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 !!

ROLE OF SWAT IN WATERSHED MANAGEMENT PLANNING AND EVALUATION

3RD SWAT (SOIL AND WATER ASSESSMENT TOOL) WORKSHOP & CONFERENCE
IN SOUTH EAST & EAST ASIA (SWAT SEEA III)
Jakarta & Bogor, Indonesia, June 16-22, 2013

LANDCON 1306

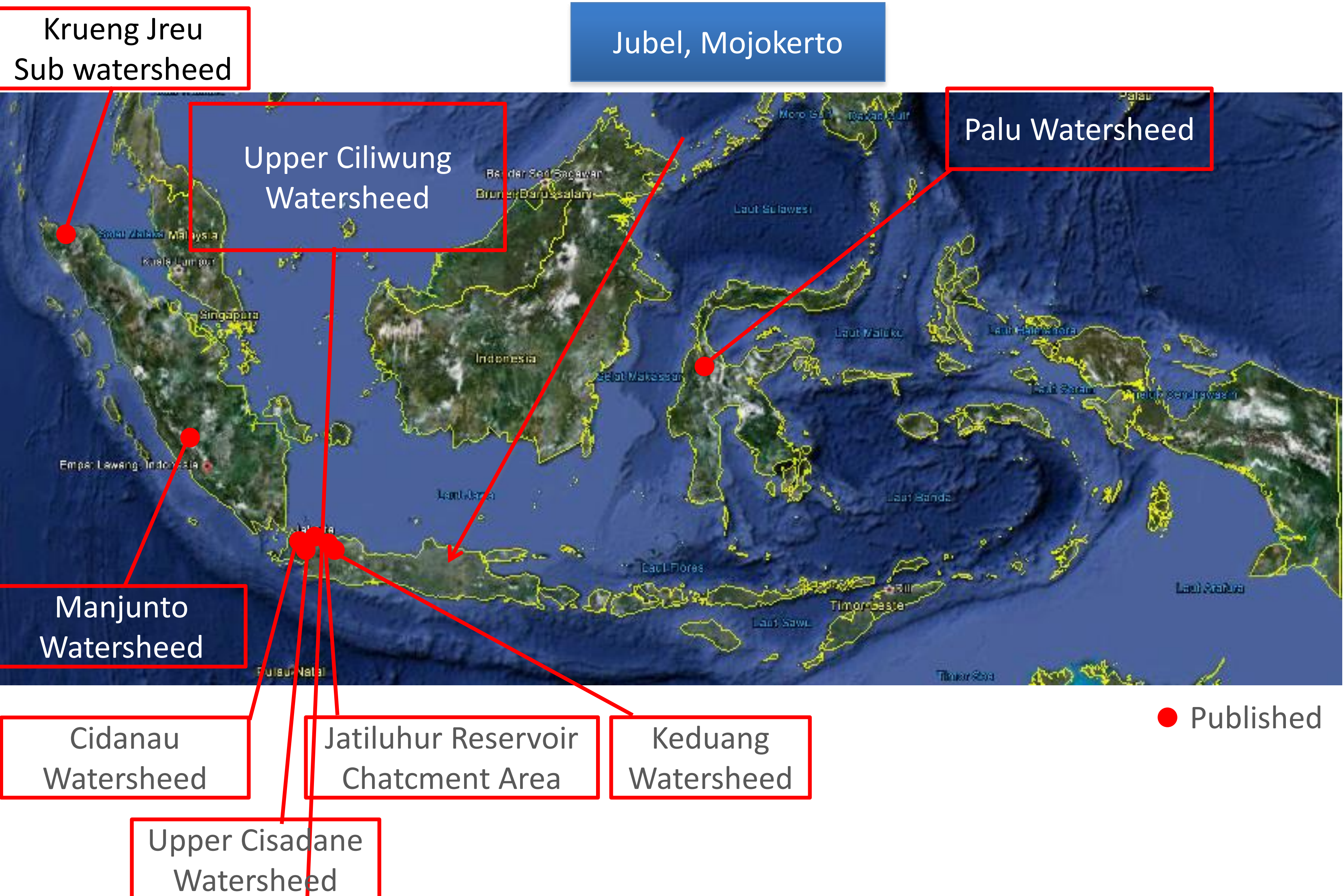
17 JUNE WORLD DAY TO COMBAT DESERTIFICATION

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 Agricultuliur
- NGOS
- Regional water resources officer

SWAT MODEL APPLICATION IN INDONESIA



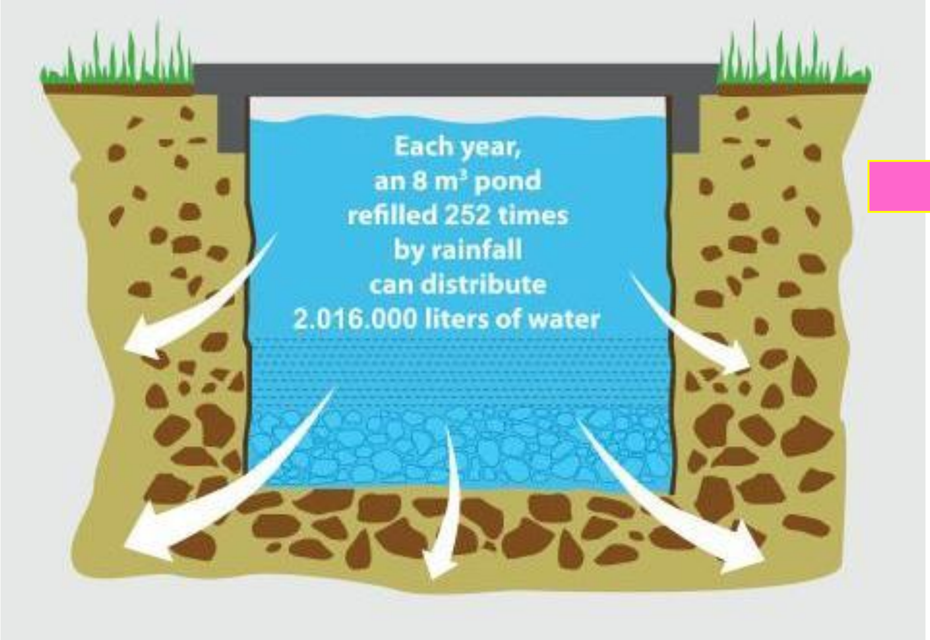
Mojokerto

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)

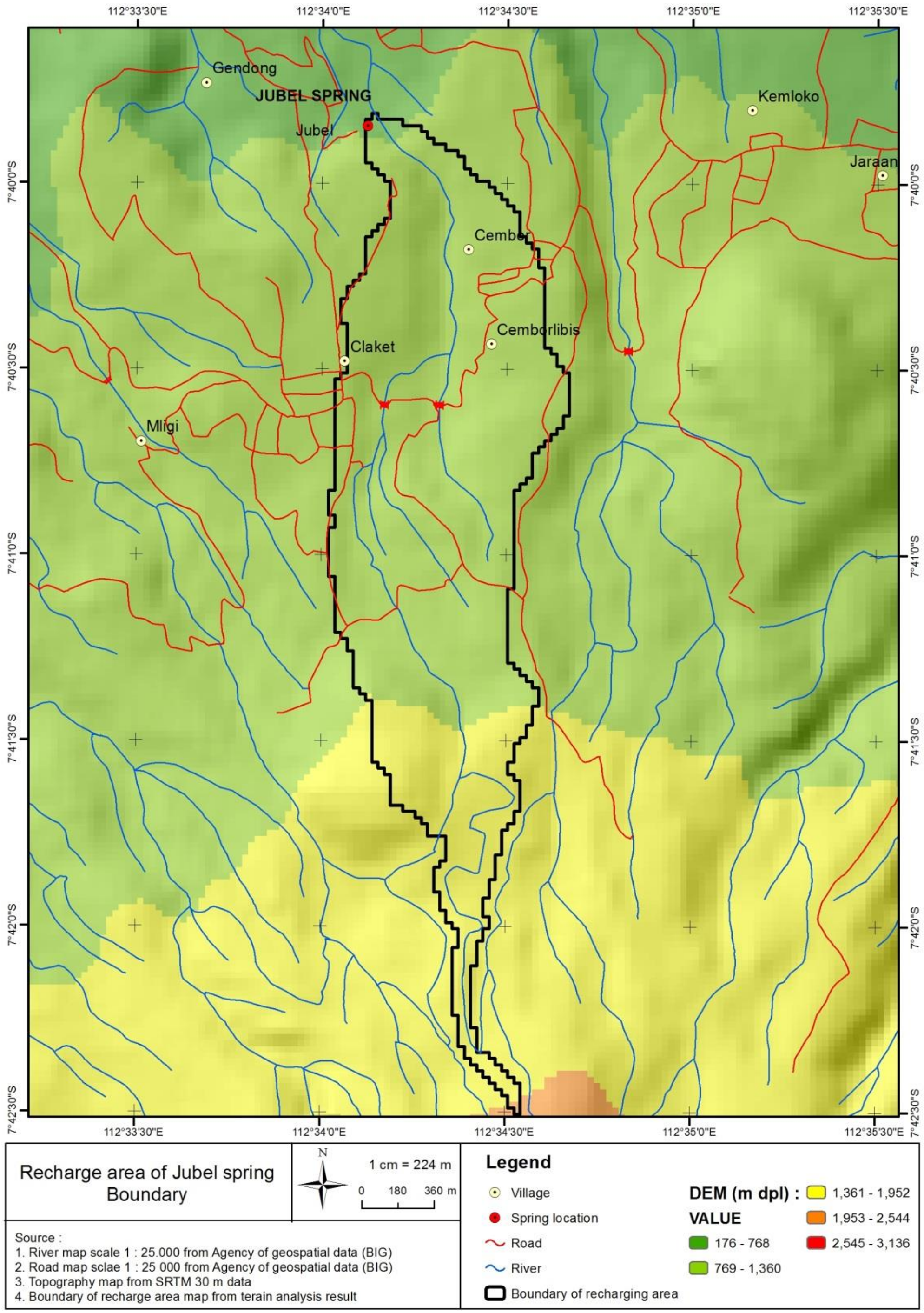
Method

- 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

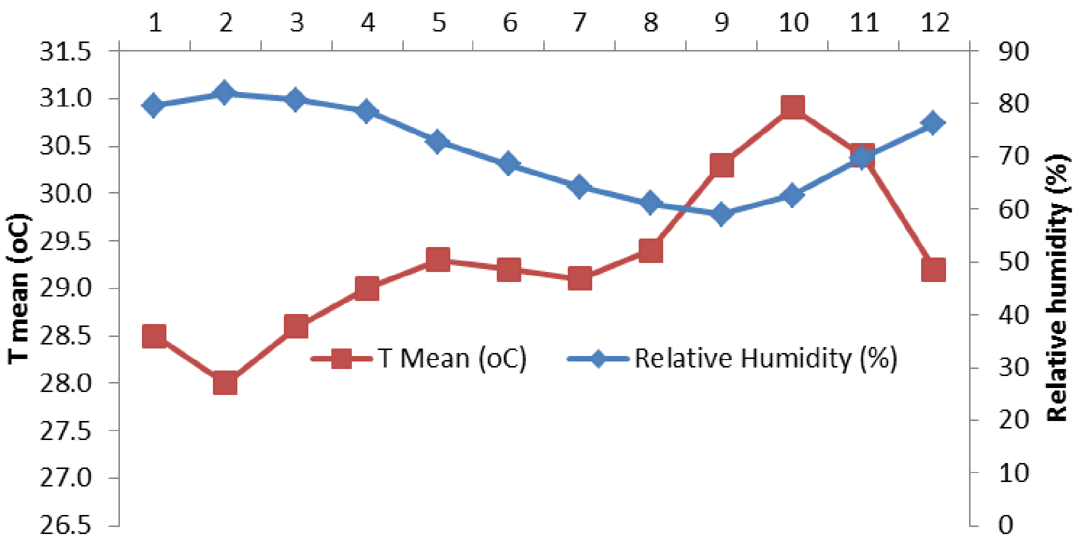
- To understand the hydrological process related to recharge and discharge of water spring or other water source.
- To determine the ability of land to retain rainfall through the infiltration process and its effect on the spring discharge
- To determine the ability of infiltration wells in replenishing 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

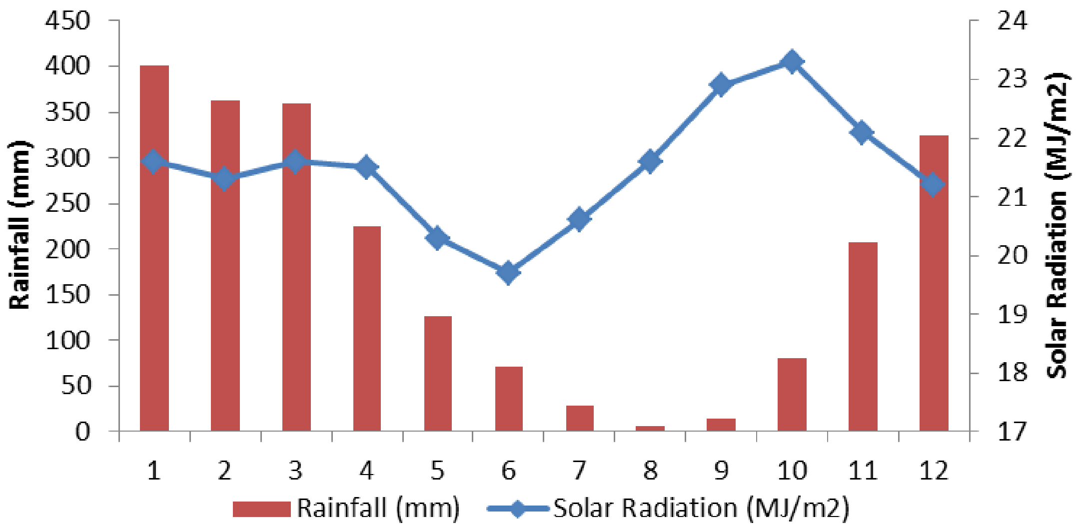
Recharge area of Jubel Spring



- Administration area : Desa Claket, Cembor dan Nogosari di Kec.Pacet, Kab. Mojokerto
- Recharge area of spring : 311 Ha
- Soil type : andosol and litososl
- Texture silty loam, permeability 7.4 cm/hour, AWC 19.1 %V, Bulk density 0.86 g/cm^3
- 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 %).

Climate

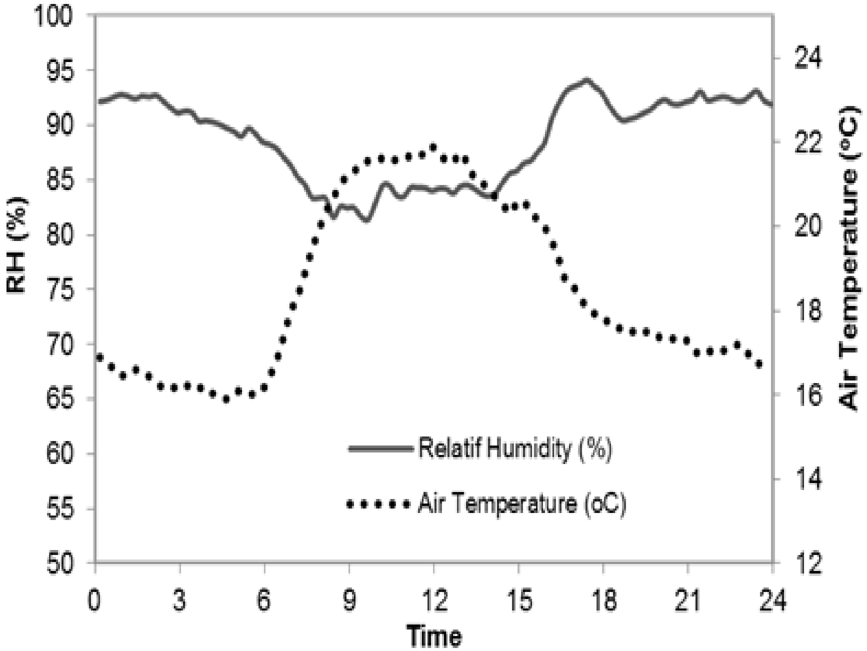


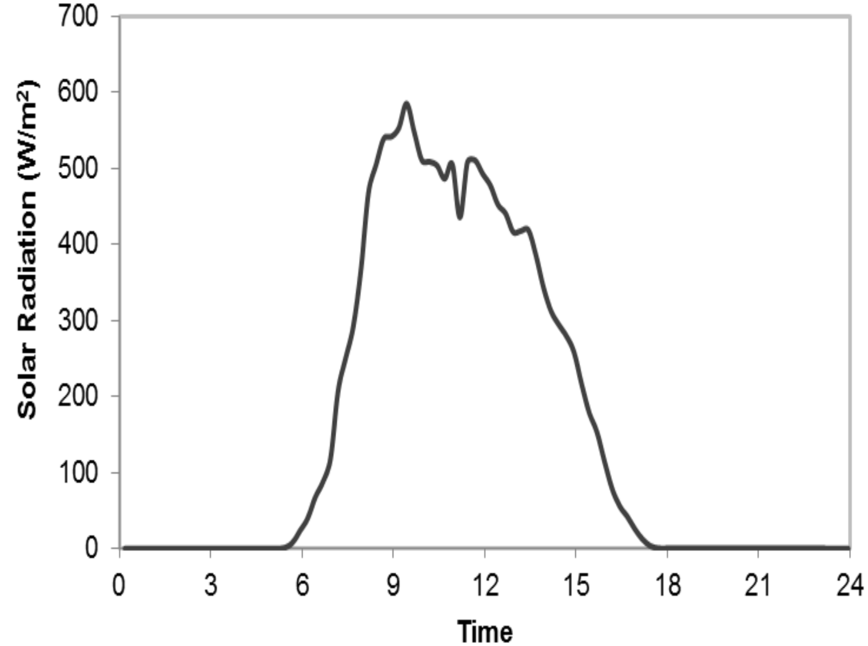


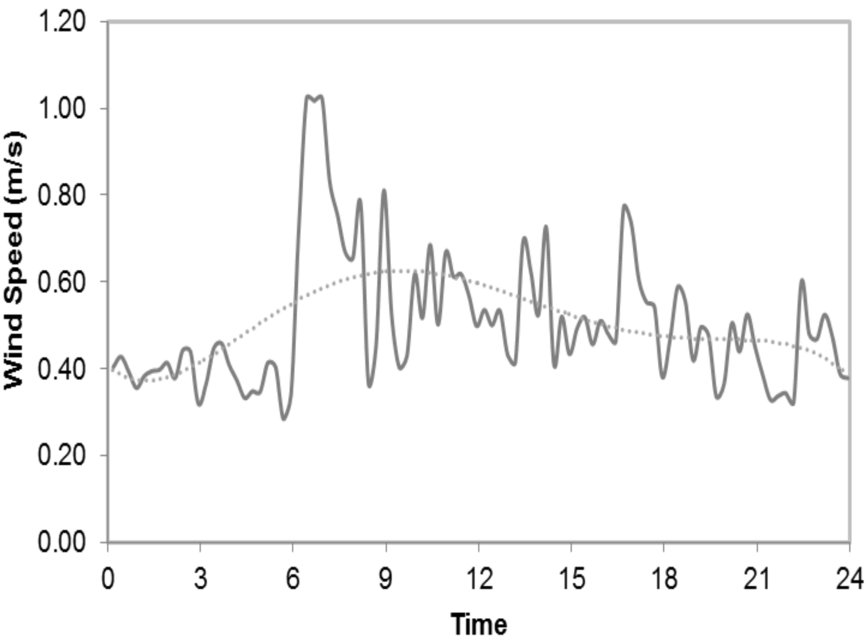
Seasonal Variation*

- Data from year 1998 – 2013*
- Average number of rainfall yearly 2,206 mm
- Average mean air temperature 29.3 ^{o}C
- Average relative humidity 71.3 %
- Average solar radiation 21.5 MJ/m^2
- Average wind speed 1.99 m/s

Ket : *) Station Mojosari, NCEP







Diurnal Variation*

- Average solar radiation 585 W/m^2
- Average minimum air maximum 22 ^oC dan minimum 16 ^oC
- 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

	Mojokerto
Soil sampling	26
Soil moisture checker	44
Soil infiltration measurement	6
Infiltration well rate measure	34
Pumping test at infiltration well	17
Community well	10
Community well pumping test	1
Spring discharge measurement	17
Automatic Water Station	1

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List of Data Sources

- Climate data from BMKG StationKota 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

Pine Forest (Perhutani area)

Natural Forest

Residential

Dry land agriculture

Water tank simulation for infiltration well

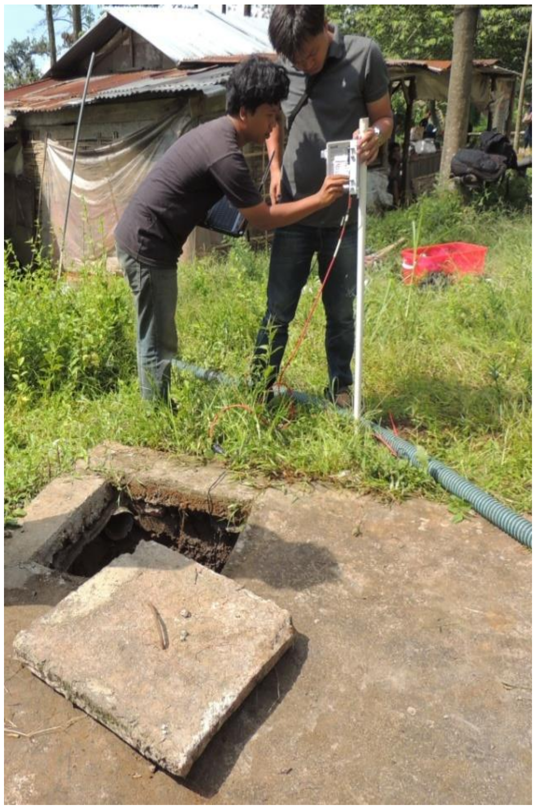
Field Measurement Activity

Sumur Resapan Claket Village

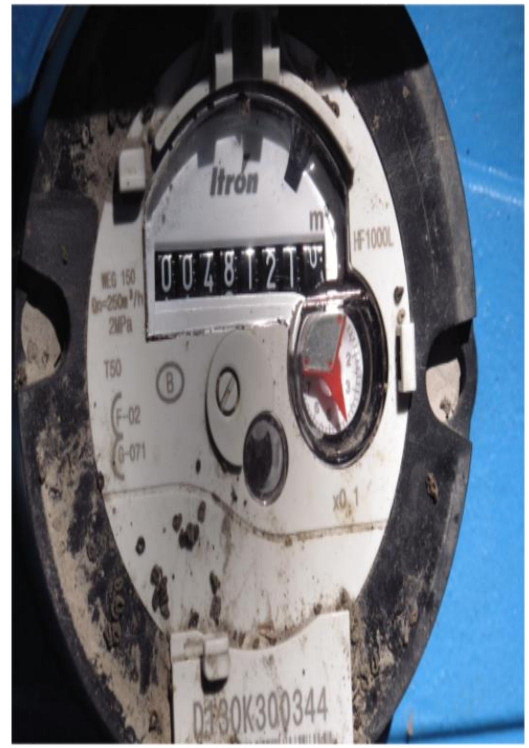
Sumur resapan Perhutani Area

Susteran Carmel,
Claket Village,

Soil moisture instrument



Hydrology instruments



Location of Infiltration Wells has been Constructed

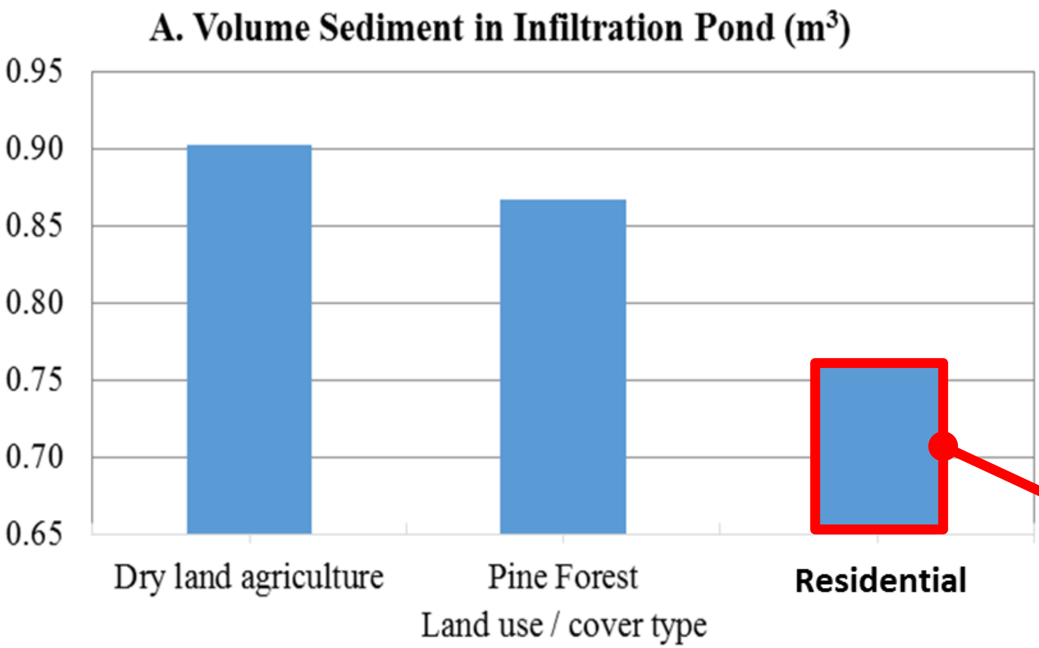
Land Use Types	Recharge Area of Jubel Spring
forestry areas (pine forest)	95 units
residential area	34 units
mixed farming / Dry land agriculture	10 units
Total	139 units

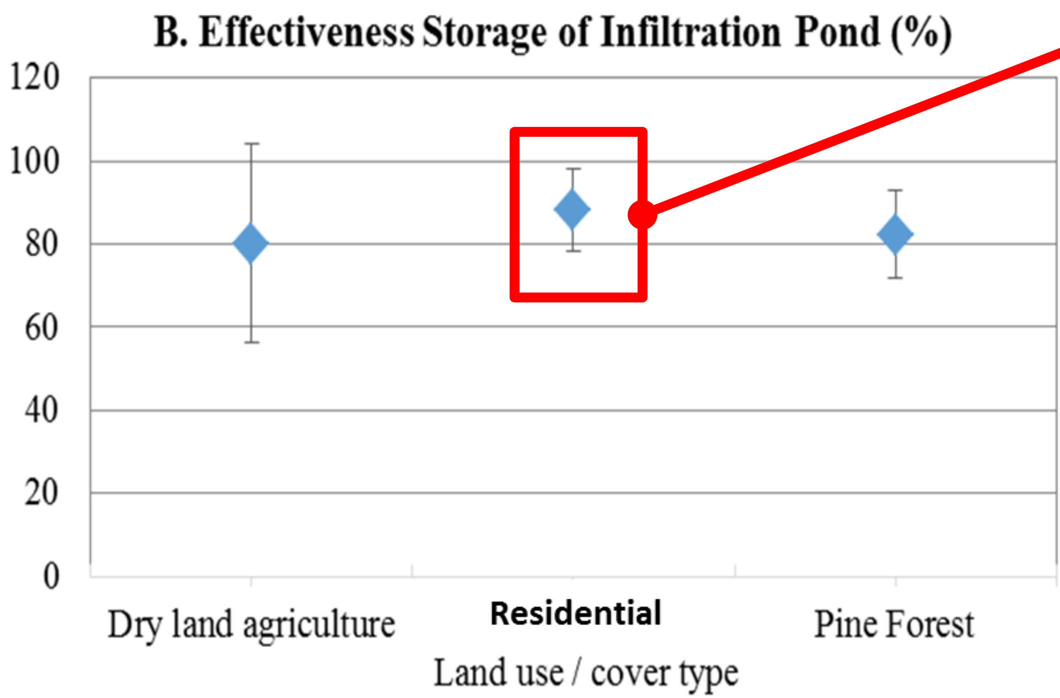
Sample of Infiltration Wells at field

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)

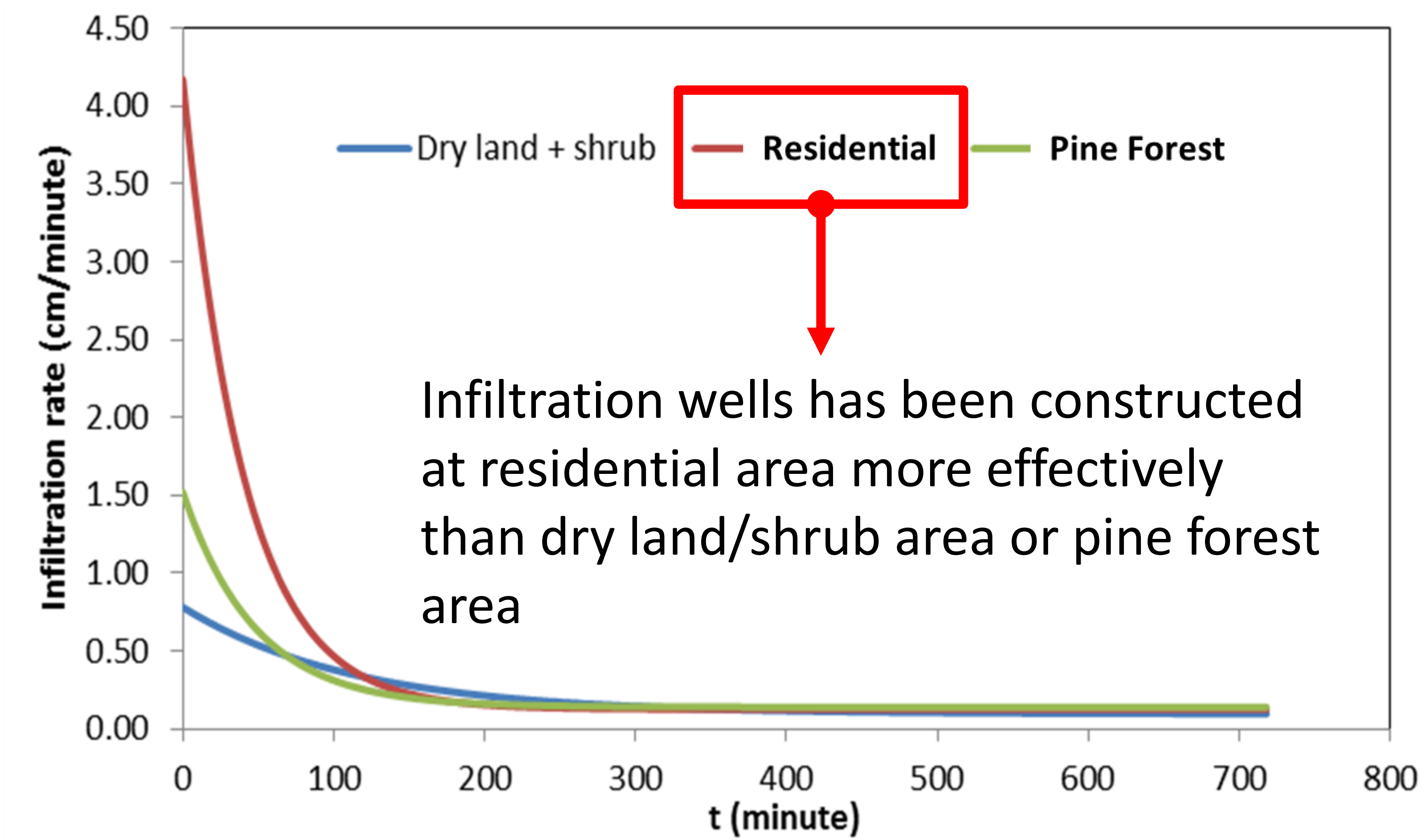
Infiltration pond at pine forest area.
Control box, about 40% , was filled by sediment

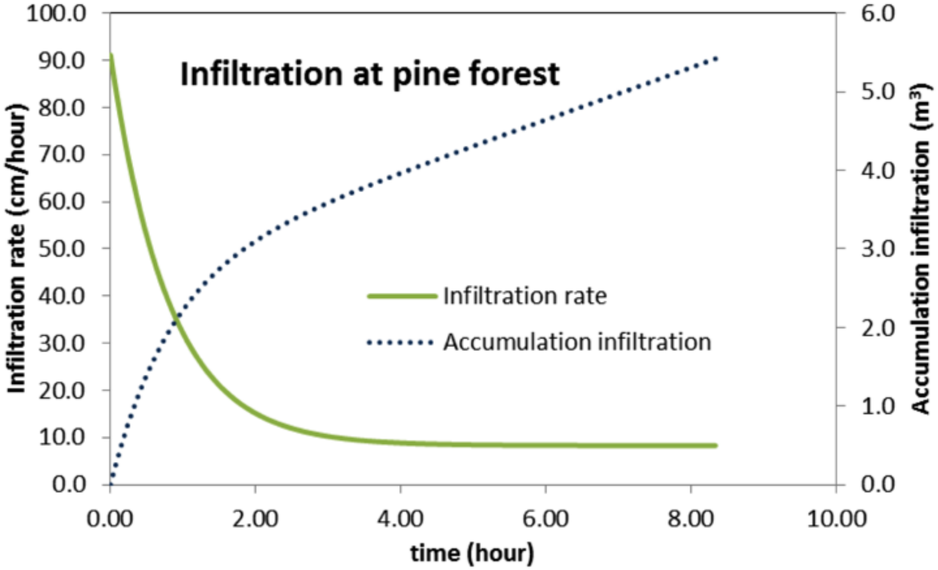


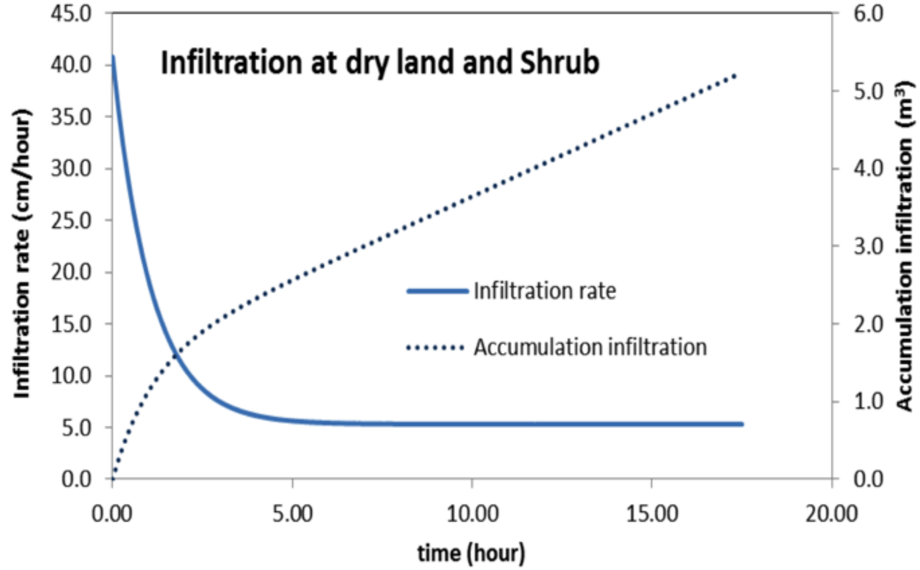


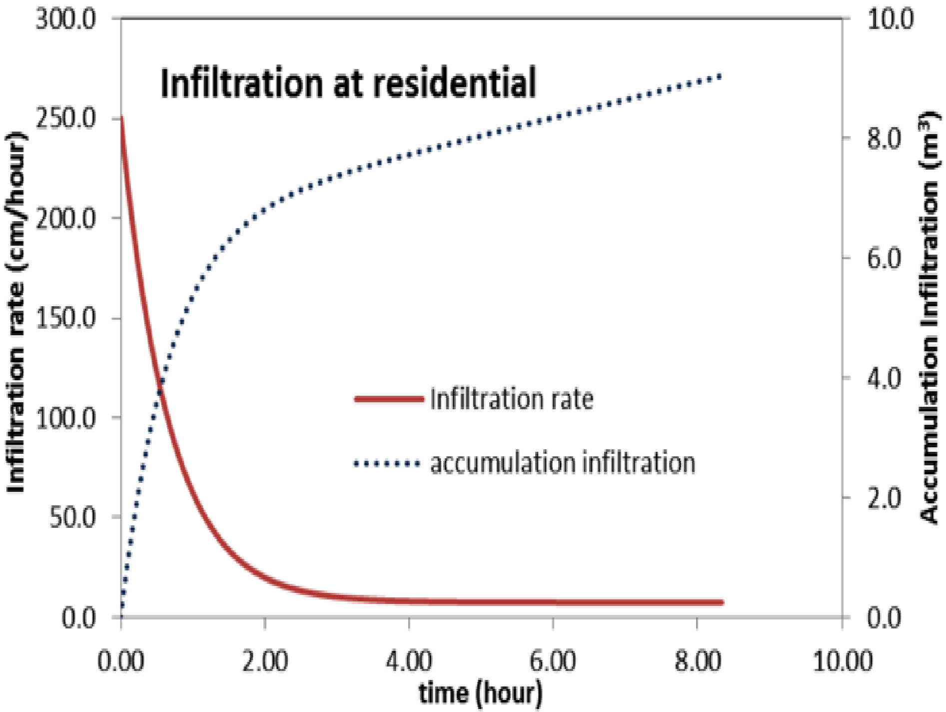
Infiltration wells has been constructed at residential area more effectively than dryland/shrub area or pine forest area

Infiltration Rate at different land use and soil type



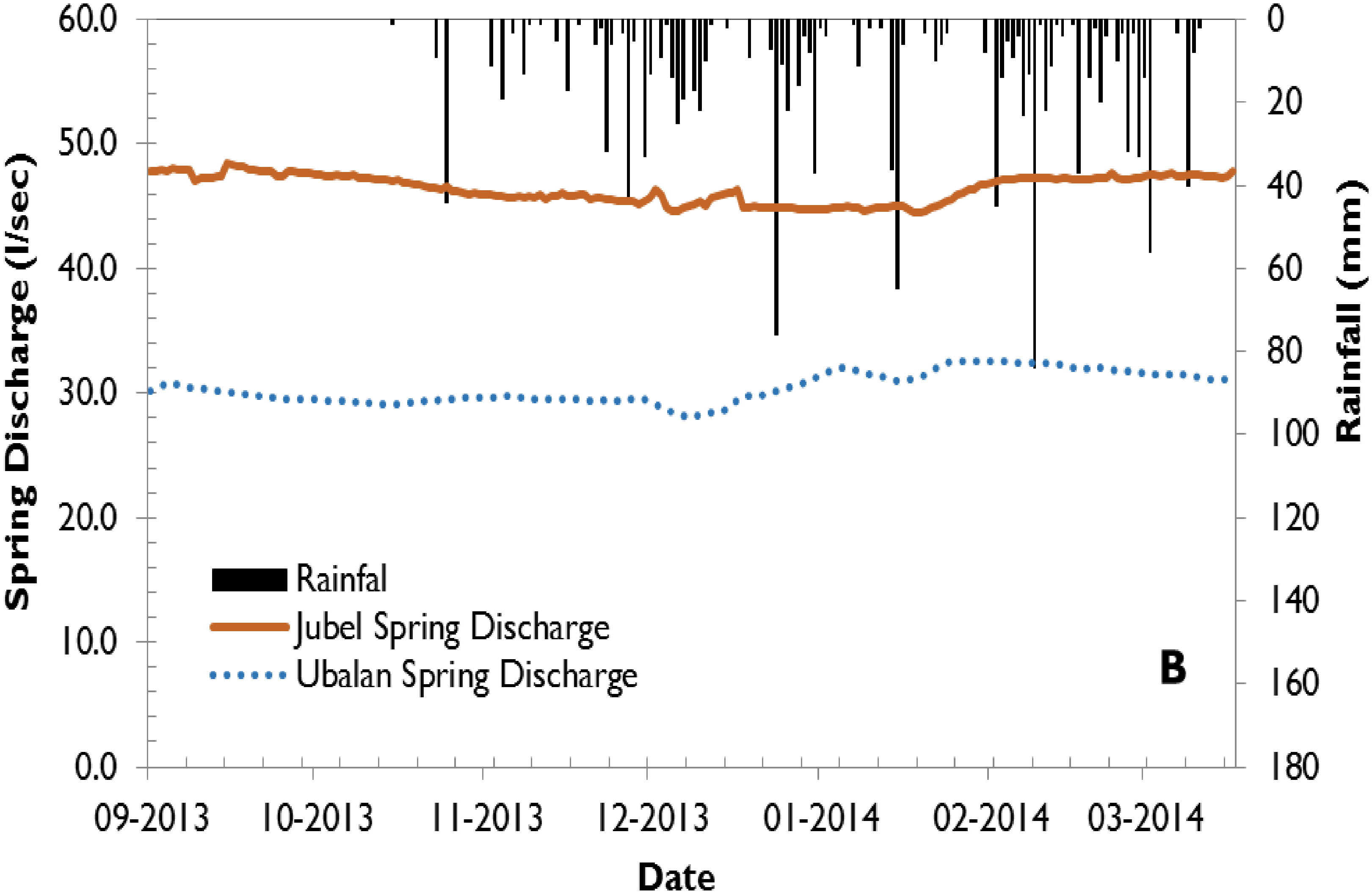






- Accumulation infiltration at residential more larger than infiltration at pine forest area and dry land / shrub

Discharge of Spring

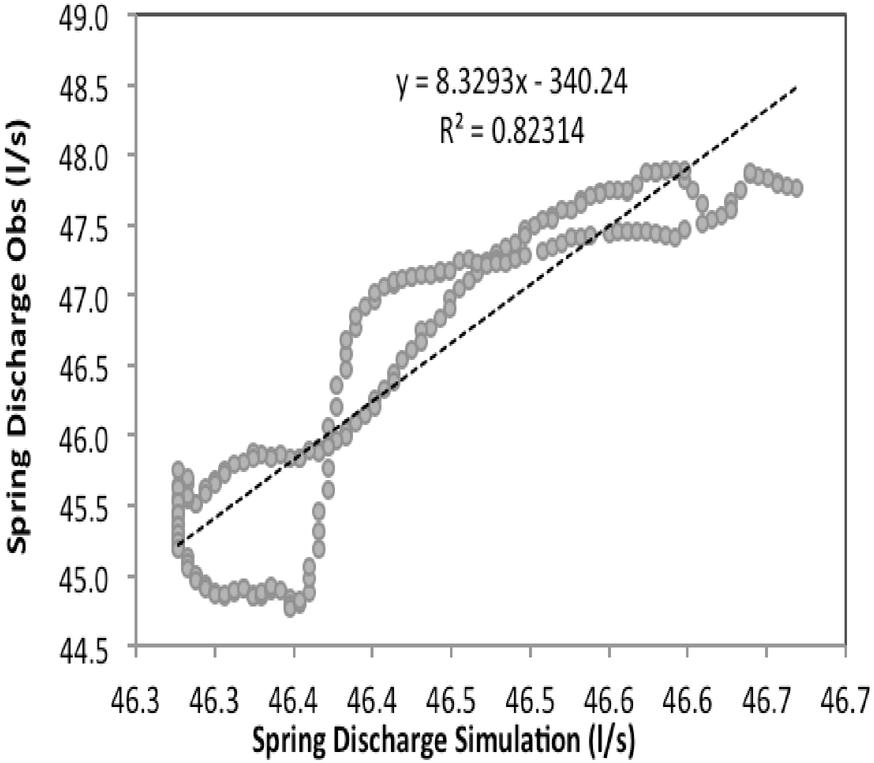


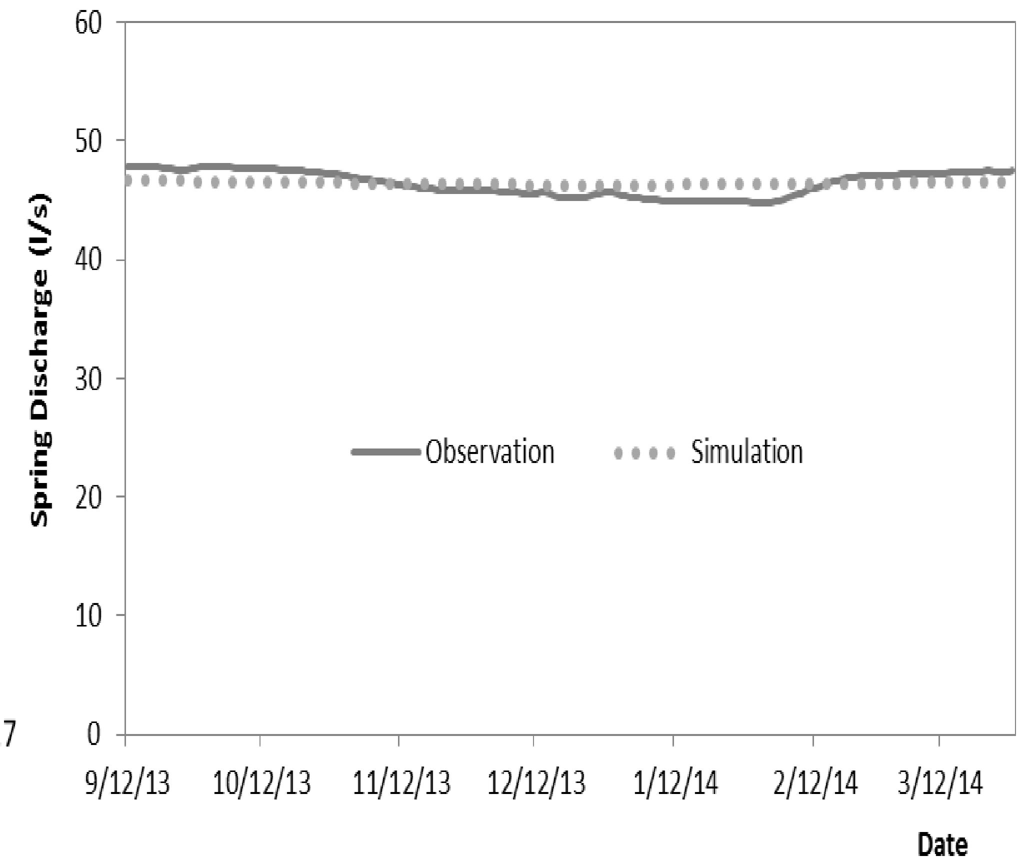
- ❑ Spring discharge is used to calibrate the model
- ❑ Spring discharge is obtained from PDAM Mojokerto
- ❑ Data measurement date of September 9, 2013 - March 24, 2014

Calibration & Sensitivity Analysis

- There are 12 parametesr 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 $R^2 = 0.8231$;.

Parameter	Description	Unit	Value			
			Min	Max	default	Calibration Jubel
ALPHA_BF	Baseflow alpha factor	days	0	0.05	0.048	0.015
GW_DELAY	Groundwater delay	days	0	500	31	351.3
GWQMN	Treshold depth of water in the shallow aquifer required for return flow to occur	mm	0	2	0	1.65
GWHT	Initial groundwater height	m	0	25	1	15.125
CH_K1	Manning's "n" value for the tributary channels	mm/hr	0	300	55	52.5
CH_N1	Effective hydraulic conductivity in tributary channel alluvium		0.01	30	0.014	5.258
SOL_K	Saturated hydraulic conductivity	mm/hr	0	2000	750	890
SOL_AWC	Available water capacity of the soil layer	mm/mm	0	1	0.15	0.515
SOL_BD	Moist bulk density	gr/cm3	0.9	2.5	1.15	1.236
CH_N2	Manning's "n" value for the main channel		0	0.3	0.014	0.0315
CH_K2	Effective hydraulic conductivity in main channel alluvium	mm/hr	5	130	26	41.875
SURLAG	Surface runoff lag time		0.05	24	4	11.91
Coefficient of determination (R^2)						0.8231

Impact of Infiltration Well to Reduce RunOff

Treatment	Parameter	Spring	
		Jubel	
		m^3	%
Without Infiltration well	Total Run off/year	216,940	100
With Infiltration well	Total Run off/year	203,182	93.66
	Entry to infiltration well	13,758	6.34
Number of infiltration well		139 unit	
Recharge area of spring		311.37 Ha	

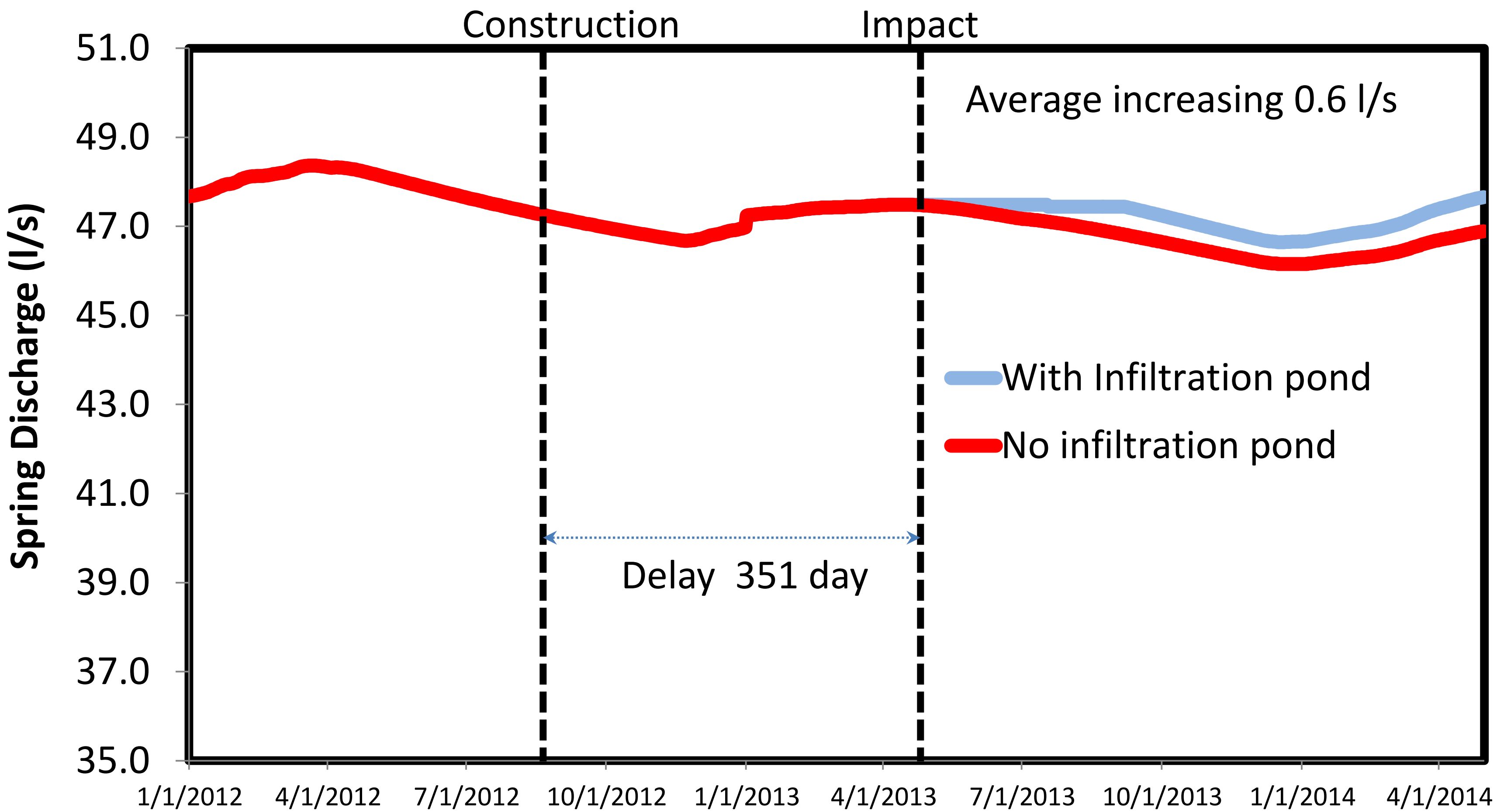
Scenario Impact of Infiltration Well to spring Discharge

Spring	Number of infiltration well (Unit)		Increase in Discharge (l/s)
Jubel	Existing	139	0.6
	Planning	195	1.2
	Maximum	511	5.5

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



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 m^3/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