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Ecosystem-based adaptation at scale through Building with Nature: towards Resilient Coasts in Indonesia

Exploratory Integrated Water Resources Management (IWRM) Study in Demak Coastal Area: Water Availability and Water Users

Deltares

Ecosystem-based adaptation at scale through Building with Nature: towards Resilient Coasts in Indonesia

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1220476-000

Title
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Project	**Reference**	**Pages**
1220476-000	1220476-000-ZKS-0006	41

This report was written in the context of the Building with Nature Indonesia programme by Ecoshape, Wetlands International, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), and the Indonesian Ministry of Public Works and Human Settlement (PU), in partnership with Witteveen+Bos, Deltares, Wageningen University & Research Centre, UNESCO-IHE, Blue Forests, and Von Lieberman, with support from the Diponegoro University, and local communities.

"Building with Nature Indonesia" is supported by the Dutch Sustainable Water Fund, the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of the International Climate Initiative (IKI), Waterloo Foundation, Otter Foundation, Topconsortia for Knowledge and Innovation, and Mangroves for the Future.

The cover photo is a drone picture showing permeable structures in Bedono, Demak district, by Building with Nature Indonesia.

Keywords

Building with Nature, Indonesia, resilience, coasts, climate change, adaptation, ecosystem

Disclaimer

Project partners are committed to drive the current Building with Nature innovation trajectory, by demonstrating the approach in a case study site in Demak. Successful implementation requires in-depth system understanding, extensive stakeholder engagement, and adaptive management on the basis of monitoring and evaluation. We stimulate and support upscaling of the approach by disseminating knowledge, lessons learned and implementation guidance. Stakeholders interested to replicate our approach are strongly recommended to adhere to this guidance and bear full responsibility for the success and sustainability of the approach.

Summary

Coastlines of Northern Java are facing a rapidly growing population and extensive industrial and agricultural developments. Their geological composition, existing of hundreds of meters thick alluvial clay deposits, and their low elevation make them extremely vulnerable to anthropogenic and environmental pressures. Subsidence and sea level rise are resulting in recurring flood events and massive coastal erosion. This is severely hampering economic development due to blocked transportation routes, loss of land for agriculture and aquaculture and costs for continuous repairs of public and private infrastructure.

To reduce erosion and limit flooding, construction of hard infrastructure is the most widely accepted approach. However, this will not be a feasible protection strategy for the whole of coastal Java as these measures are expensive, focus on single purpose solutions and require continuous and costly maintenance, especially, on soft muddy sub-soils. Therefore, the Building with Nature project is exploring innovative techniques that aim to halt erosion and restore sedimentation processes in the intertidal area through construction of permeable

bamboo and brushwood dams. Newly built land with this approach will be conserved as a mangrove greenbelt that protects earthen seawalls and the hinterland, from wave impact, but also provide an indispensable nursery for fish, shellfish and shrimps. In addition, the project aims to rehabilitate aquaculture to improve livelihoods of coastal communities and focusses strongly on building capacity in the community but also on knowledge transfer to different government levels.

In the current study, we aim to increase our understanding of the fresh water system of Demak. Hereby, we explore possibilities for availability and sustainable use of fresh water in the area. Unsustainable water use severely impacts water and environmental quality, hence endangering our final project goal of strengthening the mangrove greenbelt and stopping coastal erosion. For example, uncontrolled groundwater extraction resulting in subsidence is a problem along many coastal areas of Norther Java. Note that subsidence threatens long-term survival of a mangrove greenbelt and induces coastal erosion and flooding, thereby jeopardizing success of our project. Also, in general, Building with Nature measures are strongly based on system understanding. To gain this system understanding, we evaluate the supply and demand of fresh water in the coastal communities in our project area. To do this, we use the SIWAMI model which makes use of a hydrological model in combination with meteorological, elevation, land use and soil type data. Agricultural irrigation intakes are also directly included in the model. Once the supplies are defined, the demands have to be studied. These demands are first quantified and later compared with the available supply at relevant locations. The demands included in this study are limited to users from the coastal communities, though our conclusions have consequences for other water users as well, which are discussed and evaluated thourghout the report.

In our project area there are three main rivers and their catchments that end up at the coast. From west to east these are: the Jragung, Buyaran and the Serang-Lusi. These rivers contain 80% of the total available fresh surface water. In the Serang-Lusi river in the East of Demak 50% of available water is concentrated. Fresh water availability in Western Demak, where most people and industry is concentrated, is limited. Upstream there are two main reservoirs, Rawa Pening and Kedung Ombo. Those reservoirs are not included in the SIWAMI model, which assumes natural flows. In the study, demands are constituted by agriculture, mainly consisting of rice production, aquaculture, for fish and shrimp, and by domestic needs for coastal communities. Industrial needs, livestock, and other upstream user groups are not directly evaluated in this study. For each user group the following conclusions were derived:

1. Crop farming: During the wet season supply exceeds demands largely. However, at certain years water availability in the dry period does not meet demand at main intakes for rice production. Especially at the end and start of the cropping season this may pose problems.
2. Aquaculture: Overall there is enough available river water to support downstream aquaculture demands. However, water distribution to individual ponds may be a problem. More intensive industrial aquaculture systems that are scarcely distributed over the area use fresh water from deep wells to maintain salinity levels during the dry season. Coastal ponds report low productivity due to high salinity levels and with ongoing subsidence

salinity intrusion will threaten aquaculture, livestock and agriculture productivity more inland as well.
3. Domestic: Coastal communities in the East of Demak receive fresh water from a water supply company and do not experience shortages. Communities in the West rely on ground water for their domestic needs. Demands of these communities cannot be met by the available river water within their own watershed. However, river water availability in the whole of Demak does suffice for domestic use solely. Once domestic use is combined with aquaculture use shortages may occur parts of the time.
4. Livestock: The production of broilers (poultry meat) in Demak requires at least five times more fresh water from wells than aquaculture, as the surface water is not of appropriate quality. Goat, buffalo and cattle are not produced in huge numbers.
5. Industry: although industry is likely responsible for most water use in Demak it was not included as a user group in the SIWAMI model. First, there is no data gathered of industrial uses of surface water and second, industry generally relies on ground water provided by their own wells.

There are several important aspects that have a large influence on water quantity and quality, that are not taken into account by this study. First, the current study does not specifically investigate water quality, but pollution of the Serang-Lusi river has been reported. Second, industrial uses have not been included but maps with registered ground water wells indicate that they may rely largely on ground water as their main water source. Lowering of the ground water level in Demak is measured at an alarming rate and from other areas across Indonesia and the world this lowering is linked directly to subsidence of the land. Local inhabitants of coastal villages report the occurrence of brackish water in their deep wells which points at depletion of the deep fresh ground water. Several scientific publications report subsidence rates of more than 8 cm/year in coastal areas of Semarang and in industrial areas of Demak. Comprehensive and continuous studies of land subsidence in Semarang and Demak are needed to understand the land subsidence behaviour and its causes in detail. Reliable and continuous monitoring of ground water levels and subsidence is crucial. In addition, it is recommended to put an action plan of how to tackle and stop subsidence for Semarang, Demak and surrounding areas, in place as soon as possible.

Although the current modelling study shows that there is abundant yearly water supply in Demak through the three main rivers, the availability of water is unequally distributed over time and space. Water supply throughout the year is characterized by a wet and a dry season and the Eastern part of the province receives about 80 % of the river water. Therefore, water users are likely to experience shortages. Under natural flows that are assumed in the model these shortages become visible in both domestic and agricultural demands. Possible measures to manage shortages are:

1. Retain more water during wet periods, locally with storage tanks, retention basins or with extra reservoirs;
2. Optimize distribution of water throughout the year but also spatially by diverting water from one river to another;
3. Have a flexible cropping season;
4. Revert to other crops or aquaculture species;

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5. Improve quality of available water and thereby increase potential for use.

The existing upstream reservoirs, not included in the model, could already be helping with the distribution of water throughout the year. However, reported upstream rates of erosion are responsible for the infilling of the reservoirs, with eventually ends up in a loss of capacity of the reservoirs. Therefore we still advice to pay attention to water distribution over time and possible associated measures.

Considering increasing pressure on water resources from growing population and industrial development in Demak a more extensive study to optimize fresh water supply is urgently required. During future study it is strongly advised to consider all user groups, including those upstream, but also to link fresh water supply and demand in the Demak coastal area with Semarang city. Urban issues arising in Semarang, such as shortage of surface water, overexploitation of ground water and land subsidence, have large effects on the more rural coastal area and its inhabitants. In the same way as developments along urbanized coastlines will influence integrity of adjacent rural coastlines, water shed management impacts the long term development of coastal zones, by influencing input of fresh water and sediments. Therefore, resilience of coastal landscapes is only ensured through land-use practices that take into account coastal dynamics, river management and groundwater resources. Regulatory frameworks to ensure this are largely in place in Indonesia and need to be enforced. Participatory planning processes that are part of Coastal Zone Management (CZM) and Integrated Water Resource Management (IWRM) can help to achieve desired objectives and thereby ensure sustainable development of Indonesian coastlines.

Version	Date	Author	Initials	Review	Initials	Approval	Initials
final	Aug. 2018	Aditya Taufani (Deltares)		Tom Wilms (Witteveen + Bos)		Frank Hoozemans (Deltares)	
		Miguel de Lucas Pardo (Deltares)		Fokko van der Goot (Ecoshape)			
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Contents

1 Introduction

Coastlines of Northern Java are facing a rapidly growing population and extensive industrial and agricultural developments. Their geological composition, consisting of hundreds of meters thick alluvial clay deposits, and their low elevation make them extremely vulnerable to anthropogenic and environmental pressures. Subsidence and sea level rise are resulting in recurring flood events and massive coastal erosion. This is severely hampering economic development due to blocked transportation routes, loss of land for agriculture and aquaculture and costs for continuous repairs of public and private infrastructure.

To reduce erosion and limit flooding, construction of hard infrastructure is the most widely accepted approach. However, this will not be a feasible protection strategy for the whole of coastal Java as these measures are expensive, focus on single purpose solutions and require continuous and costly maintenance, especially, on soft muddy sub-soils. Therefore, the Building with Nature project is exploring innovative techniques that aim to halt erosion and restore sedimentation processes in the intertidal area through construction of permeable bamboo and brushwood structures. Newly built land with this approach will be conserved as a mangrove greenbelt that protects earthen seawalls and the hinterland, from wave impact, but also provide an indispensable nursery for fish, shellfish and shrimps. In addition, the project aims to rehabilitate aquaculture to improve livelihoods of coastal communities and focusses strongly on building capacity in the community but also on knowledge transfer to different government levels.

The Building with Nature project's first pilot is being currently implemented in Demak, next to the urban area of Semarang[1]. At this stretch of the coast massive erosion has occurred over the last decade, with the coastline retreating several kilometres inland (see Figure 1.1).

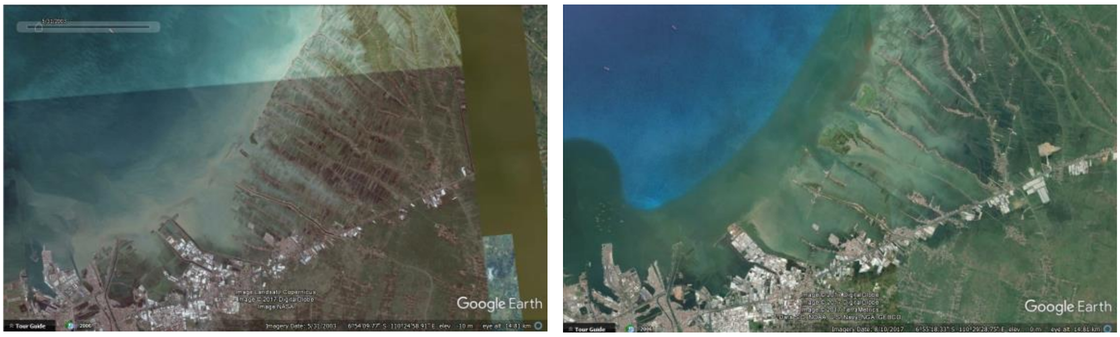


Figure 1.1 (left) Coastal area of Demak in 2003; (right) area in 2017

The Building with Nature approach has been already proven to be effective in stoping erosion and restablishing the sediment balance of the coast over short time scales. However, over the first years of project life time it has also become evident that subsidence is importantly contributing to the massive erosion of the coastline in the area as well, to the point that it threatens the success of the Building with Nature approach. Prior to the project beginning, data from research initiatives on subsidence did already exist, but did not extent into the rural area of Demak. As a consequence its severity and scale were certainly underestimated. However, during project lifetime observational data points at very high and worrying

[1] https://www.deltares.nl/app/uploads/2016/07/Deltares-WI-2014-Sustainable-solution-massive-erosion-Central-Java.pdf

subsidence rates in the area. Subsidence is known to be an issue at other locations of the coast of North Java, including Jakarta[2] and is largely connected with overexploitation of deep ground water.

Furthermore, proper management of fresh water is also key to maintain a healthy mangrove forest and productive aquaculture ponds in the coastal zone. Therefore, as part of the Building with Nature approach we aim to increase our understanding of the fresh water system. In general, Building with Nature measures are strongly based on system understanding. In this study we evaluate the supply and demand of fresh water in the coastal communities in our project area. To do this, we use the SIWAMI model which makes use of a hydrological model in combination with meteorological, elevation, land use and soil type data to provide the supply of fresh water into the study area. Agricultural irrigation intakes are already included in the model. Once the supplies are defined, the demands have to be studied. These demands are first quantified and later compared with the available supply at relevant locations. The demands included in this study are limited to users from the coastal communities, though our conclusions have consequences for other water users as well, which are discussed and evaluated thorhougtout the report.

This report starts with a literature review on subsidence in the study area. Later, the modeling tool used to understand the fresh water dynamics and quantify the water supply is presented, and the overview of the supply over the area provided. Once the supply is defined, a study on water users and demands is given. The report concludes with with recommendations for managers and policy makers. As annexes to this work, we provide first the some detailed results from the model, followed by notes taken as summary of the many community and participatory meetings that took place to collect information and serve the goal of the report: understand the fresh water system.

[2] https://www.deltares.nl/en/news/stop-pumping-groundwater-save-sinking-jakarta/

2 Land subsidence in Semarang-Demak

2.1 Introduction

Land subsidence in Semarang and its surrounding area including Demak has been widely reported through scientific publication and its impacts have been presented and confirmed. The coastal community experiences more frequent and deeper inundation from the tidal activity. In the past decades, they had to heightened their houses and floor, even at a number of times.

Land subsidence itself has been recognized, published and used by the Semarang City Government, especially for their spatial planning (see Figure 2.1). Scientific publications by Abidin, et al. (2010) and Chaussard, et al. (2012) stated that the northern coastal areas of Semarang are subsiding with rates larger than 8cm/year and industrial area subside with rates about 8cm/year. This number has been proven within several investigations. The investigations were performed with various methods, from levelling in 1999 until 2003 by Centre of Environmental Geology, GPS and InSAR monitoring as well as using microgravity by ITB (Geodesy research group) and Undip (Geodesy research group) (Abidin, et al. 2010, Andreas, et al., 2016, Yuwono, et al. 2016).

Although land subsidence at Semarang's surrounding area has been reported, its cause remains poorly known quantitatively. In general land subsidence can be caused by 1) groundwater drawdown, 2) civil building and constructions, 3) natural compaction of unconsolidated sediments, and 4) geologic structure movement (Hutasoit and Pindratno, 2004). From those causes, the first and second factors are induced by human activity while the others factors are natural phenomena which cannot be controlled by humans.

2.2 Land subsidence in Semarang and Demak

The phenomenon of land subsidence in Semarang has been widely recognized and reported. However land subsidence in Demak area, though reported through a limited number of scientific publications, should be analysed in more depth and more data should be produced to verify and strengthen the findings so far. Chaussard, et al. (2012) already indicated land subsidence in Demak from InSAR data, while Yuwono et al, (2016) and Andreas et al, (2016) just published preliminary studies about land subsidence in Demak.

There are many discussions already about the subsidence in Semarang. Semarang government itself is already aware that land subsidence is happening in the area. There is already a map showing the rate of subsidence published by the government of Semarang (Figure 2.1). In the map, it is shown that the north-eastern part of Semarang is expected to subside by 8 cm per year over the period 2011-2030. This map is also supported by the research done by other parties.

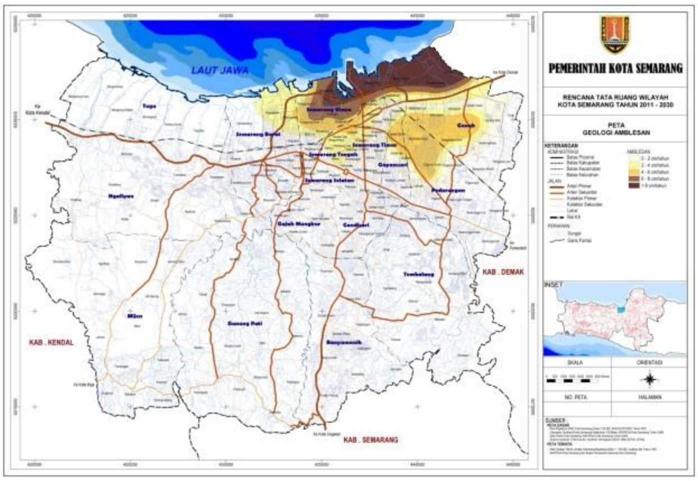


Figure 2.1 Subsidence map published by Semarang Government

Yuwono et. al (2016) measured the subsidence rate in Semarang by using GPS method. The results were in agreement with the map generated by the government. Yuwono et.al (2016) measured the subsidence rate in Semarang with GPS method, and showed that in the north eastern part of Semarang, where the land subsides by more than 8 cm per year, the local maximum subsidence rate even reaches up to 15 cm per year (Figure 2.2). Andreas et al (2016) also stated that Semarang subsided at an average rate of about 6-7 cm/ year, with maximum rates of 14-19 cm/year at certain locations. Figure 2.3 shows InSAR- derived subsidence in Semarang from January 2015 to January 2016 by Andreas, et al. (2016). It also shows that the land subsidence in the northeast of Semarang has accelerated during the period of 2012-2016. Figure 2.4 shows the acceleration locations measured by GNSS method since 2008 until 2016 (Andreas et al., 2016).

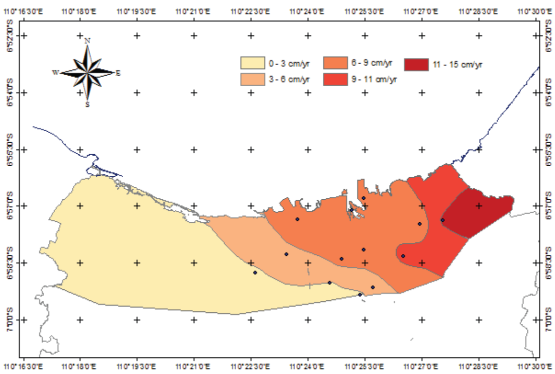


Figure 2.2 Subsidence rate by Yuwono et.al (2016)

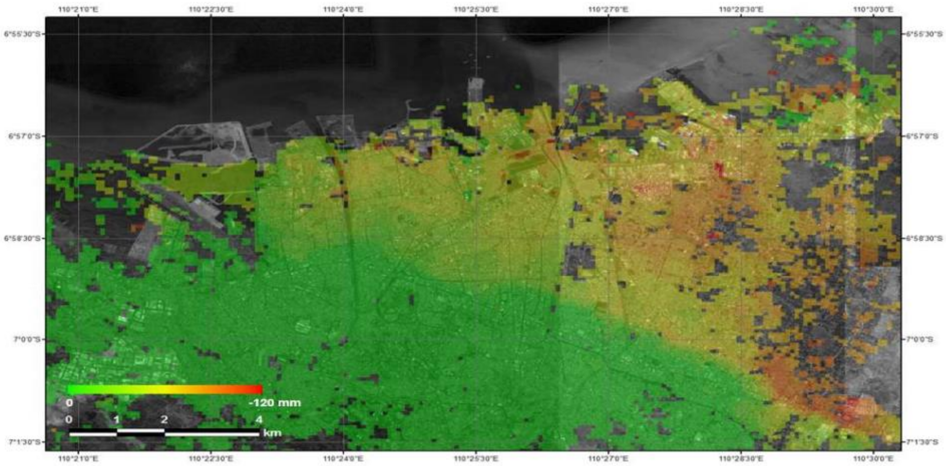


Figure 2.3 Land subsidence rate 2015-2016 by InSAR (Andreas et al., 2016)

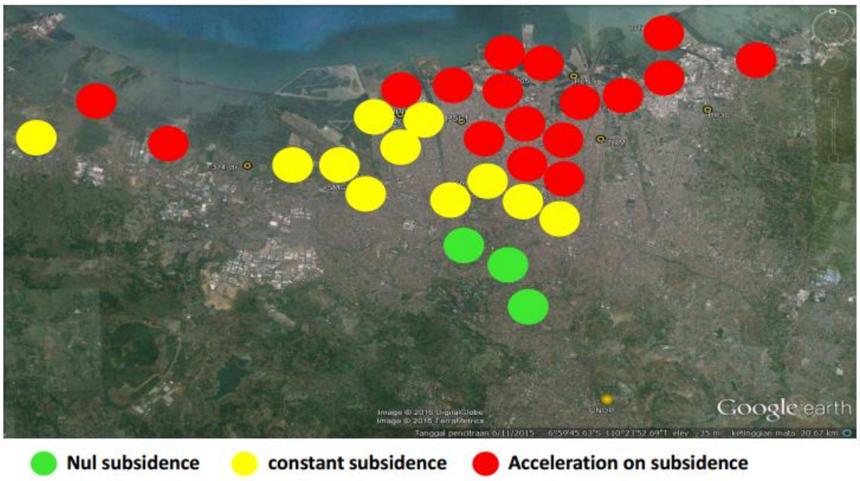


Figure 2.4 Land subsidence rate analysis (Andreas et. Al., 2016)

Chaussard, et al. (2012) indicated that Demak also subsides based on InSAR data. Figure 2.5 shows that Demak also suffered subsidence at a rate of about 8 cm/year. Andreas et al, (2016) also stated that Demak suffered subsidence by using time-series satellite images analysis and field inspection. Subsidence led to an expansion of area affected by tidal floods, and resulted in more frequent inundation events. Field inspections have confirmed that these conditions do occur in the north coast of Demak. Figure 2.6 and Figure 2.7 show field photos of the impacts of land subsidence in Semarang and Demak.

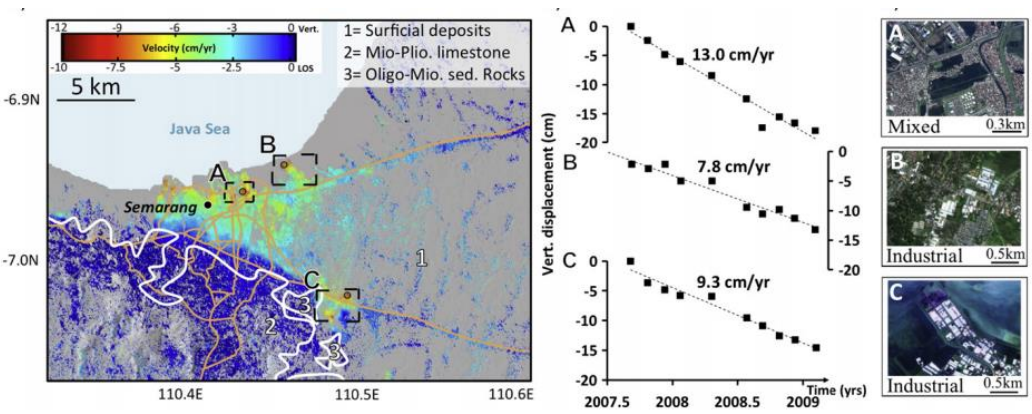


Figure 2.5 Land subsidence rate from InSAR method (Chaussard, et al., 2012)

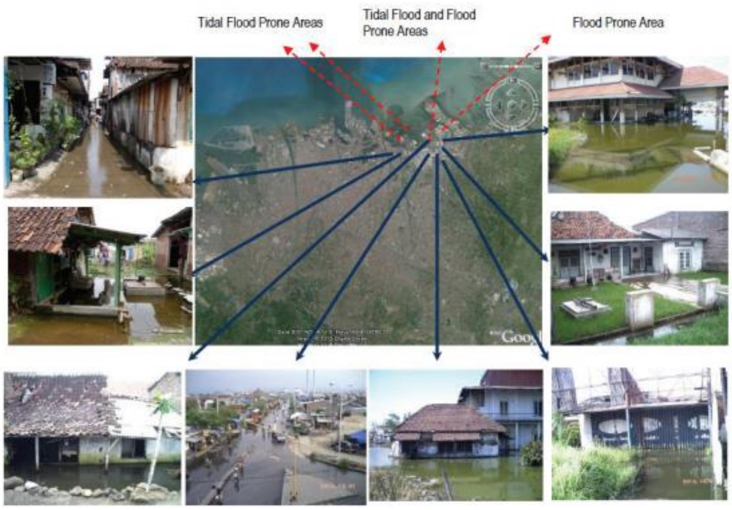


Figure 2.6 Impact of land subsidence in Semarang (Yuwono, et al., 2016)

Figure 2.7 Tidal inundation in Demak (Anderas, et al., 2016)

2.3 Land subsidence and its causes

Land subsidence is caused by the combination of natural consolidation of young alluvial soil, groundwater drawdown due to excessive groundwater extraction, load of buildings and infrastructure, and tectonic activity. A comprehensive study needs to be conducted to study the causes of land subsidence in detail. Erkens (Deltares, 2016) stated that excessive groundwater extraction linked to urbanisation and population growth is the main cause of severe land subsidence in mega–coastal-cities that build on soft soil like clay and peat like Jakarta, Ho Chi Minh City, Tokyo, Bangkok, and in numerous other coastal agglomerations. A graph (Figure 2.8) by Kumihiro (2015) shows the relation of groundwater level and land subsidence in Tokyo over time. The land subsidence corresponds very well with the groundwater level due to extraction.

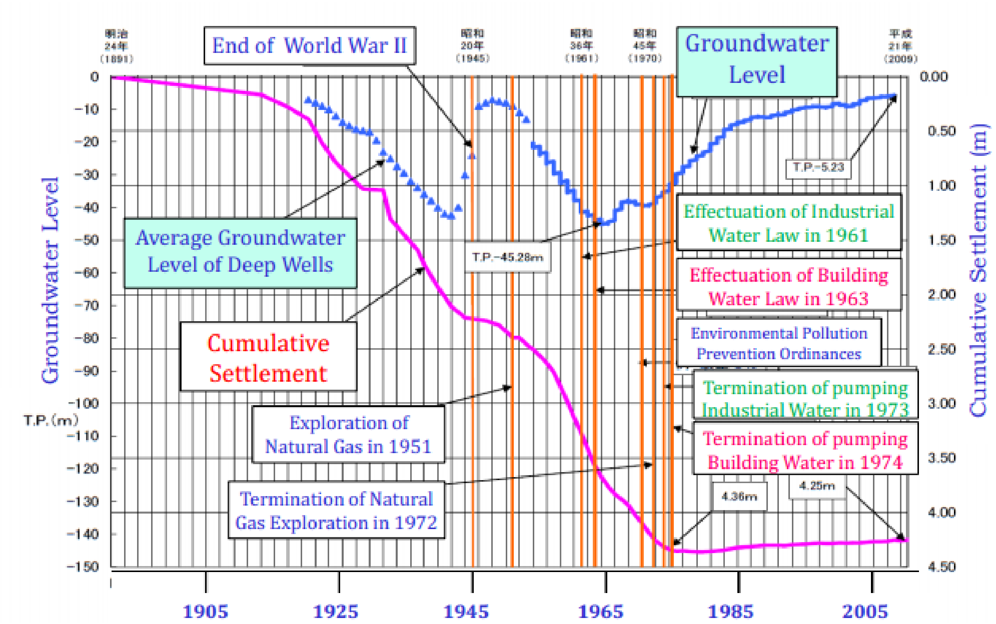


Figure 2.8 Groundwater level vs land subsidence (Kunihiro, 2015; Source: Tokyo Metropolitan Government, Edited by JICA expert)

Yuwono, 2013 also analyses the causes of land subsidence in Semarang using correlation technique between land subsidence data, groundwater level data, compressibility index data, and the weight of buildings. In the Figure 2.9, it can be seen that in all the darkest green area, where the subsidence rate is highest, groundwater use factor is marked as high, or most important. Yuwono, 2013 concluded that groundwater level drawdown plays a major role in causing land subsidence in Semarang.

Figure 2.9 Land subsidence causes indication in Semarang (Yuwono, 2013)

Comprehensive and continuous studies of land subsidence in Semarang and Demak are needed to understand the land subsidence behaviour and its causes in detail. A taskforce of land subsidence that include all researchers that have been studying land subsidence and governments of Semarang and Demak are recommended to have a centralized and sophisticated research on subsidence in Semarang and Demak in order to find an optimal way to tackle land subsidence in Semarang and Demak.

3 Hydrology of Demak Catchments

This study aims to understand the fresh water system in the project area. As first part of the system understanding, we studied the characteristics of the hydrology of the area. The hydrological characteristics data presented in this report was collected by Deltares and supported by Pusair. River networks and catchments were first generated from a combination of Indonesian Geospatial Agency and global topography maps. Rivers and catchment, together with main intake points and canals are then further studied and validated by using Google Earth Engine.

The hydrological modelling and the water availability were modelled within the framework of SIWAMI. SIWAMI (Information System of Water Availability in Main Intakes) is owned by the Indonesian Research Centre for Water Resources, Ministry of Public Works (Pusair) and was developed by Pusair and Deltares. Originally, SIWAMI was developed to assess water availability in the main intakes irrigation, across Indonesia. In combination with irrigation management software, SI RP2I-PAI, the system is also used as a participatory modelling system.

In this project, SIWAMI was extended via the addition of a refined hydrological model of Demak. This refinement encompasses more detailed delineation of the river in the model, as well as a higher spatial resolution (see Figure 3.9). The functionality of SIWAMI has been expanded from only calculating irrigation intakes, to giving an overview of the total amount of surface water in the Demak region.

3.1 Demak Catchments and Rivers

The generation of the river and channel network in the Demak region was conducted using the data available in SIWAMI. SIWAMI generates the rivers and catchments based on global topology maps and river maps by the Indonesia Spatial Agency. To improve the accuracy of the rivers delineation, these maps are then further refined using Google Earth satellite plugin. An overview of the obtained catchments and the locations of the river mouths on the coastline are shown in the picture below (Figure 3.1). This picture constitutes an important new insight into the local fresh water system.

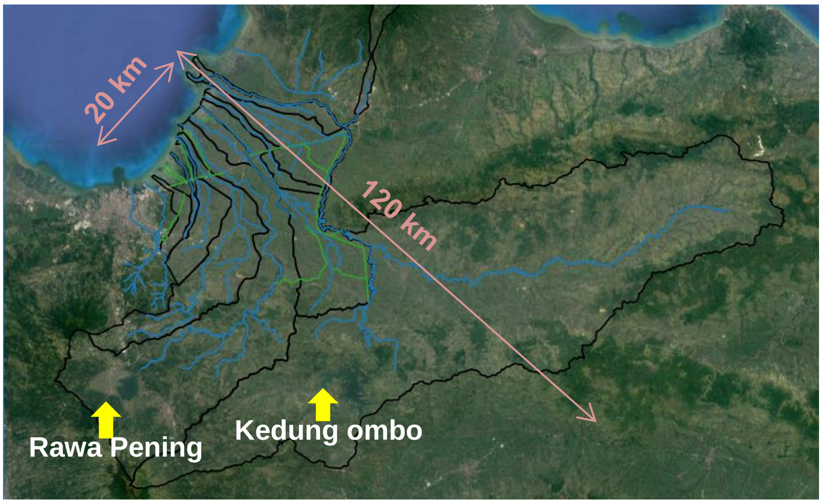


Figure 3.1 Catchments (black), rivers (blue), canals (green). The yellow arrows indicate the location of reservoirs.

This study is restricted to the ten river catchments that are located within Demak region. The upstream area is hilly, whereas the downstream area is flat. The downstream area stretches 20 km along the coast, while the upstream area reaches up to 120 km from the coastline. Upstream, a natural lake (Rawa Pening) and a man-made reservoir (Kedung Ombo) are located. There are three big rivers in the area, each with their corresponding catchments: River Jragung, River Buyaran (in the western part), and River Lusi-Serang (in the eastern part). River Jragung and River Buyaran together contain 30 percent of all available river water in the area, whereas River Lusi-Serang contains 50 percent. So in total, the water in these three rivers amounts to around 80 percent of all water available in the rivers.

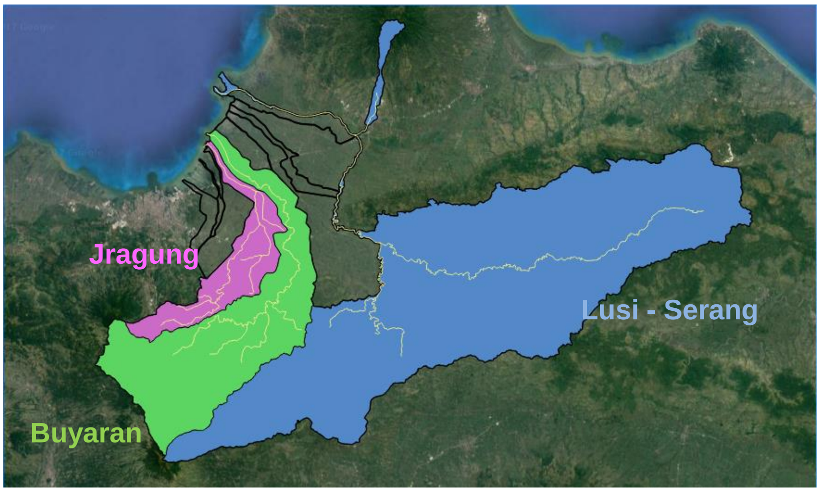


Figure 3.2 Biggest catchments and rivers

3.2 SIWAMI and WFlow

SIWAMI is built up out of free Deltares software: Delft-FEWS operational management software and WFlow distributed hydrological model. Delft-FEWS was used as a tool to automate the system. The automation includes real time download meteorological satellite data, as well as a platform for running the model.

The hydrological model to calculate water availability is computed with a free and open source hydrological model framework, WFlow[3]. The WFlow hydrological model is a distributed hydrological model. In this system, WFlow _sbm[4] was used. WFlow_sbm uses the framework of topog_sbm model, with additional improvements. Figure 3.3 shows a conceptual picture of how the model works.

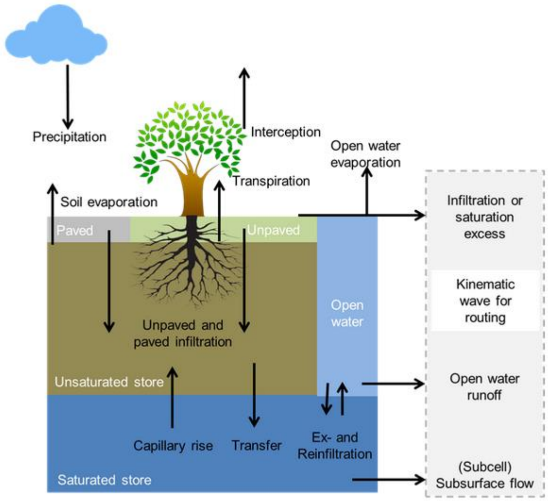


Figure 3.3 Overview of the different processes and fluxes in the wflow_sbm model

There are some limitations in the use of WFlow_sbm model. The wflow_sbm concept has been developed for steep catchments and relatively thin soils. This means that, in our model, lateral movement of groundwater may be incorrect for terrain that is not steep. Additionally WFlow is not developed to calculate the effect of tidal movement. So at intertidal channels, results might be less accurate.

The Wflow_sbm model requires static data, so called static maps (the natural condition) and dynamic data (meteorological data) as its inputs. In SIWAMI where a refined model of Demak is implemented, the following maps were used to generate the static map:

- A Digital Elevation Model (DEM): for SI WAMI SRTM 90m is used, but in Demak model, it is refined by SRTM 30m
- River and catchment, generated from DEM SRTM 30 m, and validated by Google Earth Engine
- Land use, land cover (LULC): for SI WAMI BIG Rupa Bumi topographical maps are used at the highest resolution available varying per island (BIG, 2007)
- Soil classifications: for SI WAMI a classification based on FAO soil texture (FAO, 2007) is used

[3] https://publicwiki.deltares.nl/display/OpenS/WFlow+rainfall-runoff+model
[4] https://wflow.readthedocs.io/en/2016.03/wflow_sbm.html#module-wflow_sbm

Figure 3.4 shows the input needed for the hydrological analysis in Demak.

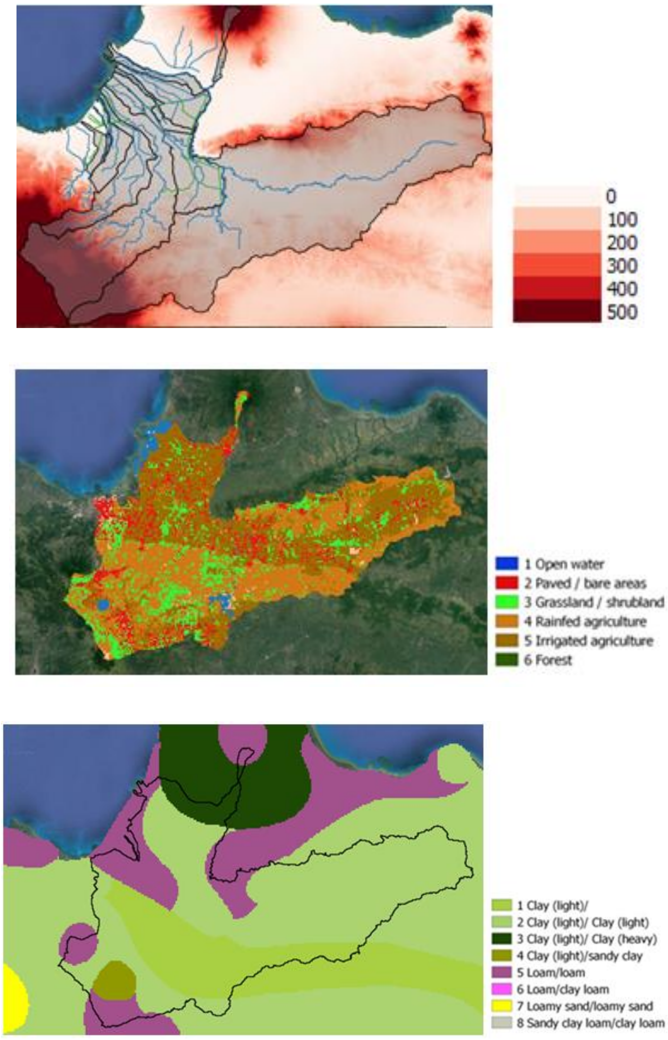


Figure 3.4 (top) DEM, river and catchments of Demak; (middle) land cover map; (bottom) soil type

WFlow model of Java has been validated with some observed discharges data across the island. Physical parameters have been tuned accordingly, obtaining satisfactory correlations between model results and data.

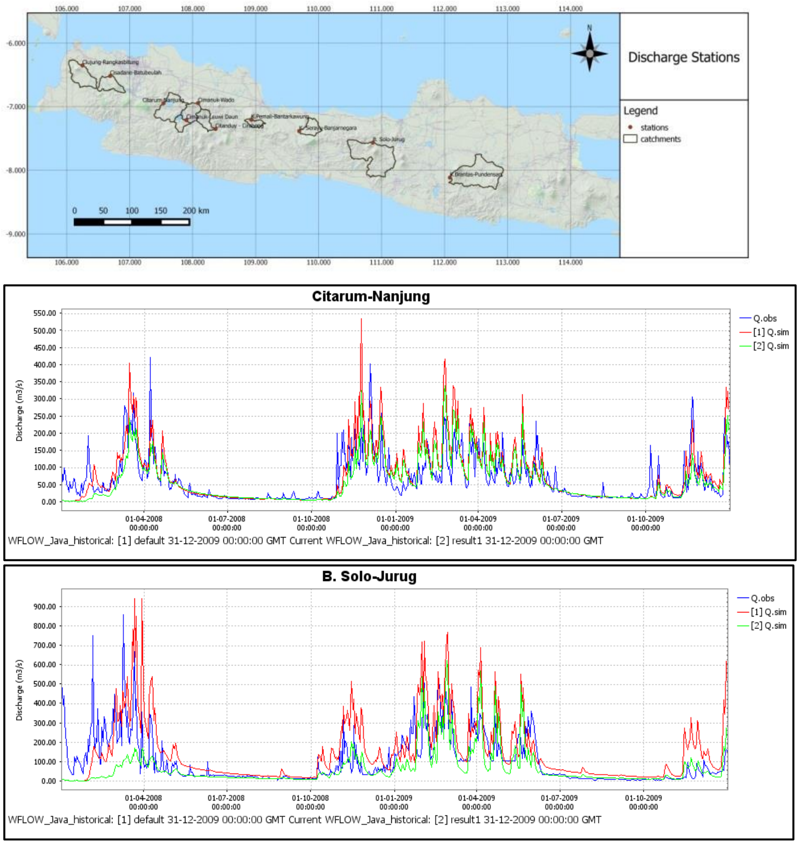


Figure 3.5 (top) Validation discharge station data across Java (bottom) result of validation

WFlow (Figure 3.6) was then configured in SIWAMI as the system's hydrological model analysis. SIWAMI will collect all the data needed for the hydrological model to run (precipitation, evaporation, water intake by irrigation), and WFlow will do the hydrological computation. As a result, information on water availability is obtained.

Below is the framework of SIWAMI :

1. SIWAMI will download the observed satellite rainfall, tropical rainfall measurement mission (TRMM) 3B42RT from NASA and evaporation from CGIAR. By using WFlow, the hydrological analysis will then be conducted.

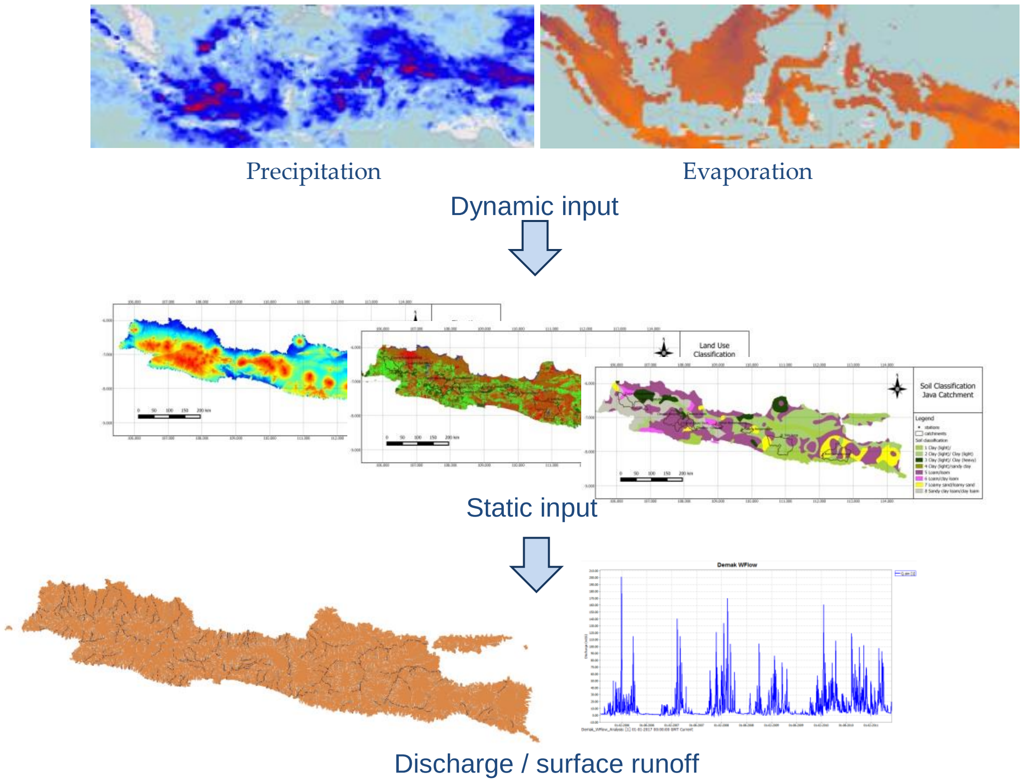


Figure 3.6 WFlow Framework

2. Before doing the analysis, additional information is collected on the water intakes / water use by irrigation. This information includes where the irrigation intakes are, and what are the crop patterns. Based on this, the system can calculate how much water is extracted from the river (Figure 3.7).

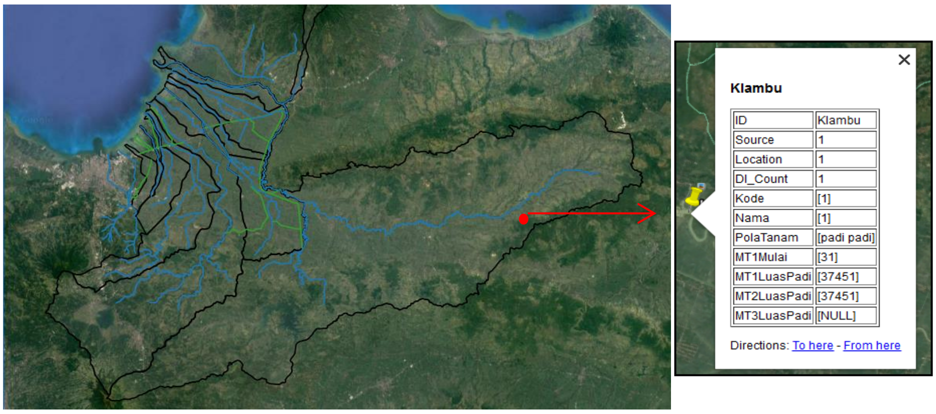


Figure 3.7 Information from the water intakes

Thus the remaining water left in the river is after the water extraction for agricultural purposes. Apart from calculating the river discharge after agriculture, the model also provides an overview of the water available at the intakes. As an example, a time series chart showing the demand of irrigation water and the available water supply at one specific intake point of the model (Klambu[5]) is shown in the figure below (Figure 3.8). Note that during wet season the available water often exceeds the demand in more than one order of magnitude, with supplies repeatedly larger than 1000 m^3/s.

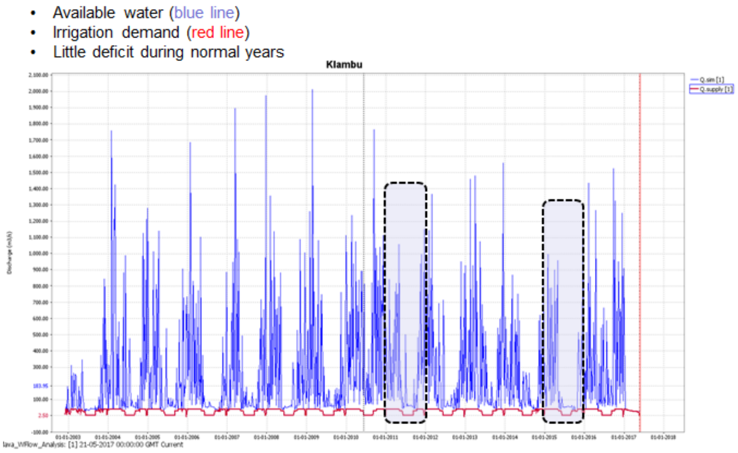


Figure 3.8 Chart showing available water, water demand

The SIWAMI system gives an overview of how much river water is left in the downstream area (Demak coastal zone) after agricultural use upstream. Combined with the information of water demand by the community that will be later provided, the availability of surface water in the area can be then estimated.

3.3 SIWAMI result of Demak

SIWAMI was developed for the whole Indonesia. It has 7 model domains of BaliNusaTenggara, Java, Sumatra, Kalimantan, Sulawesi, Maluku and Papua. For this project, a higher spatial resolution (25x25 m) is used than that of the coarser Java model (50x50m).

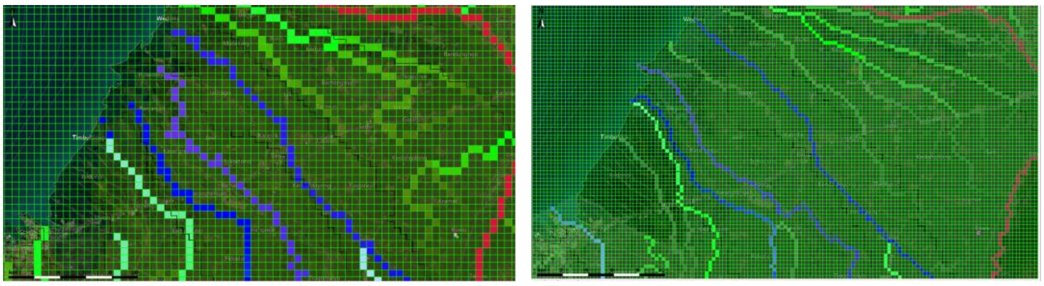


Figure 3.9 Resolution of : (left) Java model; (right) Demak model

In the Demak model, eight big irrigation intakes were added. Data of demand (cropping area, cropping patterns) and locations for these intakes was obtained from:

[5] *All intake points are introduced in section 3.3*

1. Menteri Pekerjaan Umum Republik Indonesia (2010), Keputusan meteri pekerjaan umum nomor 588/KTPS/M/2010; Pola pengelolaan sumber daya air wilayah sungai Jratunseluna
Ministerial decree, ministry of public works (2010) number 588/KTPS/M/2010: Patterns for water resources management in JratunSeluna River Basin

2. Balai Besar Wilayah Sungai Pemali-Juana (2013); Rencana Pengelolaan Sumber Daya Air Wilayah Sungai JratunSeluna
JratunSeluna River Basin Management (2013); Plan of Water Resources Management in JratunSeluna River Basin

Below (Figure 3.10) is the location and information of the irrigation intakes added into the model. The demand at Klambu's intake includes domestic use, with all other intakes only supplying to agriculture (Table 3.1).

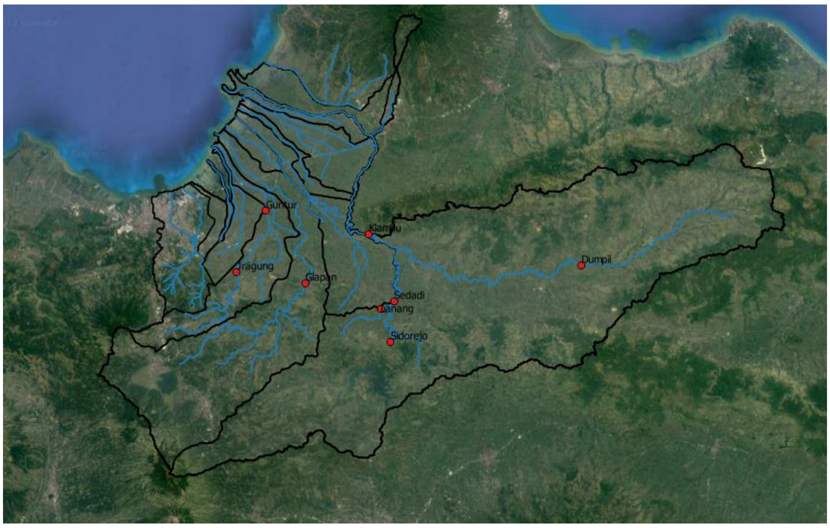


Figure 3.10 Main irrigation intakes

Table 3.1 Water demand figures found in literature (pola/rencana)

Location	Padi [ha]	Cropping pattern	Domestic use [l/s]
Klambu	37451	padi padi	2500
Lanang	1615	padi padi	0
Sedadi	16055	padi padi	0
Glapan	18740	padi padi palawija	0
Dumpil	9719	padi padi	0
Sidorejo	6038	padi padi	0
Jragung	4053	padi palawija	0
Guntur	2036	padi	0

In Demak, there are two reservoirs in the upstream region of the catchment, Rawa Pening and Kedung Ombo. SIWAMI – WFlow does not yet consider water retention by those reservoirs. Thus it models natural flows only (taking into account water extracted for agriculture). Therefore the results of the model are likely conservative. Including the effect of the reservoirs should lead to a better regulation of the discharges over time (if reservoirs were properly designed and are operated efficiently). However, without data on the reservoirs capacity and regulation dynamics no actual conclusions on the effect of the inclusion of the reservoirs in the model can be withdrawn.

The dynamic rainfall data for the model input uses TRMM (Tropical Rainfall Measurement Mission), measured by NASA. TRMM in SIWAMI has been corrected (for Indonesia) by using the method from Vernimmen (2012). The data is available from 2002 – 2017. The model of Demak runsfrom 01-01-2002 until 01-01-2017. From one model run, an overview is obtained of discharge/surface runoff available in the system (after agricultural use, see Figure 3.11).

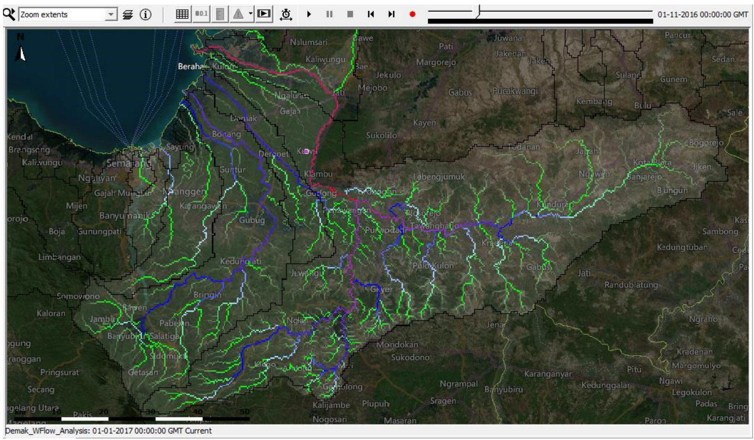


Figure 3.11 SIWAMI result of Demak Model

A time series of discharge can be given in any grid requested. For instance if we want to know the water availability in the downstream area, it can be obtained for the whole period. Figure 3.12 shows again that water supply during the wet season is very abundant.

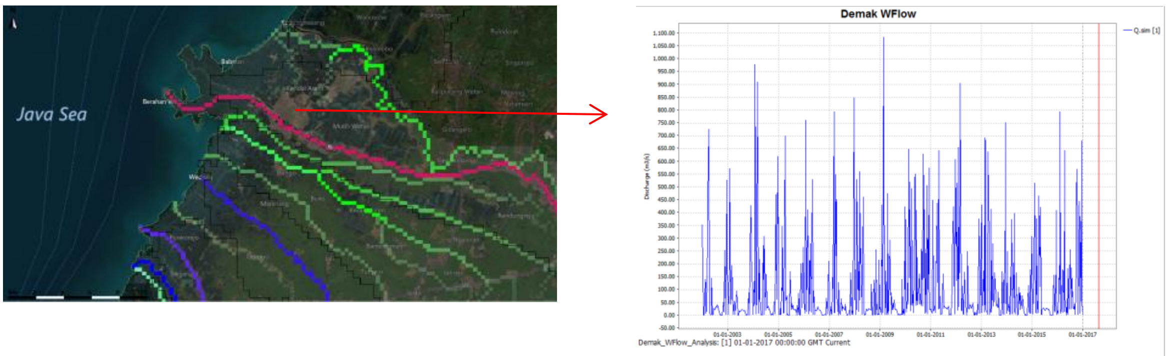


Figure 3.12 SIWAMI result, time series value of surface runoff

As explained in section 3.2, SIWAMI does not only analyse the amount of water in the river, but also whether a main irrigation intake is enough to meet the demand or not. The water availability in main intakes is shown as follows:

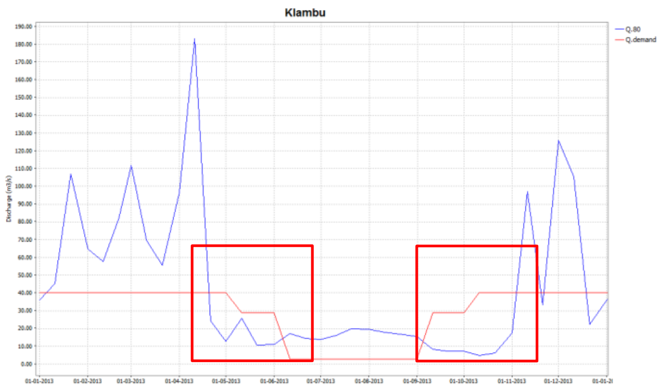


Figure 3.13 Water availability in Klambu main intakes

Figure 3.13 shows the status of water availability in Klambu main intakes. The chart is decade – statistic of water demand and availability. The statistic period is 2003 – 2017. In agriculture, water availability is expressed with Q80, where Q80 being the amount of discharge that will be available 80 percent of the time. The water availability in an intake is considered as enough, if the demand is below the Q80. From the figure above, it can be seen that there are shortages (shown in the red box)

From 8 the main intakes in SIWAMI model in Demak, 4 intakes have sufficient water supply, while 4 other intakes indicate shortages (see Appendix I for detailed chart). The latter is shown in Figure 3.14.

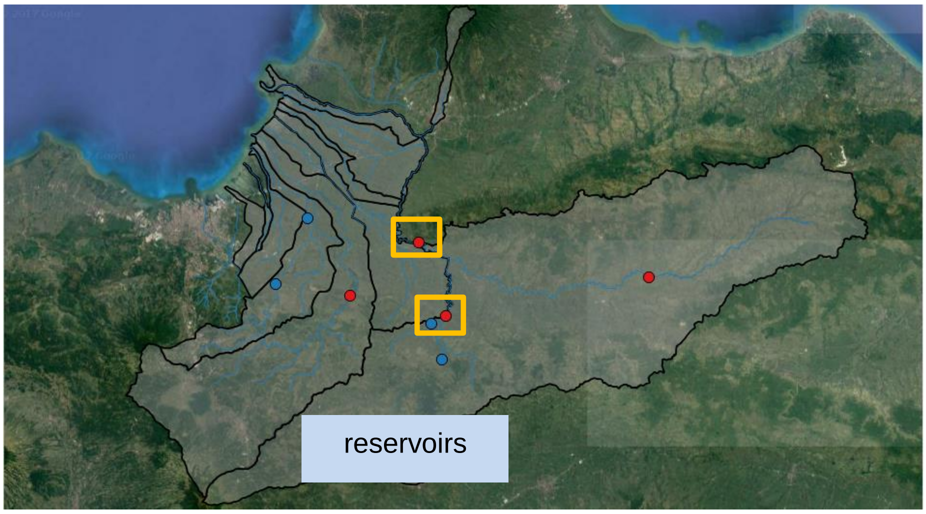


Figure 3.14 Water availability of main intakes

Note that the two intakes with shortage and highlighted in the yellow rectangle are in the downstream area of Kedungombo reservoir. As explained, the effect of reservoir is not yet modelled in the SIWAMI. The obtained shortages could be affected by the inclusion of the Kedyngombo reservoir in the model.

4 Water availability in Demak coastal communities

In the previous chapter, SIWAMI was presented as a tool to obtain information of surface water availability in Demak region. Extraction of river water by existing irrigation intakes is already taken into account by the model. It can further be analysed whether the remaining river water in the downstream area is enough to meet the demand by the coastal communities. To this purpose, the water demand / water use by the community should be studied first. Residents in the coastal villages of Demak mainly work in the fisheries industry (aquaculture, fisherman, etc.). Their water use is primarily for aquaculture and domestic consumption.

Information and knowledge on the water use by the community was gathered from a meeting with several stakeholders. This community meeting, attended by local residents, local government representatives and the BwN Indonesia team was held on 19 July 2017. The local residents were from 9 coastal villages of Demak region, which covers the downstream area of Demak-SIWAMI model (see Figure 4.1). The meeting mainly elaborated on the water use for aquaculture and domestic purposes. The information gathered was then further processed and analysed, and presented in the following section.

Figure 4.1 Villages represented in the community meeting

4.1 Aquaculture water use

The discussion for aquaculture water use aimed to understand how much fresh water from rivers the community would need for aquaculture activities. The water use for aquaculture varies based on the method applied by the farmer. The aquaculture activity in coastal Demak is schematised in the map below (Figure 4.2):

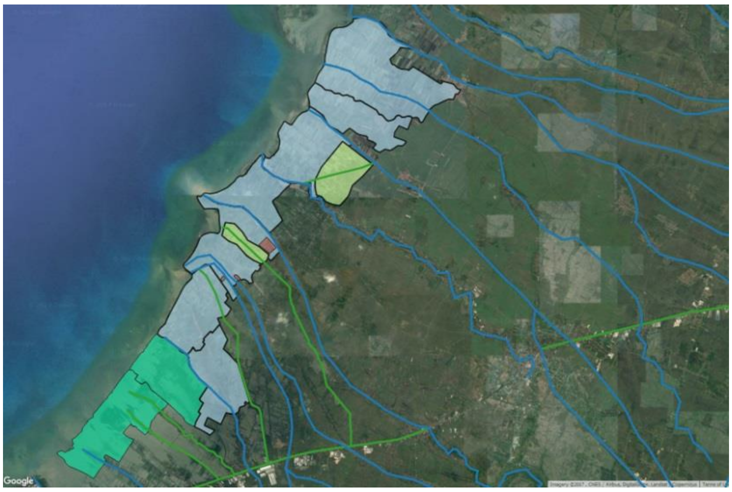


Figure 4.2 Overview of aquaculture type activity

Legends:

- **Green** (Pen Culture)
  In the green area the pen culture is the dominant type of aquaculture, in which aquaculture activities are carried out at sea, and at the border of the ponds with fishing nets (Figure 4.3).


Figure 4.3 Pen culture method

- **Light blue** (traditional tidal flow movement)
  In the light blue area aquaculture activities are mainly carried out with the traditional method (Figure 4.4). The water cycle in the pond relies on the tidal flow. During rising tide, the water enters the channels / river, and continues flowing upstream until finally entering the ponds. During falling tide, the water exits the pond, and flows back to sea.

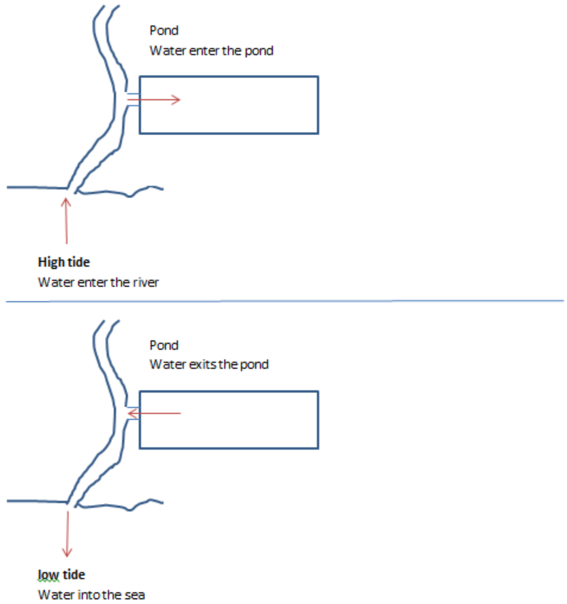


Figure 4.4 Traditional tidal flow movement

With this traditional method, water quality (salinity) in the pond cannot be controlled. During the wet season, when there is a lot of water in the river/channel and rainwater falls in the pond, the salinity decreases. However in the dry season, when there is no or little water in the channel, the water at the pond comes from the sea, and the pond becomes too salty. When water becomes too salty, the productivity of the pond decreases. Also with uncontrolled water quality, the fish often becomes prone to disease.

However this method is still preferred by the farmers, because when the tidal water enters the pond, it brings natural shrimp. During falling tide water exits the pond and farmers put nets in the water gate, to harvest natural shrimp. So by applying this method, the farmers have additional revenues from natural shrimp harvesting on a daily basis.

- **Light green** (intensive / controlled water quality method)

Light green areas represent the aquaculture areas at which the water quality is controlled. These area are mostly located close to the irrigation channel, so that the ponds can be filled with fresh water. The amount of fresh water needed for this method is around 50% of total water in the pond. So, as an example, if on average the depth of the pond is 50 cm, to replace water in the pond 25 cm of fresh water is needed (Figure 4.5).

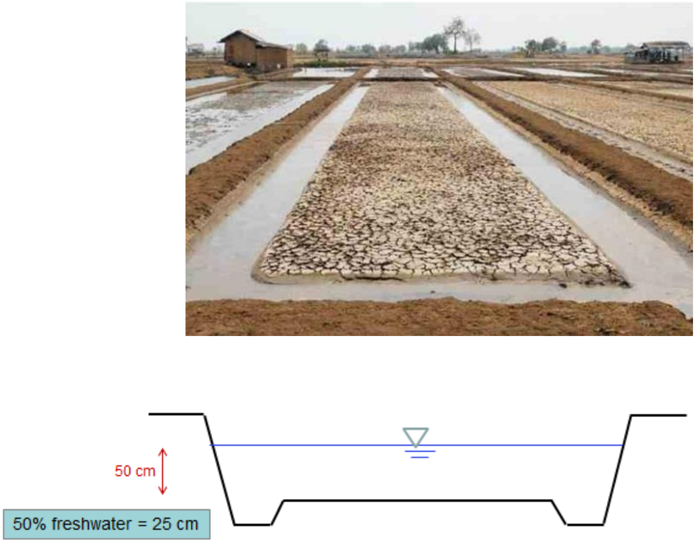


Figure 4.5 Amount of fresh water needed to replace water in the pond

Ponds which water quality is controlled do no longer rely on the daily tidal cycle for their water supply. So the pond owner / farmer cannot harvest natural shrimp anymore when applying this method (as opposed to the traditional method).

- **Brown** (intensive / additional supply from groundwater)
  In the overview map of aquaculture areas, there some small brown areas are included. This area represents intensive aquaculture ponds, where groundwater is used as fresh water source. When the ponds lack of river water, the farmers extract water from the well to supply the pond. However, this method is not favoured, since it is generally very costly.

From the overview of aquaculture activity types, it can be concluded that most of the activities still rely on daily tidal flow movement. Currently, not so much fresh water from rivers or groundwater is used. Although most of the ponds rely on daily tidal flow, farmers still expect to have access to fresh water, especially during the dry season when the pond water gets too salty.

The surface water availability for aquaculture use is presented in this section. Assuming that all ponds will use the ‘controlled water quality’ method[6], the amounts of water needed per district can be computed based on the total area of ponds. This can then be compared to the fresh water availability per district. The total area of the ponds is shown in the table below:

Table 4.1 Aquaculture pond area. Source : Statistic Center Agency, Statistik Demak 2015

Kecamatan (District)	Tambak Area (Ha)
Sayung	2722
Karangtengah	612
Bonang	2073
Wedung	2540
Total Tambak Area	7947

Table 4.1 above is total area of aquaculture pond (tambak) in project area, per district. However it does not define the aquaculture method, since information of area per type of aquaculture is not available. In District Sayung, ponds in Bedono and Timbulsloko village are mostly pen culture method. An analysis was made based on the available data, assuming that all of this aquaculture area needs fresh water supply.

Now a scenario can be set up for the start of the dry season in July. In the pond 25 cm of water needs to be replaced. Moreover, water loss due to evaporation should be replenished. The mean daily evaporation in Indonesia is 5 mm/day, which means that 5 mm of water will be lost form the pond every day. This sums up to 50% of fresh water loss (since brackish water of the pond consists of 50% fresh water), or 2.5 mm of fresh water needed every day. So the monthly demand of fresh water becomes what is shown in Table 4.2.

[6] This assumption leads to the maximum possible water consumption, thus it constitutes a conservative approach to the study of fresh water needs by the aquaculture community.

Table 4.2 Amount of fresh water needed

Date	Fresh water (cm)	Remarks
11-Jul	25	Refill the pond
21-Jul	2.5	Add water due to evaporation
01-Aug	2.5	Add water due to evaporation
11-Aug	2.5	Add water due to evaporation
21-Aug	2.5	Add water due to evaporation
01-Sep	2.5	Add water due to evaporation
11-Sep	2.5	Add water due to evaporation
21-Sep	2.5	Add water due to evaporation
01-Oct	2.5	Add water due to evaporation
11-Oct	2.5	Add water due to evaporation
21-Oct	2.5	Add water due to evaporation
01-Nov	2.5	Add water due to evaporation

By multiplying the amount of fresh water needed by the total area of pond, the total volume of fresh water needed is obtained. This can be turned into a discharge by assuming the time that it takes to withdraw the water from the river network (which is 10 days in the case of refilling of the pond).
Below is a first attempt to compare the demand from all the districts with the amount of water in the three biggest rivers in the system (see Figure 4.6)

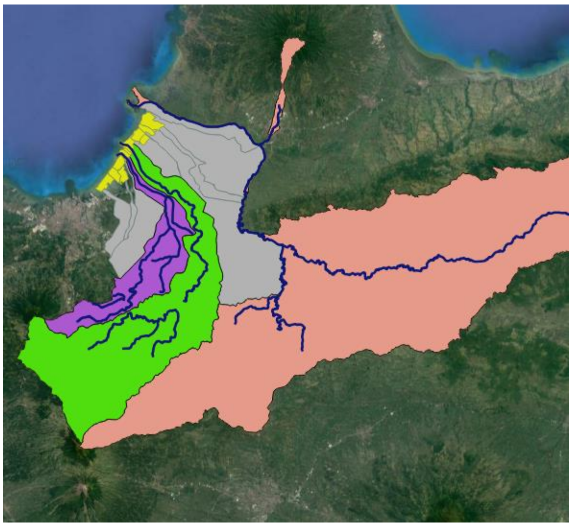


Figure 4.6 Aquaculture area (yellow) and 3 biggest rivers and catchments

Like in the framework of SIWAMI and water availability for agriculture, availability will be measured based on the Q80 criteria. The results can be seen in Table 4.3.

Table 4.3 Comparison of demand and Q80 for aquaculture use

Date	Demand		Available
	Volume (10^6 m^3)	Discharge (m^3/s)	Q80
11-Jul	19.9	22.99	22.99
21-Jul	1.99	2.29	26.3
01-Aug	1.99	2.29	28.75
11-Aug	1.99	2.29	26.35
21-Aug	1.99	2.29	25.08
01-Sep	1.99	2.29	21.33
11-Sep	1.99	2.29	5.44
21-Sep	1.99	2.29	4.06
01-Oct	1.99	2.29	3.48
11-Oct	1.99	2.29	3.03
21-Oct	1.99	2.29	2.91
01-Nov	1.99	2.29	3.71

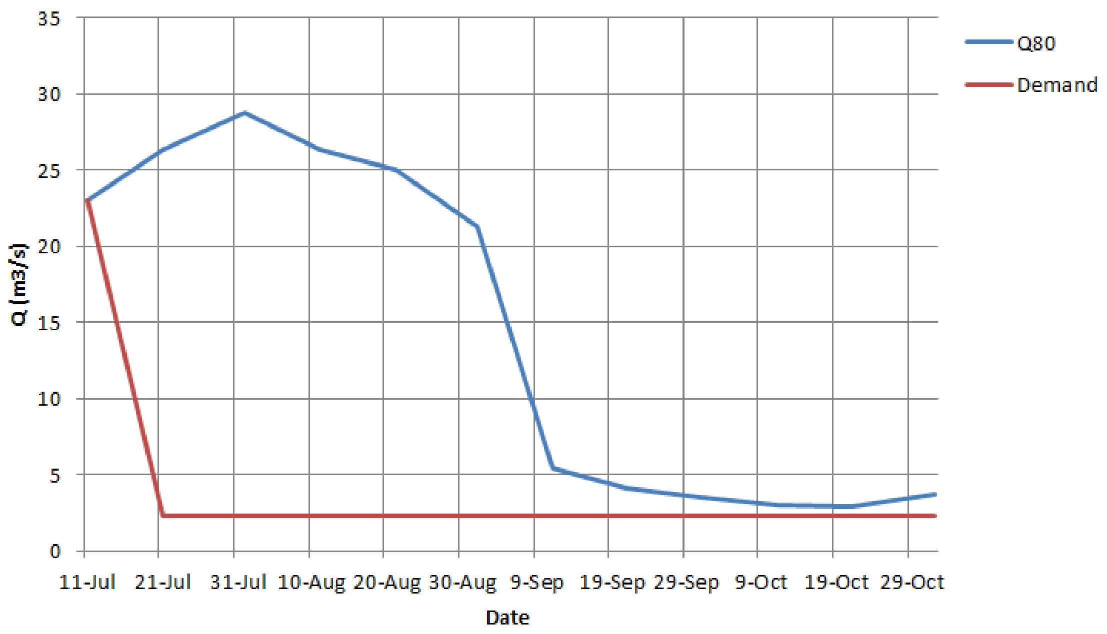


Figure 4.7 Comparison of demand and Q80

From the graph in Figure 4.7 it can be seen that the water demand is always below the Q80. So it can be concluded that surface water would be sufficient for exclusive aquaculture use under the assumptions considered in this analysis.

So far, this study has given some insight into river water availability for aquaculture. This should, however, be linked to the working practice of aquaculture farmers. Changing the aquaculture method may require farmers to change their activities to a more intensive method. From a discussion with Blue forest, a matrix of pros and cons between traditional and intensive methods was obtained (see Table 4.4), therefore adding some more context to the likeliness of farmers adopting new aquaculture techniques.

Table 4.4 Matrix of pros and cons for two aquaculture water management method

	Traditional	**Controlled**
pros	Net profit : • 5.2 million in 1 cycle (2 cycles/year) • Natural shrimp, varies from 150k – 500k per night	Net profit : • 5.2 million in 1 cycle (3 cycles/year, with 1 cycle low productivity due to monsoon) • Save 600k per cycle from not buying pesticide Less prone to disease
cons	• Prone to disease during monsoon	• No daily profit (from natural shrimp)

4.2 Domestic water use

Domestic water use was also discussed during the community meeting and the results of the discussions presented here. Some of the community members believe that, and we quote literally, "it is not the fish which need the fresh water, but actually the people". Inhabitants experienced water shortage for domestic (household) use during the dry season. During the discussion, an overview of sources for domestic water use has also been mapped, as presented in the Figure 4.8.

Figure 4.8 Map of domestic water use source

The brown area, which covers the western part, is the area where the source for domestic use is groundwater (deep wells). The blue area, in the eastern part, is the area where the source is from a water supply company. The water supply company extracts this water from surface water (i.e. rivers). Community in the blue area no longer have water shortage problems during the dry season.

Deep wells, which are the main source for the community in the western part, are wells that go into the confined aquifer layer in the subsoil. The well is as deep as 120 m below the surface and extracts water from the confined aquifer, where little pollution is found. The confined aquifer layer gets its water recharge from the upstream area (i.e. mountains) or from cracks in the impermeable layer. If the volume of water in the aquifer is large enough water will be confined under hydrostatic pressure. This pressure sometimes can cause the groundwater to 'spring' without using any pump. Figure 4.9 illustrates how a confining layer of aquifer affects the pressure of groundwater head.

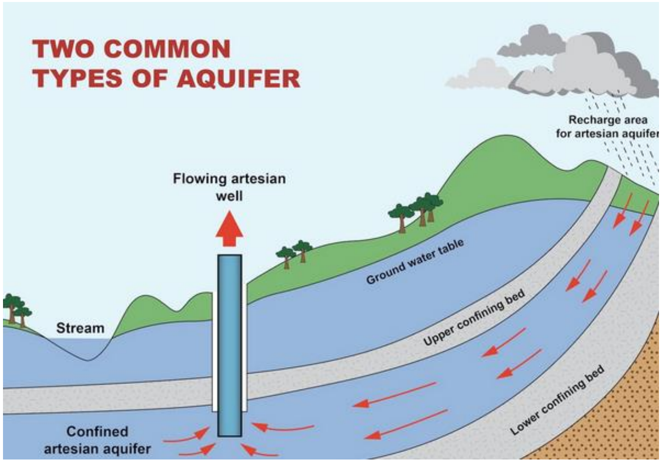


Figure 4.9 Illustration of artesian well

Interviews were conducted at the coastal communities. This interviews had the goal of gathering information over the water sources that the communities use for domestic consumption. At first, the community said that their source is from 'umbul', which in Javanese language means spring. Umbul turns out to be the term for the artesian well. From 1970 onwards, the well has been discharging water even without a pump, indicating that the confined groundwater must still be under hydrostatic pressure. The local community calls this free-flow artesian well 'umbul'.

In the 1980s, deep wells were dug, with a depth of 80 m. In 2012 the well sometimes ran out of water at this depth. Therefore the wells were deepened to 120 m. Currently, these wells with a depth of 120 m are still functioning. From the historical development of groundwater depth can be concluded that the groundwater is depleted at 80 m depth. If no other sustainable water source will be available, all the groundwater may potentially be depleted in the future and the community will have no fresh water available to them. This unsustainable use of groundwater has led to land subsidence.

Depletion of groundwater table is one of the reasons why land subsidence is happening. In Demak area, the groundwater head is depleting, and land subsidence occurring. Given the fact that groundwater level and availability is very critical, it cannot be relied on as sole fresh water source anymore. Other sustainable water sources need to be considered. Within the result of SIWAMI model, it can be checked whether the surface water from the river is enough to supply the domestic water demand by the community. In order to do so, first the demand should be estimated. This demand can be calculated from the number of people in the brown area.

Let's analyze the surface water availability for the domestic use. This analysis is done under the assumption of all river water being available for domestic water use only. Design value for domestic water use in rural area in Indonesia 60 liter/person/day (Ministry of Public Works, Indonesia, 2007). We can use this number to estimate the water use by the community. The table below gives an overview of the population per village and their total domestic water use. The domestic water use in Table 4.5 and Figure 4.10 also indicates the amount of water extracted from the groundwater by the community within the brown area.

Table 4.5 Groundwater use by Demak Coastal Community

Village	Number of People	Domestic water use (m^3/day)
Bedono	3500	210
Timbulsloko	3628	217.68
Tugu	8365	501.9
Surodadi	2988	179.28
Tambakbulusan	2419	145.14
Morodemak	6014	360.84
Total		1615

Figure 4.10 Map of groundwater use for domestic

Now, if we would assume that surface/river water is used to supply this area, the minimum discharge that must be available can be computed. Assuming that people use water only 4 hours / day (2 hours in the morning and 2 hours in the evening), then 0.12 m^3/s water is needed (1615 m^3/day divided by 3600 s in 4 hours). So the minimum river discharge to supply the community with enough fresh water is 0.12 m^3/s.

By using SIWAMI, the water available in the river can be obtained. This is done here by assuming that the western area (where there is no water supply from the company) is to be served by the two biggest rivers in the west (with the catchment area of dark blue and purple, see Figure 4.11):

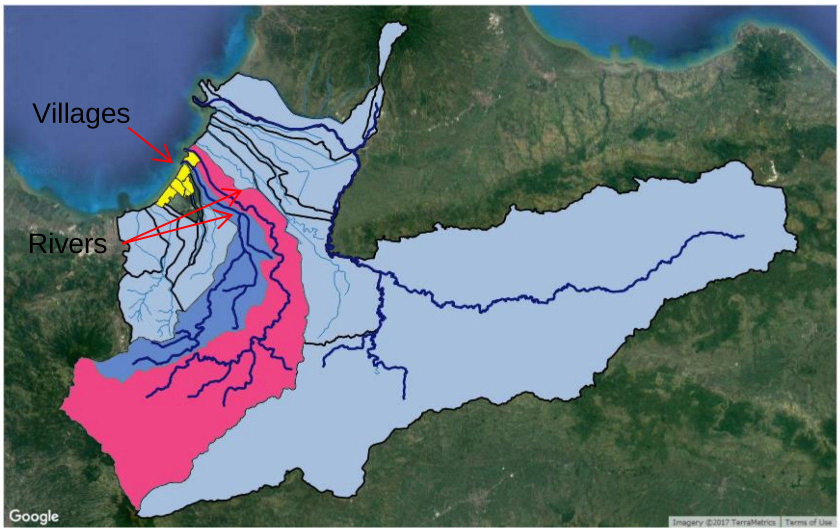


Figure 4.11 villages and river map

The demand of 0.12 m^3/s found above is compared with Q100, the amount of discharge that will be available 100% of the time. Based on SIWAMI these two rivers combined have a Q100 of 0.11 m^3/s during the period of 2003-2017. Thus, it can be concluded that the two rivers in the western part are not sufficient to supply all the domestic water use for the community, and under the assumptions we have considered. So, in order to fully cover the fresh water demand for domestic use with surface water, more water would need to be delivered from the big river in the east (Serang-Lusi river).

If the water from all the three big rivers is used, the total Q100 would amount to 0.23 m^3/s. So together of these three big rivers could supply enough water for domestic use in the coastal community. Let us emphasize that this results hold only under the assumption of the water in the rivers only be used for domestic consumption in the coastal village. In the real condition, that is probably not the case, as river water may be used by other communities, industry or agriculture.

4.3 Surface water availability for coastal village

From the two analyses above, more insight was obtained into the fresh water availability for the coastal community under the assumption of water exclusively being used either for aquaculture or for domestic purposes. In this study, the case where only the coastal community uses the water is considered, but this time combining aquaculture and domestic use. The analysis was done by considering water from the three biggest rivers Jragung, Buyaran and Lusi-Serang (see Figure 4.12). The demand discharge is given in Table 4.6.

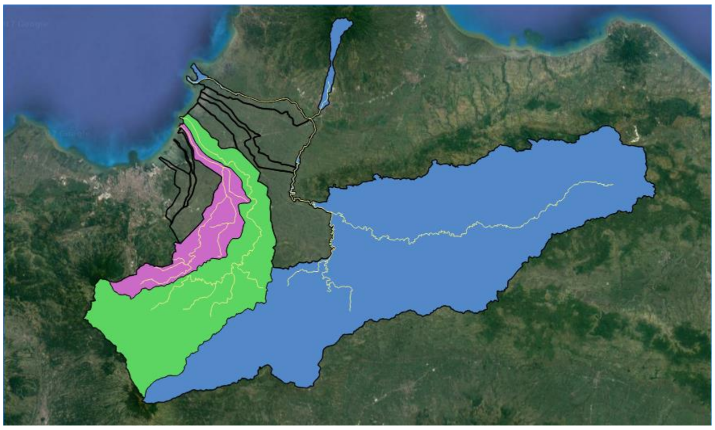


Figure 4.12 Jragung, buyaran and Lusi-Serang catchment

Table 4.6 Demand discharge for aquaculture and domestic water use (m3/s)

Date	Aquaculture	Domestic
11-Jul	22.99	0.12
21-Jul	2.29	0.12
01-Aug	2.29	0.12
11-Aug	2.29	0.12
21-Aug	2.29	0.12
01-Sep	2.29	0.12
11-Sep	2.29	0.12
21-Sep	2.29	0.12
01-Oct	2.29	0.12
11-Oct	2.29	0.12
21-Oct	2.29	0.12
01-Nov	2.29	0.12

To analyse the availability of river water, first the available water in the three rivers is added up. Then the demands of domestic water use are extracted. Hence, the amount of river water which is available for the aquaculture is obtained. That way the probability that the aquaculture water demand can be met is computed.

Table 4.7 Water availability minus domestic water use (m3/s)

Date	Aquaculture	Q80	Q75
11-Jul	22.99	21.06	21.85
21-Jul	2.29	23.13	24.68
01-Aug	2.29	26.27	26.88
11-Aug	2.29	28.97	29.83
21-Aug	2.29	26.11	28.66
01-Sep	2.29	24.72	25.69
11-Sep	2.29	21.11	21.79
21-Sep	2.29	4.72	5.01
01-Oct	2.29	3.68	4.04
11-Oct	2.29	3.27	3.46
21-Oct	2.29	2.81	3.16
01-Nov	2.29	2.72	3.27
11-Nov	2.29	1.81	3.81

From Table 4.7 we can conclude that if the water in the river is used for domestic water use and aquaculture, then Q80 is not met. This is because in average over the last decade there is more demand than Q80 at two specific times (11-Jul: 22.99 m^3/s > 21.06 m^3/s ; 11-Nov: 2.29 m^3/s > 1.81 m^3/s). However this combined demand meets Q75, which is the water that is available 75% of the time, with the exception of during the refill of the pond.

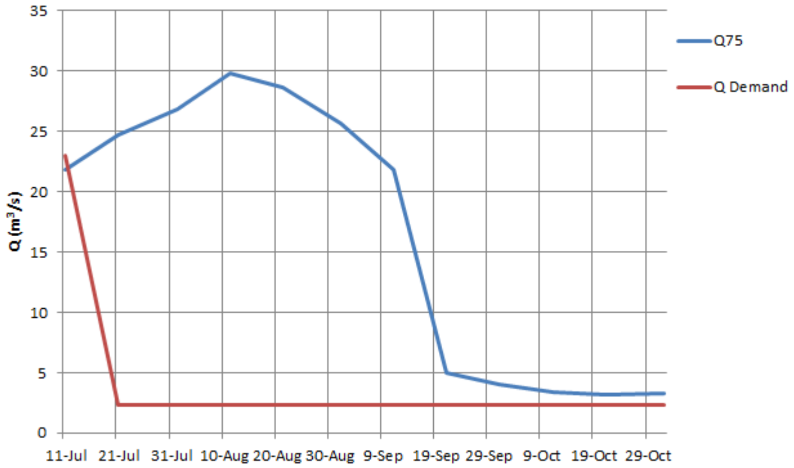


Figure 4.13 Qdemand vs Q75

From the Figure 4.13, it can again be seen that the demand in the first decade is not met within Q75 during the refill of the pond (11-Jul). Q75 is met if the filling period is elongated to, for instance, 15 days. If we change the period into 15 days, then we got the demand vs Q75 as shown in Figure 4.14.

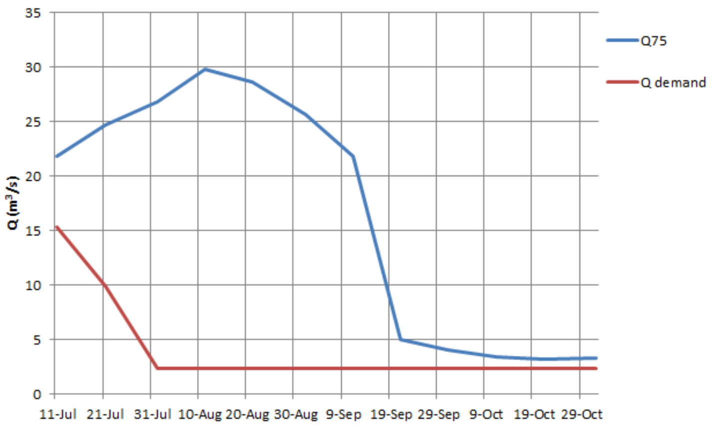


Figure 4.14 new Qdemand vs Q75

Aquaculture and agriculture water is considered as enough if Q80 is never surpassed (water can supply 80 percent of the time). And in Demak coastal, 75 percent availability is met after domestic use is withdrawn from the network. Thus without any type of water management (reservoirs, basins), 25 percent of the time there will be a water shortage for aquaculture, which is considered insufficient according to agriculture and aquaculture standards.

4.4 Surface water status in Demak catchment

Demak water catchments consist of small catchments in the west, increasing in size towards the east. There are three big river in the region that can potentially be a water source for the community. From the analysis of water use by the coastal community it was demonstrated that river water could potentially be enough for aquaculture practices if water was only dedicated to this purpose. Moreover the two main rivers arriving to the west do not provide enough water supply to domestic use in the western area, even in the case where are all the water from these two rivers would be exclusively dedicated to domestic use. Water from the third main river in Demak could add the water needed to satisfy the domestic demand, under the assumption of all water being used for domestic purposes. Therefore the water in the system can be considered as nearly enough. **Nearly enough** means that there is not enough water in the river to supply other water users (domestic water by other communities, industry). These findings are in agreement with the study of *Java Water Resources Strategic Studies* (2012), see Figure 4.15. In that study, catchment in Demak is considered as under a ‘shortage’.

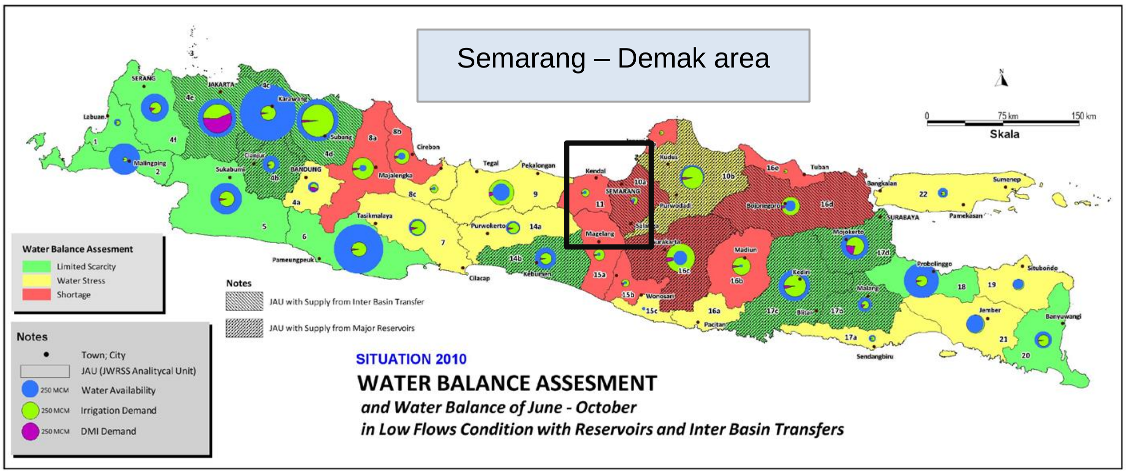


Figure 4.15 Java Water Resources Strategic Studies

In the study it was also mentioned that there is potential of water transfer from Serang-Lusi river (the big river in the east; also the third main river as mentioned in the previous paragraph) into Demak area. However this transfer (Figure 4.16) is merely hypothetical and its practicalities and challenges are unknown. Another challenge in using water from Serang-Lusi River is that the downstream part of the river is polluted by industry from the city in the upstream part (Kudus, see Figure 4.17).

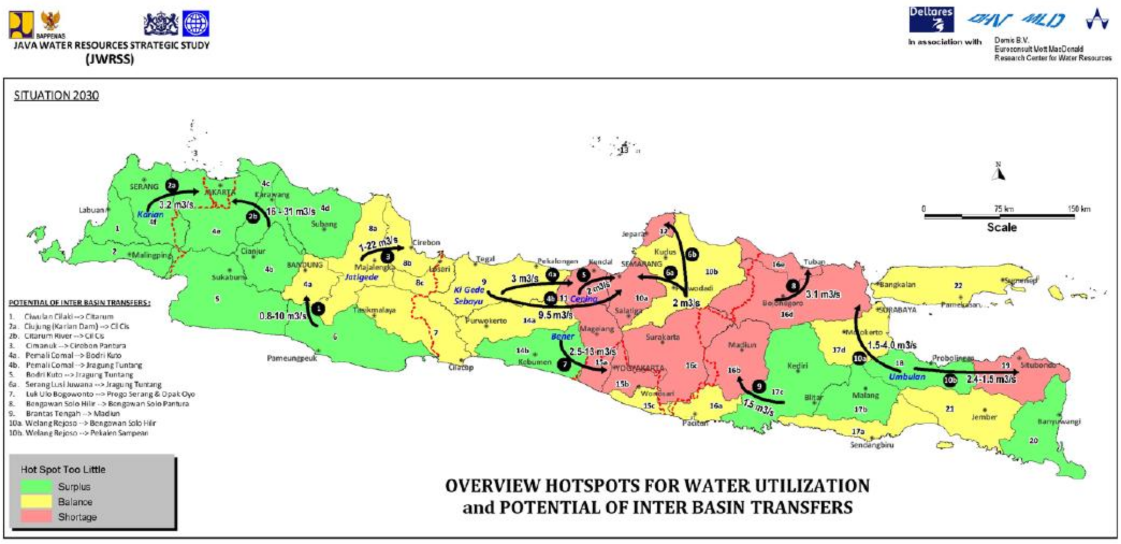


Figure 4.16 Potential transfer from Serang Lusi Catchments

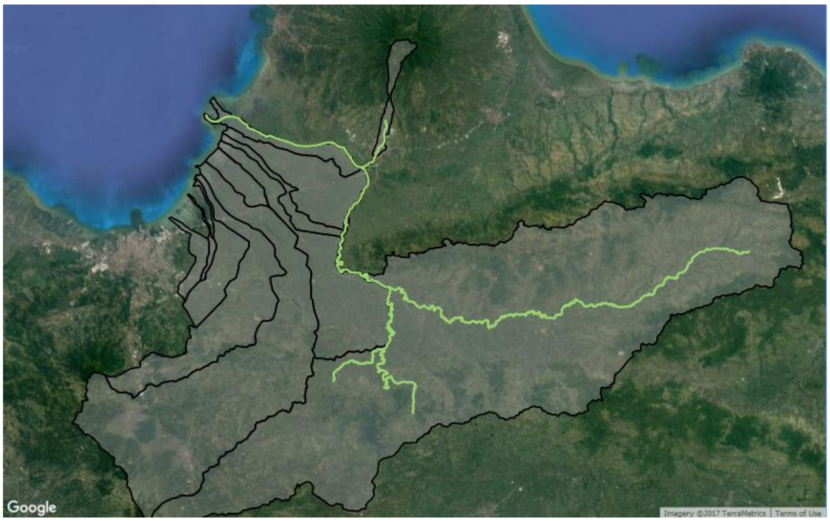


Figure 4.17 Pollution in downstream of Serang-Lusi river

5 Conclusion and Recommendations

Conclusions

In our project area there are three main rivers and their catchments that end up at the coast. From west to east these are: the Jragung, Buyaran and the Serang-Lusi. These rivers contain 80% of the total available fresh surface water. In the Serang-Lusi river in the East of Demak 50% of available water is concentrated. Fresh water availability in Western Demak, where most people and industry is concentrated, is limited. Upstream there are two main reservoirs, Rawa Pening and Kedung Ombo. Those reservoirs are not included in the SIWAMI model, which assumes natural flows. Under natural flow, discharges in the wet season are high but in the dry season shortages may be experienced.

In the model, demands are constituted by agriculture, mainly consisting of rice production, aquaculture, for fish and shrimp, and by domestic needs for coastal communities. Industrial needs, livestock, and other upstream user groups are not directly evaluated in this study. For each user group the following conclusions were derived:

1. Crop farming: During the wet season supply exceeds demands largely. However, at certain years water availability in the dry period does not meet demand at main intakes for rice production. Especially at end and start of the cropping season this may pose problems.
2. Aquaculture: Overall there is enough available river water to support downstream aquaculture demands. However, water distribution to individual ponds may be a problem. More intensive industrial aquaculture systems that are scarcely distributed over the area use fresh water from deep wells to maintain salinity levels during the dry season. Coastal ponds report low productivity due to high salinity levels and with ongoing subsidence salinity intrusion will threaten aquaculture, livestock and agriculture productivity more inland as well.
3. Domestic: Coastal communities in the East of Demak receive fresh water from a water supply company and do not experience shortages. Communities in the West rely on ground water for their domestic needs. Demands of these communities cannot be met by the available river water within their own watershed. However, river water availability in the whole of Demak does suffice for domestic use solely. Once domestic use is combined with aquaculture use shortages may occur parts of the time.
4. Livestock: The production of broilers (poultry meat) in Demak requires at least five times more fresh water from wells then aquaculture, as the surface water is not of appropriate quality. Goat, buffalo and cattle are not produced in huge numbers. The later was not specific output of this report, but is also considered as an important water use and therefore included for a complete overview of water users.
5. Industry: although industry is likely responsible for most water use in Demak it was not included as a user group in the SIWAMI model. First, there is no data gathered of industrial uses of surface water and second, industry generally relies on ground water provided by their own wells.

There are several important aspects that have a large influence on water quantity and quality, that are not taken into account by this study. First, the current study does not specifically investigate water quality, but pollution of the Serang-Lusi river has been reported. Second, industrial uses have not been included but maps with registered ground water wells indicate that they may rely largely on ground water as their main water source. Lowering of the ground water level in Demak is measured at an alarming rate and from other areas across Indonesia and the world this lowering is linked directly to subsidence of the land. Local inhabitants of coastal villages report the occurrence of brackish water in their deep wells which points at depletion of the deep fresh ground water. Several scientific publications report subsidence rates of more than 8 cm/year in coastal areas of Semarang and in industrial areas of Demak. Comprehensive and continuous studies of land subsidence in Semarang and Demak are needed to understand the land subsidence behaviour and its causes in detail. Reliable and continuous monitoring of ground water levels and subsidence is crucial. In addition, it is recommended to put an action plan of how to tackle and stop subsidence for Semarang, Demak and surrounding areas, in place as soon as possible.

Although the current modelling study shows that there is abundant yearly water supply in Demak through the three main rivers, the availability of water is unequally distributed over time and space. Water supply throughout the year is characterized by a wet and a dry season and the Eastern part of the province receives about 80 % of the river water. Therefore, water users are likely to experience regular shortages. Under natural flows that are assumed in the model these shortages become visible in both domestic and agricultural demands. Possible measures to manage shortages are:

1. Retain more water during wet periods, locally with storage tanks, retention basins or with extra reservoirs;
2. Optimize distribution of water throughout the year but also spatially by diverting water from one river to another;
3. Have a flexible cropping season;
4. Revert to other crops or aquaculture species;
5. Improve quality of available water and thereby increase potential for use.

The existing upstream reservoirs, not included in the model, could already be helping with the distribution of water throughout the year. However, reported upstream rates of erosion are responsible for the infilling of the reservoirs, with eventually ends up in a loss of capacity of the reservoirs. Therefore we still advice to pay attention to water distribution over time and possible associated measures.

Recommendations

Considering increasing pressure on water resources from growing population and industrial development in Demak a more extensive study to optimize fresh water supply is urgently required. During future study it is strongly advised to consider all user groups, including industry and upstream users. Urban issues arising in Semarang, such as shortage of surface water, overexploitation of ground water and land subsidence, have large effects on the more rural coastal area and its inhabitants. In the same way as developments along urbanized coastlines will influence integrity of adjacent rural coastlines, water shed management impacts the long term development of coastal zones, by influencing input of fresh water and sediments. Therefore it is recommended that future studies on fresh water supply and demand take into account Demak and Semarang and preferably also other areas adjacent of Semarang. Looking at water availability and needs in disconnection will not result in a sustainable water management plan for the future. In that respect, future trends considering climate change and demographics should be specifically taken into account in these studies as well, as should the current overexploitation of ground water. Sustainable management of ground water will be essential to mitigate subsidence affecting the area. Regulatory frameworks to ensure this are in place in Indonesia, but need to be reinforced and applied. Concluding, resilience of coastal landscapes is only ensured through land-use practices that take into account coastal dynamics, river management and groundwater resources. Participatory planning processes that are part of Coastal Zone Management (CZM) and Integrated Water Resource Management (IWRM) can help to achieve desired objectives and thereby ensure sustainable development of Indonesian coastlines.

6 Glossary

SIWAMI	Sistem Informasi (information system) of Water Availability on Main Intakes
Q75	Discharge of which 80 percent of the time will be exceeded
Q80	Discharge of which 80 percent of the time will be exceeded
Q80	Discharge of which 100 percent of the time will be exceeded

7 References

Balai Besar Wilayah Sungai Pemali-Juana (2013). Rencana Pengelolaan Sumber Daya Air Wilayah Sungai JratunSeluna. Menteri Pekerjaan Umum Republik Indonesia.

Chaussard , Estelle; Amelung, Falk; Abidin, Hasanuddin Z. Abidin (2012). Sinking Cities in Indoensia: Space-Geodetic Evidence of The Rate and Spatial Distribution of Land Subsidence. Proceedings ‘Fringe 2011 Workshop’, Frascati, Italy, ESA SP-697, January 2012.

Direktorat Jendral Cipta Karya (2007). BUKU PANDUAN PENGEMBANGAN AIR MINUM . Ministry of Public Works, Republic of Indonesia

Abidin , Hasanuddin Z. ; Andreas,H. ; Gumilar ,I. ; Sidiq, T.P. ; Gamal, M. ; Murdohardono ,D. ; Supriyadi, Y.; Fukuda (2010). Studying Land Subsidence in Semarang (Indonesia) Using Geodetic Methods. FIG Congress 2010, Sydney, Australia, 11-16 April 2010.
Hutasoit, L. M. and Pindratno, M. H. (2004). Amblesan tanah di DKI Jakarta, Permasalahan, Kebijakan, dan Penanggulangan Bencana Tanah Longsor di Indonesia. P3-TPSLK BPPT and HSF, Jakarta.

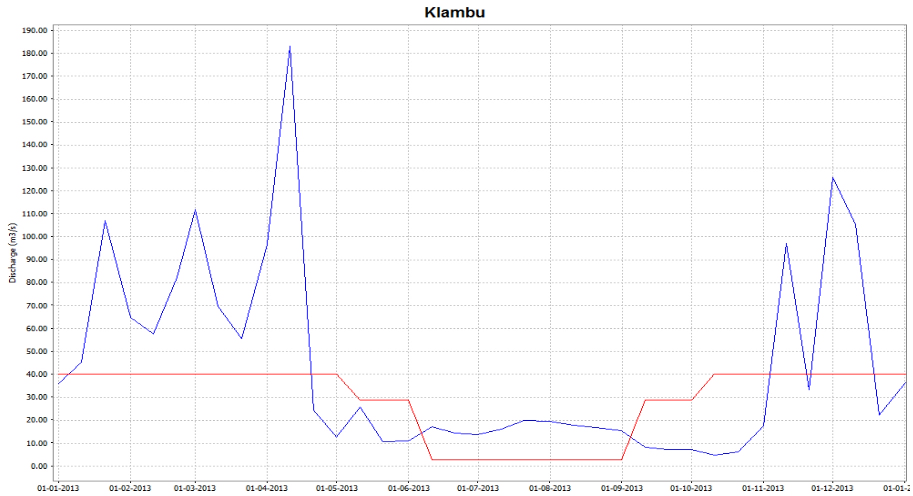
Menteri Pekerjaan Umum Republik Indonesia (2010). Pola pengelolaan sumber daya air wilayah sungai Jratunseluna Keputusan meteri pekerjaan umum nomor 588/KTPS/M/2010.

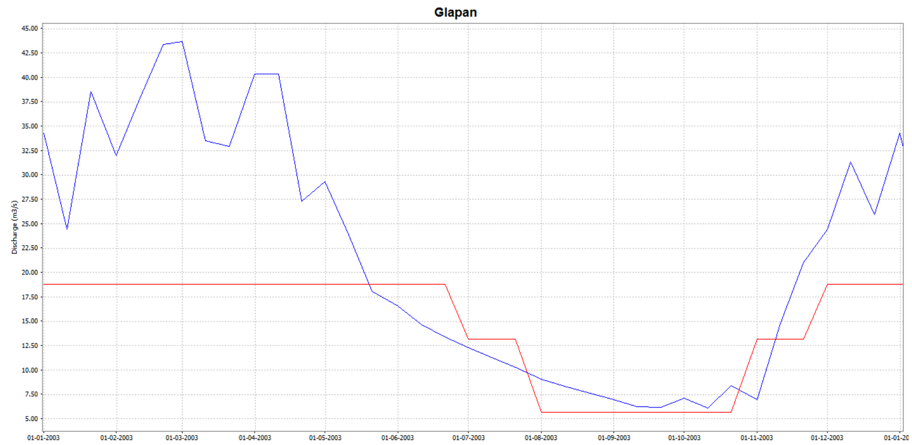
Deltares, DHV, MLD and Wiratman (2012). Java Water Resources Strategic Study. Menteri Pekerjaan Umum dan Bappenas Republik Indonesia.

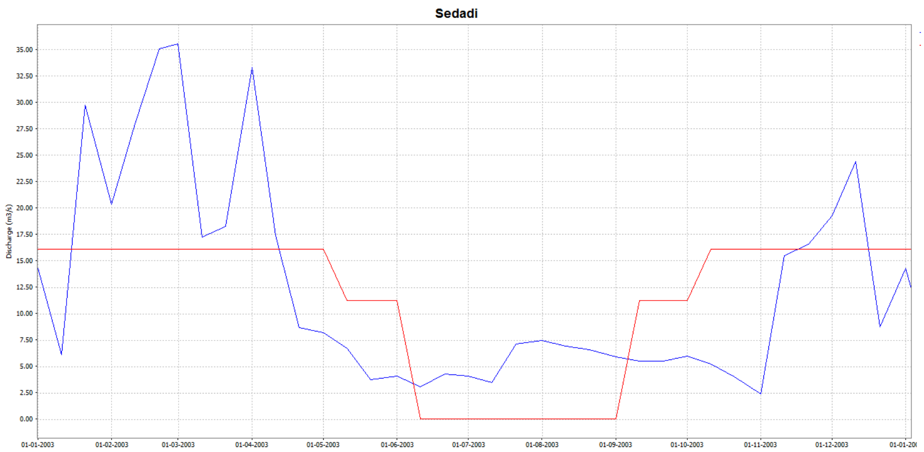
Winterwerp, Han; van Wesenbeeck, Bregje; van Dalfsen, Jan; Tonneijck, Femke; Apri Astra; Verschure, Stefan and van Eijk, Pieter (2014). A sustainable solution for massive coastal erosion in Central Java. Discussion Paper. Deltares and Wetlands International.

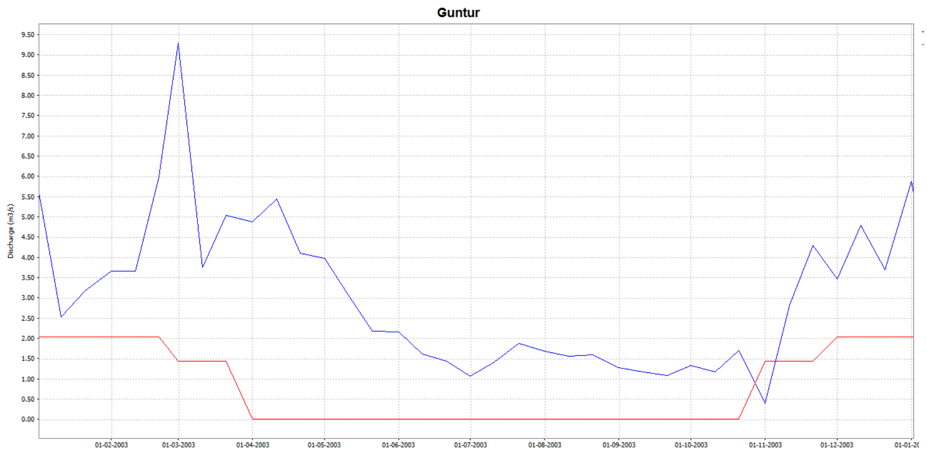
Yuwono, Bambang D.; Abidin, Hasanuddin Z., Gumilar I, Andreas, H.; Awaluddin,M.; Haqqi, K.F.; Khoirunnisa,R (2016). Preliminary survey and performance of land subsidence in North Semarang Demak. AIP Conference Proceedings 1730, American Institute of Physics.

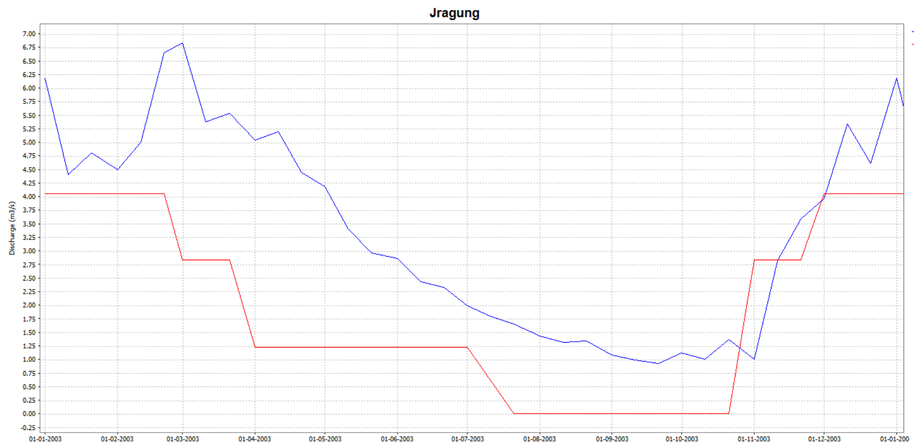
A SIWAMI result – Agriculture main intakes

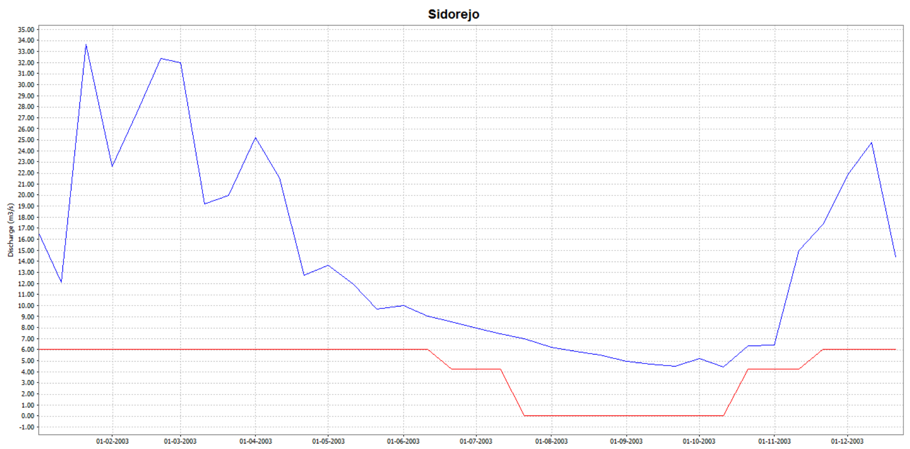


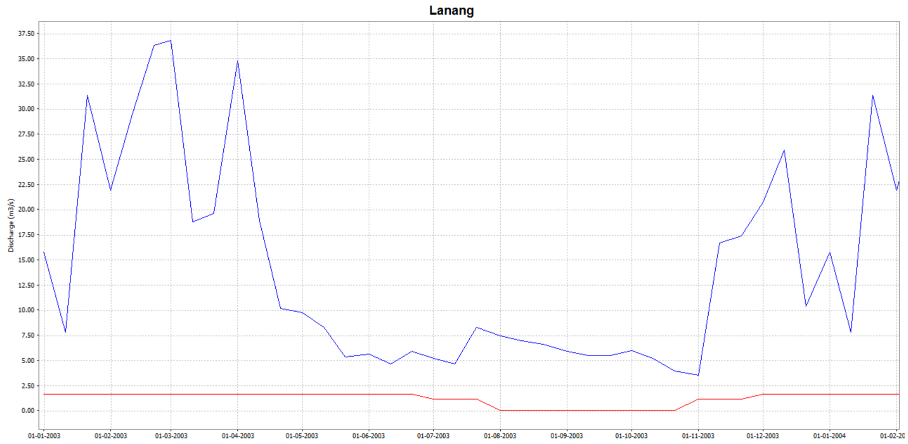





Guntur
Discharge (m3/s)


Jragung
Discharge (m3/s)


Sidorejo
Discharge (m3/s)


Lanang
Discharge (m3/s)
37.50
35.00
32.50
30.00
27.50
25.00
22.50
20.00
17.50
15.00
12.50
10.00
7.50
5.00
2.50
0.00
01-01-2003
01-02-2003
01-03-2003
01-04-2003
01-05-2003
01-06-2003
01-07-2003
01-08-2003
01-09-2003
01-10-2003
01-11-2003
01-12-2003
01-01-2004

Q80

Date	Location							
	Dumpil	Glapan	Guntur	Jragung	Klambu	Lanang	Sedadi	Sidorejo
01-01-03	13.88	34.28	5.88	6.18	43.77	15.75	14.26	16.82
11-01-03	4	24.39	2.53	4.4	8.93	7.81	6.06	12.11
21-01-03	12	38.51	3.17	4.81	42.97	31.37	29.72	33.66
01-02-03	12	31.95	3.66	4.5	28.43	21.89	20.36	22.6
11-02-03	23.85	37.89	3.65	5	57.59	29.43	27.93	27.41
21-02-03	17.49	43.38	5.99	6.65	82.77	36.32	35.05	32.37
01-03-03	21.99	43.61	9.29	6.83	97.04	36.83	35.54	31.98
11-03-03	14.05	33.5	3.74	5.38	46.17	18.74	17.21	19.17
21-03-03	13.41	32.87	5.04	5.53	39.94	19.63	18.21	19.98
01-04-03	22.96	40.33	4.87	5.04	76.26	34.77	33.3	25.19
11-04-03	9.44	40.36	5.44	5.2	35.97	18.88	17.38	21.55
21-04-03	6.43	27.3	4.1	4.44	15.9	10.16	8.65	12.74
01-05-03	7.24	29.28	3.98	4.18	13.26	9.77	8.18	13.65
11-05-03	7.98	23.85	3.08	3.41	18.34	8.27	6.73	11.97
21-05-03	4.61	18.08	2.18	2.96	9.03	5.34	3.74	9.65
01-06-03	4.33	16.5	2.16	2.86	8.6	5.65	4.05	9.96
11-06-03	6.16	14.65	1.61	2.43	12.92	4.65	3.05	9.01
21-06-03	4.97	13.38	1.44	2.33	12.94	5.87	4.25	8.55
01-07-03	4.4	12.27	1.06	1.99	12.17	5.18	4.06	7.94
11-07-03	4.17	11.28	1.42	1.79	14.63	4.61	3.49	7.45
21-07-03	3.28	10.23	1.87	1.65	18.82	8.24	7.09	7
01-08-03	3.05	9.04	1.68	1.43	18.07	7.44	7.45	6.25
11-08-03	2.96	8.28	1.56	1.31	16.19	6.91	6.92	5.81
21-08-03	2.87	7.66	1.6	1.34	15.61	6.57	6.58	5.51
01-09-03	2.48	6.93	1.28	1.08	13.76	5.87	5.88	4.94
11-09-03	2.27	6.24	1.17	0.99	6.97	5.48	5.48	4.69
21-09-03	2.43	6.12	1.09	0.92	6.73	5.45	5.49	4.5
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21-10-03	2.53	8.4	1.7	1.37	8.45	3.94	3.97	6.34
01-11-03	3.67	6.92	0.4	1	7.49	3.5	2.37	6.39
11-11-03	7.16	14.73	2.81	2.82	36.07	16.68	15.45	14.99
21-11-03	8.69	20.98	4.3	3.59	33	17.37	16.54	17.31
01-12-03	15.16	24.36	3.47	3.96	31.28	20.75	19.23	21.81
11-12-03	22.77	31.29	4.79	5.34	45.77	25.91	24.36	24.73
21-12-03	16.75	25.94	3.69	4.61	22.07	10.38	8.7	14.37

Qdemand

Date	Location							
	Dumpil	Glapan	Guntur	Jragung	Klambu	Lanang	Sedadi	Sidorejo
01-01-03	13.88	34.28	5.88	6.18	43.77	15.75	14.26	16.82
11-01-03	4	24.39	2.53	4.4	8.93	7.81	6.06	12.11
21-01-03	12	38.51	3.17	4.81	42.97	31.37	29.72	33.66
01-02-03	12	31.95	3.66	4.5	28.43	21.89	20.36	22.6
11-02-03	23.85	37.89	3.65	5	57.59	29.43	27.93	27.41
21-02-03	17.49	43.38	5.99	6.65	82.77	36.32	35.05	32.37
01-03-03	21.99	43.61	9.29	6.83	97.04	36.83	35.54	31.98
11-03-03	14.05	33.5	3.74	5.38	46.17	18.74	17.21	19.17
21-03-03	13.41	32.87	5.04	5.53	39.94	19.63	18.21	19.98
01-04-03	22.96	40.33	4.87	5.04	76.26	34.77	33.3	25.19
11-04-03	9.44	40.36	5.44	5.2	35.97	18.88	17.38	21.55
21-04-03	6.43	27.3	4.1	4.44	15.9	10.16	8.65	12.74
01-05-03	7.24	29.28	3.98	4.18	13.26	9.77	8.18	13.65
11-05-03	7.98	23.85	3.08	3.41	18.34	8.27	6.73	11.97
21-05-03	4.61	18.08	2.18	2.96	9.03	5.34	3.74	9.65
01-06-03	4.33	16.5	2.16	2.86	8.6	5.65	4.05	9.96
11-06-03	6.16	14.65	1.61	2.43	12.92	4.65	3.05	9.01
21-06-03	4.97	13.38	1.44	2.33	12.94	5.87	4.25	8.55
01-07-03	4.4	12.27	1.06	1.99	12.17	5.18	4.06	7.94
11-07-03	4.17	11.28	1.42	1.79	14.63	4.61	3.49	7.45
21-07-03	3.28	10.23	1.87	1.65	18.82	8.24	7.09	7
01-08-03	3.05	9.04	1.68	1.43	18.07	7.44	7.45	6.25
11-08-03	2.96	8.28	1.56	1.31	16.19	6.91	6.92	5.81
21-08-03	2.87	7.66	1.6	1.34	15.61	6.57	6.58	5.51
01-09-03	2.48	6.93	1.28	1.08	13.76	5.87	5.88	4.94
11-09-03	2.27	6.24	1.17	0.99	6.97	5.48	5.48	4.69
21-09-03	2.43	6.12	1.09	0.92	6.73	5.45	5.49	4.5
01-10-03	2.25	7.11	1.33	1.12	6.26	5.97	5.98	5.17
11-10-03	2.22	6.07	1.17	1	4.68	5.22	5.23	4.43
21-10-03	2.53	8.4	1.7	1.37	8.45	3.94	3.97	6.34
01-11-03	3.67	6.92	0.4	1	7.49	3.5	2.37	6.39
11-11-03	7.16	14.73	2.81	2.82	36.07	16.68	15.45	14.99
21-11-03	8.69	20.98	4.3	3.59	33	17.37	16.54	17.31
01-12-03	15.16	24.36	3.47	3.96	31.28	20.75	19.23	21.81
11-12-03	22.77	31.29	4.79	5.34	45.77	25.91	24.36	24.73
21-12-03	16.75	25.94	3.69	4.61	22.07	10.38	8.7	14.37

B Notes on Coastal Community Meeting

Coastal community meeting, Tambak Bulusan 19 July 2017

AQUACULTURE WATER USE

The participant villages (in the note below, the villages are from west to east).

Aquaculture water use is conducted as follows in the villages.

1. Bedono

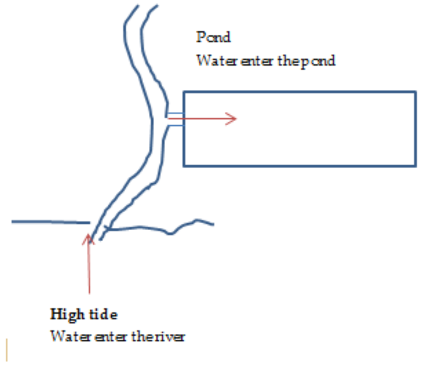
   Bedono is no longer cultivating the traditional aquaculture. Their land, basically is gone. So their pond is not a traditional pond with soil levee, but the pond is bordered with the net instead. So they purely cultivate fish in the sea water.

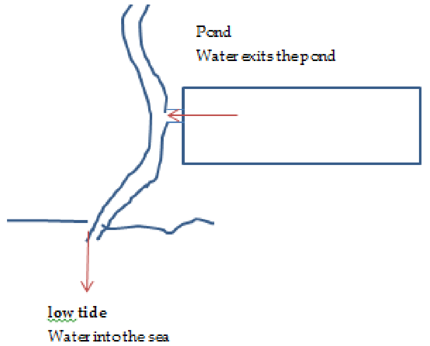
2. Timbulsloko

   Timbulsloko also like Bedono; the pond is no longer a traditional aquaculture pond. Basically they already farm the fish with sea water.

3. Surodadi

   In Surodadi, there are intensive aquaculture (industry) and local (traditional) aquaculture. However, the information gathered during the meeting was for the local aquaculture only. For the traditional aquaculture, most of the farmers use the tidal water replacement method.





Also, within this method they can harvest shrimp which are brought by high tide. When it's high tide, they open the gate so the water enters the pond, and when it's low tide, they put a net into the gate, so the shrimp is trapped in the net. This provides them with daily revenue. Since they need money to conduct their daily activities, this supplements their income from milking and fish harvesting.

The challenge with this method is that it is difficult for them to control the water quality. So they only use water which is available from tidal activity. When it is rainy season however, there is a lot of rainwater and fresh water in the river, so the water will be less saline. While in the dry period, the water is too saline, which causes slow growth of fish.

4. Tugu

   Tugu lies the most upstream of all villages. This means that the water is not much mixed with the sea water. In this village, they think that they do not need fresh water for aquaculture anymore because it will make their pond much less saline.

   In this village, the aquaculture pond used to be agriculture. Sometimes, the high tide is so high that it enters the area. Since the salt water cannot escape the area, they turn it into aquaculture.

5. Tambak bulusan

   In Tambak bulusan there are also local/traditional aquaculture and intensive aquaculture. For local, they use the tidal water farming method. However they realise that they actually need fresh water since in dry season (starting July) the water is to saline. It makes the fish grow very slowly.

The amount of water they need is half the volume of the saline water. If the height of water in the pond is 50 cm, they need 25 cm of fresh water. The intensive/industry aquaculture in this area sometimes uses a deep well to provide fresh water.

6. Morodemak

   In Morodemak, also most of the aquaculture is local. They also use the tidal water method. Since during the wet season, there is enough rainwater and fresh water in the river, the water in the pond becomes less saline. The village representative told us, that he started to grow tilapia fish during the wet season.

7. Puworejo

   The farmer is still a traditional farmer. Because farmers are in an area close to the canal which delivers fresh water, the farmers also use fresh water to cultivate the fish, where the fresh water is used to replenish water. The water replacement is done in October and March.

8. Betahwalang

   In this village aquaculture is still traditional with tidal water is being used. The river brings a lot of sedimentation that can cause sedimentation in the pond.

9. Wedung

   Also traditional method.

Conclusions

1. Every village is unique and has its own characteristics. Also each village has a group of fish farmers, and they decide things in their administrative area. That is one of the reasons why every village is unique.
2. Most of the aquaculture farms in the Project area are still traditional and are owned by the villagers. Only two villages have intensive aquaculture (Surodadi and Tambak Bulusan).
3. The traditional farmers rely on tidal water as their water source in their pond. Therefore they do not extract water from the ground, nor add fresh water into their pond.
4. They think that during dry season, the water is too saline. This causes the fish to grow slowly. They need fresh water however, no fresh water distribution is established in the area.

The intensive aquaculture uses groundwater as its water source.

DOMESTIC WATER USE

1. Desa Bedono

   3500 people with 1100 households.

   They use deep groundwater well as their water source. 15 wells in 6 sub-village. In an average household they spend 2 m^3 of water. The depth of ground water well is 120 m. The water colour is yellow. The most important problem is tidal flooding.
2. Desa timbulsloko

   3628 people and 1172 households.

   This village also uses a deep groundwater well. The depth of the well reaches 130 m. For cooking they use ‘bottled’ water.
3. Desa Tugu

   8365 people, 6750 households.

   This village uses a deep groundwater well. 16 wells, distributed over the village. Depth 125 m.
4. Desa Surodadi

   No data on the number of people.

   Here there are also deep groundwater wells distributed over village. Depth 120 m. Some people have rainwater harvesting ponds, in case the well is not functioning during dry season.
5. Desa Tambak bulusan

   No data on number of people.

   The main source of domestic water is a deep groundwater well (depth 130 m). Some of them are no longer functioning (became salt). This village has a serious problem with fresh water during dry season.
6. Purworejo

   9196 people, 2864 households.

   This village uses water from a water supply company (from river water). Therefore, there is no lack of fresh water in the dry season. There are deep groundwater wells but these are not in use anymore. The depth of the well is 120 m.

   This village has problems with tidal flooding. The representative said he already heightened the floor up to 60 cm.
7. Betahwalang

   4818 people, 1800 households.

   They use water from a water supply company (from river water). There is no lack of fresh water in the dry season.
8. Wedung

   12350 people with 2536 households.

   This village takes 70% of their domestic water from a water company, and 30% from a deep groundwater well. This village has problems with tidal flooding.

C Notes on Bappeda Demak Meeting

Discussion on Demak Water Availability,
Regional planning agency of Demak, 18 September 2017

Attended by: Deltares, Wetlands International, Bappeda Demak, Dinas Pekerjaan Umum, Dinas Lingkungan Hidup, Perusahaan Daerah Air Minum, PAMSIMAS

1. Water Supply Company only covers 23 percent of the Demak water demand.
2. The water supply company plans to make a new water treatment plant in the River Wonokerto. They have the DED already, but they have no information about the water availability.
3. Also the biggest river in the east, the Wulan river, is polluted by industry in Kudus (a city in the upstream area). So the water has bad quality and cannot be used.
4. The local disaster agency is interested whether SIWAMI can be used for early warning system for flood and drought. Yes, it can, however, the system is under authority of Pusair.

D Result discussion roundtable IWRM

On the 10th of October 2017, we engaged in a multistakeholder workshop on Opportunities and Challenges for Coastal Zone Management and Economic Development in Central Java. This workshop was attended by various stakeholders from national, regional and local government, organisations, researchers and universities, and the community.

In the workshop, there was a session of roundtable discussions, where integrated water resources management was one of the topics. One of the roundtable meetings during the workshop discussed the Strengths, Weakness, Opportunity and Challenges (SWOC) of Integrated Water Resources Management (IWRM) of the Demak River basins.

Below is the result of the discussions.

STRENGTH

- Water availability in the wet season is abundant, both from rainfall and from the rivers.
- The coordination of organizations in the government related to water management is already established. Regular meetings are taking place.
- Some regulations related to water management are already in place. It includes the restriction of groundwater use and an obligation to provide a water supply.
- There is a lot of attention from the national government, researchers and organisations for water resources management in Demak-Semarang.
- The Demak community is strong and resilient toward disasters or challenges that come into their area, which is due to historical ties to their area of living.

WEAKNESSES

- Lack of infrastructure.
- Lack of budget for water resources management.
- Lack of coordination in upstream-downstream river basin management.
- Programme to stop land subsidence is not optimal yet.
- Lack of monitoring and law enforcement of groundwater use.
- Community awareness on land subsidence is still low.
- Lack of innovation related to water resources management/use.
- In terms of aquaculture, youth tends to leave aquaculture as an activity as the environment is getting less suitable.

OPPORTUNITIES

- Abundant water availability (both rainfall and rivers) in wet season, that can be stored.
- Use sea water desalination as part of alternative.
- Innovations on water use (recycle, effective water use, etc.).
- Expansion of water supply company.
- Support from the governments (all levels), organisations and researchers.
- High motivation of the community to enhance their livelihoods.
- Improve human resources in water management.

CHALLENGES

- Flood in wet season and drought in dry season.
- Land subsidence.
- Future planning without proper plan on water resources management, which led to a decrease in environmental quality.
- Bureaucracy and coordination is getting more challenging.
- Increase in fresh water demand.
- High rate of deforestation.
- Uncontrolled groundwater use, also from industry.

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