Research results on Stormwater Harvesting at Pontificia Universidad Javeriana

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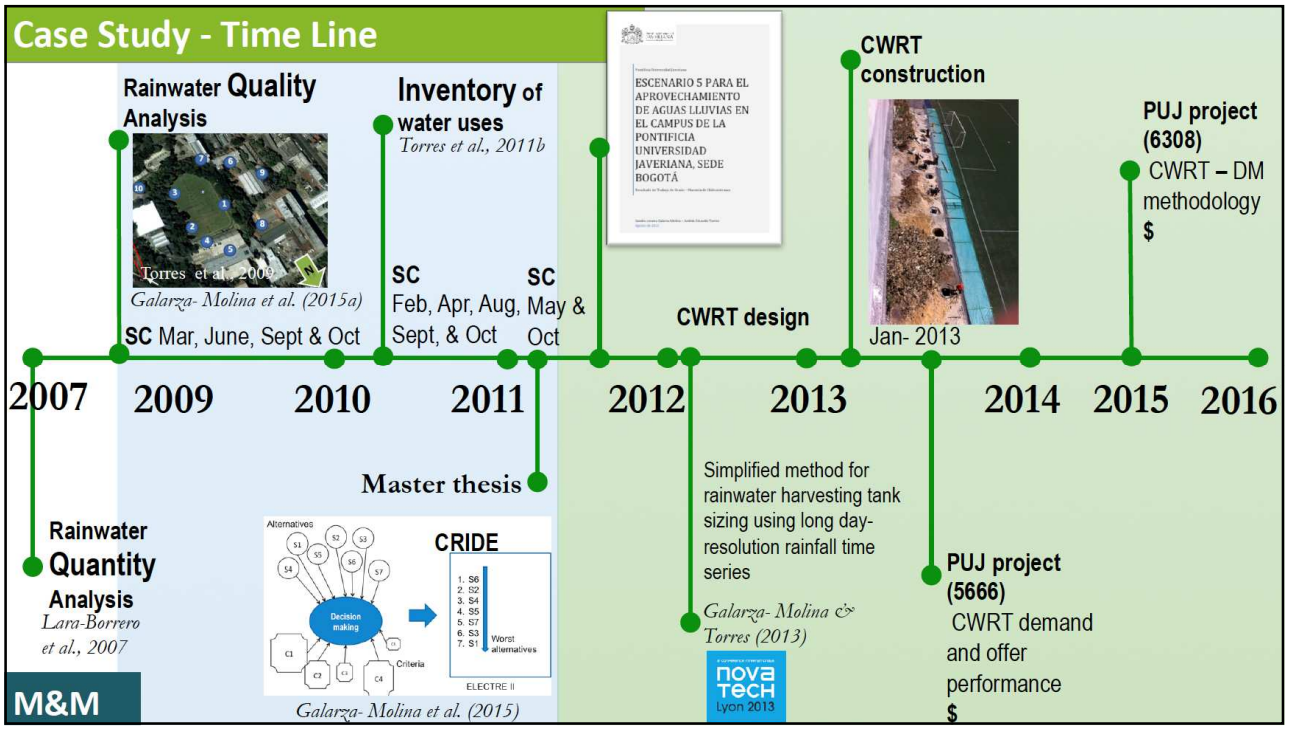
December 1st 2017



Case Study - Construction Process

January- 2013

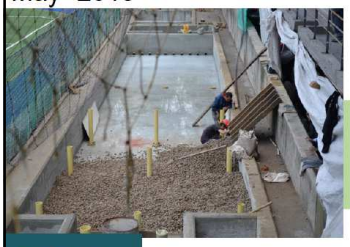
February- 2013

August 28 - 2015

June- 2013

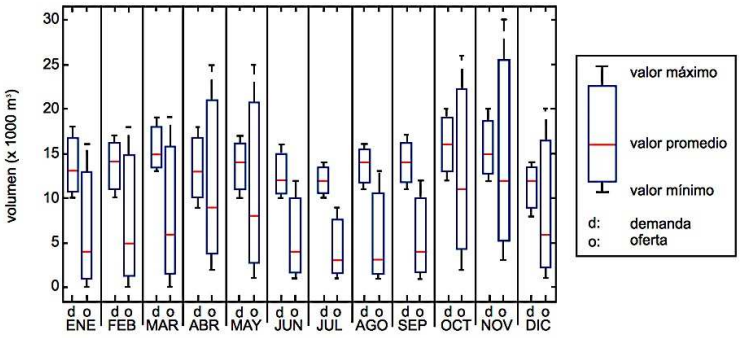
July - 2014

May- 2013



M&M

Quantity & Quality Analysis



Muestra	Fecha de toma	Coliformes fecales (UFC/ml)	Sólidos totales (mg/l)
1	26 de noviembre de 2004	<1/100	75
2	29 de noviembre de 2004	100 /100	390
3	29 de noviembre de 2004	5.000 /100	120

UFC: unidades formadoras de colonia.

JAIME ANDRES LARA BORRERO, ANDRES TORRES, PAULA ANDREA VILLEGAS GONZALEZ, LEONARDO DUARTE CASTRO, CLAUDIA CAMPOS PINILLA, JAIRO IVAN ECHEVERRI ROBAYO. (2007). "Aprovechamiento del agua lluvia para riego y para el lavado de zonas duras y fachadas en el campus de la Pontificia Universidad Javeriana (Bogotá)". Ingenieria Y Universidad *ISSN:* 0123-2126 , 11(2), 193-202

Rainwater Quantity & Quality Analysis

Summary of sample points that exceed standard limits

Analysis	Units	Landscape irrigation	Limits	Environmental and recreational uses	Limits
pH	-	1, 3 and 9	4.5 (Colombia) – 8.0 (FAO)	1 and 9	5.8 – 8.6 (Japan)
Turbidity	NTU		NS	1-10	2 (Japan)
BOD	mg/L	NS	-	1-10	10 (EPA)
Cd	mg/L	1, 3, 4, 5, 7, 9 and 10	0.01	NS	
Hg	mg/L	1, 3, 4, 5 and 10	0.01 (Colombia)	NS	-
Mn	mg/L	3 and 7	0.2	NS	-
Pb	mg/L	4 and 10	5	NS	-

NS: not specified by standard

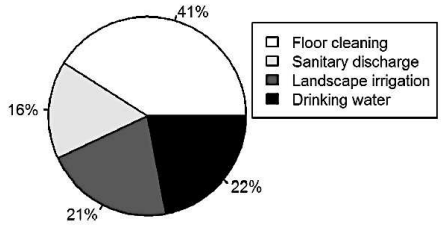
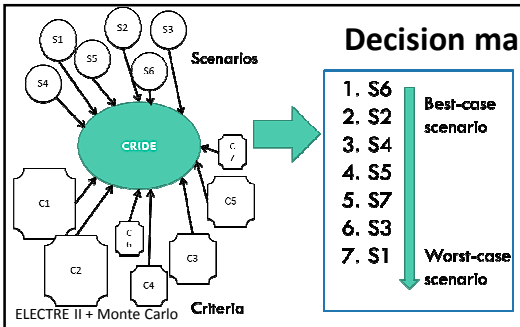


Fig. 1. PUJB's inventory of water uses, adapted from Ref. 50.

Torres A., Lara J., Torres Murillo O.M., Estupiñám Perdomo J.L., Méndez Fajardo S. (2011). "Aprovechamiento de aguas lluvias en el campus de la Pontificia Universidad Javeriana, Sede Bogotá (PUJB)" Gestion Integrada Del Recurso Hidrico Frente Al Cambio Climatico . *ISBN:* 978-958-670-914-9 *ed:* Programa Editorial Universidad Del Valle , p.325-336

Torres A., Estupiñán Perdomo J.L., Zapata García H.O. (2011). Proposal and assessment of rainwater harvesting scenarios on the Javeriana University campus, Bogota. 12th International Conference on Urban Drainage, Porto Alegre/Brazil, 11-16 September 2011

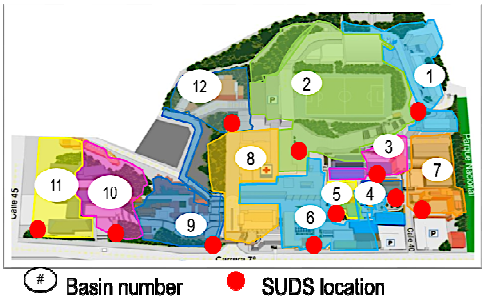
Decision making: analysis of SWH scenarios



1. S6
2. S2
3. S4
4. S5
5. S7
6. S3
7. S1

Best-case scenario

Worst-case scenario

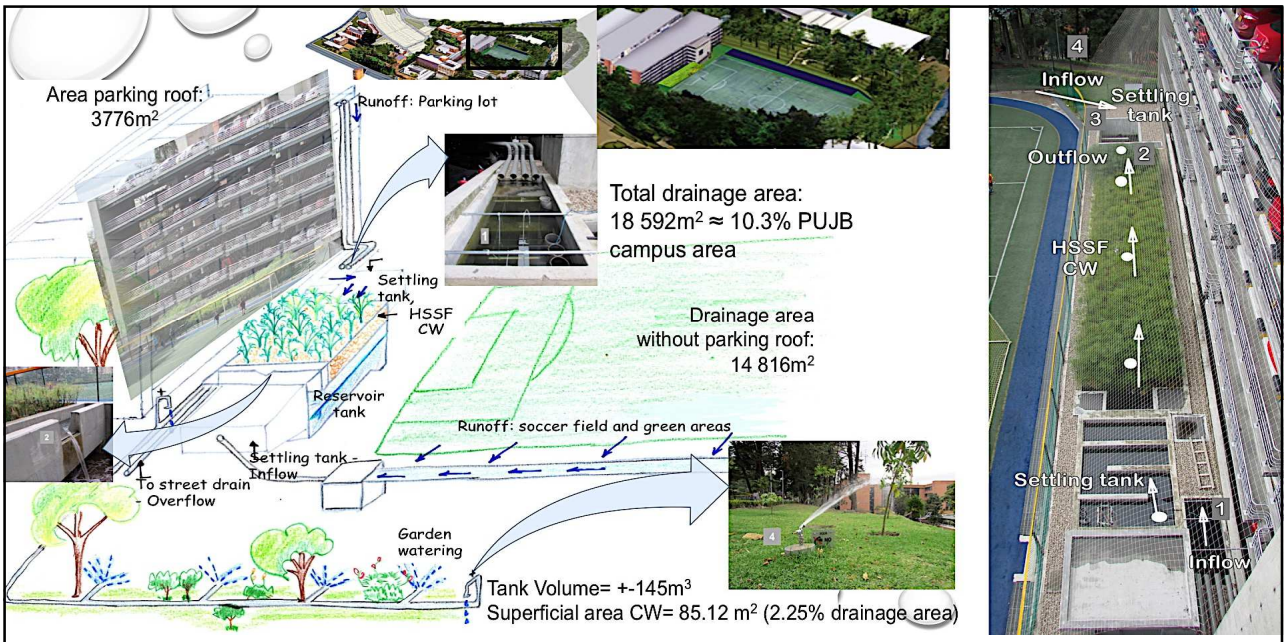


Criteria	Description
Hydraulic performance	Defines the capacity of each alternative to achieve the storm water objective (drainage and control of runoff).
Pollutant retention efficiency	Defines each alternative's capacity to retain pollutants.
Failure Probability	Establishes the probability failure of each alternative.
Frequency of system operation and maintenance	Determines the frequency of system operation and maintenance.
Level of compatibility with the University's Master Plan	Shows the level of compatibility of the alternative with the University's Master Plan.
Impact of the construction phase versus coverage	Compares the alternative construction impact versus the coverage that the solution would bring.
NPV	Determines when (in what year) the investment of each scenario would be recovered.[67]
Project's Internal Rate of Return (IRR) versus another project's IRR	Compares the scenario's IRR to that of another investment project.

Table 6. Reference simulation results (CRIDE Option Five), incorporating all variations of input data

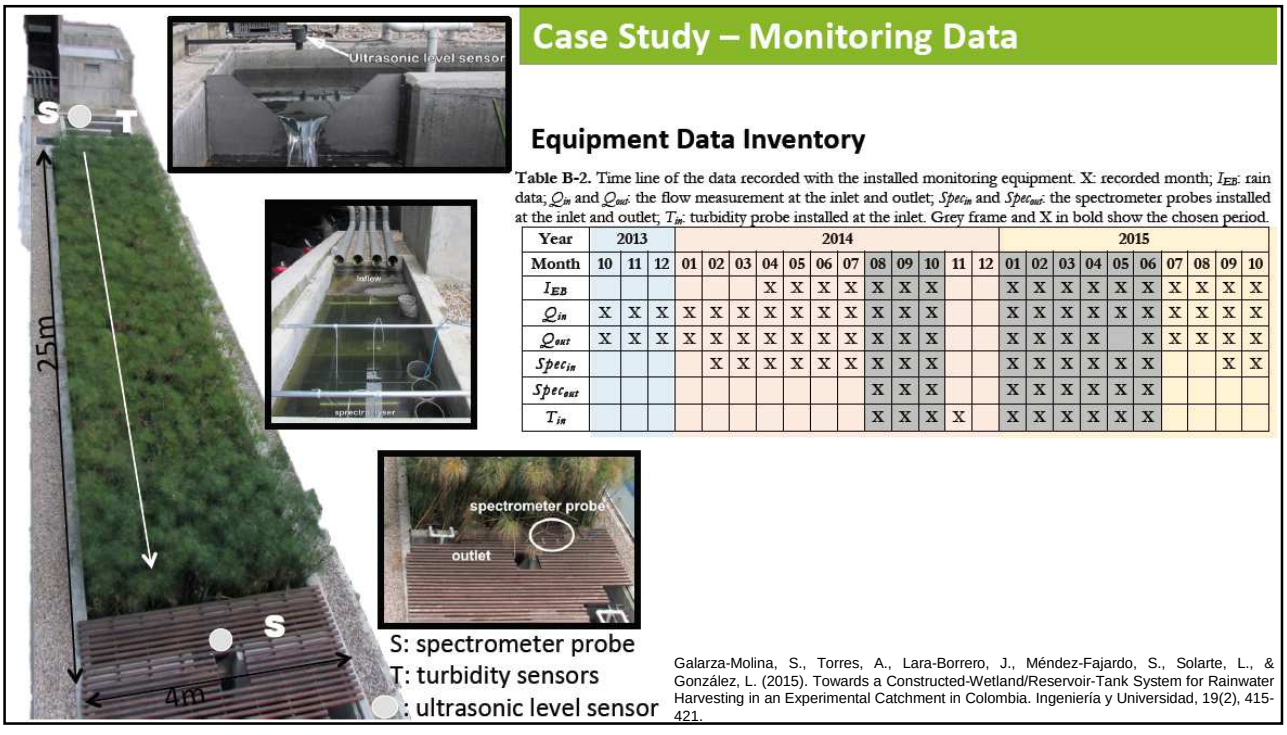
Scenario No.	NPV	Potential uses and water savings	Initial investment
Scenario 5	5-year payback period	Nonpotable uses Savings: 61%	US$ 263,000
Scenario 6	6-year payback period	Landscape irrigation Savings: 48%	US$ 262,000
Scenario 4	7-year payback period	Potable and nonpotable uses Savings: 76%	US$ 279,000
Scenario 2	8-year payback period	Nonpotable uses Savings: 62%	US$ 405,000
Scenario 3	10-year payback period	Landscape irrigation Savings: 47%	US$ 394,000
Scenario 1	5-year payback period	Potable and nonpotable uses Savings: 94%	US$ 420,000

Galarza-Molina S., Torres A., Moura P., Lara-Borrero J. (2015) CRIDE: A Case Study in Multi-Criteria Analysis for Decision-Making Support in Rainwater Harvesting. International Journal of Information Technology & Decision Making. 14 (1), pp 43-67



ArdilaQuintero, C., LeónRamírez, R., Molina, S. G., & Torres, A. (2016). Usos potenciales del efluente del humedal-construido en la Pontificia Universidad Javeriana Bogotá. *Revista UDCA Actualidad & Divulgación Científica*, *19*(1).

Torres, A., Méndez-Fajardo, S., Lara-Borrero, J. A., Perdomo, J. L. E., García, H. O. Z., & Murillo, Ó. M. T. (2013). Hacia equipamientos urbanos sostenibles: aprovechamiento de aguas lluvias en el campus de la Pontificia Universidad Javeriana en Bogotá. Cuadernos de Vivienda y Urbanismo, 5(9).



Case Study – Monitoring Data

Equipment Data Inventory

Table B-2. Time line of the data recorded with the installed monitoring equipment. X: recorded month; I_{EB}: rain data; Q_{in} and Q_{out}: the flow measurement at the inlet and outlet; $Spec_{in}$ and $Spec_{out}$: the spectrometer probes installed at the inlet and outlet; T_{in}: turbidity probe installed at the inlet. Grey frame and X in bold show the chosen period.

Year	2013			2014												2015									
Month	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10
I_{EB}							X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
Q_{in}	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
Q_{out}	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X		X	X	X	X	X
$Spec_{in}$					X	X	X	X	X	X	X	X	X			X	X	X	X	X	X			X	X
$Spec_{out}$											X	X	X			X	X	X	X	X	X				
T_{in}											X	X	X	X		X	X	X	X	X	X				

Galarza-Molina, S., Torres, A., Lara-Borrero, J., Méndez-Fajardo, S., Solarte, L., & González, L. (2015). Towards a Constructed-Wetland/Reservoir-Tank System for Rainwater Harvesting in an Experimental Catchment in Colombia. Ingeniería y Universidad, 19(2), 415-421.

Water Quality Calibration Probes

u(TSS)
Torres (2011)

multivariate outliers
Torres et al. (2013a)
Filzmoser et al. (2008)

PLS
Torres & Bertrand-Krajewski (2008)
Zamora & Torres (2014)

SVM
Torres et al. (2013b)

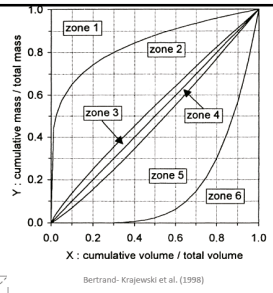
Spectrometer probes

Table B-3. Water samples (WS) per event used for the spectrometer calibration

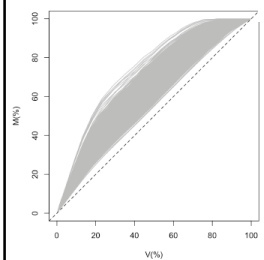
Events	Inflow	Outflow
Apr-22-14	5	2
May-6-14	5	5
Oct-9-14	5	5
Mar-3-15	5	3
Mar-16-15	5	5
Nov-5-15	5	5
Nov-19-15	6	4
Total of WS	**36**	**29**

65 water samples used

First Flush Phenomenon



Bertrand- Krajewski et al. (1998)



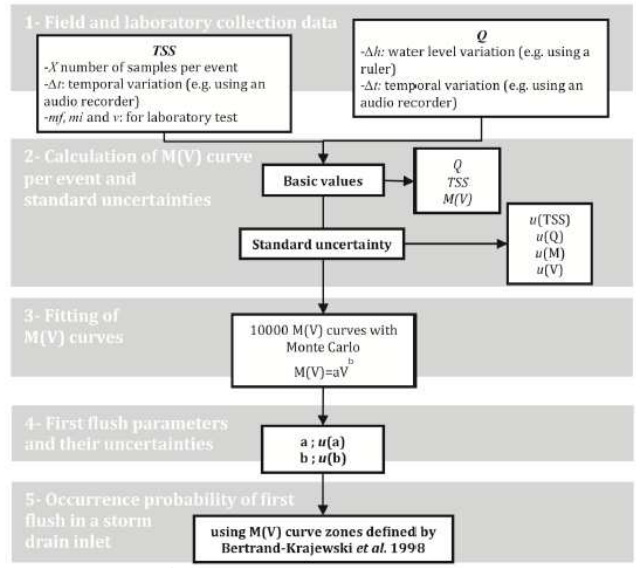
63 storm events

2 events in zone I (3.2%)
36 in zone II (57.1%)
9 in zone III (14.3%)
16 in zones IV to VI (25.4

13:17 2014 and event EV-42 March 22nd 16:33 2015

Table D-7. Typology of the *M(V)*curve zones proposed by Bertrand-Krajewski et al. (1998) and the dis occurrence probability of FF for some events. EV: event spectrometer probe

b Value		ZONE	Space between M(V) curve and bisector		EV-1	EV-24	EV-39	EV-46	EV-49		
	0<b≤ 0.185	I	Positive space	High	0	0	11%	4%	0		
b<1	0.185<b≤ 0.862	II		Medium	1%	45%	85%	4%	20%		
	0.862<b≤ 1.000	III		Insignificant	48%	49%	2%	13%	67%		
	1.000<b≤ 1.159	IV	Negative space	Insignificant							
b>1	1.156 < b ≤ 5.395	V		Medium	50%	6%	3%	79%	13%	0	0
	5.395 < b < ∞	VI		High							



Torres, A., Salamanca-López, C. A., Prieto-Parra, S. F., & Galarza-Molina, S. (2016). OFFIS: a method for the assessment of first flush occurrence probability in storm drain inlets. *Desalination and Water Treatment*, *57*(52), 24913-24924.

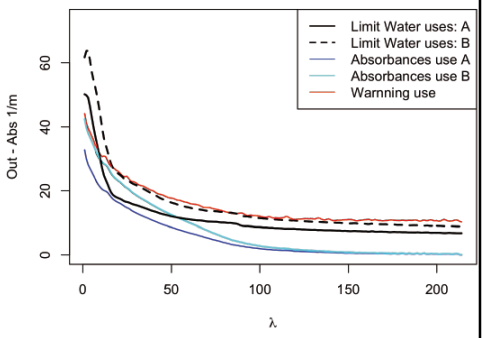
Water Use and Reuse Guidelines

Table C-2. Defined water group uses with the selected indicators values (Adapted from: Colombia 1985[1]; EPA 2004[2]; EU 2006[3]; MLIT 2005[4]; Pescod, M.B. 1992[5])

Group Uses	Description	TSS (mg/L)	BOD_5 (mg/L)	T (NTU)	pH	Total coliform (MPN/100mL)	Fecal Coliform (MPN/100 mL)
A	Urban reuse, agricultural reuse, recreational impoundments	<= 5 [2]	<=10 [2]	<= 2 [2&4]	5.0 [1]–8.6 [4]	ND [2]	ND [1&2]
B	Agricultural reuse (food processed & non-food crops), landscape impoundments, restricted areas irrigation	<= 30 [2]	<= 30 [2]		6.0–9.0 [2&5]		≤200 [2]

Table B-4 Suggested guidelines for the water uses of interest (Colombia 1985[1]; EPA 2004[2]; EU 2006[3]; MLIT 2005[4]; Pescod, M.B. 1992[5]) (adapted from Ardila-Quintero et al. 2016)

Water uses / Parameters	Toilet flushing and Showers	Agricultural and non-agricultural irrigation	Floor and facade cleaning	Water features
pH	6,0 – 9,0 [2] 5,8 – 8,6 (Toilet flushing[2]) 5,0 – 9,0 [1]	6,0 – 9,0 [2] <7 [5]	5,8 – 8,6 [4]	6,0 – 9,0 [2] 5,0 – 9,0 [1]
BOD_5	<= 10 mg/L [2]	<= 10 mg/L (non-agricultural irrigation[2]) <= 30 mg/L [2]		<= 10 mg/L [2]
TSS	<= 5 mg/L [2]	<= 5 mg/L (non-agricultural irrigation[2]) <= 30 mg/L [2]		<= 30 mg/L [2]
T	<= 5 NTU (Toilet flushing[2]) <= 2 NTU [2&4]	<= 5 NTU (non-agricultural irrigation[2])	<= 2 NTU [4]	
E.coli	ND [2&1] < 500 cfu/100 mL (Showers[3])	ND (non-agricultural irrigation[2]) < 500 cfu/100 mL (non-agricultural irrigation[5])		
Total Coliform	ND (Toilet flushing[4]) < 1000 microorganisms/100mL[1]		ND [4]	< 5000 microorganisms/100mL[1]



Galarza Molina, Sandra Lorena (2017). Decision-making tool for the operation of a stormwater harvesting system. PhD thesis, November 16th 2017. Pontificia Universidad Javeriana

Table E-1. Recorded spectra of each month that fulfill uses A and B. P: total precipitation per month.

Month & Year	P (mm)	min fulfill for uses A & B	min fulfill for uses B	Total minutes recorded	Total days	% for uses A	% for uses B	Longest consecutive period (days) with	
								use A & B	only use B
August 2014	8.4	13945	13956	13956	9.7	100	100	9.7	9.7
September 2014	25.9	0	5383	19245	13.4	0	28	0	2.9
October 2014	91.2	0	7313	23250	16.1	0	31	0	4.9
January 2015	28.4	9211	14994	16344	11.35	56	91	4.7	4.7
February 2015	51.1	31611	38778	40320	28	78	96	6	6
March 2015	78.7	4574	27536	44640	31	10	62	1.9	5.4
April 2015	29.7	0	0	28198	19.6	0	0	0	0
May 2015	14.0	22646	6600	31507	21.9	72	21	14.1	14.1
June 2015	38.0	326	10612	43200	30	0.8	25	0.2	5.3

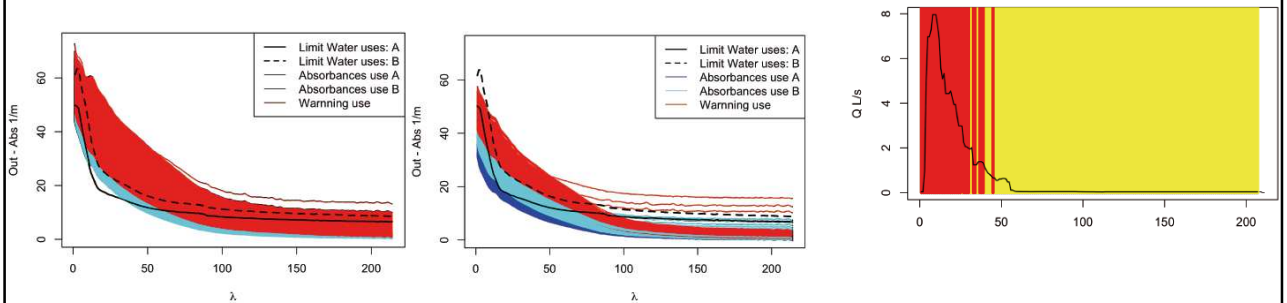


Figure E- 1. Observed spectra during September 2014 and March 2015. Spectra in blue: the water fulfills water use A and B. Spectra in cyan: the water fulfills water use B. Spectra in red: (warning spectrum) the water cannot be used.

August to October of 2014 and January to June of 2015

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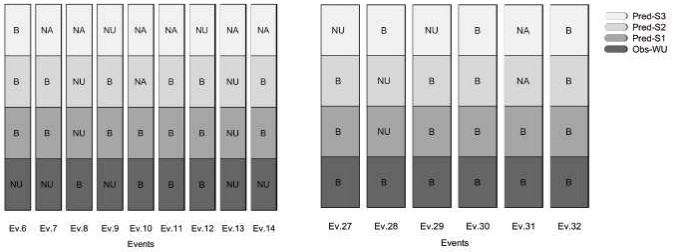
I Scenario – Using Spectrometer

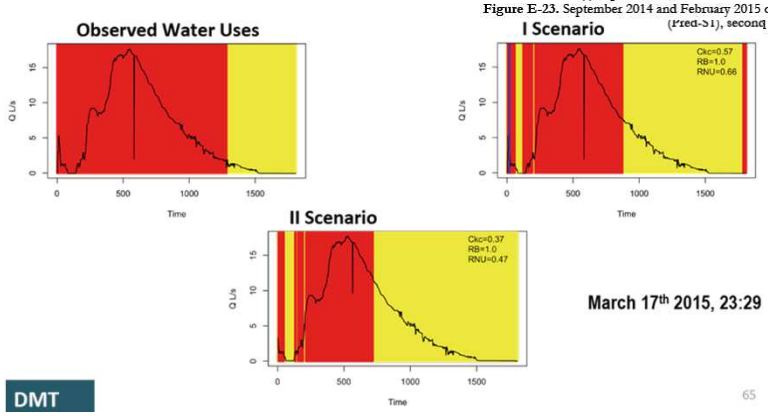
II Scenario – Using Turbidity Probe

II Scenario – Using SVM



(a) September 2014 (b) February 2015

Figure E-23. September 2014 and February 2015 observed water uses (Obs-WU) per event versus general results of the first (Pred-S1), second (Pred-S2), and third (Pred-S3) scenarios.



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I Scenario – Using Spectrometer

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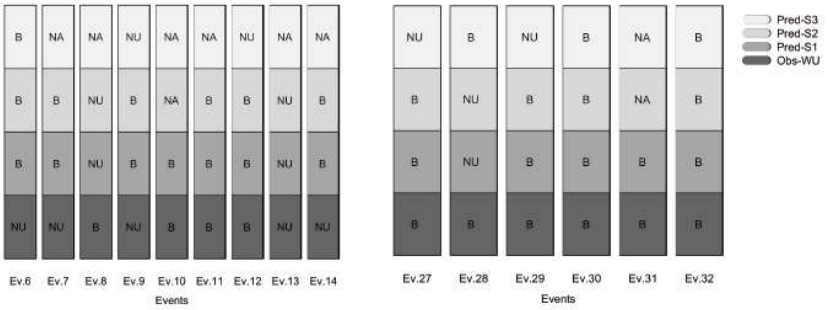

(a) September 2014 (b) February 2015

Figure E-23. September 2014 and February 2015 observed water uses (Obs-WU) per event versus general results of the first (Pred-S1), second (Pred-S2), and third (Pred-S3) scenarios.

Table E-19. Kappa coefficients (Ckc) and reliabilities (RB and RNU) for all the scenarios

			FF Ckc results		Water use Kappa Coefficients and Reliabilities		
Section	**DM tools**	**Database used**	**Rules method**	**SVM method**	**Ckc**	**RB**	**RNU**
19.1	First scenario – spectrometer probe	94 events	0.49	0.30	0.11	0.83	0.29
19.2	Second scenario – turbidity probe	34 events	0.24	0.31	-0.08	0.83	0.10
19.3	Third scenario – SVM method	43 events	-	-	0.28	0.39	0.90

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CONCLUSIONS

- CWRT system as a device for research:
  - Research Projects : 4
  - Researchers PUJ: 5
  - BSc: 8
  - MSc: 3
  - PhD: 1
  - Journal papers: 6
  - Book chapters: 1
  - Conference papers: 8

- Methods proposed for on-line or differed DM in UD

- Modelling, O&M, sediments

Thank you

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