Application SWAT Model for Hydrological Study of Artificial Recharge Through Infiltration Pond in The Water Replenishment, at Jubel Spring Mojokerto Indonesia

By

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Overview

• SWAT development in Indonesia
• Back Ground and Introduction
• Method
• Discussion
• Conclusion
Introduction of SWAT Developing in Indonesia

• 2012   Bogor SWAT Scholl
• 2013   SWAT International conference
• 2014   SWAT School and training extend in 28 Provinces in Indonesia
• 2015   SWAT Legal Basis by government (Ministry of Environment and Forestry) for modeling, evaluating and monitoring watershed in Indonesia
◆ Bogor SWAT School
(27-29 June 2012)
Sprit of SWAT School...
Yes  We Can !!
SWAT Conference at Bogor 16-22 Juni 2013
Agencies which application SWAT in Indonesia

- University
- Ministry of environment and Forestry
- Regional office Planning
- Department of Agriculture
- NGOs
- Regional water resources officer
SWAT MODEL APPLICATION IN INDONESIA

Published: Jubel, Mojokerto

- Krueng Jreu Sub watershed
- Upper Ciliwung Watershed
- Jatiluhur Reservoir Catchment Area
- Keduang Watershed
- Palu Watershed
- Cidanau Watershed
- Manjunto Watershed
- Upper Cisadane Watershed
Mojokerto

Terrain, settlements and land use: the environment of Mojokerto springs, Jubel, on Mt Arjuno-Welirang, 50km south of Surabaya.
Introduction

- Indonesia Urban Water, Sanitation and Hygiene Project (WR IUWASH Project) is to assess the impact of an intervention, infiltration ponds, constructed to replenish aquifers at catchment areas feeding springs to improve the hydrological performance of watersheds.

- All infiltration ponds are already built and operating with dimension 2 m x 2m x 2m, the number of infiltration ponds located is 195 units.
Sumur resapan technology

Technology is innovative in providing a standardized design of the infiltration ponds appropriate to implementation at the household level. Anticipates high level of hydrological impact.

Source: David Hemson (2014)
Method

- SWAT model ver. 2012 was used to determine proper places of the infiltration wells, amount of time required by water to flow from infiltration point to water spring,
- In addition, the model allows us to distinguish which discharge coming from spring, seepage, lateral flow, base flow, and run-off.
Objectives

• To understand the hydrological process related to recharge and discharge of water spring or other water source.
• To determine the ability of land to retain rainfall through the infiltration process and its effect on the spring discharge
• To determine the ability of infiltration wells in replenishing ground water and its effects on the discharge
• To measure effect of infiltration wells to reduce run off and resiliencies in adaptation to climate change
Recharge area of Jubel Spring

- Administration area: Desa Claket, Cembor dan Nogosari di Kec. Pacet, Kab. Mojokerto
- Recharge area of spring: 311 Ha
- Soil type: andosol and litosol
- Texture: silty loam, permeability 7.4 cm/hour, AWC 19.1 %V, Bulk density 0.86 g/cm³
- Land cover: forest (28 %), residential (10 %) dry land agriculture (51 %) dan shrub (11 %).
- Elevation: 720 - 1978 m
- Slope class dominant: 15-25% (46.5 %), 25-40% (28.5 %), >40% (15.4 %).
Data from year 1998 – 2013

Average number of rainfall yearly 2,206 mm

Average mean air temperature 29.3 °C

Average relative humidity 71.3%

Average solar radiation 21.5 MJ/m²

Average wind speed 1.99 m/s

Ket: *) Station Mojosari, NCEP
Average solar radiation 585 W/m²
Average minimum air maximum 22 °C dan minimum 16 °C
Average minimum relative humidity 82 % & maximum 94 %
Wind speed is varied, ranging from 0.3 – 1 m/s (average 0.51 m/s).

Ket : *) Result from field measurement
Instrumentations:

1. Water level meter + Logger
2. Double ring infiltrometer
3. GPS
4. Automatic Weather Station
5. Current Meter
6. Soil moisture Sensor
### List of field activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil sampling</td>
<td>26</td>
</tr>
<tr>
<td>Soil moisture checker</td>
<td>44</td>
</tr>
<tr>
<td>Soil infiltration measurement</td>
<td>6</td>
</tr>
<tr>
<td>Infiltration well rate measure</td>
<td>34</td>
</tr>
<tr>
<td>Pumping test at infiltration well</td>
<td>17</td>
</tr>
<tr>
<td>Community well</td>
<td>10</td>
</tr>
<tr>
<td>Community well pumping test</td>
<td>1</td>
</tr>
<tr>
<td>Spring discharge measurement</td>
<td>17</td>
</tr>
<tr>
<td>Automatic Water Station</td>
<td>1</td>
</tr>
</tbody>
</table>
List of Data Sources

• Climate data from BMKG Station Kota Salatiga (1983 – 2012)
• Climate data from BMKG station Mojosari Year (1998 – 2014)
• Spring of PDAM Salatiga City (2012)
• PDAM Mojokerto (Sept 2013 – March 2014)
• Hydrogeology map (1 : 250.000 : Yogyakarta sheet year 1982 Geology Research center, Bandung
• Kediri sheet year 1984 (Geology and Environment Research center, Bandung,
• Land use map (1 : 100.000 Forestry Department 2011, was correction with Quick Bird image from Google Earth year 2013
• Soil map 1:250.000 Land system map (Reppprot, 1986) Land research center, Bogor
• Topography map ( Spatial resolution 30 m (DEM SRTM)
Land Use / Land Cover

- Brush & shrub
- Natural Forest
- Residential
- Pine Forest (Perhutani area)
- Dry land agriculture
Water tank simulation for infiltration well
Field Measurement Activity

Sumur Resapan Claket Village

Sumur resapan Perhutani Area

Susteran Carmel, Claket Village,
Soil moisture instrument
Hydrology instruments
**Location of Infiltration Wells has been Constructed**

<table>
<thead>
<tr>
<th>Land Use Types</th>
<th>Recharge Area of Jubel Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>forestry areas (pine forest)</td>
<td>95 units</td>
</tr>
<tr>
<td>residential area</td>
<td>34 units</td>
</tr>
<tr>
<td>mixed farming / Dry land agriculture</td>
<td>10 units</td>
</tr>
<tr>
<td>Total</td>
<td>139 units</td>
</tr>
</tbody>
</table>
Sample of Infiltration Wells at field

Infiltration pond at agricultural land. Control box was filled by sediment (Padusan Village, Mojokerto)

Infiltration pond at residential area in good condition (Claket Village, Mojokerto)

Infiltration pond at pine forest area. Control box, about 40%, was filled by sediment
Infiltration wells have been constructed at residential area more effectively than dryland/shrub area or pine forest area.
Infiltration wells have been constructed at residential areas more effectively than dry land/shrub area or pine forest area.
Accumulation infiltration at residential more larger than infiltration at pine forest area and dry land / shrub
Spring discharge is used to calibrate the model.

Spring discharge is obtained from PDAM Mojokerto.

Data measurement date of September 9, 2013 - March 24, 2014.
Calibration & Sensitivity Analysis

- There are 12 parameters in the model input to calibrate and sensitivity analysis.
- Calibration and Sensitivity Analysis use Software SWAT CUP version 5.1.6 (2012) with algorithm Sequential Uncertainty Fitting Ver.2 (SUFI2).
Comparing Simulation of Jubel Spring discharge with Observation

- Coefficient of determination ($R^2$) = 0.82
- Parameter yang paling sensitive: GW_DELAY, ALPHA_BF, CH_K1 dan GWHT
• The model developed was calibrated and then retested to ensure that it effectively models the past and present spring discharge. The relationship between the observed data and data from the SWAT model has a coefficient of determination $R^2 = 0.8231$.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
<th>Min</th>
<th>Max</th>
<th>default</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPHA_BF</td>
<td>Baseflow alpha factor</td>
<td>days</td>
<td>0</td>
<td>0.05</td>
<td>0.048</td>
<td>0.015</td>
</tr>
<tr>
<td>GW_DELAY</td>
<td>Groundwater delay</td>
<td>days</td>
<td>0</td>
<td>500</td>
<td>31</td>
<td>351.3</td>
</tr>
<tr>
<td>GWQMN</td>
<td>Threshold depth of water in the shallow aquifer required for return flow to occur</td>
<td>mm</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1.65</td>
</tr>
<tr>
<td>GWHT</td>
<td>Initial groundwater height</td>
<td>m</td>
<td>0</td>
<td>25</td>
<td>1</td>
<td>15.125</td>
</tr>
<tr>
<td>CH_K1</td>
<td>Manning's &quot;n&quot; value for the tributary channels</td>
<td>mm/hr</td>
<td>0</td>
<td>300</td>
<td>55</td>
<td>52.5</td>
</tr>
<tr>
<td>CH_N1</td>
<td>Effective hydraulic conductivity in tributary channel alluvium</td>
<td></td>
<td>0.01</td>
<td>30</td>
<td>0.014</td>
<td>5.258</td>
</tr>
<tr>
<td>SOL_K</td>
<td>Saturated hydraulic conductivity</td>
<td>mm/hr</td>
<td>0</td>
<td>2000</td>
<td>750</td>
<td>890</td>
</tr>
<tr>
<td>SOL_AWC</td>
<td>Available water capacity of the soil layer</td>
<td>mm/mm</td>
<td>0</td>
<td>1</td>
<td>0.15</td>
<td>0.515</td>
</tr>
<tr>
<td>SOL_BD</td>
<td>Moist bulk density</td>
<td>gr/cm3</td>
<td>0.9</td>
<td>2.5</td>
<td>1.15</td>
<td>1.236</td>
</tr>
<tr>
<td>CH_N2</td>
<td>Manning's &quot;n&quot; value for the main channel</td>
<td></td>
<td>0</td>
<td>0.3</td>
<td>0.014</td>
<td>0.0315</td>
</tr>
<tr>
<td>CH_K2</td>
<td>Effective hydraulic conductivity in main channel alluvium</td>
<td>mm/hr</td>
<td>5</td>
<td>130</td>
<td>26</td>
<td>41.875</td>
</tr>
<tr>
<td>SURLAG</td>
<td>Surface runoff lag time</td>
<td></td>
<td>0.05</td>
<td>24</td>
<td>4</td>
<td>11.91</td>
</tr>
<tr>
<td>R²</td>
<td>Coefficient of determination (R²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.8231</td>
</tr>
</tbody>
</table>
# Impact of Infiltration Well to Reduce RunOff

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Parameter</th>
<th>Spring</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Jubel</td>
<td>m$^3$</td>
<td>%</td>
</tr>
<tr>
<td><strong>Without Infiltration well</strong></td>
<td>Total Run off/year</td>
<td>216,940</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td><strong>With Infiltration well</strong></td>
<td>Total Run off/year</td>
<td>203,182</td>
<td></td>
<td>93.66</td>
</tr>
<tr>
<td></td>
<td>Entry to infiltration well</td>
<td>13,758</td>
<td></td>
<td>6.34</td>
</tr>
<tr>
<td><strong>Number of infiltration well</strong></td>
<td></td>
<td>139 unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recharge area of spring</strong></td>
<td></td>
<td>311.37 Ha</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Scenario Impact of Infiltration Well to spring Discharge

<table>
<thead>
<tr>
<th>Spring</th>
<th>Number of infiltration well (Unit)</th>
<th>Increase in Discharge (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jubel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing</td>
<td>139</td>
<td>0.6</td>
</tr>
<tr>
<td>Planning</td>
<td>195</td>
<td>1.2</td>
</tr>
<tr>
<td>Maximum</td>
<td>511</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Jubel Springs characteristic

• Ratio of ground water/total flow : 0.66
• Ratio streamflow run off/total flow : 0.34
Impact of Development Infiltration pond with Spring Discharge at Jubel Spring

Average increasing 0.6 l/s

Delay 351 day

With Infiltration pond

No infiltration pond
Conclusion

• GW_Delay factor (ground water delay), ALFA_BF (base flow alpha factor), and CH_KI (Manning’s “n” for tributaries), related to land cover type, affect the size of the discharge at Jubel springs. Travel time is 357.3 days, almost 1 year, indicating that holding capacity and ability to retention the water is long enough in Catchment Jubel, thus increasing or decreasing rainfall and land cover changes will be impact to spring discharge on the next year.

• The average amount of surface run-off that could be captured by infiltration ponds was 98.9 m³/well/year. As indicated through the SWAT analysis, construction of infiltration ponds can improve the flow of springs, 0.28 l/s.

• The decrease in surface run-off in 6.34%. Increased spring discharge results in more water being available to the population, and less seasonal fluctuation.

• Construction of 1 unit of infiltration pond in the catchment areas can increase the number of customers 3 people.

• These indicate that the SWAT represents field conditions accurately with R² =0.82.
Thank You