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2 D QUANTITATIVE MODEL USING NUMERICAL UNDERGROUND WATER FLOW RATE EQUATION TO STUDY THE DAMAGE TO GROUNDWATER RESOURCES

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Damage over water resources occur due to land degradation, population pressure and industry. The purpose of this study is to analyze the damage to groundwater resources based on the results of the mapping and the cross section of the unconfined aquifer. The study area was conducted at Pekanbaru in Riau province. The method used was a field survey to measure the coordinates of the points of the samples and measure the depth of the unconfined aquifer of dug wells and drilled wells. The grid method used was a model Kriging 17 × 17 using surfer version 11. Input data $h^k_{i,j}$ (baseline 2015) subsequently used to predict the depth of the unconfined aquifer in 2016 up to 2020 ($h^{k+1}_{i,j}$) using numerical finite difference method. The results showed that based on the cross-section of the A-B, then the total area of the zoning secure 2016 and 2020 respectively were 169.05 km^2; 3.76 km^2; 3.76 km^2; 3.76 km^2; 0 km^2, while the total area of insecurity were 0 km^2; 165.29 km^2; 165.29 km^2; 165.29 km^2 and 169.05 km^2. The causes of the damage to the water resources were due to changes in land use, population pressure and industry.

INTRODUCTION

The damage to water resources cannot be separated from land degradation and population pressures. Several factors led to issues of groundwater, among others (Salim, 1979): 1). Rapid industrial growth in a region accompanied by the growth of settlements causes a trend of rising demand for groundwater. 2). Water users are diverse so that differed in interests, purposes and how to get the water source. 3). Need to change the attitude of most of the people who tend to be wasteful in the use of water as well as the neglect of conservation element. 4). The presence of water crisis due to environmental degradation needs the effort to maintain the existence or availability of groundwater resources.

Based on the idea that the activities of underground water utilization by conducting an excessive ground water extraction regardless of the ability of the aquifer would disrupt the environmental balance, given the availability of underground water is not evenly distributed in all places and highly dependent on local hydrological conditions. The balance of the environment needs to be considered because of the limited resources of underground water.

Excessive extraction of ground water resulted in a decreased level of groundwater. Decrease in ground water level will result in a reduction in the lifting force of the ground so as to increase the effective tension of the ground. As a result of the increasing of this effective tension will cause shrinkage of soil particle and land subsidence (Chapuis et al, 2005). On the other hand, led to the possibility of soil erosion in the inner layer of soil due to the lifting of granular soil under the soil surface by absorption of ground water through excessive wells pumping.

The process of development and construction in Pekanbaru will affect changes in land use. A city green open space in Pekanbaru has 6653.47. A green open space is indispensable for the availability of underground water. Based on the spatial aspects have changed land use in the city of Pekanbaru namely plantation of 12.03% in 2005 to 12.67% in 2009. Based Real Estate stated that the settlements increased by 7.9% in 2008 to 15.5% in 2011. Increased woke space is growing with increasing population and economic aspects [1]. Based on data from the department of industry and commerce Pekanbaru City stated that the average population growth is 3% per year and growth of the industry average is 11.65% per year. The excessive extraction of groundwater resulted in a decreased level of groundwater. The decline in ground water level will result in a reduction in the lifting force of the ground so as to increase the effective voltage ground. As a result of the increased effective stress will cause shrinkage of soil particle back and land subsidence (Chapuis et al, 2005). The new equilibrium can occur only if the rate of groundwater abstraction is smaller than the charging by rainwater catchments (Yadav et al, 2012). The consumptive water use is calculated based on the model of sector water use (Doil et al, 2011). This research uses the population and industrial sector.

QUANTITATIVE MODEL OF GROUND-WATER FOR SUSTAINABLE DEVELOPMENT

The Brunsland Commission stated that sustainable development is a development that meets the needs of the present generation without compromising the ability of future generations to meet their needs. Sustainable development according to Fauzi and Ana (2005) that the concept of sustainability can be specified into three aspects of the understanding, namely:

1. Social sustainability,
2. Economic sustainability,
3. Environmental Sustainability.

The excessive extraction of groundwater, causing the declining of underground water level, which can cause the critical clean-water conditions, especially during the dry season. This will cause the condition of head hydraulic in unsafe condition

The impact of this unsafe head hydraulic condition will cause disruption of the availability of underground water supply or will not be able to meet the water needs of the current generation nor future generations.

Quantitative models of underground water, the results of this study have provided a safety zone for the hydraulic head so as to ensure the continuous availability of underground water for current and future generation.

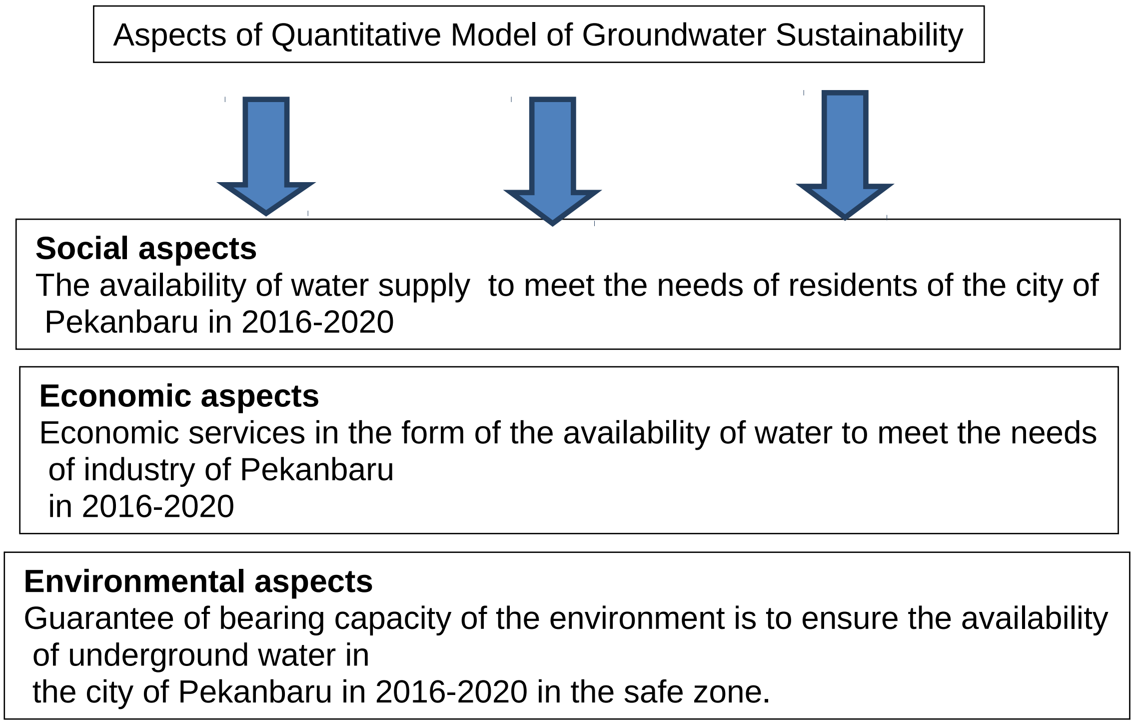

Figure 1. Three Pillars of Sustainability of Quantitative Model

Groundwater Flow

The steady flow in and out of the aquifer volume element is shown in Figure 3. Based on the law of conservation of mass and if there is no source in the volume, then the mass of water that goes into volume are formulated (Driscoll and Fletcher, 1987).

According to Darcy's law that each flux can be expressed in the amount of hydraulic conductivity and hydraulic gradient, namely:

$$\frac{\partial}{\partial x}\left(k_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_{yy}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial z}\left(k_{zz}\frac{\partial h}{\partial z}\right)=0 \qquad (1)$$

Homogeneous aquifer and hydraulic conductivity are assumed do not change the position, then equation (1) can be written as:

$$k_{xx}\frac{\partial^2 h}{\partial x^2}+k_{yy}\frac{\partial^2 h}{\partial y^2}+k_{zz}\frac{\partial^2 h}{\partial z^2}=0 \qquad (2)$$

For a homogeneous and isotropic $k_{xx}=k_{yy}=k_{zz}$ aquifer, so equation (2) can be written as:

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=0 \qquad (3)$$

Equation (3) can be written in the form of operator, then become:

$$\nabla^2 h=0 \qquad (4)$$

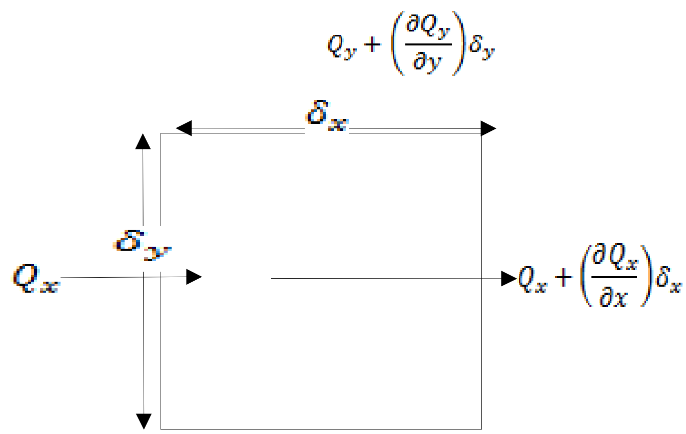

Figure 2. Recharge water mass equal to the mass of discharge water, for the z component perpendicular to the image plane (Driscoll and Fletcher, 1987).

Equation (4) is known as the Laplace equation.

Unsteady state flow concept is based on the condition that the flow of fluid into or out of the element of a volume is fluctuated over time. Water mass in the volume element is expressed as the difference between fluid flow in and out, mathematically can be expressed as follows (Driscoll and Fletcher, 1987):

$$\frac{\partial(\rho_w V_w)}{\partial t}=\left(Q_x+\frac{\partial Q_x}{\partial x}\delta_x\right)\rho_w+\left(Q_y+\frac{\partial Q_y}{\partial y}\delta_y\right)\rho_w+\left(Q_z+\frac{\partial Q_z}{\partial z}\delta_z\right)\rho_w-(Q_x+Q_y+Q_z)\rho_w \quad (5)$$

Equation (5) can be written as:

$$\frac{-1}{\rho_w}\frac{\partial(\rho_w V_w)}{\partial t}=\frac{\partial Q_x}{\partial x}\delta_x+\frac{\partial Q_y}{\partial y}\delta_y+\frac{\partial Q_z}{\partial z}\delta_z \quad (6)$$

The right side rate of equation (5) and (6) express the amount of fluid flow out of the volume element in any coordinate direction. If the outflow is positive, then the volume of fluid in the volume element will be reduced.

The volume of fluid (water) in a volume element is the multiplication between porosity and the volume of the element, so that equation (6) can be written as:

$$\frac{-1}{\rho_w}\frac{\partial(\rho_w V_w)}{\partial t}\delta_x\delta_y\delta_z=\frac{\partial Q_x}{\partial x}\delta_x+\frac{\partial Q_y}{\partial y}\delta_y+\frac{\partial Q_z}{\partial z}\delta_z \quad (7)$$

Furthermore flux (Q_x, Q_y, Q_z)in equation (7) is substituted by Darcy's law, then divided by the volume, thia will be obtained:

$$\frac{1}{\rho_w}\frac{\partial(\rho_w \mu)}{\partial t}=\frac{\partial}{\partial x}\left(k_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_{zz}\frac{\partial h}{\partial z}\right) \quad (8)$$

Equation (8) shows that the mass of water in the volume element can be changed dramatically because of the water density changes or because the porosity is changed. Equation (8) can be written as:

$$\left[\frac{1}{\rho_w}\frac{\partial(\rho_w \mu)}{\partial h}\right]\frac{\partial h}{\partial t}=S_s\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left(k_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_{zz}\frac{\partial h}{\partial z}\right) \qquad (9)$$

Equation (9) also can be written in differential operator notation as follows:

$$\nabla\cdot\acute{k}\cdot\nabla h=S_s\frac{\partial h}{\partial t} \qquad (10)$$

Equation (10) is to state the condition of underground water flow in case of time-dependent (unsteady state).

Cases where the area is so large that must modeling of aquifers, meaning that the breadth far greater than the thickness of the aquifer, so that the H has not changed in the vertical direction so that the system can use two-dimensional flow.

Law of conservation of mass for the two-dimensional hydraulic flow to the source can be written as follows (Guymon, 1994):

$$\frac{-\partial(\rho_w V_w)}{\partial t}=\left(Q_x+\frac{\partial Q_x}{\partial x}\delta_x\right)\rho_w+\left(Q_y+\frac{\partial Q_y}{\partial y}\delta_y\right)\rho_w-(Q_x+Q_y)\rho_w+V_R\rho_w \qquad (11)$$

V_R is the volume of ground water that is added to or removed from aquifer $\delta_x\delta_y$ per unit time.

Furthermore, Q is substituted by Darcy's law and divided by the surface areathen obtained the following equation:

$$bS_s\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left(bk_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(bk_{yy}\frac{\partial h}{\partial y}\right)+\frac{V_R}{\delta_x\delta_y} \qquad (12)$$

Aquifer B thickness change in position but is not dependent on time. Multiplication hydraulic conductivity and thickness of aquifer is called transmissivity, whose dimensions L^2/T, and the multiplication of specific storage and thickness of aquifer is called storatovity, so that equation (12) can be written as:

$$S_{\square}\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)+R \qquad (13)$$

For a homogeneous and isotropic aquifer, then the equation (13) can be converted into (Guymon, 1994):

$$\frac{S}{T}\frac{\partial h}{\partial t}=\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{R}{T} \qquad (14)$$

MATERIALS AND METHODS

The method used is a field survey to measure the coordinates of the point of the samples and measure the depth of the unconfined aquifer of dug wells and drilled wells. Grid method was a model Kriging 17 × 17 by using surfer version 11 with input data $h_{i,j}^{k}$ (baseline 2015) subsequently used to predict the depth of the unconfined aquifer in 2016 up to 2020 ($h_{i,j}^{k+1}$)using numerical finite difference method.

Simulation of the predicted value of the depth of the unconfined aquifer to do with entering secondary data population, taking underground water by residents, industries and land conservation, in order to obtain the predictive value of the depth of the unconfined aquifer in 2016 to 2020, then by using a program surfer version 11 to be mapped two-dimensional and cross-section.

Numerical Analysis

An Unsteady state conditions state is a condition where the amount of incoming underground water (recharge) is not equal to the number that comes out (discharge). This means there has been a disruption to the natural system of underground water flow. It can be caused by an excessive underground water extraction exploitation because of high industry activity and the high rate of population growth and the lack of green open land as water catchment areas.

Differential equations groundwater to a state of 'unsteady state "is a theory which will be developed in this study, as stated in equation (14) can be seen a few parameters that can be considered as a constant, it is to facilitate the equation (14) can be formed into;

$$\frac{\partial h}{\partial t}=b_1\left[\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}\right]\pm a_1, \qquad (15)$$

where;

$$a_1=\frac{\beta}{A},$$

$$A=\frac{S}{T},$$

$$b_1=\frac{1}{A},$$

$$\beta=\left[\frac{E_d+E_i+R}{T}\right].$$

Total consumption of ground water by the population can be calculated using the equation (16).

$$E_d=P_t\times k_p \qquad (16)$$

where E_d is the need of ground water by the population, k_p is the requirement amount of ground water per person per day ranged from 0.10 to 0.15 m^3/person/day, where P_t is the total population in the target.

Water needs for industry can be calculated based on the standard of the average water needs by SNI (Indonesian National Standard) (2002) is equal to 2,000 liters / unit / day formulated as follows:

$$E_i = S_{ki} \times J_i \tag{17}$$

where E_i is the need for water by industry, S_{ki} is the standard industrial water needs, Ji is the number of industries.

A catchment area (recharge) is an area where groundwater flows direction away from the surface. This infiltration calculations need to consider the physical properties of rock / soil and existing locations. The Calculation of recharge (R) was conducted fortropical regions based on water level fluctuation and rainfall depths as given by (Saghravani,2013):

$$R=1.35(P-14)^{0.5} \tag{18}$$

Where R is the net recharge due to precipitation during the year and P is the annual precipitation. This study uses backward difference to declare the finite difference in time domain, in the form of double index backward difference portion time-dependent can be written (Gerald, 1978),

$$\left(\frac{\partial h}{\partial t}\right)_{i,j} = \left(\frac{h_{i,j}^{k+1} - h_{i,j}^{k}}{\Delta t}\right) \tag{19}$$

with an error in the order of one is expressed in the form 0 (Δt).

A numerical statement of underground flow equations in unsteady conditions can be written as:

$$h_{i,j}^{k+1} - h_{i,j}^{k} = \lambda\left[-4h_{i,j}^{k+1} + h_{i+1,j}^{k+1} + h_{i-1,j}^{k+1} + h_{i,J+1}^{k+1} + h_{i,j-1}^{k+1}\right] \pm c \tag{20}$$

where;

Suppose that points $U_{i,j}$ are discrete approach for areas with a uniform space and let be taken $n = m =$ 4, then the form of discrete simulation same with the area as in Figure 4. If equation (20) was applied to the area as indicated in Figure 4 then we obtain a linear equation at each interior point of the grid at any point $U_{i,j}$ which can be expressed in the form of a matrix:

$$H^k = G\,H^{k+1} + D \tag{21}$$

To predict the fluctuation in the value of underground groundwater hydraulic head, then the equation (21) can be written as (Lancaster, 1980),

$$H^{k+1} = G^{-1}\left(H^k - D\right) \tag{22}$$

Where in the matrix H^{k+1}can be expressed:

$$H^{k+1} = \begin{pmatrix} h_1^{k+1} \\ h_2^{k+1} \\ \cdot \\ \cdot \\ \cdot \\ h_9^{k+1} \end{pmatrix} \quad (23)$$

Matrix H^k can be expressed as

$$H^{k} = \begin{pmatrix} h_1^{k} \\ h_2^{k} \\ \cdot \\ \cdot \\ \cdot \\ h_9^{k} \end{pmatrix} \quad (24)$$

Matrix G can be expressed as

$$G = \begin{pmatrix} (4\lambda+1) & -\lambda & 0 & -\lambda & 0 & 0 & 0 & 0 & 0 \\ -\lambda & (4\lambda+1) & -\lambda & 0 & -\lambda & 0 & 0 & 0 & 0 \\ 0 & -\lambda & (4\lambda+1) & 0 & 0 & 0 & 0 & 0 & 0 \\ -\lambda & 0 & 0 & (4\lambda+1) & -\lambda & 0 & -\lambda & 0 & 0 \\ 0 & -\lambda & 0 & -\lambda & (4\lambda+1) & -\lambda & 0 & -\lambda & 0 \\ 0 & 0 & -\lambda & 0 & -\lambda & (4\lambda+1) & 0 & 0 & -\lambda \\ 0 & 0 & 0 & -\lambda & 0 & 0 & (4\lambda+1) & -\lambda & 0 \\ 0 & 0 & 0 & 0 & -\lambda & 0 & -\lambda & (4\lambda+1) & -\lambda \\ 0 & 0 & 0 & 0 & 0 & -\lambda & 0 & -\lambda & (4\lambda+1) \end{pmatrix} \quad (25)$$

Matrix D is the boundary condition. Matrix G is a c*oefficient matrix* which is known based on the parameters set. Matrix H^k is an initial requirement (note) of field data measurements. Furthermore matrix H^{k+1} is a matrix that will be sought after, is the value of head hydraulic underground water predicted model of sustainability with a variety of simulated model parameters. Matrix D can be expressed as,

$$D = \begin{pmatrix} -\lambda \left[h_{0,3}^{k+1} + h_{1,4}^{k+1}\right] \pm c \\ -\lambda \; h_{2,4}^{k+1} + c \\ -\lambda \left(h_{4,3}^{k+1} + h_{3,4}^{k+1}\right) \pm c \\ -\lambda \; h_{0,2}^{k+1} \pm c \\ -\lambda \; h_{4,2}^{k+1} \pm c \\ -\lambda \left(h_{0,1}^{k+1} + h_{1,0}^{k+1}\right) \pm c \\ -\lambda \; h_{2,0}^{k+1} \pm c \\ -\lambda \left(h_{3,0}^{k+1} + h_{4,1}^{k+1}\right) \pm c \end{pmatrix} \tag{26}$$

Validation of Numerical Results

Validation can be used as a tool to determine whether the relationship between the results of simulation data with measurement data field linked correctly or significantly different. So the validation is quite representative to provide evidence that the simulation results could have been accepted or rejected (Nazir, 1985). In this study as for numerical simulations related to the matrix system, then to be able to see the validation can be used the TOL definitions, to validate will be used TOL = 10%, so the numerical results are said to be valid if: $\|r\| \leq TOL$.

VALIDATION TEST USING SECONDARY DATA

Secondary data model study was conducted to see the accuracy of numerical methods analyze the unconfined aquifer system damage. As a secondary data during the tests of numerical methods are taken from the literature with a secondary model parameter that will be used to test the simulation results are as follows (Schnoor, 1996):

Hydraulic conductivity (k= 100 $\text{gald}^{-1}\text{ft}^{-2}$)

Initial head (H_0= 500 ft)

Grid Spacing (Δx = 7 ft)

Gradient hydraulic = 0.05

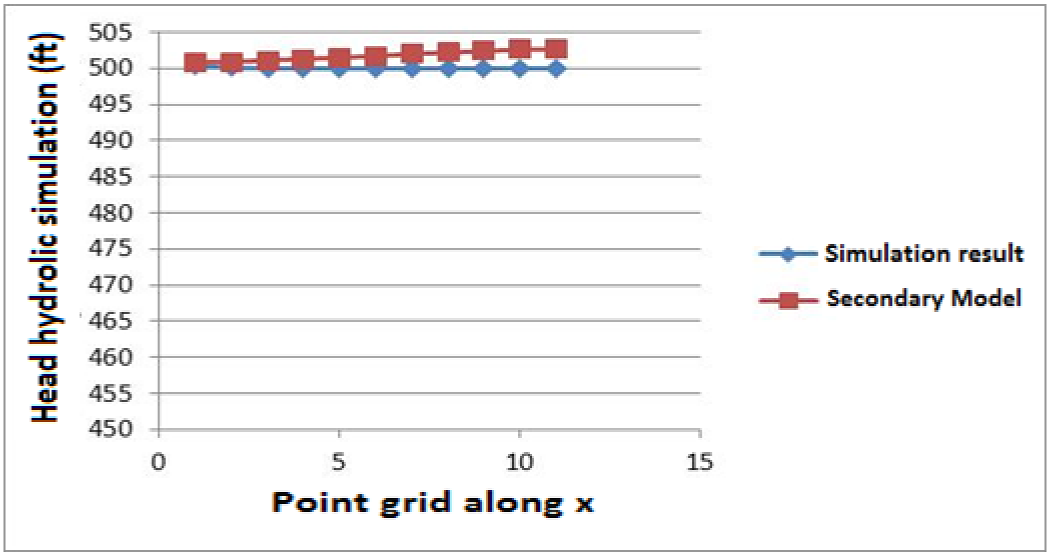

Figure 3. Showing the successful deployment of simulation of the secondary model.

Based on Figure 3 it can be seen that the head hydraulic changes at the points (3, j) both the simulation results and secondary apparently showing adjacent numbers means the difference in value between the secondary and the simulation results are less than 10%.

Figure 4 is a comparison between the head hydraulic simulation results with secondary it can be seen that the deployment of values both the simulation and the secondary is not much deviated from a straight line with a difference of less than 10% as shown in Table 1.

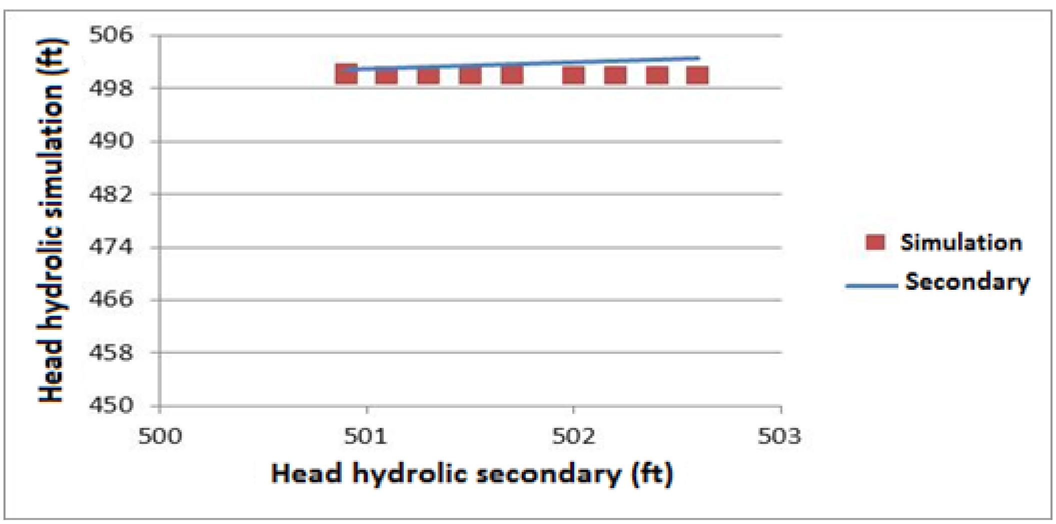

Figure 4. A comparison between the head hydraulic simulation results with secondary.

Table 1. The difference between the simulation results with the secondary model (3, j)

No	Head hydraulic (ft)	Simulation(ft)	Secondary Model (ft)	Percent difference (%)
1	Minimum	500	500	0
2	Maximum	500,7	502,6	0,4
3	Average	500,35	501,3	0,2

UNCONFINED AQUIFER PARAMETERS IN PEKANBARU

Unconfined aquifer parameters are a physical quantity that is related to the characteristics of the aquifer which plays an important role to determine the condition of the unconfined aquifer water in an area.

Unconfined aquifer parameters should be analyzed in advance, before determining the prediction of the damage of unconfined aquifer in Pekanbaru. Determination of unconfined aquifer parameters can be done with the geoelectric investigation.

As for the unconfined aquifer parameters required to predict the free-aquifer water damage in the city of Pekanbaru is:

1) Unconfined aquifer lithology ,

2) Unconfined aquifer thickness (m)

3) Hydraulic conductivity (m / day),

4) Specific yield or storativity (%),

5) Transmissivity ($m^{2/}$day)

The natural condition of the unconfined aquifer of Pekanbaru is a condition that requires the initial calculation of natural head hydronic, means a condition where there is no interference from outside.

Data that can portray natural conditions of the free aquifer of Pekanbaru in this study used the data in 1998 that is the measurement geoelectric data of Pekanbaru City area that has been done by the Department of Mines Regional Government of Riau Province.

The geoelectric data is then processed using software called VES (Vertical Electrical Sounding) to obtain the lithology model of Pekanbaru City area as shown in Table 2.

Table 2 demonstrates the value detainee type can be seen as five different types of layers with different thicknesses. Each layer is characterized by a certain type of lithology, which for each lithology has a specific resistivity value.

Based on the distribution of resistivity we have been able to interpret that the first layer is the lithology of the covered ground with resistivity rate 30.55 Ohm.m, the second layer with sand lithology has a resistivity value of 10.18 Ohm.m and interpreted as an unconfined aquifer layer with a thickness

Table 2. Unconfined aquifer thickness values based on the measurement point geoelectric in Pekanbaru City area.

Geoelectric	Coordinate		Resistivity	Estimated lithology	Thickness (m)
Point	X	Y	(Ohm.m)		
K1	776453	63204	30,55	Land Cover	
			10,18	Sand	7,79
			3,46	Clay sand	
K2	769336	56855	7,15	Land Cover	
			22,43	Sand	4,27
			3,58	Clay sand	
K3	767500	57750	100,75	Land Cover	
			15,11	Sand	8,34
			3,02	Clay sand	
K4	768000	57250	35,55	Land Cover	
			10,16	Sand	8,79
			3,15	Clay sand	
K5	776450	63200	10,16	Land Cover	
			32,55	Sand	7,13
			4,06	Clay sand	
				Amount	36,32
				Average	7,264

of 7.79 m, while the third layer is the lithology of sandy loam with a resistivity rate of 3.46 Ohm.m , as an impermeable layer.

At the measurement point K2 also has three layers with the first layer interpreted as covering the soil with resistivity 7.15 Ohm.m, the second layer with sand lithology is a unconfined aquifer layer with resistivity 22.43 Ohm.m and has a thickness of 4.27 m , as well as for another measurement point can be seen in Table 3.

Based on the lithology value found in Pekanbaru City unconfined aquifer system, it can be determined the unconfined aquifer hydraulic conductivity in Pekanbaru City as shown in Table 3.

Based on Table 3. it can be seen that the rock's ability to pass the water in the cavities of rocks without changing the nature of the water has an average number of 1.87 m / day. Table 3. shown that the level of water ability to penetrate is very influenced by the compilers lithology of thefree aquifer.

Table 3 shows that the lithology geological structure affects the amount of movement of groundwater, as well as determines the type and potential of the unconfined aquifer. This lithology structure will form stratigraphic unit which is composed of several layers of rocks and would affect the unconfined aquifer thickness (Table 1), also the position of groundwater. This lithology types will also affect electrical conductivity.

The lithology also determines the geological formations, such as permeable (permeability), known as of the unconfined aquifer (also called groundwater reservoir, the formation of water-binding, the

Table 3. Unconfined Aquifer Hydraulic Conductivity value based on the geoelectric measurement point in the city of Pekanbaru.

Geo electric Point	Coordinate		Resistivity	Estimated lithology	k (m/day)
	X	Y	(Ohm.m)		
K1	776453	63204	30,55	Land Cover	0,0002
			10,18	Sand	3,1
			3,46	Clay sand	2,5
K2	769336	56855	7,15	Land Cover	0,0002
			22,43	Sand	3,1
			3,58	Clay sand	2,5
K3	767500	57750	100,75	Land Cover	0,0002
			15,11	Sand	3,1
			3,02	Clay sand	2,5
K4	768000	57250	35,55	Land Cover	0,0002
			10,16	Sand	3,1
			3,15	Clay sand	2,5
K5	776450	63200	10,16	Land Cover	0,0002
			32,55	Sand	3,1
			4,06	Clay sand	2,5
				Amount	28,001
				Average	1,87

bottoms of a translucent ground water) which is the formation of water-binding which allows the the large amount of water moving through it, at the common field conditions.

The specific yield or storativity also can be determined based on the interpretation of lithology of unconfined aquifer in the city of Pekanbaru as shown in Table 4.

The specific yield, showing the percentage ratio of the amount of water that can be taken from the ground or rock that is saturated with water, compared to the total volume of rock or soil.

Table 4 shows that the unconfined aquifer of Pekanbaru, the amount of water that can be taken from the soil or rock that is saturated with water to a total volume of rock is an average of 17.67%. It really depends on the type of lithology of the unconfined aquiferlayer.

Physical quantities relating to the amount of the allowed water uptake from unconfined aquifer by residents and industries is the specific yield factor or storativity. It can reflect that in order not to be disturbed, the unconfined aquifer ground water balance system should have a ratio between the amount of water that can be taken from the soil or rock that is saturated with water to a total volume of rock ranging from 17.67%. If this factor can be maintained then the damage of the unconfined aquifer in Pekanbaru can be avoided. The unconfined aquifer transmissivity of Pekanbaru furthermore, can be determined that is equal to 13.58 m^2 / day.

Table 4. The specific yield value of unconfined aquifer based on the geoelectric measurement point in the city of Pekanbaru.

Geo electric	Coordinate		Resistivity	Estimated lithology	Specific yield
Point	X	Y	(Ohm.m)		%
K1	776453	63204	30,55	Land Cover	3
			10,18	Sand	27
			3,46	Clay sand	23
K2	769336	56855	7,15	Land Cover	3
			22,43	Sand	27
			3,58	Clay sand	23
K3	767500	57750	100,75	Land Cover	3
			15,11	Sand	27
			3,02	Clay sand	23
K4	768000	57250	35,55	Land Cover	3
			10,16	Sand	27
			3,15	Clay sand	23
K5	776450	63200	10,16	Land Cover	3
			32,55	Sand	27
			4,06	Clay sand	23
				Amount	265
				Average	17,67

TWO DIMENSIONAL MAPPING OF UNDERGROUND WATER DEPTH

Four patterns of uniformity, that the dominant pattern uniformity is blue color with a depth of 8 meters to 16 meters, the second dominant is green color with a depth of 18 meters to 26 meters, the third dominant uniformity is yellow with a depth of 28 meters to 32 meters and fourth is red with a depth of 34 meters to 42 meters.

The depth contours of underground water with patterns enclosed can be interpreted happen relationships between the pores in the rocks that exist below the Earth's surface, where the water can flow to the pores are interconnected, whereas for the area limit field generally has an open contour pattern that can be interpreted that the water flow out into other administrative areas. Patterns of different contour can also be caused because of the different physical properties of the subsurface which include porosity, permeability, and the difference in lithology.

Two-dimensional depth of the underground water in 2020 showed four patterns uniformity. The first is the dominant pattern in red with a depth of 46.2 m to 46.8 m. The second dominant pattern uniformity is green with a depth of 45 m to 45.4 m. The third dominant pattern uniformity is yellow with a depth of 45.6 m to 46 m. The fourth dominant pattern uniformity is blue with a depth of 44 m to 44.8 m.

2D mapping for the condition in 2020 showed that there are four closed contour, located on the inside of the administrative city of Pekanbaru. his existing closed contour can be interpreted that there is a rock with interconnected pores which can be energized by the fluid

Open contour generally occurs at indicates that the rock pores continuously connected with the rocks that are outside the administrative city of Pekanbaru, as shown in Figure 6.

Based on the contour open in Figure 5 and Figure 6 requires policy measures integral between the government, whose land is directly adjacent to undertake efforts to protect the water resources underground, so that the system unconfined aquifer always in a safe condition, thus ensuring water availability below land for the purposes of population and industry. The policy can be taken is to increase land conservation to recharge.

THE ZONE UNCONFINED AQUIFER OF PEKANBARU 2016 TO 2020

Zoning pattern secured and unsecured by AB cross section shown in Figure 5, that the zoning area unsafe increased from 2016 until 2020, this was due to the factor of population pressure, industrial and limitations of conservation land. Comprehensive zoning secure steadily decreased from 2016 to 2017, but the constant changes from 2018 up to 2020. The decrease is due to secure broad zoning factor urging residents and industrial and limitations of green open land.

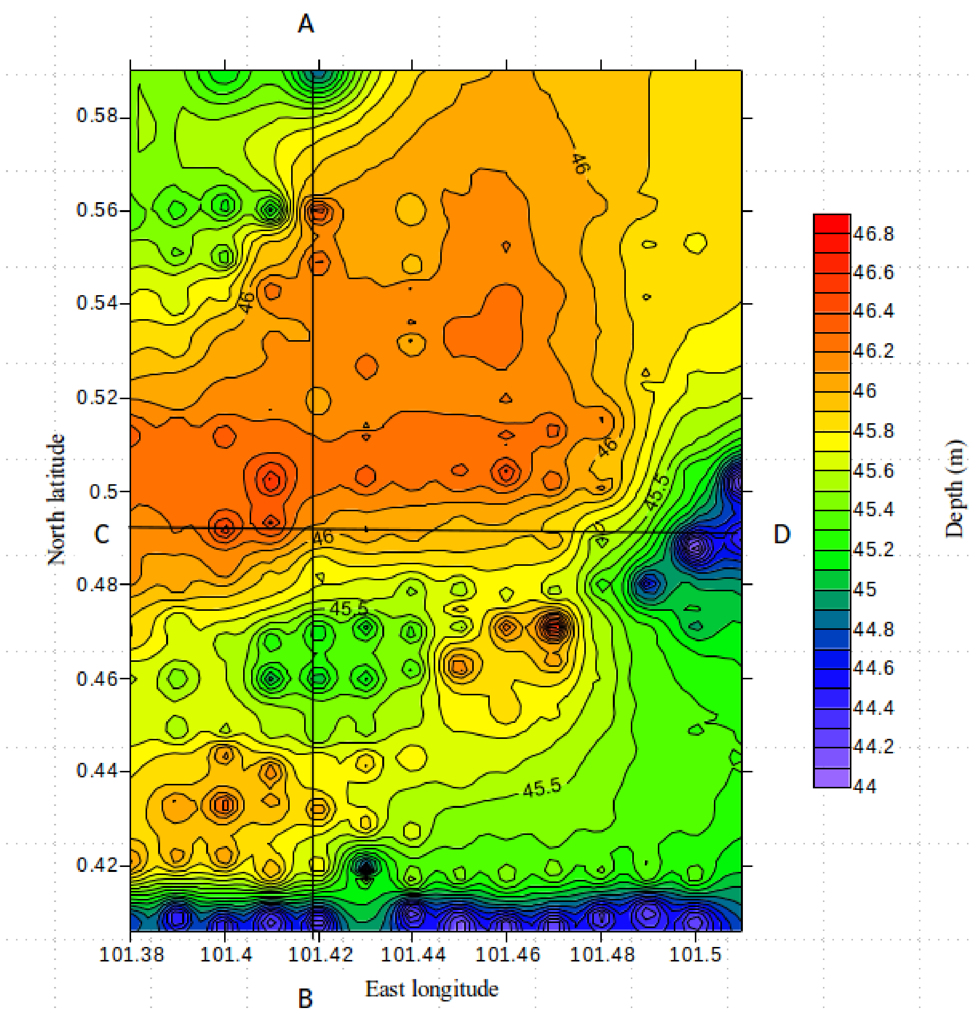

Figure 5. Mapping 2D depth of the unconfined aquifer of Pekanbaru 2015.

A constant pattern in 2018 until 2020 showed that there was no change in the industry factor and land conservation. This means that the factor urging residents to have little effect on changes in the aquifer. Need additional catchment areas to address zoning unsafe.

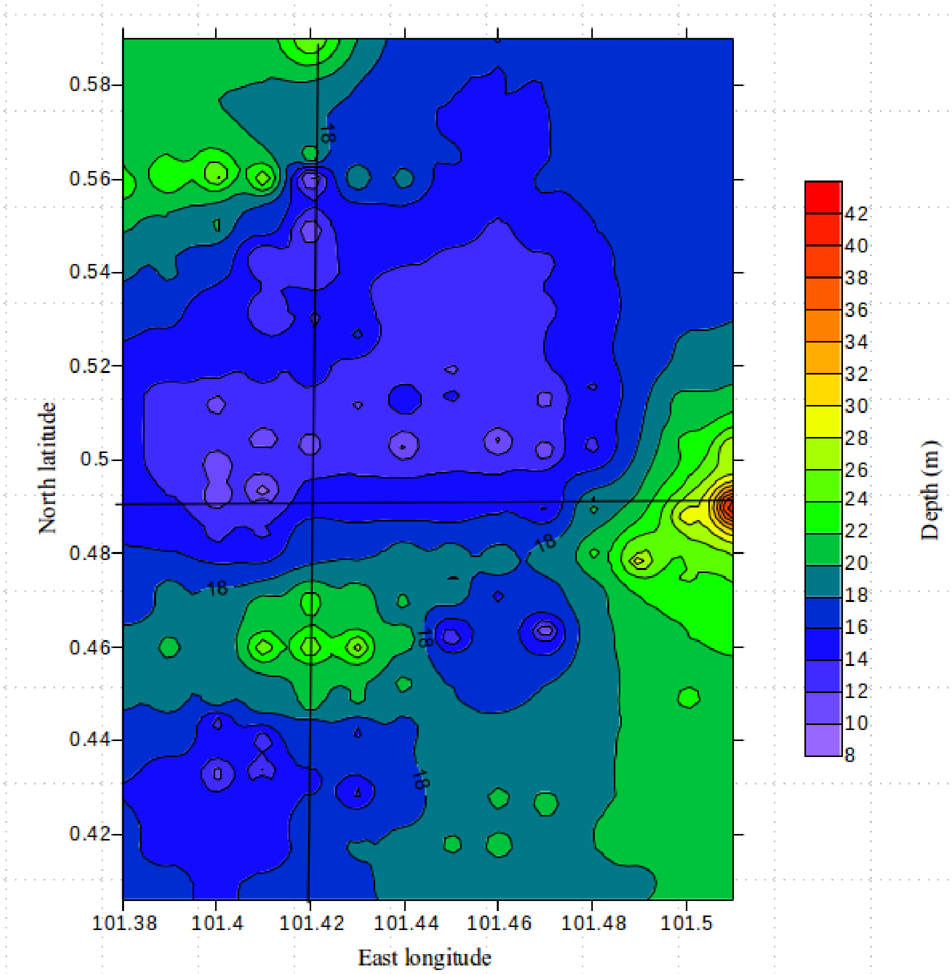

Figure 6. The predictive depth of the unconfined aquifer of Pekanbaru 2020.

Value zoning unconfined aquifer is obtained by comparing the depth of the unconfined aquifer in the destination with the value of the depth of the unconfined aquifer early 2015, when the percentage difference is >80% said damaged zone or behavior anthropocentrism. Safe zone or behavior biocentrism decreased water level of the unconfined aquifer smoking <40% of the original value, in order to obtain a zoning unconfined aquifer as shown in Figure 7. Based on Figure 8 it can be seen that the total area of the zoning secure 2016 and 2020 respectively is 169.05 km^2; 3.76 km^2; 3.76 km^2; 3.76 km^2 ;0 km^2, while the total area of insecurity is 0 km^2; 165.29 km^2; 165.29 km^2; 165.29 km^2 and 169.05 km^2.

The pattern of zone of the unconfined aquifer are based cross-sectional CD observed is shown in Figure 8, that the pattern of zone secure the unconfined aquifer 2016 and 2020 has decreased, this was due to the insistence of the population and industry, while the pattern of constant 2018 until 2020, it is due to the influence of environmental factors that are not much affect the unconfined aquifer conditions. Zoning patterns insecure 2016 to 2020 showed a pattern increases, it due to lack of land conservation factor and the insistence of the population, while the constant value indicates that the small population insistence factor influence. In general pattern similar to the pattern AB profile CD profile, meaning characteristics physical properties of the earth has the same effect both on the cross section AB and CD.

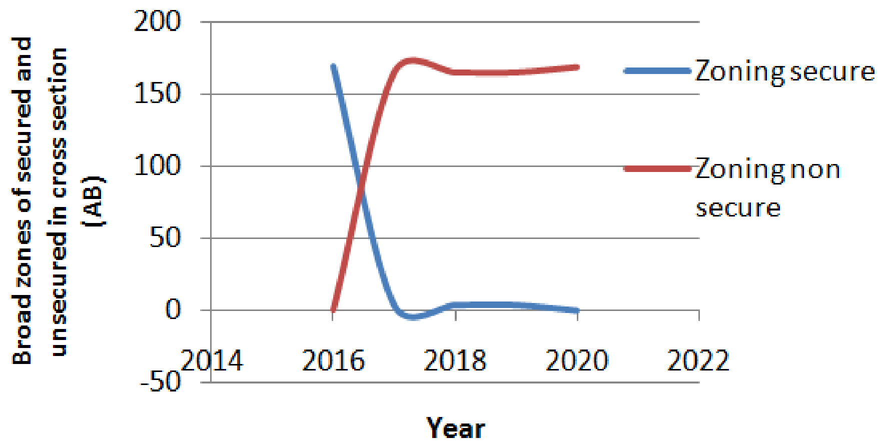

Figure 7. Chart comprehensive zoning secure and non-secure unconfined aquifer of Pekanbaru in cross section (A-B) in 2016-2020.

Analysis of unconfined aquifer zoning is obtained by comparing the depth of the unconfined aquifer in the destination with the value of the depth of the unconfined aquifer early 2015, when the percentage difference is > 80% said damaged zone or behavior anthropocentrism. safe zone or biocentrism behavior decreased water level of the unconfined aquifer smoking <40% of the original value, thus obtained Figure 4. According to Figure 4 can be seen that the zoning secure occurred in 2016 with a total area of 228.93 km2, while the area of zoning unsafe occurred in 2017 until 2020 with an area of each zone is not safe at 228.93 km2.

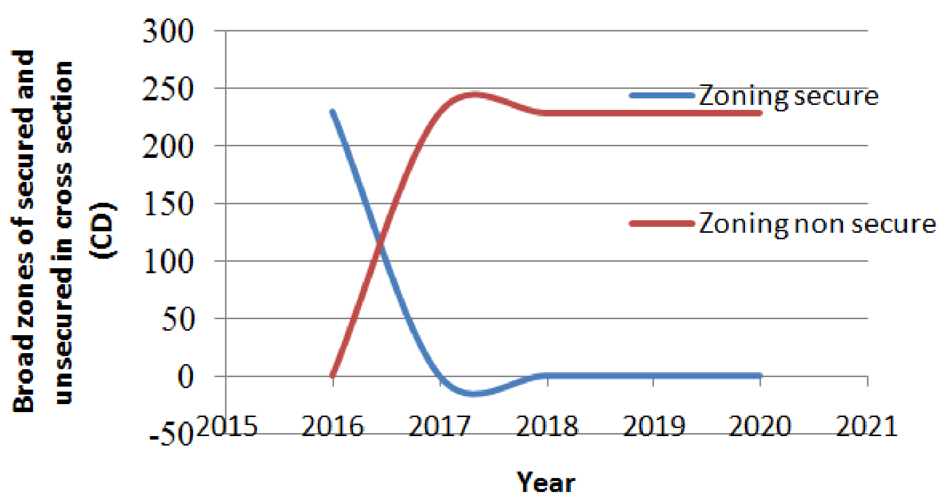

Figure 8. Chart comprehensive zoning secure and non-secure unconfined aquifer of Pekanbaru in cross section (C-D) in 2016-2020

A comparison of the results of this study with the results of research conducted by Subastaryo 2003 is just to say that conservation index < 0.75 for the condition of underground water and has not been able to predict the conservation index the following years, and only provide conservation policy proposals (Subastaryo, 2003). However, this study was able to give a quantitative conditions unconfined aquifer in Pekanbaru City until 2020.

Based on reviews these results by taking into account models that have been researched can be said that the city of Pekanbaru is still a shortage of green space land for water absorption, so the government needs to conduct a policy for the addition of artificial recharge. The results of this study are supported by Riswandi 2006 the says that the number of green open space macros to Pekanbaru not suffice; there are flaws with 12,499.27 ha area (Riswandi, 2006)

CONCLUSION

Based on this research it can be concluded that there has been damage to underground water resources characterized by the formation of zoning which is not safe at the unconfined aquifer of Pekanbaru City from 2016 until 2020 which is tending to increase. Damage to water resources is there because of the insistence of the population, industry and limited land for the conservation of ground water recharge. A secure zoning pattern for the unconfined aquifer in Pekanbaru tends to decline from 2016 to 2020.

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