Ensuring Water Availability in Surabaya Through Integrated Water Resources

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***Abstract*—Surabaya is inhabited by 3.074.883 lives with majority drinking water comes from local water company (97%). It uses raw water from Surabaya River that is located in the downstream of Brantas River Basin. The streamflow is smaller than upstream because it is used by another water user. Moreover, the pollution load is accumulated so that the degree of treatment is complicated. Brantas River Basin management is needed to ensure water availability, especially in Surabaya. It can be achieved with the implementation of integrated water resources management (IWRM). A survey using in-depth interview (IDI) were conducted to management agency of Brantas River Basin called Jasa Tirta 1 Public Company (Perum Jasa Tirta 1). It will be compared with the principle of IWRM to assess the state of implementation on the Brantas River Basin. The result shows that the management pattern corresponding with IWRM, except for the mitigation of climate change. Climate change influences water availability and sustainability. An important factor in ensuring water availability in Surabaya is the adoption of effective water management. Even though the implementation of IWRM is not complete yet, it can be achieved by making water supply and demand effectively.**

***Keywords*—Surabaya, Water Availability, Brantas River Basin, Management Pattern, IWRM, Mitigation of Climate Change.**

I. INTRODUCTION

A river basin system is made up of three components, such as water source, in-stream and off-stream demand, and intermediate as in treatment and recycling components[1]. It is characterized by a natural process, physical projects, and management policies. River basin management must include these components into planning. Human behavior toward implemented policies like water cost is needed to take into account so that complete management is constructed.

The river basin is an accepted analysis unit in water resources management. United Nations Conference on Environment and Development (UNCED) uses it in Agenda 21, chapter 18 as integrated water resources management analysis unit.

Water is a commodity used for agricultural, industrial, and domestic use. It makes water has a position as an economy goods. Water allocation and utilization need to be more rational.

Water resources problems require multidiciplinary knowledge because it consists of environment, economy, and social components. Water resources management needs to prevent and mitigate risk while considers social economy development[2].

The idea to manage water resources using multidiciplinary approach began in 1977, but it is not until 2002 that it is adopted and impelemented by 80% countries in 2012[3]. IWRM has four principles, (1) water as limited and vulnerable resource, (2) participatory approach, (3) women role in managing water, and (4) water as economic goods[4]. The challenge for water resurces management is the balance between water use and the growing population. Moreover, protection and conservation are needed to maintain its functions and characteristics. IWRM is required to ensure the water availability. It involves all the natural aspects, as well as the interests between water user. Moreover, the spatial scales needs special care such as upstream-downstream interactions, natural seasonal, annual and long-term fluctuation in water availability, and the development for future generations[5].

In 2018, UN Environment carried out assessment on implementation of IWRM in 172 countries. Indonesia is classified as medium low that is unconvincing to meet the global target unless there is a significant progress[6]. It means that Indonesia has adopted the idea, approved by government, and starting to be used to guide work.

In the assessment carried out by UN Environment, there is concern on the four dimensions of IWRM, such as enabling environment, institutions and participation, management instruments, and financing. Indonesia has low scoring on the financing dimension. It means that the budgeting and financing is not enough to be used for water resources development and management.

On the urban water management, there are six levels of management: (1) water supply city means there are efficiency on water allocation and safe drinking water supply for growing community, (2) sewered city means there are seperated sewer systems to prevent the spread of pathogenic bacteria, including local WWTP, (3) drained city means there are technology and model development that is enable to bring runoff water to waterbody as soon as possible, (4) waterways cit means water is integrated in city planning as important element and has tourism value so there are policies to reduce the pollution load and treat waste water, (5) water cycle city means water as limited resources as raw water supply so there is sustainability concept in water resources management, and (6) water sensitive city[7].

On existing conditions, water management in Surabaya in the level between Water Supply City and Drained City.The concept of Surabaya as water sensitive city began in 2017[8]. It means that there is integration among normative values of environmental repair and protection. The infrastructure and urban design will be inclined to be more adaptive, multifunctional and reinforcing water sensitive behaviours. The goal ahead is communities and envionments are resilient to climate change.

To alter the present condition into ideal one, there are many steps and change needed. There is long road ahead to transfor Surabaya into Water Sensitive City. Although it is a conceptual model, it can be implemented in Surabaya using Musrenbang mechanism[9]. It is doable as long as poverty eradication, education, and sanitation is discussed during Musrenbang. Moreover, it needs to practiced daily rather than discussed as a concept.

Warming trends and increasing temperature have been detected across the Asian region. It is followed by increasing warm days and decreasing cold days. The increasing temperature on the Southeast Asia is at a rate of $0,14^0$ C to $0,2^0$ C per decade since 1960s [10].

Climate change influences sustainability on developing country such as Indonesia. It gives pressure on natural resources like water and other environment related while rapid urbanization, industrialization, and economic development happening.

Climate change affects water resource availability. The increasing temperature leads to presipitation and seasonal change. In Southeast Asia, annual total wet-day rainfall has increades by 22 m, while rainfall from extreme rain days has increased by 10 mm. Increasing rain intensity induces seasonal flash floods which is often occur in Southeast region in recent years[11].

Climate change also affects freshwater availability, especially surface water. It is determined by water catchment area sensitivity to climate change characteristic, magnitude, and seasonal distribution of presipitation, temperature, and evaporation. It controls runoff that flows to water body. Annual runoff is predicted to increase in high altitude with wet tropical climate, while in dry tropical climate is expected to decrease. In Java, average annual streamflow is predicted to change at a rate 10%[12].

To face the challenge of climate change, policies and practice adaptation is needed is water resources management. A flexible solutions that produces benefits regardless the impact and can be implemented adaptively is valuable. Adaptive masures that is proven particularly efective include rainwater harvesting, conservation tillage, maintaining vegetation cover, planting trees in steeply sloping ields, mini-terracing for soil and moisture conservation, improved pasture management, water reuse, desalination, and more efficient soil and irrigation water management.

II. METHOD

A. Case Study

Brantas River Basin is the second biggest river in Java. It has approximately 320 km long and 14.103 km^2 catchment area (Fig. 1). It is divided by 4 watershed: Brantas, Tengah, Ringin Bandulan, and Kondang Merak. This river flows through 9 regencies (Sidoarjo, Mojokerto, Malang, Blitar, Kediri, Nganjuk, Jombang, Tulungagung, and Trenggalek) and 6 cities (Surabaya, Mojokerto, Malang, Kediri, Blitar, and Batu)[13].

Water catchment area of Brantas River Basin is inhabited by 15.901.645 lives in 2005. It is 42,89% from total population of East Java. They utilizes water from Brantas to fullfill their daily needs. With the growth population 0,99% per year, the availability of water becomes important.

Surabaya located in the downstream of Brantas River Basin. In the water management scheme (Fig. 2), Brantas River Basin is divided into two rivers. One flows to Surabaya from Mlirip floodgate called Surabaya River, the other one to Sidoarjo called Porong River. The former one is used to provide raw water for Surabaya.

Local water company Surabaya uses water from Kali Surabaya with production capacity of 10.830 L/s [14]. It is extracted with two intake points, Karangpilang and Ngagel. It is the only source of raw water, so the water availability becomes crucial.

Aside from quantity, quality is important factor in drinking water treatment. As regulated in Regulation of the Governor of the Province of East Java No. 61/2010 concerning Determination of Water Classess in River, Surabaya River started from Mlirip floodgate to Jagir dam is appointed as 2nd class. It is designated for water sport, cultivation of freshwater fish, farming, gardening, and other uses. Even though it doesn't meet the standard, it is used as raw water because it's the only option.

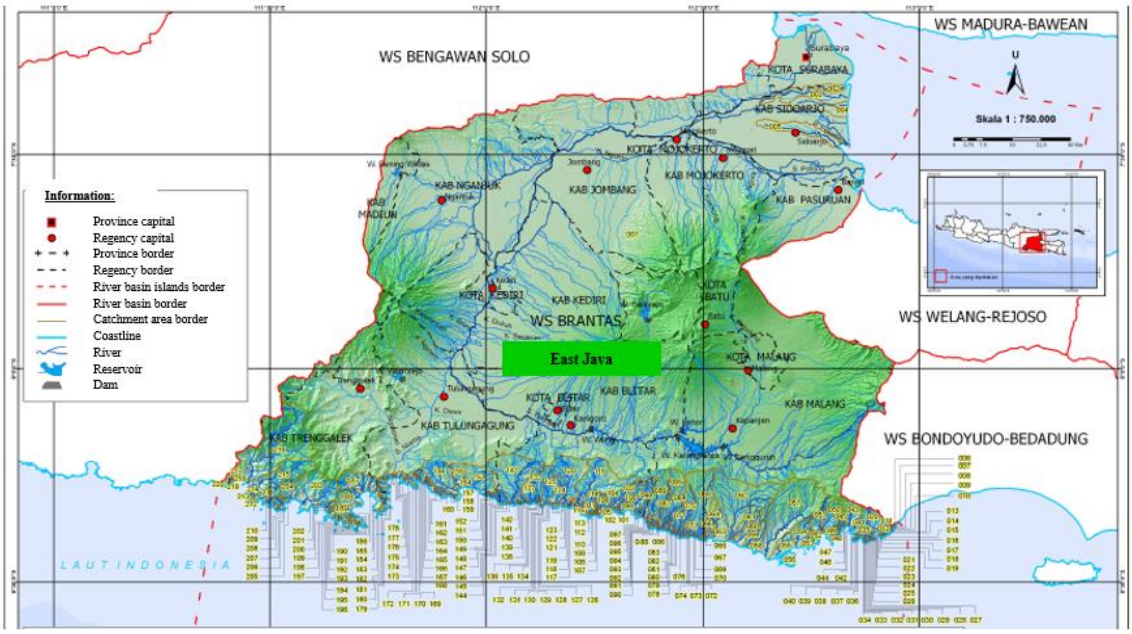

Figure 1. Brantas River Basin Borderline

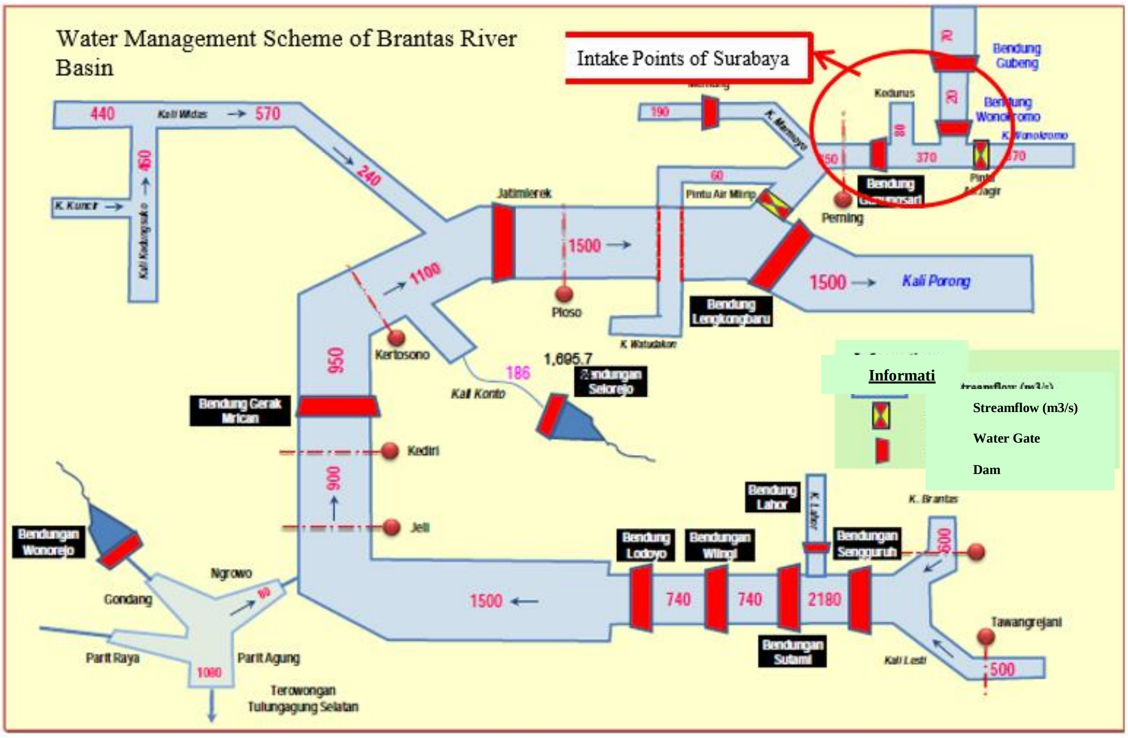

Figure 2. Water Management Scheme of Brantas River Basin

Water quality monitoring on Brantas River Basin is conducted at 51 points with parameter such as DO, BOD, COD, and TSS. Based on the result (Table 1), not all part of Surabaya River is classified as 2nd class. The test was conducted at 2005.

As can be seen at Table 1, DO and COD are the only paramater that meets standard. TSS which is important parameter in drinking water treatment is classified as 3rd class. It indicates difficult degree of treatment so the output can meet drinking water standard.

Table 1.
Water Quality Monitoring at 2005

No.	Location	Water Class			
		DO	BOD	COD	TSS
	Surabaya River				
1	Canggu – Cangkir	I/II	III	II	III
2	Bambe – Sepanjang	III	IV	III	III
3	Gunungsari – Ngagel	III	IV	II	III

B. *Methodology*

Information about management of Brantas River Basin can be got easily from Jasa Tirta 1 Public Company (Perum Jasa Tirta 1). An in-depth interview is conducted to get better knowlodge about the existing management. It will be crosschecked with the management plan of Brantas River Basin from Decision of Minister of Public Works No. 268/KPTS/M/2010.

Regarding IWRM, it is interpreted into model for better understanding (Table 2). This model will be compared with the existing management so that the status of IWRM implementation can be easily known.

From Table 2, it can be seen that IWRM considers various aspects, such as environment, economy, hydrology, and social aspect. It is included because it is influence each other.

IWRM is said to guarantee the sustainability of water availability. If it can be implemented properly, the water availability can be confirmed.

Surabaya is located in the downstream of Brantas River Basin. If the management considers relation between upstream and downstream, then the water allocation in the downstream can be maintained according to designated use.

Table 2.
Model of IWRM

Aspect	Variable
Planning	Water user engagement Discussion
Management	Water resources Environmental effect Waste and recovery Water cost
Water allocation	Domestic Industry Agriculture
Reliability	Flood mitigation Drought mitigation Climate change mitigation
Sustainability	Conservation Water efficiency Cost recovery

III. RESULTS AND DISCUSSION

Management of Brantas River Basin uses approach one river basin, one plan, and one integrated management. The objective is integration in planning, proximity in implementation, and involvement in supervision.

Water resources management of Brantas River Basin is grouped into four: (1) water resources conservation, (2) water resources utilization, (3) restrain the destructive power of water, and (4) community participation and water resources information system.

Management planning was collecting data from identification of water availability and demand. It is used to predict the condition in 20 years time. With the scenario generated, the management policies is formulated to meet the demand with water that is available.

Identification of water availability and demand engages water users to get better understanding about problems and requirement of water supply. It is discussed by a team named

Water Resources Management Coordination Unit (TKPSDA / Tim Koordinasi Pengelolaan Sumber Daya Air). It consist of local agency that is responsible in water resources managing, water user, and water resources expert from academics fields.

Water resources reliability in Brantas is guaranteed by two mitigation plan, drought and flood mitigation. Mitigation of drought is conducted with operating annual reservoir, such as Sutami, Selorejo, Bening, and Wonorejo. They preserve water on rainy season to be utilized on dry season.

Water availability in Brantas River Basin depens on the storage capacity of the reservoirs. It can be hampered by sedimentation. The cause is the damage in water catchment area of reservoirs which is located in upstream. Runoff water brings soil along into the reservoir inducing siltation. The solution is normalization of reservoirs and conservation in the green belt area.

Flood mitigation is achieved by operating Flood Early Warning Early Action System (FEWEAS)[15]. In Brantas River Basin, there are 24 units installed consisting of three gauges (peilschale), seven rainfall monitoring stations, and 14 river water level monitoring stations[16].

Management of wastewater disposal is conducted with license enforcement to permit disposal named Wastewater Disposal License (Izin Pembuangan Limbah Cair / IPLC). This license allows the concessionaire to dispose of their waste into waterbody on a certain amount.

Water quality and pollution control is conducted with operating two GSM based On-Line monitoring station located in Perning Dam and Mrican Dam. This data is transmited to be analyzed and sent to other stakeholders. Local water company Surabaya accept this data once a month so the water quality in Surabaya River is suitable as raw water.

Table 3.
Water Turbidity on Ngagel Intake Point

Month	Year		
	2017	2016	2015
Jan	146,57	121,83	157,41
Feb	143,75	182,26	245,87
March	165,98	182,09	224,39
Apr	174,95	156,48	221,74
May	52,22	89,39	49,85
Jun	25,83	75,32	20,93
Jul	21,58	51,75	22,46
Aug	18,34	41,84	14,41
Sep	16,75	44,64	11,19
Oct	14,23	132,72	10,33
Nov	87,16	100,65	10,31
Dec	0,00	185,30	154,69

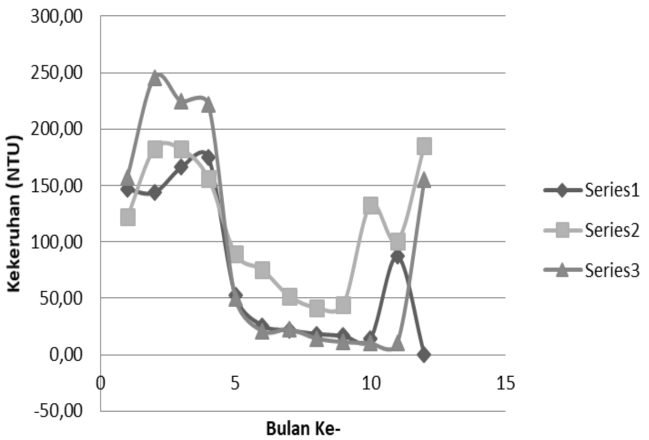

Figure 3. Fluctuation on Turbidity in Ngagel Intake Point

Water pollution monitoring is reported monthly to local water company Surabaya. In 2015-2017, there is decline in turbidity. It is an important aspect in water treatment process because it affects the chemical use.

The reduction of turbidity indicates improvement in water quality management. Join forces from local agencies on water patrol, on-line monitoring system, and development of WWTP plays a role in managing water quality.

Water is no longer free goods. It has an economic value. In effort to manage and monitor water resources, there’s a certain amount of cost involved. Water charging is needed to ensure cost recovery, indicate the willingness to pay for additional investment in water service, provide incentive in managing water demand, and empower water users on conservation and water use efficiency.

Water charging on Brantas River Basin is regulated in Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 18/PRT/M/2015 concerning Exploitation and Building Maintenance Dues Watering. It oversees the one who is the mandatory paying party, the cost calculation, and the collector.

The water charging is called the cost of water resources management services (Biaya Jasa Pengelolaan Sumber Daya Air/ BJPSDA). It covers the cost for information system, management planning, construction, operational and maintenance, monitoring, evaluation, and community engagement. Its principle is from water to return to water, so the cost collected is used to manage water resources. With this scheme, it is expected to recover the cost needed in water resources management.

BJPSDA is mandatory for the one who gets benefits from water resources, such as industry, water supply system, hydroelectric power plant, agriculture, farming, and fishery. The amount is different based on the rational calculation as mentioned in the regulation.

BJPSDA is not mandatory for community agriculture because it uses water from existing irrigation network. It is utilized by organization of water user farmers and there is different regulation which oversees it.

Finance is important factor on profit-based business. Water resources management has social and economy values. Nevertheless, not all water utilization can be charge and the water cost can not be a burden for water user. There should be rational and wise calculation to determine the paying party and water cost.

Water resources management has a certain goal that is water resouces sustainability. To reach it, there are aspects that must be fulfilled, such as conservation, water allocation efficiency, and cost recovery.

Conservation aspect on Brantas River Basin management pattern involves soil and spring conservation, river ecosystem, and water conservation. Main concern on conservation in Brantas River Basin is environmental damage on upstream as water recharge area. The solution is forest and land rehabilitation to repair and restore function and productivity of the natural resources.

Water conservation can be achieved with water allocation efficiency. When the upstream flow decreases, the water allocation needs to be more efficient so that all the demand can be fulfilled. The amount of efficiency can be arranged based on the priority sequence.

Water allocation is discussed by TKPSDA. They holds an open discussion twice a year when the season changes. It arranges water allocation for each of water user on dry season and wet season. There is stream flow fluctuation caused by natural season so that water allocation differs between season. It also determines the operation on annual reservoir in a year time.

Brantas River Basin management pattern compares with IWRM model (Table 2) to examine the conformity. Conformity matrix is used to conduct the examination as seen in Table 4. Brantas River Basin Management corresponds with IWRM model. Almost all variables is included in the management, but variable of mitigation of climate change. It contains mitigation of flood and drought which means that there is effort to maintain the streamflow amidst seasonal change. However, to face a bigger challenge of climate change, it is not enough.

Change of climate means there is changes in rainfall, runoff, and streamflow prediction. When rainfall happens with higher intensity and shorter time, the storage needs to be bigger than regular to harvest rainwater, store, and use it on dry season.

IWRM model concerns to hydrological aspect of water. All part of water cycle must be considered, such as evaporation, precipitation, and percolation. Groundwater recharging is a form of percolation. There is connection between groundwater and surface water because one of the source of streamflow is groundwater. If there is no recharge on groundwater, then there is no recharge on surface water.

Table 4.
Corresponding between IWRM and Management Pattern of Brantas River Basin

No.	Management Pattern	Correspond with IWRM
1	**Water Resources Conservation**	
	Planting vegetation in the beginning of wet season	v
	Penalty for conservation offender	v
	Community engagement in conservation and coordination between stakeholders	v
	Community counseling about the importance of conservation	v
	Giving the license of establishment and other public services selectively	v
	Controlling the water quality, giving the permission of waste disposal, upgrading the capacity of wastewater treatment (WWTP) plant existing, and developing communal WWTP	v
	Spreading fish seeds in the beginning of dry season on the reservoir and river that experience eutrophication	v
	Routinely dredging up solid waste, restricting illegal disposal, and penalty for offender	v
2	**Water Resources Utilization**	
a	**Water resources maintenance**	
	Planning and determining water sources utilization and allocation zone	v
	Water source, spring, and reservoir protection for raw water provision	v
	Protection of river, reservoir, spring, and water resources	v
	Controling and monitoring water allocation	v
b	**Water resources provision**	
	Water resources provision for basic need	v
	Determining the priority of water allocation by local government	v
	Synchronization of water provision with treatment and distribution	v
c	**Water resources utilization**	
	Utilization is adjusted with water allocation pattern	v
	Utilization is adjusted with reservoir operating pattern and water allocation	v
	Farmer empowerment as water user to manage irrigation network	v
	Irrigate land optimization	v
	Increasing the water efficiency	v
d	**Water resources development**	
	Hydroelectric power plant development	v
	Integrated groundwater development	v
e	**Water resources cultivation**	
	Concerning the social fuction and environmental sustainability	v
	Water supply for local water company, industry, agriculture, and electricity	v
	Service quality control	v
3	**Restrain the Destructive Power of Water**	
a	**Prevention of water destructive power**	
	Vegetation planting and monitoring of river cliff	v
	Check dam construction	v
	Developing and constructing reservoir and dam	v
	Irrigation facilities inspection	v
	Community empowerment in controlling flood	v
	Developing the community-based early warning sistem	v
b	**Overcome the water destructive power**	
	River cliff protection	v
	River nomalization	v
	Retarding basin preservation	v
c	**Recovery from water destructive power**	
	Reservoir and other waterworks rehabilitation	v
	River cliff and dam constructive rehabilitation	v
	Reservoir dredging	v
	River normalization	v
4	**Community Participation and Water Resources Information System**	
	Giving information about integrated water resources information system, creating database system, utility, and consistency in providing reliable information	v
	Establishing the water resources council on local scale	v
	Empowering community in managing the river basin and fund raising	v

Recharge rate of groundwater is influenced by condition of soil and land in the recharge area. The damage of reharge area in Brantas River Basin has been detected in the management pattern. Although there are efforts to overcome the problem, decreasing streamflow is projected in 20 years time. Better understanding on permeability and sensitivity of water catchment area is needed.

Rainwater harvesting is one of the adaptive measures against climate change. On Brantas River Basin, it is conducted with the operation of annual reservoir such as Sutami, Selorejo, Bening, and Wonorejo. The storage capacity on these reservoirs is preserved with sedimentation dredging.

Maintaining vegetation cover and planting trees in steeply sloping fields are another measures used to deal with climate change. It is included in the management pattern. However the rate of damage is faster than measures. It is indicated by main concern of conservation on the upstream of Brantas River Basin.

On the good side, there is community engagement in conservation. If community understands the importance of conservation, they can help stakeholders to maintain and control vegetation cover. Community as water users can take a part in the water resources management, not only in planning, but also in operational.

Tillage conservation is one of the adaptive measures against climate change. Agriculture participates in degrading water quality. The residual from chemichal used in crop is dissolved in water, enter the irrigation channel, and flows into the waterbody.

Agriculture in Brantas River Basin is mainly maintained by community. There is no treatment for agricultural waste so the water quality is on risk. Education about the risk of chemical residual from agriculture is needed so farmer can choose to lessen the usage or to alter the chemical to environmental friendly one.

Beside conservation, efficiency in water use can be used as adaptive measures. On Brantas River Basin management, water efficiency will be executed only if the streamflow from upstream is decreasing. Then the water allocation for each water user will be adjusted.

Although it's already included in planning, it is a passive approach. If the flow continously decreases, then the water availability is no longer safe.

An active approach such as community engagement in saving water and using it efficiently is more appealing as adaptive measures. Water consumption in Surabaya is 180 L/person/day. It is higher than standard from Ministry of Public Works that is 150 L/person/day. The approach become urgent to be implemented so the water consumption can be reduced and water availability can be maintained.

Beside the absence of the mitigation of climate change, IWRM in Indonesia has low score in financing. It is a global average based on the assessment carried out by UN Environment in 2018. Financing needs to increase through improved cost-recovery. Although water manager of Brantas claimed that cost recovery is already achieved, the score of overall IWRM implementation in Indonesia is low in financing.

The low score is mainly caused by the absence of budget allocating at the subnational level or the budget allocated only partly covered planned investment. Other problems are budget allocations are made for only few elements or implementation at an early stage.

Effective revenue raising must also be applied. Revenue from water must be adequate for OM of water resources management so the programme planned can be executed. Beside revenue from water, payment for environmental services (PES) can also be initiated that contributes to natural resources conservation and compensation.

PJT 1 as water manager of Brantas River Basin is given authority to collect, receive, and utilize BJPSDA. it will be used to carry out the task of water resources management.

Operational activities of PJT 1 is founded from business and non-business activities. BJPSDA is one of funding from business activities. Other fundings come from non-business activities, such as tourism, construction service, equipment rent, etc.

PES scheme has been initiated since 2004 with implementation on three micro-sites of Brantas catchment area. Eventhough the pilot project has succeed, the significant concerns remained about the potential to scale up at watershed scale. In 2012, it was confirmed that regulation of PES at Brantas River Basin had failed to pass parliament and the scheme had faded off[17].

Integrated water resources management and water sensitive city concept have the same vision. They aim for sustainable living with adaptive policies and practices against challenges such as climate change, population growth, and environmental quality degradatian. The other similarity between the concepts is water management aspect.

Water is basic need for human living. Cities located near water resources are usually more prosperous than the one without. Modern concept of water resources management assumes that water is every human right. Even cities without water resources must be supplied by safe drinking water.

Surabaya is located in the downstream of Brantas River Basin. It means that Surabaya gets 'leftover' flow and water with accumulated pollution. However, in the modern concept, Surabaya has the right to be supplied by adequate and clear water.

Water availability in Surabaya is determined by continuous water recharge along the basin, efficiency in water allocation, and water quality management. Although implementation of IWRM is not complete yet, it can be achieved as long as there is adoption of effective water management.

Effective water management needs to be applied not only on water supply, but also water demand. High water demand gives pressure to water resources. Lowering the demand means decreasing the pressure. When pressure decreases, so is the risk.

Lowering water demand is everyone responsibility. Not only government, but also community. They need to understand the consequences of overconsumption of water resources. With this approach, community can lessen the burden of water manager and participate in water resources management.

Community participation is good point on water resources management in Indonesia, specially Brantas River Basin. It can act as source of information on planning, public supervisor on managing, and partner in maintaining. With so many ideas, it can lead management to be more sustainable and effective.

IV. CONCLUSION

Management pattern of Brantas River Basin corresponds with the principle of IWRM, except the mitigation of climate change. Climate change is the real challenge in water resources management that hasn't yet to be addressed by Brantas River Basin management. It changes some environmental aspects that induced great risk on sustainability, such as inability of reservoir to store water, damage on the water recharge area, high water consumption.

With the location in the downstream, the water availability in Surabaya River depends on the good water management of Brantas River Basin. It includes continuous water recharge along the basin, efficiency in water allocation, and water quality management.

Important factor in ensuring water availability is adoption of effective water management. Eventhough the implementation of IWRM is not complete yet, it can be achieved by making water supply and demand effective.

Lowering water demand is everyone responsibility, not only government. Community needs to understand the consequences of overconsumption of water resurces so they can lessen the burden of water manager and participate in water resources management. If community along river basin participates in lowering water demand, then water availability on the downstream, specially Surabaya, can be ensured.

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