Sustainable water provision in Tarakan City

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Abstract. Clean water provision is the sixth goal of SDGs, in which all countries are struggling to achieve those goals. Indonesia is archipelagic where only 12.38% or around 2,342 islands are inhabited by a total of 17,504 islands. Clean water provision for all inhabited islands, particularly for small islands, have been a significant issue for Government of Indonesia. Availability of fresh water, ground and surface, in a small island is often critical since the island is surrounded by the sea. Hydrological process in providing annual regional fresh water is relatively stagnant. Tarakan City is an island city, located at north-east of the mainland of Kalimantan. Water provision planning is important to close the gap between the supply and demand. The latest local statistics data of population in Tarakan (2015) was 227,200 people and therefore the estimated maximum demand of fresh water was 74,158,080 liters per day or 838.3 liters/second. The capacity of Local State Own Water Enterprise was only 400 liters/second, less than half of the demand. Strategies that can be taken, apart of the efforts to maximize efficient use to save water, are to minimize storm water run-offs, promote better land use planning, and strictly preserve watershed regions to have at least 30% green area.

1. Introduction

Fresh and drinking water is one of the most important goal of global sustainable development because water is the basic need of human life. The availability of water will guarantee the life of all living creatures. It is very important to meet between the need, which is constantly increasing, and the availability, which is relatively constant or even tends to decrease due to changes in hydrological functions within the watersheds and global climate changes. Water is also a factor that determines the level of prosperity of the people in a nation.

Water resources in Indonesia was initially used for agriculture, but nowadays due to changes in economic activities and population growth, the allocation of fresh water resources is shifting from agricultural purposes. In many regions of the country, water scarcity is already occurred in dry season [2]. Fresh water crises is often found in small islands in Indonesia because of limited underground freshwater reservoirs, since the small island is surrounded by sea/salty water, then, the degree of salt water permeation against fresh water is high. The intensity of rain, regionally on an annual scale is relatively constant since the hydrological cycle in the region does not change rainfall level significantly. In this circulation process, water in-flow (input) cannot be modified but the out-flow can. Surface flow can be modified by increasing water infiltration (aquifer recharge), rain harvesting, and holding surface water in dams for many purposes. This water balance process is important to all stakeholders to understand, particularly those are in charge in the decision making process. Water balance should be a central element in awareness raising campaign in such islands. It is important to
strengthen cross-sectoral (water supply, irrigation, drainage, hydropower, flood control, and environment) roles of water institutions, i.e., the main water subsectors that often do not work synergistically [3].

Hydrological cycle is important to wisely managed to provide fresh water need in the island. The hydrological cycle is the perpetual circulation and exchange of water between different reservoirs: atmosphere, land surface, soils, groundwater systems, and the oceans [4]. In the cycle of hydrology, solar energy and other hot climate factors cause the process of evaporation on the surface of vegetation and soil, seas, rivers, or lakes. Water vapor as a result of the evaporation process will be carried away by wind across mountainous or flat land, and some of the water vapor will condense and fall as rainwater. Society and ecosystems critically depend on fresh water circulation which makes up only little part of total amount of water.

In hydrological planning a water balance calculation can help to explain the flow of water entering and exiting on one system. In calculating the water balance there are actually parameters that are difficult to measure in the field, especially those related to parameters in groundwater, but simplification is often done in accordance with local field conditions. Water balance calculation is often carried out to:

- estimate the amount of water available for drinking or irrigation [5];
- estimate water recharge [6];
- show spatial and temporal patterns in groundwater and surface water use [7].

Tarakan is a small island city in the northern part of North Kalimantan Province. The development of Tarakan City, which has a goal to improve the welfare of the community, has used local natural resources. Fresh water is a basic natural resource which is needed in people’s activities in Tarakan City. Well management of water resources in the City of Tarakan is absolutely necessary for sustainable development in the city. But often the exploitation of natural resources which lack consideration of water balance and environmental carrying capacity results in a deterioration in the quality of the environment and inadequate fresh water supply. Availability of fresh water in this small island is accommodated by 18 watersheds, as shown in figure 1, formed by the topography of the island. The sources of fresh water are mainly from surface water, water hauling from mainland Kalimantan and groundwater extraction. Desalination, which requires much cost in installation and operation has not been carried out in Tarakan City. Rain water harvesting, which is low cost and more sustainable [8] has not also been implemented due to lack of promotion and guidance from local authorities.

Based on these grounds, this study calculates fresh water demand of current population with their activities and formulates strategies for 18 watersheds within the small island (City of Tarakan).

2. Research methods

Based on the objectives of the research, the paper evaluates the need of fresh water for urban population in the Island of Tarakan City. The evaluation also estimates the availability of fresh water to fulfill urban activities, domestic and non-domestic demand. The estimation showed the gap between the demand and supply and propose strategies for fresh water management in the island city. Secondary data were obtained from relevant sources, i.e. agencies in the respective fields, while primary data was collected from interview with the community and local authority related to problems and quality of fresh water provision in Tarakan Island.

Water balance analysis was used to estimate the amount of available water (input) and the water output. The scope of the water input was limited from water service data provided by Local State-Owned Water Enterprises (PDAM) of Tarakan City. The water output was estimated by calculating water demand of the population in the city which consisted of: a) domestic water needs, the domestic needs was calculated from the population multiplied by average per capita water needs; and b) non-domestic water needs, consisted from water demands for public facilities, offices, commercials, and industries; and c) estimated needs for fire protection and water loss. The needs for non-domestic uses are calculated from the average percentage of the demand of each non domestic use compared to the
need of domestic use. Water needs for irrigation (agriculture) were not included in the analysis of this paper.

Projections of population used the most optimal population growth model, namely exponential regression assuming that population growth was multiplied by itself. The equation is:

\[ Y_i = \beta \cdot e^{\beta X_i} \cdot e_i, \quad i=1,2,...,n \]

where: \( Y \): dependent variable for observation \( i \); \( X \): independent variable; \( \beta \): regression model parameter; \( e \): 2.71828; \( e_i \): residual (independent variable).

Land suitability analysis was conducted by superimposing six units of land capability, i.e., morphology; topography; ground water availability; disaster vulnerability; drainage; and erosion. Based on this analysis, current land uses were evaluated and resulted in some land use scenarios that more ‘water friendly’.

3. Results and discussion

3.1. Overview of Tarakan City

Tarakan is a city located on an island and its geographical location is 3°14′30″ North Latitude – 3°26′37″ North Latitude and 117°30′50″ East Longitude – 117°40′12″ East Longitude. The island is at 0 m - 100 m above sea level. Tarakan City covers a land area of 250.80 sq.km (38.15%) and sea area of 406.53 sq.km (61.85%). The administrative area of the City of Tarakan is divided into four sub-districts, namely North Tarakan, West Tarakan, East Tarakan and Central Tarakan sub-districts. North Tarakan sub-district is the largest sub-district among other sub-districts in Tarakan City with an area of 109.36 sq.km or around 43.6% of the total area of Tarakan City. West Tarakan sub-district is the smallest sub-district. The area of West Tarakan subdistrict is only 27.89 sq.km or 11.12% of Tarakan City (figure 2).

![Figure 1. 18 Watersheds in Tarakan [9]](image1)

![Figure 2. Four Sub-districts in Tarakan.](image2)

3.2. Fresh/clean water supply

Clean water supply in Tarakan City has been provided by Local State-Own Drinking Water Enterprise (PDAM) since 1980. The main source of clean water managed by the company, through a complete water treatment system, is from surface water, i.e., taken from rivers and three water mini dams [10]. Currently the local government builds two new mini water dams to increase the coverage of clean water service. The coverage of current clean water services by PDAM so far is only 52% of the total...
households in Tarakan City. The rest of the population uses rainwater storage (27.3%) and dig well (3.5%) [11]. The production capacity of the local water company is about 400 liters/second. With the completion of new mini dams, it is hoped that, at optimum water discharge during rainy season, the production may reach 900 liters/second. However, the main problem is that the water discharge supplied by local rivers is often very low, therefore existing effective capacity is only 302.42 liters/second, while the need is about 800 liters/second.

### 3.3. Water demand

Water demand of the population can be grouped into domestic and non-domestic uses of water. Domestic needs are the required amount of water for daily activities at home. Based on the average need of fresh water for domestic activities in Tarakan, daily water demand for domestic uses was 130 liters/person. With a population of 227,200 in 2015, the water demand for domestic uses was 29,536,000 liters/day or 341.85 liters/second. The need for non-domestic uses were for public facilities, offices, commercials, and industries. The water demand for public facilities and offices in Tarakan was estimated 30% of domestic use, while the need for commercials was 20% and for industries was 10%. These demands may vary depends on the character of the city. The estimated total of non-domestic uses was 17,721,600 liters/day or 205.11 liters/second. Besides these needs, it is necessary to reserve water to anticipate fire hazards and water loss/leakage (estimated about 10% of domestic need for each). Therefore, the need for this contingency water was 5,907,200 liters/day or 68.37 liters/second. The total demand was therefore 29,536,000+17,721,600+5,907,200 = 53,164,800 liters/day or 615.33 liters/second. It shows that current demand exceeds the capacity of piped water distribution in the island. The effective capacity was 302.42 / 615.33 = 49.15%.

Based on the calculation above, the demand of water in the 2025, grouped into each watershed area, is described in the following table (table 1).

#### Table 1. Water demand in 2025 for each watershed in Tarakan.

| Location (watersheds) | Population | Domestic (D) | Non Domestic (ND) | Contingency Fire (hydrants + leakage) | Total demand |
|-----------------------|------------|--------------|-------------------|---------------------------------------|--------------|
|                       |            | (130 liters × population) | (60% × D) | (20% × D) | Liters/day | Liters/second |
| Baru                  | 8,673      | 1,127,474    | 676,484           | 225,495                             | 2,029,453   | 23          |
| Belalung              | 16,523     | 2,147,958    | 1,288,775         | 429,592                             | 3,866,324   | 45          |
| Bengawan              | 19,599     | 2,547,828    | 1,528,697         | 509,566                             | 4,586,090   | 53          |
| Binalatung            | 19,732     | 2,565,168    | 1,539,101         | 513,034                             | 4,617,303   | 53          |
| Bunyu                 | 863        | 112,193      | 67,316            | 22,439                              | 201,947     | 2           |
| Karanganyar           | 12,174     | 1,582,660    | 949,596           | 316,532                             | 2,848,788   | 33          |
| Karungan              | 5,428      | 705,582      | 423,349           | 141,116                             | 1,270,047   | 15          |
| Keterangar            | 32,404     | 4,212,508    | 2,527,505         | 842,502                             | 7,582,514   | 88          |
| Kuli                  | 4,687      | 609,342      | 365,605           | 121,868                             | 1,096,816   | 13          |
| Mambulua              | 5,289      | 687,548      | 412,529           | 137,510                             | 1,237,586   | 14          |
| Mangantal             | 15,566     | 1,503,588    | 902,153           | 300,718                             | 2,706,458   | 31          |
| Mankepio              | 20,120     | 2,615,629    | 1,569,377         | 523,126                             | 4,708,132   | 54          |
| Mantogog              | 2,996      | 298,429      | 179,057           | 59,686                              | 537,171     | 6           |
| Pamusian              | 28,472     | 3,701,312    | 2,220,787         | 740,262                             | 6,662,362   | 77          |
| Persemaian            | 27,865     | 3,622,413    | 2,173,448         | 724,483                             | 6,520,344   | 75          |
| Semu                 | 16,496     | 2,144,490    | 1,286,694         | 428,898                             | 3,860,081   | 45          |
| Sesapin               | 32,328     | 4,202,624    | 2,521,574         | 840,525                             | 7,564,723   | 88          |
| Simaya                | 7,973      | 1,036,437    | 621,862           | 207,287                             | 1,865,586   | 22          |
| **Total**             | **272,486**| **35,423,180**| **21,253,908**    | **7,084,636**                       | **63,761,724**| **738** |

Without any substantial strategy, the ratio between the supply capacity and the demand, using current maximum capacity, will be 400/738 = 54%, and the effective capacity will be only 302.42
/738 = 40.98%. During the rainy season, the maximum discharge, when the other two new mini dams are operated, is 900 liters/second then the water supply by the local water company will be enough, but often the water discharge at the 18 rivers in the island is lower than expected, particularly during dry season from April to October.

3.4. Land use strategy

Water Traditional rain harvesting has been practiced by 27.3% population, however this cannot cover their need during dry season. Efforts to maintain better water discharge for the 18 rivers is another possible strategy to tackle water shortage in the island. Optimizing water recharge can be obtained from better land use strategy. Better land use will keep water discharge of the surface water stable and support more ground water reserves. The land use strategy is not based on administrative areas (sub districts) but based on the boundary of the watershed.

To take an example, Baru watershed covers an area of 6,798 sq.km with estimated population in 2025 of 8,673 people. The highest rainfall in the island is in December, i.e., 24,467 mm/day, and the longest rainfall in a day is 7 hours. Rainfall intensity in the island is calculated using the following formula:

\[ I = \frac{24 \times 467}{24 \times \left(\frac{24}{7}\right)^{2/3}} \]

\[ I = 7.990 \text{ mm/hour} \]

Peak discharge (Q) is calculated from rational runoff coefficient (C) * drainage area (A) * rainfall intensity (I). Based on this formula, the character of the land in Baru watershed can be described in the following table (table 2).

| No | Land use                  | Runoff coefficient (C) | Area km² (A) | Percentage (%) | I (mm/hour) | Q=CAI (m³/second) |
|----|---------------------------|------------------------|--------------|----------------|-------------|-------------------|
| 1  | Forest                    | 0.15                   | 2.030        | 29.85          | 7.99        | 0.676             |
| 2  | Traditional settlement    | 0.40                   | 0.994        | 14.62          | 7.99        | 0.882             |
| 3  | Housing Real Estate       | 0.68                   | 1.617        | 23.79          | 7.99        | 2.441             |
| 4  | Coastal area              | 0.70                   | 0.949        | 13.96          | 7.99        | 1.474             |
| 5  | Commercial area           | 0.75                   | 1.198        | 17.62          | 7.99        | 1.994             |
| 6  | Market                    | 0.65                   | 0.010        | 0.15           | 7.99        | 0.015             |
|    | **Total**                 |                        | **6,798**    | **100**        |             |                   |

**Table 2.** Land use and discharge character of Baru Watershed.

![Figure 3. Land uses in Baru Watershed.](image)

Land use strategy may improve water recharge since it will manipulate land cover which then
changes percentage of area with lower runoff coefficient and this is hoped to increase water table and maintain water discharge on the rivers during dry season. The existing land use on Baru watershed is shown in figure 3. It is important to preserve green areas (urban forest and other green open spaces) and impose water recharge related regulation on urban built up areas. Forest, river’s buffer zone and green spaces must be preserved. In each watershed, areas that can absorb rainfall and slow down rain water runoff should be at least 30% of total area. New development, particularly housing and commercials must provide ground water recharge installations (water injection well) and rain-harvesting equipment. Compact urban environment which allows more green space is highly recommended.

Other scenarios for Baru watershed, based on table 2 and land suitability analysis (superimposing of six units of land capability) are to enlarge urban forest by 0.049 sq.km and to impose high urban development control so that the built-up area does not expand. In fill development is encouraged. Similar scenarios were conducted for other 17 watersheds in Tarakan. The largest watershed in Tarakan is Keterangan watershed. It covers an area of 33.617 sq.km with the length of the river is 36.392 km. The land suitability analysis found that there were nonconformity uses in four land uses: 0.12% of the golf course area; 0.004% of mangrove area; 1.56% of residentials; and 2.27% of tourism area. In accordance with the analysis, those nonconformity uses should converted to forest uses (production / cultivation forest land).

4. Conclusion
Current capacity of the local water company to cater population in Tarakan is effectively 302.42 liters/second, while the need of fresh water is 341.85 liters/second for domestic uses + 273.48 liters/second for non-domestic uses and contingencies, then the capacity of water supply is about 49.15% of the total demand. Without any substantial development, the capacity in 2025 will be 40.98%. Construction of water dams may increase the supply, but the discharge of those dams is very low during dry season. Land use policies and high controlled urban development are necessary to maintain water discharge of water supply in Tarakan. Land use scenario should be particularly planned for each watershed of 18 watersheds in Tarakan. Land capability analysis shows that some uses should be converted to land use that allow more absorption of rainwater to the ground. Compact urban form and development are significantly recommended.

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