Department of Civil and Environmental Engineering

Islamic University of Technology (IUT)

Boardbazar, Gazipur

Developing Design Curves for Rainwater Harvesting in the Coastal Region of Bangladesh

by

Md. Sharmon Hossain Arnob (170051064)

Nazratun Nawar (170051083)

Supervisor

Professor Dr. Md. Rezaul Karim

بِسْمِ ٱللَّٰهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the name of Allah, The Most Gracious and The Most Merciful

Developing Design Curves for Rainwater Harvesting in the Coastal Region of Bangladesh

by

Md. Sharmon Hossain Arnob (170051064)

Nazratun Nawar (170051083)

Supervisor

Professor Dr. Md. Rezaul Karim

An undergraduate thesis submitted to the Department of Civil & Environmental Engineering of Islamic University of Technology in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil and Environmental Engineering

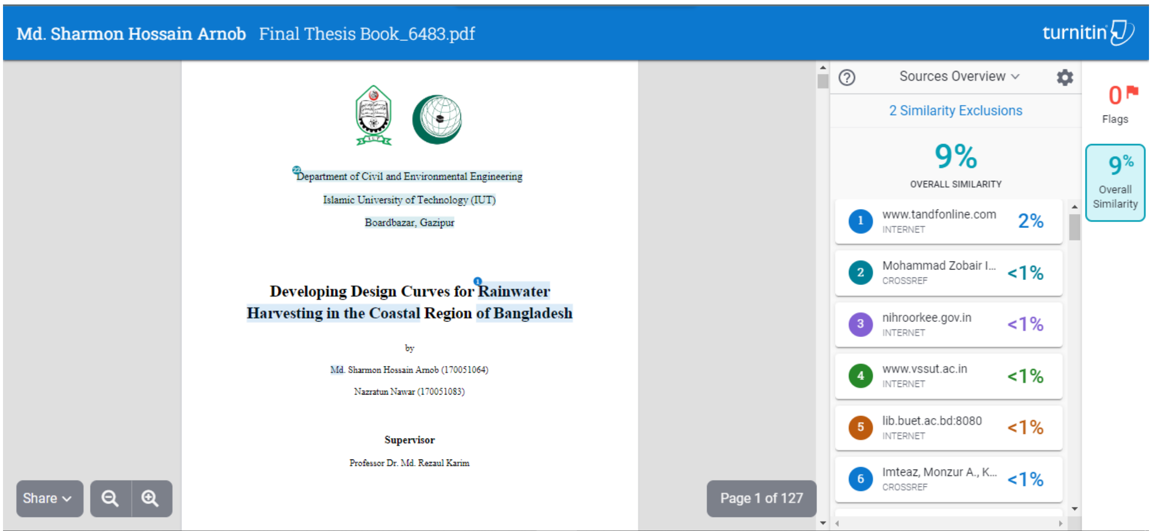
Department of Civil and Environmental Engineering

Islamic University of Technology (IUT)

Boardbazar, Gazipur

Approval

This is to certify that the work presented in this thesis was carried out by Md. Sharmon Hossain Arnob and Nazratun Nawar entitled as “Developing design curves for Rainwater Harvesting in the coastal region of Bangladesh” under the direct supervision of Dr. Md. Rezaul Karim, Professor, Department of Civil and Environmental Engineering, Islamic University of Technology - IUT. The work has been approved, in partial fulfillment of the requirements for the Bachelor of Science degree in Civil Engineering.



Approved by:

____

Prof. Dr. Md. Rezaul Karim
Professor,
Department of Civil & Environmental Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh.

Date:

Declaration

We hereby declare that the undergraduate research work reported in this thesis has been performed by Md. Sharmon Hossain Arnob and Nazratun Nawar under the supervision of Professor Dr. Md. Rezaul Karim and this work has not been submitted elsewhere for any purpose (except for publication).

May, 2022

Md. Sharmon Hossain Arnob	**Nazratun Nawar**
Student ID: 170051064	Student ID: 170051083

Supervisor:

Prof. Dr. Md. Rezaul Karim
Professor,
Department of Civil & Environmental Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh.

Acknowledgement

First and foremost, praise and appreciation to Allah for His showers of blessings throughout our research, which enabled us to successfully conclude our study.

We would like to convey our heartfelt appreciation to Dr. Md. Rezaul Karim, our thesis supervisor, for his guidance, patience, and encouragement throughout our undergraduate studies. His technical and editorial help was critical to the completion of this dissertation, and he has taught us countless lessons and insights into how academic research works in general. This paper would not have been completed without his guidance and dedicated engagement in every step of the process.

Furthermore, we thank our thesis supervisor and Shanjana Haider for supplying valuable daily rainfall data from the Bangladesh Meteorological Department (BMD) for all essential stations, which served as the foundation of this study.

Furthermore, we want to thank our parents for their love, prayers, and sacrifices for our education. We also like to thank our respected teachers, seniors, and friends for their help and encouragement throughout this research.

Table of Contents

List of Tables

List of Figures

Abstract

People in Bangladesh's southwestern coastal zone confront a potable water crisis as a result of saline intrusion into surface and groundwater caused by anthropogenic and climate change. Locally available sources of water, such as ponds and wells, frequently become saline when affected by a tidal surge or embankment failure, limiting the availability of non-saline water for the population. Bangladesh's coastline region receives a large quantity of annual rainfall, making rainwater harvesting a potential water supply source for the people. Government agencies and many non-governmental organizations (NGOs) supply storage tanks ranging from 500 to 3000 liters for a normal household RWH system. The optimal storage tank required for inhabitants based on rainfall, family size, water demand, and catchment area has not been assessed, restricting the source's usability to a limited period of the year (6 to 7 months). To address this issue, the current study aims to create a comprehensive decision-making tool for a reliable rainwater harvesting system throughout the coastal belt. Design curves for the optimum storage tank have been developed for three climate conditions (wet year, dry year, and average year) taking into account available catchment area (20 – 70 m2), rainfall loss factor, drinking water demand (10 lpcd) for a range of household sizes (4 to 11) using mass curve and subsequent peak algorithm for 13 different stations along the coastal zone. A spreadsheet-based daily water balance model was developed with the goal of assessing the tank's reliability (volume and time-based) and determining the spilled volume. Slight variation has been observed in dry and average year climates, although reliability for the same tank during the wet year ranges between 82 and 85 percent. A large amount of rain water is wasted as spilled water, thus if the capacity of the tank is raised, the water may also be used for other purpose too; the economic analysis also reveals a return period of 3 – 4 years for the tank. The design curves will serve as a guideline for the development of an optimal storage tank for the inhabitants of coastal Bangladesh in order to provide drinking water for the longest period of time possible inside a year.

1 Introduction

1.1 Background

Access to clean, equitable, and microbe-free potable water has long been a major issue for people all over the world. Potable water sources are classified by the World Health Organization (WHO, 2011) as any water source that provides no major health risk over time. Surface and groundwater are both potable water sources in Bangladesh (Islam et al., 2020), but due to improved microbiological quality, the population rely on groundwater to meet their water demand (Ahmed, 1999). A large number of people (35 million) of the coastal region of Bangladesh rely on rivers, ponds, ground water sources for washing, bathing, and drinking purposes (MoWR, 2005; Ghosh et al. 2015). However, due to increasing saline intrusion rates into these water sources, these populations are mostly deprived of safe potable water (Habiba, et al., 2014). Lack of potable water forces people to drink water from unsafe sources, thus posing major health issues (WHO, 2006; Harun and Kabir, 2013).

Bangladesh, as a tropical country, experiences high rainfall due to its geographic location. Bangladesh receives almost 2400 mm of rainfall per year, according to a study report published by the Bangladesh Bureau of Statistics (BBS), with the coastline region receiving up to 2700 mm (Atikul, et al., 2013; Karim et al., 2015). According to Ahmed (2003), the available catchment area necessary for rainwater harvesting is suitable in the coastal region, hence RWH could be a viable alternative for supplying drinking and cooking water in the coastal zone. The main concern with rainwater harvesting is that the water is only available during the rainy season, and a lack of storage might limit water availability all year. However, if the storage tank is designed considering rainfall and other design factors, it can serve as a backup source for coastal residents (Biswas and Mandal, 2014).

Rainfall harvesting refers to the collection of rainwater for storage in surface or subsurface aquifers before it is carried away as surface runoff (Gupta, 2006; Rahman et al., 2014). The catchment area, collecting devices, and overall transportation system make up a rainwater harvesting system. Rooftops, microbe-free surfaces, and compacted surfaces are common rainfall catchment area, where rainwater is collected and then stored in storage tanks upon filtration and disinfection (Notaro, et al., 2017). The rainwater is free from salinity and the physical, chemical and bacteriological characteristics of harvested rainwater represent a suitable and acceptable means of potable water (Parajuli, 2018). Due to the environmental, economic, and health benefits, rainwater harvesting has become a popular alternative source in minimizing the scarcity of water for residential use in developing nations like Bangladesh (Oweis, and Taimeh, 1996; Pachpute, et al., 2009; Fewkes, 2006; Matos, et al., 2015; Farreny, et al., 2011). The quality and quantity of harvested rainwater shows temporal and spatial variation due several factors – geographical location, climatic condition, rainfall distribution, available catchment area, household size. Thus an optimal tank size required to sustain a family cannot be standardized. As a result, several authors propose that the optimal storage tank be estimated using these criteria, but evaluated using system reliability and economic feasibility (Liaw and Tsai, 2004; Khan, et al., 2017).

1.2 Objective of the study

- Developing design curve using mass curve & sequent peak algorithm for whole coastal region using historical daily rainfall data
- Analysis of the reliability (time-based and volume-based) of the proposed tank and spillage volume from the tank
- Economic analysis of a typical storage tank

2 Literature Review

2.1 Current water supply practices of coastal region

In coastal region of Bangladesh, due to unavailability of fresh potable water, people rely on rain-feed ponds, pond sand filters, tubewell and harvested rainwater. PSF has been considered a sustainable drinking water source to reduce the scarcity of water usage in Bangladesh's coastal zone. A questionnaire survey was conducted in Dacope upazilla (sub-district of Khulna) in Bangladesh, which revealed that just 20% of people in Dacope upazilla were satisfied with the usage of PSF, while 30% were unsatisfied. The prevalence of salinity in ponds, which results in poor water quality, was the primary cause of this dissatisfaction (Harun and Kabir, 2013). PSF is not ideal for ponds with salty water, hence it is not suitable for Bangladesh's coastal zone. On the other hand, Department of Public Health and Engineering (DPHE) claimed that tube wells are not suitable for the coastal region because of the underground permeable layer whereas, DPHE and UNICEF, 1989 both found the depth of 700-1000 unsuitable in terms of ground water extraction. NWRPo (1999) also reveals that the sediments of the coastal region of Bangladesh are not capable to store water because of having very low permeability whereas, the medium sand is suitable for the ground water extraction. However, deep tube well can be more reliable since it can reduce salinity (Rahman and Islam, 2018) but due to prevalence of arsenic, it becomes unsuitable.

As a result, rainwater harvesting technology has been adopted in the coastal region to reduce any such limits. However, due to the bad economic conditions, people are unable to pay the installation cost of a rainwater harvesting system. The Bangladesh government and numerous other non-governmental organizations (NGOs) took the initiative to supply various tanks to meet the demand. Donor agencies provided the household with locally accessible tanks ranging from 1000 to 5000 liters without taking into account any rainwater collecting system design parameters (Karim, 2010). As a result, the residents cannot have water all year, making the system unstable because they can only rely on it for six to eight months (Karim et al., 2015). Residents must rely on alternative unsafe sources of water for the remainder of the year. According to the author, a suitable in-depth analysis of the RWH factors can provide a proper system with a higher range of reliability.

2.2 Household size and roof catchment area

The average household size in a rural coastal house is from 4 to 6 people for a single family, but it can reach more than 10 people for joint families (BBS, 2011).

There is no data available for the catchment area directly, rather from a survey report conducted by Ferdausi (1999) in a coastal region has been shown in **Table 1**.

Table 1: Catchment area available in rural coastal region. *Collected from Ferdausi (1999)*

Available catchment area in a rural coastal region (m^2)				
< 20 m^2	20 – 40 m^2	40 – 60 m^2	60 – 80 m^2	> 100 m^2
21.43 %	18.86 %	35.71 %	14.29 %	10.71 %

2.3 Previous works on rainwater harvesting

Bangladesh is a densely populated country which paves the way of shortage of water and one of the major challenges of 21st century is to overcome this deficiency. Rainwater harvesting has been practiced for centuries in terms of drinking, washing, cooking purposes. It is a simple low cost strategy and a great alternative for the drought period and ground water declination (Worm and Hattum, 2006; Islam et al., 2014). Since rainwater harvesting is a great alternative, it should be designed properly for which optimum tank size, family size, catchment area, and water demand are significant parameters and the reliability should be tested for different tank sizes used for rainwater harvesting. Khan (2017) created a tool for quick and reliable prediction of tank size necessary for rainwater collection, with their respective reliability at a sufficient level taking into account all parameters. Fewkes and Butler (2000) have also conducted a relative investigation on the accuracy of behavioral analysis using hourly, daily, and monthly time steps and a YAS and both YBS computational operating rules for different combinations of (D/I).

A study in the Satkhira district shows that Satkhira experiences nearly 1,710 mm rainfall in every year where 2000-liter storage tank is required for 6 members in a family with the cost of $171 (Islam et al., 2014). Another study conducted in Chittagong reveals that the usability of rainwater harvesting system depends upon the storage system where up to 20 liters/person/day was found to solve the water blockage problem by around 26% (Akter and Ahmed 2015; Bashar et al., 2018). A comparative study within six major cities (Dhaka, Chittagong, Rajshahi, Khulna, Sylhet, and Barishal) of the Bangladesh was conducted where higher potentials of rainwater harvesting was found in Sylhet and Chittagong and the maximum reliability is found to be 30-40%. The reliability was determined using 200 m2 catchment area for 6 storied residential building having 50 residents (Bashar et al., 2018).

Rainwater harvesting system is proposed for Paikgacha, situated at the coastal urban region in Bangladesh where SWMM was used to form the design curves and 99% reliability was obtained for 100 L per day household demand (Islam et al., 2021). A study by (Karim et al., 2014) shows that the maximum achievable reliability of RWH tanks is about 70% under average and dry climatic conditions of the coastal regions in Bangladesh. A large quantity of water is lost as spilled water even with a tank size of 5,000 L. Another study by (Karim et al., 2005) stated that in some areas of the coastal region with high salinity problem, about 36% households have been found to practice rainwater harvesting in the rainy season for drinking purpose (Hussain and Ziauddin, 1992).

A study was conducted in Melbourne using the Water Balance Model for three different climatic conditions (dry, average, and wet years) which revealed that 100% reliability can be achieved with a roof size of 150–300 m2, a tank size of 5000–10,000 L for a family size of 2 (Imteaz et al., 2011). In Malaysia, Tangi NAHRIM app was developed in 2008 for determining the optimal tank size for rainwater harvesting. In this study, Daily Water Balance Model and Yield After Spill (YAS) were used and 3m3 storage tank was found to be the optimal rainwater harvesting tank (Goh et al., 2021). According to BBS (1997), the population of most households in rural areas is 4 to 12; Mostly a family size of 6. According to (Ferdausi, 2000) survey, the available catchment area for RWH in rural Bangladesh varies from 20 to 80 m^2. The daily drinking water demand was found to be 10 liters (Ahmed, & Rahman, 2000; Levallois et al., 1998).

Rooftop RWH has attracted considerable attention in recent years as a potential alternative water supply source in Bangladesh's coastal and arsenic-affected rural districts. Several programs have been conducted in recent years to promote and install both home and community-based RWH systems in order to ameliorate drinking water problems in both coastal and arsenic-affected areas of the country (Ahmed, et al., 2005; Karim, 2010). However, very few studies have been undertaken to investigate the development of design curves for Bangladesh's coastal region, taking into account all design factors and their associated reliability curves. As a result, the current research focuses on the development of design curves for a rural coastal house, defining the tank volume required to supply people with water for drinking and cooking.

3 Methodology

3.1 Rainfall data collection and analysis

Daily rainfall data for last 29 years (1991 – 2020) has been collected from Bangladesh Meteorological Department (BMD). A total of 13 rainfall stations - Bhola, Barishal, Chittagong, Cox's Bazaar, Feni, Khepupara, Khulna, Mongla, Patuakhali, Sandwip, Satkhira, Shitakunda, and Teknaf has been selected as study area covering all the districts of the southern coastal of Bangladesh; **Fig. 1** shows their relative location of the stations. From the selected historical daily rainfall data, three climatic conditions were selected – wet year, dry year, and average year for developing several design curves for storage volumes and analyzing volumetric and time reliability for a range of tank volume. The year with highest annual rainfall and lowest rainfall were selected to be wet and dry year respectively; whereas the year receiving annual rainfall to the average annual rainfall over 29 years was considered to be average year. The selected years according to the climatic categorization with their respected rainfall has been shown in the **Table 2** for all districts.

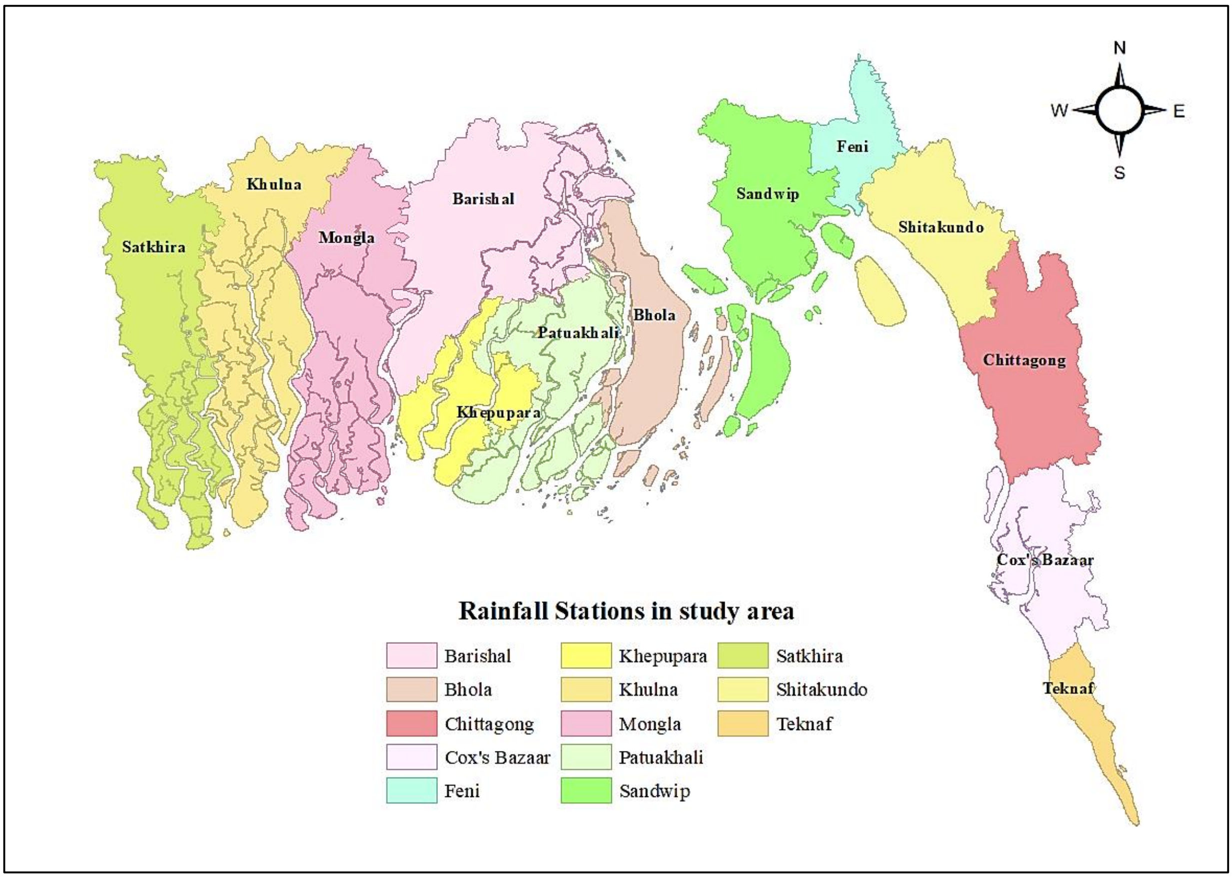


Fig. 1: Study area – coastal area of Bangladesh

A relatively limited research of the available catchment area for houses in the rural area has been undertaken, but according to Ferdausi and Bolkland (2000), the catchment area typically ranges from 20 to 70 m^2. A catchment area of 20 to 70 m^2 has been considered in the study for developing the design curves for storage tanks, as well as a water demand of 10 lpcd, because the usual range of water demand for drinking and cooking purposes in a rural community in Bangladesh is suggested to be around 10 – 12 lpcd (Armed and Rahman, 2000). The average household size in a rural coastal house is from 4 to 6 people for a single family, but it can reach more than 10 people for joint families (BBS, 2011). The current study focuses on the water demand for all thirteen stations for a family size ranging from 4 to 11. Furthermore, reliability curves were developed, and spilled water volume has been estimated for a variety of tank sizes (200–9000 L) for each station, taking into account the catchment area, water demand, and family size under each climatic condition.

3.2 Estimation of design surface runoff

In order to predict the peak surface flow runoff, Q, the rational method is widely used in the field of civil engineering. The rational method is mostly suitable for estimating the peak surface runoff, yield rate for small watersheds (Somprasong and Chaiwiwatworakul, 2015). Monthly accumulated rainfall from the historical data is calculated by the following formula –

$$Q = ciA \tag{1}$$

Where,

Q = monthly yield by a catchment (m^3)

c = coefficient of runoff

A = catchment area (m^2)

i = intensity of rainfall (m)

The daily runoff volume is calculated using the formula where the accumulated rainfall from the catchments are considered as the inflow for the storage tank. A 10 percent deduction of accumulated water has been considered for several losses like – first flushing, spilling, evaporation, leakage etc. Thus the coefficient of runoff, c, is considered here is 0.9.

3.3 Optimum Storage design curves

There are several approaches for calculating storage capacity for hydrological applications mainly in irrigation and water supply. The most commonly used reservoir capacity computation methods are Mass curve and Sequent peak algorithm based on the types of data and computing approach (Jain). Both strategies use cumulative daily water consumption and accumulated rainwater to produce design curves for optimal tank size (Aksoy, 2001). It should be noted that the mass curve is extensively used for calculating tank capacity even when rainfall data is limited, but the sequent peak approach is utilized to estimate and analyze big datasets using computerized programming (Thomas, 1963).

In Microsoft Excel, a behavioral model was constructed that took into account daily rainfall, roof-catchment area, runoff coefficient, tank volume, and water consumption. To estimate the optimum storage volume required to meet the water demand, the model was run at a daily time resolution using daily rainfall amounts for three climatic situations. (Imteaz, et al., 2011; Imteaz, et al., 2012; Karim, et al., 2015).

3.3.1 Mass curve – Ripple method

Ripple introduced the mass curve technique in 1883 to evaluate reservoir storage capacity. It is a graphical technique that is widely used due to its simplicity and intuitiveness. This method is also known as the Ripple mass curve method after its developer. This method is widely used during the project planning stage to estimate the needed storage capacity of a reservoir. The reservoir capacity is calculated by calculating the greatest difference between the cumulative inflow and cumulative demand curves (Ripple, 1883).

The mass curves of inflow and demand are built independently on a graph to determine the minimum required storage. A line parallel to the demand mass curve is drawn at each high point on the mass inflow curve. depicts a mass curve of reservoir inflows. The mass curve of demands is represented by the line AB. Two lines, lines CD and EF, are drawn parallel to line AB and tangent to the mass curve of inflows at points and E. The maximum vertical distance between the inflow mass curve and the lines CD and EF is recorded.

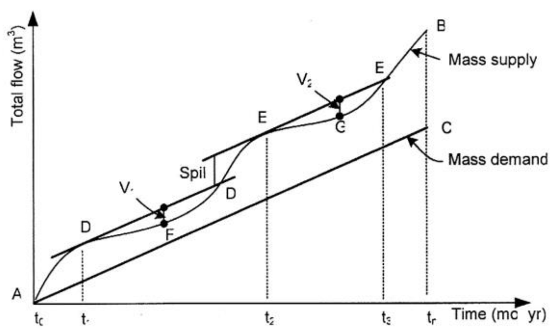


Fig. 2: Mass curve analysis *(adopted from Subramanya, 1994).*

3.3.2 Sequent peak algorithm

The sequent peak algorithm is a proposed approach that avoids the requirement to select the correct starting storage in the mass curve procedure. The reservoir is presumed to be empty at the start. The mass curve of cumulative net flow volume (Inflow - Outflow) against chronological time is utilized. This curve will have peaks and troughs (local maximums and minimums). For each peak P_i, the next peak of magnitude bigger than Pi is referred to as a sequent peak. The computations are carried out for twice the length of the inflow record, assuming that inflows repeat after the first cycle ends. This assumption is made to account for the situation in which the key time falls at the end of the record (Subramanya, 1994). The equation for determining storage, S_t, is calculated by the following equation. The required storage capacity is the maximum value of S_t.

$$S_t = S_{t-1} + R_t - I_t;\ if\ positive \quad (2)$$

$$S_t = 0;\ if\ negative\ or\ zero \quad (3)$$

Where,

I_t = The inflow to the reservoir during t;

R_t = Release from the reservoir during t;

S_t = Storage at the start of period t.

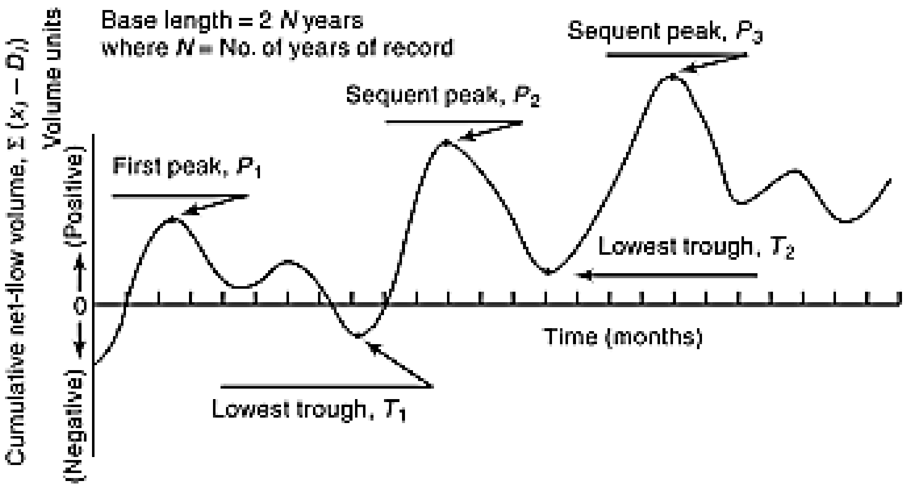


Fig. 3: Residual Mass curve – sequent peak algorithm *(adopted from Subramanya, 1994).*

3.4 Developing Water Balance Model

A daily water balance model was developed based on the approach of Imteaz et al. (2017) to assess the reliability of a rainwater harvesting system. The model assumes rainfall runoff to be the only source of water supply in a residential building and that it can meet the daily water demand with no other sources. Imteaz et al. (2011) and Karim et al. (2015) provided detailed descriptions of the mathematical formulations and logical sequences employed in the daily water balance model. The model computes total annual rainfall consumption, total spilled water, and total reliability of the system. The water balance equation states –

$$S_t = V_t + S_{t-1} \quad (4)$$

$$S_t = 0; for\ S_t < 0 \quad (5)$$

$$S_t = C; for\ S_t > C \quad (6)$$

Where,

S_t = Cumulative volume of water stored in the rainwater tank after t^{th} day;

V_t = Harvested rainwater on t^{th} day;

S_{t-1} = Storage in the tank at the beginning of t^{th} day;

D = Water demand;

C = Capacity of rainwater tank (L).

If the harvested water for any given day exceeds the tank capacity C, the excess water will spill over, and the tank storage level will be reset to C at the end of the day. The amount of water spilt is calculated –

$$Spilled\ water = S_t - C\ for\ S_t > C \quad (7)$$

3.4.1 Volumetric Reliability

The volumetric reliability or overall efficiency of RWH is the ratio of the water volume harvested by the system to the total water demand. According to Liuzzo et al. (2016), the formulation of volumetric reliability –

$$R_{e(v)} = \frac{Volume\ of\ rainwater\ harvested\ in\ a\ year}{Total\ annual\ water\ demand} * 100 \quad (8)$$

Where, Re (v) is the efficiency or volumetric reliability of a RWH system (%).

3.4.2 Time Reliability

The proportion of the total number of days the RWH system could meet the daily demand to the entire number of days in a calendar year. Time reliability is defined by, according to Baek and Coles (2011) –

$$R_{e(t)} = \frac{N - X}{N} * 100 \quad (9)$$

Where, Re (t) is the reliability of the RWH system to be able to supply the intended demand (%), X indicates the number of days in a year when rainfall runoff failed to meet the daily water demand of a residential building alone, and N is the total number of days in a that year.

3.5 Economic Analysis

The payback period was calculated using the annual monetary savings, installation, operation, and maintenance costs of a rainwater harvesting system for the economic analysis. The following formula was used to calculate payback periods (n) as proposed by Blank and Tarquin (2012), with the value of present worth (PW) set to zero.

$$PW = -FC + S * \frac{1 - \left(\frac{1 + g_S}{1 + i}\right)^n}{i - g_S} - AC * \frac{1 - \left(\frac{1 + g_{AC}}{1 + i}\right)^n}{i - g_{AC}} \quad (10)$$

Where,

PW = Net present worth of the RWH (BDT);

FC = Fixed cost for installation (BDT);

S = Yearly monetary savings (BDT);

AC = Annual cost for maintenance and operation (BDT);

n = Payback period (years);

i = Internal rate of return (%);

g_1, g_2 *= geometric gradients water price and annual costs (%).*

4 Result & Discussion

4.1 Rainfall analysis

The daily rainfall data was analyzed in order to initially investigate the total annual rainfall in order to access the climates variation for all the stations. As mentioned in art. 3.1, from the selected historical daily rainfall data, wet year, dry year, and average year were selected for developing several design curves optimum storage tanks and analyzing volumetric and time reliability.

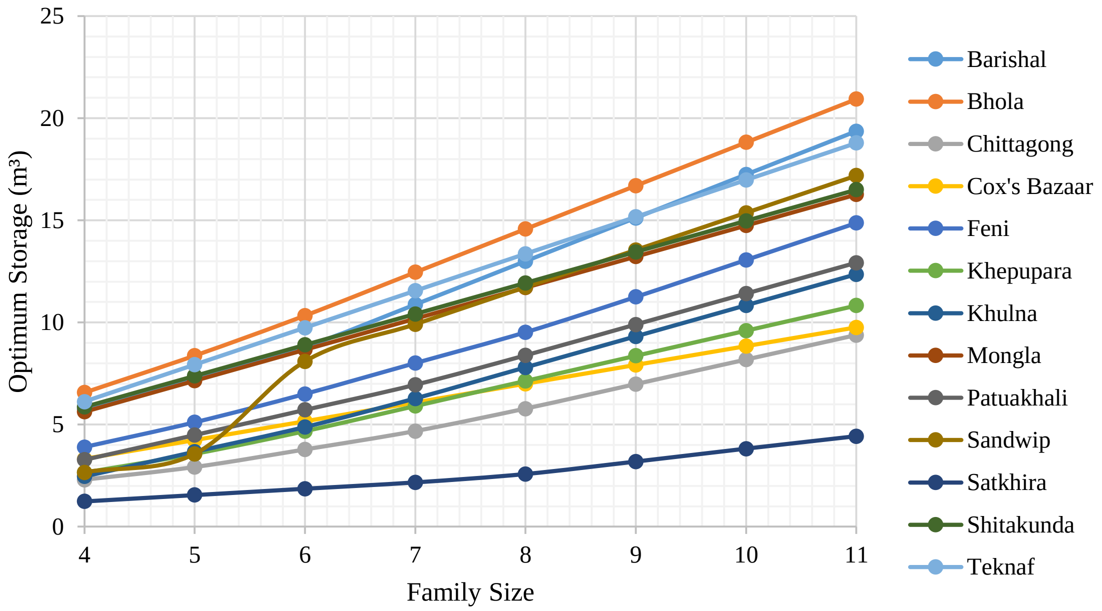
Table 2: Wet, average and dry year rainfall for different districts

Rainfall Stations	Dry Year		Wet Year		Average Year	
	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)
Bhola	2012	1493	2004	3080	2006	2160.28
Barishal	2018	1418	1998	2858	2006	2048.72
Chittagong	2016	2208	2007	4340	1997	2974.17
Cox's Bazaar	2014	2483	2015	4716	1996	3736.62
Feni	1992	1748	2017	4476	2009	2952.93
Khepupara	2014	1877	1995	3510	1997	2890.34
Khulna	2018	1073	2002	2594	1997	1815.62
Mongla	1992	1232	2002	2786	2004	1926.17
Patuakhali	2012	1895	2015	3098	1997	2563.69
Sandwip	1995	2234	2001	6095	2007	3693.62
Satkhira	2018	1292	2011	2121	1998	1716.69
Shitakunda	2006	2031	2017	4868	2004	3249.03
Teknaf	2014	3507	2015	5447	2003	4401.55

4.2 Storage capacity design curve

Design curves were developed for average, wet, and dry year circumstances to estimate the storage capacity necessary for a range of household sizes ranging from 4 to 11 and catchment areas ranging from 20 m^2 to 70 m^2. The design curves, also known as storage volume-demand relationships, for all climatic conditions are included in the appendix, whereas **Fig. 2** shows the design curves for an average year for a household of 6 with a catchment area of 50 m^2 and 60 m^2 for all 13 selected stations. The graph shows that storage volume increases with home demand and decreases with catchment area increase. **Fig. 5:** Optimum storage volume required for a family size of 6shows a GIS map of the spatial variation of optimum storage volume required to sustain a household having a catchment area of 50 m^2 and 6 family members. According to the storage volume-demand relationship, Bhola, Barishal, Bagerhath, Noakhali, Shitakunda, and Teknaf require a higher storage volume due to the scarcity of rainfall, whilst other stations require adequate storage due to the higher concentration of precipitation. However, due to a lack of rainfall, the needed storage volume for a single station during a dry year appears to be substantially higher than the storage volume calculated based on ordinary year conditions. The rainfall statistics indicate that, while total rainfall was higher, the number of rainy days for that year was significantly lower, indicating that rainfall was less effective in meeting daily demands.

Catchment Area 50 m²



Catchment Area of 60 m²

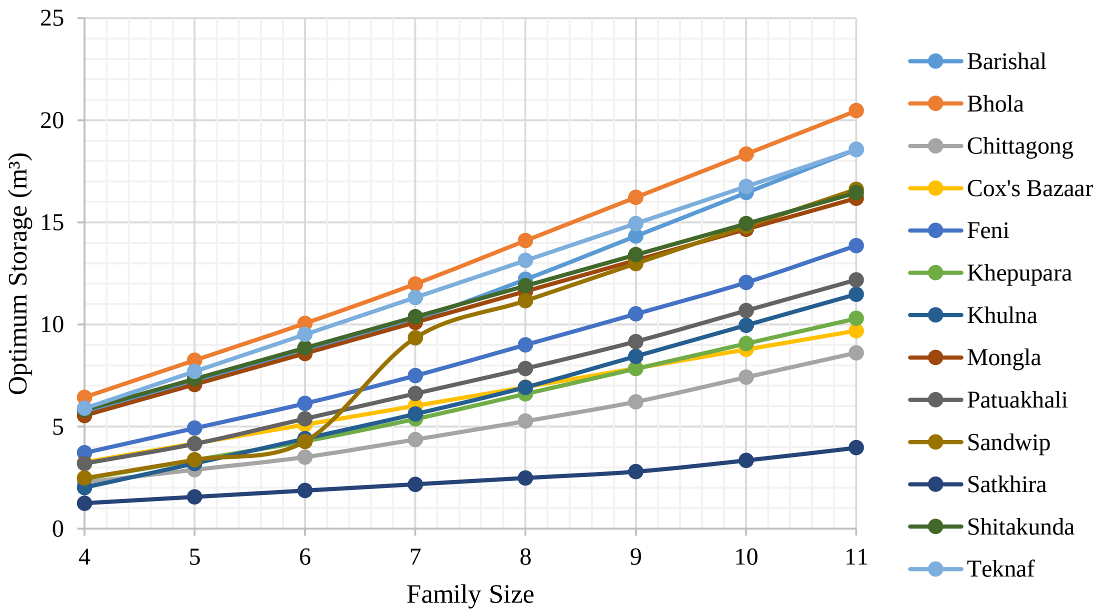


Fig. 4: Typical storage volume-demand relationship of rainwater

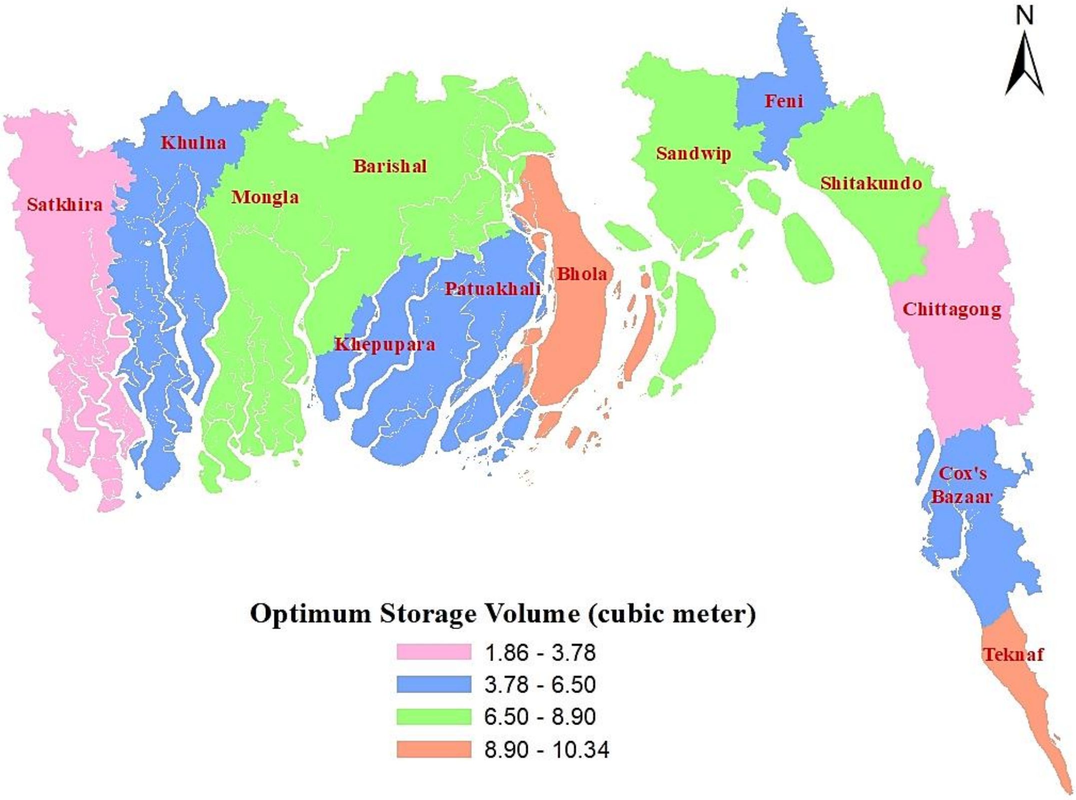


Fig. 5: Optimum storage volume required for a family size of 6

4.3 Reliability curves with climatic variation

The reliability curves for different tank sizes for roof catchment areas of 30 – 50 m2 for a family of 4 – 6 people with 10 lpcd of water use have been evaluated under different climatic situations (wet, average, and dry years).

4.3.1 Varying Catchment Area

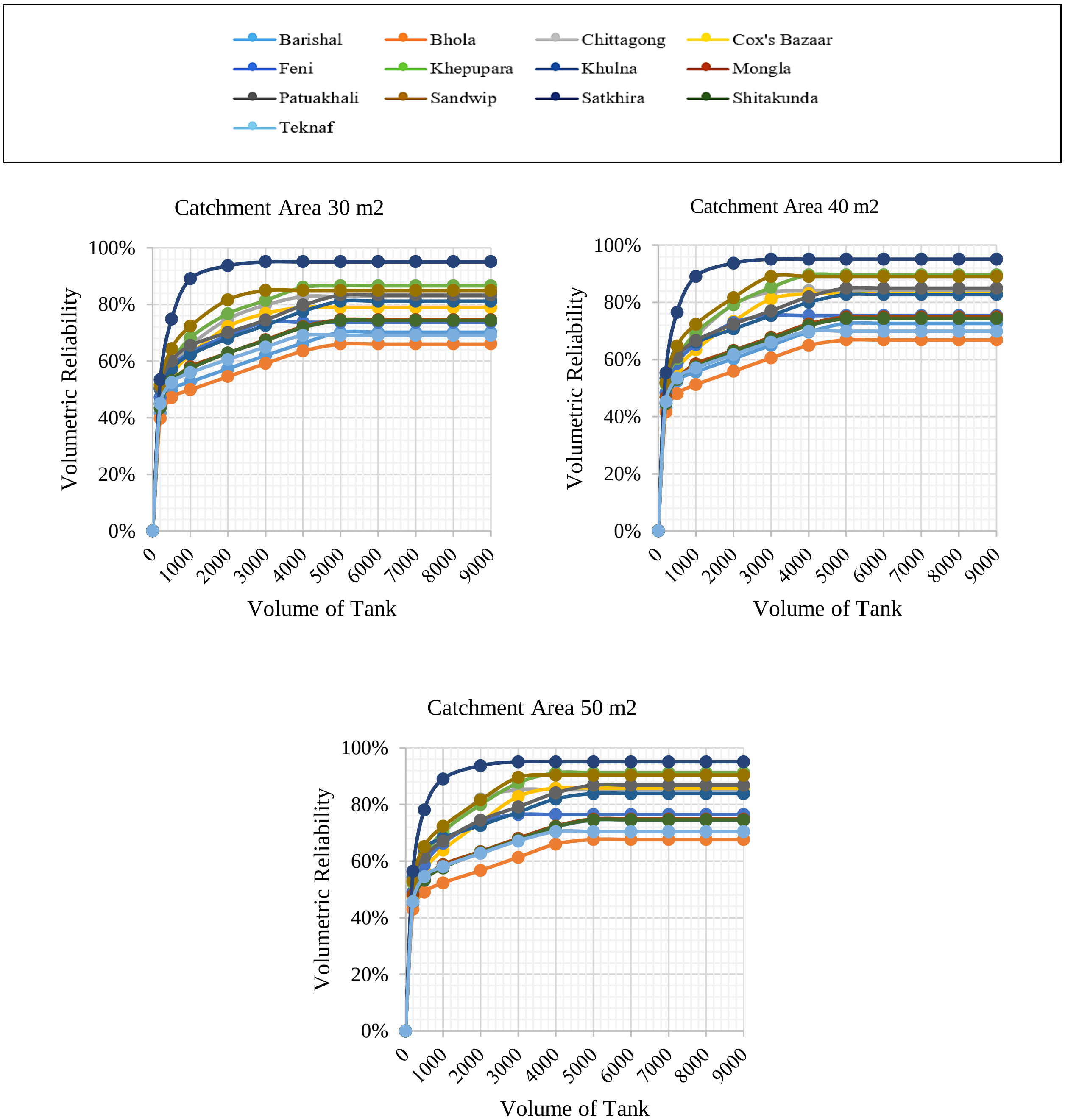


Fig. 6: Volumetric reliability for catchment area of 50 m^2

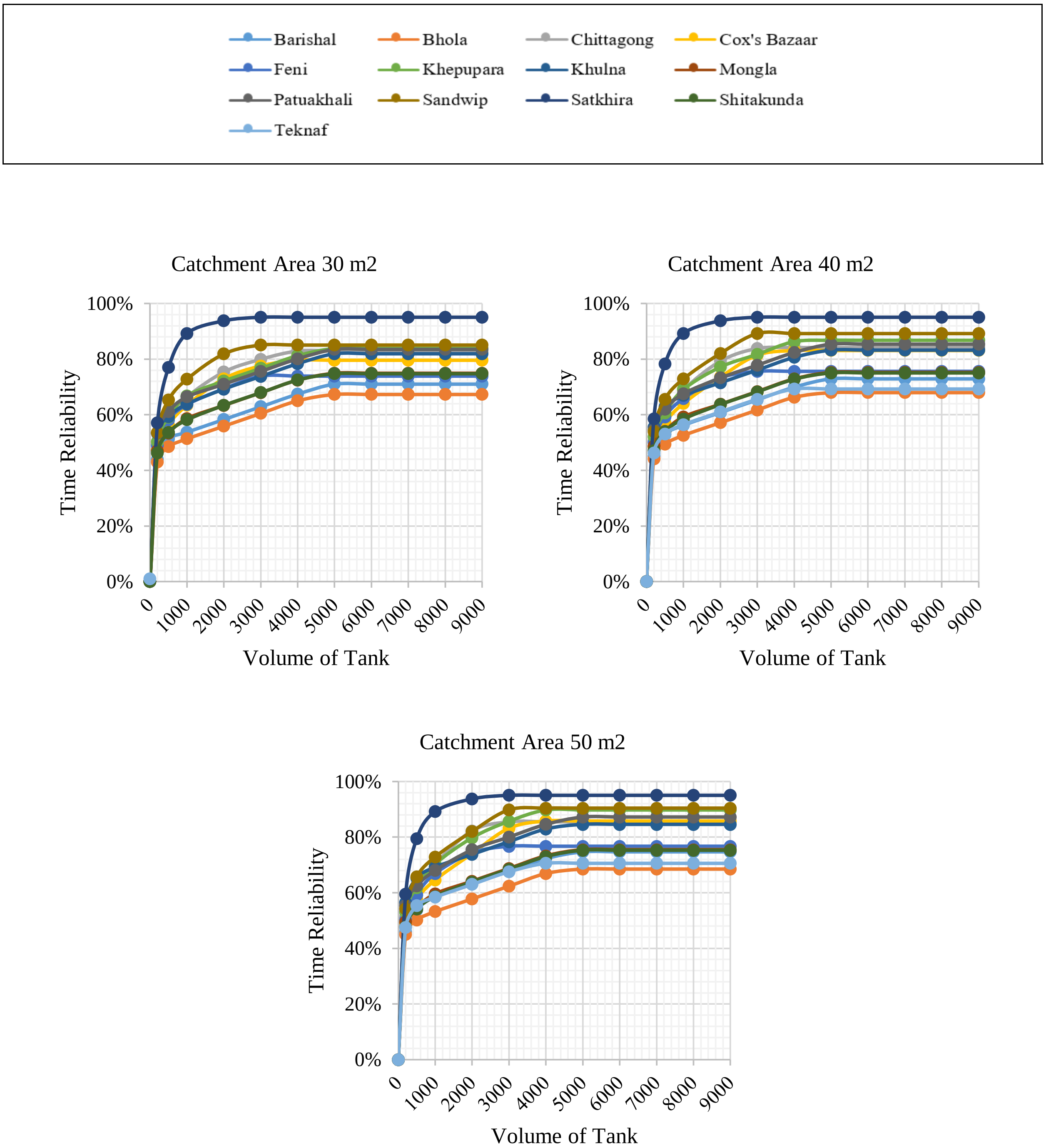


Fig. 7: Time reliability for catchment area of 50 m2

Error! Reference source not found. and **Fig. 6** illustrates the time and volumetric reliability curves for 13 different stations in Bangladesh's coastline region, respectively; whereas the Appendix section contains all other design curve for specific stations. For a family of six, Satkhira has the best reliability (above 80%) while Bhola has the lowest reliability (60-70%) for catchment areas of 30 m^2, 40 m^2, and 50 m^2. As a result, the 13 stations' reliability varies usually from 60 to 100 percent. From the figure, the maximum reliability of Bhola and Teknaf ranges in between 60-70%; Mongla, Feni, Shitakunda, and Barisal ranges in between 70-80%; Chittagong, Cox's Bazaar, Khepupara, Khulna, Patuakhali, Sandwip, Satkhira ranges in between 80-100%. In case of volumetric reliability, the highest reliability is found in Satkhira which is 95.07% for the catchment area of 50 m^2. From these variation of graphs, it can be concluded that the reliability increases with the increase of the size of catchment area and with the reduction of family size.

4.3.2 Varying Family Size

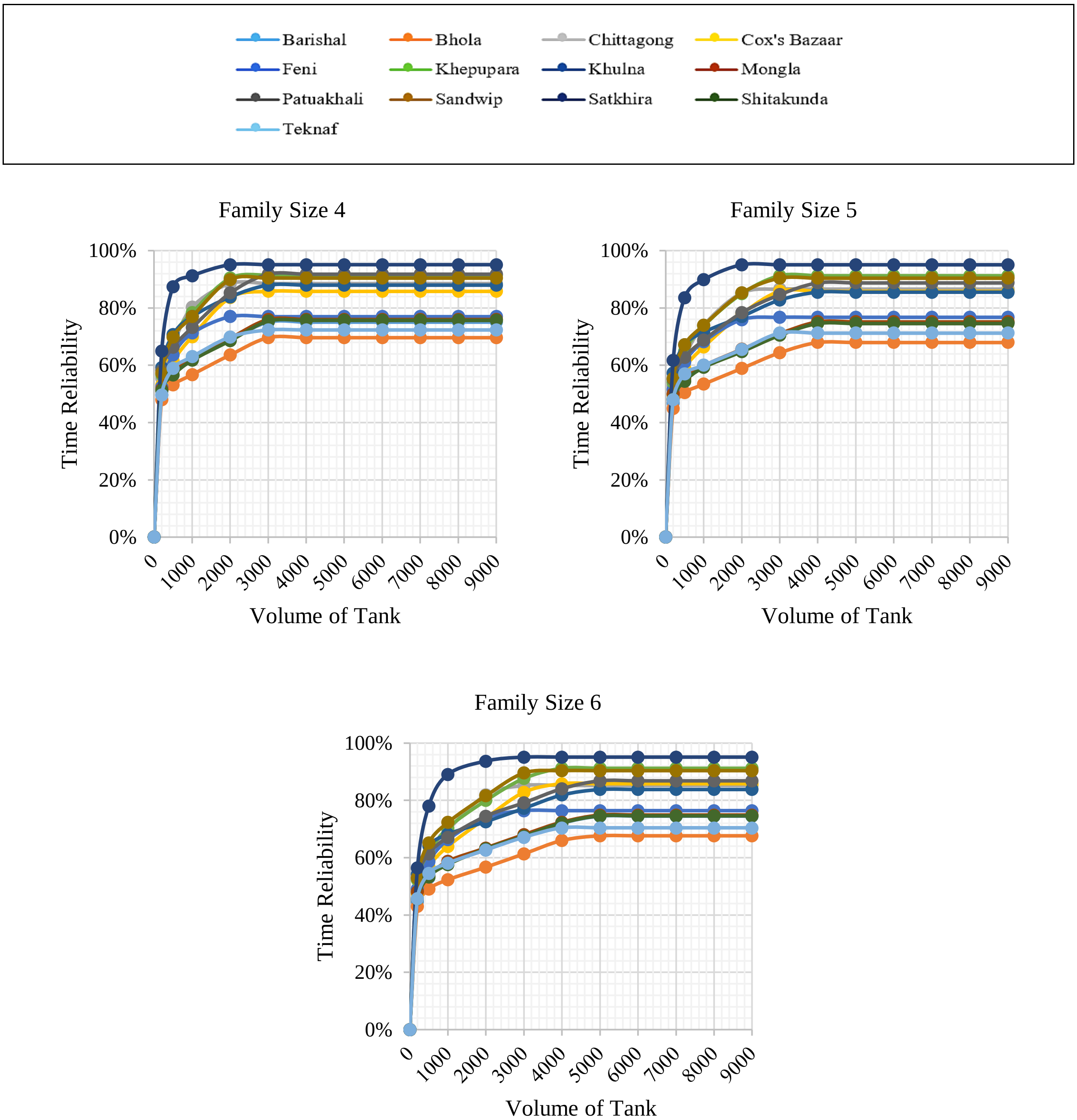


Fig. 8: Time reliability for catchment area for family size 4

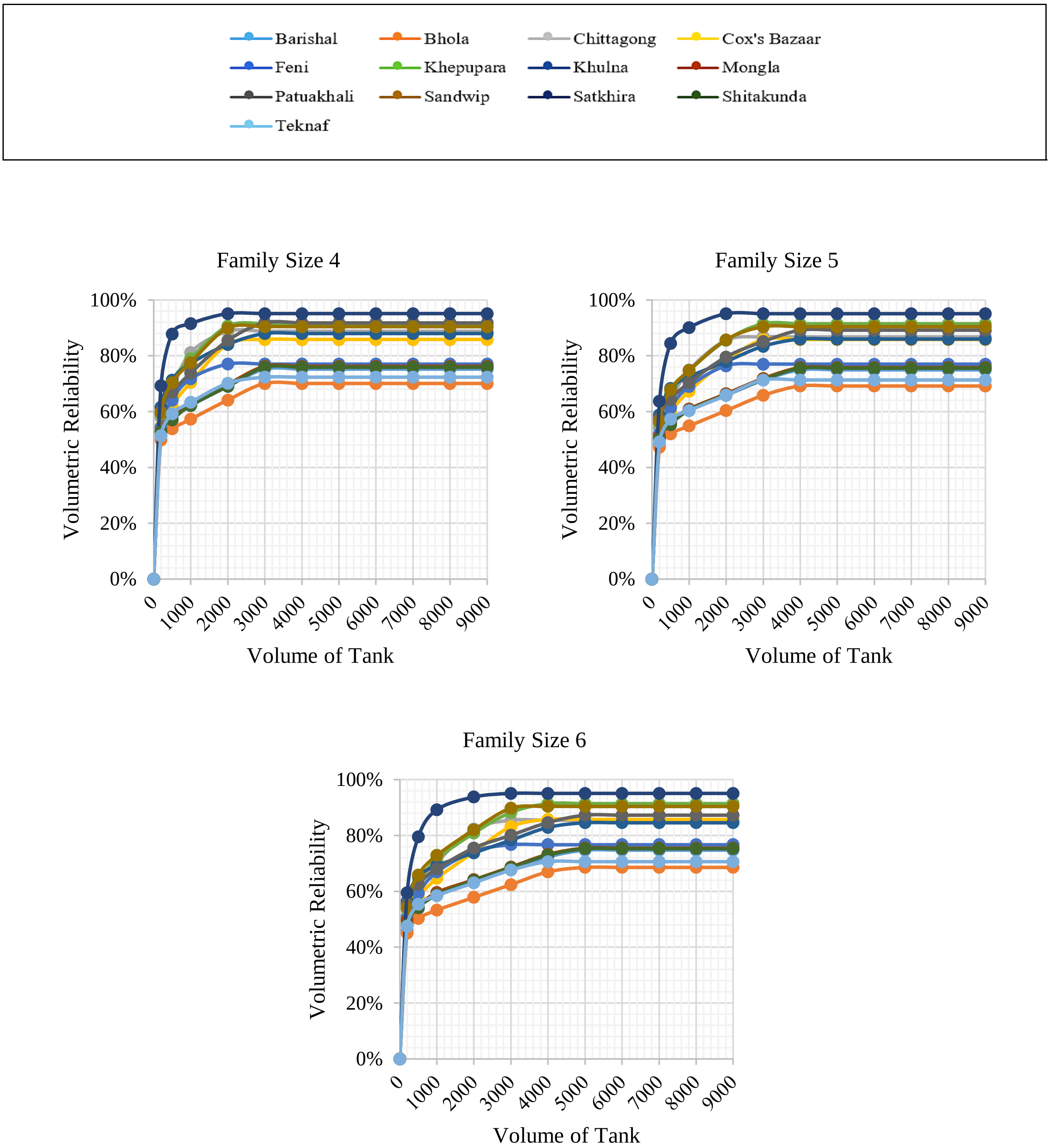


Fig. 9: Volumetric reliability for catchment area for family size 4

Time and volumetric reliability is found fixing the catchment area ($50m^2$) and considering the family sizes of 4, 5, and 6 as shown in **Fig. 8** and **Fig. 9**. The highest reliability is found in Satkhira which is above 90% and the lowest reliability is found in Bhola which is in between 60-70% for the catchment area of 30 m^2, 40 m^2, and 50 m^2. Therefore, the reliability of the 13 stations ranges in between 60-100%. From the graphs, 4 data clusters are formed as 60-70%, 70-80%, 80-90%, 90-100%. The maximum reliability of Bhola and Teknaf ranges in between 60-70%; Mongla, Feni, Shitakunda, and Barisal ranges in between 70-80%; Chittagong, Cox's Bazaar, Khulna, Patuakhali, ranges in between 80-90%;

Satkhira, Khepupara, Sandwip ranges in between 90-100%. This combination is found more reliable than the first combination. However, the reliability has been decreased with the increase of family size.

Fig. 10 and **Fig. 11** depicts the spatial variation of the maximum time based reliability and volume based reliability respectively of a 5000 L tank to sustain the residents to meet their demand of water for drinking and cooking purpose.

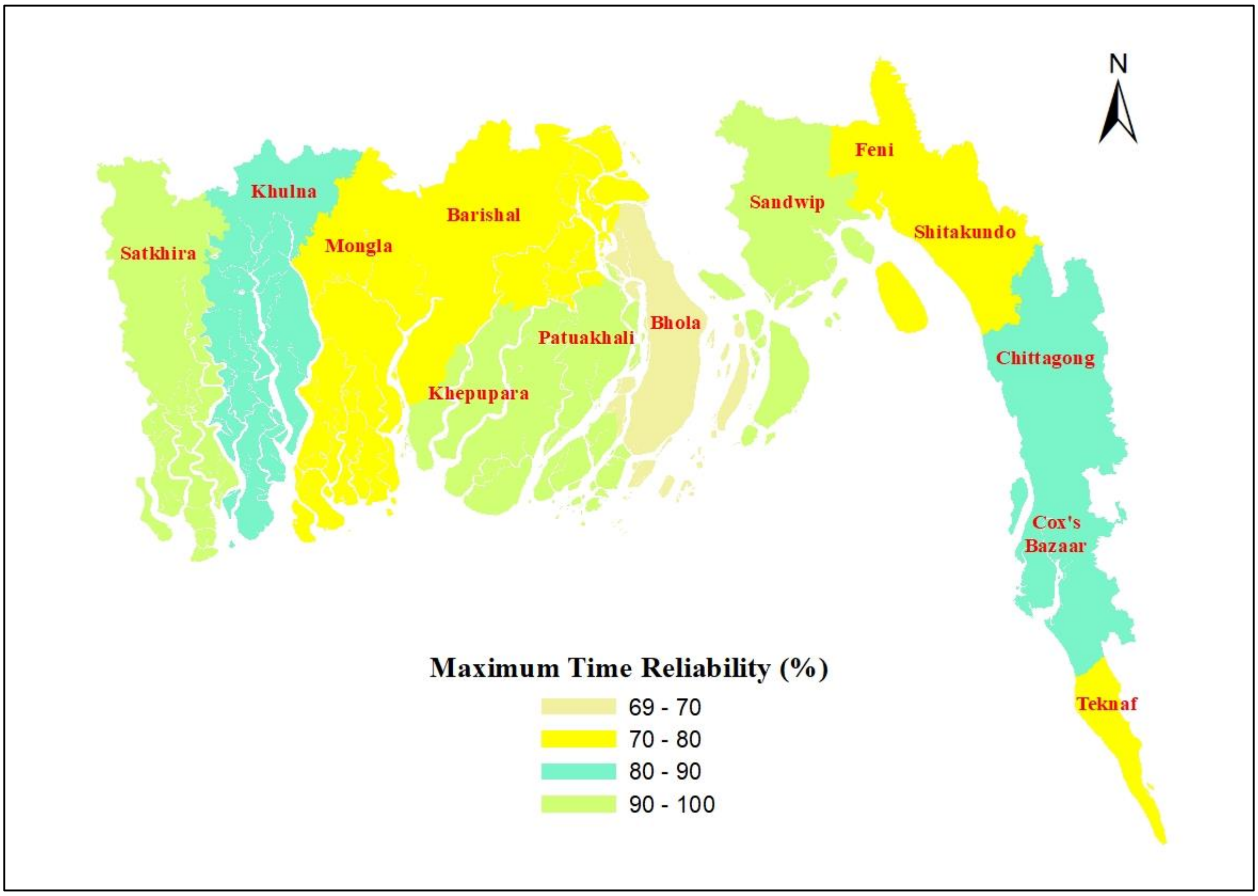


Fig. 10: Spatial variation for maximum time reliability for a tank size of 5000L and family size of 6 people

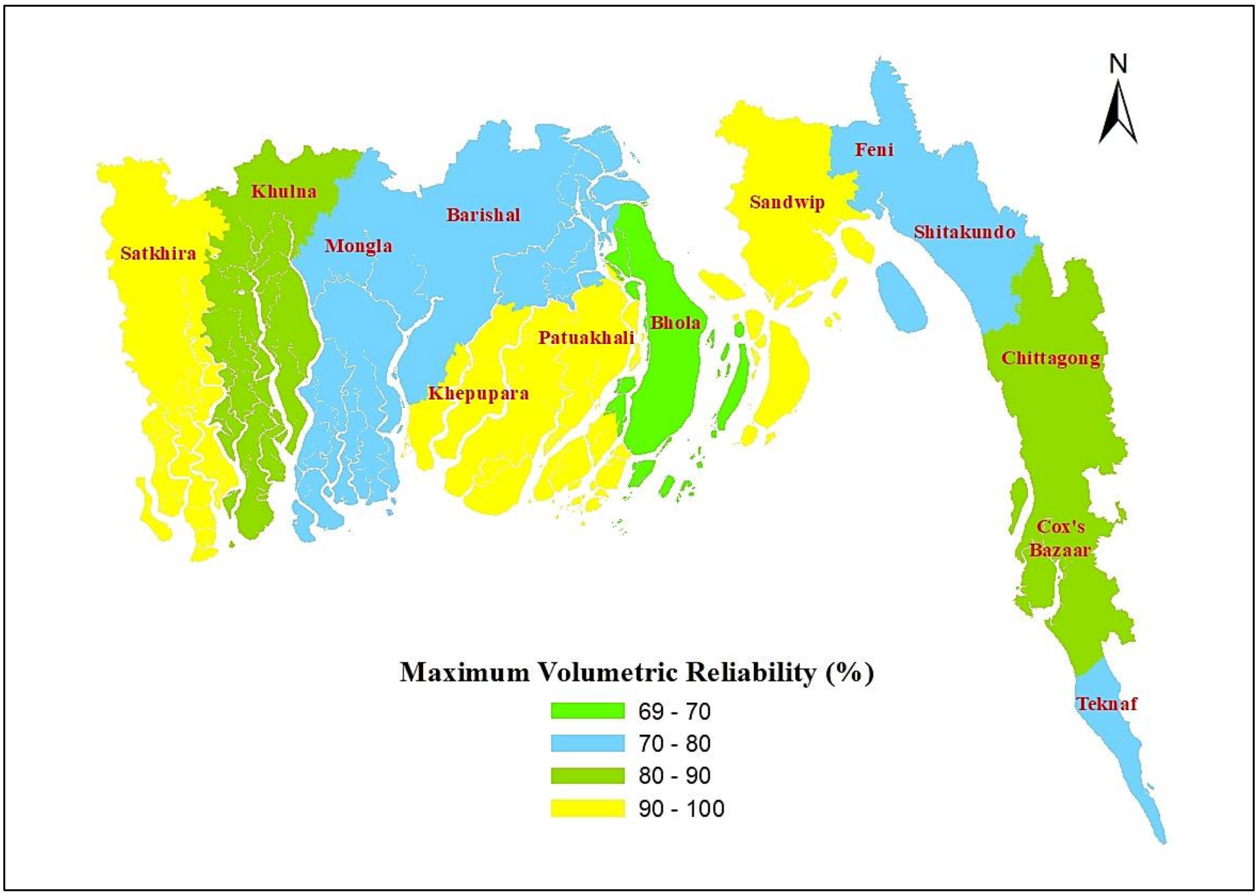


Fig. 11: Spatial variation for maximum volumetric reliability for a tank size of 5000L and family size of 6 people

4.4 Volume of Spilled water curves

The spillage is depicted in the graphs above using catchment areas of 30m2, 40m2, and 50m2 for a fixed family size of 6. Teknaf has the most spillage, varying from 100 to 200 m3, while Satkhira has the lowest, varying from 40 to 70 m3. The spillage volume ranges from 30-112 m3, 50-150 m3, and 50-193 m3 for the catchment area of 30m2, 40 m2, and 50 m2 respectively which demonstrates the proportional relation between spillage volume and catchment area.

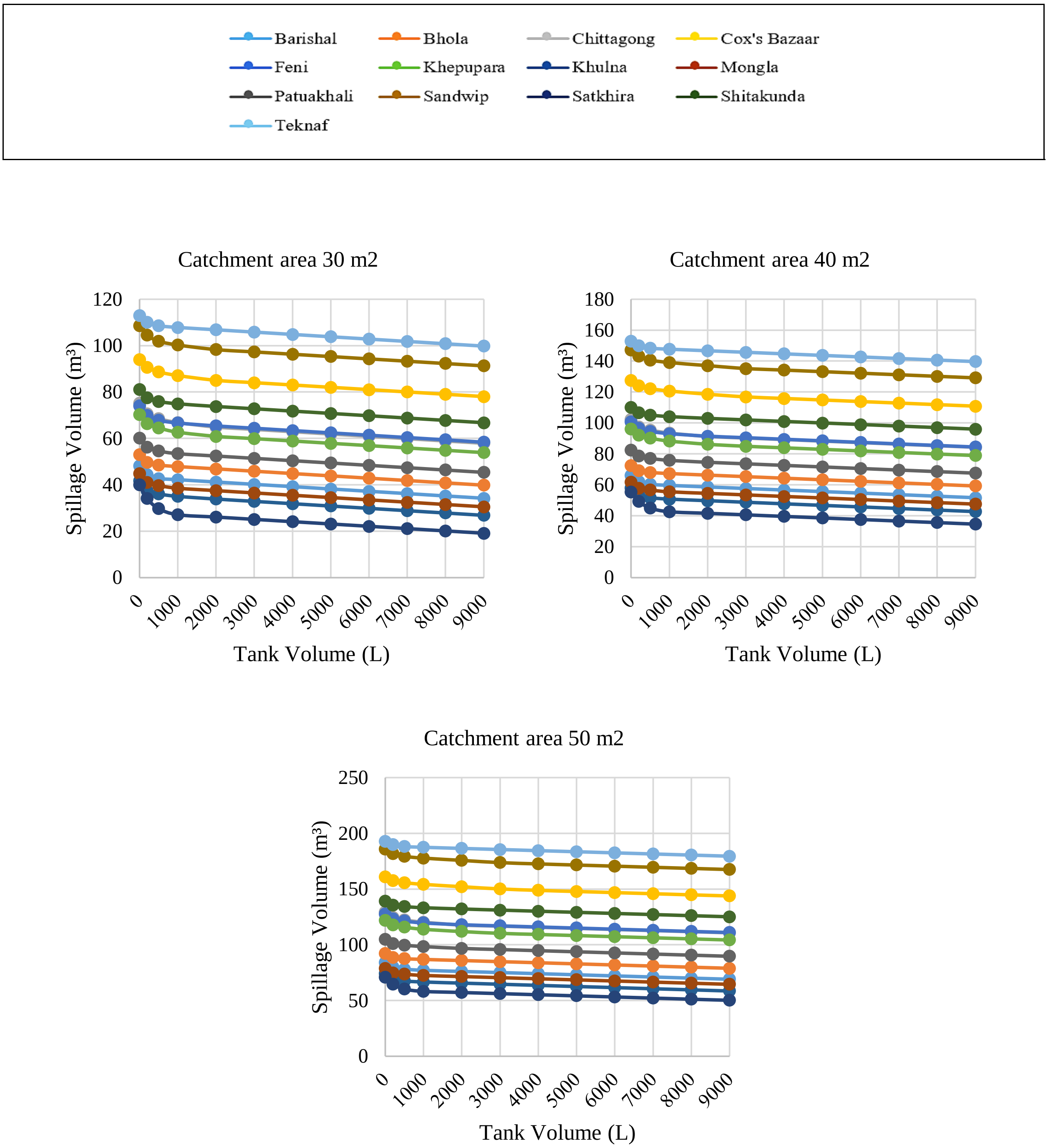


Fig. 12: Spilled volume for an average year with 6 family members

The spillage is depicted in the **Fig. 12** using catchment areas of 30 m^2, 40 m^2, and 50 m^2 for a fixed family size of 6. Teknaf has the most spillage, varying from 100 to 200 m^3, while Satkhira has the lowest, varying from 40 to 70 m^3. The spillage volume ranges from 30-112 m^3, 50-150 m^3, and 50-193 m^3 for the catchment area of 30 m^2, 40 m^2, and 50 m^2 respectively which demonstrates the proportional relation between spillage volume and catchment area.

4.5 Payback Period

Payback periods for various situations were computed using a simple economic analysis. By multiplying the unit price of water with the unit volume of water saved, potential water savings were transformed to monetary savings. Due to the inevitability of datasets to provide the possible monetary savings for different cities under varied climatic circumstances for a tank with a 5000L volume, several datasets were assumed as shown in **Table 3**. The payback times were determined to be between 2 and 3.5 years, indicating that the system is financially viable.

Table 3: Payback period for an initial investment on a 5000L tank with varying catchment area.

Tank Volume (L)	**5000**	**5000**	**5000**
Catchment Area, m^2	40 m^2	50 m^2	60 m^2
Annual Saving (BDT) *		10000	
Installation Cost (BDT) *	40000	50000	55000
Maintenance Cost (BDT) *	3000	3250	3500
Rate of return, i (%) *		10%	
*Geometric gradients water price, g_S (%)**		5%	
*Geometric gradients annual cost, g_{AC} (%) **		2%	
Payback Period (Years)	2.012	2.10	3.01

*(*Values were considered)*

5 Conclusion

Rainwater collection is emerging as a viable water supply solution for coastal areas threatened by salinity. Since the catchment or roofing of coastal dwellings varies greatly, determining the optimal tank size to meet the drinking and cooking water demand is challenging. The storage tank is a crucial component of a rainwater harvesting system because the tank volume determines the water supply option's reliability. A comprehensive decision-making tool was developed in this study to address this gap. The current study analyzes 13 rainfall sites to develop curves to predict optimum tank volume using a water balance model for the entire coastal zone. A comparison of the reliabilities of different districts along the coast has been presented under various climatic situations. Government agencies and non-governmental organizations can effectively estimate the required storage tank based on criteria such as family size, catchment area, and rainfall to meet water demand throughout the year using the supplied design curves for coastal districts.

Due to the seasonal variance of rainfall in the districts, analysis of daily rainfall data shows that 100 percent reliability for household harvesting systems is difficult. Patuakhali, Chittagong, Feni, Sandwip, Satkhira, Mongla, and Khulna, among the study rainfall stations, have the most potential to meet the people's water demands. In general, for an average year, a tank of 5000L with a catchment area of 50m2 can reach a maximum volumetric reliability and time reliability of 75 - 95%. The greatest possible reliability under wet and dry weather conditions is around 80%. It should be noted that the average year has a higher reliability than the wet year because the selected rainfall data may not exactly match the average year, resulting in residual rainfall. However, a family can maintain 100 percent reliability if the family builds a larger catchment area, which is not economically viable. It has also been found that the volume of spilt water increases with catchment area; huge volume of harvested rainwater can be used in other potential uses. As a result, increasing tank capacity can be considered because it can hold water for a longer period of time while also ensuring reliability, but do not impose rapid change in reliability.

According to the economic analysis, the initial cost of a typical rainwater harvesting system with a tank volume of 5000L and a catchment area of 40 – 60 m2 is predicted to have a payback period of 3–4 years, making it an economically viable option for coastal residents.

In this study, various design curves were developed for optimum storage capacity while only considering water demand for drinking and cooking. The developed graphs can be simply utilized to plan a reliable and sustainable rainwater harvesting system for the residents of Bangladesh's coastal region. To ensure overall water quality, the water should be thoroughly cleaned and disinfected before consumption.

6 References

Ahmed, M. F. (1999). Rainwater harvesting potentials in Bangladesh.

Ahmed, M. F., & Rahman, M. M. (2000). Water Supply and Sanitation: Rural and low income urban communities, ITN-Bangladesh. Center for water supply and waste management, BUET, Dhaka, Bangladesh, 191-195.

Ahmed, M. F., & Rahman, M. M. (2000). Water Supply and Sanitation: Rural and low income urban communities, ITN-Bangladesh. Center for water supply and waste management, BUET, Dhaka, Bangladesh, 191-195.

Ahmed, M. F., Shamsuddin, S. A., Mahmud, S. G., Rashid, H., Deere, D., & Howard, G. (2005). Risk assessment of arsenic mitigation options (RAAMO).

Aksoy, H. (2001). Storage capacity for river reservoirs by wavelet-based generation of sequent-peak algorithm. Water Resources Management, 15(6), 423-437.

Akter, A., Ahmed, S., 2015. Potentiality of rainwater harvesting for an urban community in Bangladesh. J. Hydrol. 528, 84–93. http://dx.doi.org/10.1016/j.jhydrol.2015.06.017.

Armed, M. F. (2003). Alternative Water Supply Options for Arsenic Affected Areas of Bangladesh. Arsenic Mitigation in Bangladesh.

Atikul Islam, M., Sakakibara, H., Karim, M. R., & Sekine, M. (2013). Potable water scarcity: options and issues in the coastal areas of Bangladesh. *Journal of water and health, 11*(3), 532-542.

Baek, C. W., & Coles, N. A. (2011, December). Defining reliability for rainwater harvesting systems. In 19th International Congress on Modelling and Simulation (pp. 12-16).

Bangladesh Bureau of Statistics. (2011). Population & Housing Census 2011 (Zila series and Community Series). Retrieved from http://www.bbs.gov.bd/site/page/47856ad0-7e1c-4aab-bd78-892733bc06eb/Population-and-Housing-Census

Bashar, M. Z. I., Karim, M. R., & Imteaz, M. A. (2018). Reliability and economic analysis of urban rainwater harvesting: A comparative study within six major cities of Bangladesh. Resources, Conservation and Recycling, 133, 146–154.

Farreny, R., Gabarrell, X., & Rieradevall, J. (2011). Cost-efficiency of rainwater harvesting strategies in dense Mediterranean neighbourhoods. Resources, Conservation and Recycling, 55(7), 686-694.

Ferdausi, S. A. (1999). Study of Low-cost Arsenic mitigation technologies for application in rural Bangladesh. Department of Sanitary and Environmental Engineering. IHE, Delft.

Ferdausi, S. A., & Bolkland, M. W. (2000). Rainwater harvesting for application in rural Bangladesh (Version1). Loughborough University. Retrieved from https://hdl.handle.net/2134/28797([])

Fewkes, A. (2000). Modelling the performance of rainwater collection systems: towards a generalised approach. Urban water, 1(4), 323-333.

Ghosh, G. C., Jahan, S., Chakraborty, B., & Akter, A. (2015). Potential of household rainwater harvesting for drinking water supply in hazard prone coastal area of Bangladesh. Nature Environment and Pollution Technology, 14(4), 937.

Goh, Y. C., & Ideris, M. (2021). Tangki NAHRIM 2.0: An R-based water balance model for rainwater harvesting tank sizing application. Water Practice and Technology, 16(1), 182-195.

Gupta, A. K. (2006). Rainwater Harvesting. Indian Railways Institute of Civil Engineering, Pune, India.

Habiba, U., Abedin, M. A., Shaw, R., & Hassan, A. W. R. (2014). Salinity-induced livelihood stress in coastal region of Bangladesh. In Water insecurity: A social dilemma. Emerald Group Publishing Limited.

Harun, M. A., & Kabir, G. M. M. (2013). Evaluating pond sand filter as sustainable drinking water supplier in the Southwest coastal region of Bangladesh. Applied Water Science, 3(1), 161-166.

Hussain, M. D., & Ziauddin, A. T. M. (1992). Rainwater harvesting and storage techniques from Bangladesh. Waterlines, 10-12.

Imteaz, M. A., Adeboye, O. B., Rayburg, S., & Shanableh, A. (2012). Rainwater harvesting potential for southwest Nigeria using daily water balance model. Resources, Conservation and Recycling, 62, 51-55.

Imteaz, M. A., Ahsan, A., Naser, J., & Rahman, A. (2011). Reliability analysis of rainwater tanks in Melbourne using daily water balance model. Resources, Conservation and Recycling, 56(1), 80–86.

Imteaz, M. A., Karki, R., Shamseldin, A., & Matos, C. (2017). eTank and contemporary online tools for rainwater tank outcomes analysis. International Journal of Computer Aided Engineering and Technology, 9(3), 372-384.

Islam, A. R. M. T., Siddiqua, M. T., Zahid, A., Tasnim, S. S., & Rahman, M. M. (2020). Drinking appraisal of coastal groundwater in Bangladesh: An approach of multi-hazards towards water security and health safety. Chemosphere, 255, 126933.

Islam, K. S., Xue, X. Z., & Rahman, M. M. (2009). Successful Integrated Coastal Zone Management (ICZM) program model of a developing country (Xiamen, China)–implementation in Bangladesh perspective. Journal of Wetlands Ecology, 35-41.

Islam, K. Z., Islam, M. S., Lacoursière, J. O., & Dessborn, L. (2014). Low cost rainwater harvesting: An alternate solution to salinity affected coastal region of Bangladesh. American Journal of Water Resources, 2(6), 141-148.

Islam, M. M., Afrin, S., Tarek, M. H., & Rahman, M. M. (2021). Reliability and financial feasibility assessment of a community rainwater harvesting system considering precipitation variability due to climate change. Journal of Environmental Management, 289, 112507.

Jain, S. K. Determination of reservoir storage capacity. Natl. Inst. Hydrol, 1-10. Retrieved from http://nihroorkee.gov.in/sites/default/files/uploadfiles/Reservoir-Sizing.pdf

Karim, M. R. (2010). Assessment of rainwater harvesting for drinking water supply in Bangladesh, J. Water Sci. Technol. Water Supply 10. pp 243–249.

Karim, M. R. (2010). Assessment of rainwater harvesting for drinking water supply in Bangladesh. Water Science and Technology: Water Supply, 10(2), 243-249.

Karim, M. R., Bashar, M. Z. I., & Imteaz, M. A. (2015). Reliability and economic analysis of urban rainwater harvesting in a megacity in Bangladesh. Resources, Conservation and Recycling, 104, 61-67.

Karim, M. R., Rimi, R. A., & Billah, M. S. (2015). Analysis of storage volume and reliability of the rainwater harvesting tanks in the coastal area of Bangladesh. Desalination and Water Treatment, 54(13), 3544-3550.

Karim, M. R., Shelly, A. B., & Biswas, M. (2005, November). People perception and acceptance of rainwater harvesting in a coastal area in Bangladesh. In 12th international rainwater catchment systems conference, New Delhi, India—November.

Khan, S. T., Baksh, A. A., Papon, M. T. I., & Ali, M. A. (2017). Rainwater harvesting system: an approach for optimum tank size design and assessment of efficiency. International Journal of Environmental Science and Development, 8(1), 37.

Khan, S. T., Baksh, A. A., Papon, M. T. I., & Ali, M. A. (2017). Rainwater harvesting system: an approach for optimum tank size design and assessment of efficiency. International journal of Environmental Science and Development, 8(1), 37.

Leland Blank, A., & Anthony Tarquin, P. E. (2005). Engineering economy. McGraw-Hill.

Levallois, P., Guevin, N., Gingras, S., Levesque, B., Weber, J. P. & Letarte, R. (1998). New patterns of drinking-water consumption: results of a pilot study. Sci. Total Environ. 209, 233–241.

Liaw, C. H., & Tsai, Y. L. (2004). Optimum storage volume of rooftop rain water harvesting systems for domestic use 1. JAWRA Journal of the American Water Resources Association, 40(4), 901-912.

Loucks, D. P., & Van Beek, E. (2017). Water resource systems planning and management: An introduction to methods, models, and applications. Springer.

Matos, C., Bentes, I., Santos, C., Imteaz, M., & Pereira, S. (2015). Economic analysis of a rainwater harvesting system in a commercial building. Water Resources Management, 29(11), 3971-3986.

MoWR. 2005. The national coastal zone policy. Ministry of Water Resources, Dhaka, Bangladesh.

Notaro, V., Liuzzo, L., & Freni, G. (2016). Reliability analysis of rainwater harvesting systems in southern Italy. Procedia engineering, 162, 373-380.

Notaro, V., Liuzzo, L., & Freni, G. (2017). Evaluation of the optimal size of a rainwater harvesting system in Sicily. Journal of Hydroinformatics, 19(6), 853-864.

Oweis, T. Y., & Taimeh, A. Y. (1996). Evaluation of a small basin water-harvesting system in the arid region of Jordan. Water resources management, 10(1), 21-34.

Pachpute, J. S., Tumbo, S. D., Sally, H., & Mul, M. L. (2009). Sustainability of rainwater harvesting systems in rural catchment of Sub-Saharan Africa. Water Resources Management, 23(13), 2815-2839.

Parajuli, I. (2018). Potential and Practices of Rain Water Harvesting System in Nepal. Smart Water Grid International Conference, 12-13 November 2018, Incheon, Republic of Korea.

Rahman, M., & Islam, M. (2019). Scarcity of Safe Drinking Water in the South-West Coastal Bangladesh. Journal of Environmental Science and Natural Resources, 11(1-2), 17–25. https://doi.org/10.3329/jesnr.v11i1-2.43361

Ripple, W., 1883. Capacity of storage reservoirs for water supply. Minutes of Proc., p. 71.

Somprasong, K., & Chaiwiwatworakul, P. (2015). Estimation of potential cadmium contamination using an integrated RUSLE, GIS and remote sensing technique in a remote watershed area: a case study of the Mae Tao Basin, Thailand. Environmental Earth Sciences, 73(8), 4805-4818.

Subramanya, K. (1994). Engineering hydrology. Tata McGraw-Hill Education.

Vedula, S., & Mujumdar, P. P. (2005). Water resources systems: modelling techniques and analysis. Tata McGraw-Hill.

Water, S., & World Health Organization. (2006). Guidelines for drinking-water quality [electronic resource]: incorporating first addendum. Vol. 1, Recommendations.

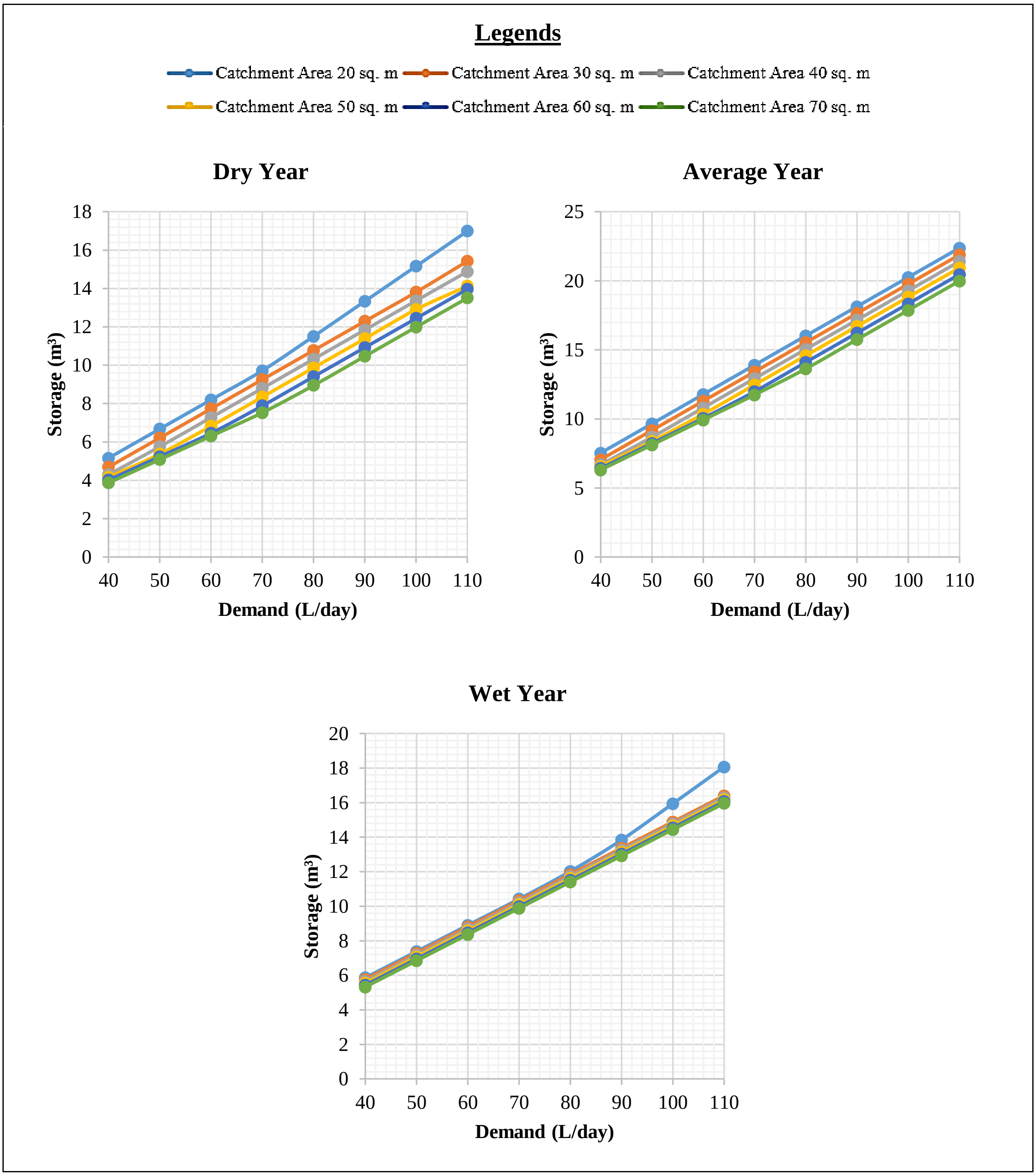
Worm, J. (2006). AD43E Rainwater harvesting for domestic use (No. 43). Agromisa Foundation.

7 Appendix

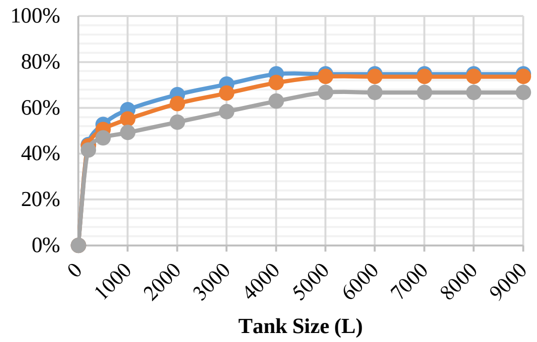
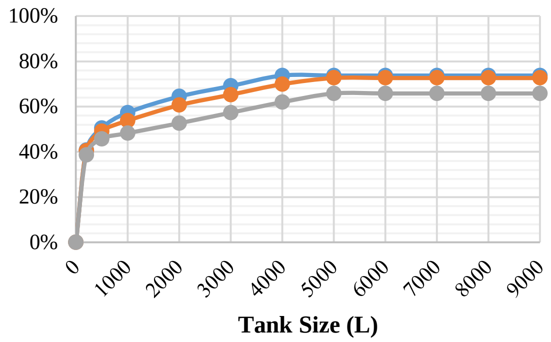
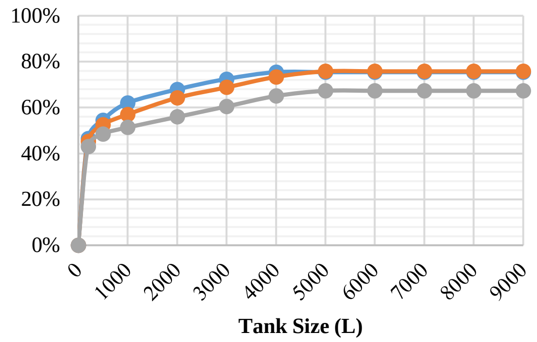
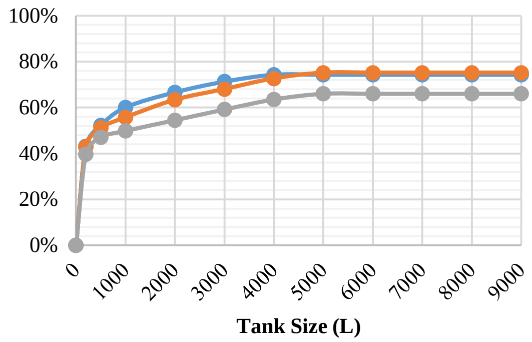
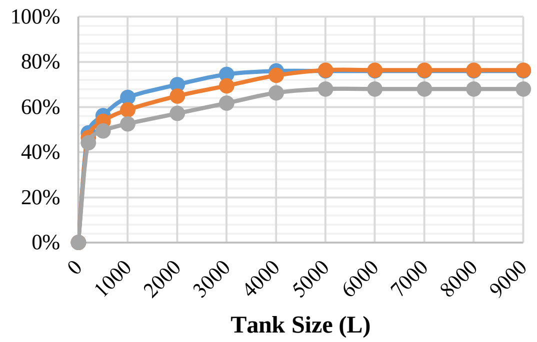
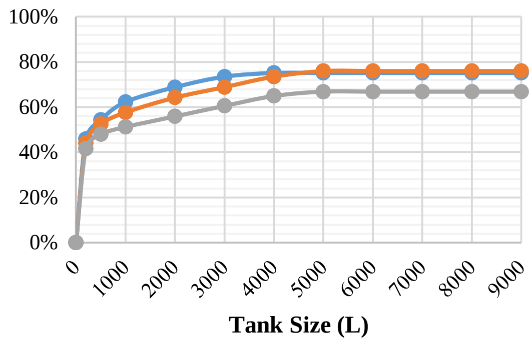
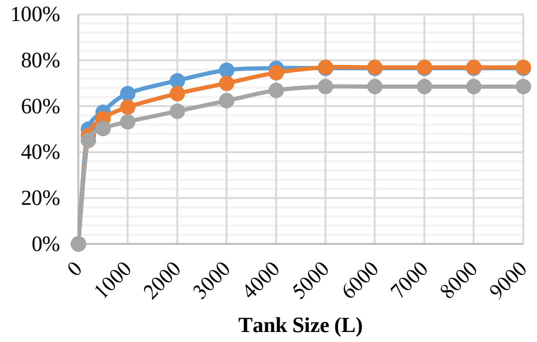
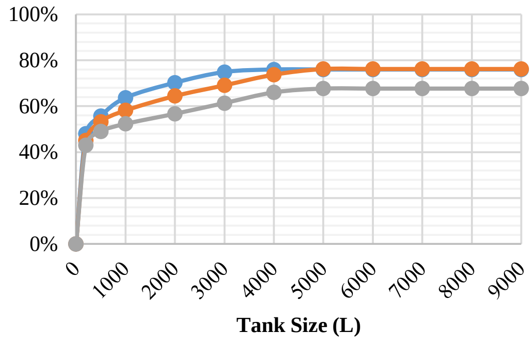
7.1 Station wise design curves

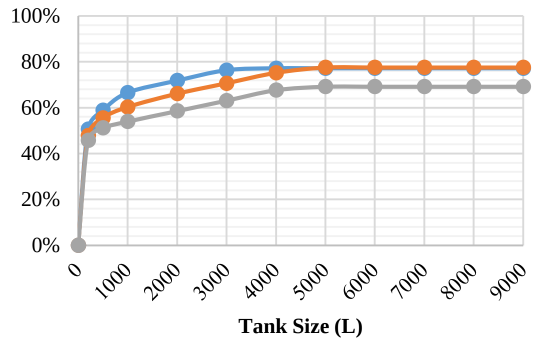
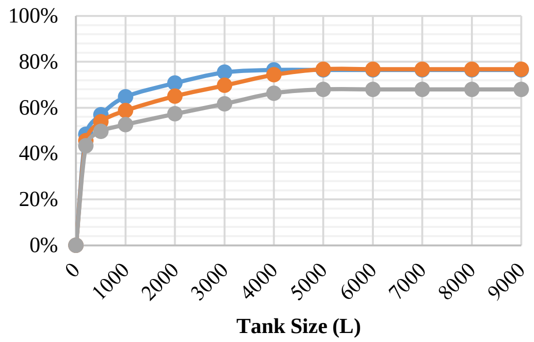
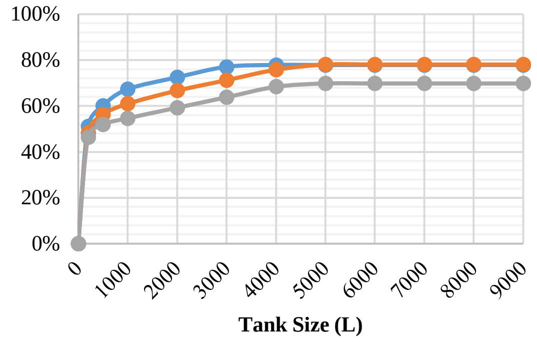
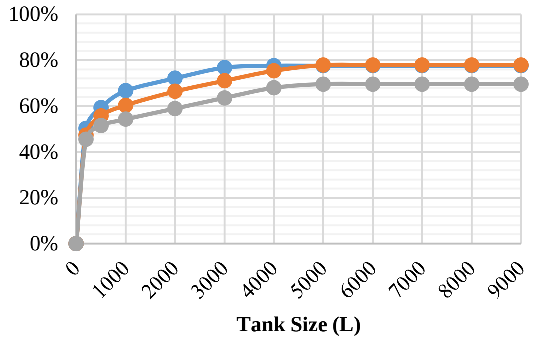
7.1.1 Bhola

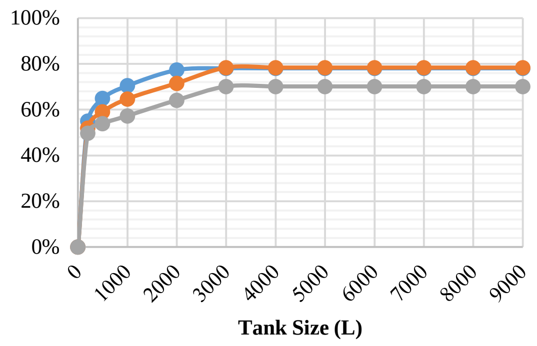
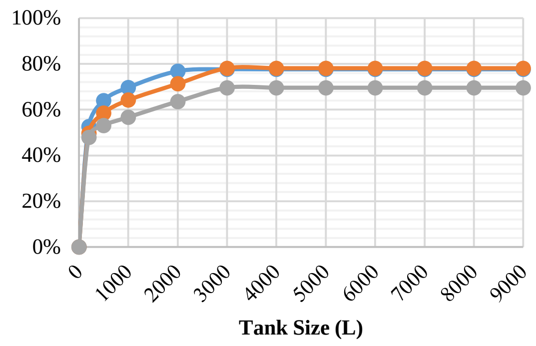
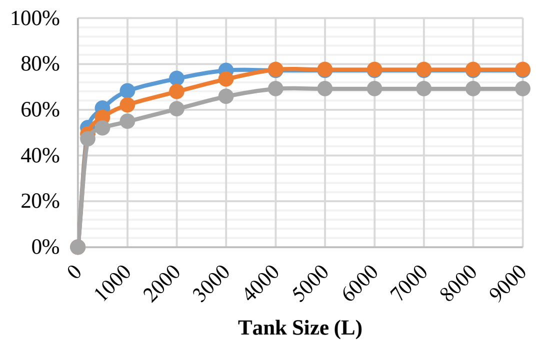
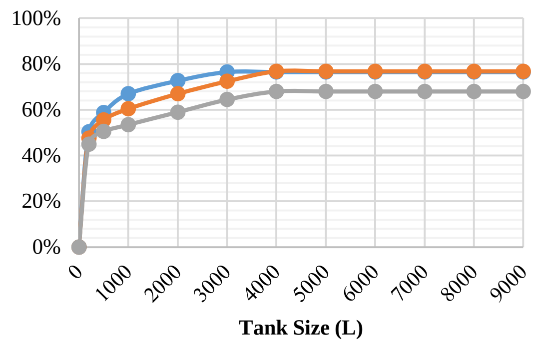
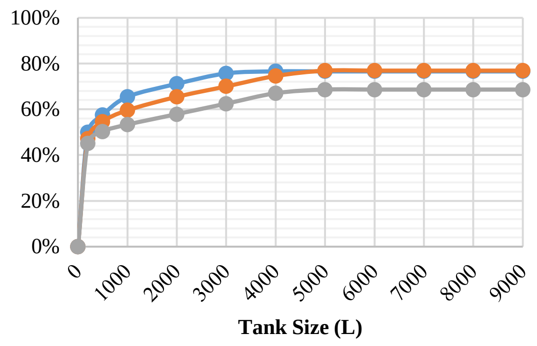
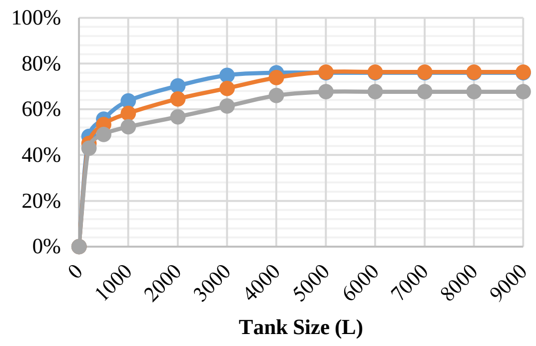
7.1.1.1 Optimum volume design curves

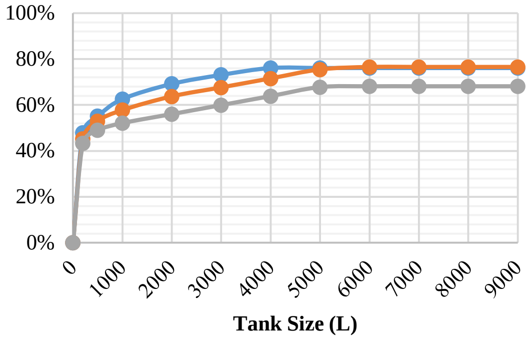
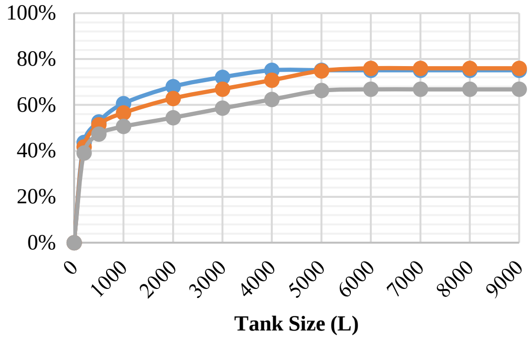
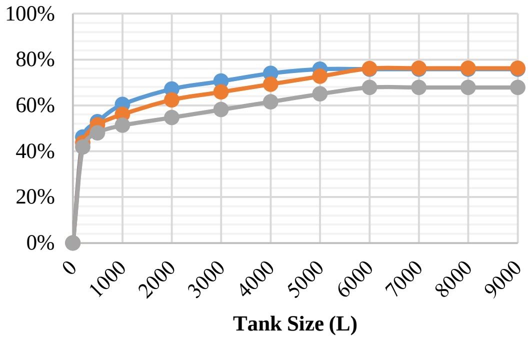
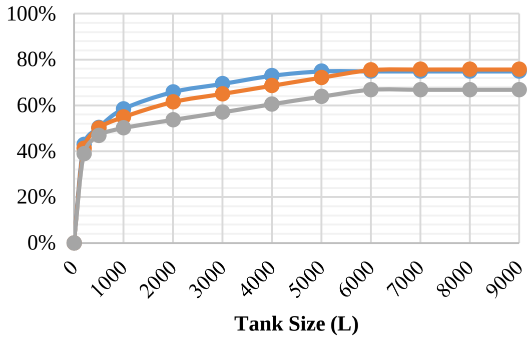
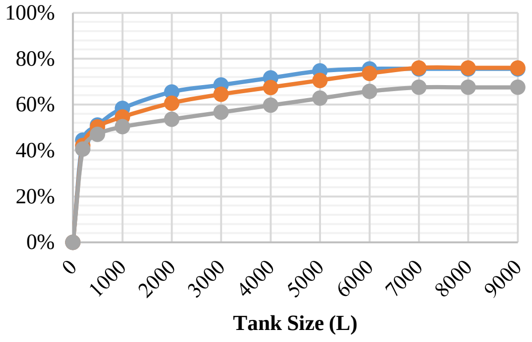
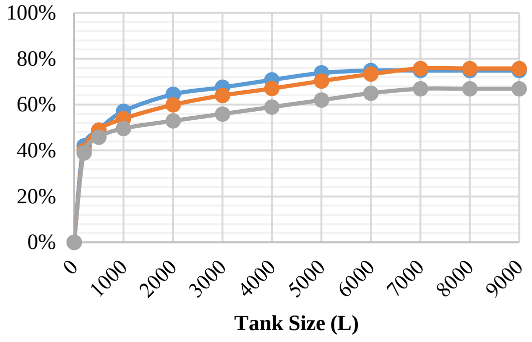


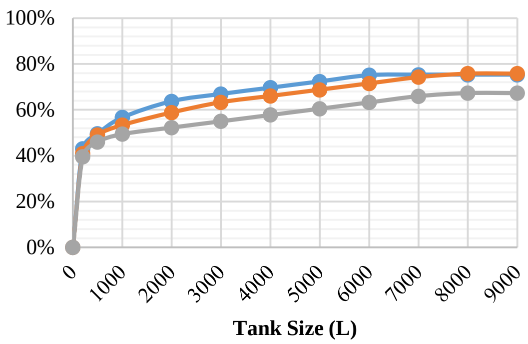
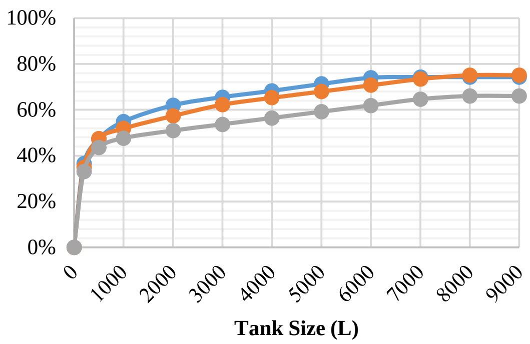
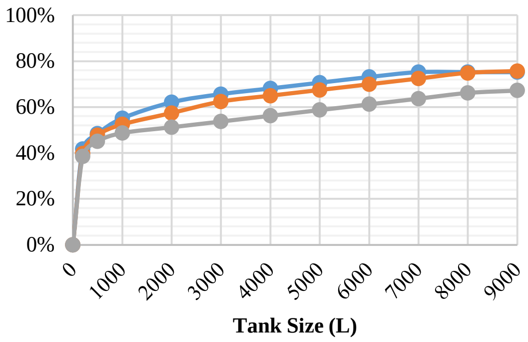
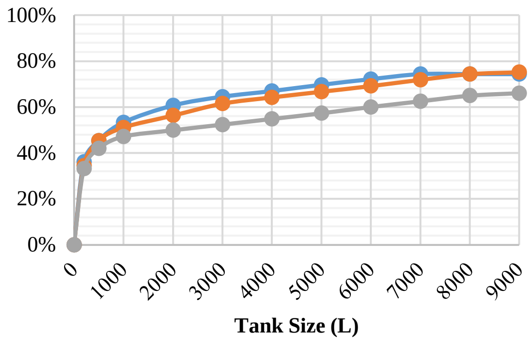
7.1.1.2 Volumetric and time reliability curves

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year, Wet Year, Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td></td><td></td></tr>
<tr><td>30</td><td></td><td></td></tr>
<tr><td>40</td><td></td><td></td></tr>
<tr><td>50</td><td></td><td></td></tr>
</table>

Fixed Family Size (6)		
Dry Year · Wet Year · Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

Fixed Catchment Area (50 m^2)		
Dry Year Wet Year Average Year		
Family Size	Volumetric Reliability	Time Reliability
4		
5		
6		

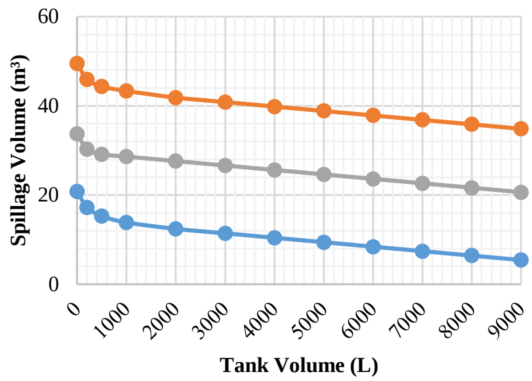
Fixed Catchment Area (50 m^2)		
	Dry Year, Wet Year, Average Year	
Family Size	Volumetric Reliability	Time Reliability
7		
8		
9		

Fixed Catchment Area (50 m^2)		
Dry Year, Wet Year, Average Year		
Family Size	Volumetric Reliability	Time Reliability
10		
11		

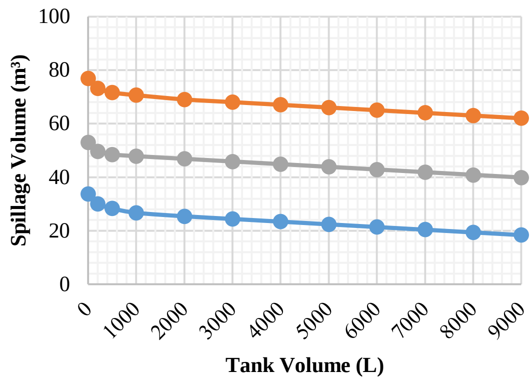
7.1.1.3 Spilled water volume

Family size (6)

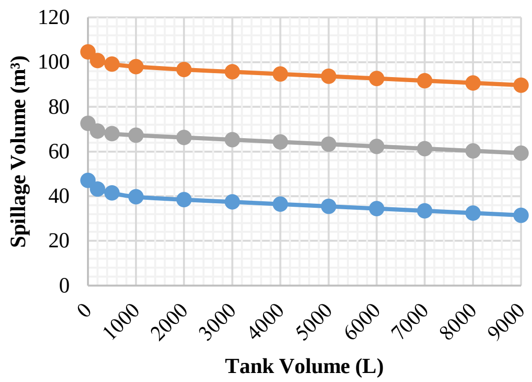
Dry Year Wet Year Average Year



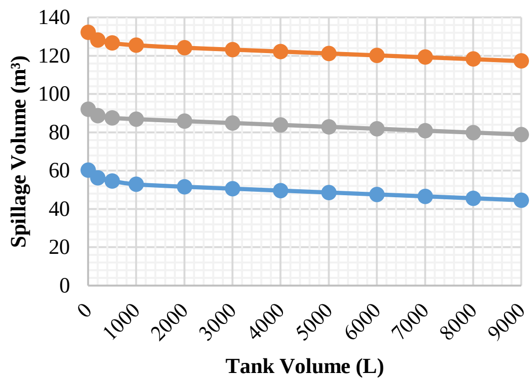
Catchment Area 20 m²



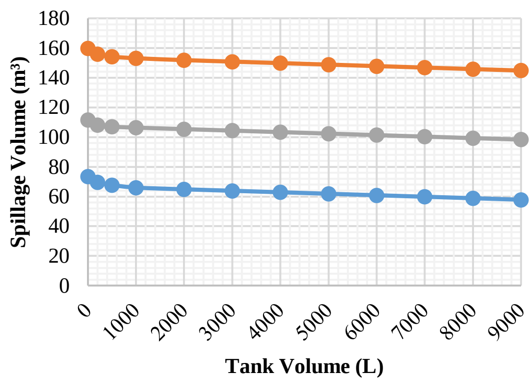
Catchment Area 30 m²



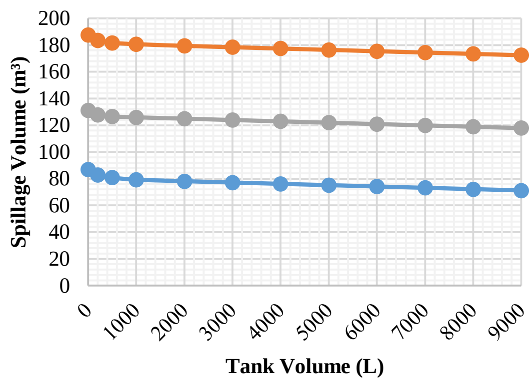
Catchment Area 40 m²



Catchment Area 50 m²



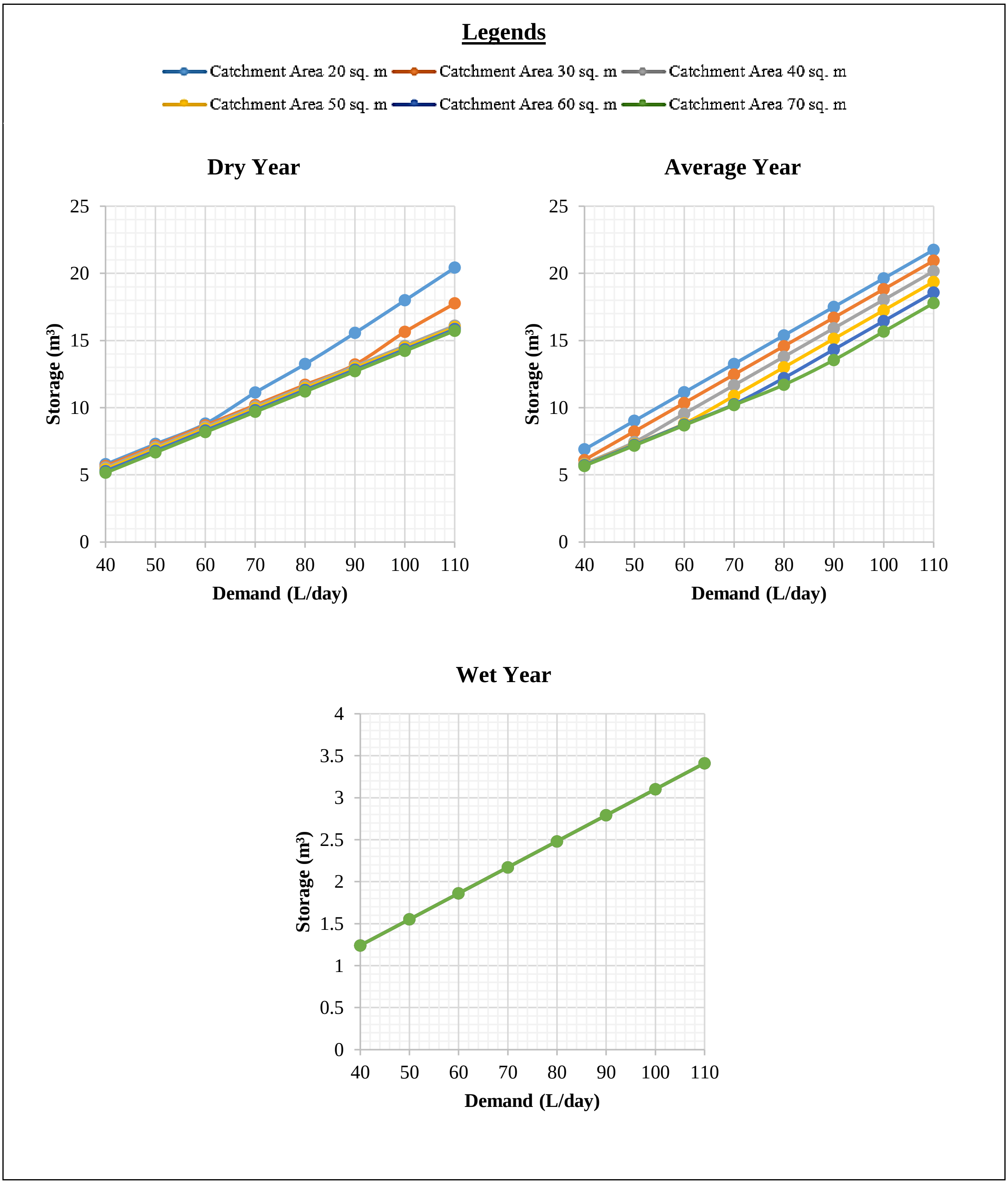
Catchment Area 60 m²



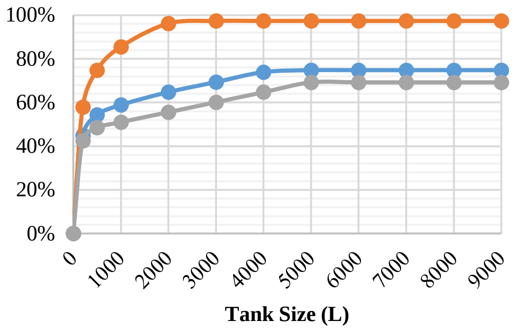
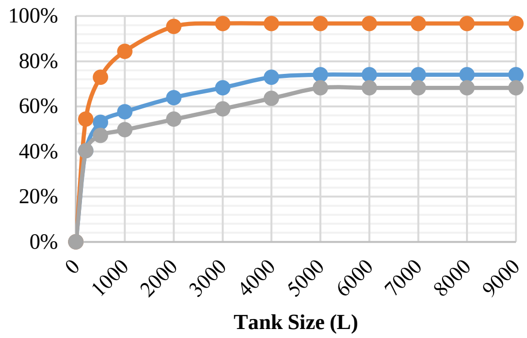
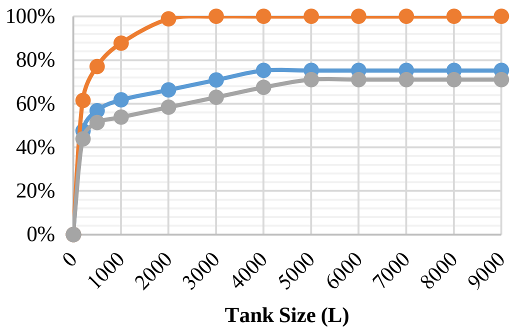
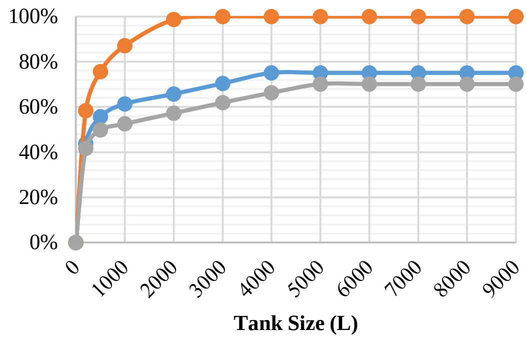
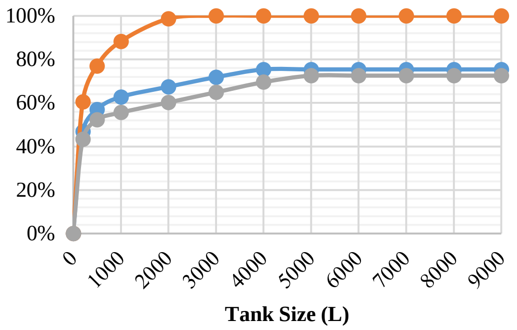
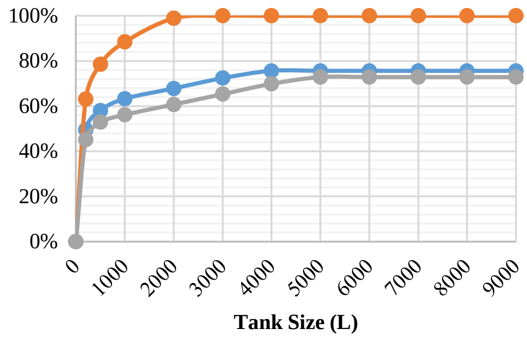
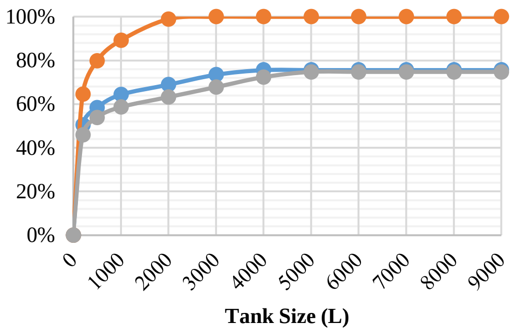
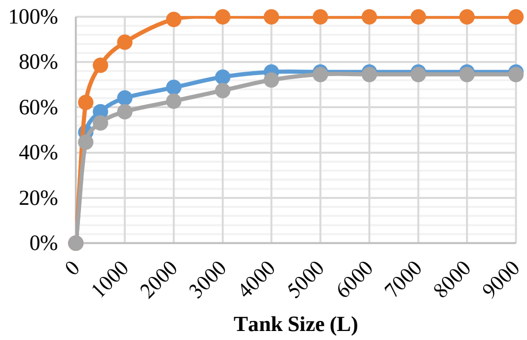
Catchment Area 70 m²

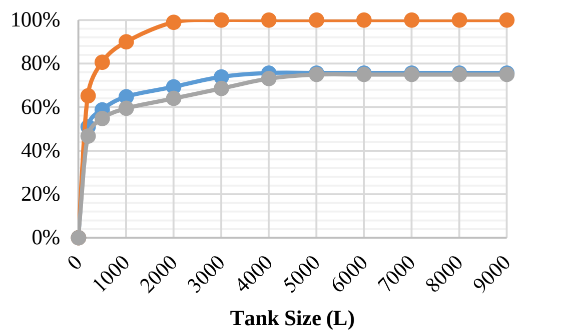
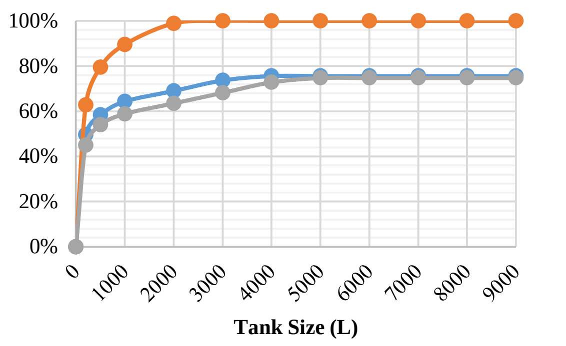
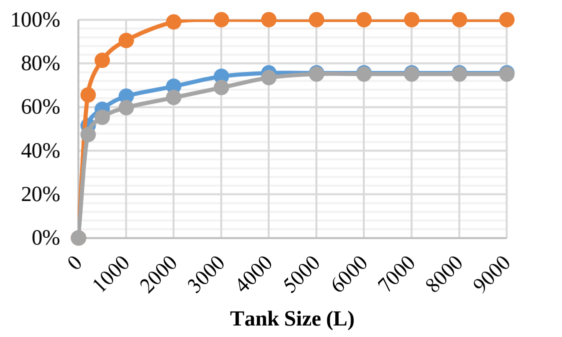
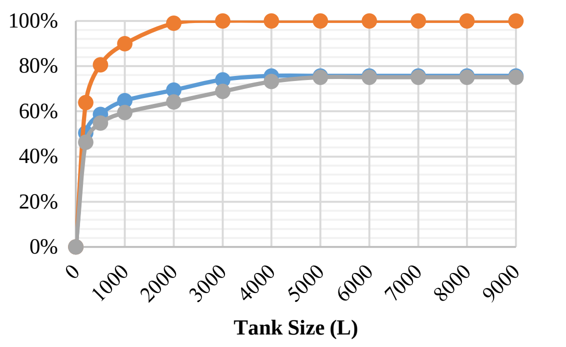
7.1.2 Barisal

7.1.2.1 Optimum volume design curves



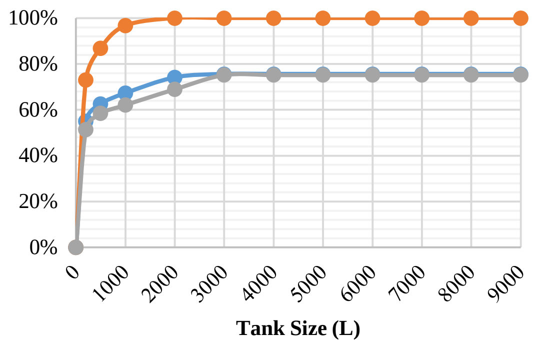
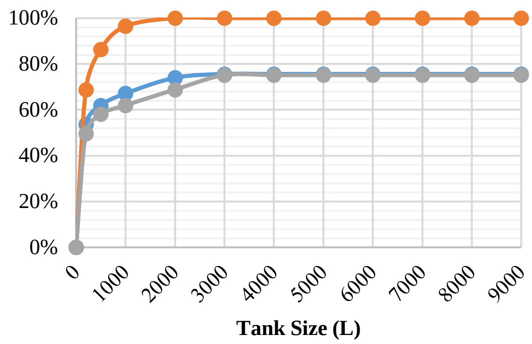
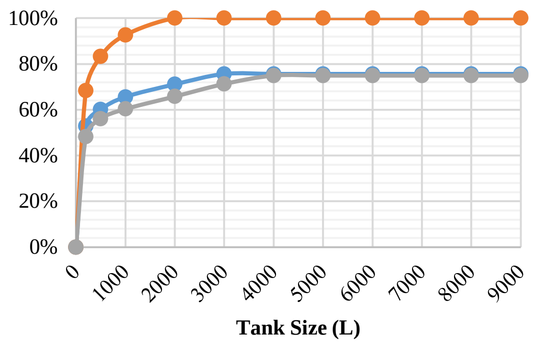
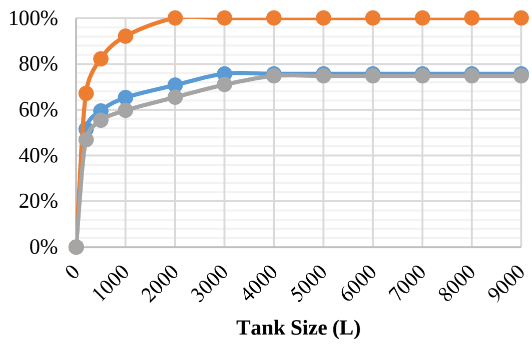
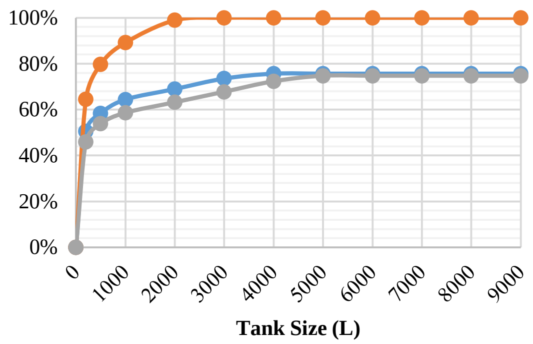
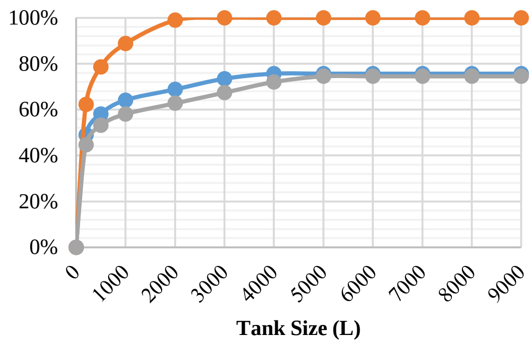
7.1.2.2 Volumetric and time reliability curves

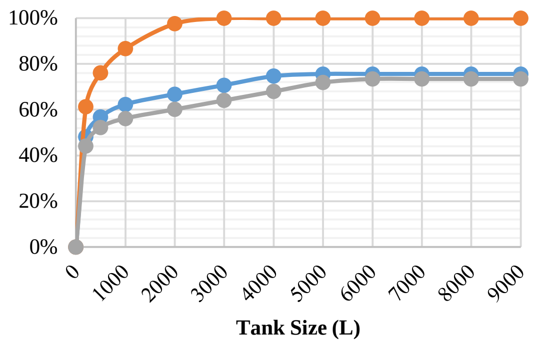
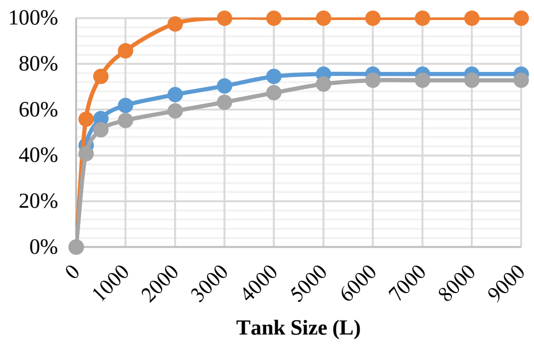
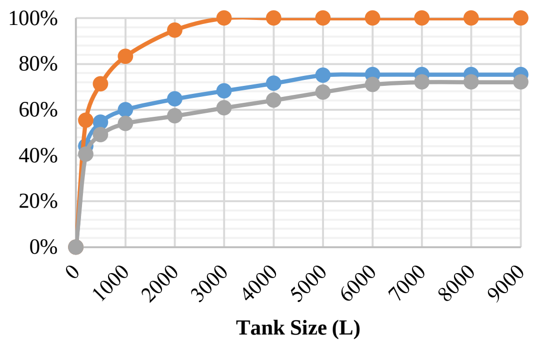
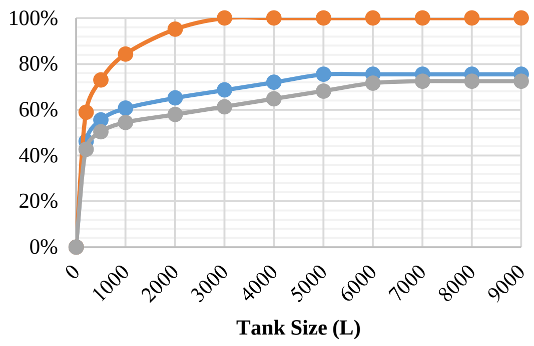
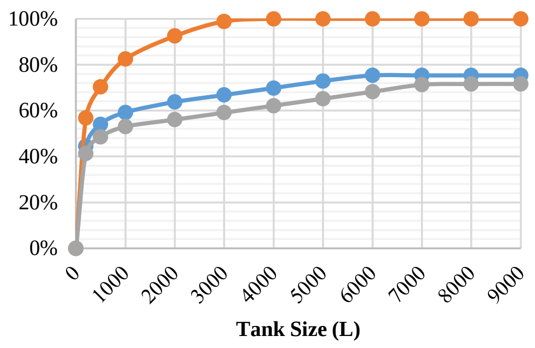
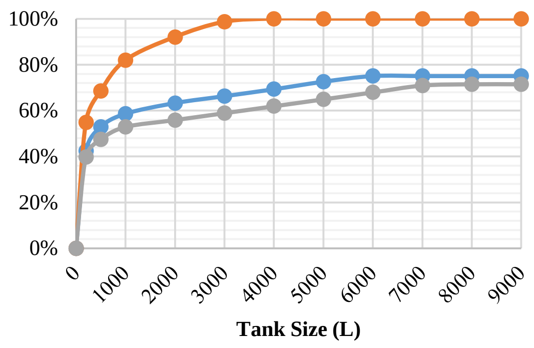
Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

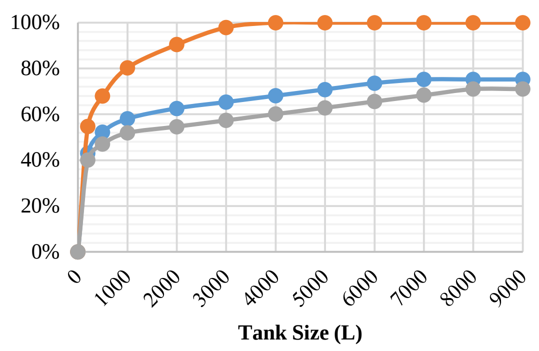
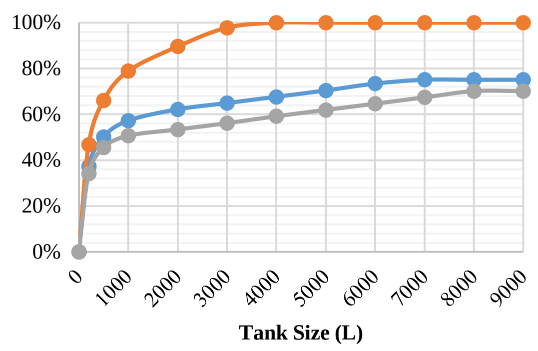
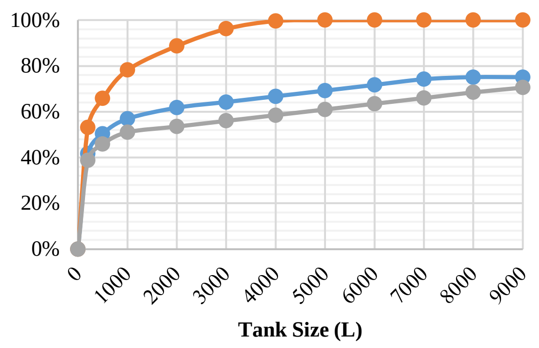
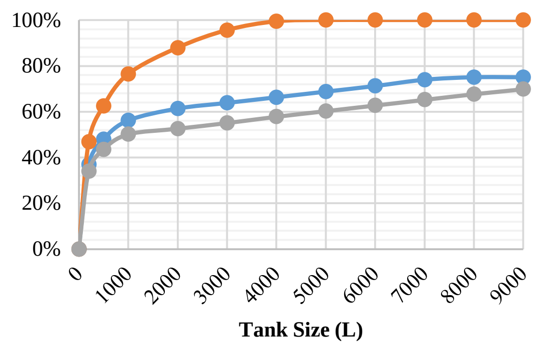
<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

Fixed Catchment Area (50 m^2)

Dry Year — Wet Year — Average Year

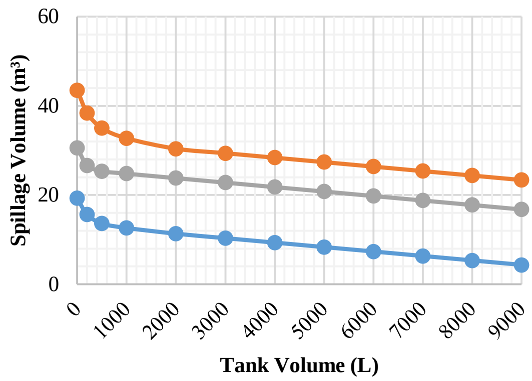
Famil y Size	Volumetric Reliability	Time Reliability
4		
5		
6		

Fixed Catchment Area (50 m^2)		
Dry Year, Wet Year, Average Year		
Family Size	Volumetric Reliability	Time Reliability
7		
8		
9		

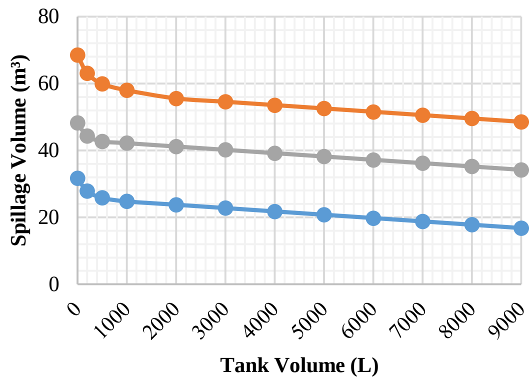
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

7.1.2.3 *Spilled water volume*

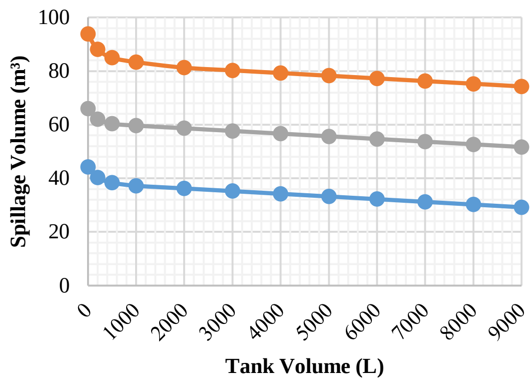
Family size (6)



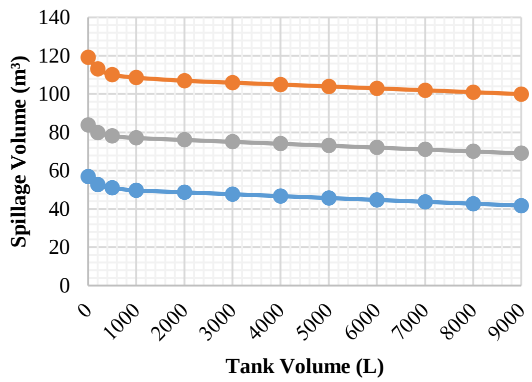
Catchment Area 20 m^2



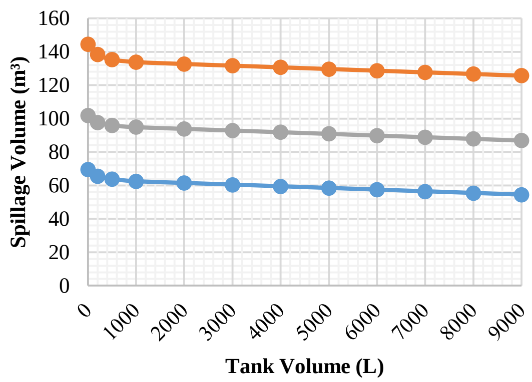
Catchment Area 30 m^2



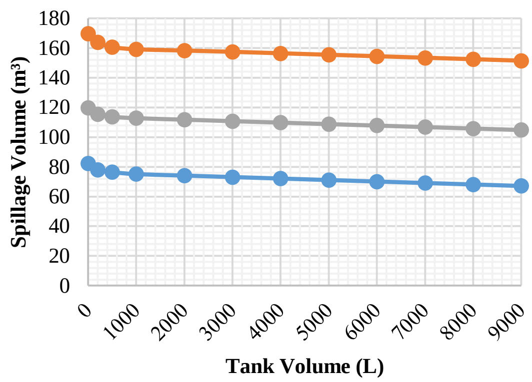
Catchment Area 40 m^2



Catchment Area 50 m^2



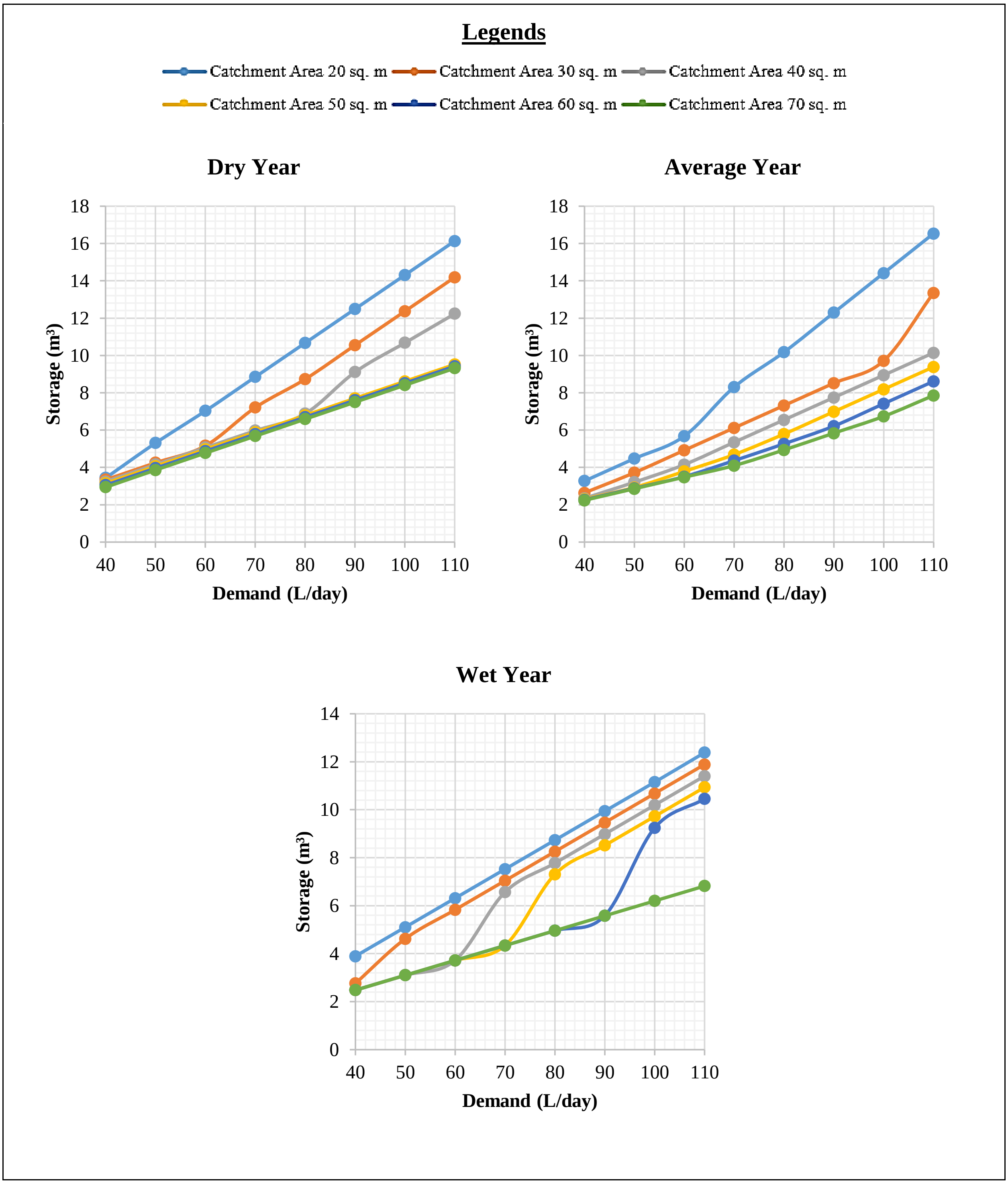
Catchment Area 60 m^2



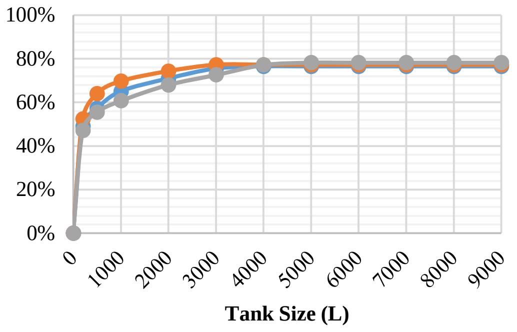
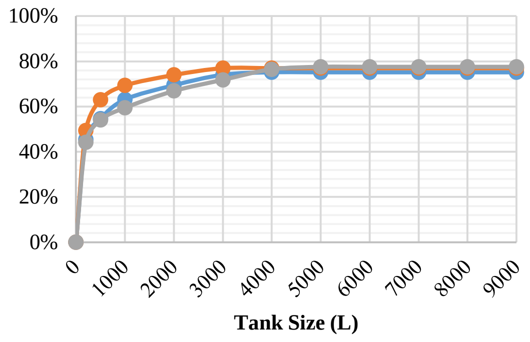
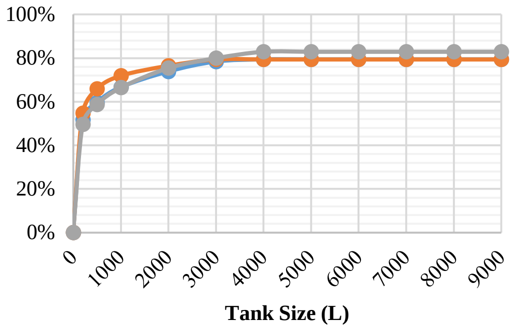
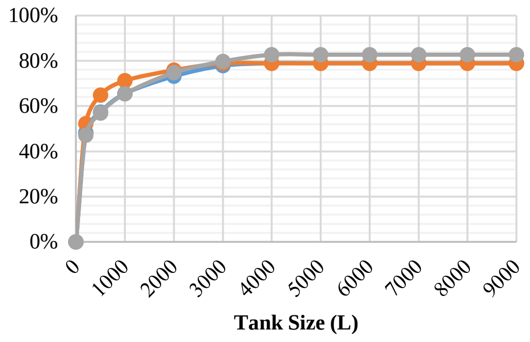
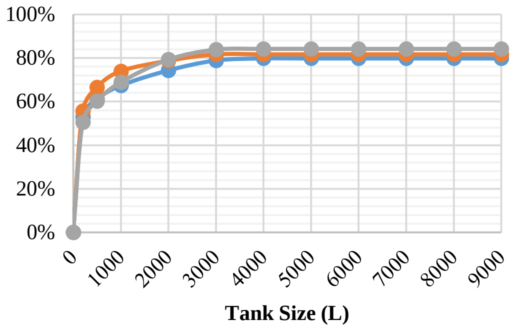
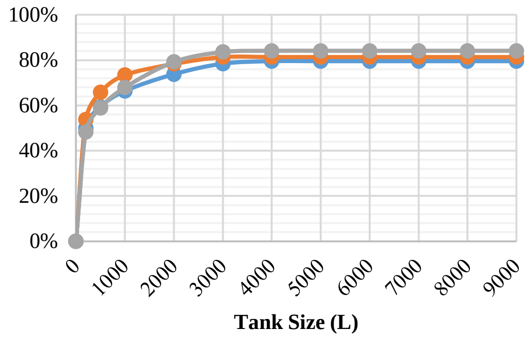
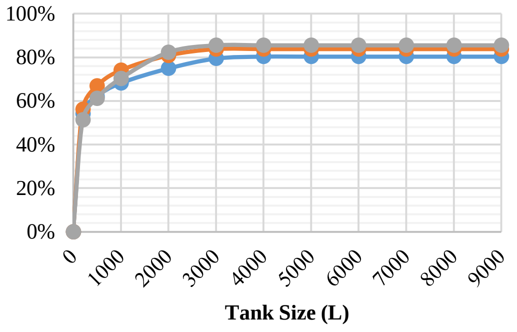
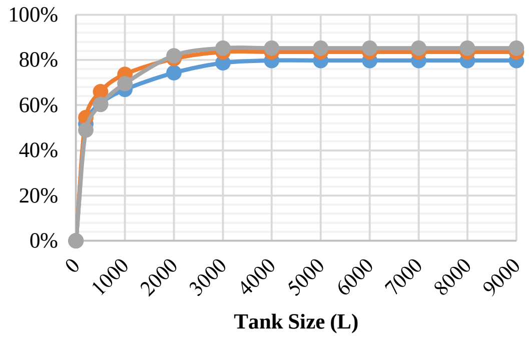
Catchment Area 70 m^2

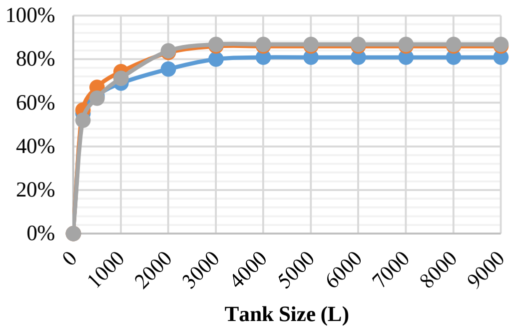
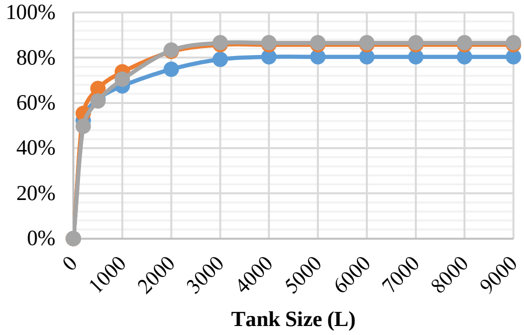
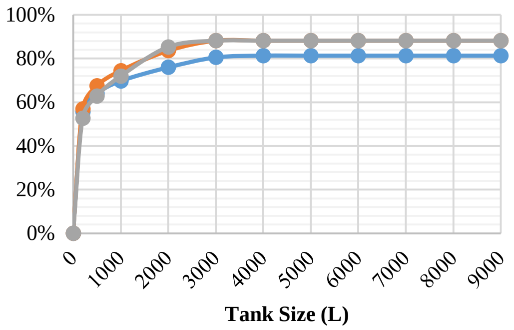
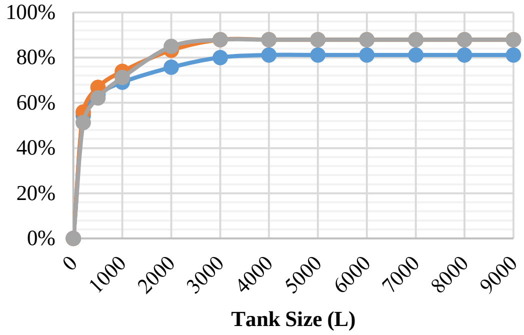
7.1.3 Chittagong

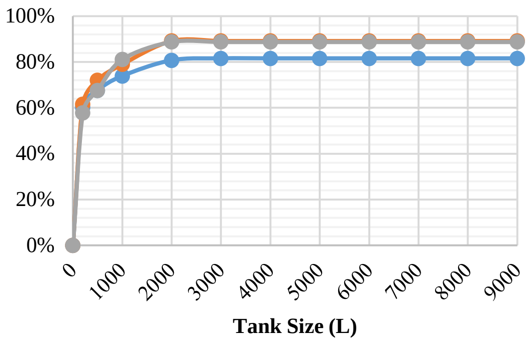
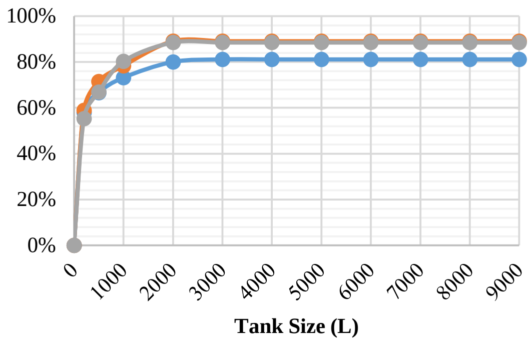
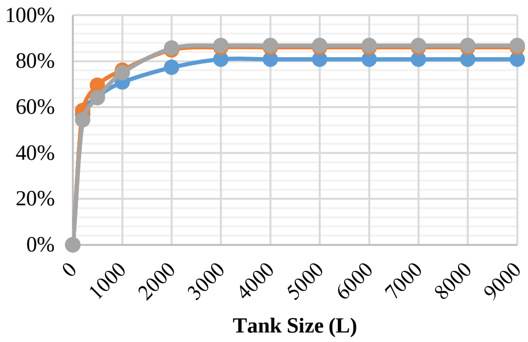
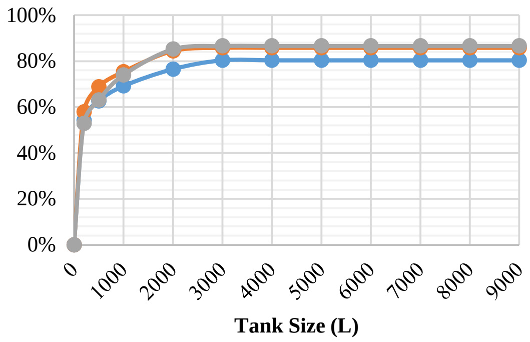
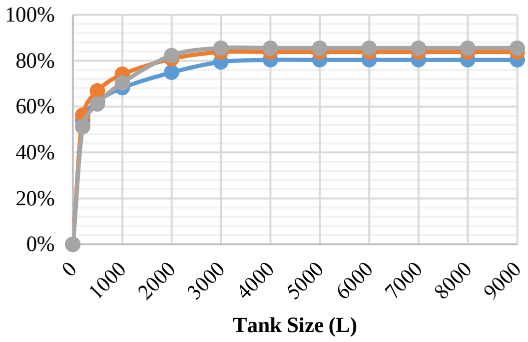
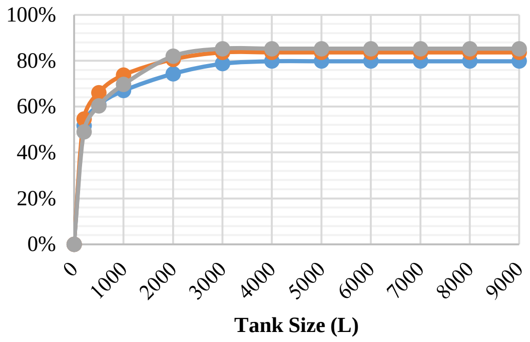
7.1.3.1 Optimum volume design curves

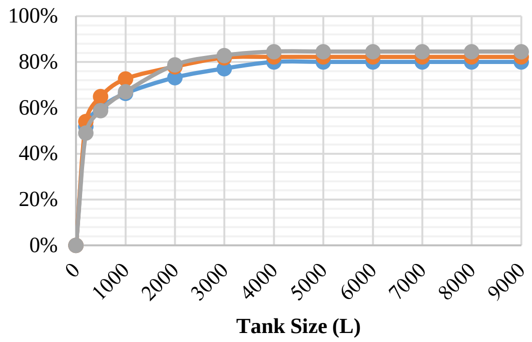
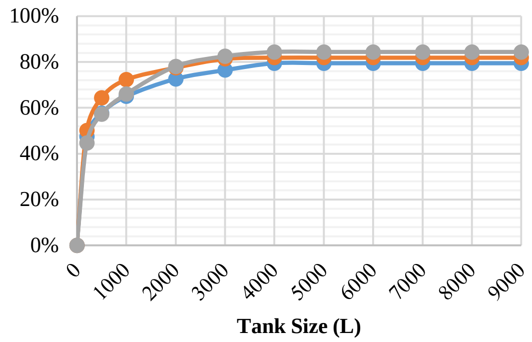
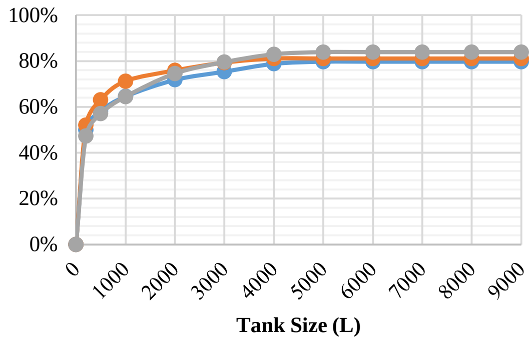
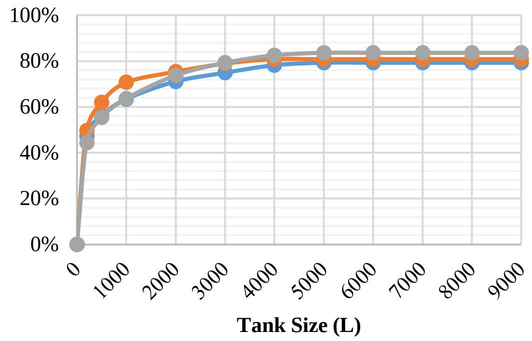
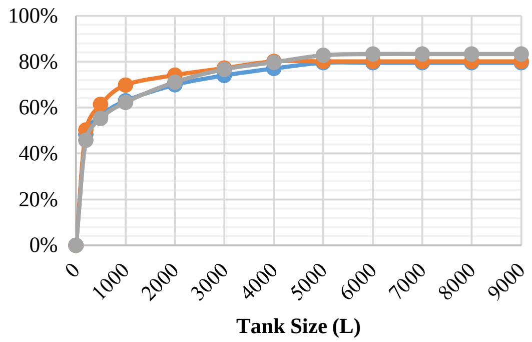
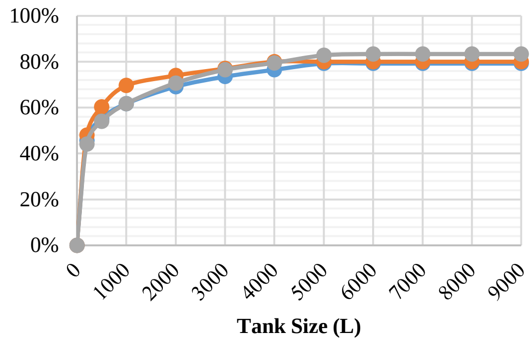


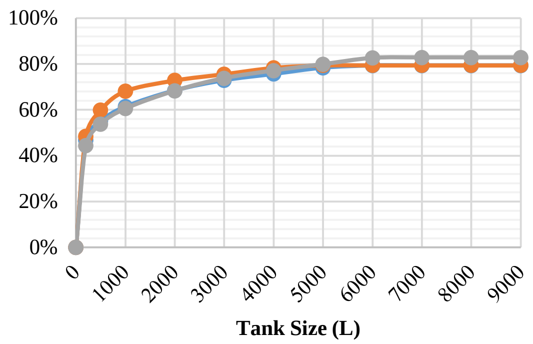
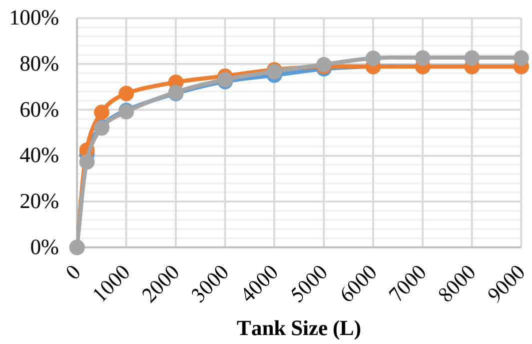
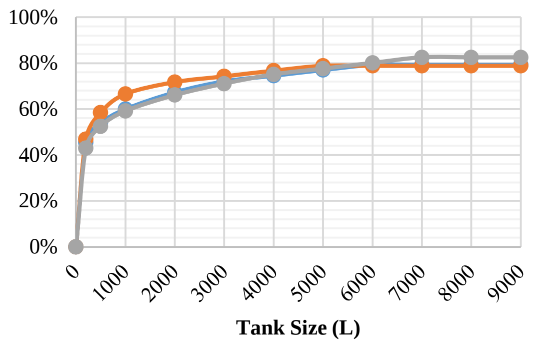
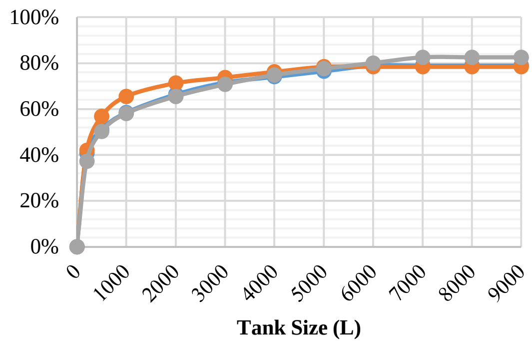
7.1.3.2 *Volumetric and time reliability curves*

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td></td><td></td></tr>
<tr><td>30</td><td></td><td></td></tr>
<tr><td>40</td><td></td><td></td></tr>
<tr><td>50</td><td></td><td></td></tr>
</table>

Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

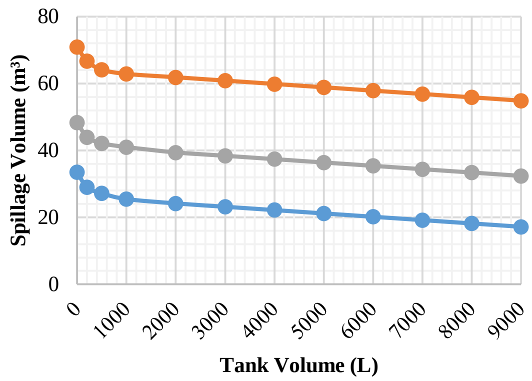
Fixed Catchment Area (50 m^2)		
Dry Year Wet Year Average Year		
Famil y Size	Volumetric Reliability	Time Reliability
7		
8		
9		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

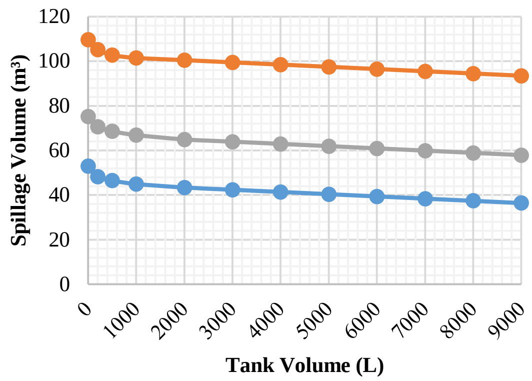
7.1.3.3 Spilled water volume

Family size (6)

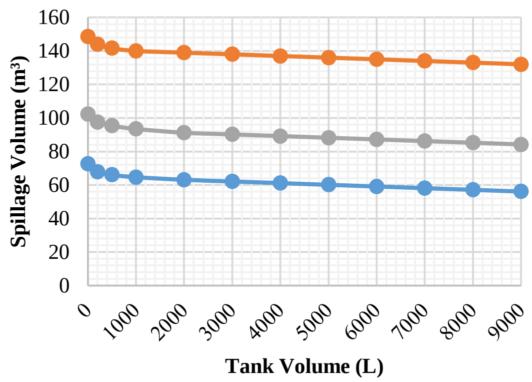
Dry Year Wet Year Average Year



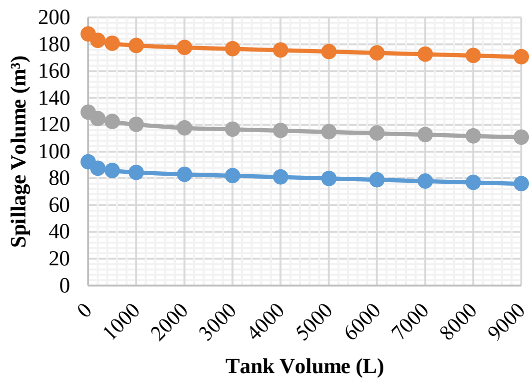
Catchment Area 20 m²



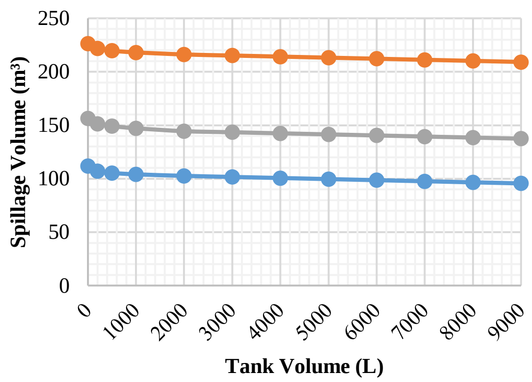
Catchment Area 30 m²



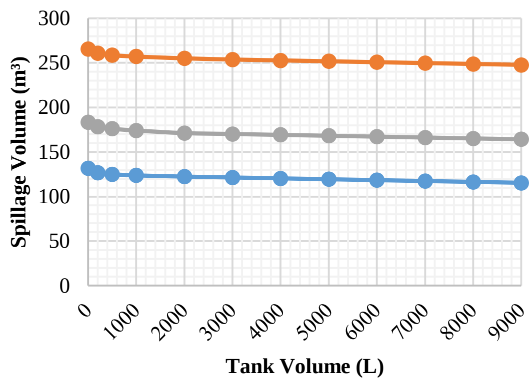
Catchment Area 40 m²



Catchment Area 50 m²



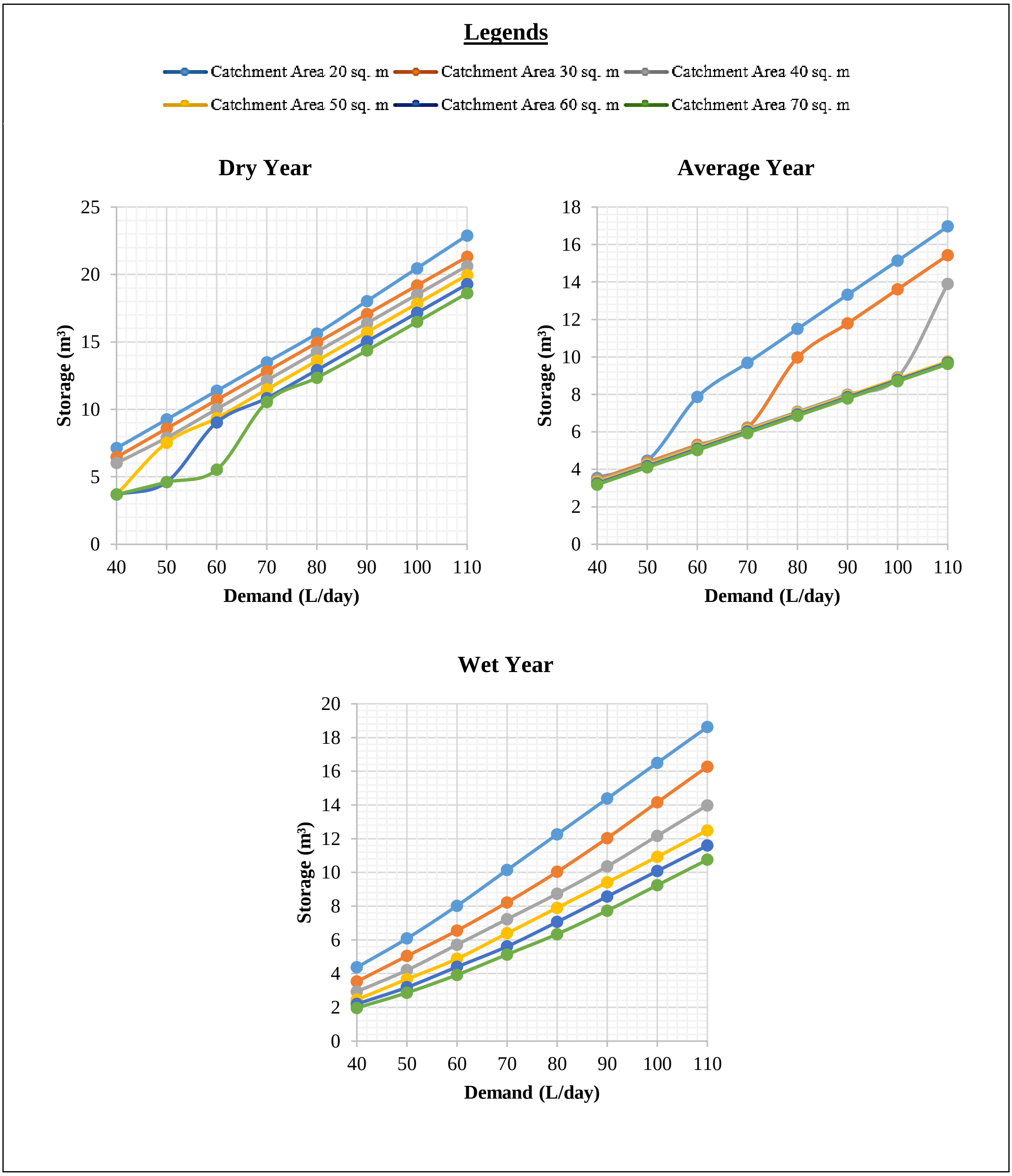
Catchment Area 60 m²



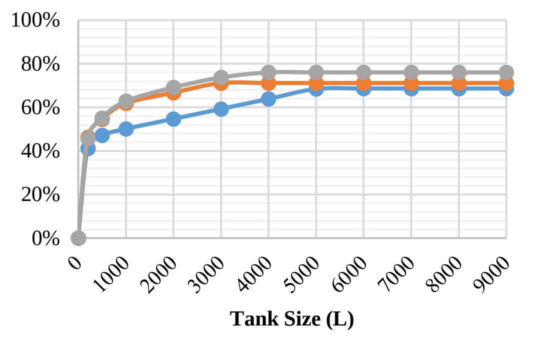
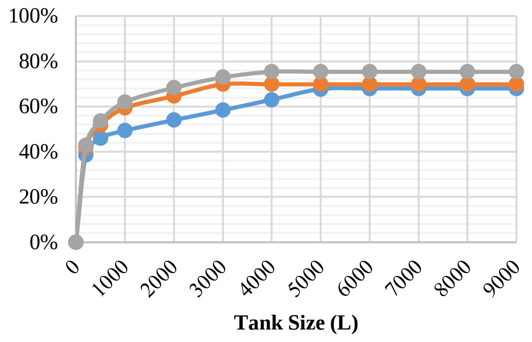
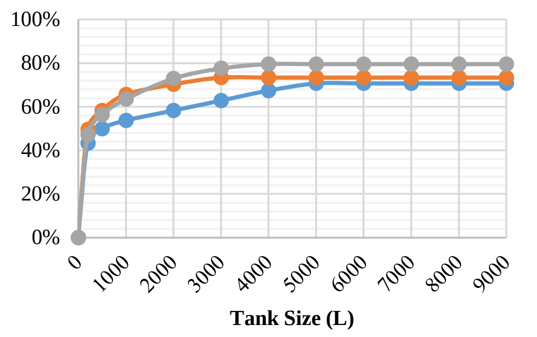
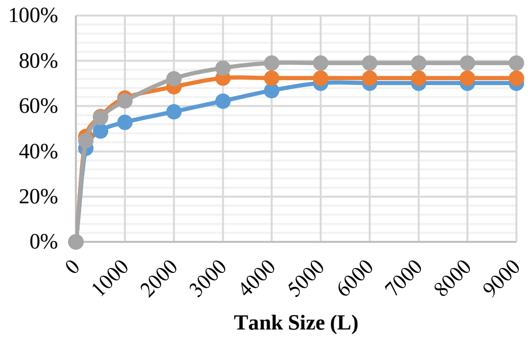
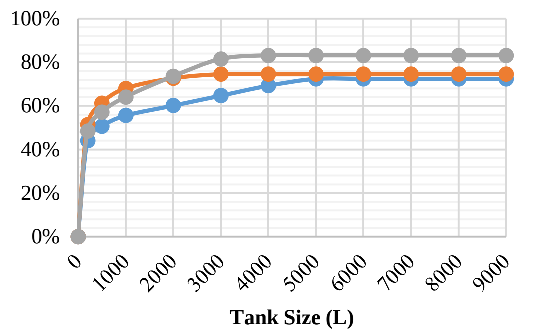
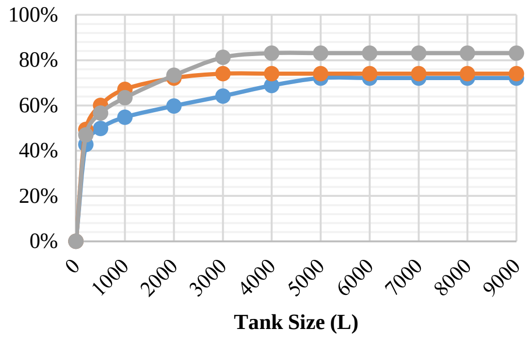
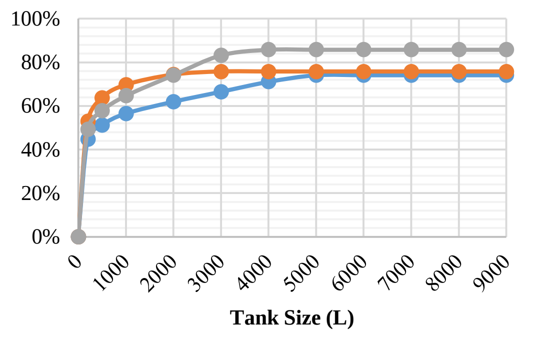
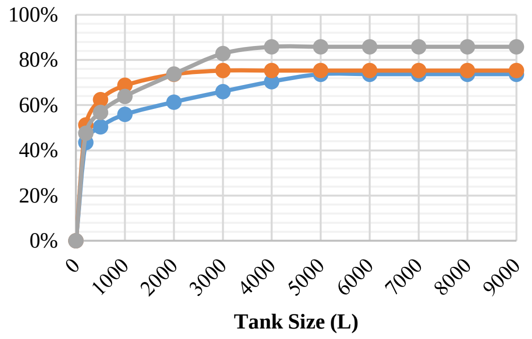
Catchment Area 70 m²

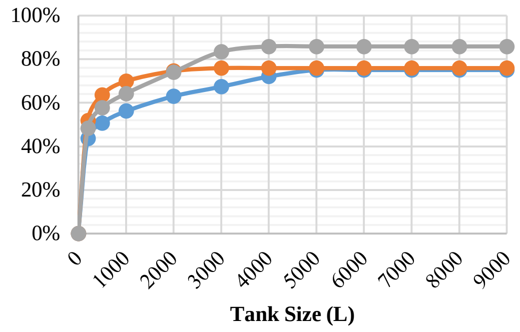
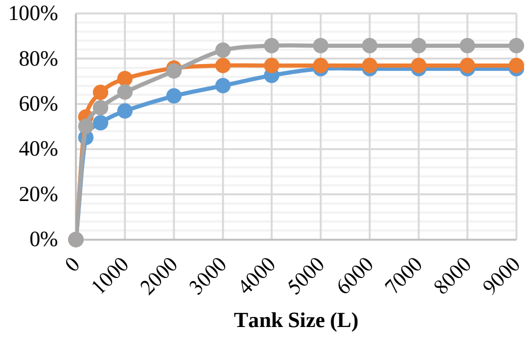
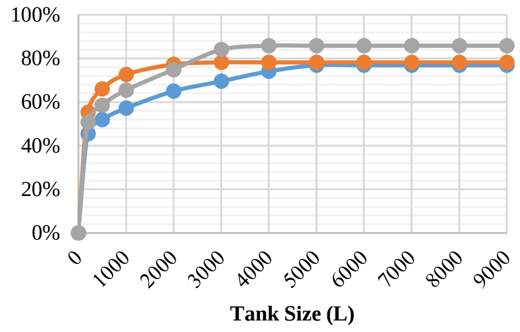
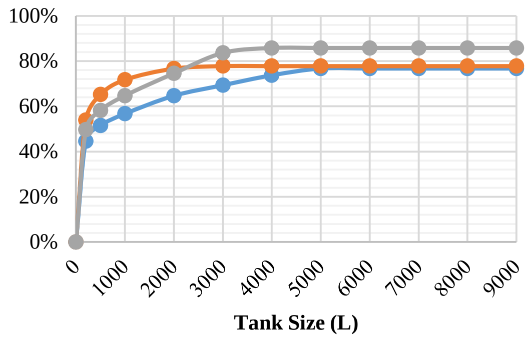
7.1.4 Cox's Bazaar

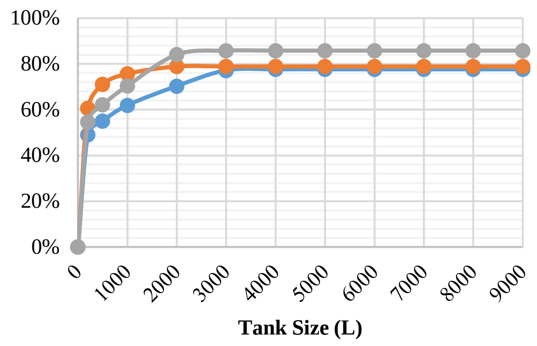
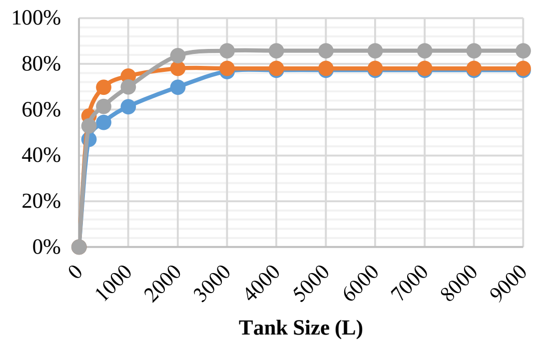
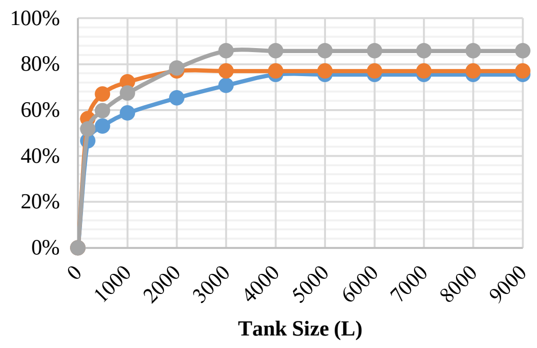
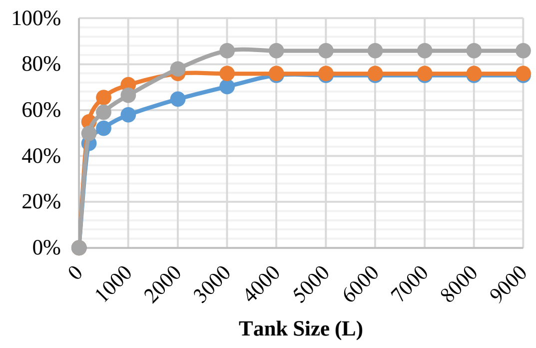
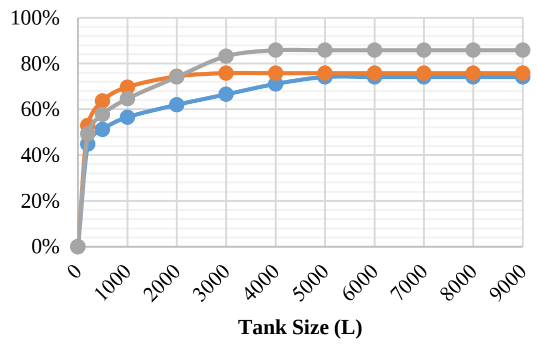
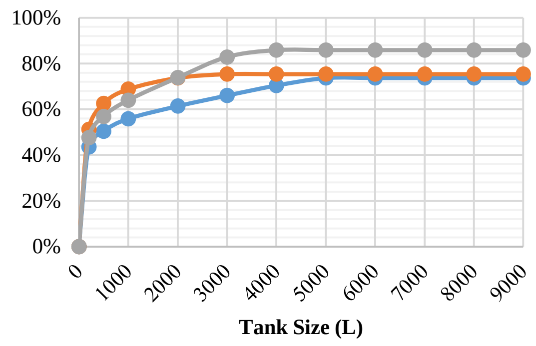
7.1.4.1 Optimum volume design curves

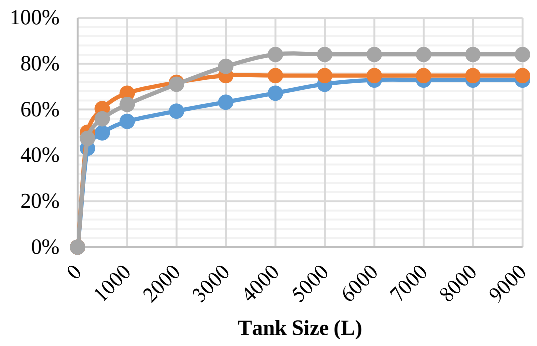
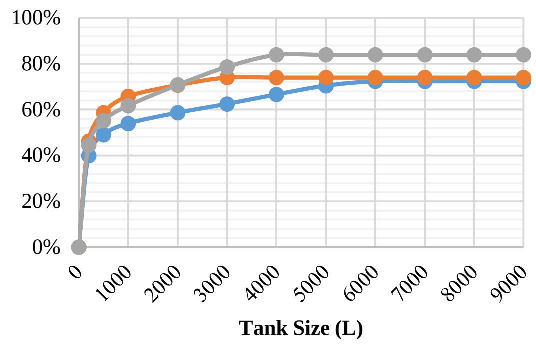
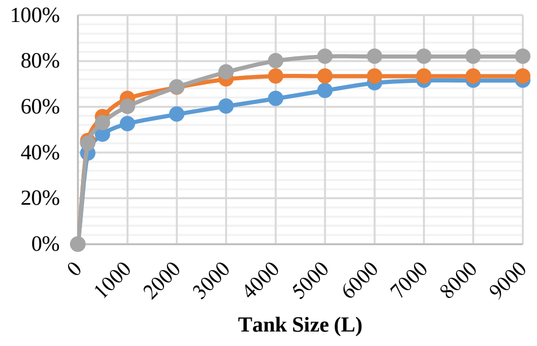
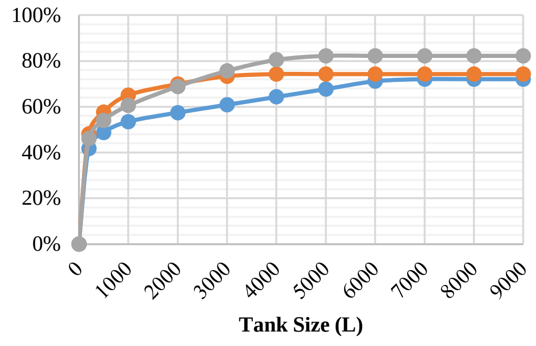
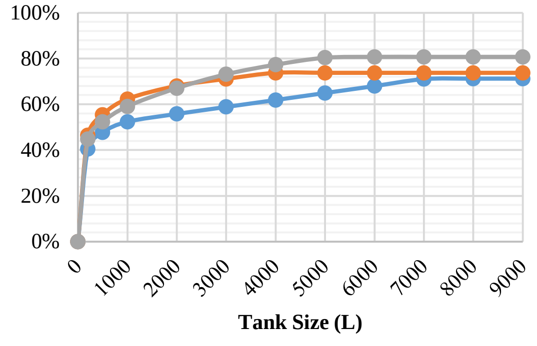
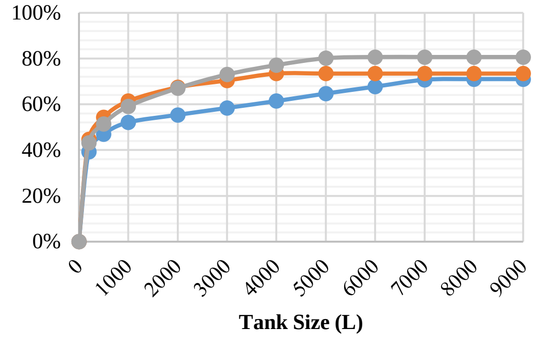


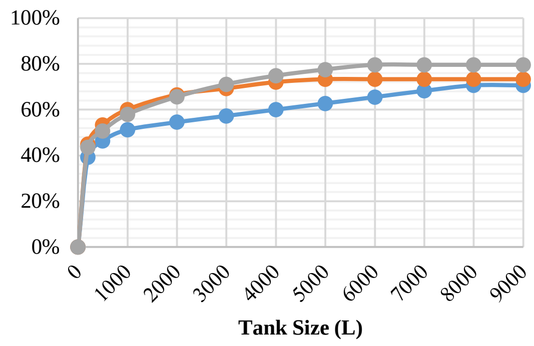
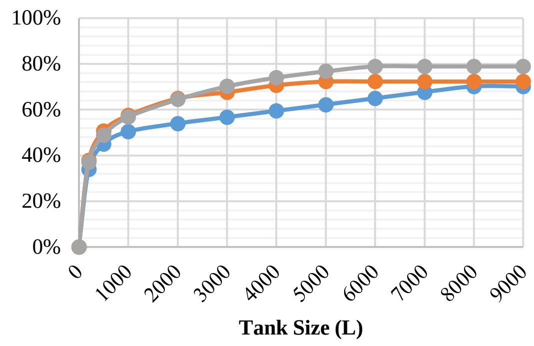
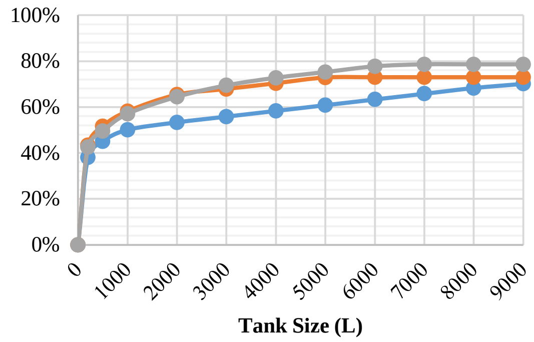
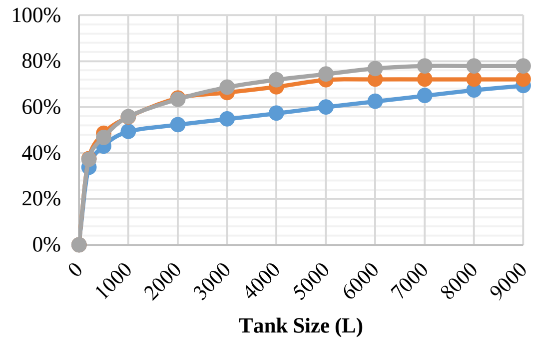
7.1.4.2 *Volumetric and time reliability curves*

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td>
</td><td>
</td></tr>
<tr><td>30</td><td>
</td><td>
</td></tr>
<tr><td>40</td><td>
</td><td>
</td></tr>
<tr><td>50</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td></tr>
</table>

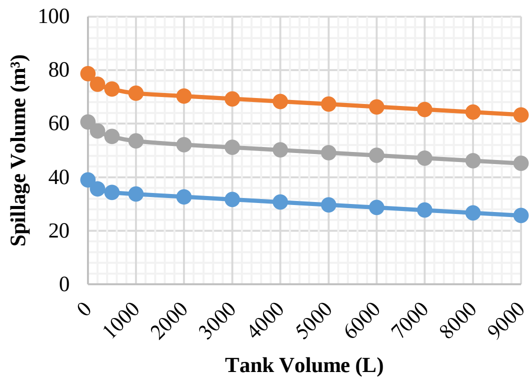
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><th>Family Size</th><th>Volumetric Reliability</th><th>Time Reliability</th></tr>
<tr><td>10</td><td></td><td></td></tr>
<tr><td>11</td><td></td><td></td></tr>
</table>

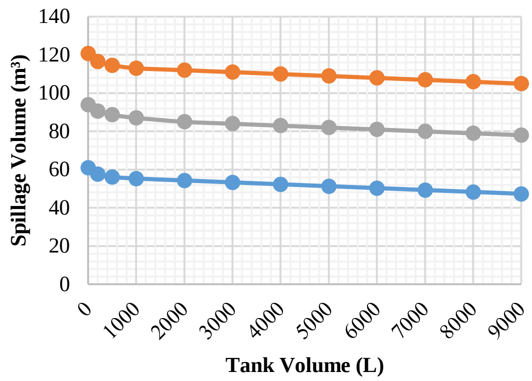
7.1.4.3 Spilled water volume

Family size (6)

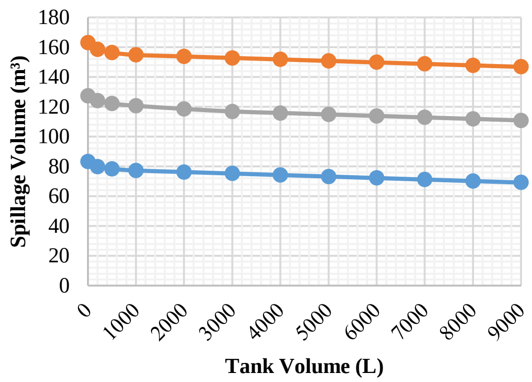
Dry Year — Wet Year — Average Year



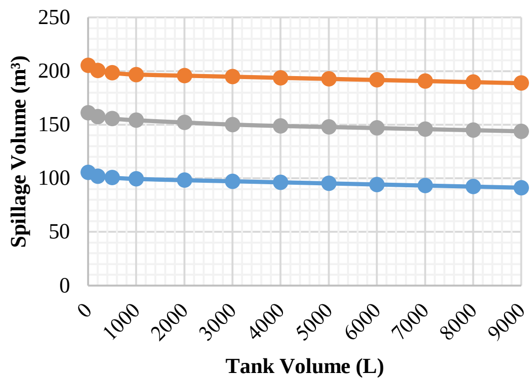
Catchment Area 20 m²



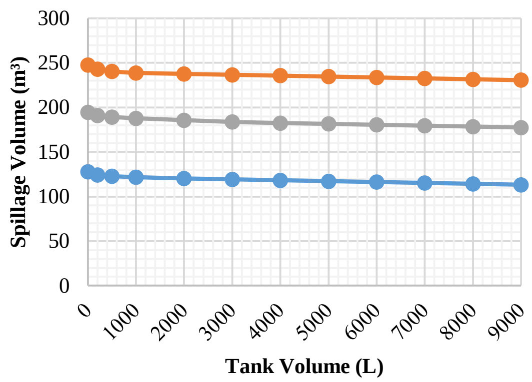
Catchment Area 30 m²



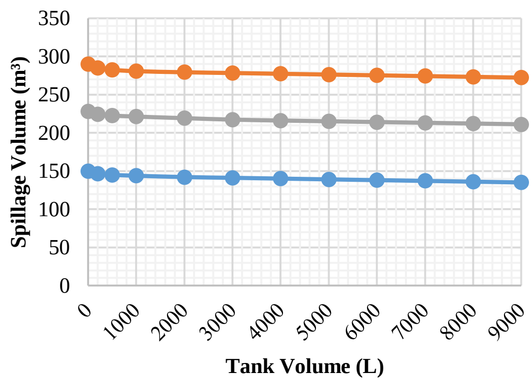
Catchment Area 40 m²



Catchment Area 50 m²



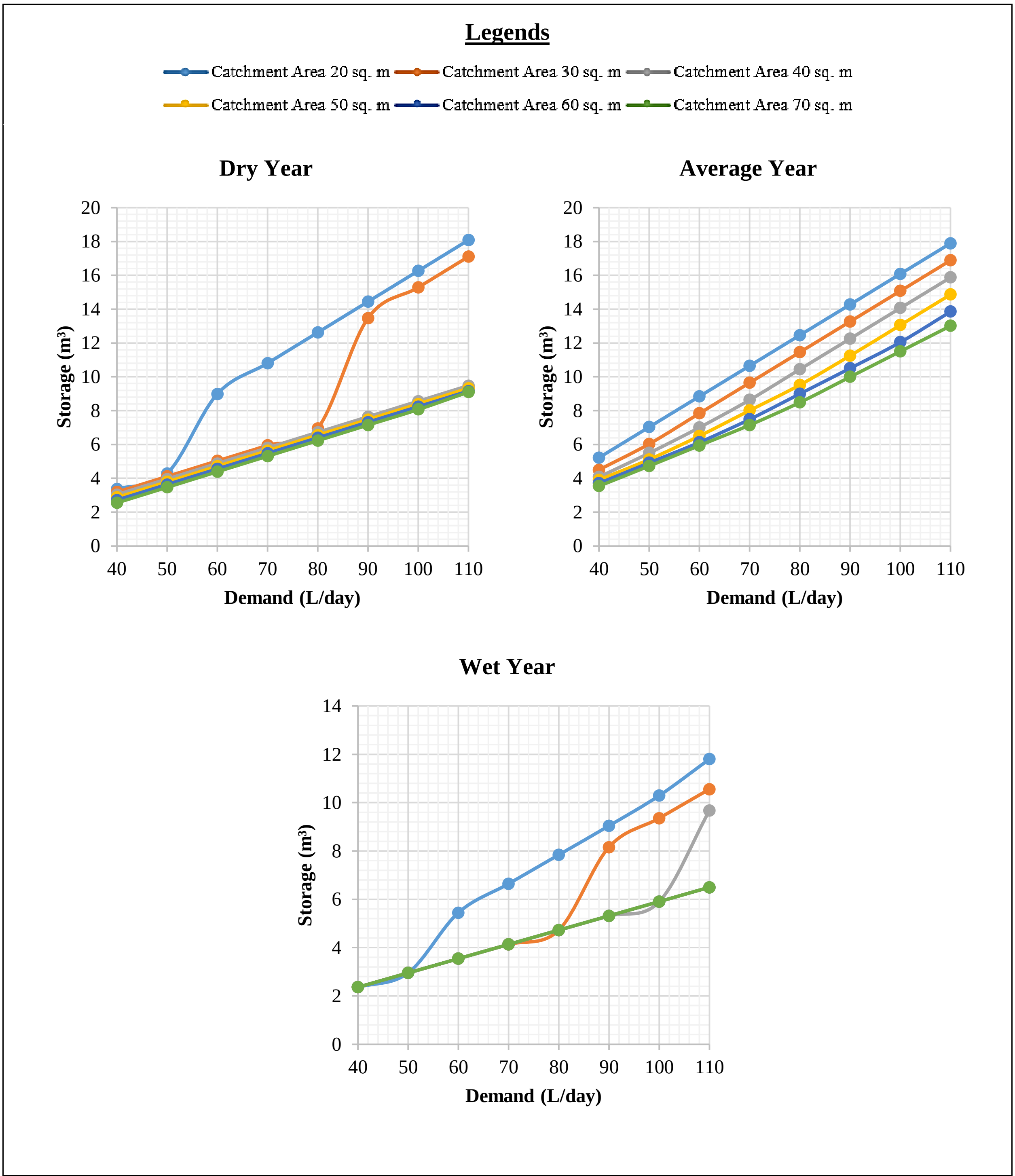
Catchment Area 60 m²



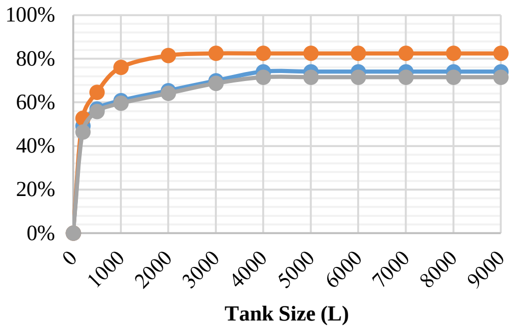
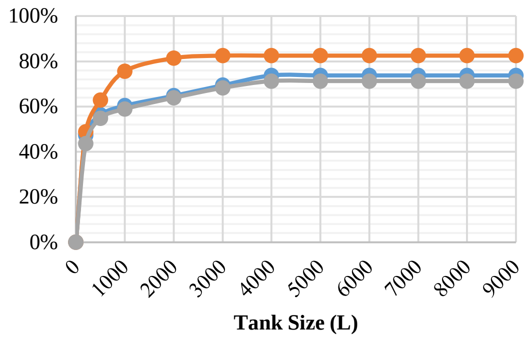
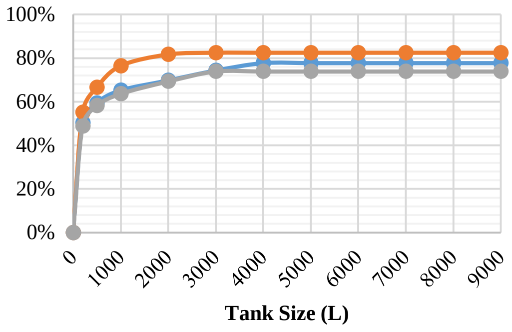
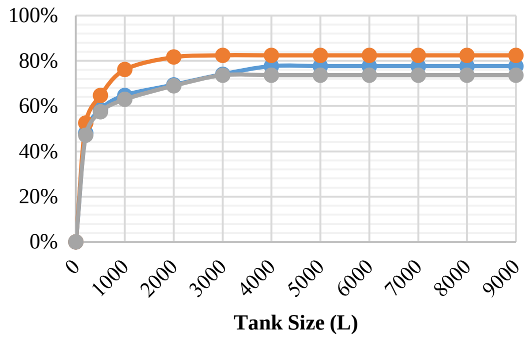
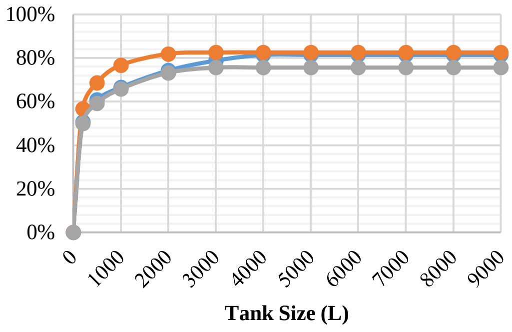
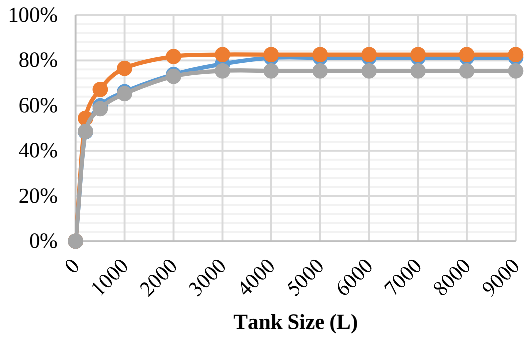
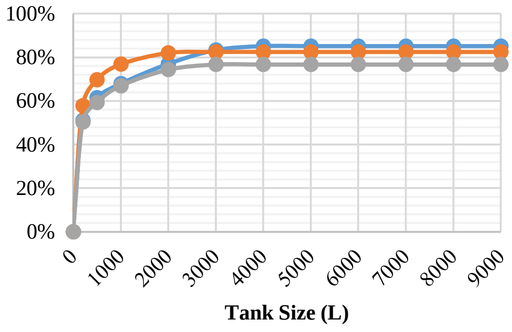
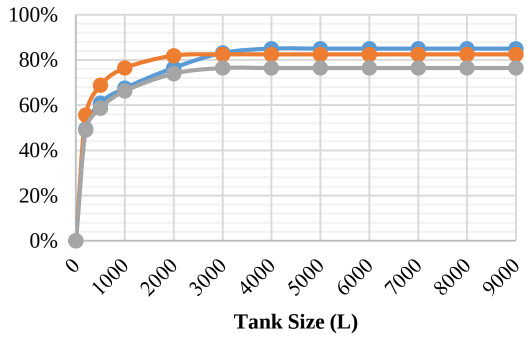
Catchment Area 70 m²

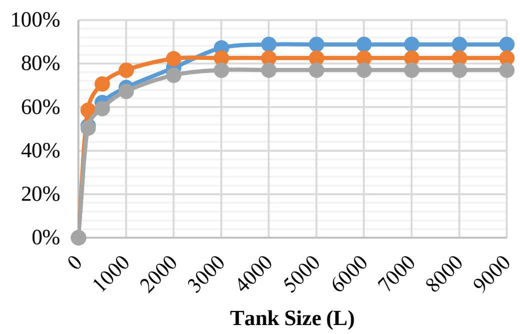
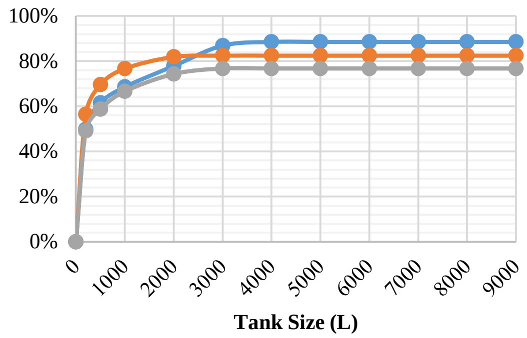
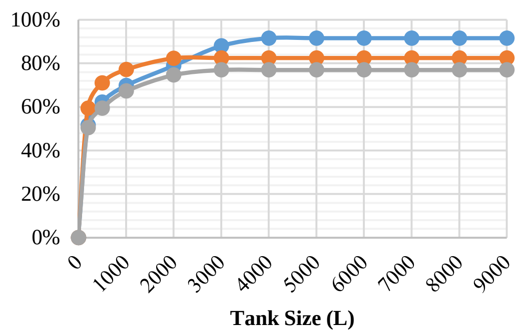
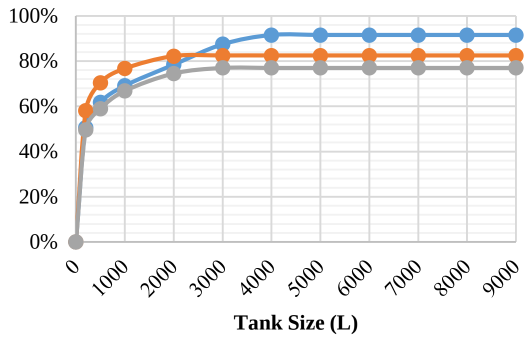
7.1.5 Feni

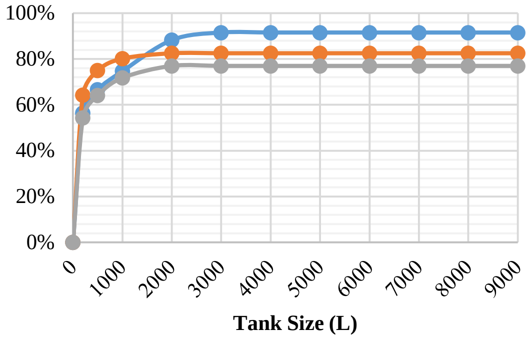
7.1.5.1 Optimum volume design curves

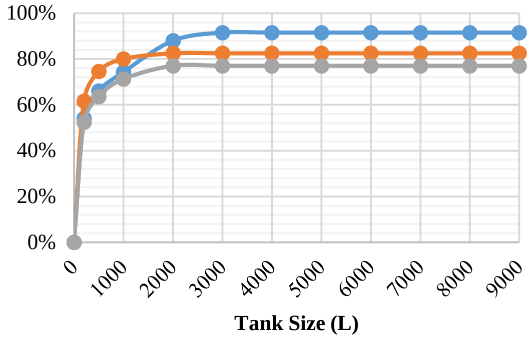


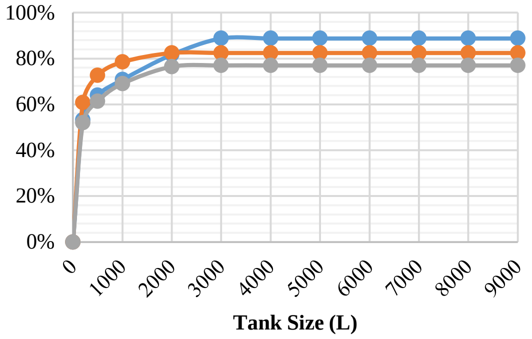
7.1.5.2 Volumetric and time reliability curves

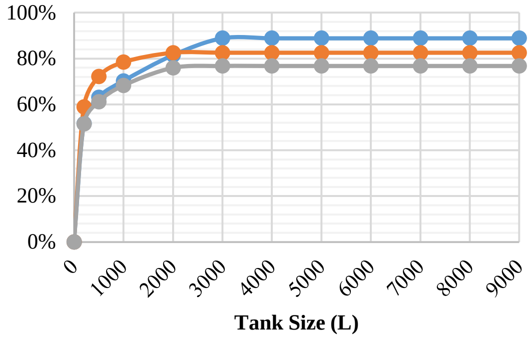
Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

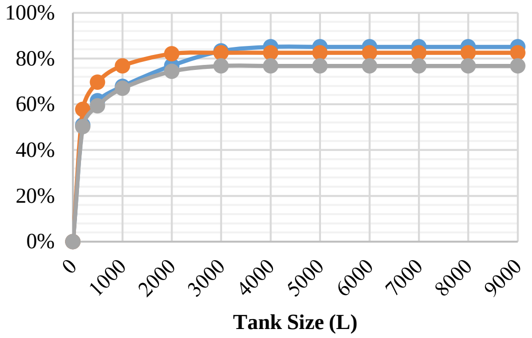
<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

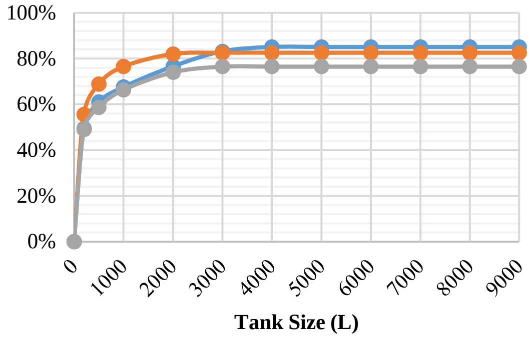
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>


</td><td>


</td></tr>
<tr><td>5</td><td>


</td><td>


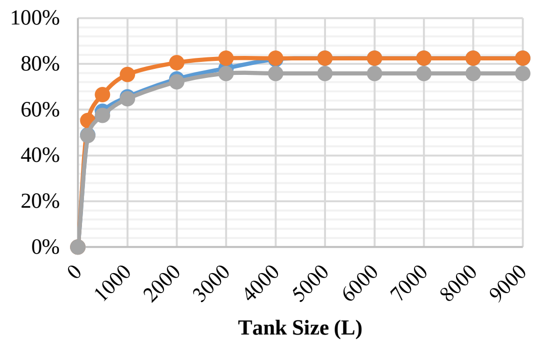
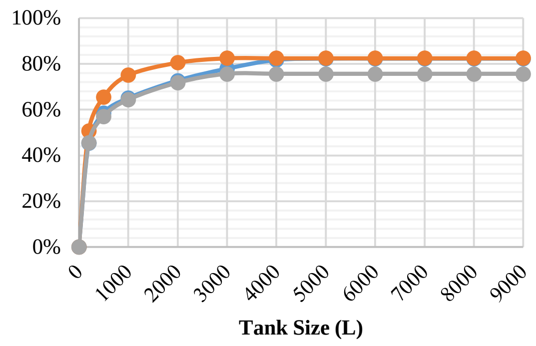
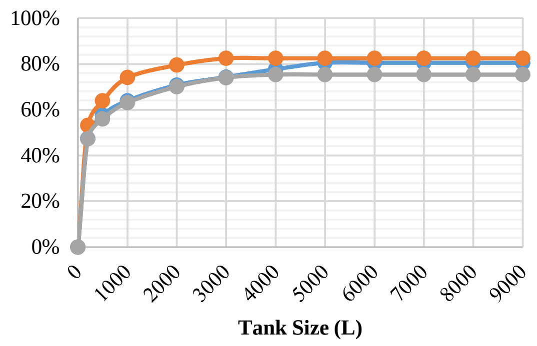
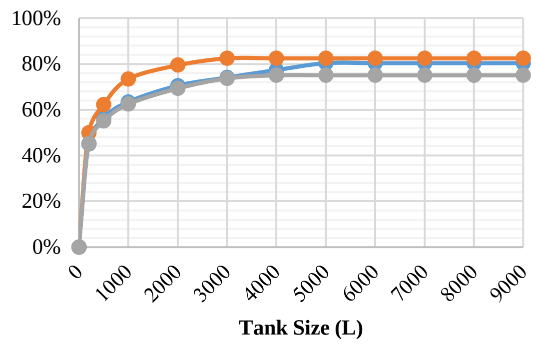
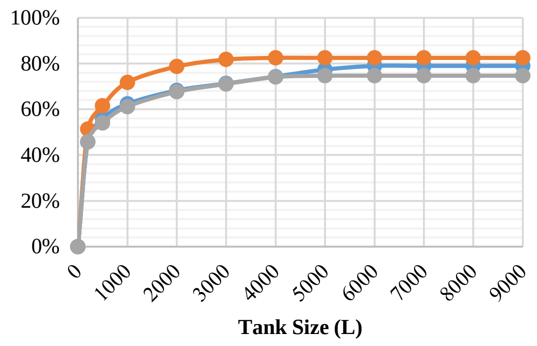
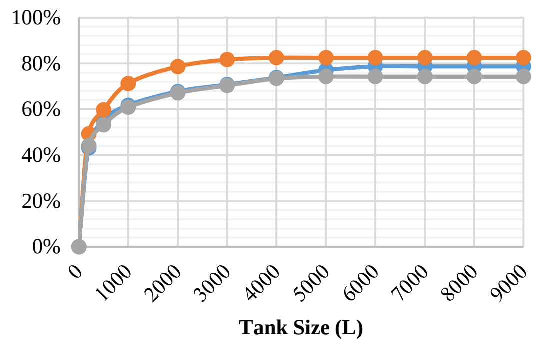
</td></tr>
<tr><td>6</td><td>


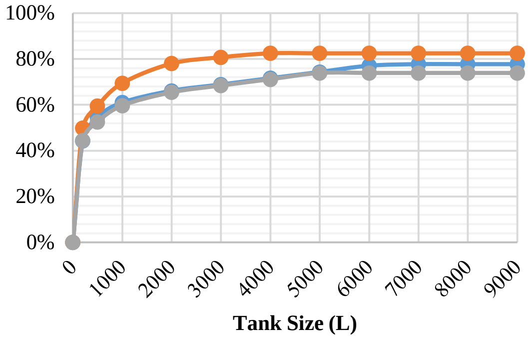
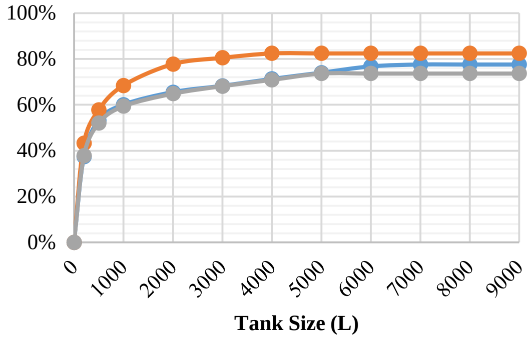
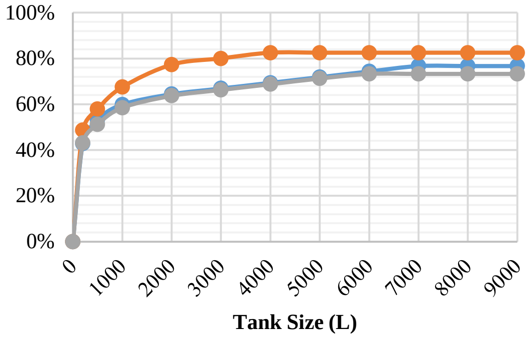
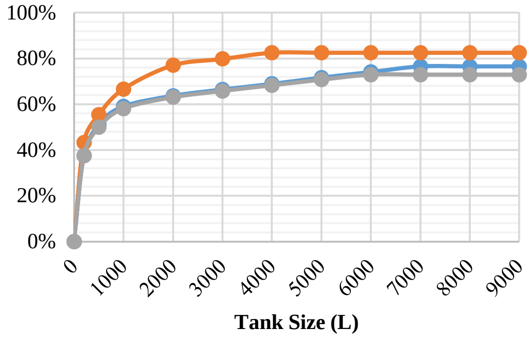
</td><td>


</td></tr>
</table>

Fixed Catchment Area (50 m^2)

Dry Year — Wet Year — Average Year

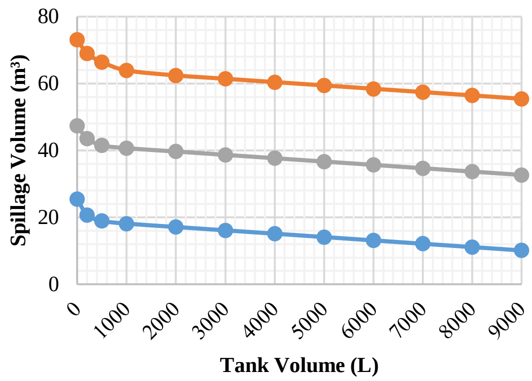
Family Size	Volumetric Reliability	Time Reliability
7		
8		
9		

Fixed Catchment Area (50 m^2)		
Dry Year — Wet Year — Average Year		
Family Size	Volumetric Reliability	Time Reliability
10		
11		

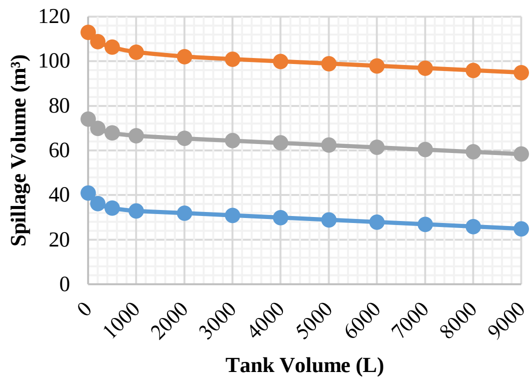
7.1.5.3 *Spilled water volume*

Family size (6)

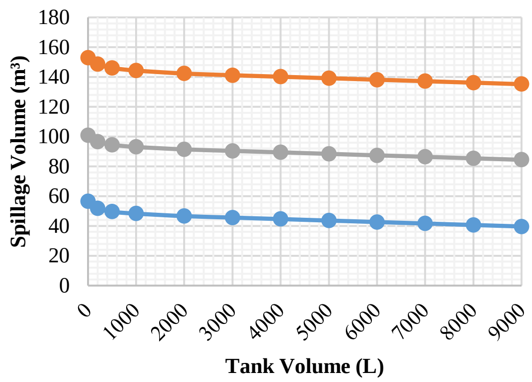
Dry Year — Wet Year — Average Year



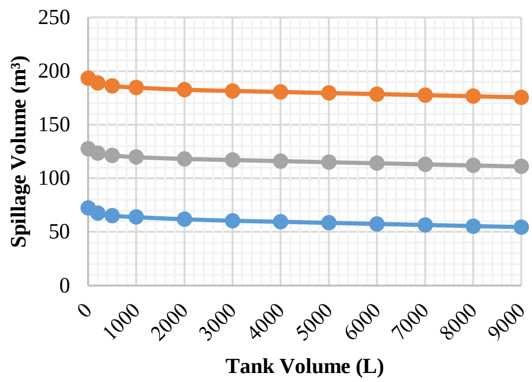
Catchment Area 20 m²



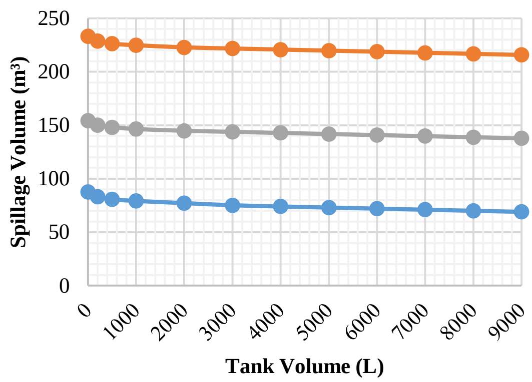
Catchment Area 30 m²



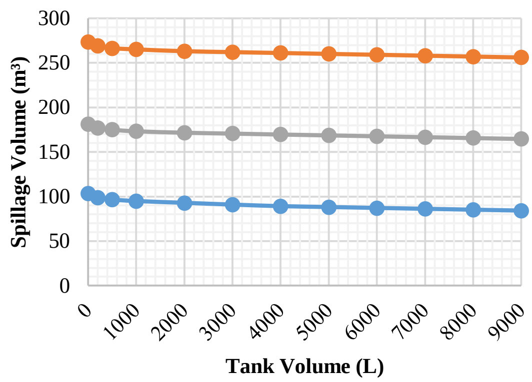
Catchment Area 40 m²



Catchment Area 50 m²



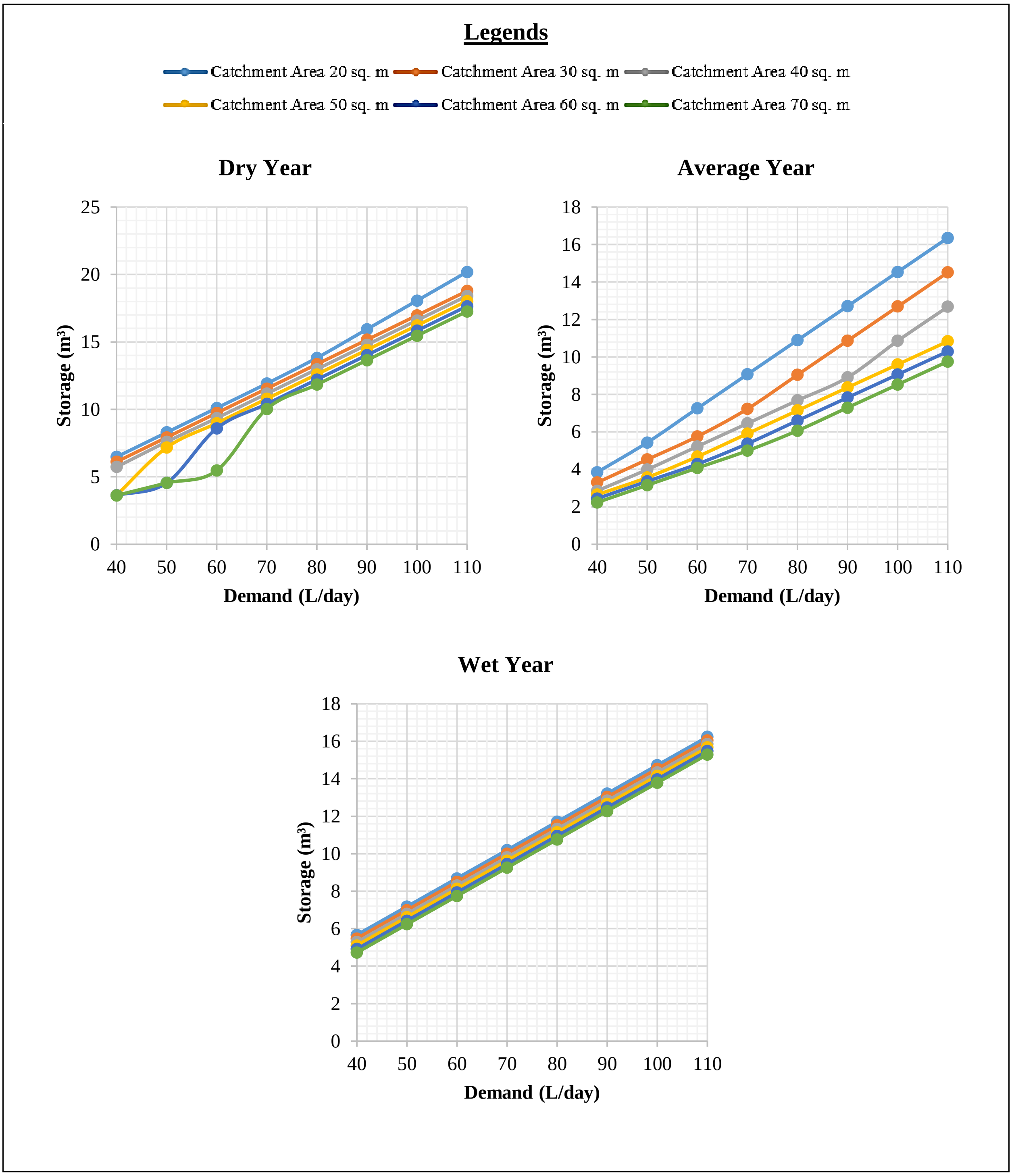
Catchment Area 60 m²



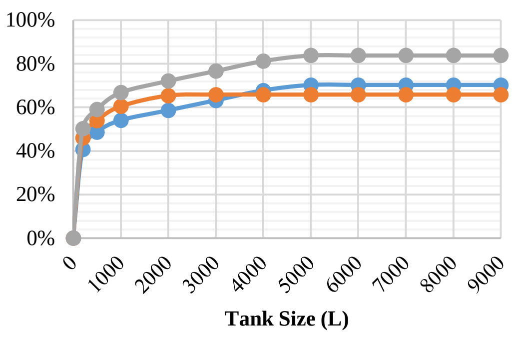
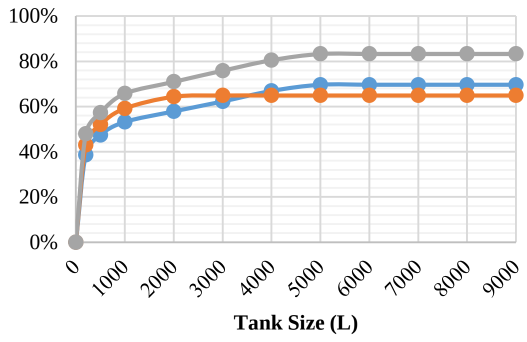
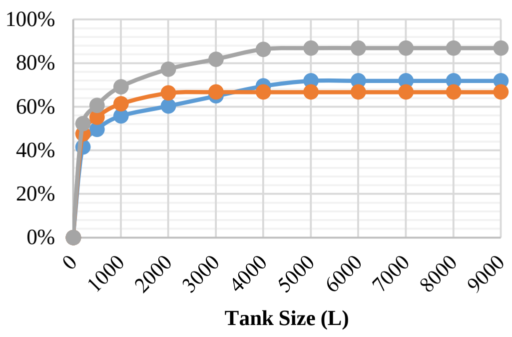
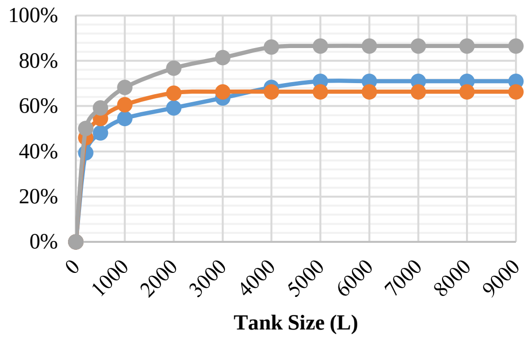
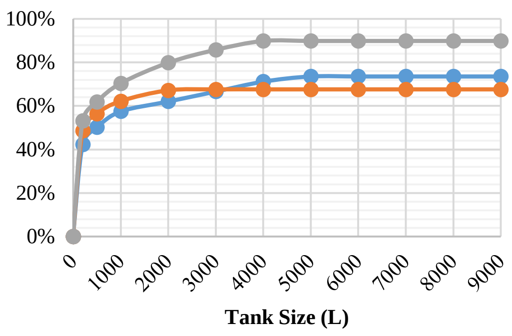
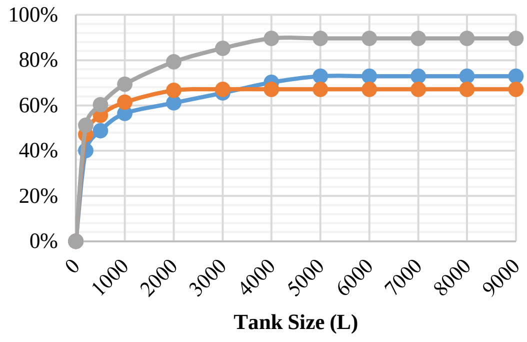
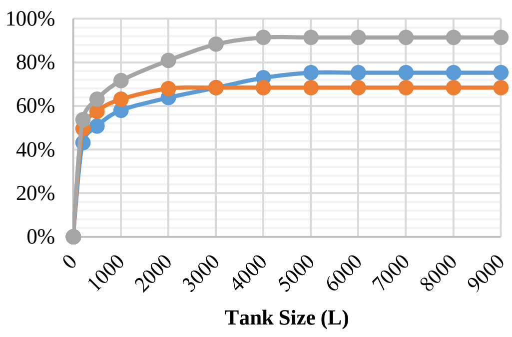
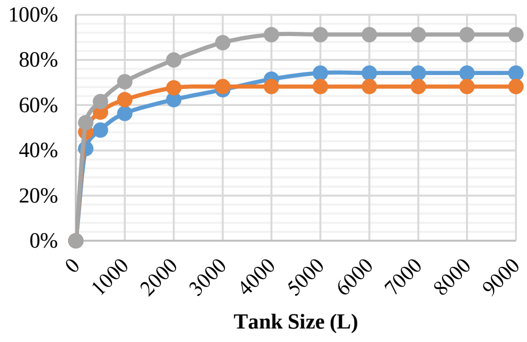
Catchment Area 70 m²

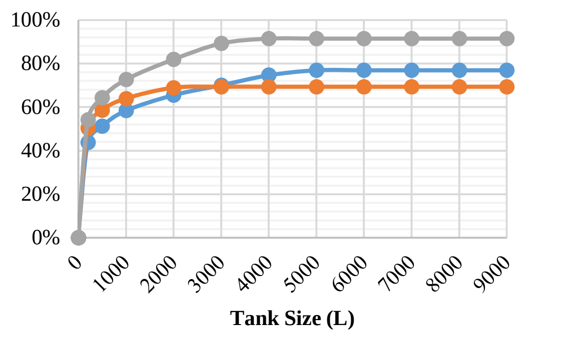
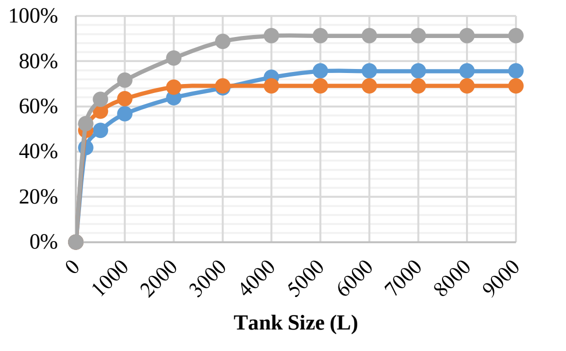
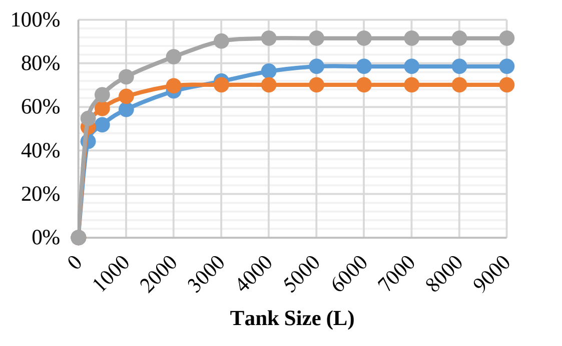
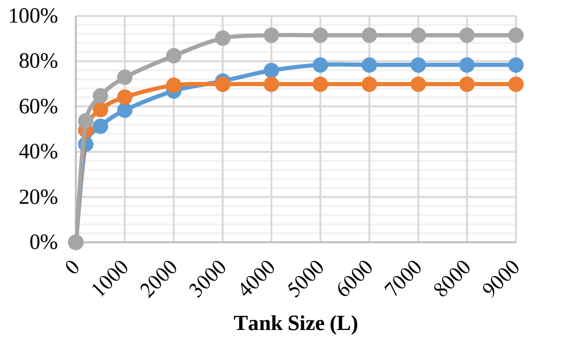
7.1.6 Khepupara

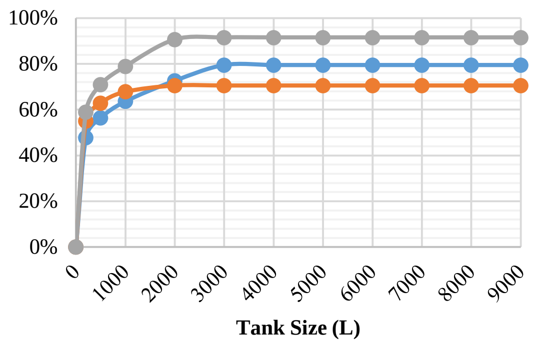
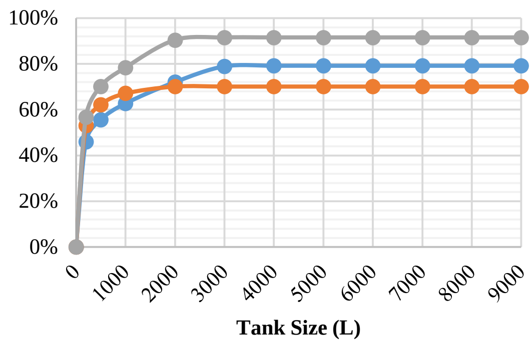
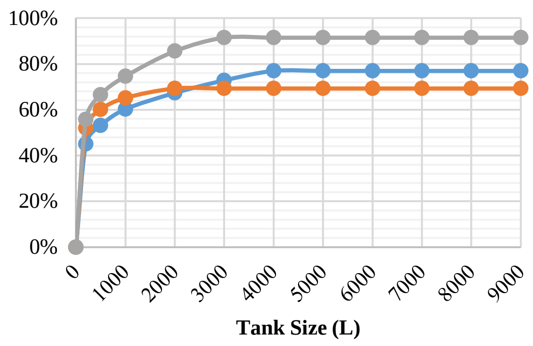
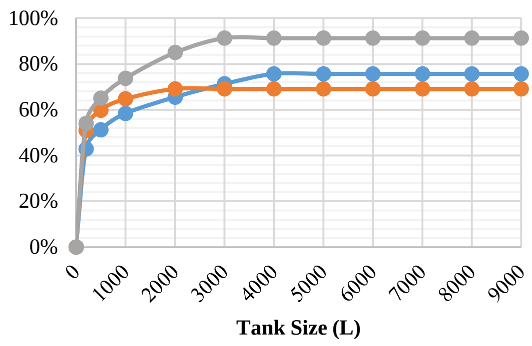
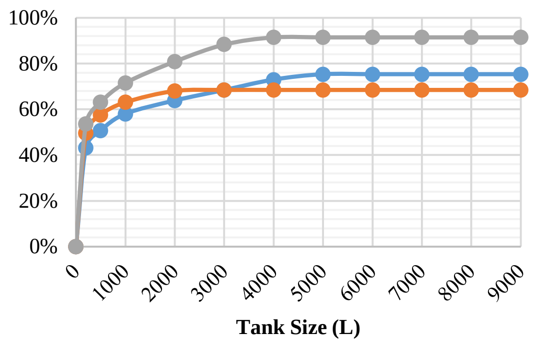
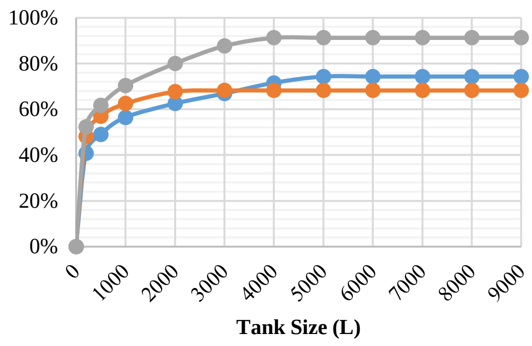
7.1.6.1 Optimum volume design curves

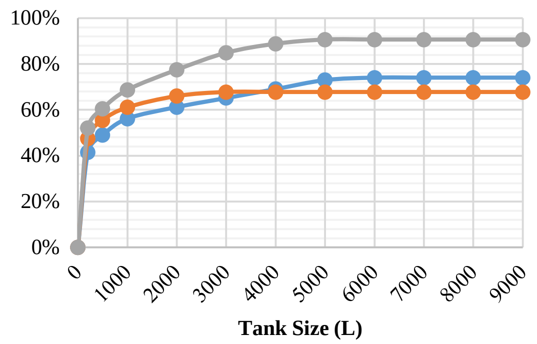
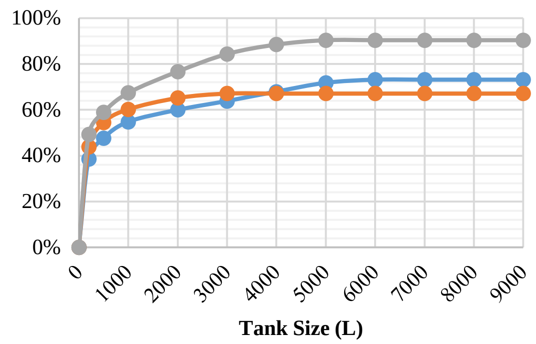
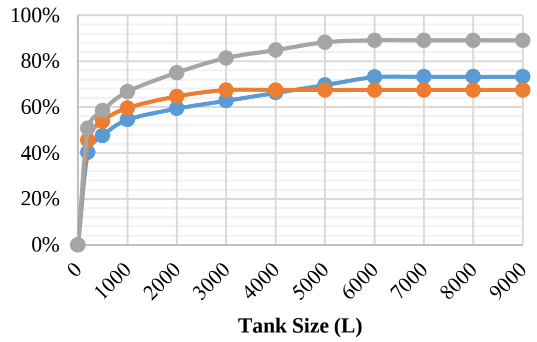
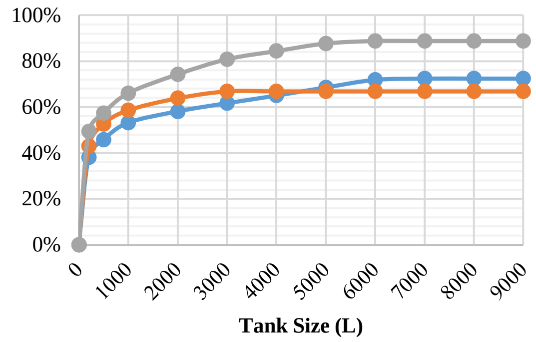
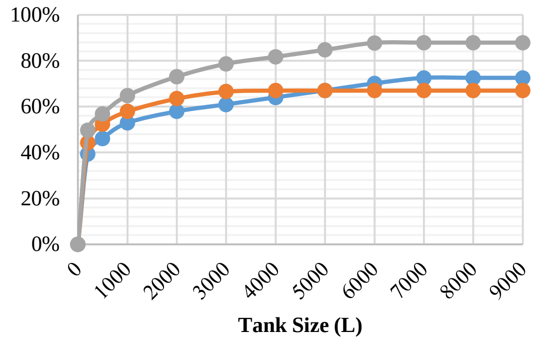
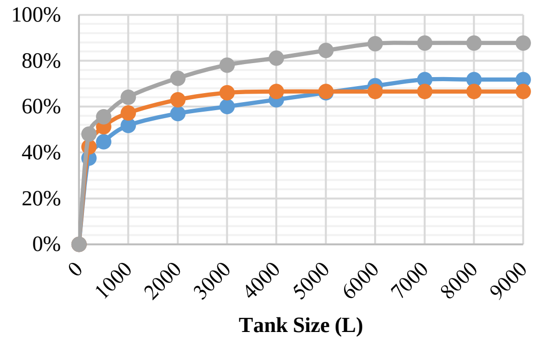


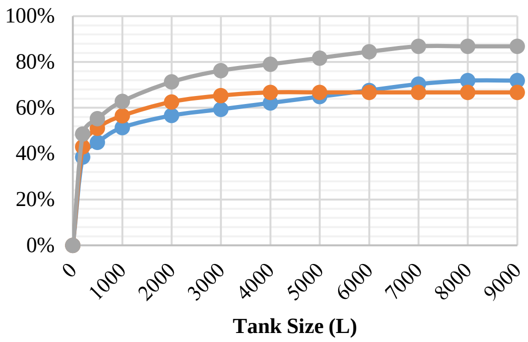
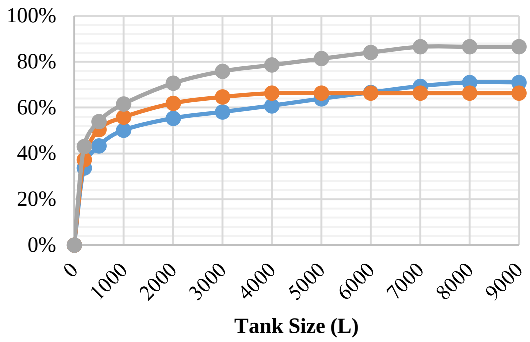
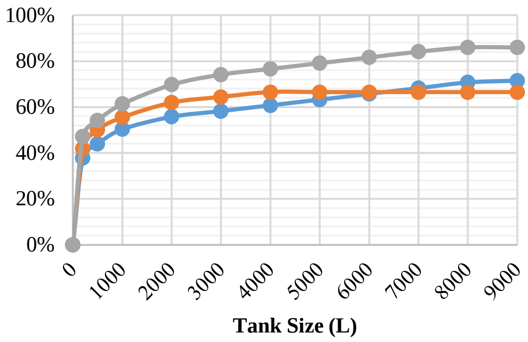
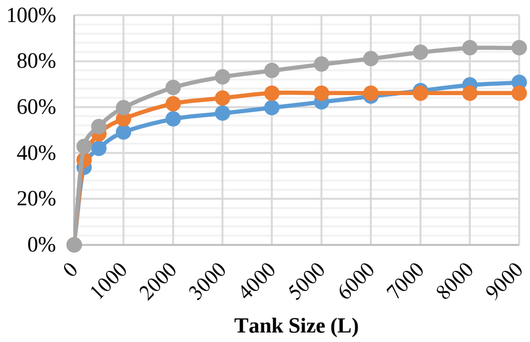
7.1.6.2 Volumetric and time reliability curves

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td></td><td></td></tr>
<tr><td>30</td><td></td><td></td></tr>
<tr><td>40</td><td></td><td></td></tr>
<tr><td>50</td><td></td><td></td></tr>
</table>

Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><th>Famil
y Size</th><th>Volumetric Reliability</th><th>Time Reliability</th></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

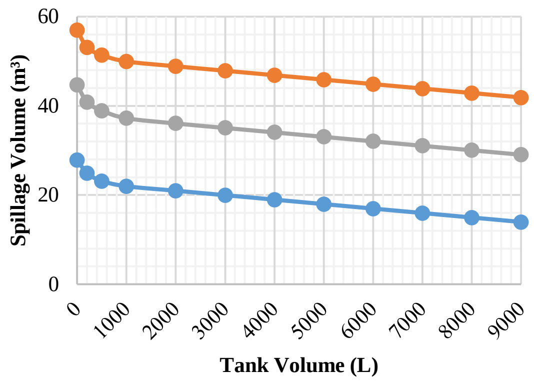
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Famil
y Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

Fixed Catchment Area (50 m^2)		
Dry Year — Wet Year — Average Year		
Family Size	Volumetric Reliability	Time Reliability
10		
11		

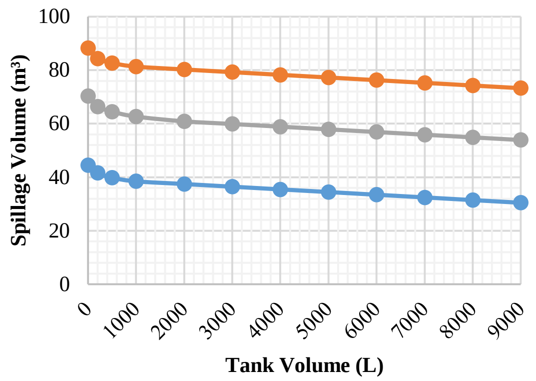
7.1.6.3 Spilled water volume

Family size (6)

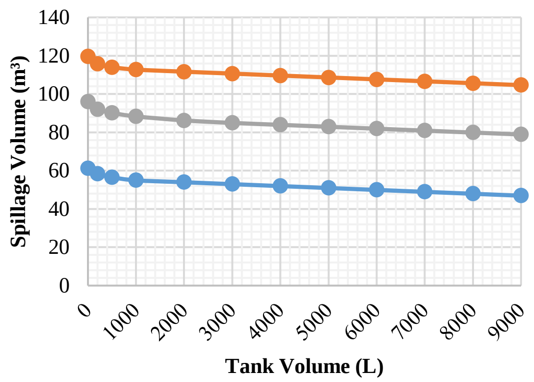
Dry Year   Wet Year   Average Year



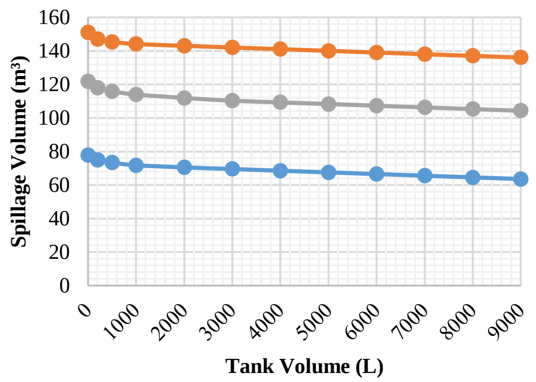
Catchment Area 20 m²



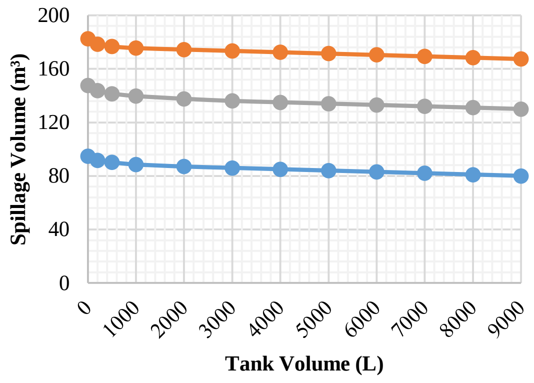
Catchment Area 30 m²



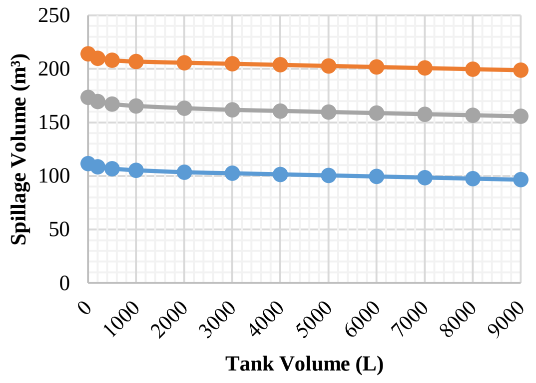
Catchment Area 40 m²



Catchment Area 50 m²



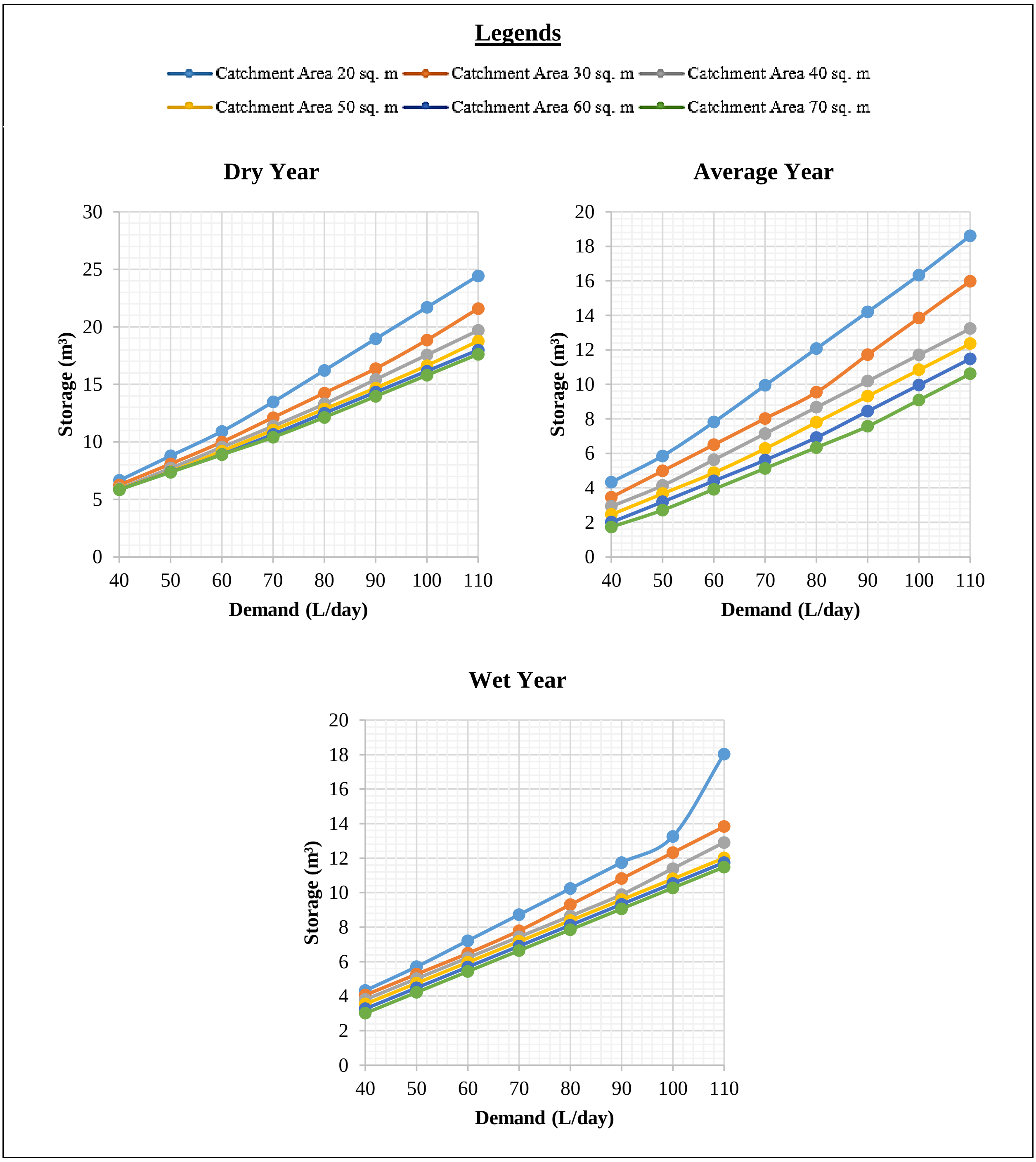
Catchment Area 60 m²



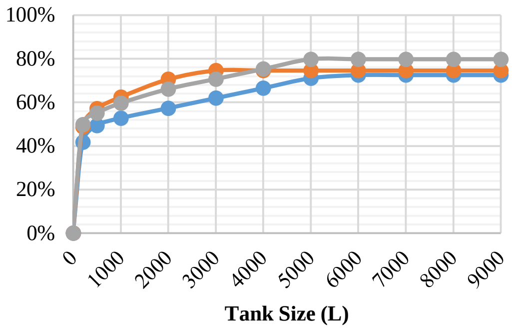
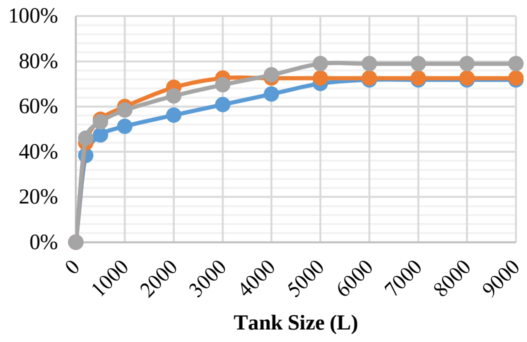
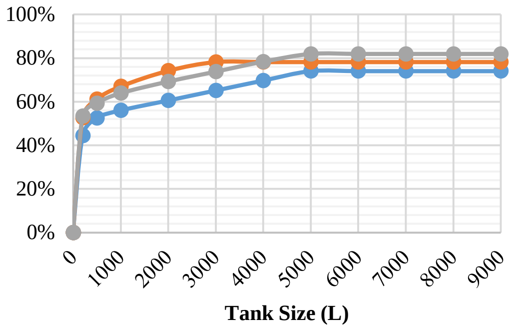
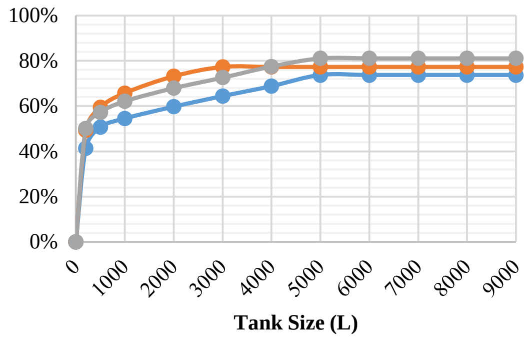
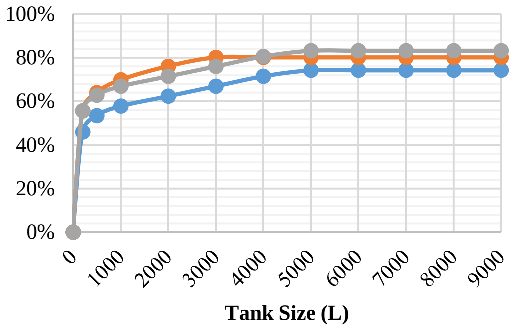
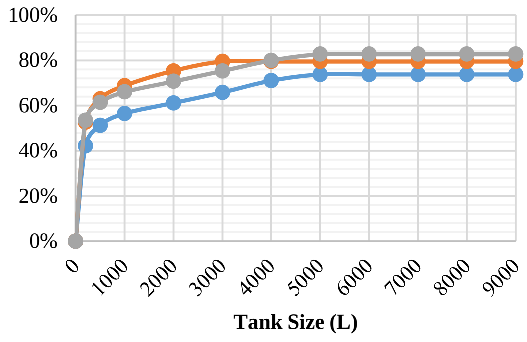
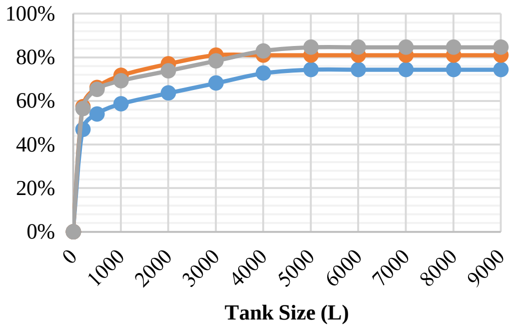
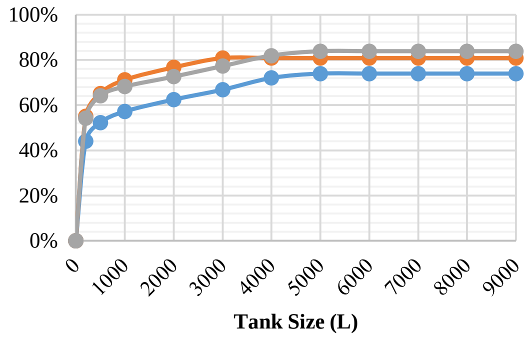
Catchment Area 70 m²

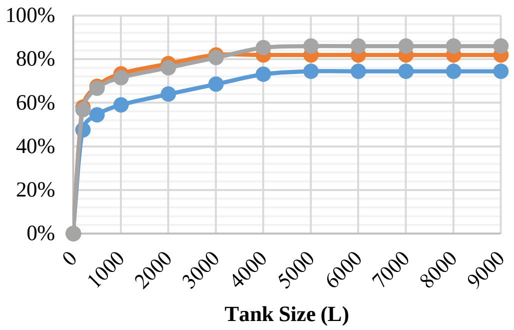
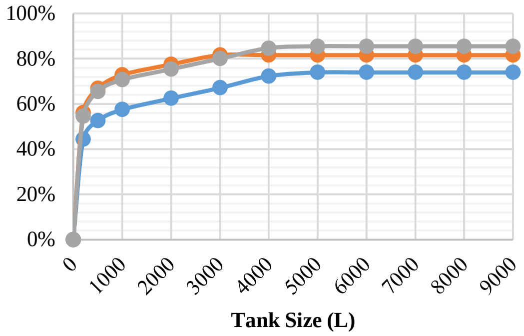
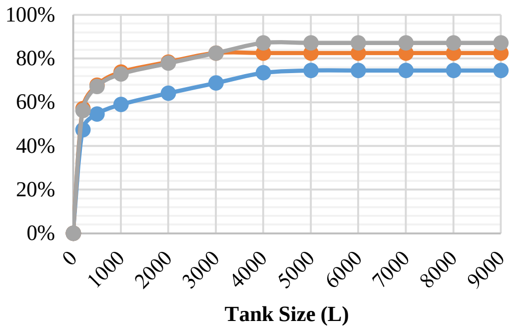
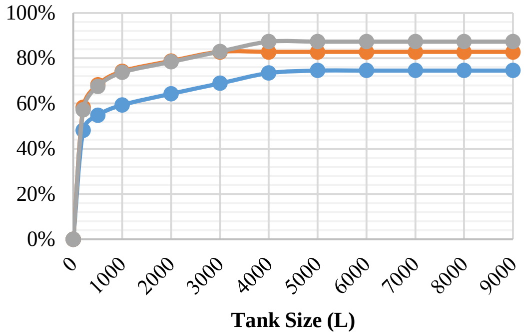
7.1.7 Khulna

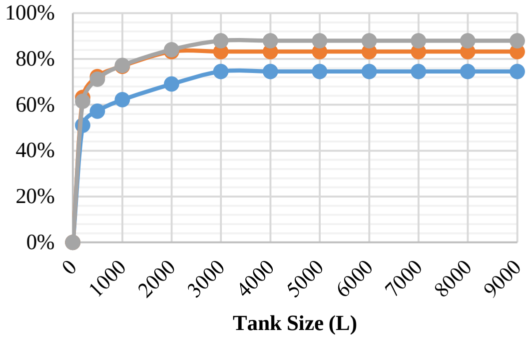
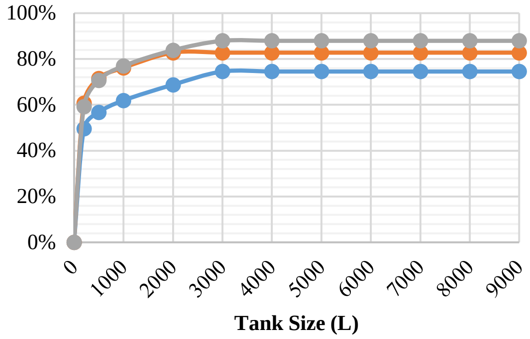
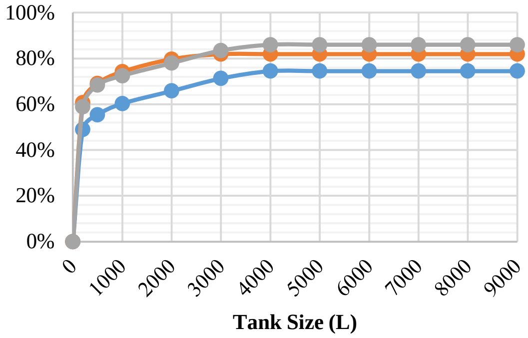
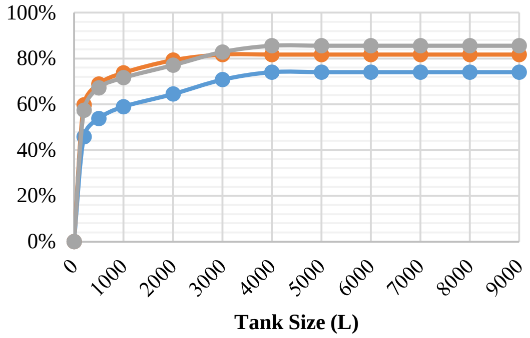
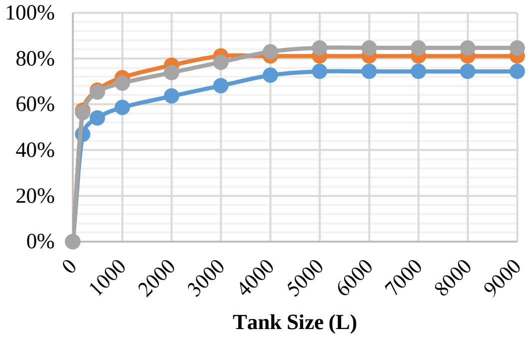
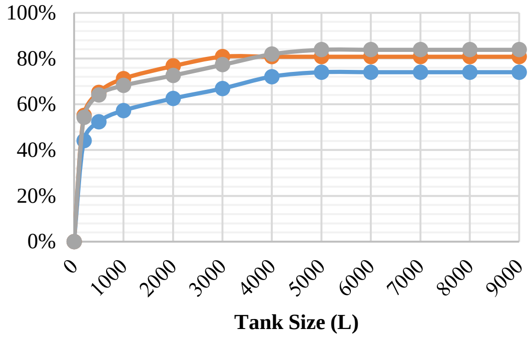
7.1.7.1 Optimum volume design curves

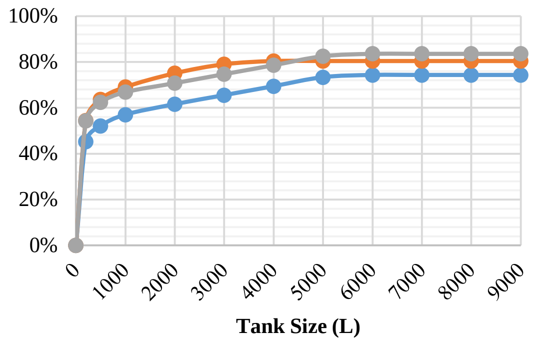
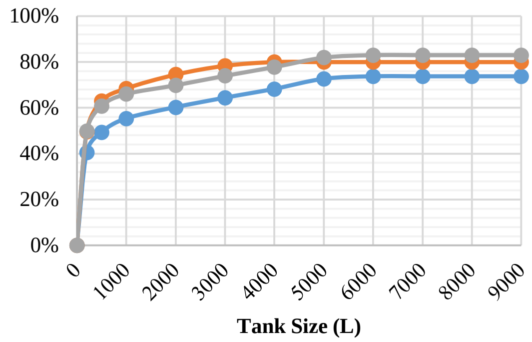
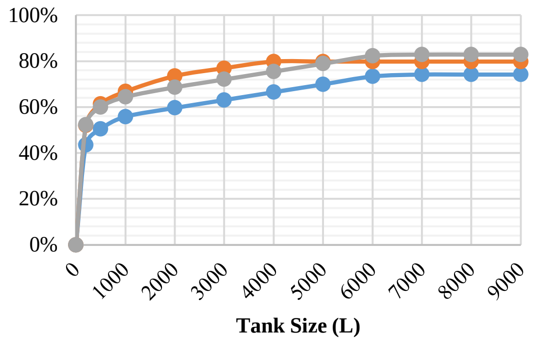
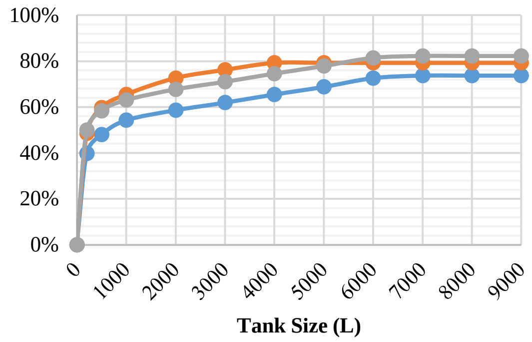
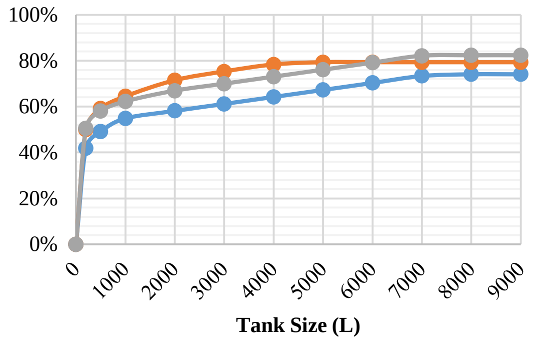
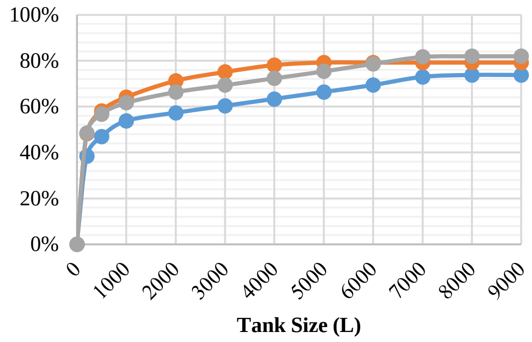


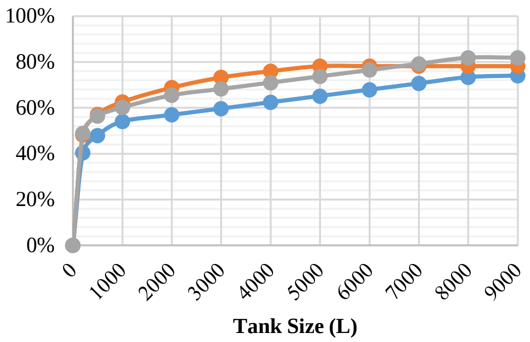
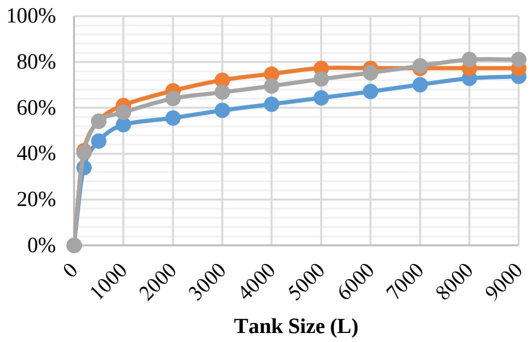
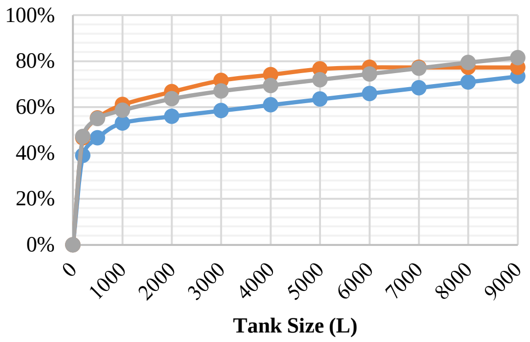
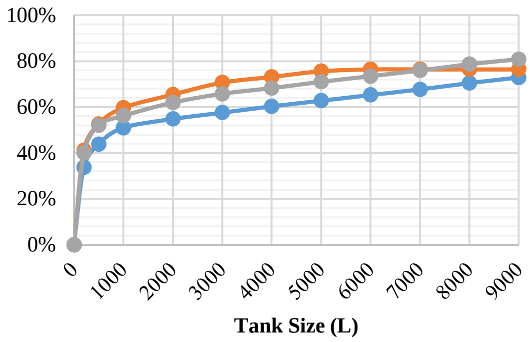
7.1.7.2 Volumetric and time reliability curves

Fixed Family Size (6)		
Dry Year Wet Year Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

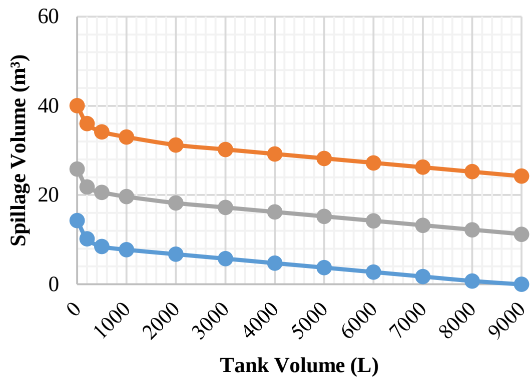
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

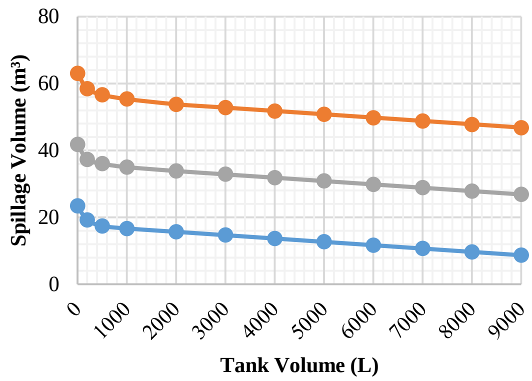
7.1.7.3 *Spilled water volume*

Family size (6)

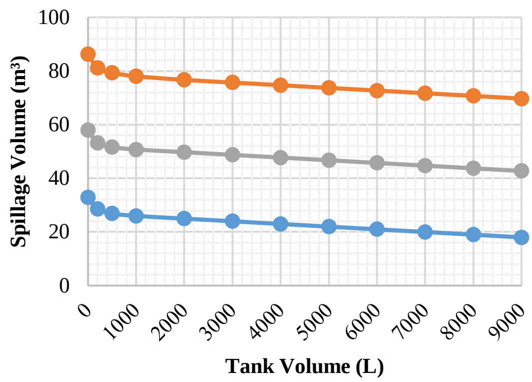
Dry Year   Wet Year   Average Year



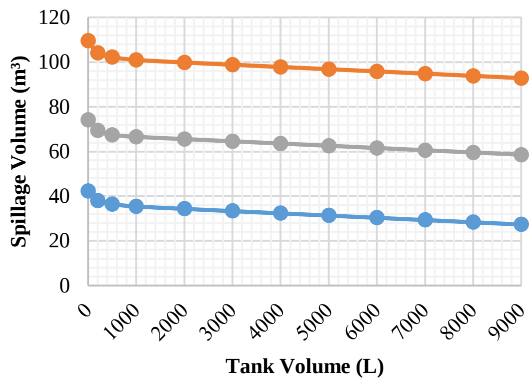
Catchment Area 20 m^2



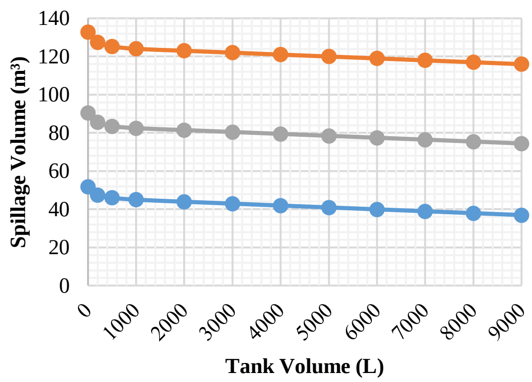
Catchment Area 30 m^2



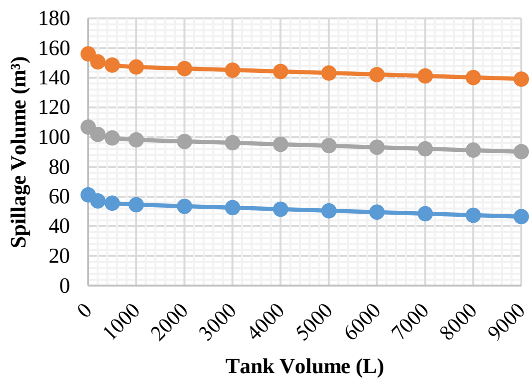
Catchment Area 40 m^2



Catchment Area 50 m^2



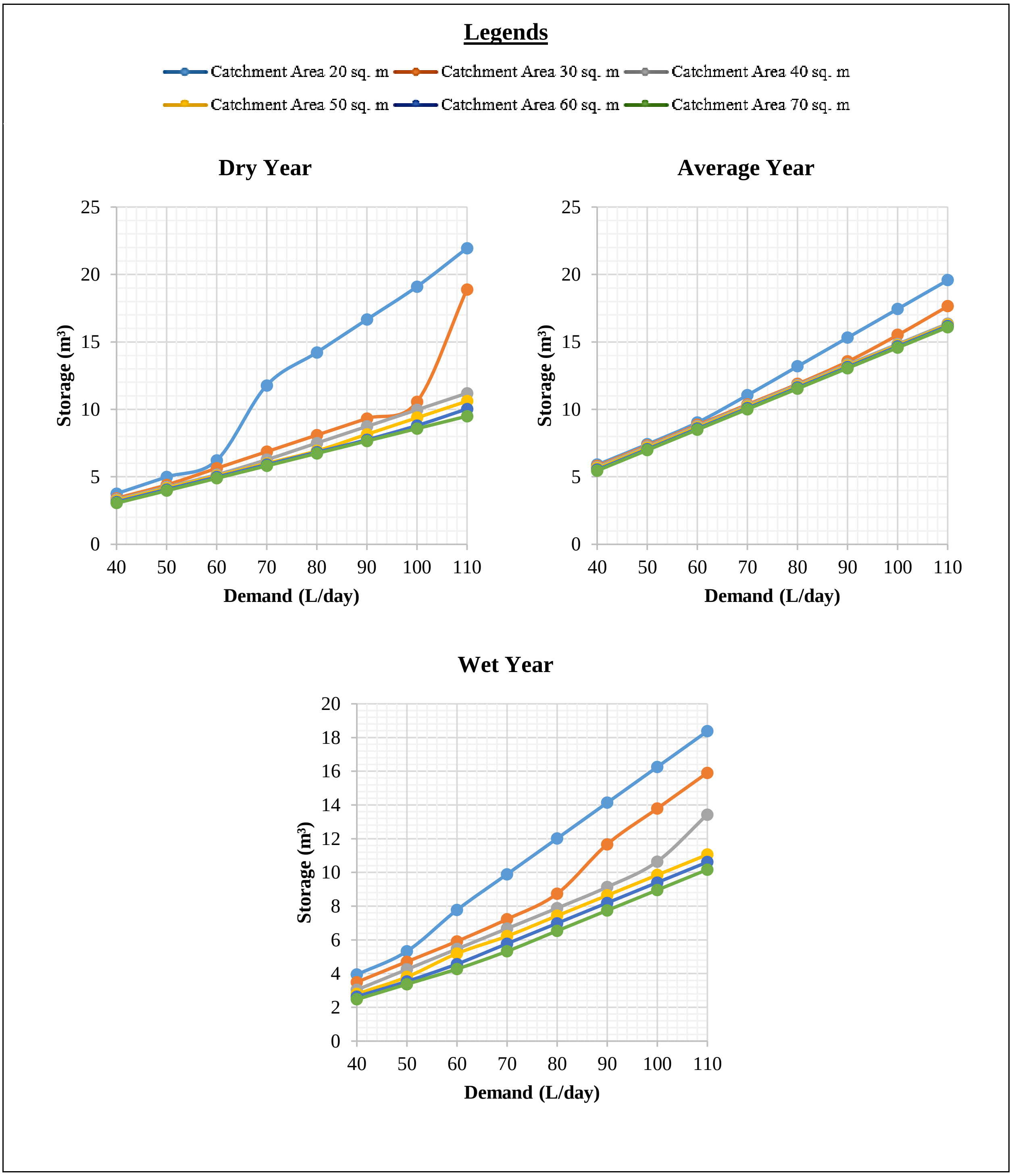
Catchment Area 60 m^2



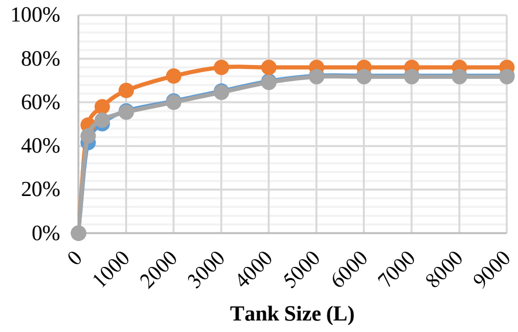
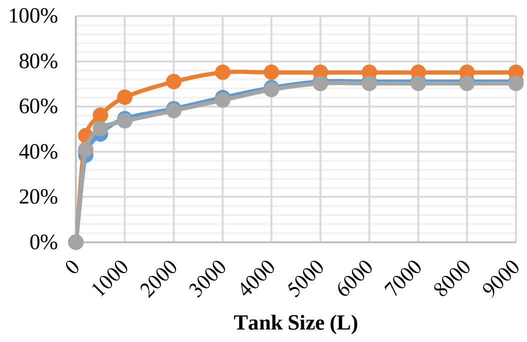
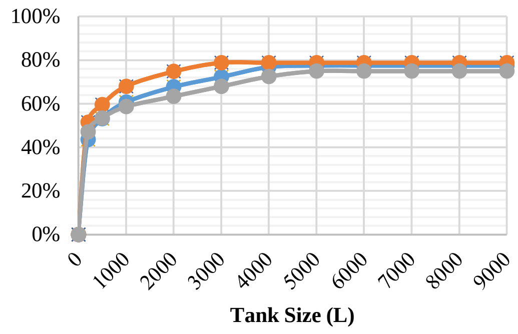
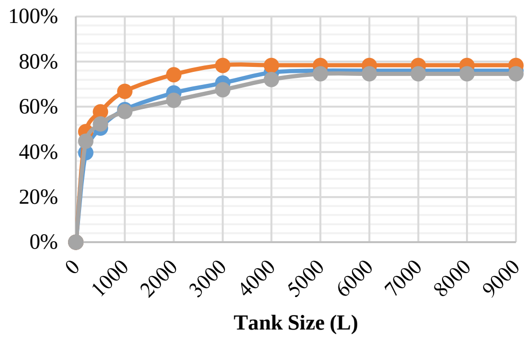
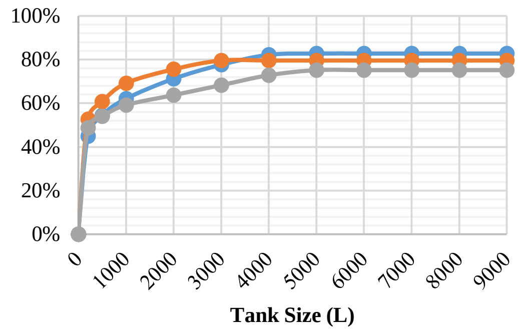
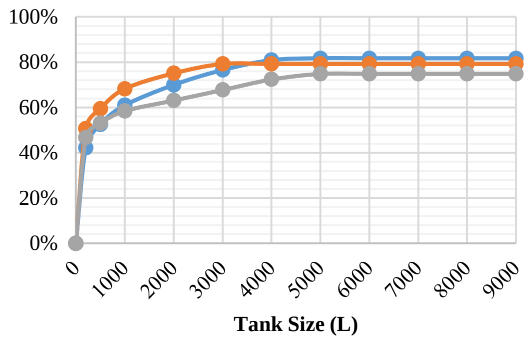
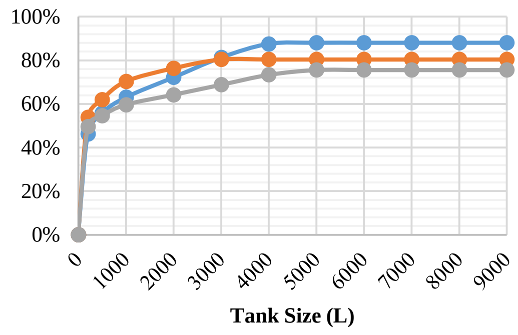
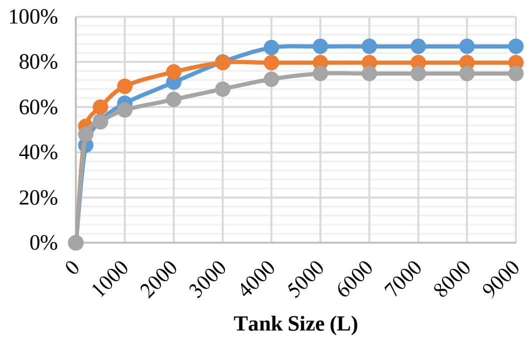
Catchment Area 70 m^2

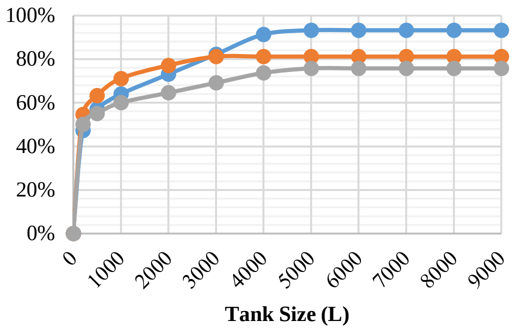
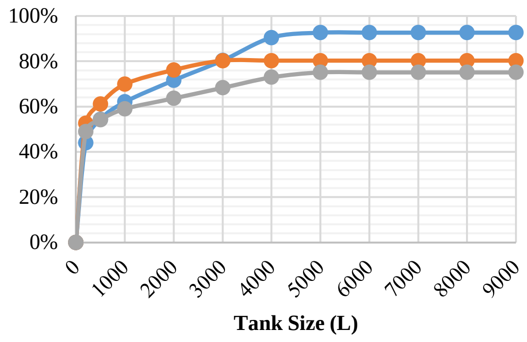
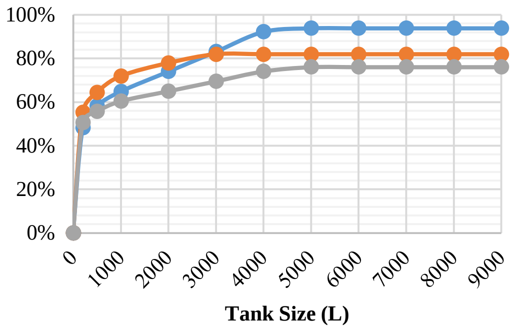
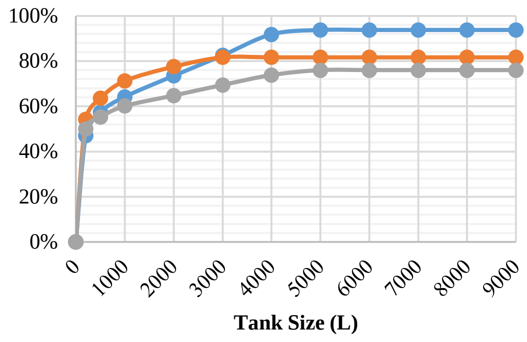
7.1.8 Mongla

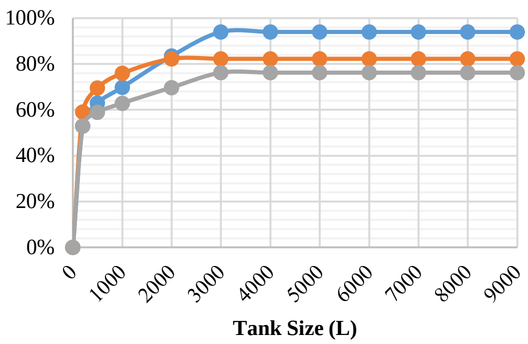
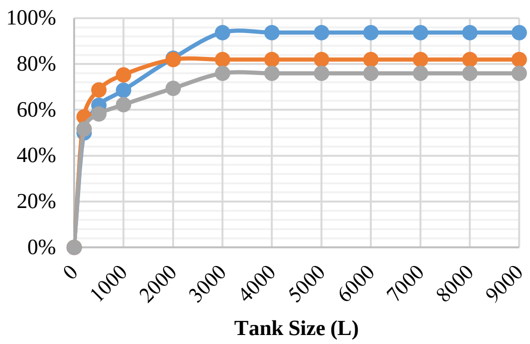
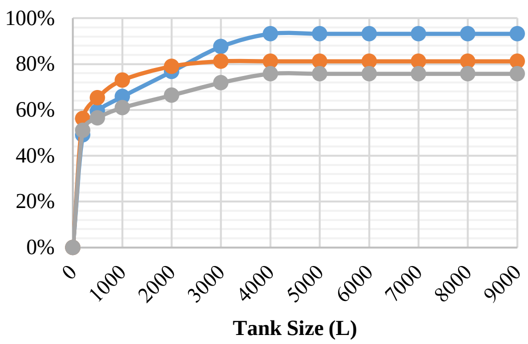
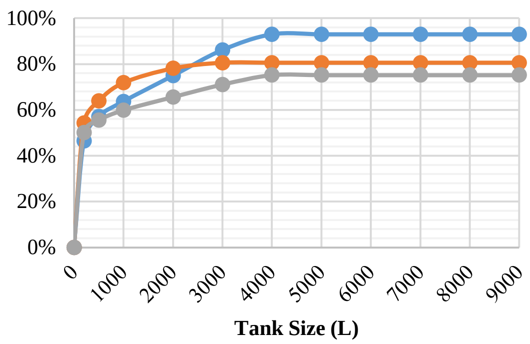
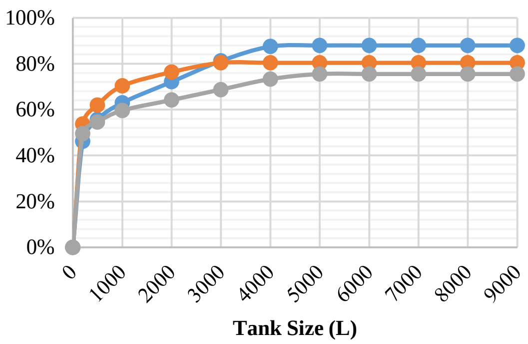
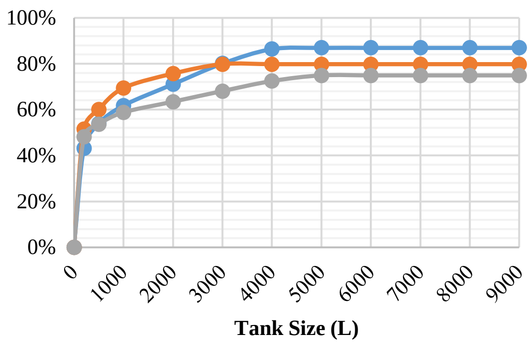
7.1.8.1 Optimum volume design curves

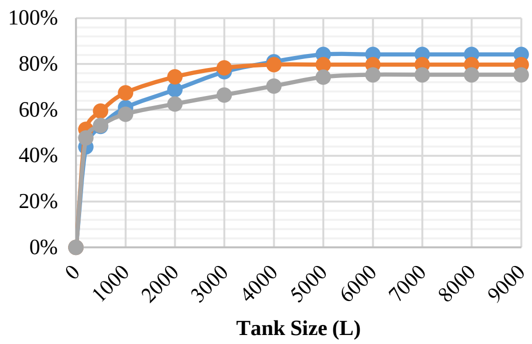
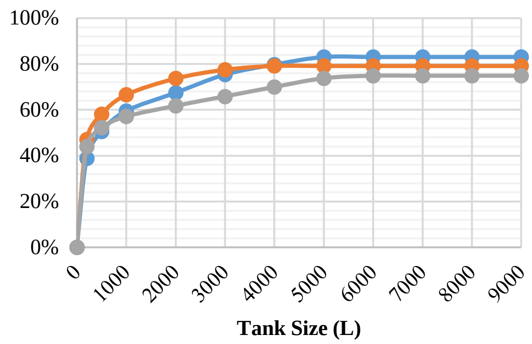
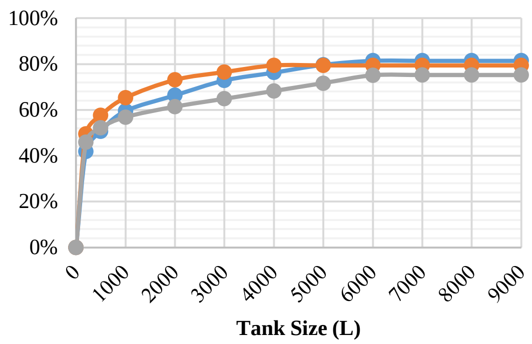
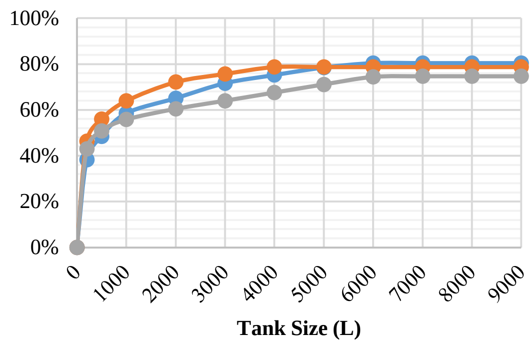
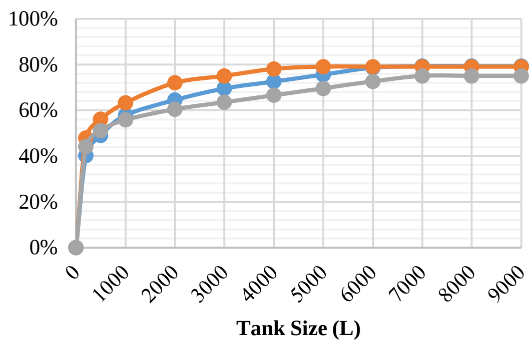
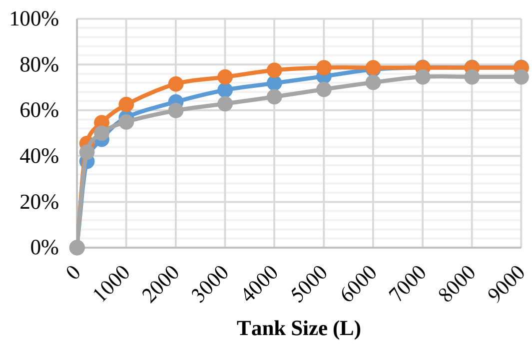


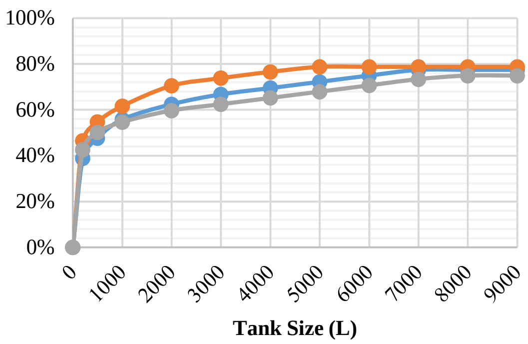
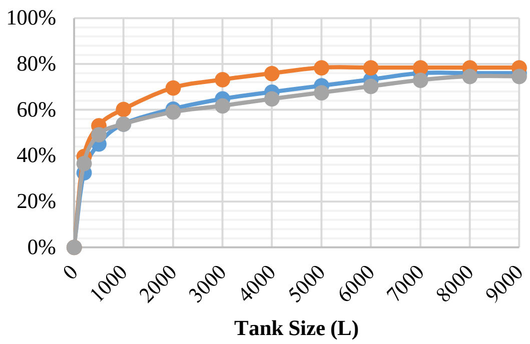
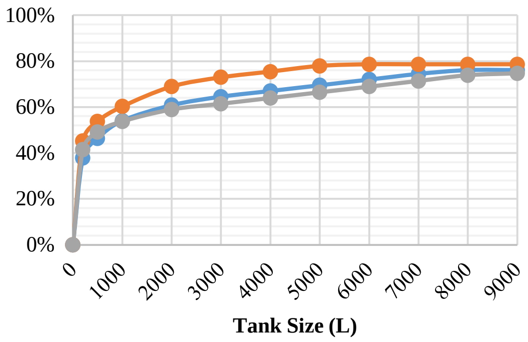
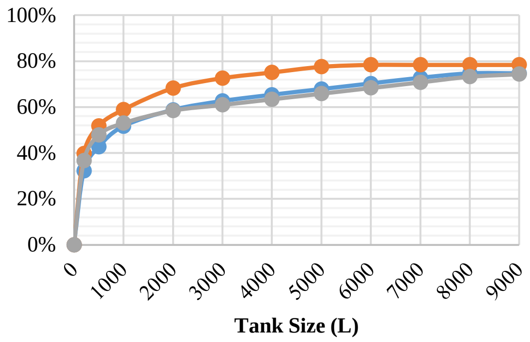
7.1.8.2 Volumetric and time reliability curves

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year · Wet Year · Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td>
</td><td>
</td></tr>
<tr><td>30</td><td>
</td><td>
</td></tr>
<tr><td>40</td><td>
</td><td>
</td></tr>
<tr><td>50</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

Fixed Catchment Area (50 m²)		
Dry Year / Wet Year / Average Year		
Family Size	Volumetric Reliability	Time Reliability
4		
5		
6		

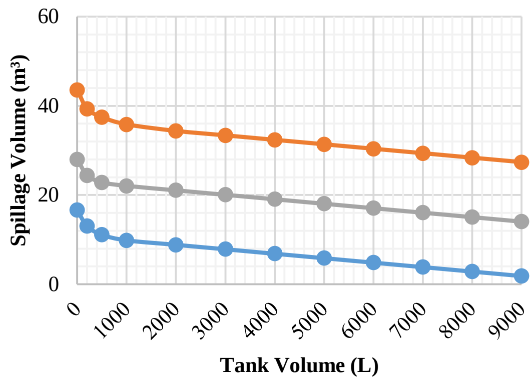
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><td colspan="3">Fixed Catchment Area (50 m^2)</td></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

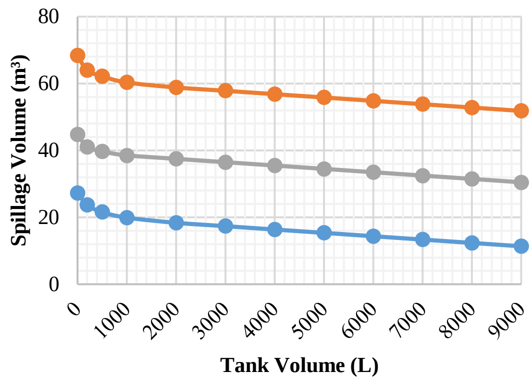
7.1.8.3 Spilled water volume

Family size (6)

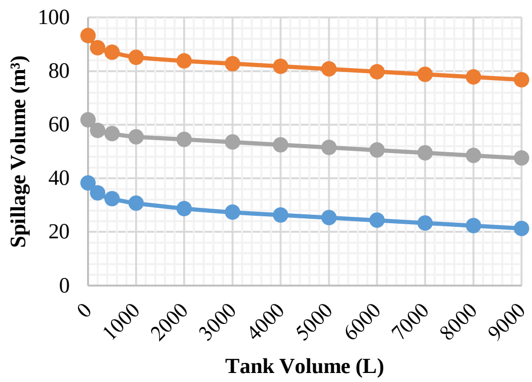
Dry Year   Wet Year   Average Year



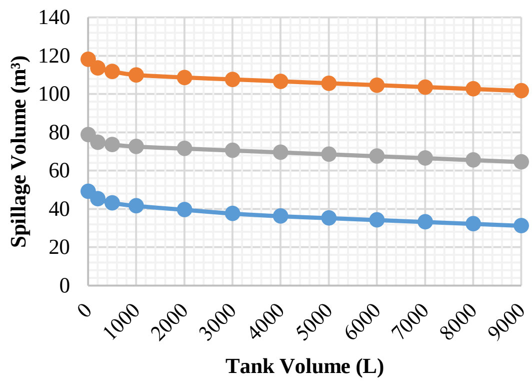
Catchment Area 20 m^2



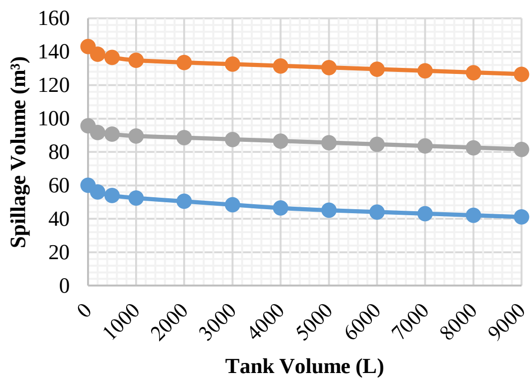
Catchment Area 30 m^2



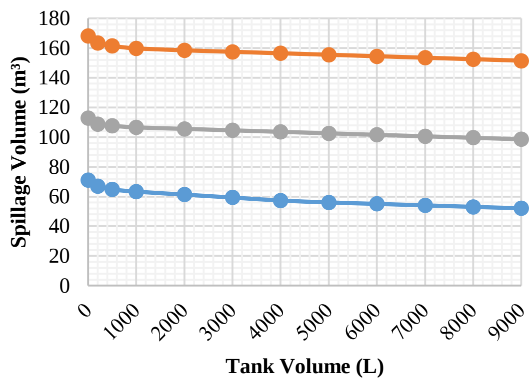
Catchment Area 40 m^2



Catchment Area 50 m^2



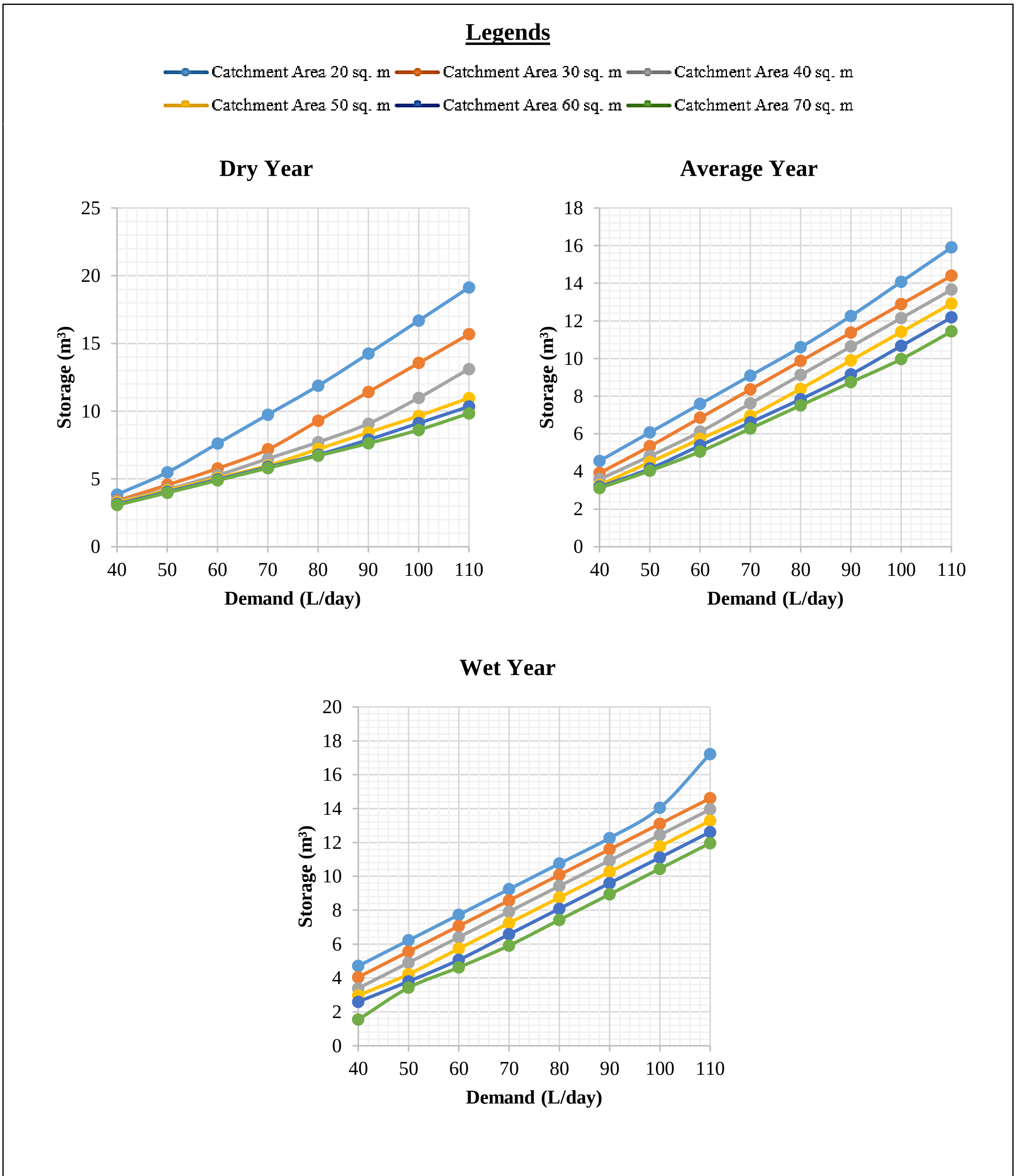
Catchment Area 60 m^2



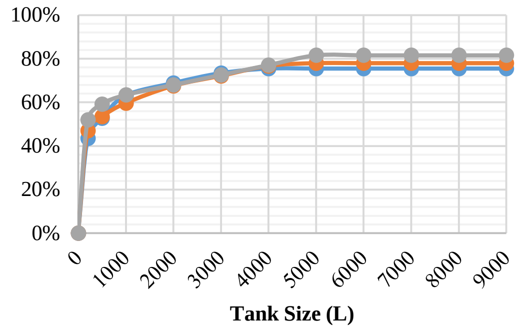
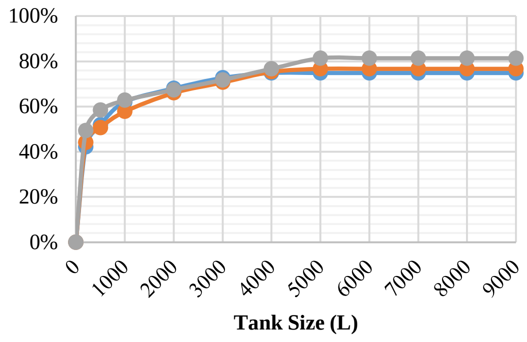
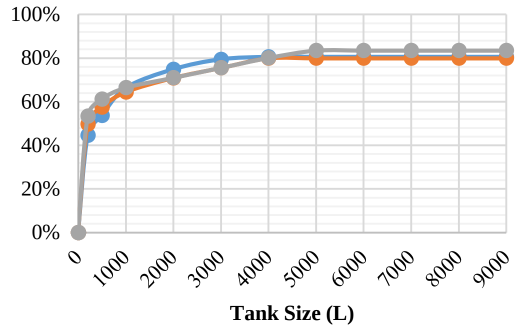
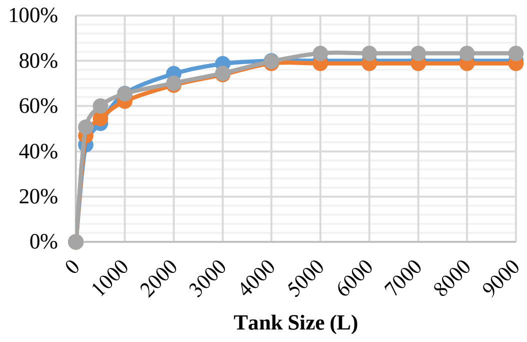
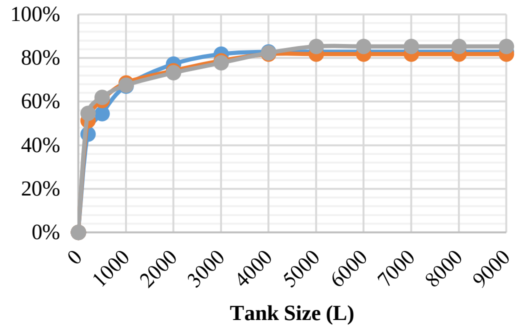
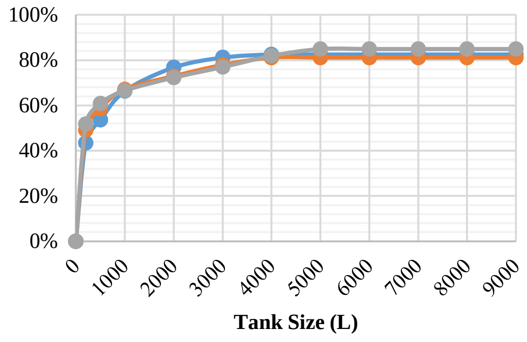
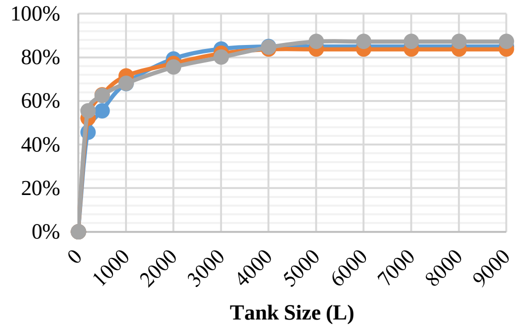
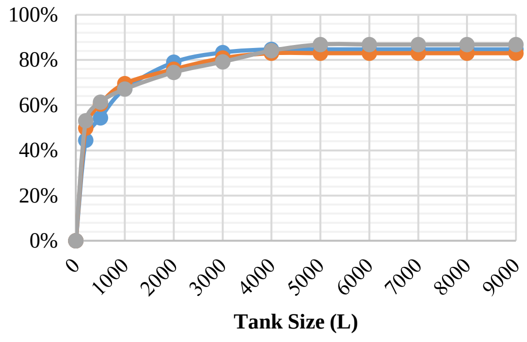
Catchment Area 70 m^2

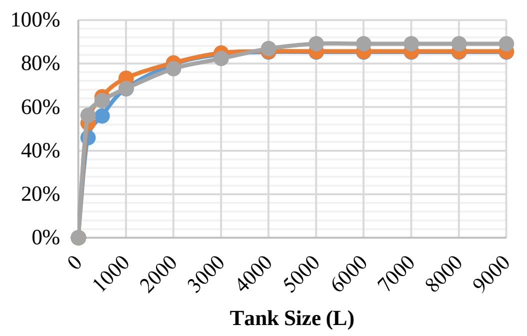
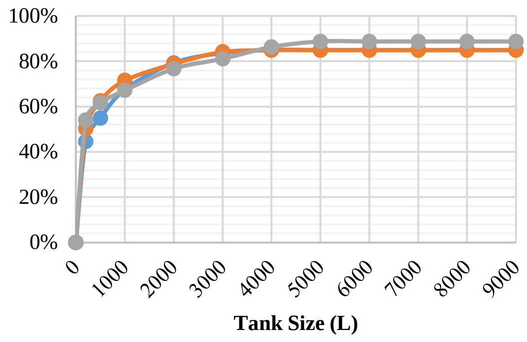
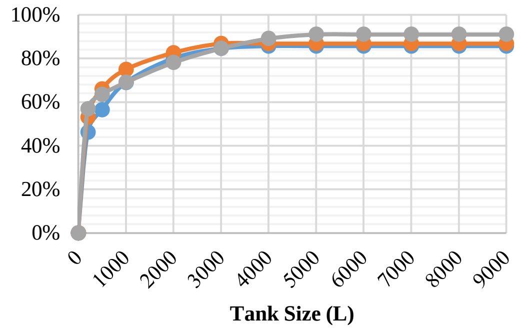
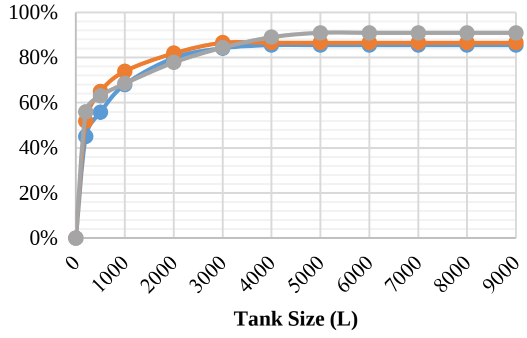
7.1.9 Patuakhali

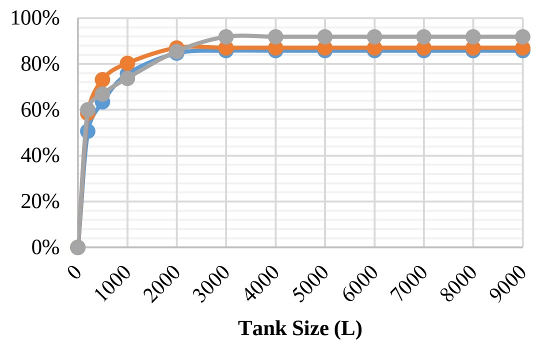
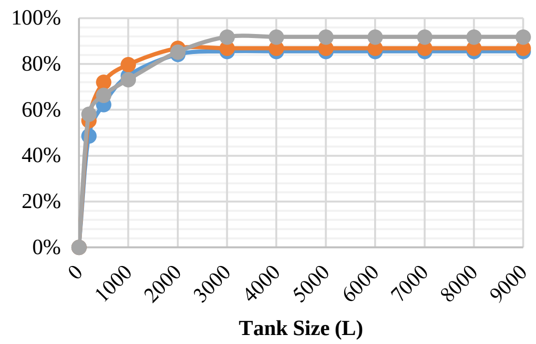
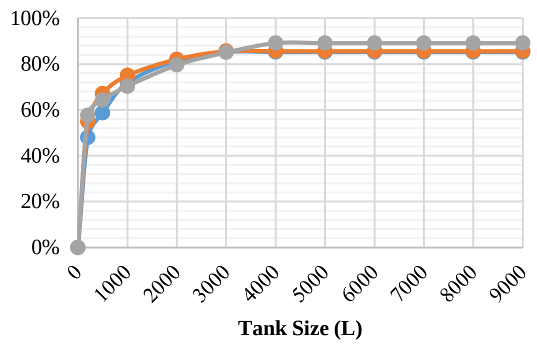
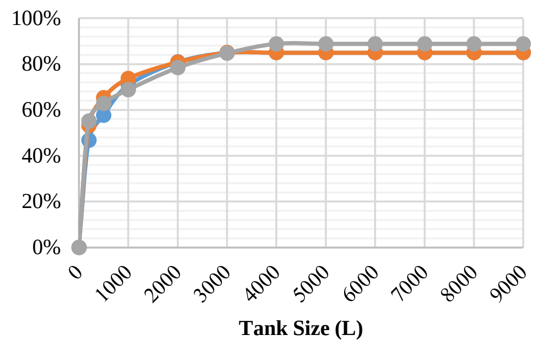
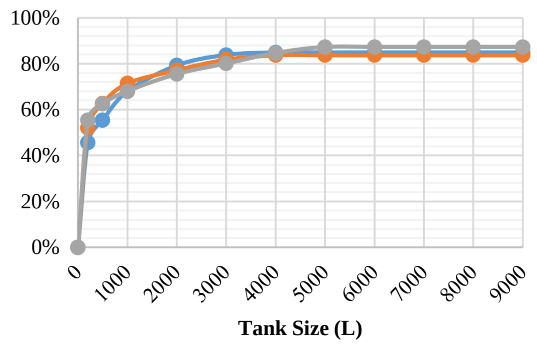
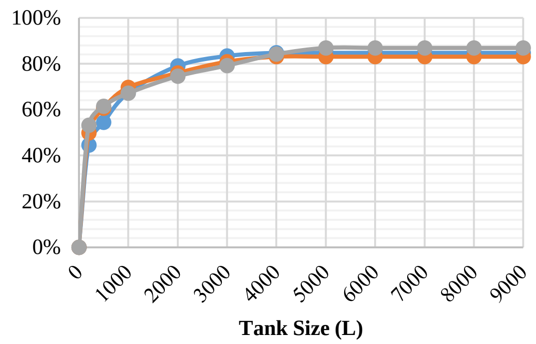
7.1.9.1 Optimum volume design curves

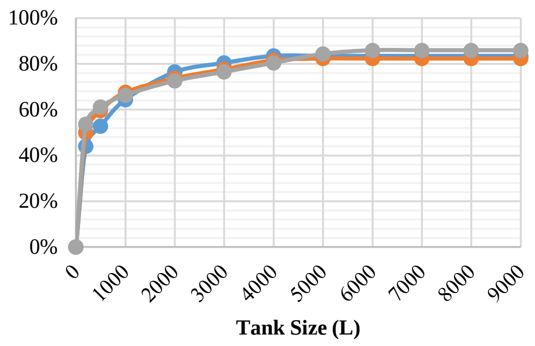
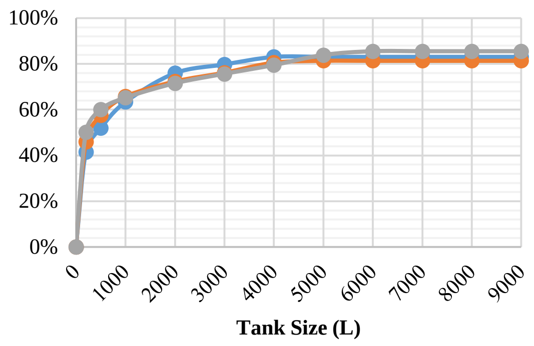
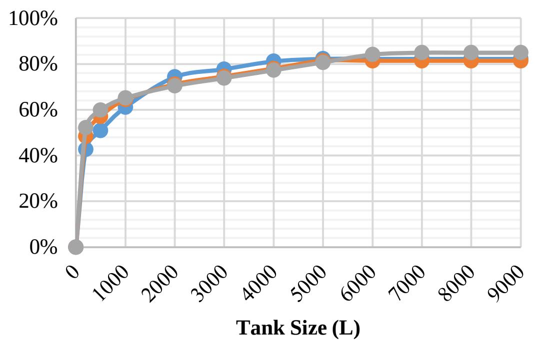
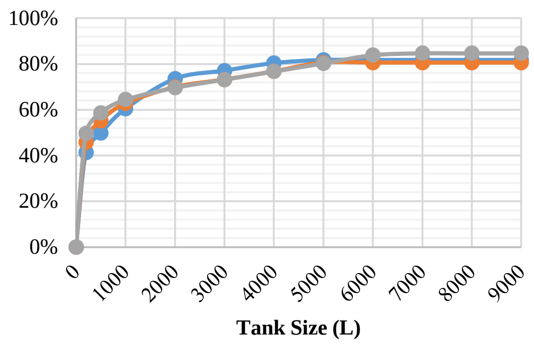
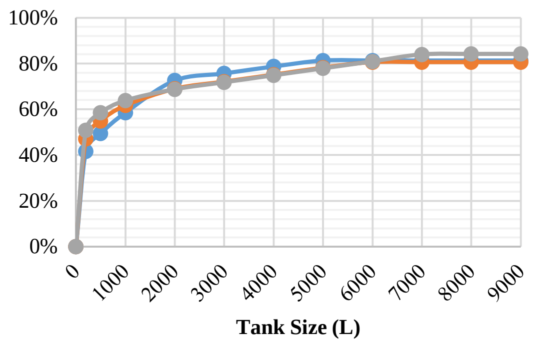
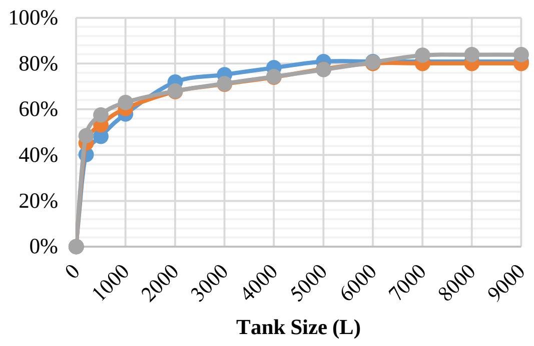


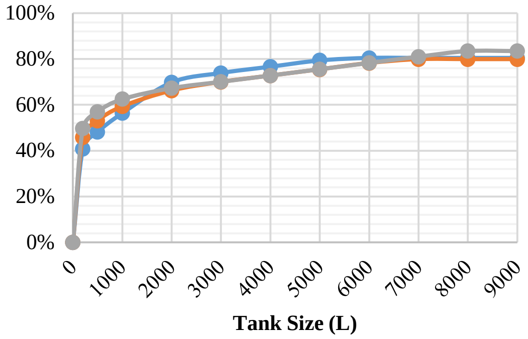
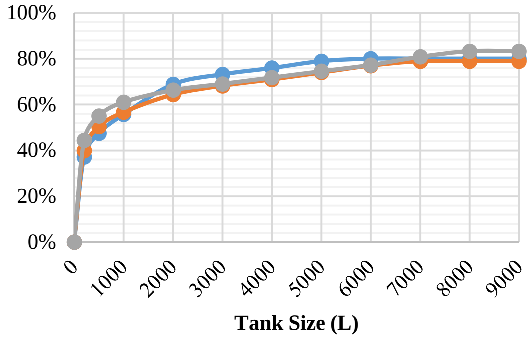
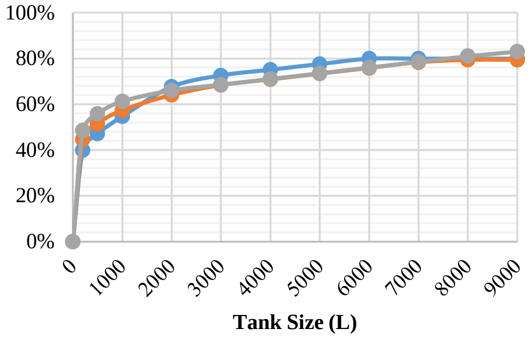
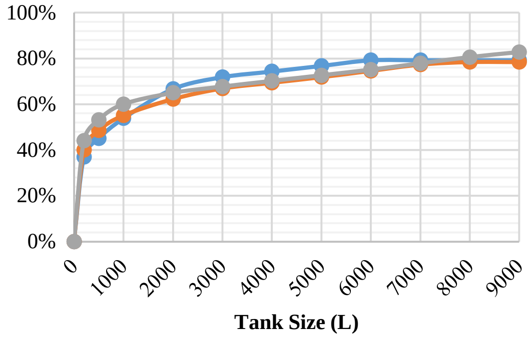
7.1.9.2 *Volumetric and time reliability curves*

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>20</td><td>
</td><td>
</td></tr>
<tr><td>30</td><td>
</td><td>
</td></tr>
<tr><td>40</td><td>
</td><td>
</td></tr>
<tr><td>50</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year Wet Year Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

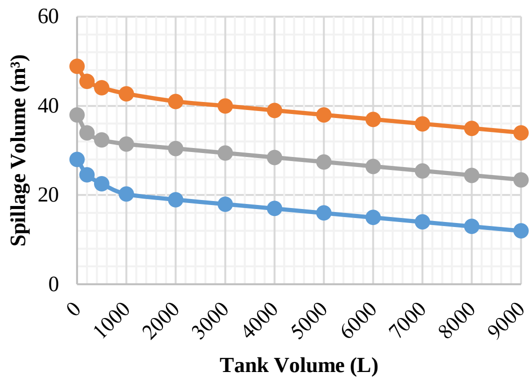
Fixed Catchment Area (50 m²)		
Dry Year Wet Year Average Year		
Family Size	Volumetric Reliability	Time Reliability
7		
8		
9		

<table>
<tr><td colspan="3">Fixed Catchment Area (50 m^2)</td></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Famil
y Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

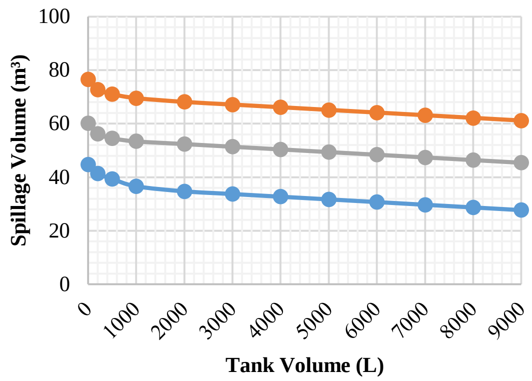
7.1.9.3 Spilled water volume

Family size (6)

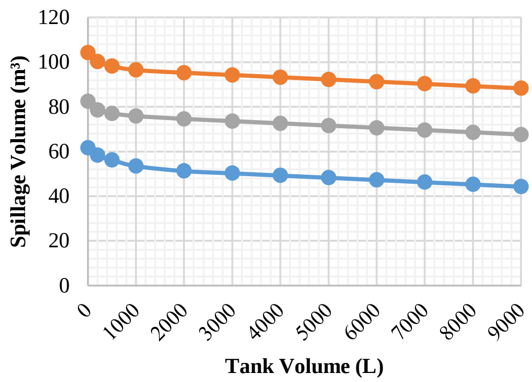
Dry Year — Wet Year — Average Year



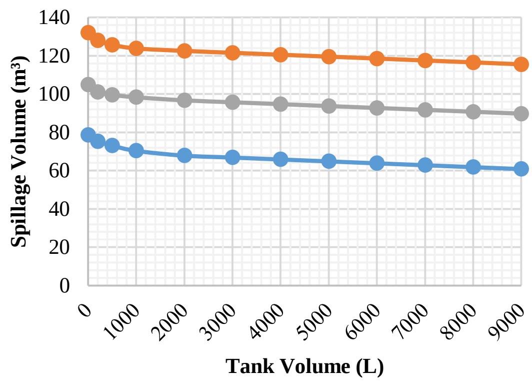
Catchment Area 20 m²



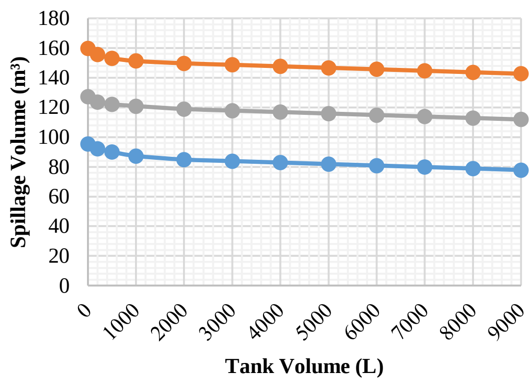
Catchment Area 30 m²



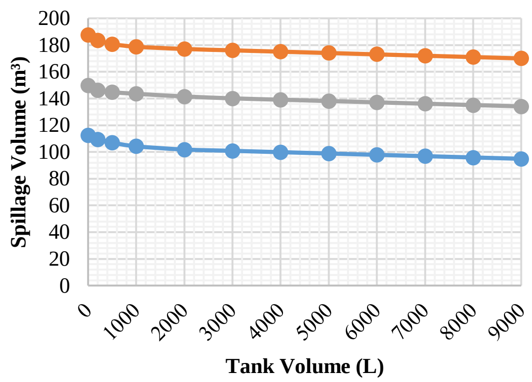
Catchment Area 40 m²



Catchment Area 50 m²



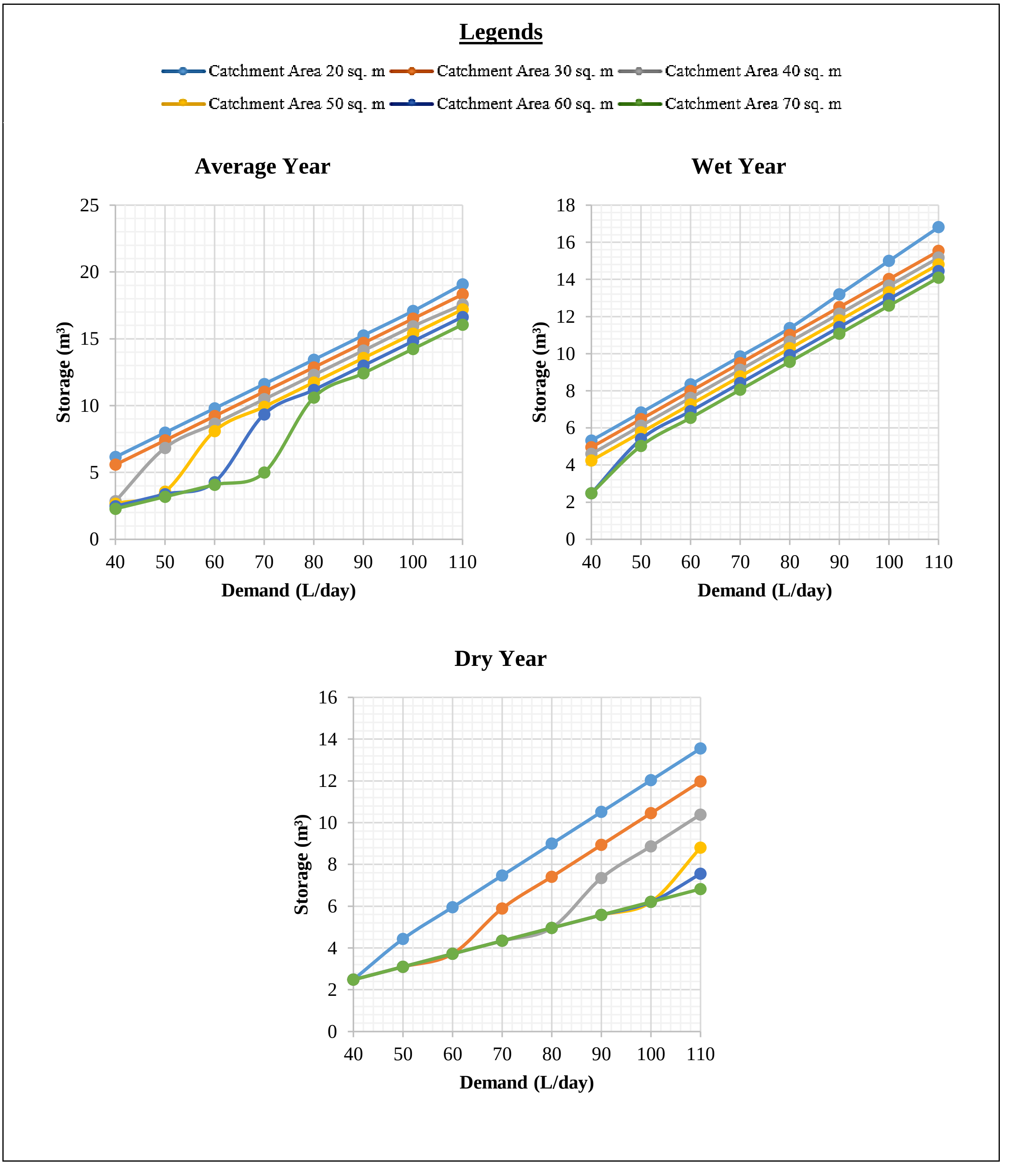
Catchment Area 60 m²



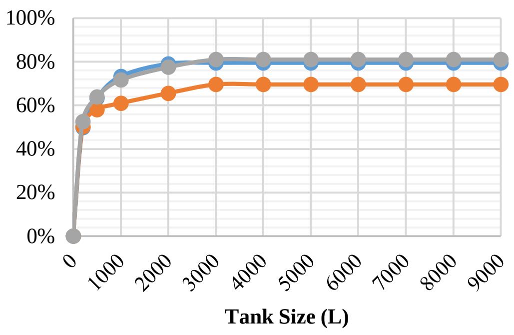
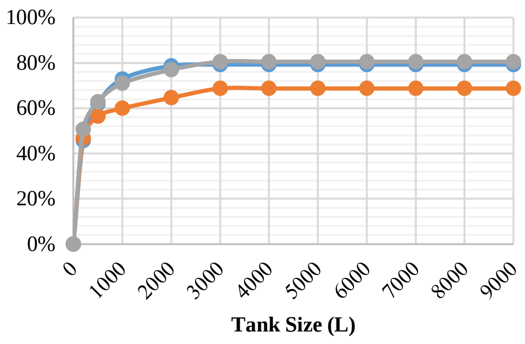
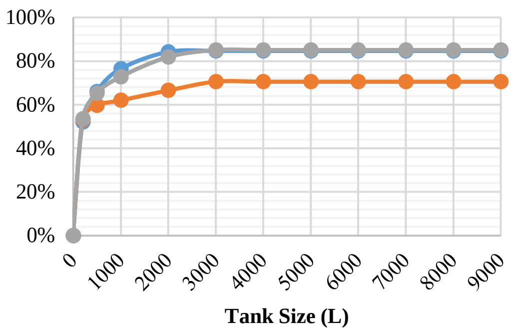
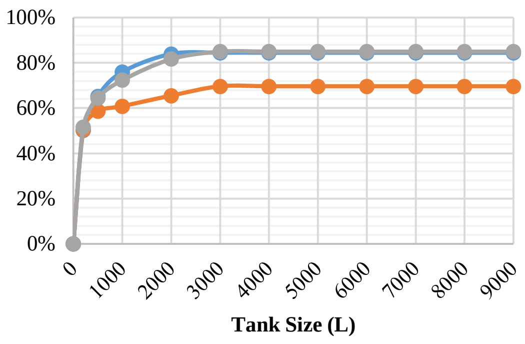
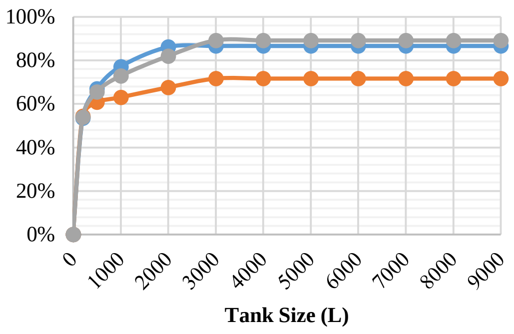
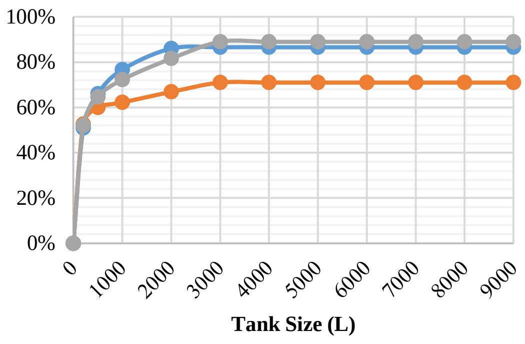
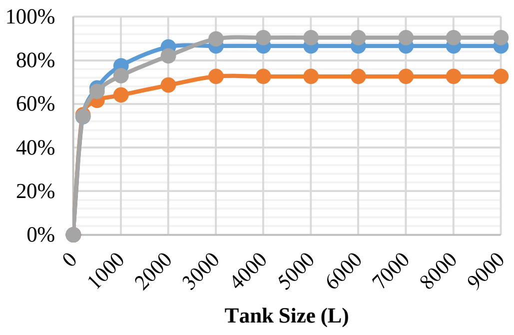
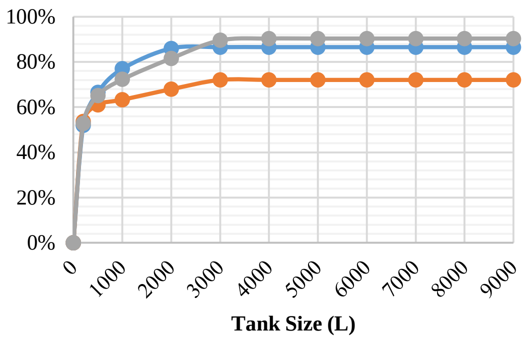
Catchment Area 70 m²

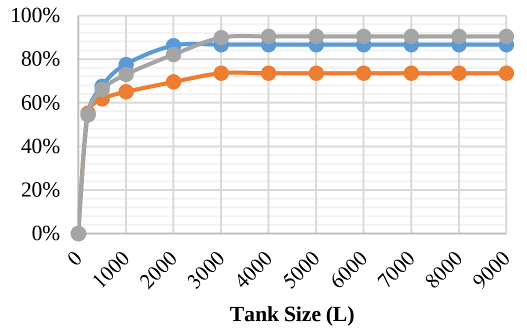
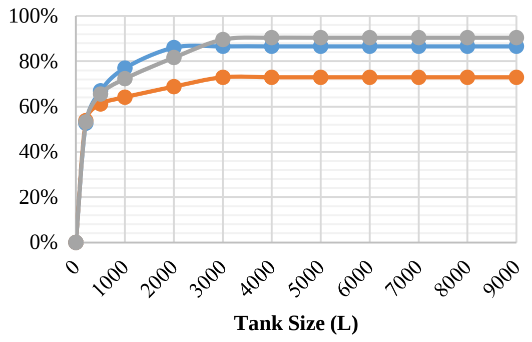
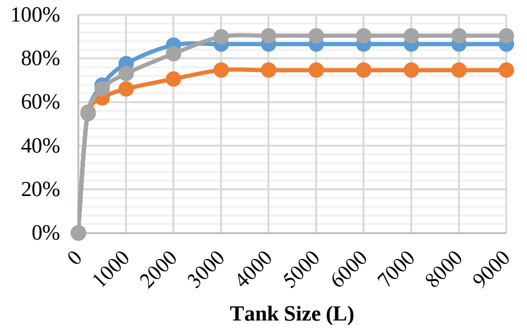
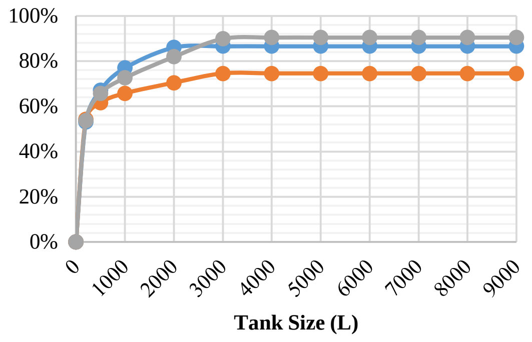
7.1.10 Sandwip

7.1.10.1 Optimum volume design curves



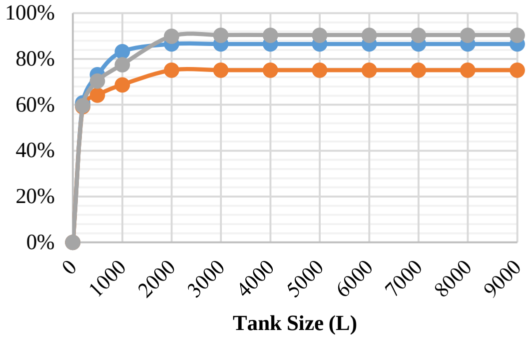
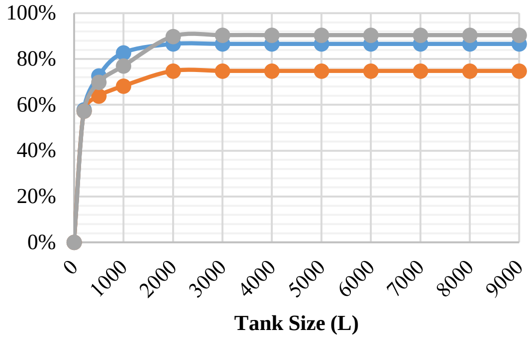
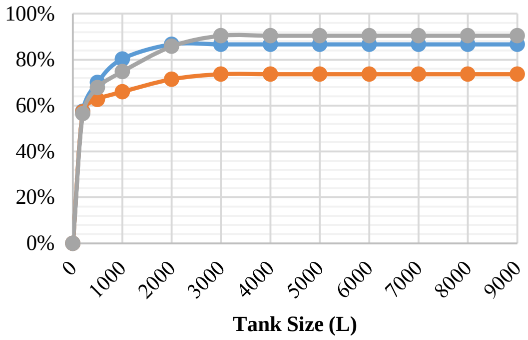
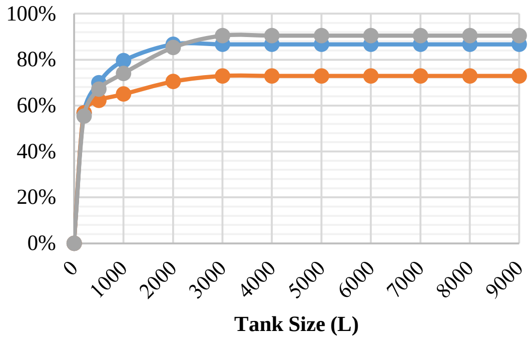
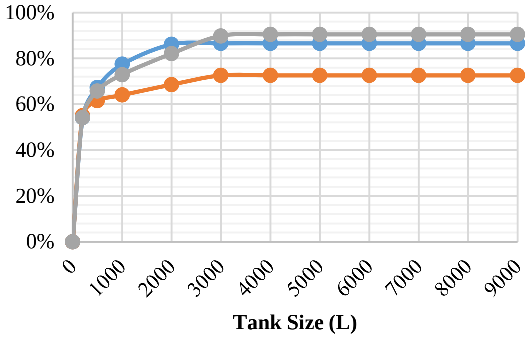
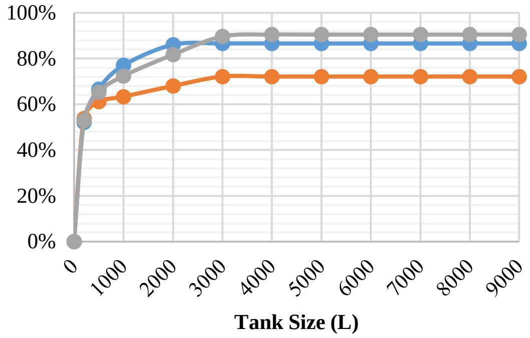
7.1.10.2 Volumetric and time reliability curves

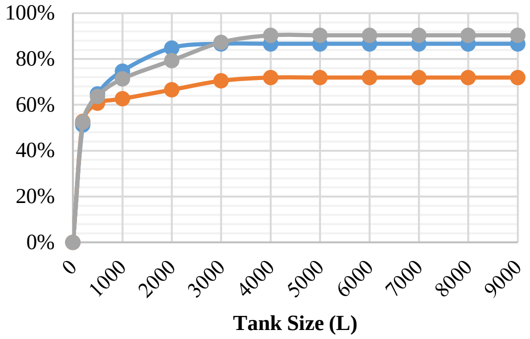
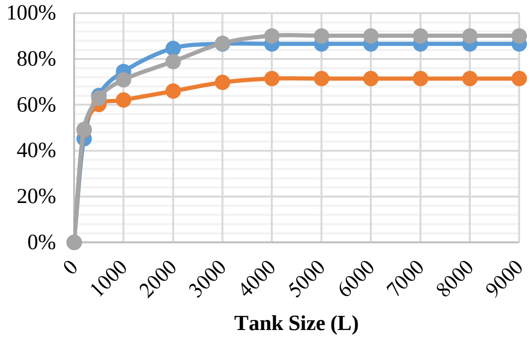
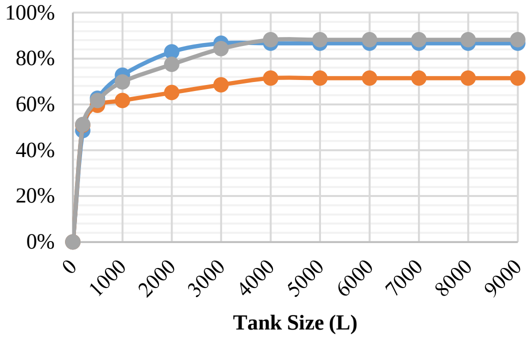
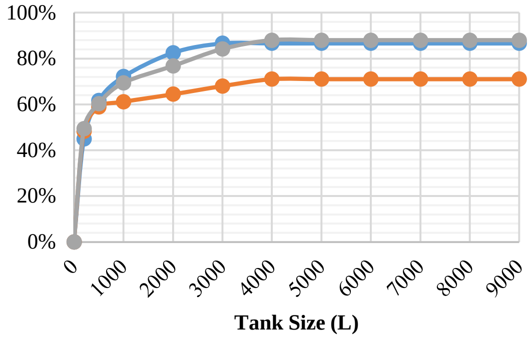
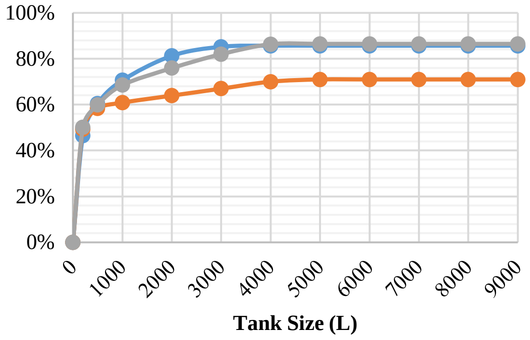
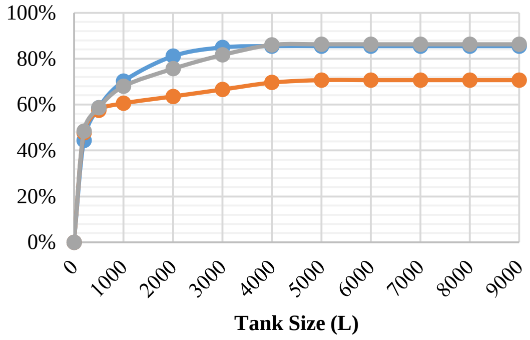
Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

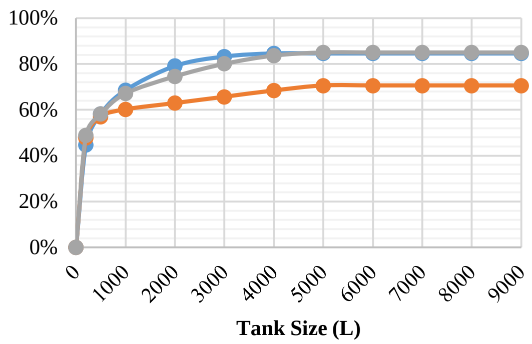
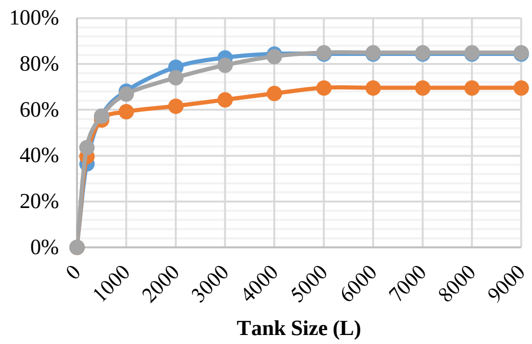
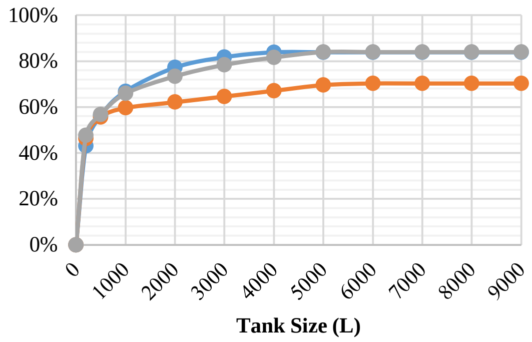
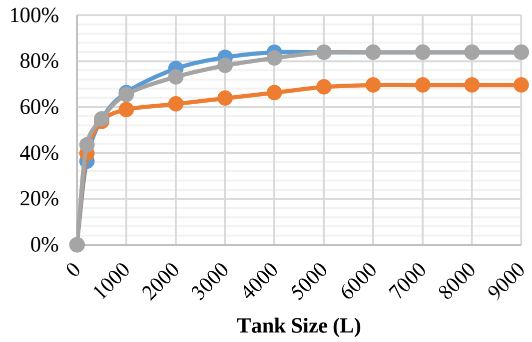
Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

Fixed Catchment Area (50 m^2)

Dry Year — Wet Year — Average Year

Family Size	Volumetric Reliability	Time Reliability
4		
5		
6		

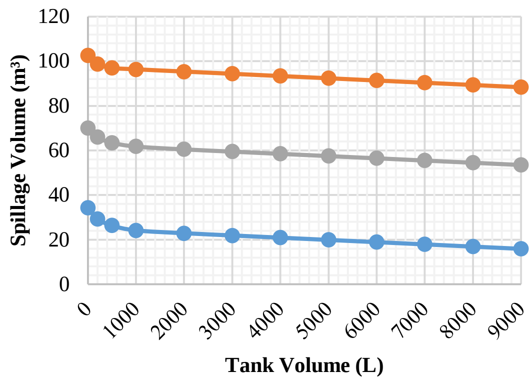
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year — Wet Year — Average Year</td></tr>
<tr><td>Famil
y Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

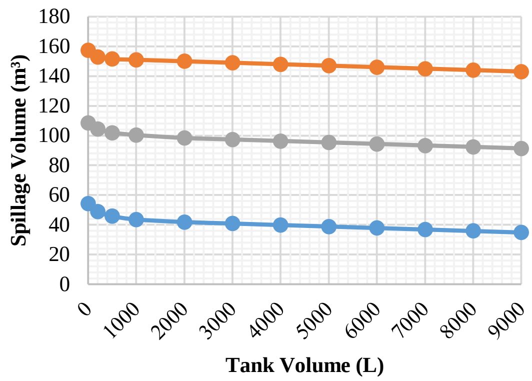
7.1.10.3 Spilled water volume

Family size (6)

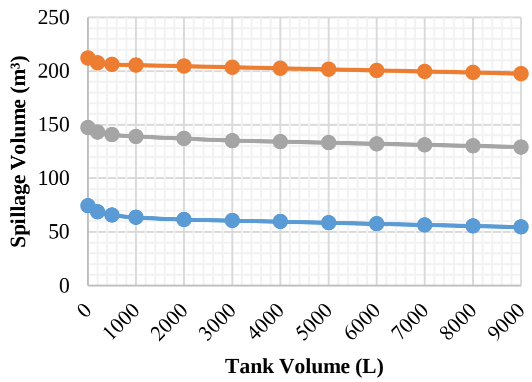
Dry Year   Wet Year   Average Year



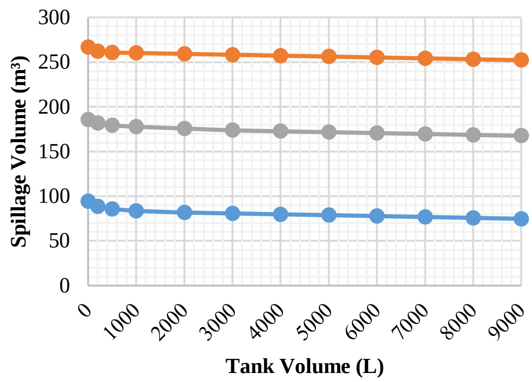
Catchment Area 20 m²



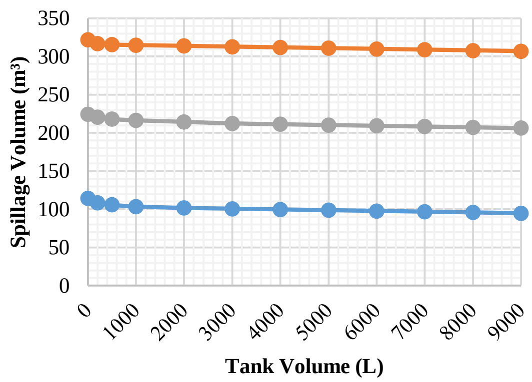
Catchment Area 30 m²



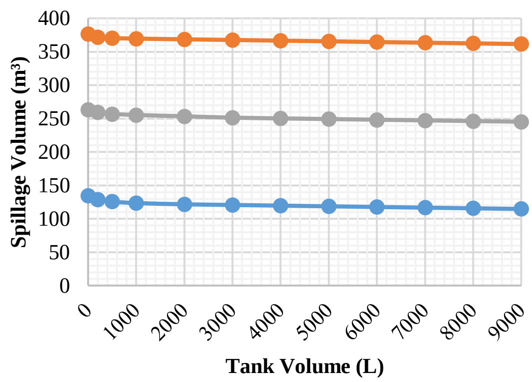
Catchment Area 40 m²



Catchment Area 50 m²



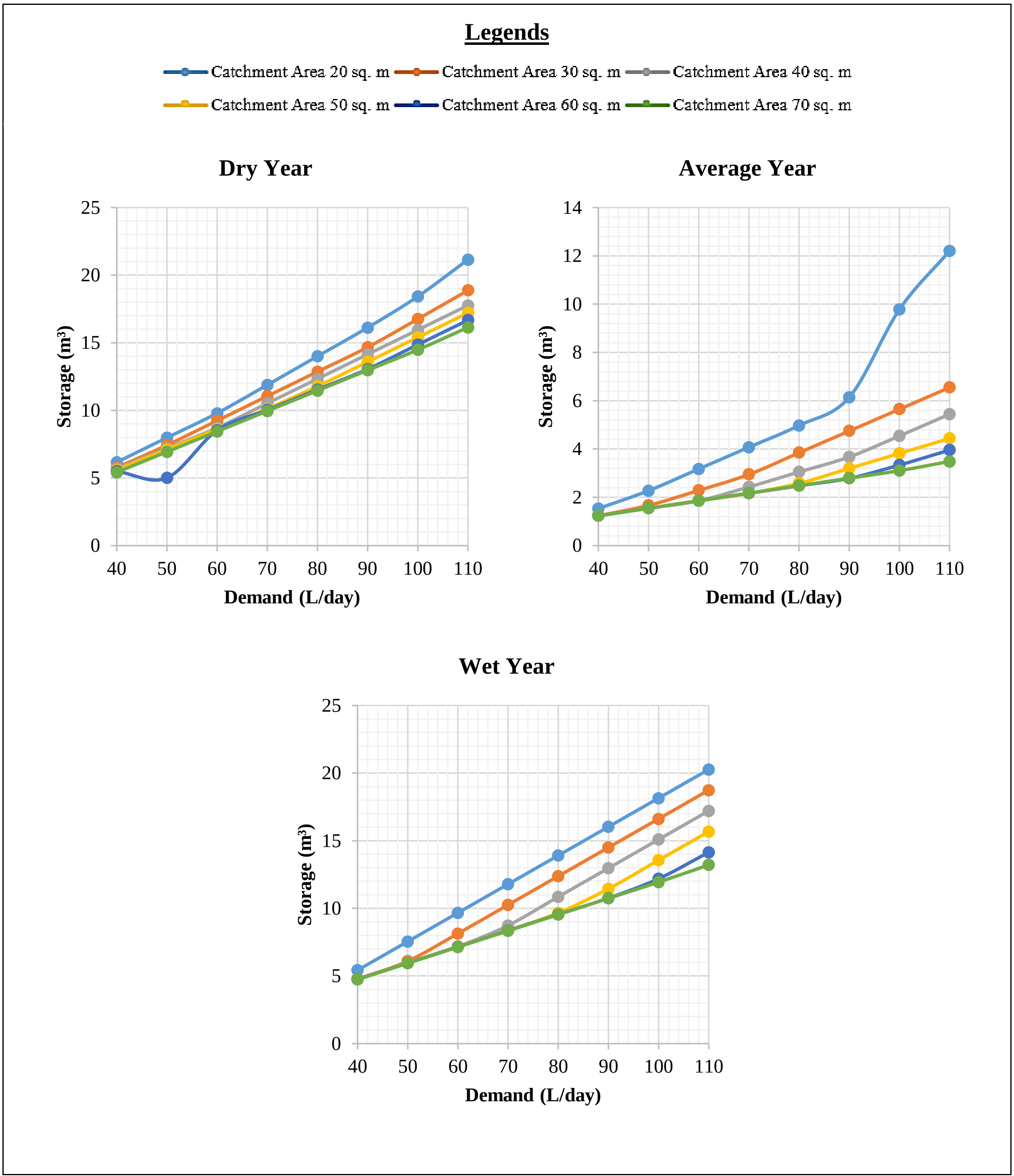
Catchment Area 60 m²



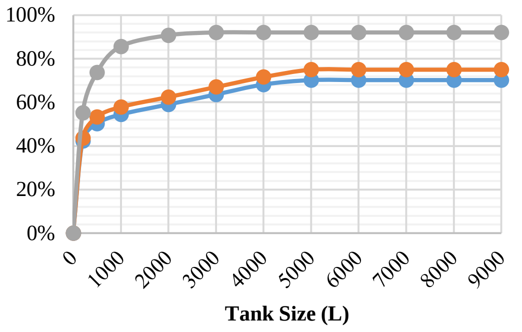
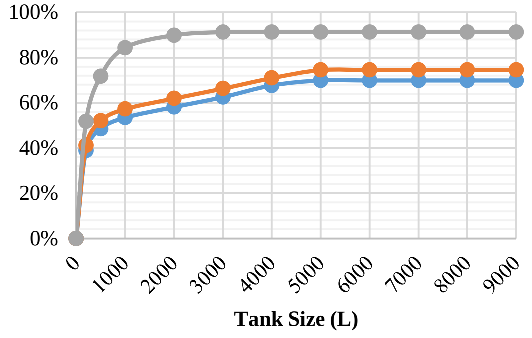
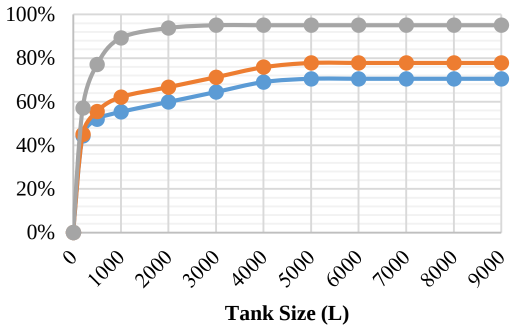
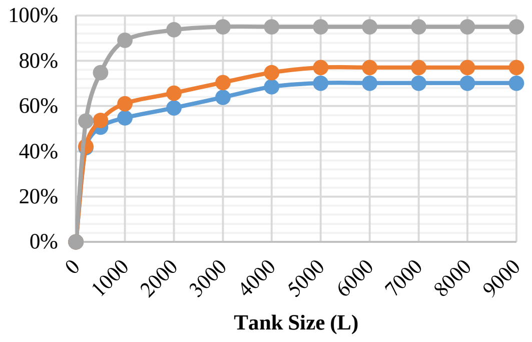
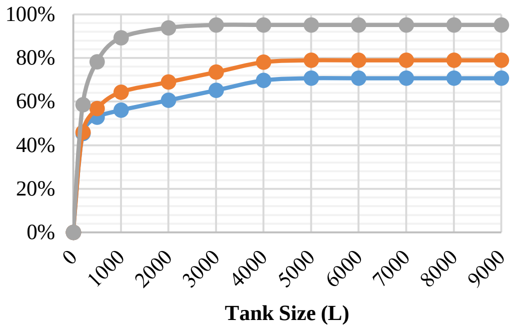
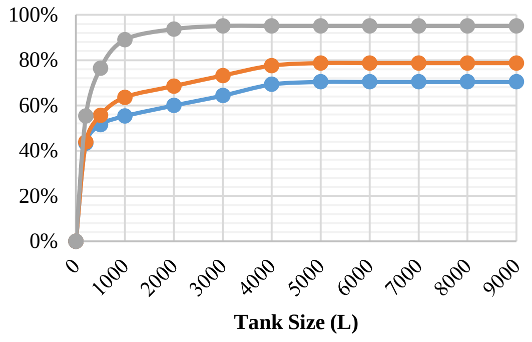
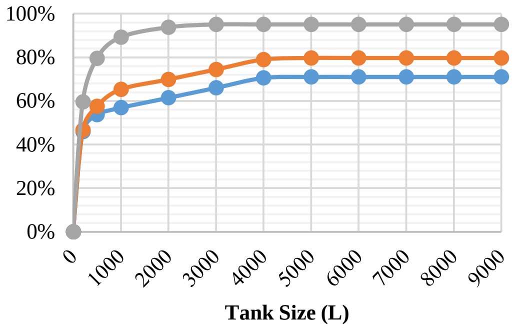
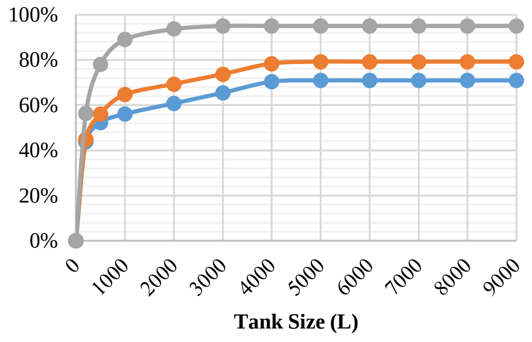
Catchment Area 70 m²

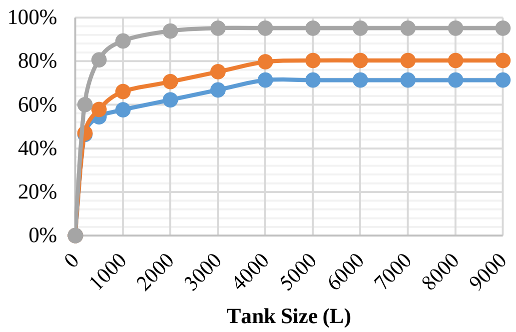
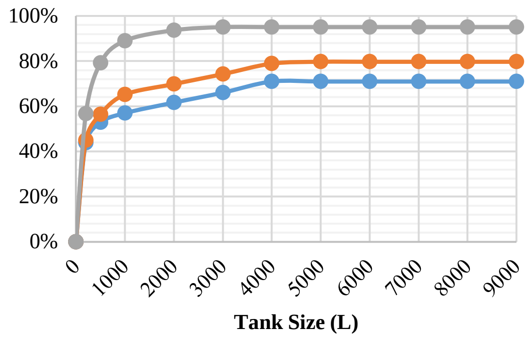
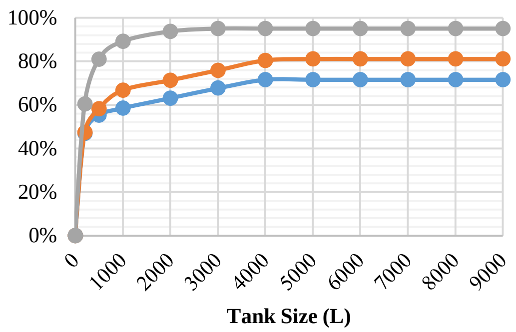
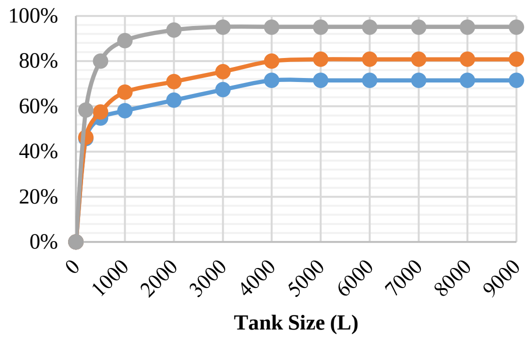
7.1.11 Satikhira

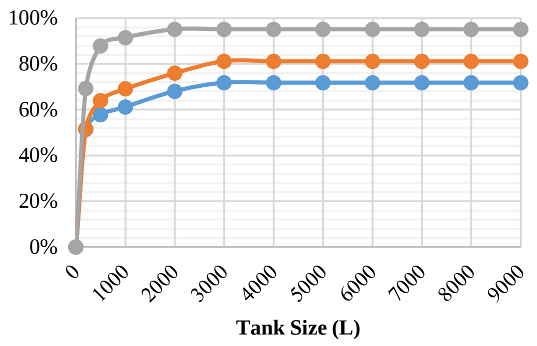
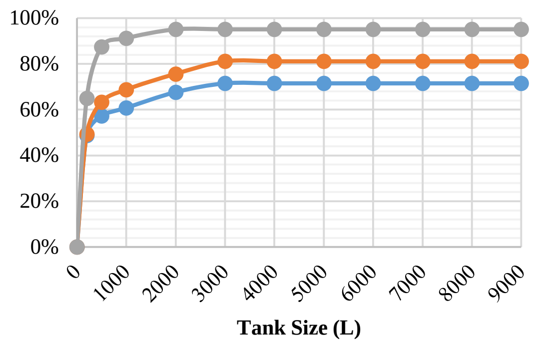
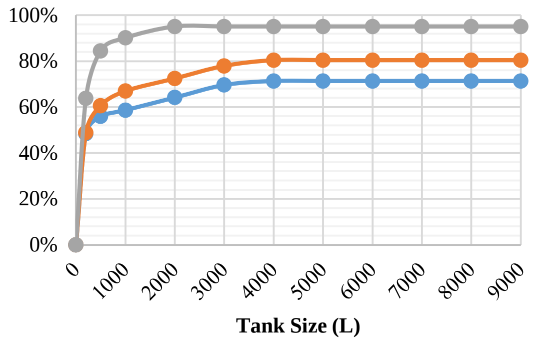
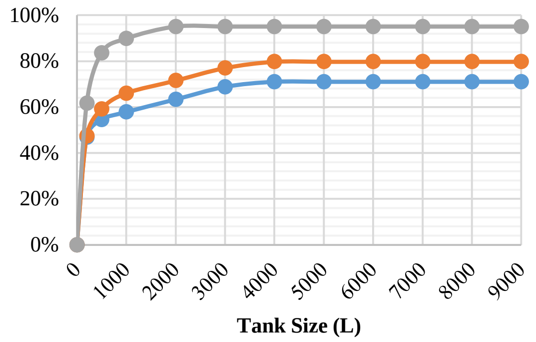
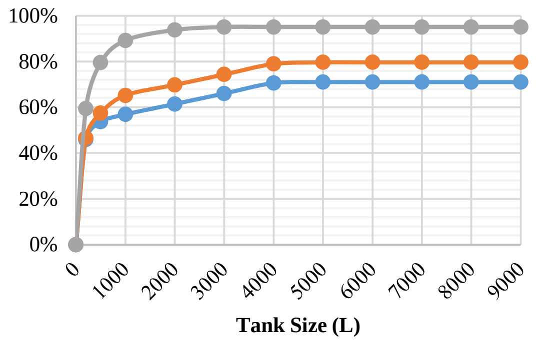
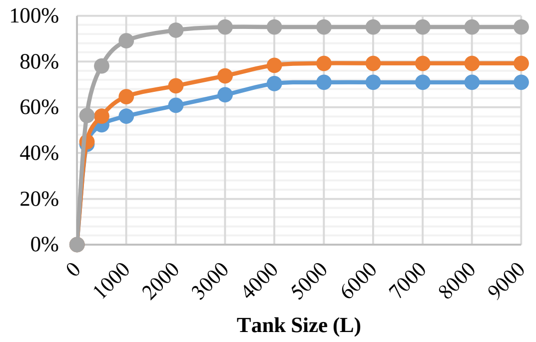
7.1.11.1 Optimum volume design curves



7.1.11.2 Volumetric and time reliability curves

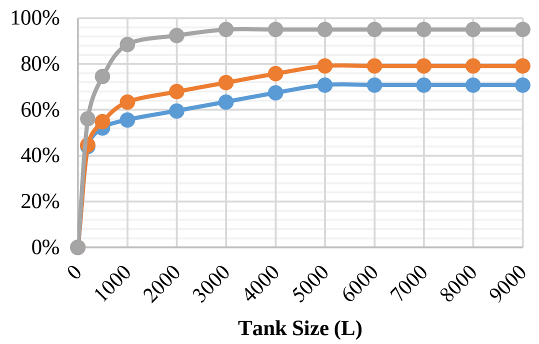
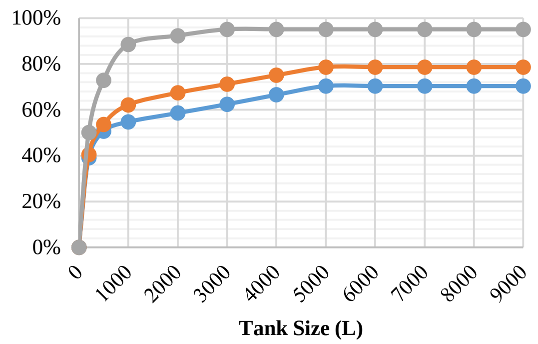
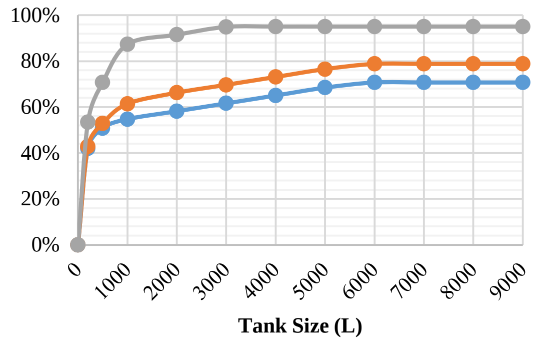
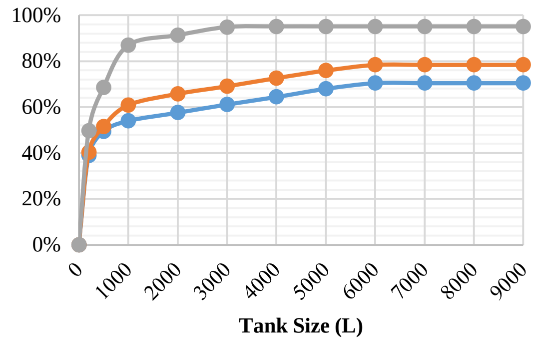
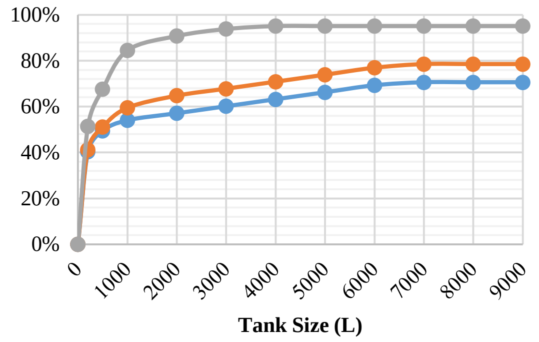
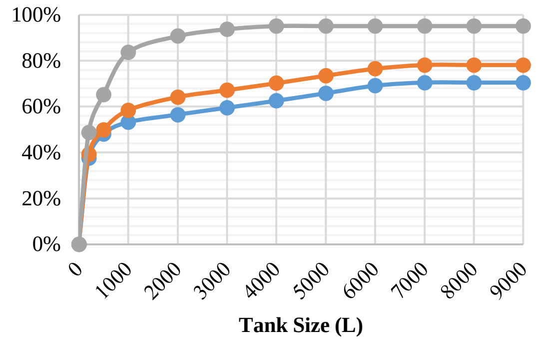
Fixed Family Size (6)		
Dry Year / Wet Year / Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

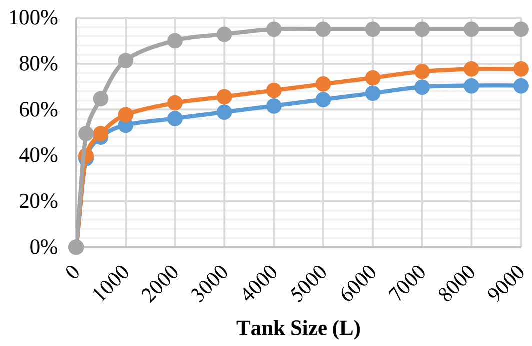
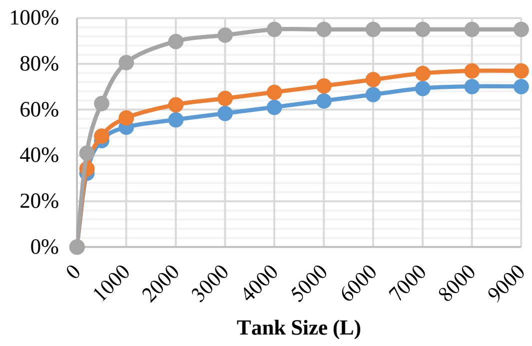
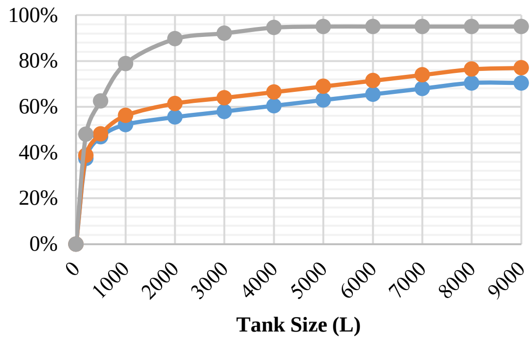
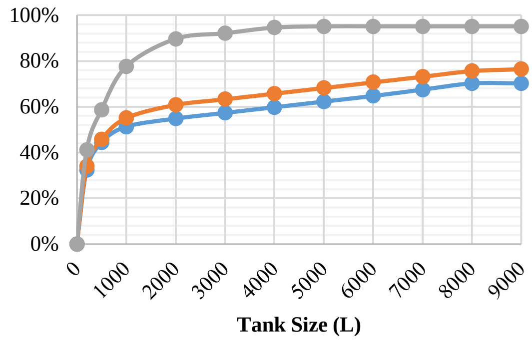
<table>
<tr><th colspan="3">Fixed Family Size (6)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Catchment Area (m^2)</td><td>Volumetric Reliability (%)</td><td>Time Reliability (%)</td></tr>
<tr><td>60</td><td>
</td><td>
</td></tr>
<tr><td>70</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

Fixed Catchment Area (50 m^2)

Dry Year — Wet Year — Average Year

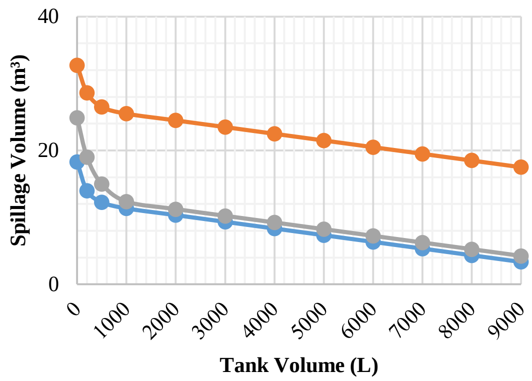
Famil y Size	Volumetric Reliability	Time Reliability
7		
8		
9		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

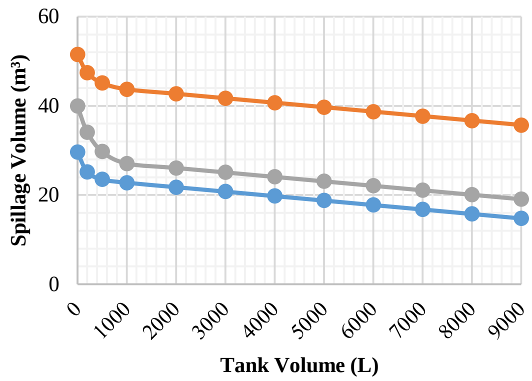
7.1.11.3 Spilled water volume

Family size (6)

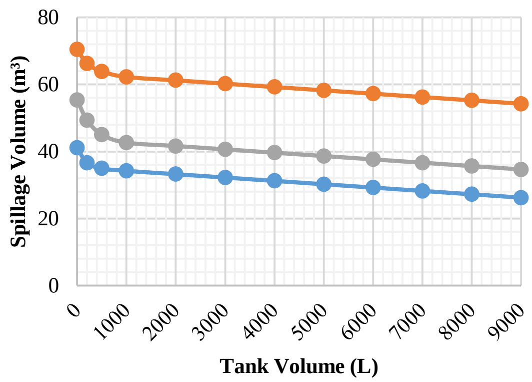
Dry Year — Wet Year — Average Year



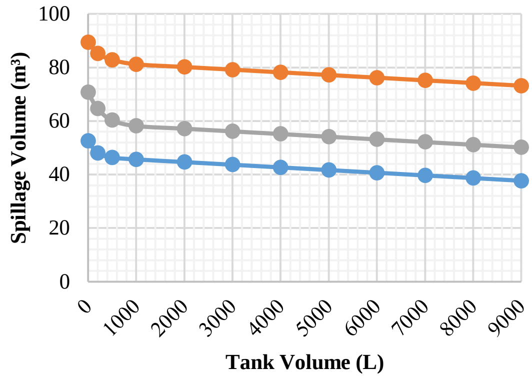
Catchment Area 20 m²



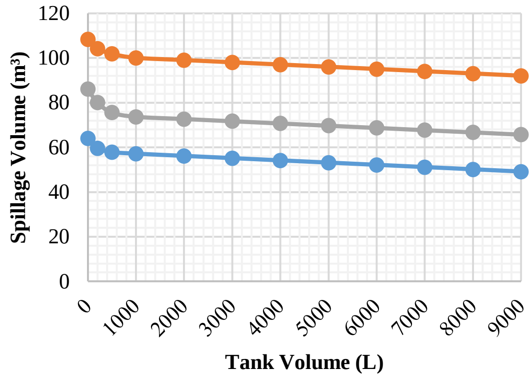
Catchment Area 30 m²



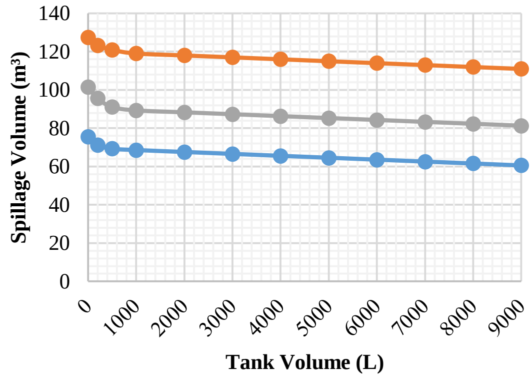
Catchment Area 40 m²



Catchment Area 50 m²



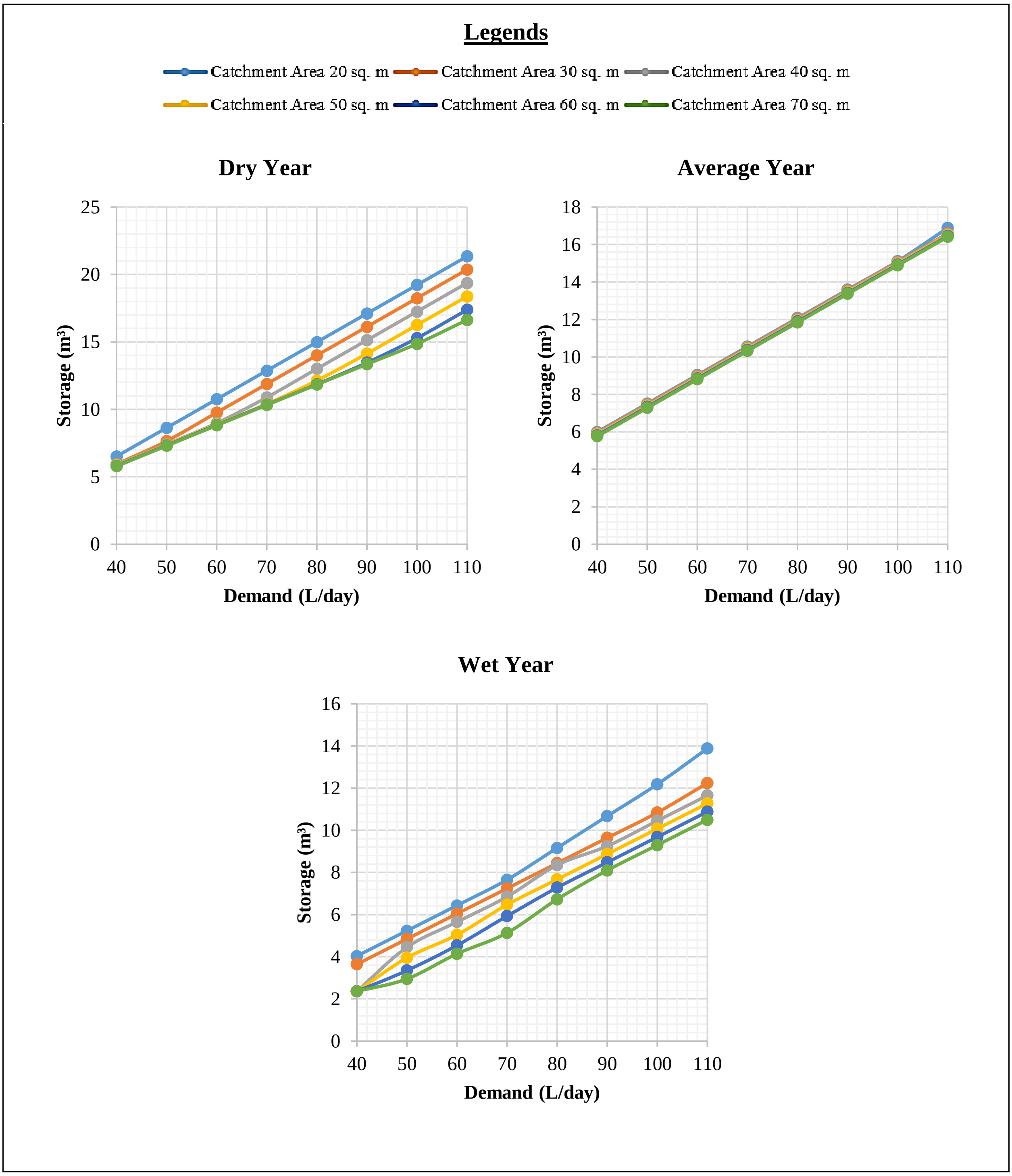
Catchment Area 60 m²



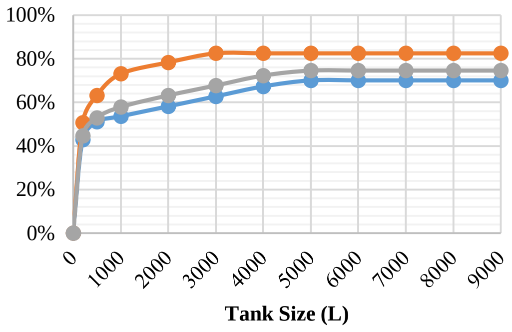
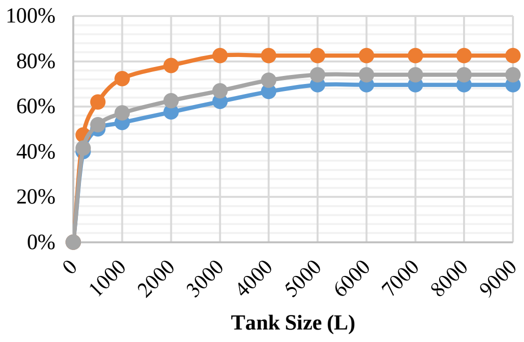
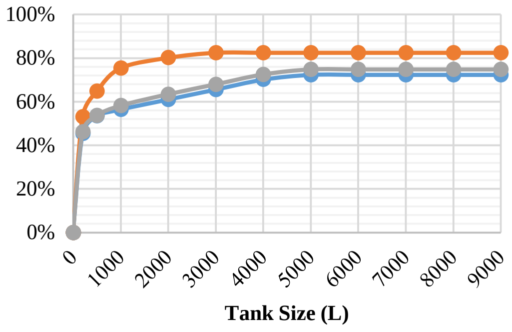
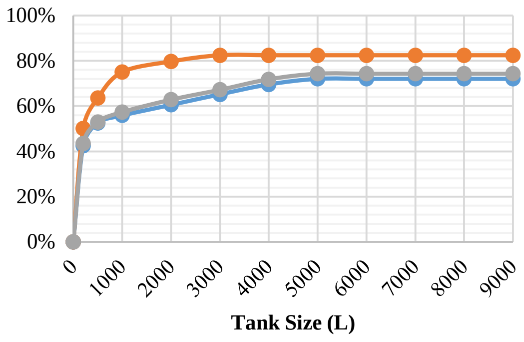
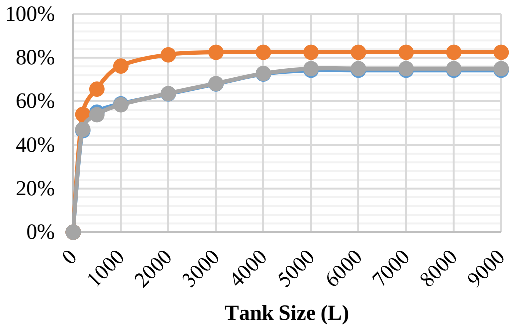
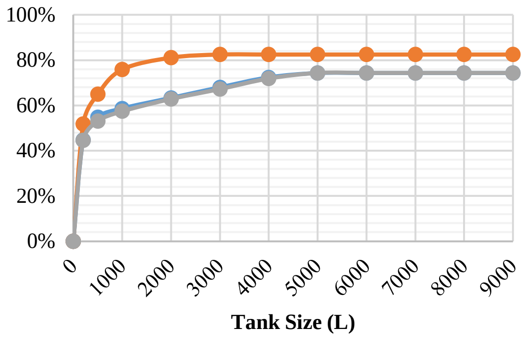
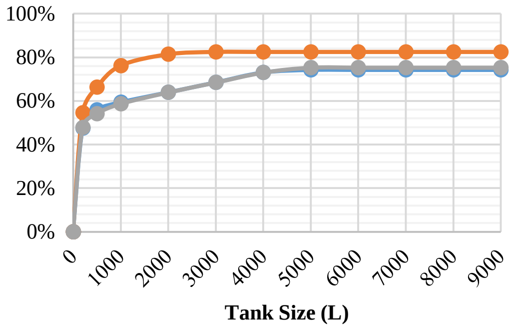
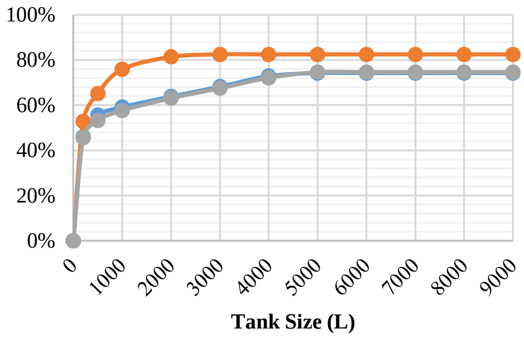
Catchment Area 70 m²

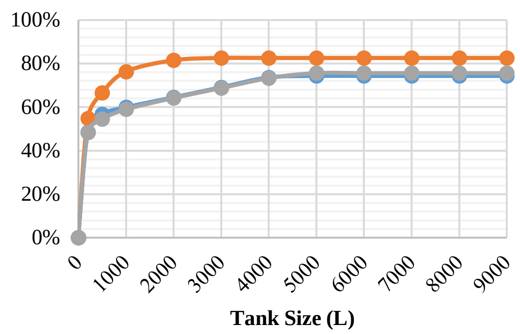
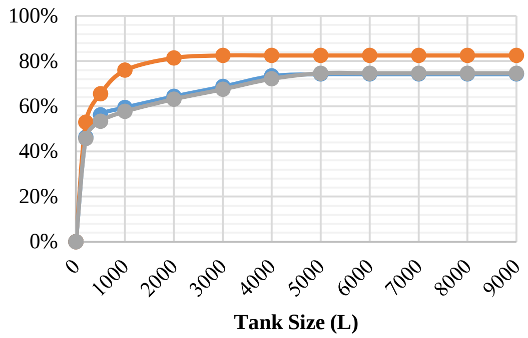
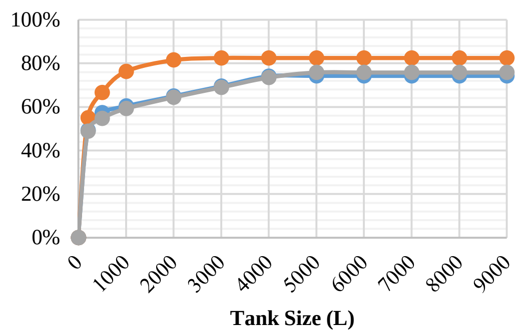
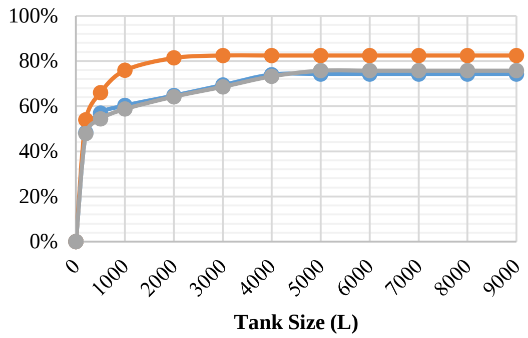
7.1.12 Shitakunda

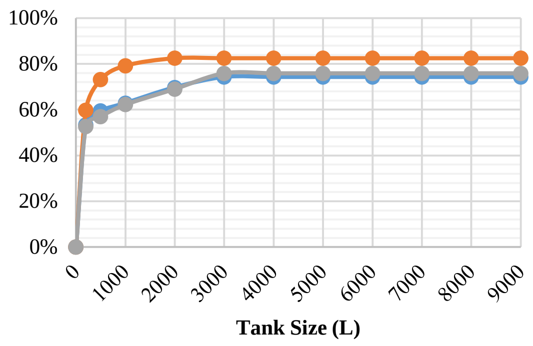
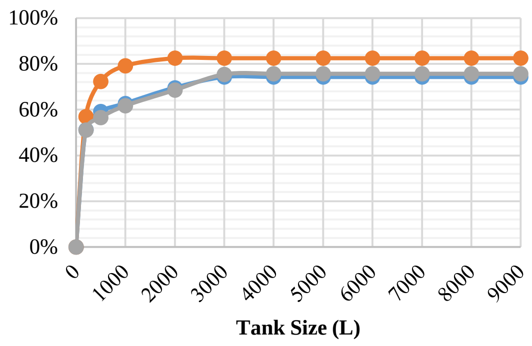
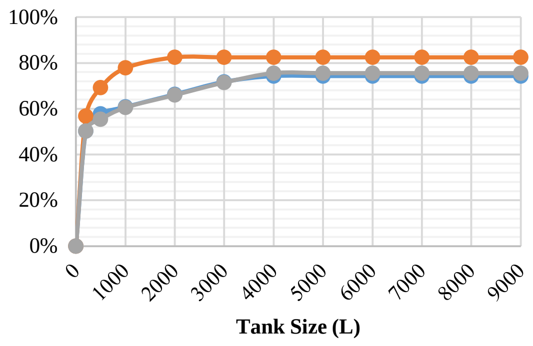
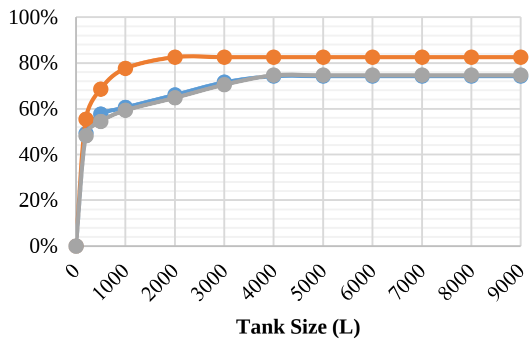
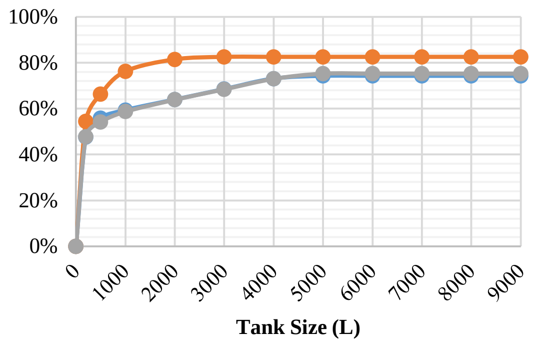
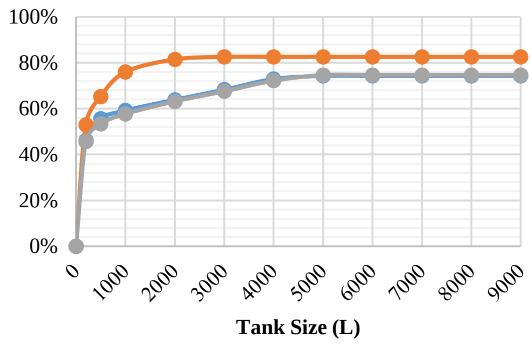
7.1.12.1 Optimum volume design curves

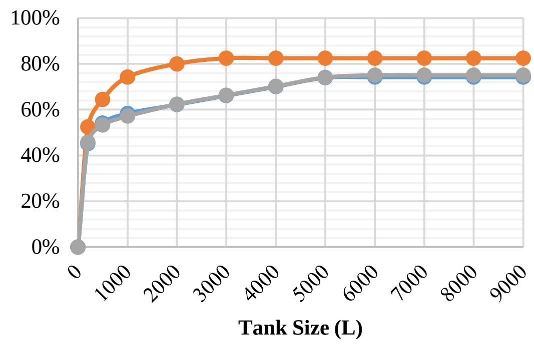
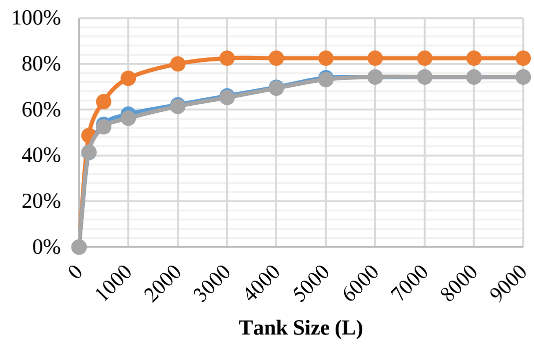
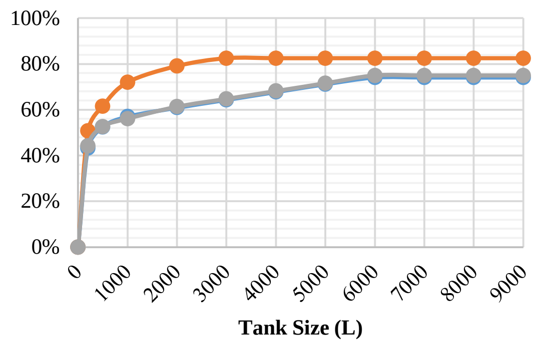
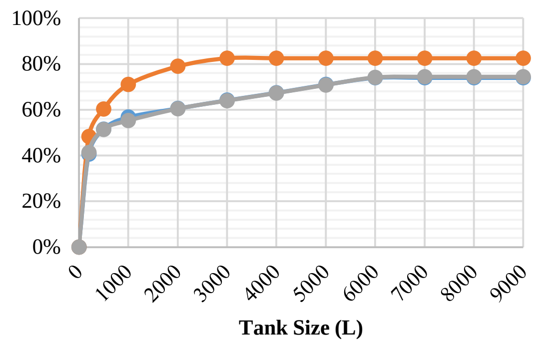
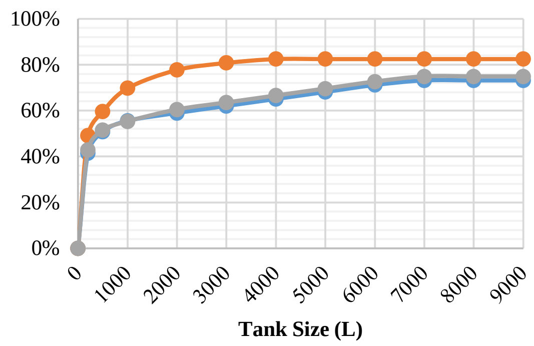
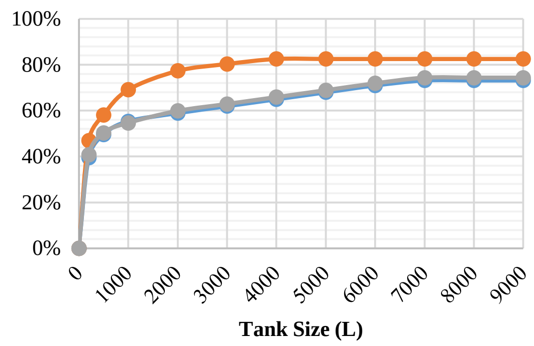


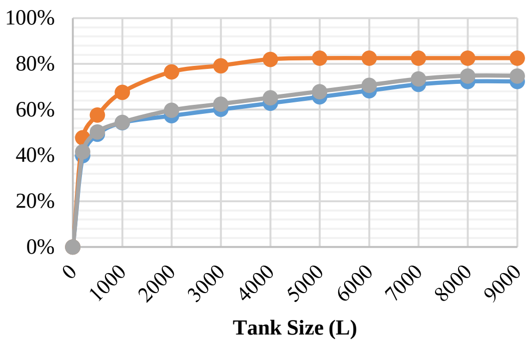
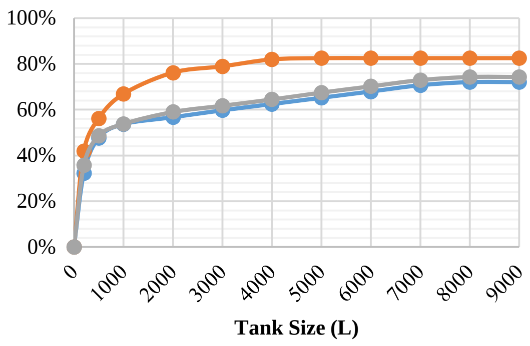
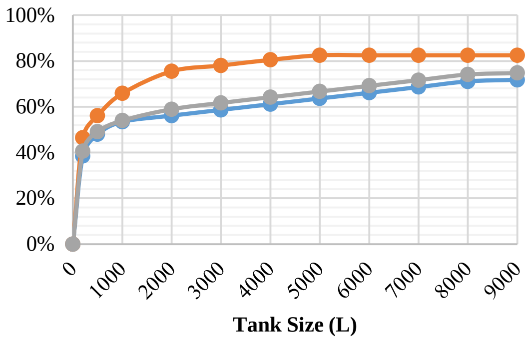
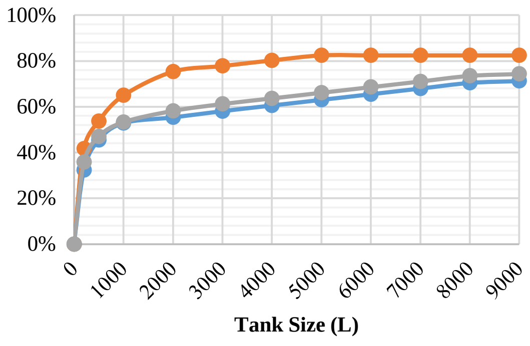
7.1.12.2 Volumetric and time reliability curves

Fixed Family Size (6)		
Dry Year / Wet Year / Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

Fixed Family Size (6)		
Dry Year / Wet Year / Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m^2)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>4</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td>
</td><td>
</td></tr>
</table>

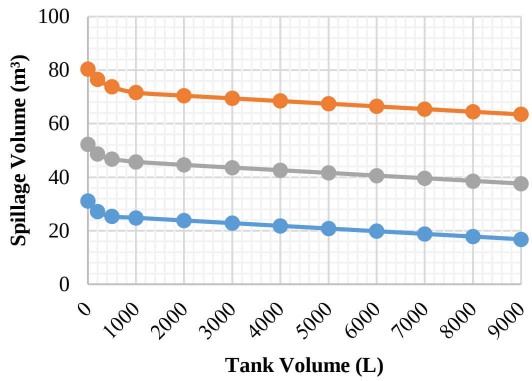
<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Family Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
<tr><td>8</td><td>
</td><td>
</td></tr>
<tr><td>9</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Famil
y Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

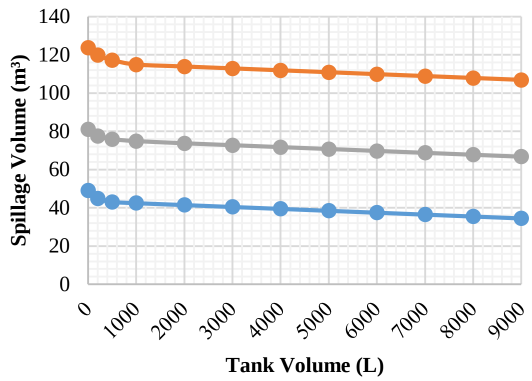
7.1.12.3 Spilled water volume

Family size (6)

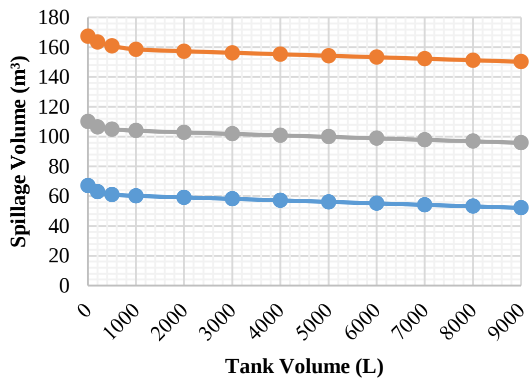
Dry Year — Wet Year — Average Year



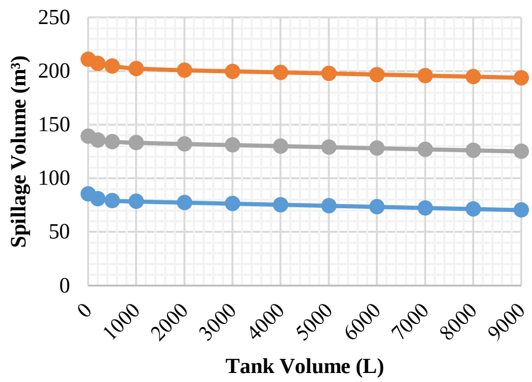
Catchment Area 20 m^2



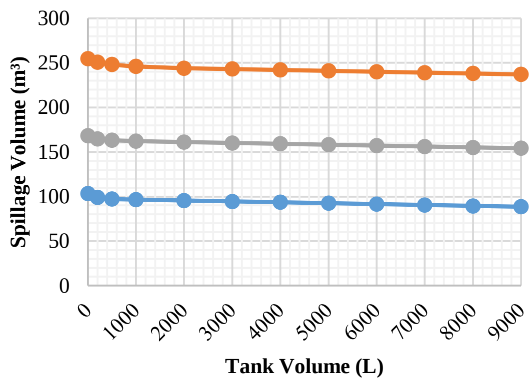
Catchment Area 30 m^2



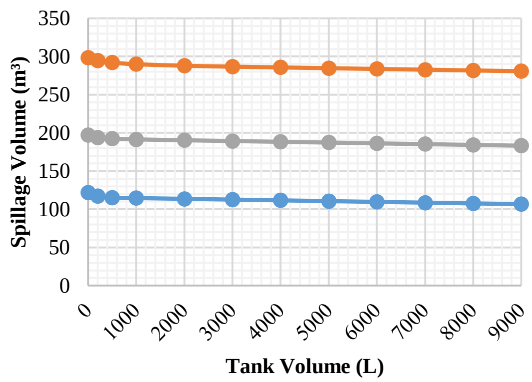
Catchment Area 40 m^2



Catchment Area 50 m^2



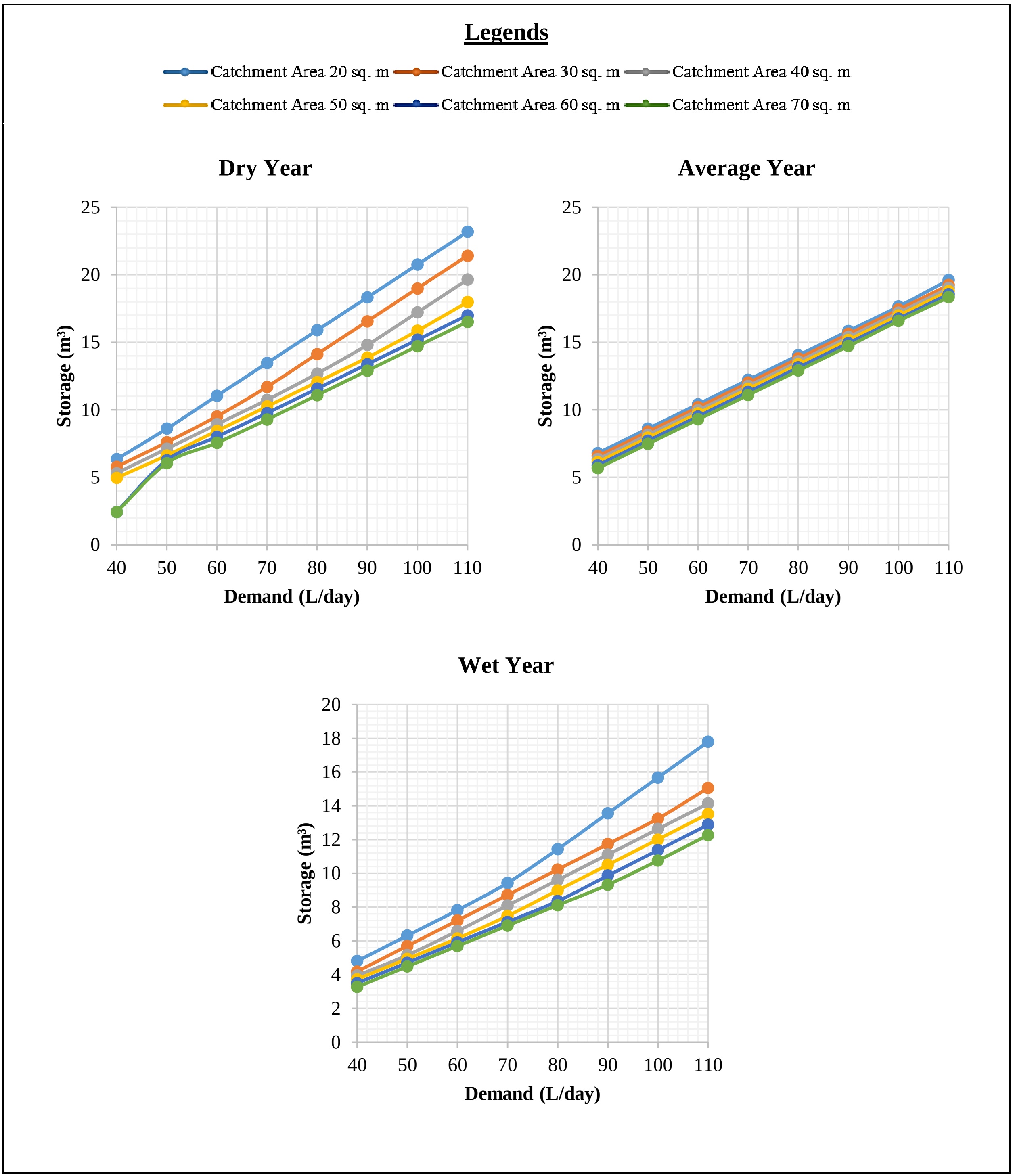
Catchment Area 60 m^2



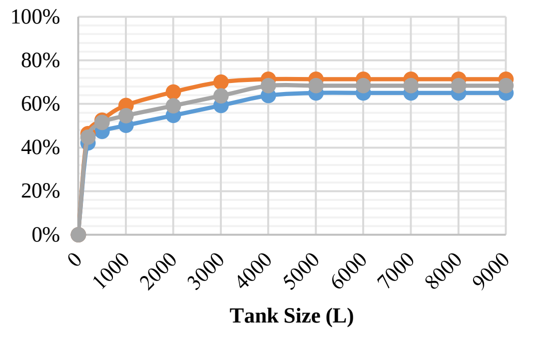
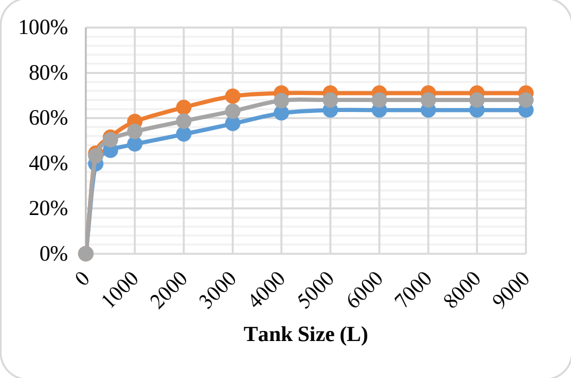
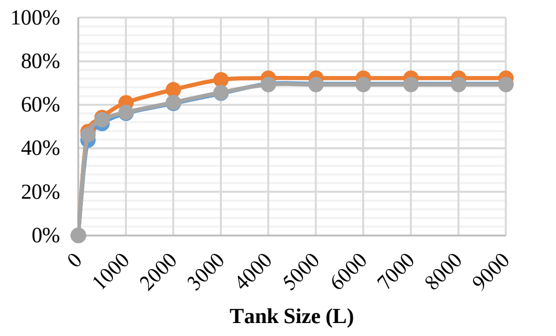
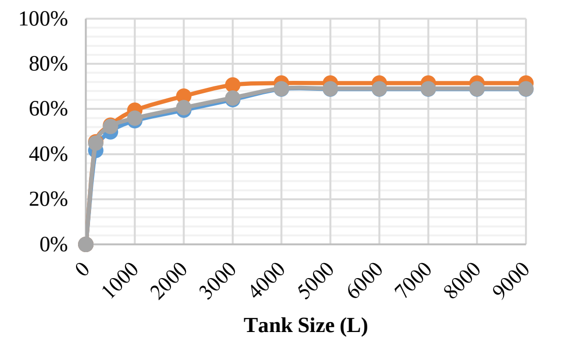
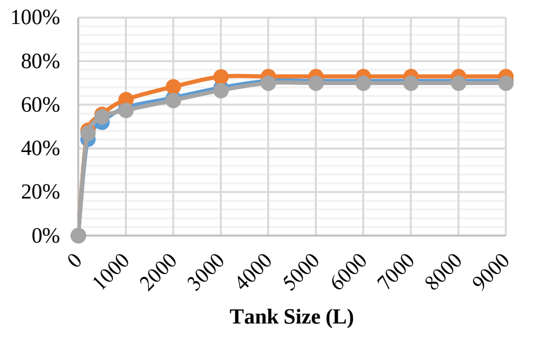
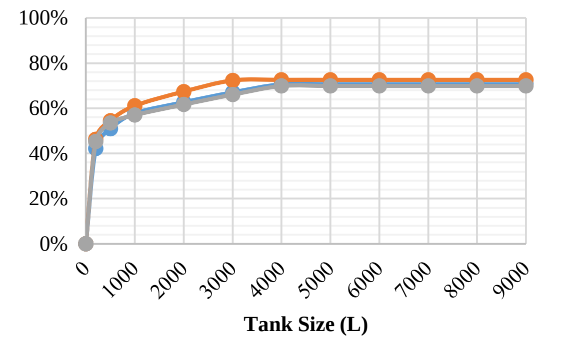
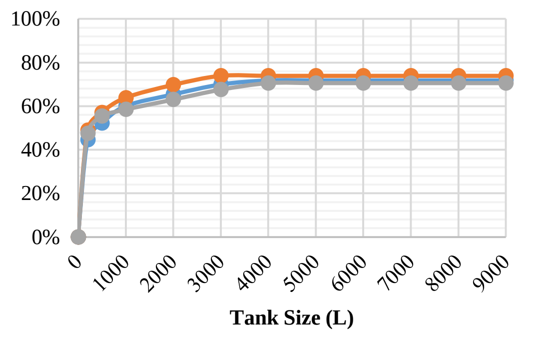
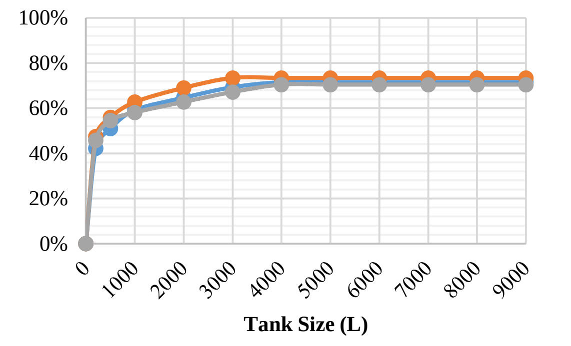
Catchment Area 70 m^2

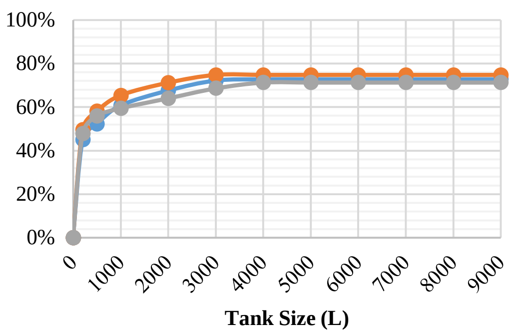
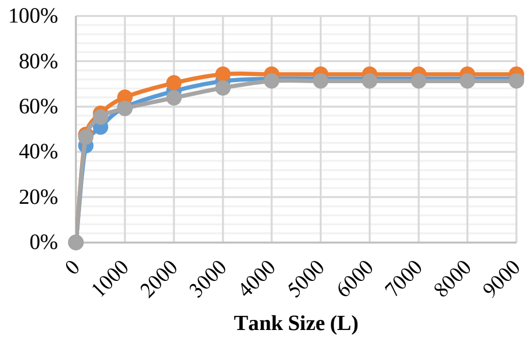
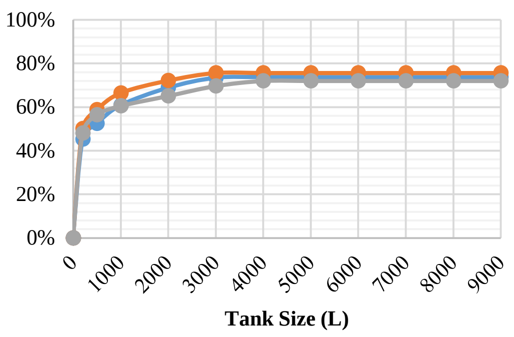
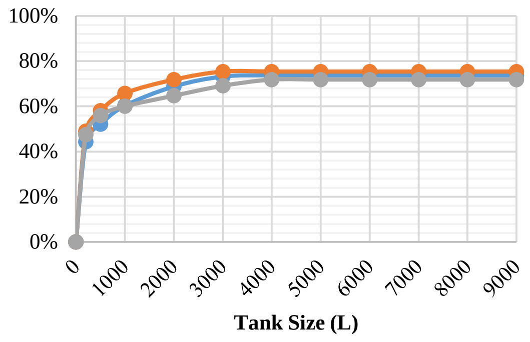
7.1.13 Teknaf

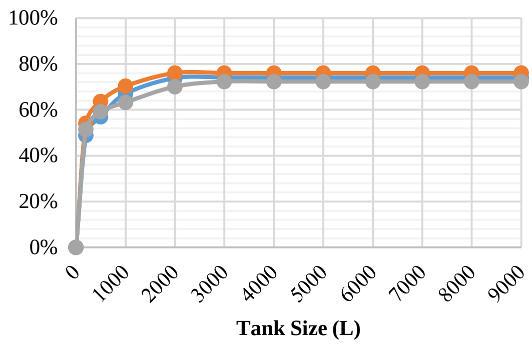
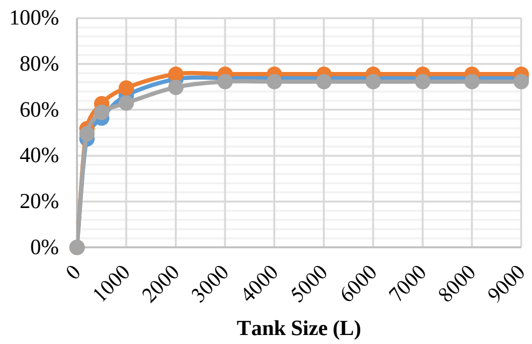
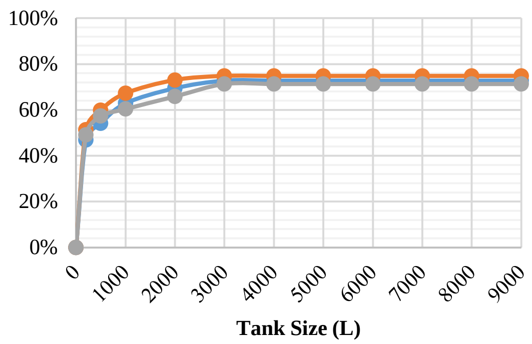
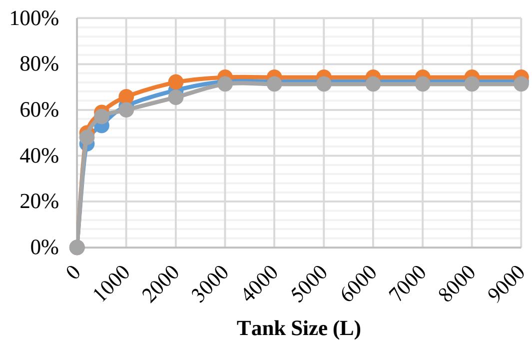
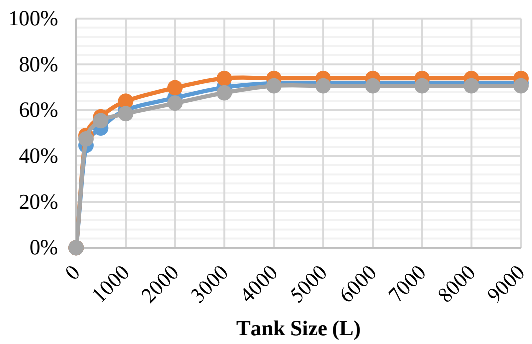
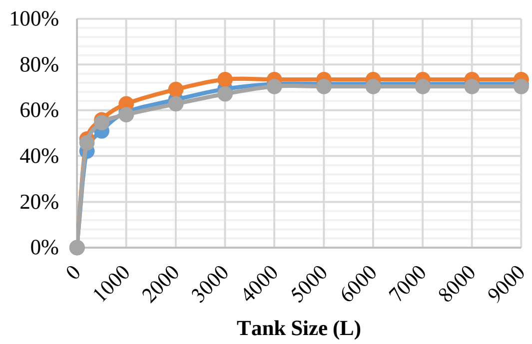
7.1.13.1 Optimum volume design curves

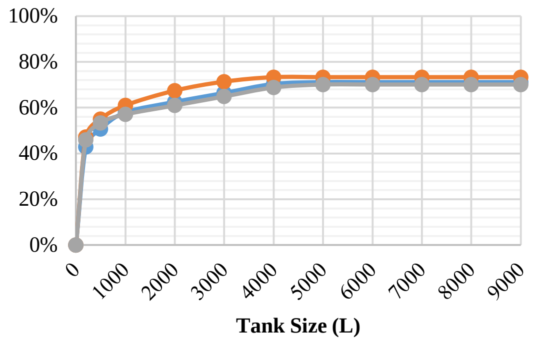
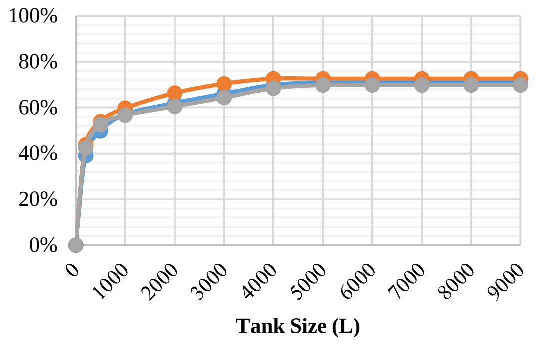
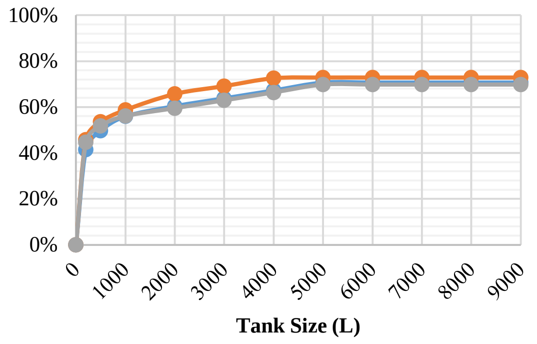
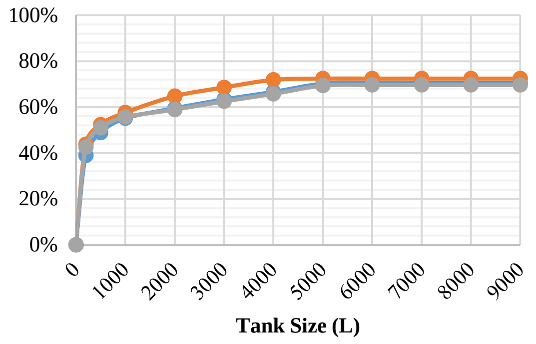
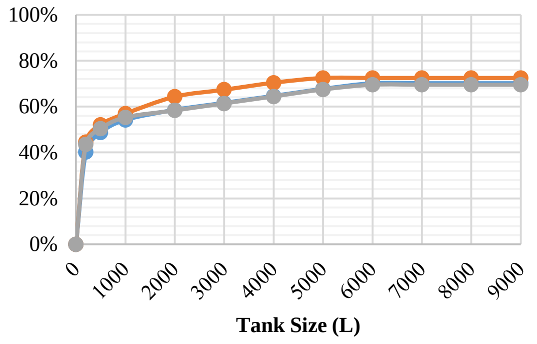
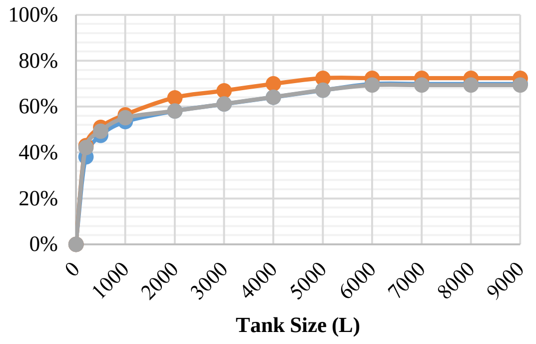


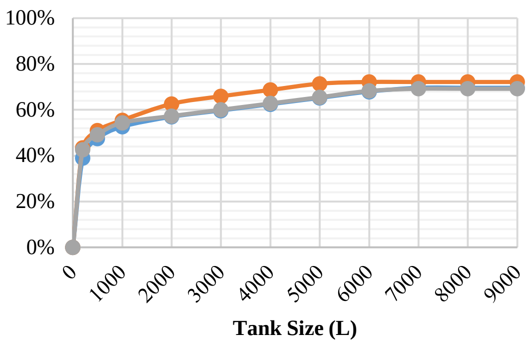
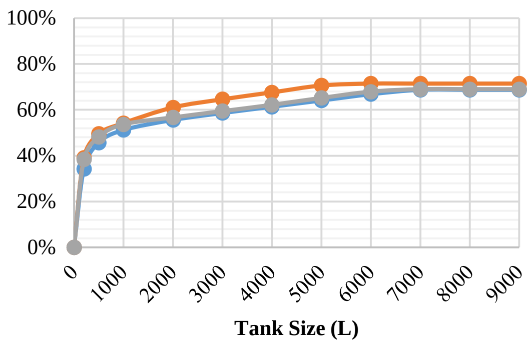
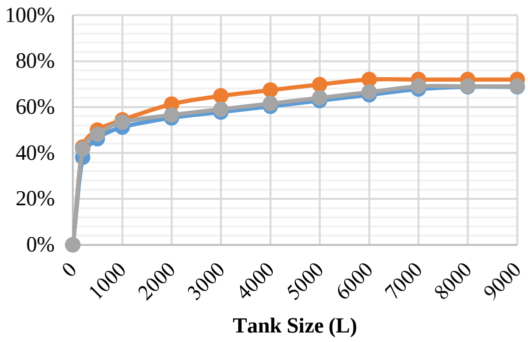
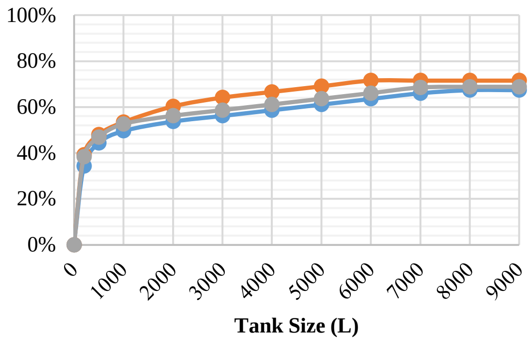
7.1.13.2 Volumetric and time reliability curves

Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
20		
30		
40		
50		

Fixed Family Size (6)		
Dry Year — Wet Year — Average Year		
Catchment Area (m^2)	Volumetric Reliability (%)	Time Reliability (%)
60		
70		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><th>Family Size</th><th>Volumetric Reliability</th><th>Time Reliability</th></tr>
<tr><td>4</td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td></tr>
</table>

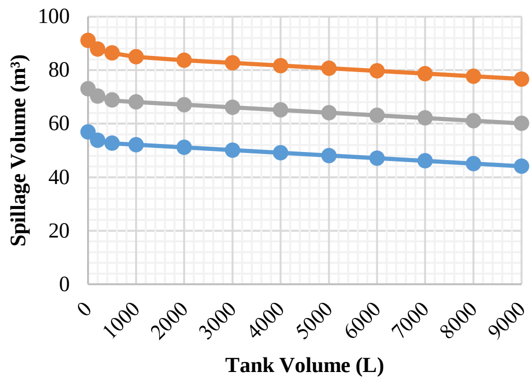
Fixed Catchment Area (50 m^2)		
Dry Year — Wet Year — Average Year		
Family Size	Volumetric Reliability	Time Reliability
7		
8		
9		

<table>
<tr><th colspan="3">Fixed Catchment Area (50 m²)</th></tr>
<tr><td colspan="3">Dry Year   Wet Year   Average Year</td></tr>
<tr><td>Famil
y Size</td><td>Volumetric Reliability</td><td>Time Reliability</td></tr>
<tr><td>10</td><td>
</td><td>
</td></tr>
<tr><td>11</td><td>
</td><td>
</td></tr>
</table>

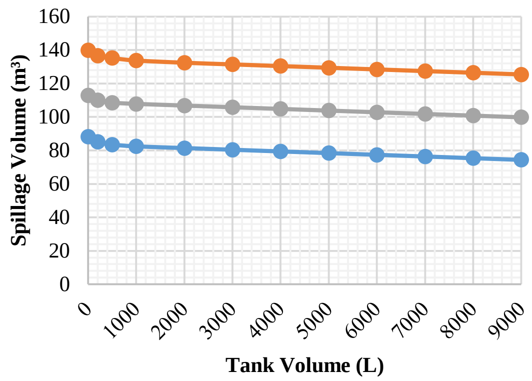
7.1.13.3 Spilled water volume

Family size (6)

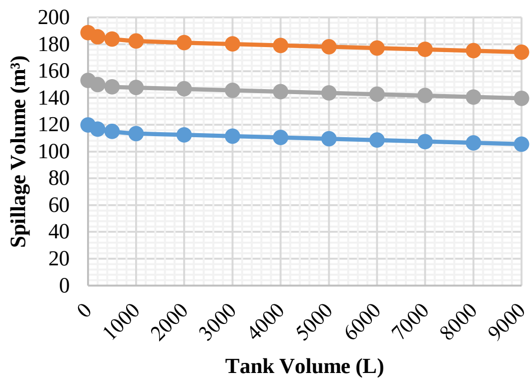
Dry Year   Wet Year   Average Year



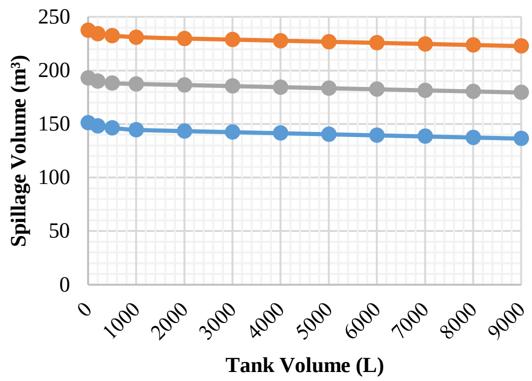
Catchment Area 20 m²



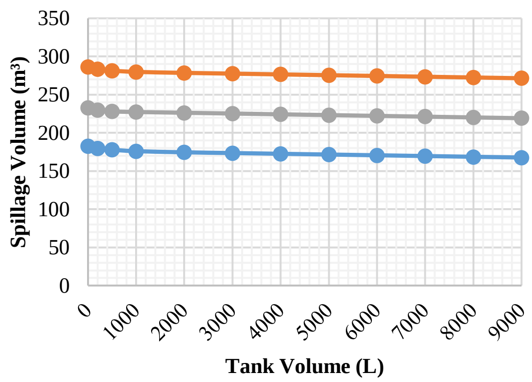
Catchment Area 30 m²



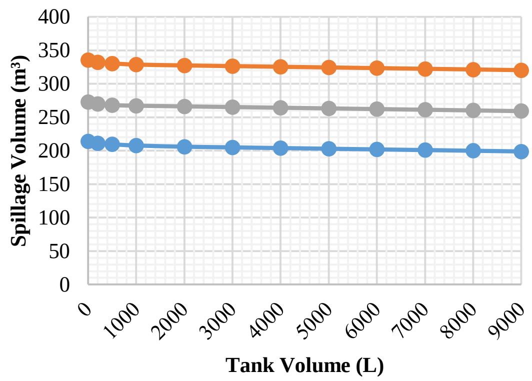
Catchment Area 40 m²



Catchment Area 50 m²



Catchment Area 60 m²



Catchment Area 70 m²