International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 2, Issue 7 (July 2013), PP.14-22
www.irjes.com

Water Resources Management Strategies On Non-Groundwater Basin (Non-Cat) Small Islands (Study Case: Batam Island) Happy Mulya Nim L5a 007 012

Promoter: Prof. Ir. Jutata Hadihardadja
Co. Promoter: Dr. Ir. Robert Kodoatie, Msc
Doctoral Student Department of Civil Engineering of Diponegoro University, Semarang, Indonesia.

ABSTRACT:- *Indonesia is the largest archipelago in the world, which insist of ± 17.508 islands. Based on boundary of the islads' area, where small island (≤ 2.000 km^2), very small island (≤ 2.000 km^2 and ≤ 2.000 km^2) (Hehanusa and Bhakti, 2005), therefore 99,83% islands in Indonesia are small islands, very small islands, and very-very small islands.*
Small Islands' problem which is surrounded by the ocean is the limitation of water resourcess wether is runoff or groundwater (Falkland, 1991) and of the serious threat from the small islands' environment degradation is the depletation of water availability or water crysis.
Batam Island, as a case study is one of the Non-CAT small island. Water balance analisis are conducted by using modified Mock method calculation, while to fulfill water availability and the continuity of water resources in Non-CAT small island, harmony and integrity of water resources, water spatial and island spatial management are conducted (UU No.27 Year 2007, UU No. 7 Year 2004 and UU No. 26 Year 2007 with modification by Kodoatie and Syarief, 2007 and Kodoatie, 2008)

Keywords*: Non-CAT Small Islands – water crysis – Modified Mock – Water Resources Management Strategies.*

I. PRELIMINARY

1.1 Background

Indonesia is the biggest archipelago in the world, consist of ±17.508 big or small islands, around 6.000 islands are inhabited (http:id.wikipedia.org/wiki/daftar_pulau_di_Indonesia, download September 2013). The main/big islands are Sumatera, Java, Borneo, Sulawesi and Papua, whereas other islands are small islands, very small islands, and very-very small islands with its area boundary consecutively are 2.000 km², 200 km² and 20 km² (Hehanussa and Bakti, 2005), or islands with and area less than 2.000 km² which has a width less than 10 km (UNESCO,1991; UU No 7 Year 2004; UU No 27 Year 2007).

According to Djuwansah et al (2005) in Hehanussa and Bakti (2005), limitation of water resourcces in small islands are caused by the low rainfall and the narrow of the water catchment area, therefore the availability of water is relative short if compared with the river flowing in continent or big islands.

Small islands are characterized by coastal areas (alluvial plain) which is relative narrow, and hills and highlands with a steep to very steep topography. With a small plain caused the condition of the topography to influences on the river or nature drainage of the hydrology system, which is surface runoff wasted to the ocean and only small portion are infiltrate to the ground (Laurentia, 2009; Kodoatie and Suripin, 2000).

Along with the rapid expansion of the new area in the autonomy, therefore concern to the role of the area and small islands as the center of the development because it is rich in natural resources and biodiversity are also increasing (Dahl, 1998; Bengen and Retraubun, 2006). Consequences is that development in new area effecting to the change of the spatial planning. Therefore, if the speed of the changes is not controlled and exceed the limit of the islands ability to accept changes, then degradation of environment will occur. One of the serious threat from the environment degradation in small islands is the depletion of water availability or water crysis.

A lot of research about development and management of water resourcess in small islands have been done. However, until now there is no integrative research or reference which are agreed to the nation as a basic policy to determine a water resources management strategies on small islands, especially Non-CAT small islands, thus leading the effort to small islands management is not optimal yet. Beside that, spesifically research about Non-CAT small islands have not been done. CAT area has a confined and unconfined aquifer, also a groundwater flow whereas becoming a base flow when it reaches river. On the contrary, Non-CAT area, not having a groundwater flow, therefore does not have a baseflow. Because of that, CAT and Non-CAT area has a

significant influence to the fluvial system (Kodoatie, 2012). Based on KepPres No 26 Year 2011 and Indonesian's Islands CAT map, it is know that Non-CAT occupies almost all of the small islands.
Therefore, journal with a title of "Water Resources Management Strategies On Non-Groundwater Basin (Non-Cat) Small Islands" is considered important, because it can be one of the thoughts donation to the small islands water resources management, which has a total number of 99,83% from the total number of Islands in Indonesia.

1.2 Study Case Location

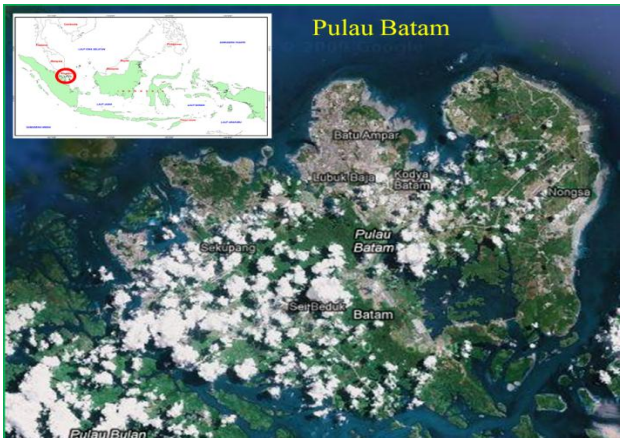


Figure 1 Map of Indonesia and the location of Batam Island

According to the Batam City Regulation No 2Year 2005 about the Expansion Changes and Formation of District and Village, the number of district in Batam City is 9 District with 44 Vilages. Batam has an area of 398,80 km2, according to the RTRW Batam Islands compiled on the year 2010, which is Draft Government Regulation of the Indonesian Republic Year 2010 about Batam, Bintan and Karimun Draft Spatial Planning . Batam Island is divided into conservation and cultivation area as big as 31% and 69%.

II. CIVIL ENGINEERING ASPECT

By analising water resources on Non-CAT small islands, present and prediction of the incoming future of water balance are achieved, therefore, develompent from civil engineering aspect can be made to overcome or minimize the problems now or in the future.

1.3 Water availability in CAT and Non-CAT Area

In CAT area, water flows inside the shallow ground (soil water zone) nor ground underneath (groundwater. In groundwater zone, water flows in the aquifer wether confined or unconfined aquifer. In the discharge area of the unconfined aquifer, where spring comes in one groundwater formation system on some condition may fused with soil zone. In other words, in some topographic condition, soil water may fused with groundwater (Kodoatie, 2012).

Groundwater zone is call groundwater basin (CAT). Water also flows in Non-CAT area wether in groundwater or surface water flow. Inside the ground, Non-CAT area, water flows onli in soil water zone because there is no groundwater zone. In the surface of the CAT and Non-CAT area, water flow s a runoff in the watershed and river systerm (Kodoatie, 2012).

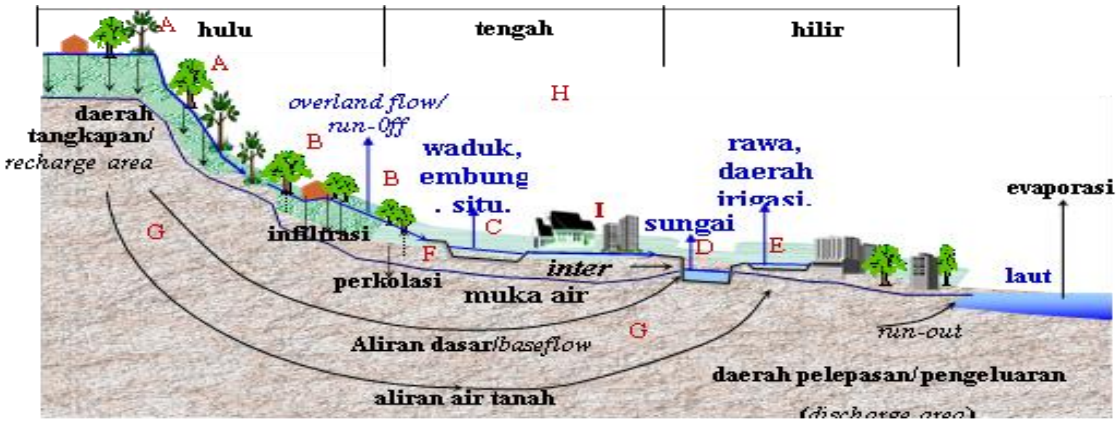


Figure 2 Hydrological cycle in CAT area (Kodoatie, 2012)

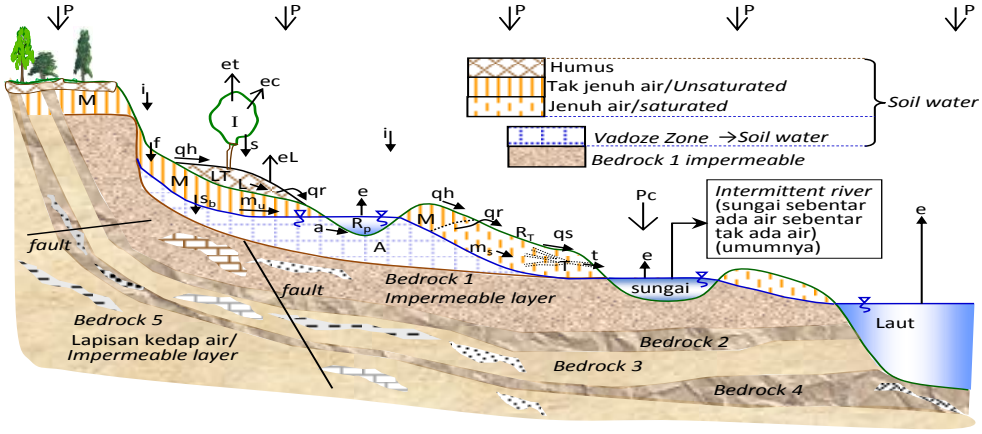


Figure 3 Hydrological cycle in Non-CAT area (Kodoatie, 2012)

Generally, the existance of groundwater are divided into two types, which is water on vadose zone and phreatic zone. In vadose zone, types of water are divided into three: soil water, intermediate vadose water, and capillare water. In phreatic zone or saturated zone, groundwater existed. These division of the zone can be seen on figure 4, which shows the water availability of ground water and soil water in a piece of sliced earth.

Most of the soil water are used for agriculture needs. These area are also a water resources for plants. Water will disappear from the zone from transpiration from the plants, evaporation and percolation if it gets saturated. The depth of the zone is about 3 – 30 ft (0,91 – 9,1 meter), depends on the type of the ground and vegetation (Driscoll, 1987)

In these zone, water occurs by the movements of the molecules, capillarity force which oppose gravity. Molecule movements tend to fill groundwater on the surface layer from each of the ground particles. When the capacity of the small space around ground particles are full, therefore water will percolate caused by the gravitation (Driscoll, 1987)

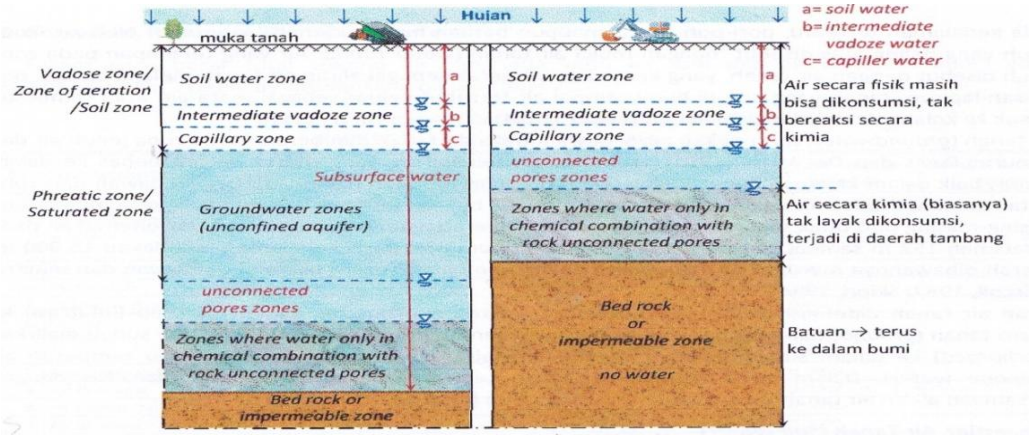
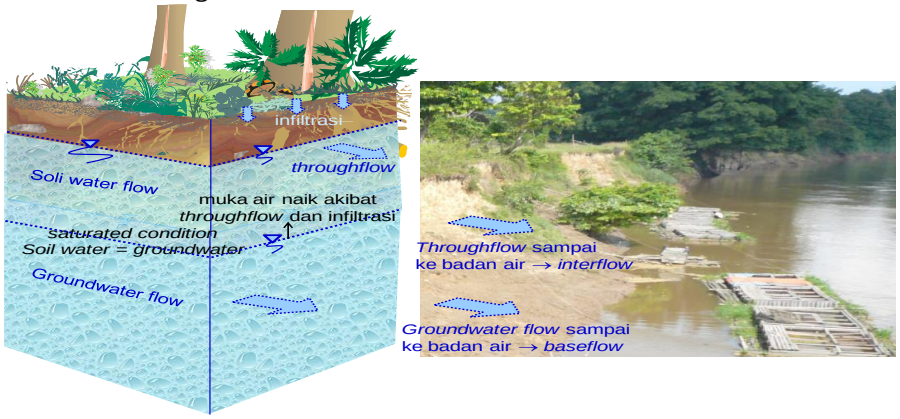
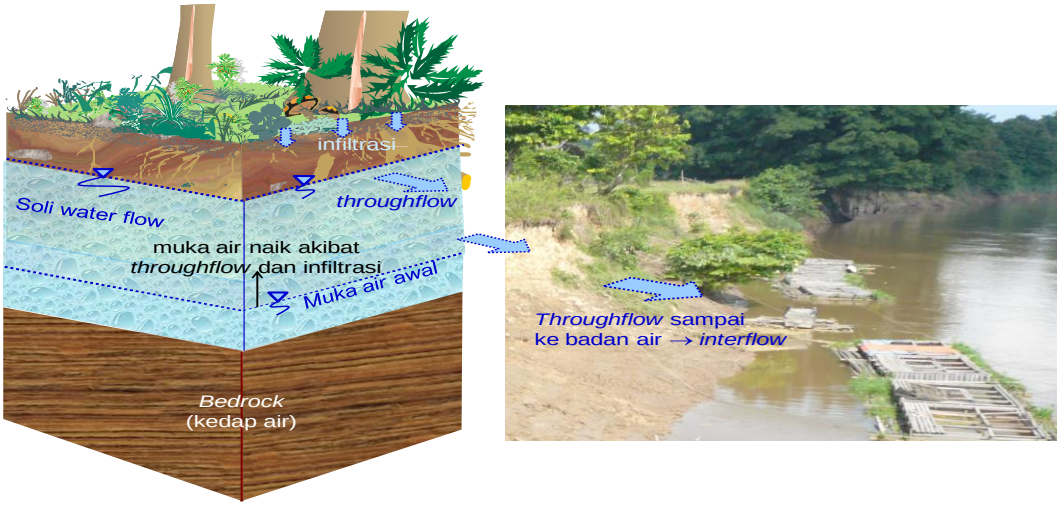


Figure 4 Cross section of CAT and Non-CAT area



a. illustration of throughflow, interflow and groundwaterflow in CAT area.



b. illustration of throughflow and interflow in Non-CAT area.

Figure 5 Illustration of throughflow and interflow in Non-CAT area and addition of groundwaterflow in CAT area (Kodoatie, 2012)

In CAT area throughflow, interflow and groundwater flow occur, while in Non-CAT area only throughflow and interflow occur, because layer after soil water zone is rock layer.

1.4 Modified Mock Calculation Methode

Flow chart of the mock method is as follows.

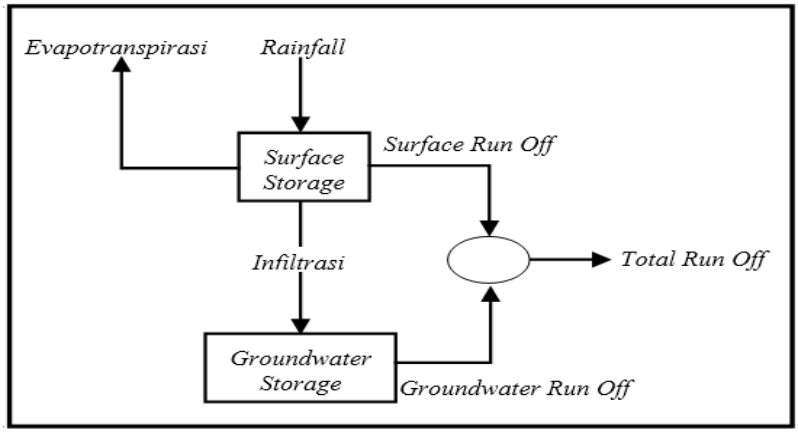


Figure 6 Flow chart of Mock method, 1973 (Bappenas, 2006)

Based on the hydrological cycle in CAT and Non-CAT, shown as above, therefore the calculation of water availability of Mock Method, 1973, needs to be modified, with the following calculation:

- Calibration to the mock parameter which will be used so that the discharge calculation may represent the actual condition in the fields (compared to the discharge from the hydrometric measurments)
- On the calculation of runoff discharge using mock method, monthly discharge data are used to calibrate.

Table 1 Modified calculation of Mock Method in CAT and Non-CAT area

NON CAT AREA	CAT AREA
Actual Evapotranspiration	***Actual Evapotranspiration***
ΔE / Ep = (m / 20) x (18 – n)	ΔE / Ep = (m / 20) x (18 – n)
ΔE = (m / 20) x (18 – n) x Ep	ΔE = (m / 20) x (18 – n) x Ep
Eta = Ep – ΔE	Eta = Ep – ΔE
Water Surplus	***Water Surplus***
SMS = ISMS + (P – Eta)	SMS = ISMS + (P – Eta)
WS = (P – Eta) + SS	WS = (P – Eta) + SS
Soilwater Storage	***Soilwater Storage***
Infiltrasi (I) = WS x if	Infiltrasi (I) = WS x if
V (n) = k.V (n-1) + 0,5.(1 + k). I (n)	V (n) = k.V (n-1) + 0,5.(1 + k). I (n)
ΔVn = V (n) – V (n-1)	ΔVn = V (n) – V (n-1)
Interflow = I – ΔV (n)	*Interflow* = I – ΔV (n)
	Ground Water Storage

NON CAT AREA	CAT AREA
Water Available	Perkolasi (P)= WS x if
DRO = WS – I	V (n) = k.V (n-1) + 0,5.(1 + k). I (n)
WA = *Interflow* + DRO	ΔVn = V (n) – V (n-1)
	Baseflow = P – ΔV (n)
	Water Available
	DRO = WS – P
	WA = *Interflow* + *Baseflow*+ DRO

Where:

ΔE = Potential and actual evapotranspiration difference

Ep = Potential evapotranspiration

Eta = Actual evapotranspiration

m = Percentage of uncoverd vegetation

ISMS = initial soil moisture storage (constitute of soil moisture capacity (SMC) previous month)

P – Eta = Precipitation which experience evapotranspiration

There are two condition to determine SMC

1. SMC = 200 mm/month, if P – Eta ≥ 0
2. SMC = SMC previous month + (P – Eta), if P – Eta < 0

V (n) = Groundwater volume n month

V (n-1) = Groundwater volume (n-1) month

K = Groundwaterflow recesion factor (0,4 – 0,7)

DRO = Direct Run Off

WS = Water surplus

I = Infiltration

P = Percolation

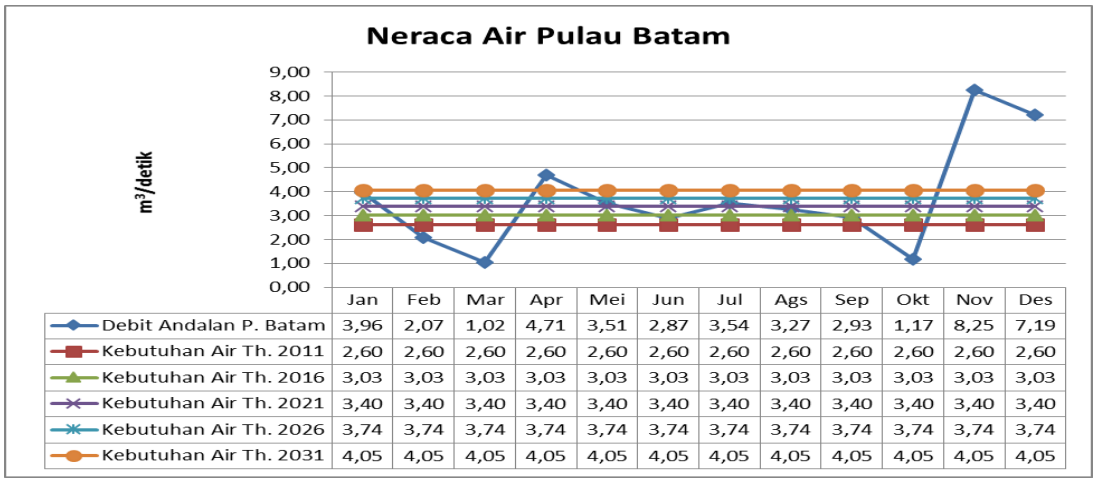
SS = Soil Storage

WS = Water surplus

If = Infiltration Coefficient

1.5 Water Balance

Water balance is a comparison of water availability and needs in some area to observe the water resources capacity. Based on this water balance, it can be know if an area experience surplus or deficit of water, therefore with this approach can give strategies on what action to take to manage water resources. Figure below shows water balance in Batam Island.



	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
Debit Andalan P. Batam	3,96	2,07	1,02	4,71	3,51	2,87	3,54	3,27	2,93	1,17	8,25	7,19
Kebutuhan Air Th. 2011	2,60	2,60	2,60	2,60	2,60	2,60	2,60	2,60	2,60	2,60	2,60	2,60
Kebutuhan Air Th. 2016	3,03	3,03	3,03	3,03	3,03	3,03	3,03	3,03	3,03	3,03	3,03	3,03
Kebutuhan Air Th. 2021	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40	3,40
Kebutuhan Air Th. 2026	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74
Kebutuhan Air Th. 2031	4,05	4,05	4,05	4,05	4,05	4,05	4,05	4,05	4,05	4,05	4,05	4,05

Figure 7 Batam Island water balance

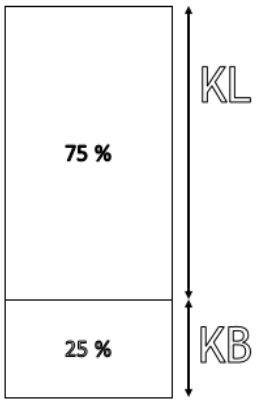
III. SPATIAL ANALISIS

Spatial is a container which includes land, ocean and air spatial, including spatial inside the earth as one regian, place where human and organism live, do activity, and maintain the continuity of living (UU No. 26 Year 2007).

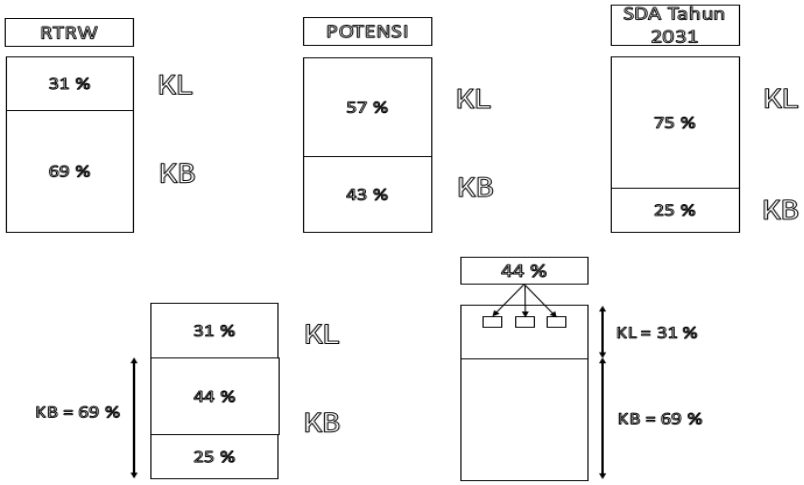
1.6 SPATIAL PATTERN

Spatial pattern is a distribution for spatial in an island wich includes allotment for conservation and cultiation function spatial (UU No. 26 Year 2007). Spatial planning transformation which overlay with RTRW of Batam Island with water availability according to topography and water needs prediction until 2031.

- Tinggi ketersediaan rata-rata per tahun = 750 mm = 0,75 m
- Luas DAS Pulau Batam = 227,64 km^2 = 227.640.000 m^2
- Volume Ketersediaan Air Pulau Batam= 0,75 x 227.640.000
  = 170.730.000 m^3
- Kebutuhan Air Pulau Batam (Tahun 2031) = 4,05 m^3/detik
- Volume Kebutuhan Air di Pulau Batam = 4,05 x 365 x 24 x 3600
  = 127.720.800 m^3
- Luasan Kebutuhan Air Pulau Batam = 127.720.800 m^3 / 0,75 m
  = 170.294.400 m^2



From the result of the analisis, description below are obtained.



As mentioned above, spatial planning in Batam Island, according to RTRW and according to water availability is not yet don. Therefore, solution are needed to obtain ideal water balance. The solution is to add a water storage in the conservation area.

After applying overlay between spatial planning in Batam Island between RTRW and water availability, needs of area of water storage are obtained so that spatial planning in Batam Island may reach its ideal balance, which is 11 %.

Not all Non-CAT groundwater basin in Batam Island can be used for water availability volume. There are spots in Non-CAT groundwater basin which can be developed as a storage, according to the topography. These spots can be used as water storage, such as dams, weir, ponds etc.

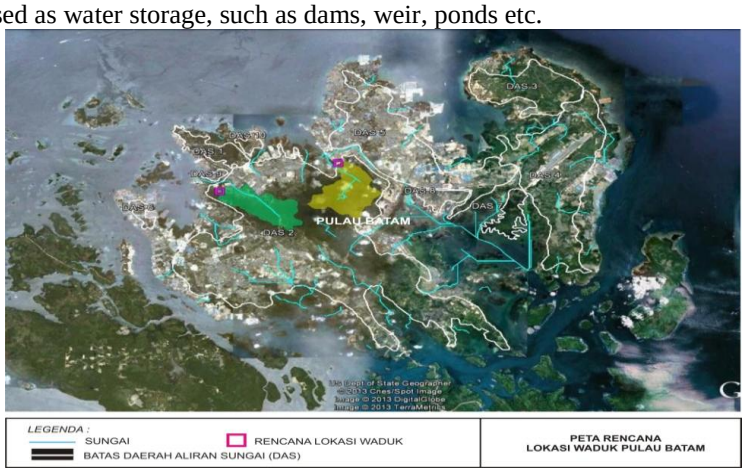


Figure 8 Alternative which can be used as water storage

Based on Batam's topography, there are 2 alternatives which can be used as water storage. With the reference of topography, conservation area in Batam are 42% and cultivation area are 58%.

Looking from RTRW, draft spatial pattern in Non-CAT Batam, conservation area has an area of 123,07 km2 or 31% and cultivation area has an area of 275,73 km2 or 69%. This matter does not match with the water availability. Water storage in conservation area are needed to harmonize between RTRW Batam area with water resources RTRW are 11%.

Spatial structure is an arrangement of settlement center and infrastructure web system functions as a supporting social economic activity which hierarchily has a functional relationship (UU No 26 Year 2007). However, this journal will not discuss about spatial structure, but about spatial pattern which is conservation and cultivation area in small island Non-CAT.

IV. WATER RESOURCES MANAGEMENT STRATEGIES ON NON-GROUNDWATER BASIN (NON-CAT) SMALL ISLANDS

Principally, water resources management on Non-CAT small islands is to unite water resources pattern and spatial planning.

1.7 Water Resources Management River Region Pattern

Principally, water resources management river region pattern is integration from surface water management, groundwater management, ocean water inland management, rainfall management, and other water resources such as river, swamp, irrigation etc. according to the definition of water on UU no 7 Year 2004 as internal integration along integration with other aspect such as environment, natural resources conservation, spatial planning, forestry and other as external integration.

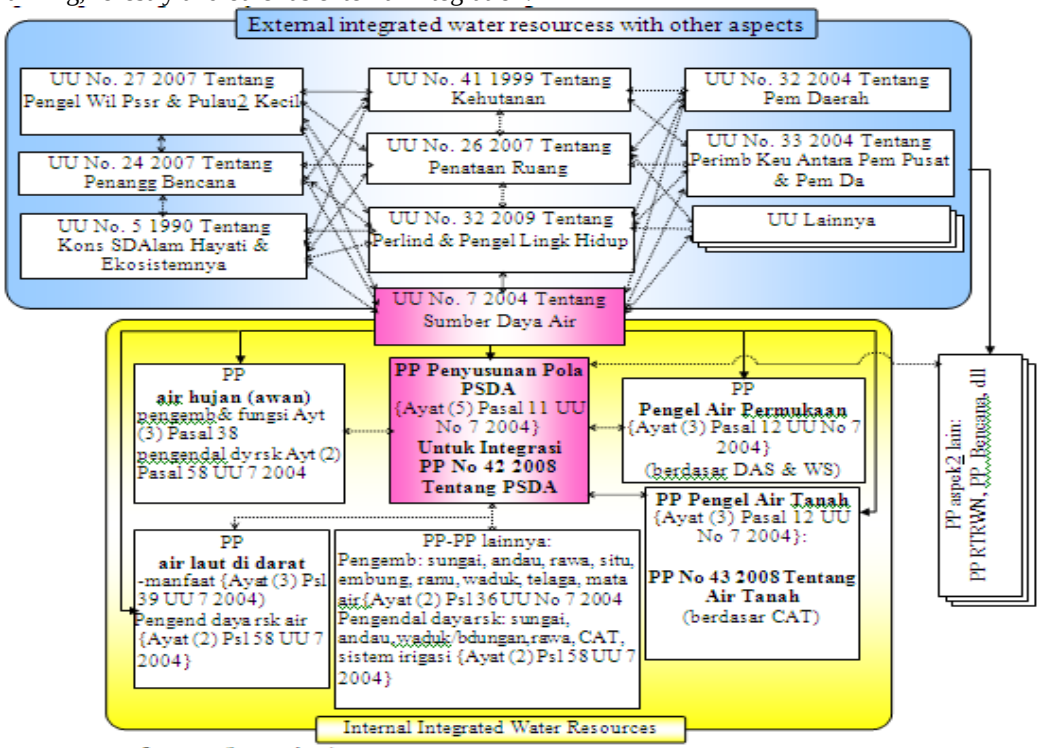


Figure 9 Integration between regulation of every aspect in internal and external with a reference of the regulation (UU No. 7 Year 2004; PP 42 Year 2007; PP 43 Year 2007; Kodoatie, 2008; Andaryanto, 2008)

1.8 Harmony and Integration of Management

Specific substantial require harmonization and integration of spatial planning and water resources management. Compare to the other natural resources, water has a specific and unique character which cause water to be special to maintain. On the other hand, needs of space wether in city or village are increasing because of the growth of the population. Relationship of increasing of the population, spatial planning and water resources management require harmonization and integration between spatial planning and water resource management along other aspect management.

As an example, river region (including watershed, CAT and Non-CAT) in water resources management must be transformed and equivalent with the Spatial Planning Administration. Therefore harmonious relationship

between spatial planning, water resources management, and groundwater management are achieved. Broadly, detailed relationship between aspect are below.

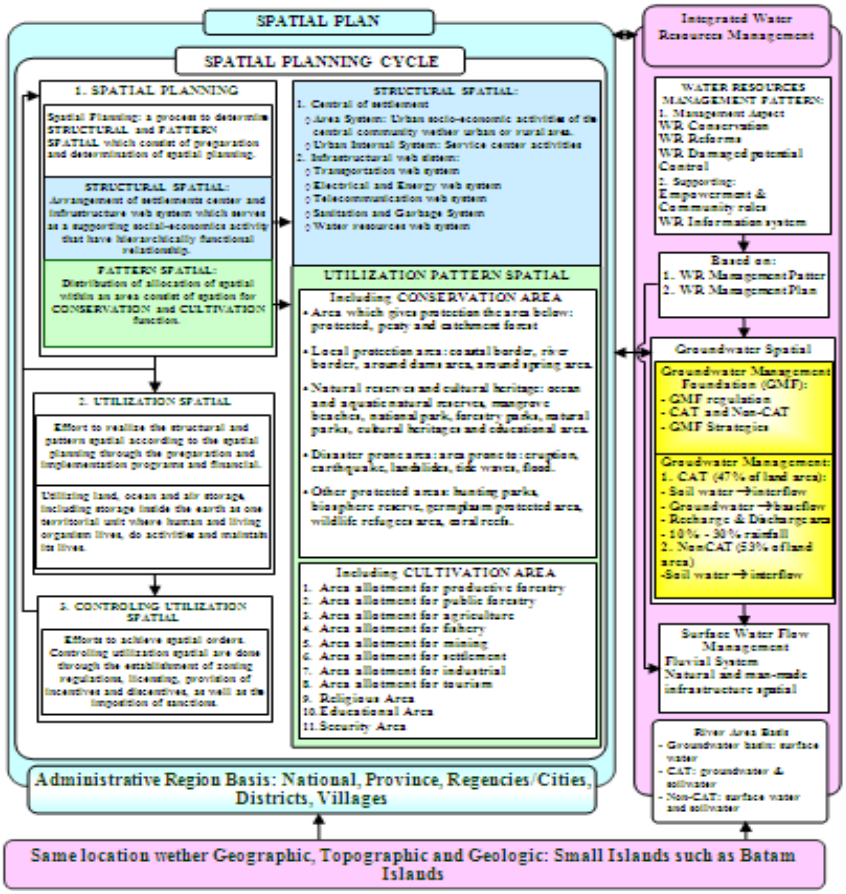


Figure 10 Water resources management, groundwater management and spatial planning harmonization (UU No. 26 Year 2007; UU No. 7 Year 2004 with modification by Kodoatie & Syarief, 2007 and Kodoatie, 2008)

V. CONCLUSION

Batam is a Non-CAT small island, area of the island is not the same as the are of watershed in the island with the relationship of the water availability calculation. There are some part from the watershed that are not reliable as a source of water availability, because the rainfall comes to th part of the watershed goes straight to the ocean. The condition of the topography is an important variable to analize the areal of the island, watershed area and water availability potential.

Based on the hydrological cycle in CAT and Non-CAT area, calculation method of water availability with mock method for Non-CAT and CAT area are different, therefore modification must be conducted. For Non-CAT mock method can be directly used, while for CAT mock method, modification must be done, which is addition of groundwaterflow where it will become baseflow. So, in conclusion, water availability in CAT area will always be bigger than water availability ini Non-CAT.

From the water balance analisys result, it can be concluded that Batam Island experience deficit in water on Februari, March and October. While in other months can fulfill even surplus of water in November and Desember.

In Non-CAT area, rivers are mostly intermittent rivers, therefore on dry season discharge measurement cannot be done, calibration from modified mock modeling calcualtion can only be done on rainy season.

Water resources management, especially on the geological spatial, however, the resulting output generally are not spatial, therefore in order to compare and merge with spatial planning, transformation water resources managemen to spatial must be done.

To fulfill the water needs and continuity of water resources in Batam Island, harmonization and integration water resources management, groundwater and Non-CAT small island spatial planning must be done, with a water resources management strategies on Non-CAT small islands, which is the development of water storage (ponds / weirs) and make an ideal spatial planning based on the water availability and needs.

REFERENCE

[1] Baand Perencanaan Pembangunan Nasional, 2006. Identification of Java Island Water Resources Management Problem. Water Resources Management on Resolving Drought and Flood Initiative Strategies. Book 2, Final Report.
[2] Bengen and Retraubun Alex, 2006. Revealing Reality and Urgency of Management based on Small Islands Eco-Socio System.
[3] Dahl, A. L, 1998. Small Island Environment Management UNEP Earthwatch. Geneva, Switzerland.
[4] Djuwansah, M.R., T.P.Sastramihardja, L.Hadi S., 2005. P. Ambon Water Resources Management: Lazirah Hitu Hydrogeology and Hydrochemistry review. LIPI Publisher.
[5] DKP (Marine and Fishery Department), 2001. General Guidelines on Continuity and Community-Based Small Islands Management. Directorate General of Marine, Coastal and Small Islands, Marine and Fishery Department. 21 pages. Jakarta.
[6] Driscoll, Fletcher G., 1987. Groundwater and Wells. Johnson Division. St. Paul, Minnesota
[7] Falkland, A. (Editor), 1991. Hydrology and Water Resources of Small Islands: a Practical Guide.
[8] Hehanussa and Bhakti, 2005. Small Islands Water Resources. Obor Indonesia Foundation Publisher.
[9] Http:/id.wikipedia.org/wiki/Daftar_pulau_di_Indonesia (Download Sept 2013)
[10] KePres No.26 Year 2011 about Groundwater Basin.
[11] Kodoatie, Robert J. and Suripin, June 3rd, 2000. Strategies and Paradigm Water Resourcess Developmnet to Commemorate local autonomy era. National Seminar "Strategies and Paradigms 21st Century Water Resources Development" Post Graduate Civil Engineering Master Program UNDIP.
[12] Kodoatie, Robert J., 2012. Groundwater Spatial. Andi Publisher. Yogyakarta.
[13] Kodoatie, Robert J., and Sjarief Roestam, 2007. Integrated Water Resources Management in Indonesian Perspective. Delivered in "Workshop review on National Policy in Water Resources Management" Bappenas Irrigation Directorate. Wednesday 4th April 2007. The Sultan Hotel (Hilton). Gatot Subroto Street, Jakarta 1002.
[14] Kodoatie, Robert J., and Sjarief Roestam, 2008. Integrated Water Resources Management. Revision Edition. Andi Publisher, Yogyakarta.
[15] Laurentia, S. Cecilia., 2009. Disertation of Rainfall Management for Agriculture on Small Islands in Indonesian Dry Areas.
[16] PP No. 43 Year 2008. About Groundwater Management.
[17] Mock, F. J., 1973. Land Capability Appraisal, Indonesia. Water Availability Appraisal - Basic Study 1 (English). FAO, Rome (Italy). Land and Water Development Div., 1973 , 81 p.
[18] UNESCO. 1991. Hydrology and Water Resources of Small Island: A Practical Guide. Studies and Report on Hydrology No. 49. Prepared by A. Falkland (Ed.) and E Custodio and Contribution from A. Diaz Arenas and L. Simler. Paris, France.
[19] UU No. 5 Year 1990 About Biological Resources and its Ecosystem Conservation.
[20] UU No. 7 Year 2004 About Water Resources.
[21] UU No. 24 Year 2007 About Disaster Management.
[22] UU No. 26 Year 2007 About Draft Spatial Planing.
[23] UU No. 27 Year 2007 About Small Island and Coastal Management.
[24] UU No. 32 Year 2004 About Local Government.
[25] UU No. 32 Year 2009 About Environmental Protection and Management.
[26] UU No. 33 Year 2004 About Financial Appeal between Central and Local Government.
[27] UU No. 41 Year 1991 About Forestry.