ECWS-8 2024 Conference
The 8th International Electronic Conference on Water Sciences
14–16 October 2024 | Online
MDPI

Integration of Rainwater Harvesting with Urban Water Systems for Simultaneous Reduction of Storm water Runoff and Groundwater Extraction: A Case Study in Lahore, Pakistan

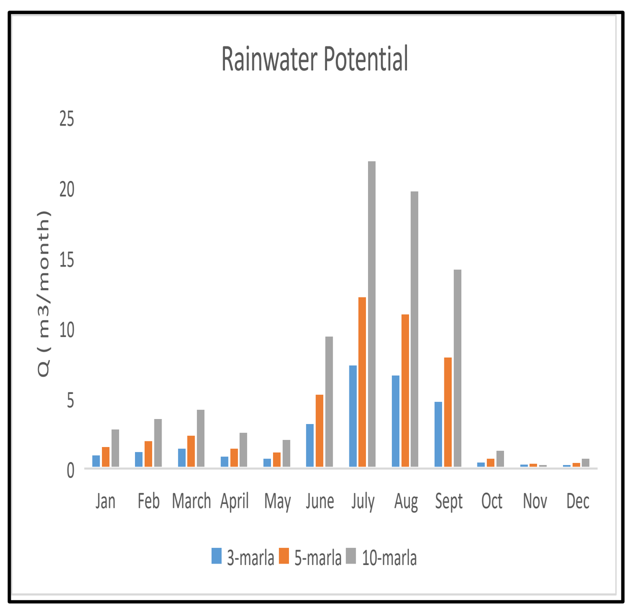
[1]Shanza Arshad, [2]Mubashra Mahmood, [2]Tanveer Ahmed, [3]Talal Naseer*
[1]Forman Christian College, University, Lahore, 54600, Pakistan
[2]University of Engineering and Technology, Lahore, 39161, Pakistan
[3]Food and Agriculture Organization of the United Nations, Pakistan

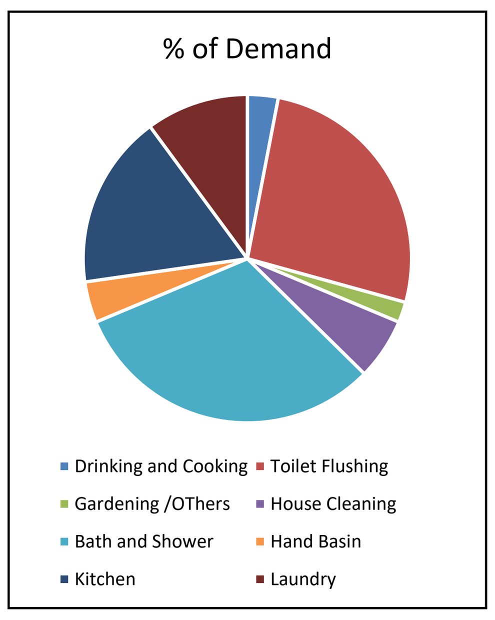
INTRODUCTION & AIM

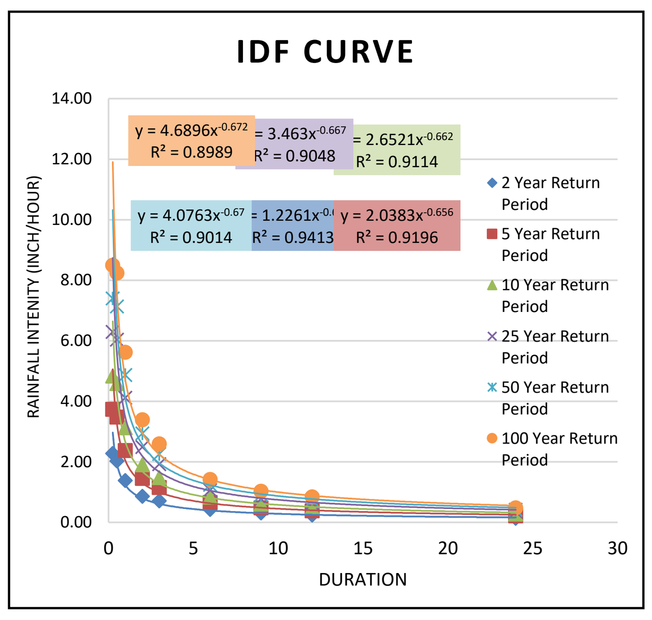
Water supply system (WSS) of the housing societies in cities like Lahore are mostly sustainable in terms of all major factors defined in Sustainable WSS definition except maintaining water resources for a long time especially groundwater (GW). Therefore, current study is focused to design a rainwater harvesting system (RWHS) at household level and evaluation of its effectiveness in terms of reduction in GW savings, cost saving, reduction of runoff and flooding in the society (SWMM), and effects of reduction of water demand on hydraulics of WSS (using WaterGEMS). It was found that implementation of RWHS, reduced 8.6% of average water demand and 17.38% reduction in electricity consumption. It was also found 99.50, 97.07, and 91.91% reduction in urban peak flooding from individual homes in society at return periods of 2, 5, and 10 years respectively as evaluated using SWMM. While there was around 20-24% reduction in flooding at society level. Cost of implementation of RWHS in 3, 5 and 10 Marla houses is Rs550,253, Rs670,890 and Rs1,112,283 respectively.

METHODOLOGY

Steps	Activities	Description of Data/Methods/Tools
1	**Data Collection for the study**	Society map, design criteria, monthly rainfall data for storage and 60 years rainfall data for IDF curves
2	**(RWHS) design and Costing**	**Cases Studied:** **Case-I** = Gardening + Laundry + House Cleaning **Case-2** = Gardening + Laundry + House Cleaning + Toilet Flushing **Case-3** = Gardening + House Cleaning **Methods evaluated for storage volume estimation**: Ripple method, Equalization Method, Web-page, General formula.
3	**Water Supply System (WSS) Design**	**Software used:** WaterGEMS, ArcGIS, and Google Earth
4	**Effects of RWHS on WSS network**	Pressure distribution, pipe velocities, water savings, energy savings, economic benefits.
5	**Effects of RWHS on Urban Flooding**	**Software used:-** USEPA- SWMM • % reduction in total and peak runoff at different return periods • % reduction in total and peak flooding at different return periods

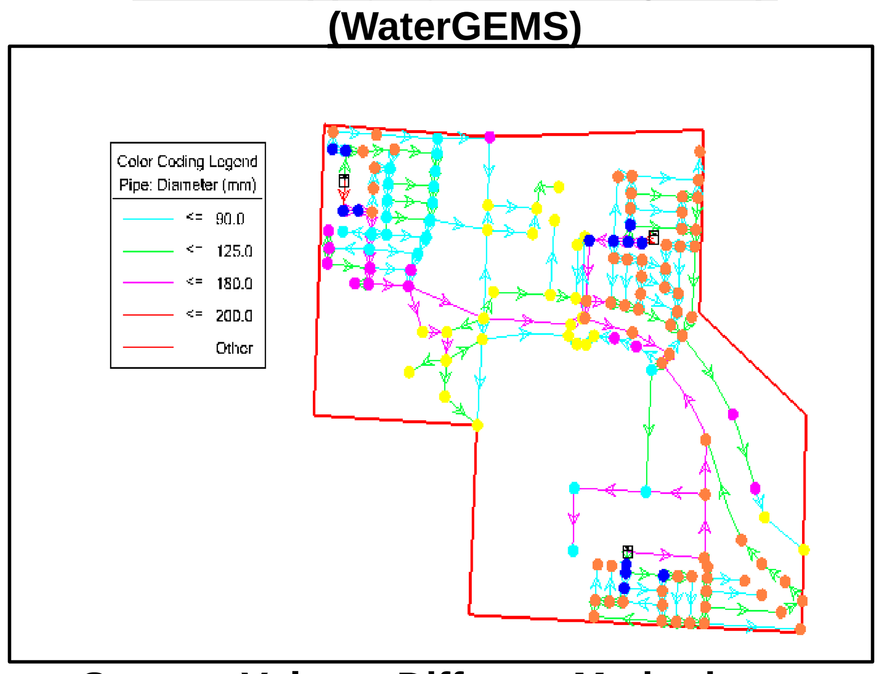




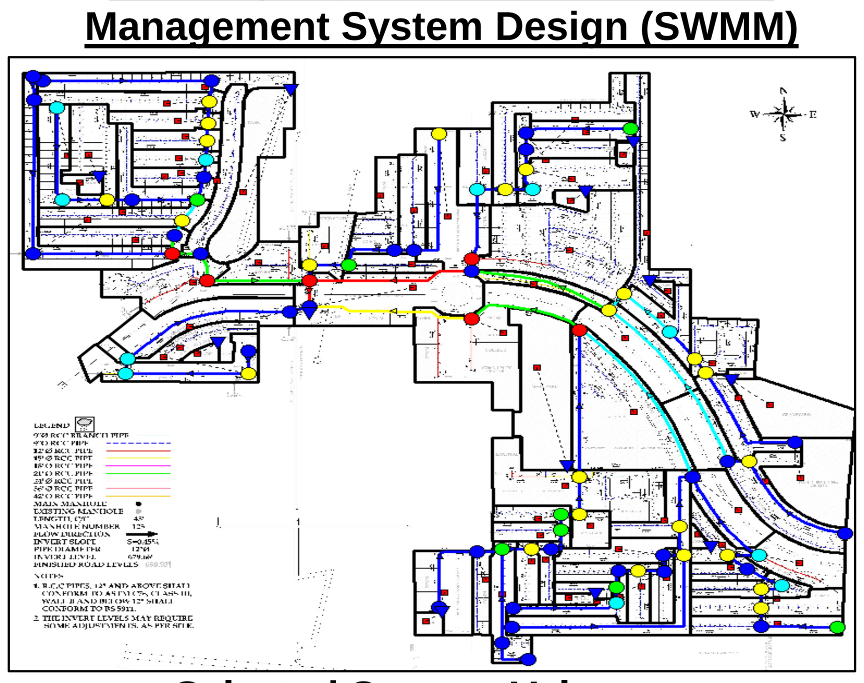


RESULTS & DISCUSSION

Water Supply System Design Map (WaterGEMS)



Sewerage System with Stormwater Management System Design (SWMM)



Storage Volume-Different Methods

Cases Evaluated	House Size	Website	Equalization Method	Ripple Method	General Formula
Case I	3 Marla	10.00	0.91	51.53	3.14
	5 Marla	15.00	6.87	58.79	5.23
	10 Marla	28.00	21.55	76.06	10.45
Case II	3 Marla	10.00	0.00	163.69	3.14
	5 Marla	15.00	0.00	193.25	5.23
	10 Marla	28.00	0.00	252.38	10.45
Case III	3 Marla	10.00	10.27	17.40	3.14
	5 Marla	15.00	21.82	25.25	5.23
	10 Marla	28.00	44.92	23.33	10.45

Selected Storage Volumes

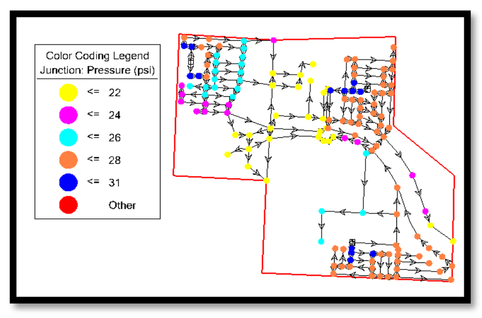
Cases Evaluated	House Size	Required Storage (m3)	Rain Barrel (m3)	Underground Tank (m3)
Case I	3-Marla	10.00	3.14	6.86
	5-Marla	15.00	5.23	9.77
	10-Marla	28.00	10.45	17.55
Case II	3-Marla	10.00	3.14	6.86
	5-Marla	15.00	5.23	9.77
	10-Marla	28.00	10.45	17.55
Case III	3-Marla	10.27	3.14	7.14
	5-Marla	21.82	5.23	16.60
	10-Marla	44.92	10.45	34.47

Demand Meeting the Requirements

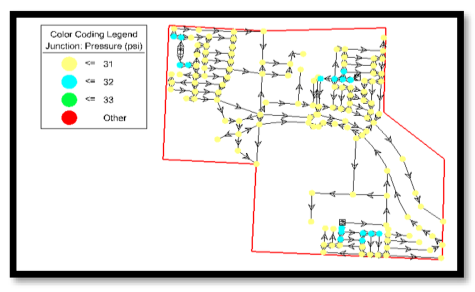
Months	Case-I (%age)				Case-II (%age)				Case-III (%age)			
	3M	5M	10M	Cumulative %	3M	5M	10M	Cumulative %	3M	5M	10M	Cumulative %
Jan	14	19	24	**18.9**	6	8	10	**7.9**	100	100	100	**100**
Feb	18	24	31	**23.9**	7	10	13	**9.9**	53	100	100	**95**
Mar	21	29	37	**28.8**	9	12	15	**11.9**	48	100	100	**94**
Apr	13	17	22	**17.0**	5	7	9	**6.9**	29	100	100	**93**
May	10	14	18	**13.9**	4	6	7	**5.8**	24	100	100	**92**
Jun	48	64	82	**63.9**	20	26	34	**26.0**	100	100	100	**100**
Jul	100	100	100	**100.0**	46	61	78	**60.9**	100	100	100	**100**
Aug	100	100	100	**100.0**	41	55	71	**54.9**	100	100	100	**100**
Sep	87	100	100	**98.2**	30	40	51	**39.9**	100	100	100	**100**
Oct	7	90	100	**82.7**	3	4	5	**3.9**	100	100	100	**100**
Nov	1	2	100	**9.9**	1	1	1	**1.0**	100	100	100	**100**
Dec	4	5	8	**5.1**	1	2	3	**1.9**	100	100	100	**100**
Annual Average	**35**	**47**	**60**	**46**	**14**	**19**	**24**	**19**	**79**	**100**	**100**	**97.9**

Cases Evaluated for Storage Volume

Pressure Distributions Before and After RWHS



Pressure before RWHS (22-31 psi)

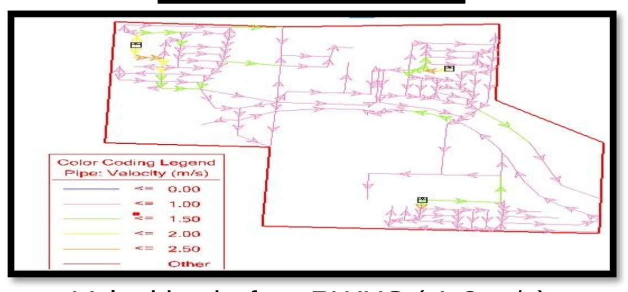


Pressure after RWHS (30-32 psi)

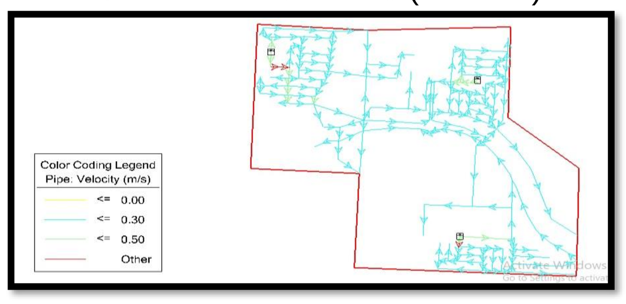
Benefits Achieved Through RWHS

Parameters		Units	Current Values	After-RWHS	Savings (%ages)
Water Demand (avg in the whole year)		m^3/Year	1436628 (302 LPCD)	1313226.2 (276 LPCD)	**8.50%**
Energy consumption (2 Tube wells of 80 BHP)		KW/Year	691200	571197.52	**17.36%**
Pumping hours		hrs	16	13.20	**17.36%**
Peak Flooding (Individual Homes)	2-Yr	ft^3	597320.36	10342.18	**98.27**
	5-Yr	ft^3	1355851.5	48938.41	**96.39**
	10-Yr	ft^3	1954924.3	427706.78	**78.12**
Total Flooding (Whole Society)	2-Yr	ft^3	3,122,244	2223349	**28.79**
	5-Yr	ft^3	5276030	3969116	**24.77**
	10-Yr	ft^3	6920043	5,392,825	**22.07**

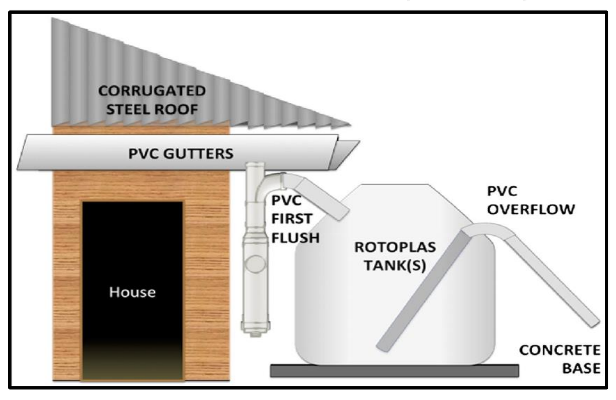
Velocity Distributions Before and After RWHS



Velocities before RWHS (1-2 m/s)



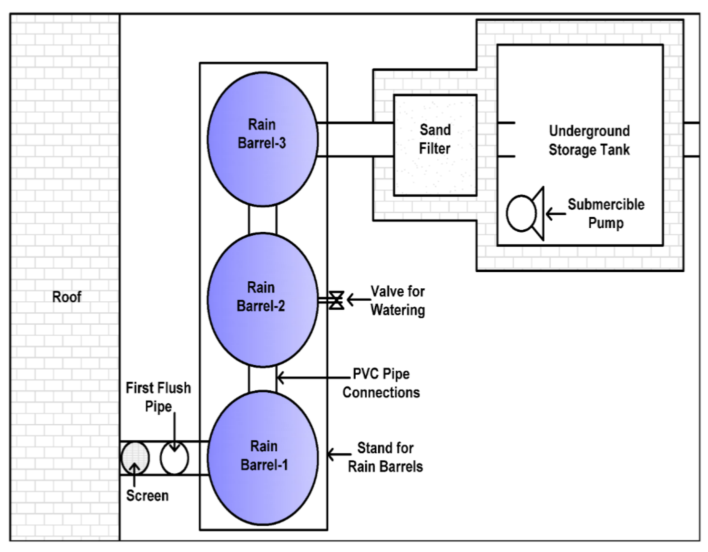
Velocities After RWHS (1-2 m/s)



Configuration of Flush Pipe and Rain Barrel

Cost Analysis of RWHS

Parameter	3-Marla	5-Marla	10-Marla
Individual Home Cost	Rs550,253	Rs670,890	Rs1,112,283
Cost for all homes in Society	112.8 M	1146.5 M	191.31 M
Total Cost	**Rs1,450.67 M**		



Layout of Rainwater Harvesting System

CONCLUSION

Four methods for designing Rainwater Harvesting Systems (RWHS) were evaluated, with the general formula (ratio of tank volume to catchment area) 0.05m^3/m^2 and SAMSAM Rainwater Harvesting Model proving most effective for rain barrels and total storage volume, respectively. The equalization and ripple methods have limitations based on rainfall, demand, household area, and size. Case-1 was the best fit for the study area, while case-2 was inadequate, and case-3 led to water wastage. RWHS enhances water sustainability by reducing groundwater extraction, boosting recharge, lowering energy consumption, and cutting water costs. New regulations mandating RWHS in housing societies, including filing, review, and audit procedures, are recommended.

REFERENCES

1. Vargas-Parra MV, Rovira-Val MR, Gabarrell X, Villalba G. Rainwater harvesting systems reduce detergent use. The International Journal of Life Cycle Assessment. 2019;24:809-23.
2. Vairavamoorthy K, Akinpelu E, Lin Z, Ali M, editors. Design of sustainable water distribution systems in developing countries. Bridging the Gap: Meeting the World's Water and Environmental Resources Challenges; 2001.
3. Kummu M, Guillaume JH, de Moel H, Eisner S, Flörke M, Porkka M, et al. The world's road to water scarcity: shortage and stress in the 20th century and pathways towards sustainability. Scientific reports. 2016;6(1):38495.
4. Srinivasan V, Lambin EF, Gorelick SM, Thompson BH, Rozelle S. The nature and causes of the global water crisis: Syndromes from a meta-analysis of coupledhuman-water studies. Water resources research. 2012;48(10).
5. Ortigara ARC, Kay M, Uhlenbrook S. A review of the SDG 6 synthesis report 2018 from an education, training, and research perspective. Water. 2018;10(10):1353.