Risk Matrix (ARM) show that the water source most vulnerable to water scarcity risk under the baseline scenario is Senjoyo Spring, which supplies almost half of PDAM Salatiga City's raw water. Senjoyo spring has a high level of risk to drought, while the deep well at Sukowati and Kalitaman Spring both face a medium level of risk under the baseline scenario.
- **Flooding**. According to stakeholders, there is almost no risk to the PDAM's natural assets from flooding. Given that the PDAM relies only on groundwater, increases in turbidity in surface water sources during floods will not impact the PDAM's ability to provide clean water to its customers.
- **Landslides**. There is almost no risk of landslides to the quantity and quality of natural assets under the baseline scenario given that landslides are unlikely to reduce the quantity of spring or well water available. Landslides will also not impact the water quality of the groundwater sources used by the PDAM.
- **Sea Level Rise**. There is no **risk** to the water quantity or water quality of the PDAM's natural assets from sea level rise.

As noted under the risk of drought/water scarcity, although there already has been rapid urbanization, land use change in the upper watershed could lead to higher incidences of water scarcity as well as flooding and landslides, **no matter how the climate may change**. As such, ensuring that infiltration levels remain sufficient to recharge the underlying aquifer will be important no matter how levels of precipitation may fluctuate in the decades to come.

Finally, the PDAM does not yet have a systematic monitoring system for regular measuring of groundwater depth levels and spring flow levels, although it is now developing a GIS information system using its own budget.Although there is abundant evidence that discharge rates are going down, the PDAM does not yet have the systems in place to measure trends over long time horizons. Accessing data on a regular basis and analyzing the status of the PDAM's natural assets will help water managers to plan for the future needs of the community and alert local government authorities when raw water resources are degrading.

2.2.2 Baseline Scenario: Physical Assets

The fundamental risk to the PDAM's constructed assets is that of physical damages to the infrastructure.For example, an intake could be covered by a landslide requiring costly rehabilitation and repairs. Also, drought conditions could lead local communities to damage transmission pipes in the hopes of accessing clean water. Based upon the vulnerability study as well as the Asset Risk Matrix, the following levels of vulnerability were identified under the current context for the constructed assets servicing Salatiga City:

- **Drought/Water Scarcity**: There is almost no risk of drought to the water supply infrastructure in Salatiga City. PDAM Salatiga city has not yet experienced purposeful damage to its water supply infrastructure during times of drought.
- **Flooding**: Flooding presents a medium level of risk to the intake at Kalitaman Spring and a low level of risk to the reservoir and transmission lines.
- **Landslides**: There is a low risk of damage to some transmissioninfrastructure at Mata Air Kalitamandue to landslides under the Baseline scenario, but no damage to the physical assets from landslides has been reported in the press or elsewhere.
- **Sea Level Rise:** There is no risk to the PDAM's physical assets from sea level rise under the current climate given the distance of these assets from the coast.

In summary, the level of risk to the PDAM's intakes (including well heads), treatment, and storage infrastructure under the baseline scenario is generally low, except in the case of the intake in Kalitaman Spring where there is a medium risk due to flood. Please see the summary results from the ARM Workshop attached as **Annex 5**.

2.3 WATER SUPPLY VULNERABILITY ASSESSMENT: CLIMATE CHANGE DRIVEN SCENARIO

Utilizing the results of the baseline scenario, the following section describes how the existing risks identified under the baseline may change as well as what new risks may emerge due to climate change. The first subsection describes the anticipated changes to the climate of Central Java and Salatiga City, focusing on a **medium term time frame (2030 to 2111)** under the **A2 Emissions Scenario**. The A2 Emissions Scenario was chosen because it correlates best with the study area and it is the most pessimistic of the scenarios. In addition to consulting existing literature on anticipated climate change impacts in the region, this report also utilized the MAGICC-SCENGEN climate change model scenario GCM (Global Climate Change Model) BCCRBCM2. The results were correlated with projections in the Indonesian Climate Change Sectoral Roadmap (ICCSR) of 2010. Groundwater projections were derived using weighted DRASTIC method based on the status of groundwater in 2011.

Notably, such climate change projections are to be interpreted as rough approximations, providing an indication of what *might* happen as opposed to what *will* happen. The selection of the emission scenario itself introduces wide variation, and it remains unclear what is the extent to which the A2 scenario will be representative over the future emissions trajectory. Thus, the reference to these models is meant as a tool to stimulate discussion, learning, and, action.

The second and third subsections of the Climate Change Driven Scenario then consider how risks identified under the baseline scenario may change as well as what new risks may be introduced. Key points of reference for the discussion include: (1) the "Water Supply Vulnerability Assessment Scoping Study PDAM Kota Salatiga, Central Java" as compiled by local partner PT Miranthi, (2) a stakeholder workshop implemented in September 2014, and (3) key information interviews and focus group discussions with PDAM and PEMDA representatives.

2.3.1 Climate Change in Salatiga City, Central Java

Current Conditions. As with other areas of Indonesia, Salatiga City has a wet, tropical climate with essentially two seasons: wet and dry. The wet season generally lasts for about 4 months, from approximately December to March, while the dry season extends from June through October. The annual mean air temperature ranged from 22.5 to 32.06 degrees Celsius with average temperature

27.3 degrees during the period 2003 to 2007. From 1983 to 2012, the highest rainfall was in January (320 mm), and the lowest was in July (35 mm).

Changes in Temperature. A simulation of climate change by PT Miranthi based on MAGICC-SCENGEN climate change model scenario GCM (Global Climate Change Model) BCCRBCM2, with predicted changes in rainfall showed that on average, global temperature will rise by0.56, 1.149, and 2.83 degrees Celsius in 2020, 2050 and 2080, respectively.

Changes in Precipitation.The higher intensity of rainfall in the wet season and reduction in dry season will create higher risks of flood, landslide, and drought. Figure 4shows that in each of three succeeding ten-year periods, the average monthly rainfall generally has gone down during the first 10 months of each year. This trend is expected to continue and to be intensified increase as a result of climate change.

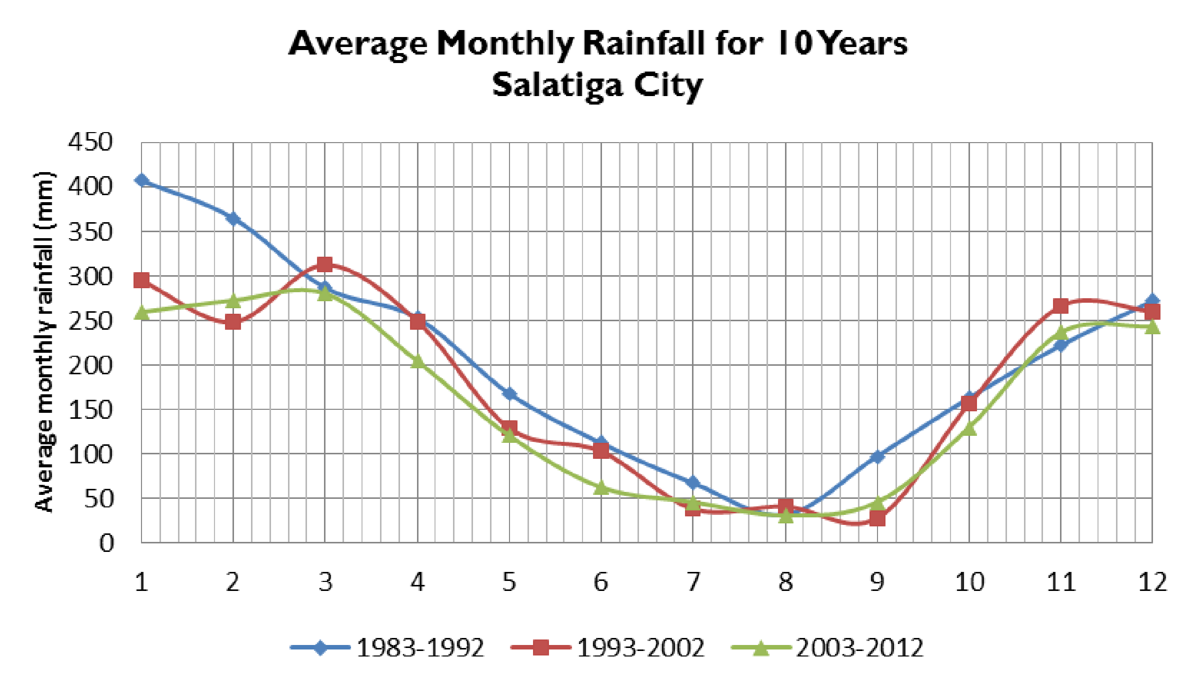


Figure 4: Average Monthly Rainfall Over Three10-year Periods.

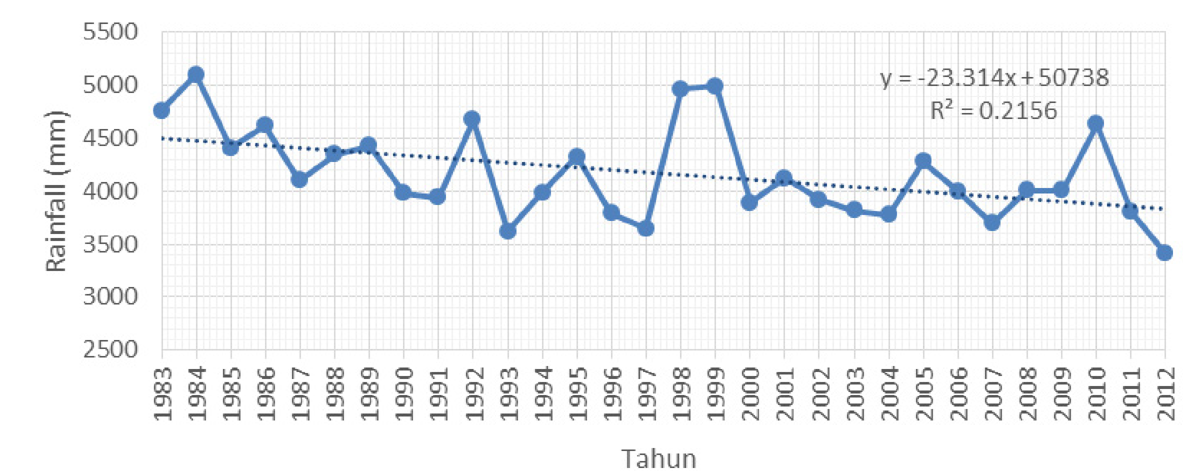


Figure 5: Total Rainfall by Year, Salatiga City, 1982 – 2012.

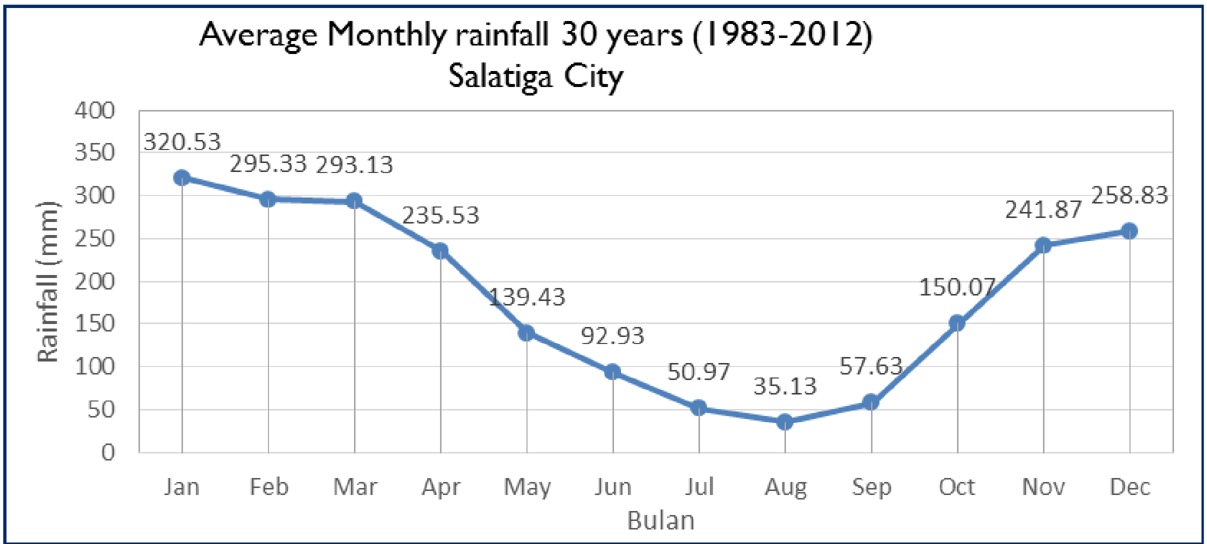


Figure 6: Average monthly rainfall, Salatiga City.

In general, December, January, and February, are expected to be wetter than normal, and the months of June, July, and August will be even drier than before.While certainly not definitive, these model predictions support the overall expectation that climate change is likely to alter the *intensity* of rainfall, with more rain received over a shorter period of time, while, at the same time, dry periods are expected to extend for a greater duration, as depicted in a general way in Figure 7.

According to the PT Miranthi research team study, based on climate studies over 30 years, the rainfall in Kota Salatiga has fallen an average of 23 %. The model shows that rainfall intensity will increase during the rainy season and it will be reduced during the dry season.

By combining the model results with field observations, it appears that *overall levels of precipitation are likely to decline, while intra-annual variations (month-to-month variations) are likely to become more extreme.*

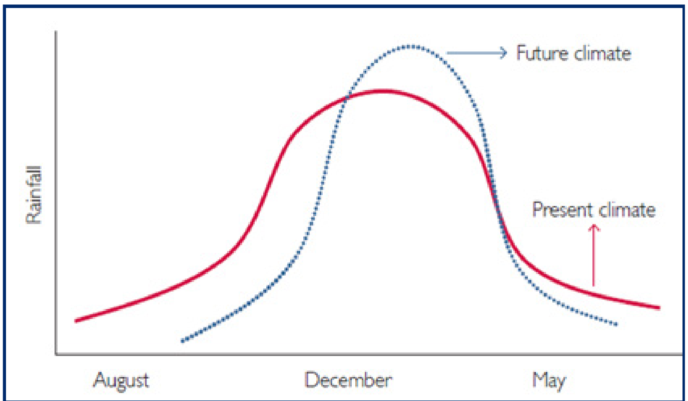


Figure 7: Future shorter but more intense rainy seasons.

To help understand the possible impacts of these changes, the PT Miranthi team created hydrological models using an assumption of continuation of a 12% decline in precipitation over30 years.

2.3.2 Climate Change Scenario: Natural Assets

Using the above climate projections, historical records, and stakeholder input gained during the Asset Risk Matrix Workshop, PDAM Salatiga City's natural assets—which, according to the above discussion, are principally composed of fresh water springs and deep wells—face the following risks under the mid-century climate change scenario:

- **Drought/Water Scarcity**: Although there is a predicted shift in intensity of monthly rainfall—including longer dry seasons and more extreme but compact rainy seasons—the climate-change scenario indicates a very high risk of drought/water scarcity at Senjoyo Spring and a high risk at both Kalitaman Spring and deep well Sukowati, and if there is no water, the associated equipment will not be useful. Under the climate change scenario, the water table is expected to recede significantly, to about 40 meters between 2011 and 2031, especially in the area that is the center of pumping.
- More intense rains will lead to lower levels of infiltration and recharge and, ultimately, to lower flow volumes. This concern was noted by stakeholders during the Asset Risk Management workshop, where the level of risk assigned to Senjoyo Spring moved from high under the current climate (baseline) scenario to **very high** under the climate change scenario as shown in Figure 8 at right. The general consensus of stakeholders was that climate change would serve to elevate this risk.
- **Flooding**. The greater intensity of precipitation events poses a low risk to the natural assets of the PDAM at Kalitaman Spring. Given that the PDAM relies wholly on springs and deep wells, floods are unlikely to threaten the water quality of these sources.

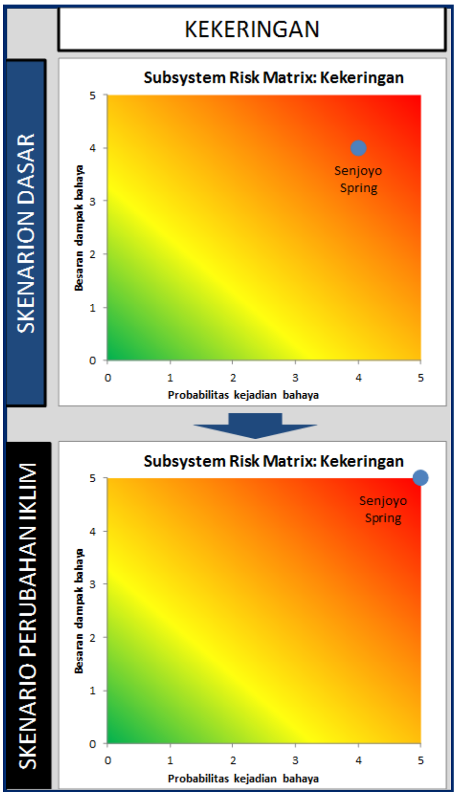
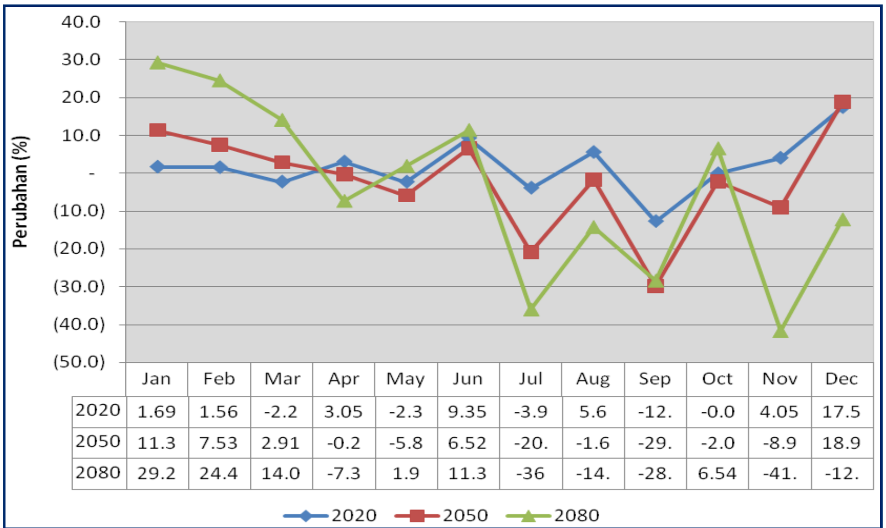


Figure 8: Senjoyo Spring vulnerability to drought.

- **Landslides**. No risk was noted to the natural assets of the PDAM due to the threat of landslides under the climate change scenario. Landslides will not impact the quality of the groundwater sources used by the PDAM.

- **Sea Level Rise**. There is no risk to the PDAM's natural assets from sea level rise under the climate change scenario given the considerable distance to the coast.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	1.69	1.56	-2.2	3.05	-2.3	9.35	-3.9	5.6	-12.	-0.0	4.05	17.5
2050	11.3	7.53	2.91	-0.2	-5.8	6.52	-20.	-1.6	-29.	-2.0	-8.9	18.9
2080	29.2	24.4	14.0	-7.3	1.9	11.3	-36	-14.	-28.	6.54	-41.	-12.

Figure 9: Projected change in rainfall, 2020, 2050 and 2080.

As indicated under the baseline scenario, it will be important to monitor the impact of land use change in the watershed recharge areas. Given the predicted changes in precipitation patterns, maintaining absorption/infiltration levels will be critical to the long term sustainability of the fresh water springs supplying the PDAM.

2.3.3 Climate Change Scenario: Physical Assets

Based upon the vulnerability study as well as the Asset Risk Matrix compilation workshop, the following levels of vulnerability were identified under the climate-driven scenario for the physical assets servicing the city of Salatiga:

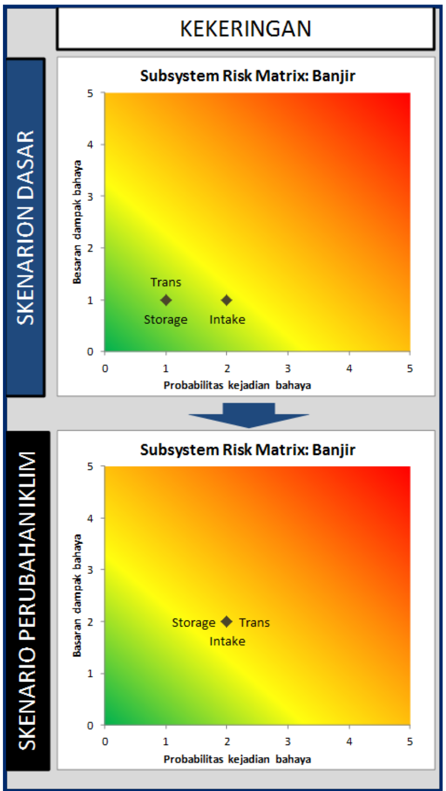


Figure 10: Flood Risk Analysis for Kalitaman Spring.

- **Drought/Water Scarcity**: There is was no significant risk attached to physical damage to the PDAM's water supply infrastructure. As noted under the baseline scenario, the PDAM does not have a history of citizen-induced damages to its infrastructure (pipeline network) during drought conditions. It should be pointed out that according to *Indonesian Climate Change Sectoral Roadmap* (ICCSR), 2010, under the high emissions scenario, Salatiga City is in area of high to very high vulnerability to drought from 2025-2030.
- **Flooding**: In the Kalitaman Spring area, the risk of flooding to the intake, reservoir, and parts of the transmission line is medium, as shown in Figure 10.
- **Landslides**: Landslides are expected to be a risk for PDAM Salatiga City under the climate change scenario, mainly in the case of transmission pipes near Kalitaman Spring, which face a medium risk of damage. Piping systems may be vulnerable to landslides in certain areas, as shown in Table 6, which lists all areas of potential vulnerability based on the slope of the terrain. As with flood hazards, a rise in storm intensity will serve to loosen soils, particularly those located in steeper areas of the watershed.
- **Sea Level Rise:** PDAM's constructed assets remain both far enough inland and high enough in elevation to avoid exposure to sea level rise.

In summary, climate change will worsen the existing threats to the PDAM's constructed infrastructure, particularly when it comes to flood hazards in the lower watershed and landslide hazards in the upper watershed. Climate change is expected to increase the threat of landslides to some assets. As the PDAM considers the construction of new assets, planning for locations of transmission lines and intakes should take into consideration the threats of landslides. Please see the summary results from the ARM Workshop attached as **Annex 5**.

Figure 11: Map of PDAM Piping system in Landslide areas. Light green-shaded areas are prone to landslides. The dark green areas are spring heads.

Table 7: Climate change potential risks to Salatiga Water Sources

No.	Water Source	Risk	Risk	Adaptations
1	Kaliprambanan Spring	Land-slide	Headworks may be buried	Protective infrastructure
2	Kaliwedok Spring	Land-slide	Headworks may be buried	Protective infrastructure
3	Kaligedangan spring	Land-slide	Headworks may be buried	Protective infrastructure
4	Kaligetek Spring	Land-slide	Headworks may be buried	Protective infrastructure
5	Kalibenoyo Spring	Land-slide	Headworks may be buried	Protective infrastructure
6	Kalitaman Spring	Land-slide	Headworks may be buried	Protective infrastructure
7	Pipes in Sub-districtTingkir	Land-slide	Pipe connections may break	Protect or move location of pipes
8	Pipes in Sub-districtSidorejo (north only)	Land-slide	Pipe connections may break	Protect or move location of pipes

2.3.4 Climate Change Scenario: Limited Water Balance Analysis

Using the results of expected changes to the local climate in Salatiga, the water balance for sources of water used by the PDAMis expected to change through mid-century with greater pressure on the supply of water of good quality. Several important points worthy of note are as follows:

- The existing sources of raw water possess capacity significantly above the current volume produced by the PDAM, meaning that the PDAM has natural assets available to continue to meet rising demand and grow its customer base in the short to medium term despite the climate change risks, but it will have to look for new sources in the medium term;
- Over the last 30 years total rainfall in Kota Salatiga fell by about 12%, and the potential for water absorption fell by 7% from 2003-2011. This trend is expected to accelerate with climate change
- Climate change is expected to accelerate the decline of the water table which will reduce the rate of discharge from springs and possibly cause the disappearance of some production wells after the year 2029.
- It was assumed that in the case of shared water sources such as Senjoyo Spring, the PDAM will withdraw the same proportion of water in all future years.
- The PDAM served 74.3% of the population in 2012 with 314 liters per second and the PDAM will withdraw water from existing sources plus additional sources phased in as needed.
- Based on the assumption that no new sources of water will be found or developed, the available supply of current and planned sources of PDAM water is not expected to be overcome by demand from all users until about 2029. But there are many remedial actions available for use by the PDAM.
- This preliminary analysis assumes that the PDAM will not increase production of water beyond currently-planned capacity.

A more detailed analysis of the water balance affecting PDAM Salatiga City would be helpful, taking into consideration the demands of other users throughout the watershed.

Figure 12 shows three scenarios for supply of groundwater for the PDAM:

Scenario 1, reduction of 7% in infiltration rate due to change in land use
Scenario 2, reduction of 12% in infiltration rate due to change in rainfall pattern
Scenario 3, reduction of 19% in infiltration rate to both rainfall pattern and land use change.

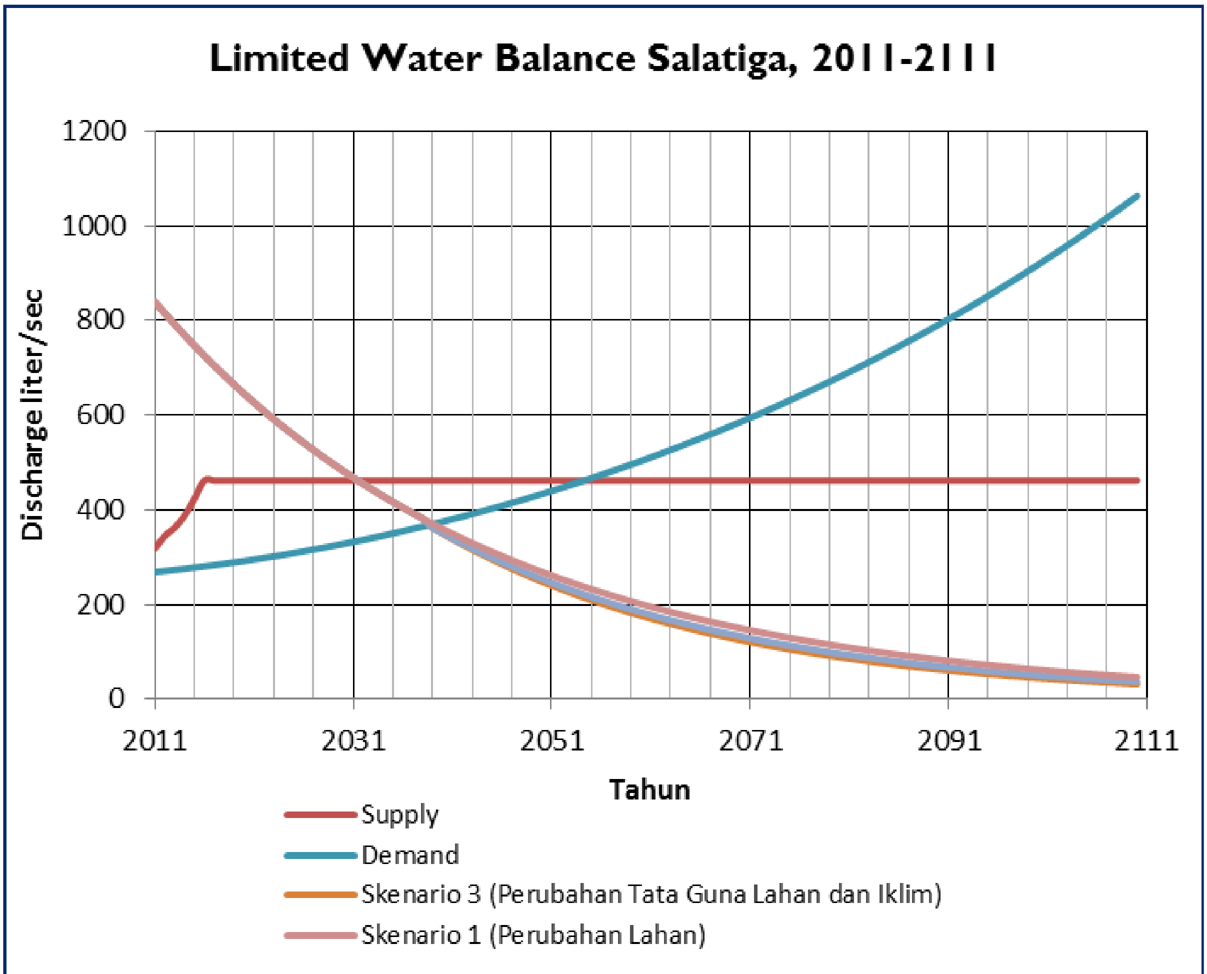


Figure 12: Groundwater Supply for PDAM and Demand curve, Salatiga City. The figure shows only the proportion of total groundwater that has been withdrawn by PDAM Salatiga City.

3 CLIMATE CHANGE ADAPTATION PLANNING

3.1 APPROACH TO ADAPTATION PLANNING

According to the IPCC (2012) adaptation to climate change is the "process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities." Adaptation actions may take many forms, including the modification of existing plans (such as providing greater distance between a planned treatment facility and the adjacent river), "soft" adaptation actions (such as rehabilitating the watershed through tree planting), or "hard" adaptation actions (such as constructing a flood wall between the river and a treatment facility or storage unit). Where possible, PDAM managers should prioritize "no regrets" adaptation actions, which are those that deliver net benefits over the entire range of anticipated future climate and associated impacts (IPCC, 2012).

The process for identifying specific adaptation options is, in many ways, similar to the decision-making path for PDAM and local government investments more broadly. More specifically, after identifying geographic "hotspots"—i.e. key assets that are deemed highly vulnerable—decision-makers move from a "long-list" of actions down to a "short-list" of actions. Further, the short-list of actions is then assigned a level of priority in terms of response to be implemented immediately and those that will be planned for the medium or longer term. To facilitate this process, IUWASH held a series of stakeholder meetings from mid-2013 through 2014 to construct a "long-list" of potential adaptation options for the identified hotspots that can be taken to boost the resilience of the PDAM's natural and constructed assets. Further, PDAM and local government representatives then discussed the costs and benefits of each potential action, using a series of criteria to identify a short-list of options and prioritize those options accordingly. The outcome of this process is described below.

3.2 VULNERABILITY HOTSPOTS

Following the vulnerability assessment process of the PDAM's natural and constructed assets, — which includes the PT Miranthi Baseline Report, a series of stakeholder meetings and workshops, and a synthesis by the IUWASH Climate Change Team—the following vulnerability hotspots were highlighted for further analysis and adaptation planning:

- **Deep well Sukowati (Natural Asset):** Located not far from the PDAM office, deep well Sukowati was established when the discharge of springs was heavily reduced during a dry season. In recent years, the PDAM has observed noticeable decreases in the flow capacity of this deep well, much more so than in other raw water sources. This natural resource is vulnerable to drought, especially under the climate change scenario.
- **Senjoyo Spring (Natural Asset)**: The spring is located in Semarang district, outside of the city limits of Salatiga, and it is the largest single source of water for PDAM Salatiga City. Its vulnerability to the effects of drought is very high under the climate change scenario. The PDAM withdraws about 15 per cent of the current discharge of Senjoyo Spring. Reduction in the discharge of Senjoyo Spring has been noticed over recent years, and there has been steadily decreased supply during the dry season. Adaptation measures must be coordinated with PDAM Semarang District and the Semarang District local government.
- **Kalitaman Spring (Natural Asset)**: The spring, located in Salatiga City, is a key source of raw water for PDAM Salatiga City, and reduction in discharge from Kalitaman Spring has been noted by PDAM staff, indicating that it is highly vulnerable to the effects of drought.

- **Kalitaman Spring (Built Assets):** The intake, reservoir, and transmission system have a medium level of vulnerability to flooding, and transmission lines have a medium level of vulnerability to landslides under the climate change scenario. As climate change brings greater intensity of rainfall, the area needs to be monitored for occurrence of landslides.

In summary, the main vulnerability hotpot for natural assets for PDAM Salatiga City appears to be Senjoyo Spring in the case of drought, but deep well Sukowati and Kalitaman Spring also have a medium level of vulnerability to drought under the climate change scenario because of reduced flow during the dry season. Kalitaman Spring is the most vulnerable hotspot as far as infrastructure is concerned with a medium level of vulnerability of its intake, reservoir, and transmission pipes to flood and a medium level of vulnerability of its transmission pipes to landslides.

3.3 LONG LIST OF ADAPTATION OPTIONS

A wide range of adaptation options exists to boost the resiliency of PDAM assets. As part of the adaptation planning process, IUWASH reviewed the different types of responses that the PDAM may consider for the vulnerability hotspots identified. Table 7 below provides an illustrative "long list" of climate change adaptation options.

Table 8: Long List of Adaptation Options.

Adaptation Classifications	Specific Responses
Source Water Protection	Watershed Protection: Establishment of protected zones critical for water recharge or spring protection
	Aquifer recharge programs
	Farmer extension programs aimed at reducing soil erosion
	Improved waste collection and treatment
	Establish a conservation forum of inhabitants at catchment area source
	Establish a forum of water users
	Maintain infiltration wells
	Payment for Environmental Services
Water Efficiency and Demand Management	Non-Revenue Water Reduction
	Water meter maintenance and replacement
	Efficient water pricing (i.e. increasing block tariffs)
	Social marketing for consumer behavior change
	Consumer incentive programs (i.e. low-flow devices)
	Advocacy/regulation to manage groundwater withdrawal
	Wastewater reuse for agriculture and industry
Infrastructure Options	Enhance/expand storage capacity through construction of new reservoirs
	Diversify water resources through construction of deep wells, new surface water intakes, and inter-basin transfers
	Check dams to slow runoff and facilitate aquifer recharge
	Increase access to improved urban sanitation systems to reduce pollution of upstream water sources and local groundwater
	Expanded wastewater treatment for water reuse in agriculture and industry
	Community-based rainwater harvesting
	Establish pumps in flood-prone areas
	Expand/upgrade urban drainage systems
	Construction of berms, dikes, or sea walls
	Relocation / strengthening water infrastructure that may be subject to flooding
Risk Management	Establish contingency fund to respond to disasters
	Insurance on equipment subject to risk
Information Management	Water Allocation Decision-Support Systems
	Hydrological / Meteorological Monitoring Stations

Adaptation Classifications	Specific Responses
	GIS-Enabled Asset Management Systems
	Disaster early-warning system
	Water security planning
	Research into water resources such as mapping of aquifer
	Computerized Billing and Accounting

3.4 SHORT LIST OF ADAPTATION OPTIONS AND VULNERABILITY HOTSPOTS

Following the selection of the vulnerability hotspot and a review of the menu of adaptation options available, PDAM representatives and IUWASH then identified key criteria with which to compare and rank potential actions. These criteria were as follows:

- Cost of the proposed adaptation;
- Complexity, including technical complexity and coordination between stakeholders;
- Political support (and level of political action required);
- Speed of implementation; and
- Overall impact on the reduction of risk to the specific assets.

Table 8 summarizes the short list of adaptation options discussed for three of the assets while also highlighting the hazards that the adaptation option will help to address. The full evaluation of adaptation options is attached as **Annex 6**.

Table 8: Prioritization of Adaptation Options using Multi-criteria Analysis

Asset	Priority Adaptation Options	Drought	Flood	Mudslide	Sea Level
Senjoyo Spring	Extension service to communities regarding infiltration well	*	*	*	
	Establish water conservation forum at source of catchment for Senjoyo spring	*	*	*	
	Maintenance of infiltration wells	*	*	*	
	Increase access to better sanitation to avoid water pollution, as with replacing latrines with toilets	*	*		
	Maintain or replace broken water meters	*			
	Consumers use basins or reservoirs	*			
	Prepare a plan and/or emergency SOP (contingency plan) for disasters such as floods in pumping areas	*	*	*	*
Kalitaman Spring	Establish a protection zone around the spring; assign people to protect the exclusion zone	*	*	*	
	Increase access to better sanitation to avoid water pollution, as with replacing latrines with toilets	*			
	Procure tanker trucks to provide water to areas affected by drought	*			
	Maintain or replace broken water meters	*			
	Use social marketing to change water users behavior	*			
	Establish emergency disaster fund (government, PDAM)	*	*	*	*

Asset	Priority Adaptation Options	Drought	Flood	Mudslide	Sea Level
Deep Well Sukowati	Strengthen regulations including permission to extract groundwater and surface water through local regulation, MOU for inter-regional cooperation for conservation	*			
	Program to return water to nature, such as infiltration wells	*			
	Payment for environmental services	*	*	*	
	Reduce leakage (PDAM) through repair/replacement of old or broken pipes	*			
	Customers use basins or reservoirs	*			
	Advocacy/regulation to control groundwater withdrawal	*			
	Install monitoring of hydrology/meteorology/groundwater	*			
	Prepare a plan and/or emergency SOP (contingency plan) for disasters such as floods in pumping areas	*			

Building on as well as in addition to the above priority adaptation options identified by the PDAM and local government officials, IUWASH also recommended consideration of the following:

- **Strengthening and/or Repositioning of Infrastructure:** In order to address the vulnerability of the intake, reservoir, and pipes to flood and some transmission lines to landslides at Kalitaman Spring, the PDAM may consider adding reinforcements, particularly at some places identified by the PTMiranthi Research Team as highly susceptible to landslides that would affect pipelines. Over the longer term, the PDAM may also consider moving some transmission mains altogether to a more secure and less landslide-prone route.
- **Improved Asset Management:** At present the PDAM is preparing a GIS-enabled system. It would be valuable to establish a GIS-based asset management system to track critical infrastructure details such as: age, depreciated value, replacement cost, and historical damages. Adopting such a system would help to identify vulnerable assets and proactively plan for maintenance and/or repairs.
- **Water Resources Decision Support Systems**: In the absence of reliable stream flow data, ground water levels, and rainfall intensity records (i.e. hourly rainfall data), it will continue to be difficult for PDAM officials and local government officials to understand how the quantity and quality of their water resources are changing and how to best plan for the future. Thus, incremental investments in automated hydrological and meteorological monitoring systems in cooperation with surrounding local governments could lead to more informed and effective water resources management decisions.

As described earlier, some of the above adaptation actions have already commenced, particularly as concerns aquifer recharge programs and watershed management improvements.

4 ACTION PLAN

4.1 NEXT STEPS FOR IMPLEMENTATION OF ADAPTATION PLAN

Based on the results of the water supply baseline study, the identification of vulnerability hotspots, completion of the asset risk matrix, and the discussion and prioritization of adaptation options, the PDAM, in cooperation with the local government, have undertaken a series of immediate actions.

- **Action #1: Development of GIS Program:** after receiving GIS training, PDAM staff developed GIS mapping of the piping network and its accessories.The PDAM paid the costs of this mapping, including the cost of MapInfo software.The PDAM plans that all of its assets and customer data will eventually be mapped based on GIS, enabling better management of the assets, including those vulnerable to climate change-driven hazards.
- **Action #2: Development of infiltration pond program**: through collaboration of IUWASH and Coca-Cola Foundation Indonesia (CCFI), the PDAM is helping construct infiltration ponds in the recharge area of Senjoyo Spring, the PDAM's main source of raw water.Among other things, the ponds serve as artificial recharge reservoirs that feed the spring's aquifer. Communities are involved in the construction and they will take the lead in maintenance once the ponds are constructed. In the long run, the PDAM is looking for the city local government to contribute to maintenance of the infiltration ponds, but most of them are in Semarang District, so they would need a legal basis for funding the maintenance costs. Future infiltration ponds many be constructed using funds from the City's Environmental Service budget.
- **Action #3: Dialogue with Senjoyo Spring users:** Senjoyo Spring is the main source of PDAM Salatiga City's raw water, and it is also used by PDAM Semarang district, a military camp, a textile industry, and local communities.The spring's users are becoming aware that they need to cooperate to withdraw water from Senjoyo Spring on a sustainable basis. Neighboring PDAM Semarang District established a secretariat in the Semarang Regional Secretary's office and took the lead in holding three meetings with stakeholders, including PDAM Salatiga city.Initial discussions between the PDAM and other users are expected to lead to consensus on water allocation for each user and to arrangements for maintenance of infiltration ponds.
- **Action #4: Water safety plan** (Rencana Pengamanan Air Minum-RPAM): PDAM Salatiga city has developed a Water Safety Plan both as commitment and guidance on how the PDAM will guarantee production and distribution of its water supply in the future.The plan lays out long-range policies so that the PDAM can continue to meet its quantity, quality, and continuity targets. Under the plan, PDAM Salatiga City has purchased and installed four water meters downstream from Senjoyo Spring.
- **Action #5: SemarSalat Cooperation**: in order to meet the city's growing water demand, PDAM Salatiga plans to cooperate with its neighbor, Kabupaten Semarang, under the SemarSalat scheme. At present, no more withdrawals can be made from the Tuntang River, but PDAM Salatiga City may use part of the allocation of 250 liters per second made to a private water company, PT STU, which is using only 80-100 liters per second. SemarSelat cooperation is expected to lead to establishment of a body to manage all raw water sent to Salatiga from Kabupaten Semarang.

4.2 INTEGRATION INTO MEDIUM AND LONG-TERM PLANNING

In conjunction with the commencement of the implementation of immediate and short-term adaptation options, it is also important that the results of this assessment and planning exercise be integrated into the PDAM and local government's broader development planning. In other words, while the preparation of a specific "adaptation plan" makes sense as an initial step towards improved climate change adaptation planning, the more sustainable approach over the long term is that the results and, more importantly, the process itself, be included in existing planning mechanisms, namely, the PDAM's Corporate Plan and/or Annual Plan (RKAP) and the Local Government's annual and medium-term plans. Specific actions in this regard are:

- The PDAM will establish a specific program for the maintenance and expansion of the infiltration wells;
- The PDAM will integrate the results of the Vulnerability Assessment and Adaptation Plan during the next revision of its 5-year corporate plan; and
- The Local Government will establish a specific program and budgetary line items for improved water resources management in the next Annual Work Plan and Annual Budget (APBD).

The integration of climate change vulnerability assessment and adaptation planning into the local planning documents will also support continuous learning and, where necessary, updating of adaptation approaches. There is still much that we do not know about how climate change will impact a specific location and the natural and built assets located therein. Thus, climate change adaptation is best approached on an iterative basis under the auspices of the local planning cycles, thereby ensuring that such plans are regularly updated based on the latest scientific knowledge and the evolving experiences and needs of the local communities.

ANNEXES

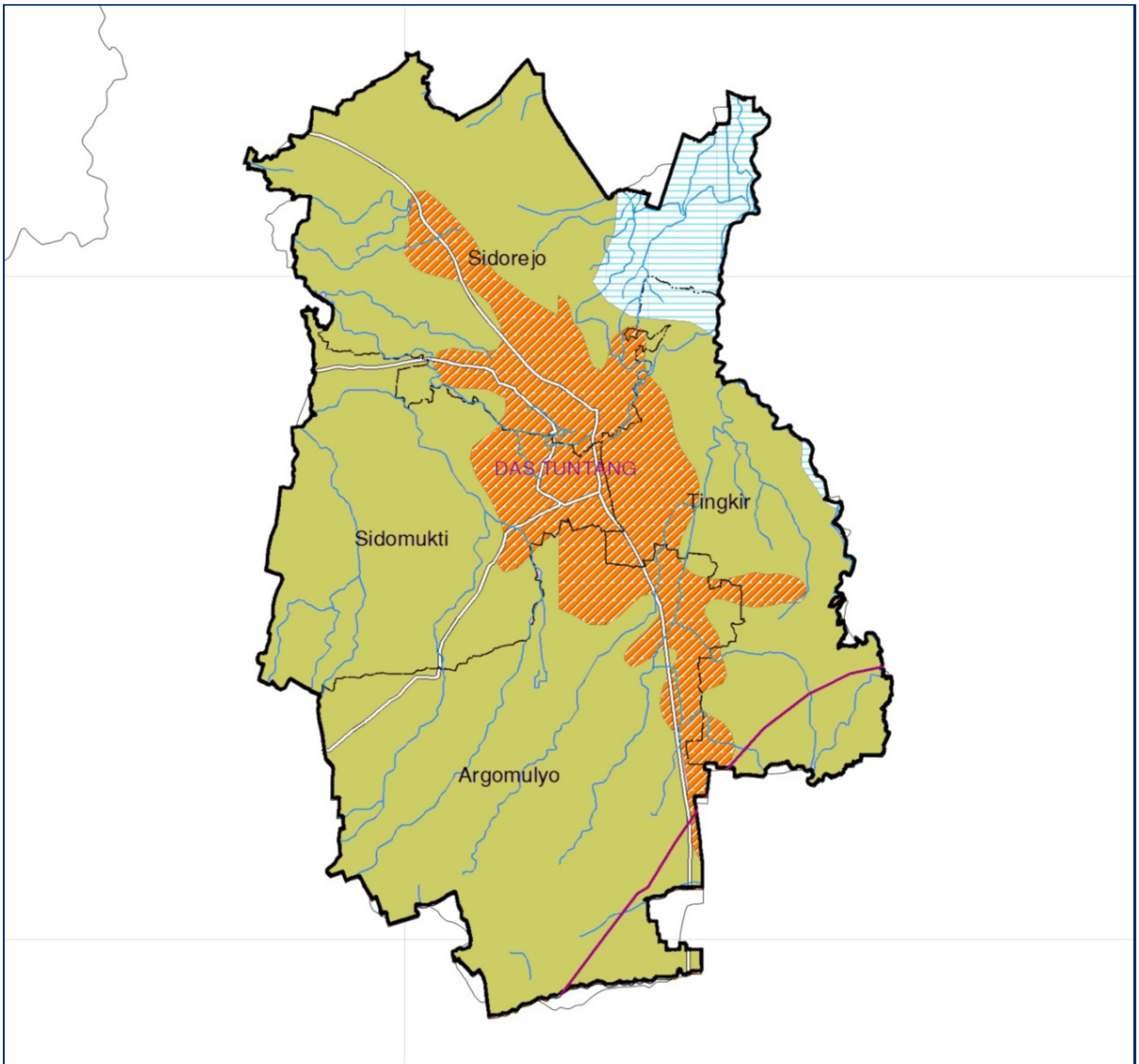
ANNEX 1: CHRONOLOGY OF VA & AP PROCESS

Date	Activity/Event	Major Output	Stakeholders
May 2012	Initial assessment: - Discussion with PDAM - Field survey of raw water sources used by PDAM	- Indication of declines in quantity of springs & deep well. PDAM recognized this fact. - Identified needs for CCVA study.	PDAM Kota Salatiga, IUWASH
November 2012	Selection of institution to conduct CCVA through tendering process	PT Miranthi qualified and was selected to conduct CCVA study	PT Miranthi, IUWASH
December 2012	Kick off meeting: Meeting and discussion among Kota Salatiga, IUWASH, and PTMiranthi	- Understanding of CCVA work activities to be undertaken - Agreement on schedule, data collection, and support of PDAM	PDAM, PT Miranthi, IUWASH
July 2013	Initial workshop on the CCVA study	Preliminary results of CCVA were discussed & items for revisions of CCVA were identified: water supply and demand, assets' vulnerability particularly on the raw water, and initial recommendation for adaptation	PDAM, Bappeda, Dinas SDA, Dinas Pertambangan dan Energi, BLH, BPBD, Dinas Kehutanan, Dinas Pertanian, Satker PK-PAM Prov. Jateng, PT Miranthi, IUWASH
July 2013	Initial ARM workshop	Initial ARM were developed by PDAM and other key local government agencies	PDAM, Bappeda, Dinas PSDA, Dinas Pertambangan dan Energi, BLH, BPBD, Dinas Kehutanan, Dinas Pertanian, Satker PK-PAM Prov. Jateng, PT Miranthi, IUWASH
August 2013	FGD on initial ARM and adaptation options development	Initial adaptation options were identified and discussed	PDAM, Bappeda, Dinas PSDA, Dinas Pertambangan dan Energi, BLH, BPBD, IUWASH
September 2014	Workshop on CCVA, ARM, and adaptation options	- Common understanding among PDAM and other stakeholders on Salatiga's water supply's vulnerability - ARMsand adaption options were developed by PDAM and other key local government agencies	PDAM Kota Salatiga, PDAM Kabupaten Semarang, BPBD, Bappeda, Dinas PSDA, Dinas Kehutanan, Dinas Pertanian, BLH, Balai Besar Wilayah Sungai (BBWS) Pemali-Juwana, LPPM Undip, PT Sarana Tirta Ungaran (STU), SPPQT, IUWASH, PT Miranthi

ANNEX 2: MAP OF WATERSHEDS IN SALATIGA CITY

Annex 2. Most of Salatiga City is located on the Tuntang watershed, but Senjoyo and Kaligojek Springs are located in Semarang District in the Serang-Lusi Watershed.

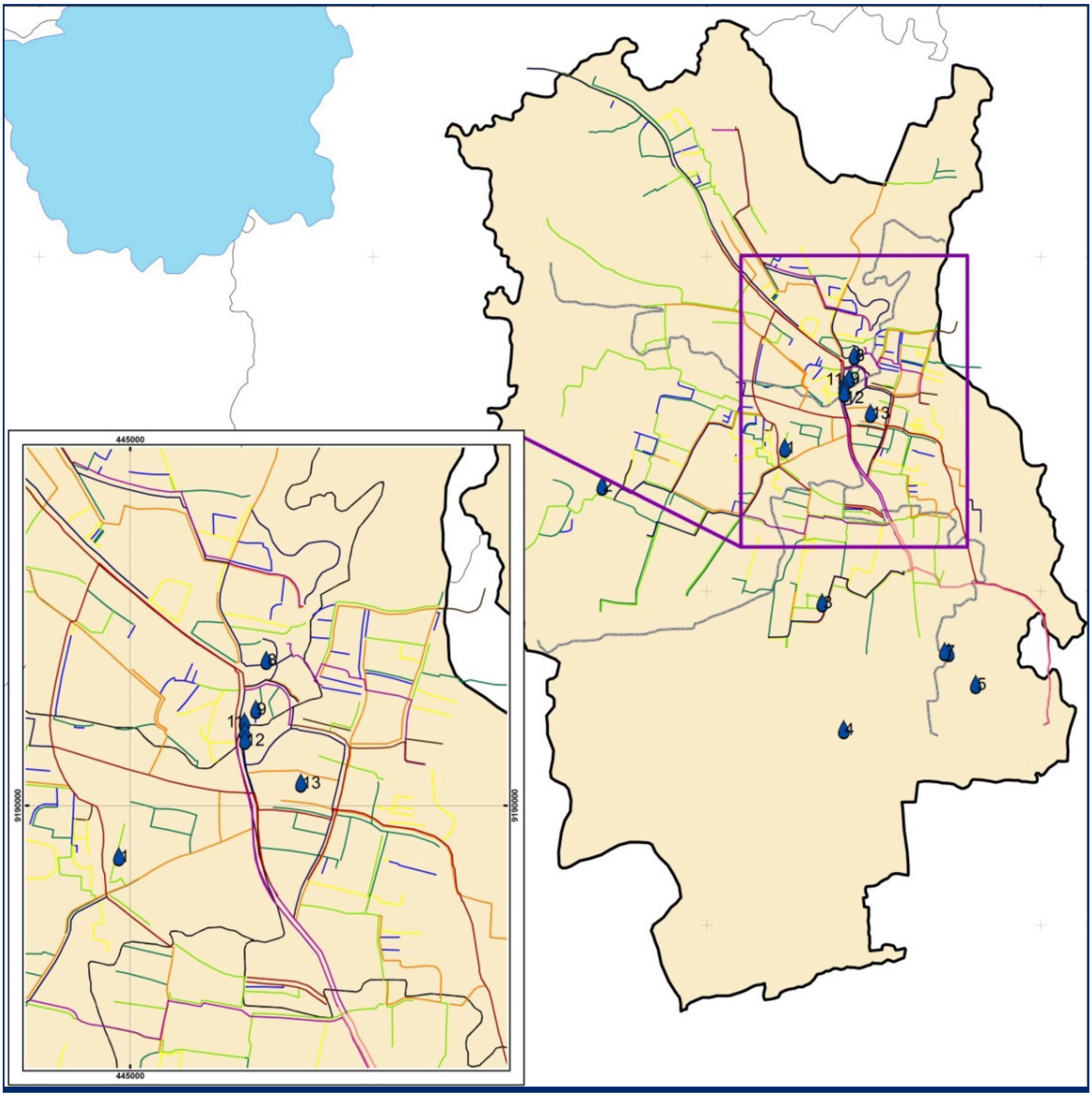
ANNEX 3: LAND USE MAP OF SALATIGA CITY, 2003



Source: PT Miranthi

The area shown in orange is settlements.
The area in green is dryland agriculture.
The blue and white area is rice fields.

ANNEX 4: MAP OF CONSTRUCTED ASSETS



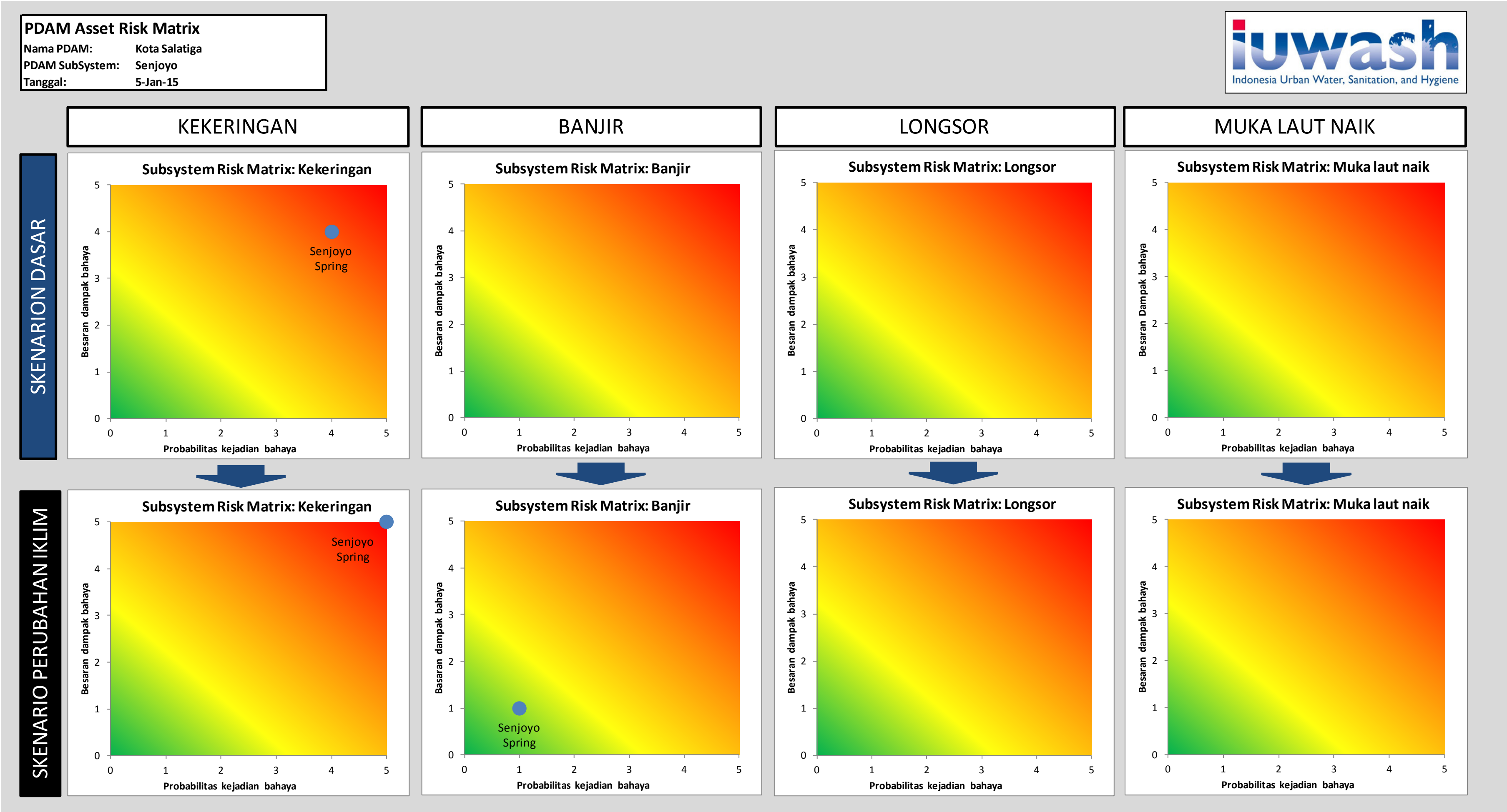
The following water sources within Salatiga City are shown on the map:

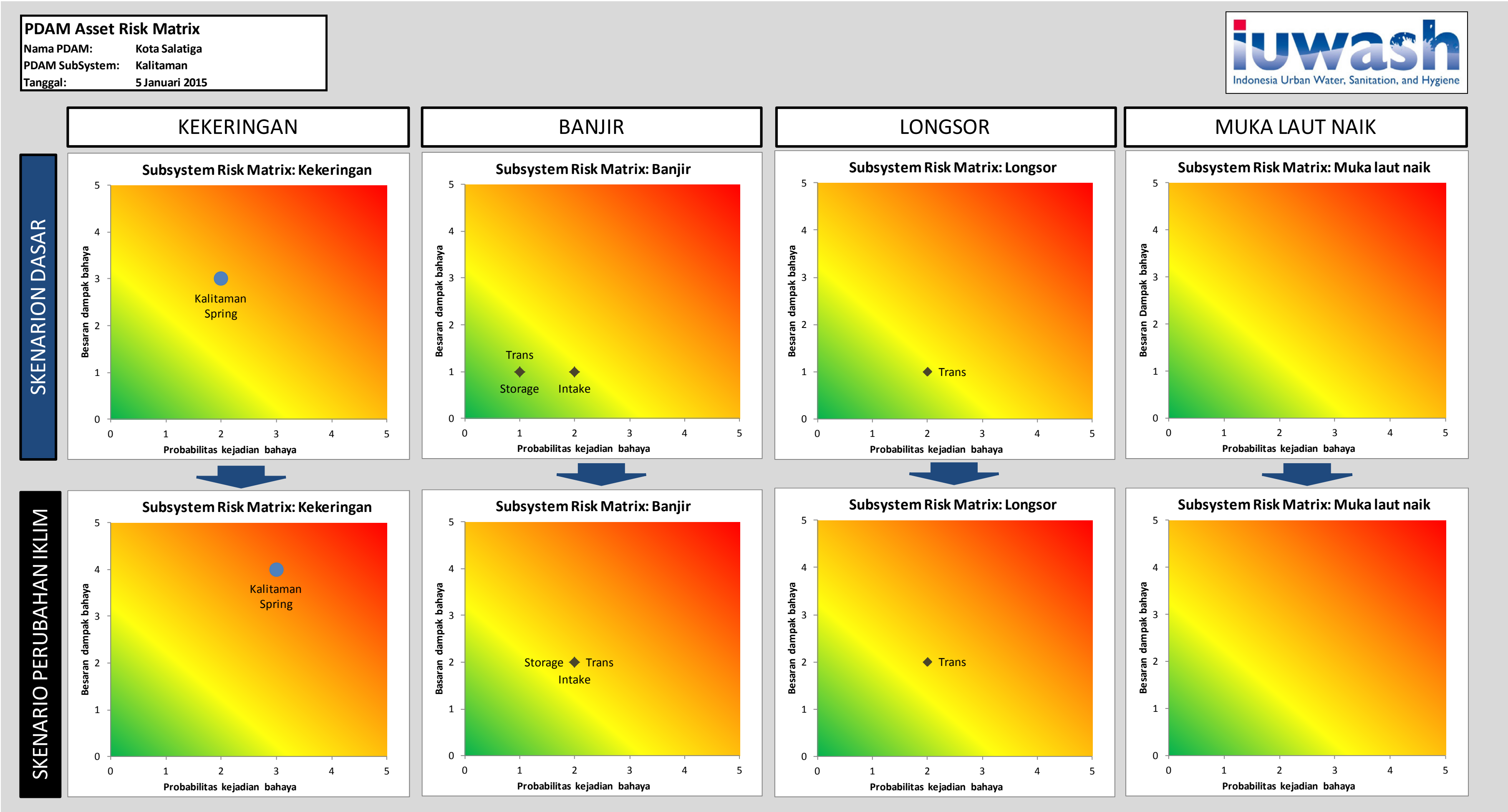
1. Sukowati Deep Well
2. Ngemplak Deep Well
3. Bulu Deep Well
4. Cebongan Deep Well
5. Kradenan Deep Well
6. Tegalsari Deep Well
7. Tegalsari 1 Deep well
8. Kaliprambanan Spring
9. Kalgedangan Spring
10. Kaligetek Spring
11. Kalitaman spring
12. Kaliwedok Spring
13. Kalibenoyo Spring

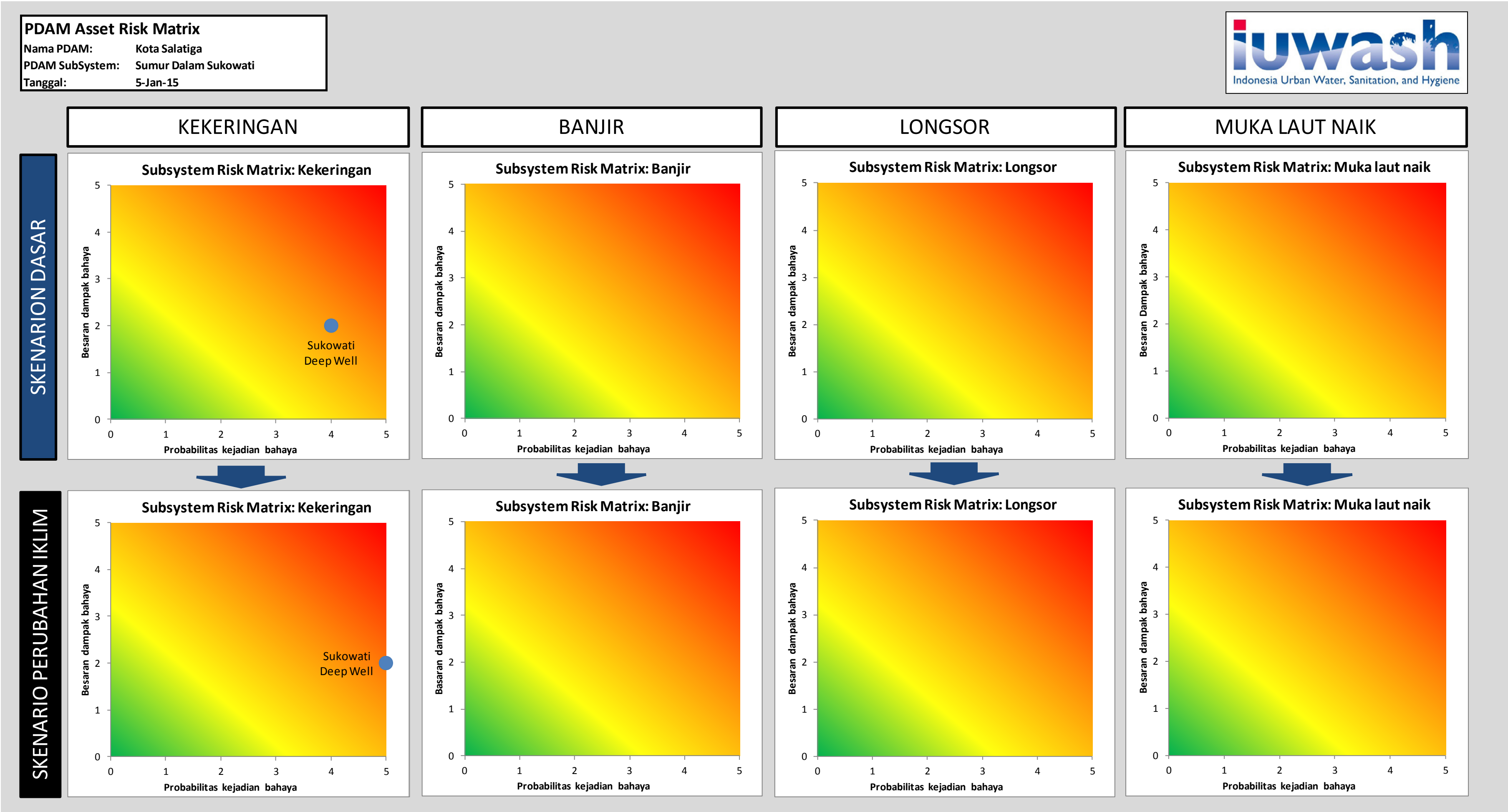
The following sizes of pipes are shown on the map:

Brown	16 inch pipe
Rose	10 inch pipe
Gray	6 inch pipe
Light brown	4 inch pipe
Yellow-green	3 inch pipe
Dark Green	2 inch pipe
Dark blue	1 inch pipe

ANNEX 5: ASSET RISK MATRIX BY SUBSYSTEM




PDAM Asset Risk Matrix
Nama PDAM: Kota Salatiga
PDAM SubSystem: Kalitaman
Tanggal: 5 Januari 2015
Indonesia Urban Water, Sanitation, and Hygiene
KEKERINGAN
BANJIR
LONGSOR
MUKA LAUT NAIK
SKENARION DASAR
SKENARIO PERUBAHAN IKLIM
Subsystem Risk Matrix: Kekeringan
Kalitaman Spring
Subsystem Risk Matrix: Banjir
Trans
Storage
Intake
Subsystem Risk Matrix: Longsor
Trans
Subsystem Risk Matrix: Muka laut naik
Besaran dampak bahaya
Besaran Dampak bahaya
Probabilitas kejadian bahaya
0
1
2
3
4
5
Subsystem Risk Matrix: Kekeringan
Kalitaman Spring
Subsystem Risk Matrix: Banjir
Storage
Trans
Intake
Subsystem Risk Matrix: Longsor
Trans
Subsystem Risk Matrix: Muka laut naik


PDAM Asset Risk Matrix
Nama PDAM: Kota Salatiga
PDAM SubSystem: Sumur Dalam Sukowati
Tanggal: 5-Jan-15
iuwash
Indonesia Urban Water, Sanitation, and Hygiene
KEKERINGAN
BANJIR
LONGSOR
MUKA LAUT NAIK
SKENARION DASAR
SKENARIO PERUBAHAN IKLIM
Subsystem Risk Matrix: Kekeringan
Subsystem Risk Matrix: Banjir
Subsystem Risk Matrix: Longsor
Subsystem Risk Matrix: Muka laut naik
Besaran dampak bahaya
Besaran Dampak bahaya
Basaran dampak bahaya
Probabilitas kejadian bahaya
Sukowati Deep Well
0
1
2
3
4
5

ANNEX 6: EVALUATION OF ADAPTATION OPTIONS

Alternative Adaptations for Provision of Piped Water PDAM Salatiga City

Water Source: Mata Air SENJOYO

Type of Adaptation	Options of Adaptation Actions	Anticipated Hazard				Selection Criteria					
		Drought	Flood	Landslide	Rise in Sea Level	Cost	Complexity	Political Aspects	Implementation Speed	Benefit	Total Score
Water Source Protection	Program to return water to the source such as infiltration well	*	*	*		1	2	2	2	3	10
	Extension service to communities regarding infiiltration well	*	*	*		3	3	3	3	3	15
	Improve wastewater and solid waste handling, especially at water source	*	*	*		2	2	3	2	2	11
	Establish water conseration forum at source of catchment for Senjoyo spring	*	*	*		3	3	2	2	3	13
	Establish a forum for efficient use of Senjoyo Spring water	*	*	*		3	3	2	2	3	13
	Maintenance of infiltration wells	*	*	*		3	3	3	3	3	15
Infrastructure Alternatives	Inspect and repair dams to delay runoff and help recharge aquifer	*	*	*		2	2	3	2	3	12
	Community-based system to gather rainwater (infiltration wells)	*	*	*		2	2	3	2	3	12
	Use many different sources of water (surface, groundwater, springs) with interregional cooperation	*	*	*		3	2	2	2	3	12
	Increase access to better sanitation to avoid water pollution, as with replacing latrines with toilets	*	*			3	3	3	3	2	14
	Recycle wastewater for use by industry or agriculture	*	*			2	2	3	2	3	12
	Improve the drainage system, especially around water infrastructure in order to avoid flood damage	*	*			2	2	3	2	3	12
	Make reservoirs to increase holding capacity for water	*	*			2	2	1	2	3	10
	Make disaster prevention infrastructure, sucha as thrust block to prevent landslides		*	*		2	1	1	2	3	9
	Move disaster-vulnerable infrastructure such as transmission pipes		*	*		2	1	1	2	3	9
	Procure tanker trucks to provide water to areas affected by drought	*				2	2	3	2	3	12
	Use idle capacity through uprating or rerating	*				3	2	2	2	3	12
Processing/Efficiency	Reduce technical NRW through repair or replacement of pipes	*	*	*		1	1	3	3	3	11
	Maintain or replace broken water meters	*				3	3	3	3	3	15
	Use progressive tariff to encourage conservation of water	*				3	3	1	2	3	12
	Use social marketing to change water users behavior	*				3	3	1	2	3	12
	Use energy efficiency to maintain the standard of service	*				1	1	2	2	3	9
	Consumers use basins or reservoirs	*				2	3	3	3	3	14
	Advocacy or regulation to reduce exploitation of groundwater	*				2	1	1	1	3	8
Planning and information management	Decision support system for allocation of water (including calculation of water resources and water balance)	*	*	*		2	1	1	2	3	9
	Install monitoring of hydrology/meteorology/groundwater	*	*	*		2	2	3	2	3	12
	Install accounting system to record and bill for water together with a system to account for provision of water/PDAM					2	1	3	2	3	11
	Map the location and characteristics of the aquifer and other sources of raw water					2	1	2	2	3	10
	Disaster plannning (contingency/emergency plans)	*	*	*		2	0	0	0	0	2
	Plan for water security/emergency fund	*	*	*		2	1	3	1	3	10
Anticipation/providing for risk	Buy (property) insurance for buildings and key infrastructure such as vehicles	*	*	*	*	0	0	0	0	0	0
	Establish emergency disaster fund (government, PDAM)	*	*	*	*	1	3	2	3	3	12
	Prepare a plan and/or emergency SOP (contingency plan) for disasters such as floods in pumping areas	*	*	*	*	1	3	3	3	3	13

Alternative Adaptations for Provision of Piped Water PDAM Salatiga City
Water Source: Mata air Kalitaman

Adaptatation Classification	Options of Adaptation Actions	Bahaya yang diantisipasi				Selection Criteria					Total Score
		Drought	Flood	Landslide	Rise in Sea Level	Cost	Complexity	Political Aspects	Implementation Speed	Benefit	
Water source protection	Establish a protection zone around the spring; assign people to protect the exclusion zone	*	*	*		3	3	2	3	3	14
	Strengthen regulations including permission to extract groundwater and surface water through Perda, Oerwal, Perbup, MOU for inter-regional cooperation for conservation	*	*	*	*	2	2	2	2	3	11
	Program to return water to the source such as infiltration well	*	*	*	*	2	2	2	3	3	12
	Maintain infiltration wells	*	*	*		0	3	3	3	3	12
Infrastructure Alternatives	Inspect and repair dams to delay runoff and help recharge aquifer					0	0	0	0	0	0
	Community-based system to gather rainwater (infiltration wells)	*				2	0	0	0	0	2
	Use many different sources of water (surface, groundwater, springs) with interregional cooperation	*				2	2	2	2	3	11
	Increase access to better sanitation to avoid water pollution, as with replacing latrines with toilets	*				3	3	3	3	2	14
	Recycle wastewater for use by industry or agriculture	*	*			2	2	3	2	2	11
	Improve the drainage system, especially around water infrastructure in order to avoid flood damage	*	*		*	0	0	0	0	0	0
	Make reservoirs to increase holding capacity for water					0	0	0	0	0	0
	Build embankments, trenches, or polders					0	0	0	0	0	0
	Make disaster prevention infrastructure, sucha as thrust block to prevent landslides					0	0	0	0	0	0
	Make disaster prevention infrastructure, sucha as thrust block to prevent landslides					0	0	0	0	0	0
	Move disaster-vulnerable infrastructure such as transmission pipes					0	0	0	0	0	0
	Procure tanker trucks to provide water to areas affected by drought	*				2	3	3	3	2	13
	Use idle capacity through uprating or rerating	*				1	2	2	2	3	10
											0
Processing/ Efficiency	Reduce technical NRW through repair or replacement of pipes	*				2	2	2	1	3	10
	Maintain or replace broken water meters	*				3	3	3	3	2	14
	Use progressive tariff to encourage conservation of water	*				3	3	1	2	3	12
	Use social marketing to change water users behavior	*				3	3	3	3	2	14
	Use energy efficiency to maintain the standard of service	*				0	0	0	0	0	0
	Consumers use basins or reservoirs	*				0	3	3	3	3	12
	Advocacy or regulation to reduce exploitation of groundwater	*		*	*	0	3	3	3	2	11
											0
Planning and information management	Install accounting system to record and bill for water together with a system to account for provision of water/PDAM	*	*	*	*	2	2	3	2	3	12
	Map the location and characteristics of the aquifer and other sources of raw water	*	*	*	*	2	2	3	2	2	11
	Plan for water security/emergency fund	*	*	*	*	2	2	3	2	2	11
	Monitoring and evaluation of adaptation steps	*	*	*	*	2	2	3	2	2	11
											0
Anticipation/providing for risk	Establish emergency disaster fund (government, PDAM)	*	*	*	*	2	3	3	3	2	13
											0

Alternative Adaptations for Provision of Piped Water PDAM Salatiga City

Water Source: Deep well Sukowati

Adaptatation Classification	Options of Adaptation Actions	Anticipated Hazard				Selection Criteria					
		Drought	Flood	Landslide	Rise in Sea Level	Cost	Complexity	Political Aspects	Implementation Speed	Benefit	Total Score
Water source protection	Establish a protection zone around the spring; assign people to protect the exclusion zone	*				2	3	3	2	3	13
	Inter regional cooperation for protection of spring	*									0
	Improve management of water resources: create forum/institution for management of water resources					0	0	0	0	0	0
	Strengthen regulations including permission to extract groundwater and surface water through local Iregulation, MOU for inter-regional cooperation for conservation	*				3	3	3	3	3	15
	Program to return water to nature, such as infiltration wells	*				3	3	3	2	3	14
	Agricultural extension program to reduce soil erosion					0	0	0	0	0	0
	Improve handling of wastewater and solid waste especially in upstream areas					0	0	0	0	0	0
	Establish a stakeholders forum at water source to stop/minimize conflicts					0	0	0	0	0	0
	Payment for environmental services	*	*	*		2	0	0	0	0	2
	Maintain infiltration wells	*				3	3	3	3	3	15
	Establish a green belt around the bronkaptering	*	*	*		2	3	3	3	3	14
											0
Infrastructure Alternatives	Maintain infiltration well sites	*				2	2	3	3	3	13
	Community rainwater harvesting					0	0	0	0	0	0
	Establish a rainwater infiltration channel, Bio pore, infiltration well, etc.	*	*			2	3	3	3	3	14
	Use of many sources, surface water, springs, groundwater, with interregional cooperation					0	0	0	0	0	0
	Increase access to good sanitation (to stop/reduce water pollution), such as replacing latrine with toilet	*				1	2	2	2	2	9
	Recycle wastewater for industry and/or agriculture					0	0	0	0	0	0
	Memperbaiki sistem drainase, mis. di sekitar infrastruktur SPAM agar terhindar dari pencemaran/genangan					0	0	0	0	0	0
	Construct reservoirs to increase water storage capacity					0	0	0	0	0	0
	Build embankments, ditches, or polders					0	0	0	0	0	0
	Provide pumps for flooding					0	0	0	0	0	0
	Strengthen infrastructure vulnerabke to disaster, such as thrust block against landslide					0	0	0	0	0	0
	Move infractruture, such as transmission pipes that are vulnerable to disasters					0	0	0	0	0	0
	Procure water tanker trucks to provide water to drought areas					0	0	0	0	0	0
	Use idle capacity through uprating or rerating					0	0	0	0	0	0
											0
Processing/Effficent use	Reduce leakage (PDAM) through repair/replacement of old or broken pipes	*				1	3	3	2	3	12
	Maintenance/replacement of old or broken water meters	*				2	3	3	2	3	13
	Establish more progressive tariff to encourage more careful use of water	*				2	1	2	2	3	10
	Social marketing to change habits of water users					0	0	0	0	0	0
	Energy efficiency to maintain high quality of customer service					0	0	0	0	0	0
	Incentive program to encourage consumers to use water-efficient devices	*				1	1	3	1	3	9
	Customers use basins or reservoirs	*				3	3	3	3	3	15
	Push industries to use recycling systems					0	0	0	0	0	0
	Advocacy/regulation to control groundwater withdrawal	*				2	3	3	2	3	13
											0
Planning and management information	Decision support system for allocation of water (including calculation of water resources and water balance)	*				3	3	3	3	3	15
	Install monitoring of hydrology/meteorology/groundwater	*				2	3	3	3	2	13
	Install accounting system to record and bill for water together with a system to account for provision of water/PDAM	*				3	3	3	3	3	15
	Map the location and characteristics of the aquifer and other sources of raw water	*				1	3	3	3	3	13
	Early warning system for disasters					0	0	0	0	0	0
	Disaster plannning (contingency/emergency plans)					0	0	0	0	0	0
	Plan for water security/emergency fund	*				1	1	3	1	3	9
	Monitoring and evaluation of adaptation steps	*				3	1	3	1	3	11
											0
Anticipation/providing for risk	Buy (property) insurance for buildings and key infrastructure such as vehicles	*				1	1	3	3	3	11
	Establish emergency disaster fund (government, PDAM)	*				1	2	3	2	3	11
	Prepare a plan and/or emergency SOP (contingency plan) for disasters such as floods in pumping areas	*				2	3	3	3	3	14

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