Plant Archives Vol. 21, No. 2, 2021 pp. 379–385 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no2.059

SUSTAINABLE WATER AVAILABILITY MODEL WITH RESERVOIR TECHNIQUE BY USING ISM (INTERPRETATIVE STRUCTURAL MODELING) METHOD IN BANGKA ISLAND INDONESIA

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(Date of Receiving : 23-04-2021; Date of Acceptanc : 27-06-2021)

ABSTRACT

The reduced of clean water availability is a problem in almost all parts of the world. This condition is caused by many factors such as population growth, industrialization, urbanization, transportation, etc. The same thing happened in Bangka Island**.** Based on the research conducted by Hambali (2013) the water balance in Pangkal Pinang was in poor condition (>100%) with a water balance value of 388.13% in 2013, 454% in 2018 and 531.04% in 2023. As the condition of the reduced of clean water availability, especially in Bangka Island, it is necessary to have alternative in providing clean water from other sources as an effort to conserve water to maintain the availability of clean water. One of the water conservation efforts that can be done to maintain the availability of clean water is by using rain harvesting technique. Rainfall source in Bangka Island is possible at reservoir(*kulong/embung*) of tin mining that has been done. By using the Interpretative Structural Modeling method, it is possible to obtain factor element, institutional element and actor element in sustainable water availability with reservoir technique in Bangka Island. Three key elements were found, namely institutional, social and environmental. Furthermore, the three main institutional elements were 1) regulatory context. 2) trust in community development and 3) positive relation with the community. Meanwhile, the 3 key actors were 1) Technical institution/unit. 2) Financial Institution and 3) Department of Public Works and Housing

INTRODUCTION

The earth we live in is made up of land, air and water. Most of the earth, which is 71% is covered by water, especially sea water (97.5%) and a small portion of 2.5% is fresh water. From 2.5% of fresh water, 68.7% fresh water is permanent snow at the North Pole and South Pole, 30.1% is underground water, then 0.86% is snow and permafrost and only 3% is located on the earth's surface. From the overall groundwater, 98% is in lakes, swamps and the remaining 2% is fresh water in rivers. (Mittermeier in Supriatna Jaya (2021).

The decrease of clean water sources is caused by several factors, namely population growth, industrialization, urbanization, transportation. Water is transformed through the hydrological cycle. As a hydrological system, the Watershed (in Indonesian: *Daerah Aliran Sungai* or DAS) receives input in the form of rainfall and then processes it according to its characteristics into flow. Rain that falls in one watershed will partly fall on the surface of vegetation, land or water bodies (Triatmodja, 2009). Precipitation is a source of water supply on the earth's surface which will be distributed according to the water cycle. As a source of water supply, precipitation is very important for the sustainability of water existence on the earth's surface. However, global climate change has affected the quantity and distribution of rainwater. Global climate change can be characterized by temperature increase as a result of the increase of human activities. The temperature increase on the earth's surface has occurred since the 19thcentury, with an estimated temperature increase about 0.15°C to 0.3°C in each decade since 1990-2005 (IPCC/Intergovernmental Panel on Climate Change, 2007).

Bangka Island is part of a group of islands in the tin belt area which contains high tin deposit. This position causes tin mining to be carried out which indirectly affects water quality. The poor condition of water quality also worsens the condition of water availability due to climate change (Sabri, 2019) Based on the report of the Department of Environment of the Bangka Belitung province in 2019, it was found that the status of water supply in 7 districts/cities in the Province of the Bangka Belitung Islands mostly in the category has not been exceeded (the amount of water available was still sufficient to meet the needs of the population). About 92% or 1,544,853.75 ha of land area in the Bangka Belitung Islands are in the not yet exceeded category, while the remaining 8% (128.268,47 ha) are in the exceeded category. The impact of climate change which is one of the causes of the lack of water availability on Bangka Island, is strengthened by research conducted by Hambali (2013) the water balance in Pangkal Pinang is in poor condition (>100%) with a water balance value of 388.13% in 2013, 454% in 2018 and 531.04% in 2023.

The decreasing availability of clean water, especially on Bangka Island, requires an alternative solution to provide clean water from other sources as an effort to conserve water and to maintain the availability of clean water. One of the water conservation efforts that can be done to maintain the availability of clean water is by using rain harvesting technique. Rain harvesting on Bangka Island is possible on the *Kulong* (reservoir) of tin mining that has been carried out. Potential reservoirthat can be used as rainwater harvesters on the Bangka Island based on the results of the analysis of remote sensing data by Sabri as many as 9.991 reservoirs spread over every regency/city on Bangka Island. From the data on the reservoir, only 24 ponds can be used for drinking water. Many factors affect the limitations of the use of reservoir as a rain harvest. Beside of physical factors such as the age of the reservoir and the quality of the water that does not meet the requirements for consumption as drinking water, there are institutional factors that can provide an overview of the actors who use of the reservoirs that have been formed because of tin mining on Bangka Island. So this study is intended to be able to see actors in the institutional model of sustainable clean water management on Bangka Island.

MATERIALS AND METHOD

Research on sustainable water availability was carried out on Bangka Island for six months, from September 2020 to March 2021. Meanwhile, expert respondents were experts who met the criteria as expert (Yusuf, 2017), including; 1) expertise at the academic or researcher level, 2) expertise as a policy maker (decision maker), and 3) expertise due to specificity such as local wisdom expert. The total expert respondents in this study were 5 (five) people. Experts who became respondents consisted of representatives from Development Planning Agency at Sub-National Level (in Indonesian: *Badan Perencanaan Pembangunan Daerah* or BAPPEDA), Municipal Waterworks (in Indonesian: *Perusahaan Daerah Air Minum* or PDAM), Department of Environment (in Indonesian: *Dinas Lingkungan Hidup* or DLH), Regional-Owned Enterprises (in Indonesian: *Badan Usaha Milik Daerah* or BUMD) and Department of Public Works and Housing (in Indonesian *Dinas Pekerjaan Umum, Perumahan, dan Kawasan Permukiman* or PUPR) representatives. The number of respondents according to Hora (2004) which states that the number of experts who are adequate and have high precision is 3 to 6 or 7 people.

Interpretative Structural Modeling (ISM) uses the analysis of paired ideas to transform a complex problem until an array of relationship models can be easily understood. The model may be used to build ideas and solutions to the problems at hand. Models can also be used to plan projects and relate to specific areas of a problem. Interpretive Structural Modeling is an inclusive tool, which does not reject or eliminate an idea but the idea is linked and analyzed. This is advantageous, where ideas and solutions are understood and analyzed simultaneously.

Eriyatno (2003), stated that ISM methodologies and techniques can be divided into two parts, namely hierarchical arrangement and sub-element classification. The basic principle is the identification of structures within a system that provide high value benefits in order to formulate the system effectively and for better decision making.

The program studied is structured by dividing it into elements where each element is broken down into a number of sub-elements. Each element is divided into a number of sub-elements until it is sufficient. Studies in related program planning provide an in-depth understanding of various elements and roles of institutions in order to achieve better and more acceptable solutions. According to (Saxena, Sushil, & Vrat, 1992) the program can be divided into nine elements, namely.

1. Affected sectors of society
2. The need of the program
3. Main obstacle
4. Possible changes
5. The Purpose of the program
6. Benchmarks for judging each goal
7. Activities required for action planning
8. Activity size to evaluate the results achieved by each activity
9. Institution involvement in program implementation

The following are the steps taken in analyzing the problem by using the ISM technique:

1. Element identification

System elements are first identified and listed. This can be obtained from research, brainstorming and others.

2. Contextual relationship

A contextual relationship between elements is established, depending on the purpose of the modeling.

3. Structural Self interaction Matrix (SSIM).

This matrix represents the elements of respondents' perceptions of the elements of the intended purpose. The four symbols used are:

V: The relationship of the element E_i towards E_j, not the other way around.

A : The relationship of the element E_i towards E_j, not the other way around.

X : The relationship between E_i and E_j can be the other way around

O : Shows that with E_i and E_j related

4. Matriks Reachability Matrix (RM)

RM can be prepared by converting SSW symbols into a binary matrix. The conversion rules for these symbols are as follows:

- V if e_{ij} =1 and e_{ji} = 0
- X if e_{ij} =1 and e_{ji} = 0
- A if e_{ij} =1 and e_{ji} = 0
- if e_{ij} =1 and e_{ji} = 0

Furthermore, the matrix is then corrected until it becomes a closed matrix that satisfies the transivity rule. The transivity rule is the completeness of the causal loop, for example, A affects B and B affects C, then A must affect C.

5. Participation rate is carried out

The Level of participation is carried out to classify elements in different levels of the ISM structure. For this purpose, the two sets associated with the E_i of the system Reachability Set (RI). Reachability Set (RI) is a set of all attainable elements of the E_i, and the Antecedent Set (A,) is a set of all elements in which the E_i element can be reached. In the first iteration, all elements where R, = R, A are level 1 elements. In subsequent iterations, elements are identified as level elements in previous iterations that are removed, and new elements are selected for subsequent levels by using the same rules. Furthermore, all system elements are grouped into different levels.

6. Canonical Matrix

The grouping of elements in the same level develops this matrix. The resultant matrix has most of the triangular elements, the higher is 0 and the lowest is 1. This matrix is then used to prepare the graph.

7. Diagraph

A diagram is a concept that originates from a directional graph, a graph and elements that are directly related to each other, and are hierarchical levels. The initial graph is prepared on the basis of the canonical matrix. The initial graph is then cut by removing all transitive components to form the final diagraph.

Sub-element classification refers to the processed products of RM that have met the transivity rules. The processed results obtained the value of Driver Power (DP) and the value of Dependence (D) to determine the classification of sub-elements. The sub-elements are classified into sectors, namely:

a. *Sector 1 : weak driver - weak dependent variables (Autonomous).*

The sub-elements included in this sector are not related to the system and may have only a few relationships, even though those relationships can be strong.

b. *Sector 2 : weak driver - strongly dependent variables* (*Dependent*).

Generally, the sub-elements included in this sector are non-free sub-elements.

c. *Sector 3 : strong driver - strongly dependent variables (Linkage)*

The sub-elements included in this sector must be studied carefully, because the relationship between the sub-elements is unstable. Every action on a sub-element will have an impact on other sub-elements and the feedback effect can magnify the impact.

d. *Sector 4 strong driver - weak dependent variables (Independent)*

The sub-elements that enter this sector are the remaining part of the system and are called boundary variables.

8. Interpretive Structural Model

ISM is generated by moving the entire number of elements with the description of the actual element. Therefore, ISM provides a very clear picture of the system elements and the flow of their relationships.

RESULTS AND DISCUSSION

Element of sustainable water availability

The identification results of elements of sustainable water availability factors obtained 5 (five) important Sub Element factors based on the results of expert opinions, including the following:

Table 1: Elements of Sustainable Water Availability Factor

Symbol	Elements of Sustainable Water Availability Factor
A1	Institutional Factor
A2	Financial Factor
A3	Environmental factor
A4	Social Factor
A5	Technical Factor

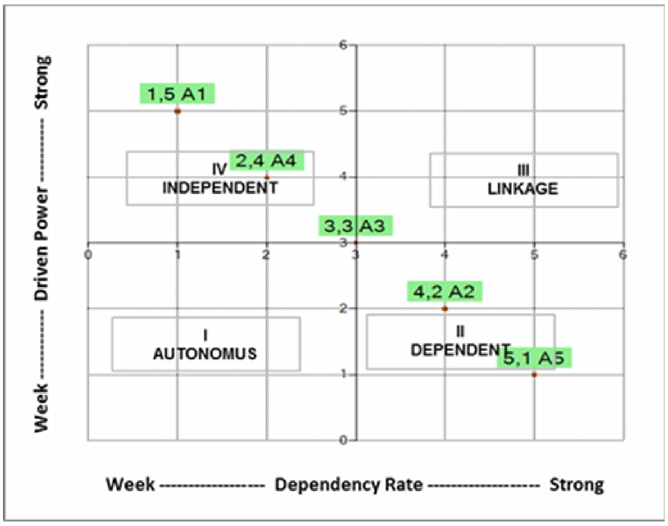

Fig. 1: The position of the sub-element factor of sustainable clean water availability between Driven Power and Dependence

Based on Fig. 1, It was showed that the result of the determination of the ranking and level on the value of driven power and dependence (Table 5.5) which was the key sub-element or the first level was the sub-element (A1) Institutional Factor. Institutional factor is the key indicator of the success in improving the management of sustainable clean water availability so it can move other elements of the factor. At the second level, the indicator of the success was the sub element (A4) Social Factor, where efforts to restore the management of clean water availability require community support so there are no social conflicts or interests. At the third, fourth and fifth levels were (A3) Environmental Factors, (A2) Financial Factors, and (A5) Technical Factors that they were sub elements of success that should receive attention in achieving the application of desalination techniques but these factor were highly determined by the influence of (A1) institutional factor and (A4) social factor.

From the result of the analysis above, it can be concluded that the main factors in the application of reservoir technique management that need to be considered and realized in order the availability of sustainable clean water can be realized is as many as 2 sub-element factors. The two sub elements of the sustainable clean water availability factor which are the basis for the successful application of desalination technique that must be significantly improved and followed up, especially by the government and all stakeholders are capacity building of sub element (A1) Institutional Factor, and sub element (A2) Social Factor. These results are in line with several studies, where the main factor of sustainable water management can be seen from institutional factors where institutional or Effective organization greatly determines the success of sustainable water management (Tadesse *et al*., 2013; Hellstrom *et al*., 2000) and social factors by involving the community in the planning, operation and management of clean water facilities that can improve the sustainability of clean water management and anticipate social conflicts (Sara and Katz, 1998; Nugraheni and Teti, 2014). In detail, the hierarchical/level structure of the elements of sustainable clean water availability is presented in the following Fig. 2:

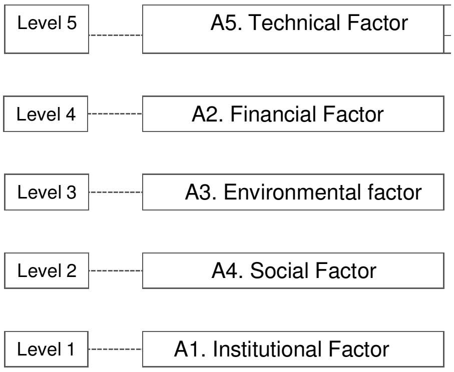

Fig. 2: Structure/Level of Sub Element of Clean Water Availability Factor.

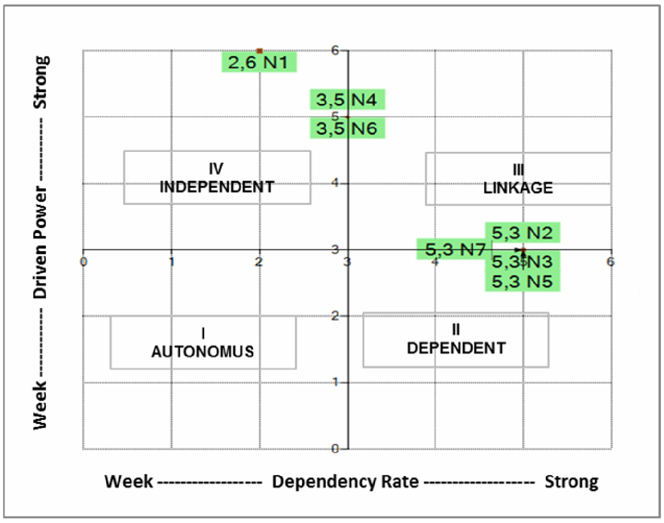

Fig. 3: The Position of the sub-element of sustainable clean water availability between Driven Power and Dependence

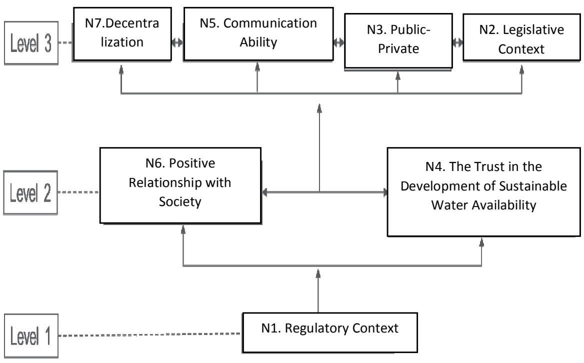

Fig. 4 : Sub Element Structure/Level of Sustainable Clean Water Availability Factor

Factor of Sustainable Clean Water Availability

Based on Fig. 4. It showed that the result of the determination of the ranking and level which referred to the value of driven power and dependence obtained the key sub-element or level 1 (first) was the sub-element (N1) of the Regulatory Context. This illustrates that the sub-element context of institutional regulation of the availability of sustainable clean water is very important to prioritize and implement immediately so it can determine legal rules and sanctions as guidelines to ensure the increase of sustainable clean water availability in the Bangka island. The second level stage that must be followed up were (N4), The trust in the development of sustainable water availability, and (N6), The Positive relationship with the society because by prioritizing good social relation with the society, it can minimize the occurrence of social conflict due to conflict of interest in the community (Kartodihardo, 2017). The last stage or sub-element level 3 (third) that needed to be followed up were sub-element (N3) Public-Private Cooperation, (N5) Communication Ability, (N2) Legislative Context, and (N7) Decentralization. The four institutional directives for the availability of sustainable clean water are the third level as the determination of the model for managing the availability of sustainable clean water in the Bangka island.

The results of the analysis conclude that in improving the institutional availability of sustainable clean water, it is necessary to immediately take further action for the 3 (three) levels of sub-element that determine the institutional increase in the availability of sustainable clean water. At the first level, the sub-element of the Regulatory Context was the basis for the success of the sustainable clean water supply management model and could be a legal guideline for the institution of clean water availability with the application of desalination technique that should be significantly improved and followed up, especially by the government and all stakeholders.

Institutional Actor Elements of Sustainable Water Availability

Institutional actor element of sustainable water availability is supporting sub-element in knowing the main tasks and authorities of each institutional actor in the Bangka Island. The study of the position or relationship between the sub-element of institutional actor in the availability of sustainable clean water is very important to see the cooperative relationship between stakeholder and institutional actor. The result of the identification of sub element based on the result of expert opinions found that institutional actor of sustainable water availability includes 14 (fourteen) sub elements, including the following

Table 2: Institutional Actor Elements of Sustainable Water Availability

Symbol	Institutional Actor Elements of Sustainable Water Availability
P1	Ministry of Public Works and Housing
P2	Central Government
P3	Provincial Government
P4	City/Regency Government
P5	Ministry of Environment
P6	Regional-Owned Enterprises
P7	Development Planning Agency at Sub-National Level
P8	Municipal Waterworks
P9	Regional Revenue Office
P10	Society
P11	University

P12	Technical Institution/Unit
P13	Financial institution
P14	Business entity

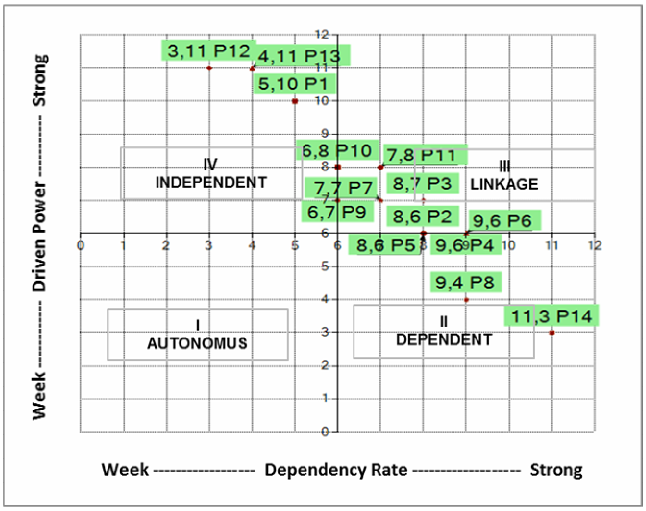

Fig. 4: The Position of institutional actor sub-element of sustainable clean water availability between Driven Power and Dependence

Fig. 5 shows that the institutional actor sub-element of sustainable clean water availability (P12 Technical Institution/Unit), (P13 Financial Institution) and (P1 Office of Public Works and Housing (in Indonesian: *Dinas Pekerjaan Umum, Perumahan, dan Kawasan Permukiman* or PUPR) are in the independent sector, this shows that actors' role of Institutional/Technical Unit (P12), Financial Institution (P13) and PUPR (P1) are important in making high contribution to other institutional sub-elements of sustainable water availability because of any changes in the sub-element of Technical Institution/Unit (P12), Financial Institution (P13) and PUPR (P1) will greatly affect the overall sub-elements of other institutional actors. Sub-elements of (P10) Society, (P11) University, (P3) Provincial Government, (P7) Development Planning Agency at Sub-National Level (in Indonesian: Badan Perencanaan Pembangunan Daerah or BAPPEDA) , (P9) Regional Revenue Office(in Indonesian: DinasPendapatan Daerah or DISPENDA), (P2) Central Government, and (P6) Regional-Owned Enterprises (in Indonesian: Badan Usaha Milik Daerah or BUMD) are in sector III which illustrates that institutional actors of sustainable clean water availability has high influence and high dependence on strong driver-strongly dependent variables (linkage), which means that the sub element included in this sector must be studied carefully because the relationship between the sub elements is unstable and highly dependent on the actor sub element in the independent sector. However, any changes to each of these sub elements will affect the relationship of institutional actor to the sustainable clean water availability in the application of desalination technique in the Bangka Island. The seven institutional actors of sustainable water availability are also determinant in improving the relationship between institutional actors of sustainable clean water availability in the application of desalination technique in the Bangka Island so they must be investigated carefully.

Meanwhile, (P4) City/Regency Government, (P5) Department of Environment, (P8) Municipal Waterworks (in Indonesian: Perusahaan Daerah Air Minum or PDAM), and (P14) Business Entity are sub-elements that are in the dependent sector, where this sub element has very small influence and depends on the independent sector and linkage because it is an institutional actor that is not in the system and does not have big driver that will affect other sub elements in the system.

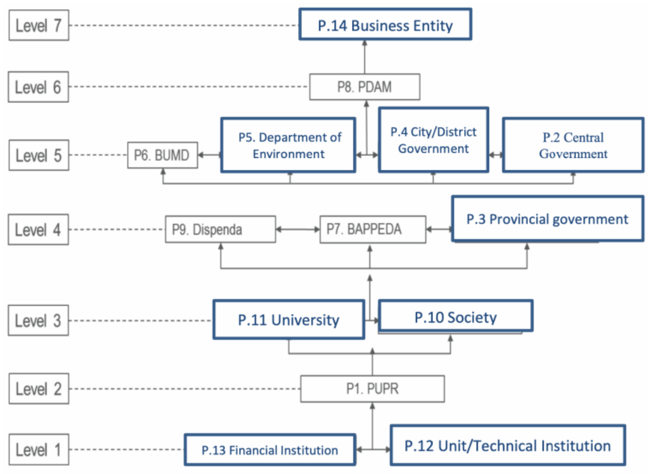

Fig. 5: Structure/Level of Sub Element Institutional Actor of Sustainable Clean Water Availability

Based on Fig. 6. It was showed that the result of ranking and level determination that referred to the value of driven power and dependence obtained key sub element or level 1 (first) were sub elements (P12 Technical Institution/Unit), and (P13 Financial Institution). This illustrates that the sub element (P12 Technical Institution/Unit), and sub element (P13 Financial Institution) become the basis and make a major contribution in moving the sub-element of other institutional actors on the other hand can support improving the management of sustainable clean water availability in the application of desalination technique in the Bangka Island. The second level stage that should be followed up was the role of Department of Public Works and Housing (in Indonesian: *Dinas Pekerjaan Umum, Perumahan, dan Kawasan Permukiman* or PUPR). At the third level was the role of (P11) University and (P10) the Community. At the fourth level was the role of other institutional actors such as (P9) Regional Revenue Office (in Indonesian: *Dinas Pendapatan Daerah* or DISPENDA), (P7) Development Planning Agency at Sub-National Level (in Indonesian: *Badan Perencanaan Pembangunan Daerah* or BAPPEDA), and (P3) ProvincialGovernment. At the fifth level was the role and relationship of institutional actors such as (P6) Regional-Owned Enterprises (in Indonesian: *Badan Usaha Milik Daerah* or BUMD), (P5) Department of Environment, Fig. 6(P4) City/Regency Government and (P2) Central Government. The relationship between other institutional actors was the role of (P8) Municipal Waterworks (in Indonesian: *Perusahaan Daerah Air Minum* or PDAM) and (P14) Business Entity which needed to be followed up immediately in unifying the relationship between institutional actors in managing the availability of sustainable clean water in the Bangka Island.

The success of sustainable clean water management with reservoir system in the Bangka Island can be done by increasing institutional capacity. Increasing institutional capacity while prioritizing the determinants of sustainability, especially the ecological, social and economic dimensions so the 3 sustainability indicators require a form of technical regulation as legal guidelines or technical rules, starting from planning and monitoring in supporting the successful implementation of rain harvest.

The management of clean water resources as stated in Law number 7 of 2004 explains that underwater and water resources contained therein are gifts from God Almighty that provide benefits for realizing prosperity for all Indonesian people in all fields. This mandate needs to be immediately implemented by the government through policies, involvement of institutions and agencies/organizations and the private sector in the clean water management sector. The availability of rain harvest of reservoir technique with government intervention can support and improve the management of clean water utilization for society.

Improving the quality of people's lives is a long process that must be initiated by strong political affirmation from the government as policy maker. One of the indicators is improving the quality of life of the people in the Bangka Island by utilizing clean water management with desalination system. The damage to the marine environment that implicitly must be addressed immediately, both the government and the private sector, because it has a long-term impact, especially for the people in Bangka Island, mainly in fulfilling clean water consumption, which will depend on the use of clean water from the reservoir system.

The condition of Bangka Island region is in a multi-administrative area where there are 7 regencies and cities (Bangka Regency, Belitung Regency, Pangkal Pinang City, West Bangka Regency, Central Bangka, South Bangka and East Bangka), it is necessary to have an integrated coordination between relevant agencies and stakeholders by increasing the opportunities for cooperation between local governments. This joint policy must be implemented immediately so sustainable clean water management with reservoir system can be effectively and efficiently implemented regardless of sectoral interests between regions but by looking at the long-term welfare principle of fulfilling community clean water.

In improving clean water management with desalination system, it is hoped that it can sustainably meet the availability of clean water to be used as the daily need of the community. Therefore, a proportional and balanced effort is needed between management, planning, preservation, and utilization with the institutional support of technical unit and financial institution. To meet the increasing water demand in various sectors, an integrated regional-based planning is needed in a professional and accountable manner and it is carried out by technical institution for clean water management with reservoir system in the Bangka Island.

The successful implementation of clean water management with reservoir system must be arranged in coordinated manner with the involvement of all parties (Fig. 7), relevant agencies, stakeholders, the private sector and the community on the basis of environmental sustainability, balance of social function, the environment, economic principle, and public use. Because of the importance of the success of sustainable clean water management, then legal regulation and technical guideline are needed as general guideline for improving clean water management with desalination system so all parties involved can carry out their roles in an integrated and comprehensive manner by prioritizing professionalism, accountability and transparency.

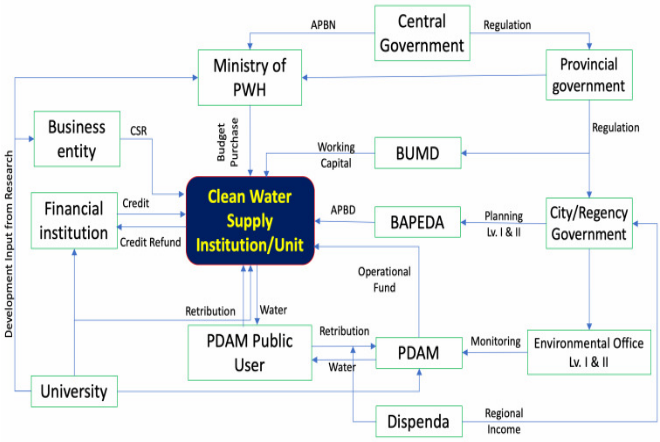

Fig. 6: Technical Operation Unit for Reservoir Management

CONCLUSION

The main factors for increasing the availability of sustainable clean water were institutional factor and social factor. Effective institutional or organizational factors could increase performance capacity among stakeholders and unite interdependent relationship. Social factor by involving the community in the planning, operation and management of clean water facilities could anticipate social conflicts.

Institutional management of clean water availability with a reservoir system could run effectively and efficiently if it was supported by the regulatory context which was the basis for the success of the sustainable clean water supply management model and could use as technical guidelines and institutional law in organizing roles, responsibilities, function of actors, stakeholders and institutions in improving the management of clean water availability by applying desalination technique so it could be followed up significantly, especially by the government and all stakeholders.

The institutional actor model for managing the availability of sustainable clean water in a hierarchical manner had a relationship and interdependence between the first structure/level to the seventh level which consisted of 14 (fourteen) actors, institutions and agencies. At the first level, the sub-elements of Technical Institution/Unit and Financial Institution were the driving force for other institutional actors in improving the management of sustainable clean water availability and could be a driver for improving the management of clean water availability by applying reservoir technique in the Bangka Island

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