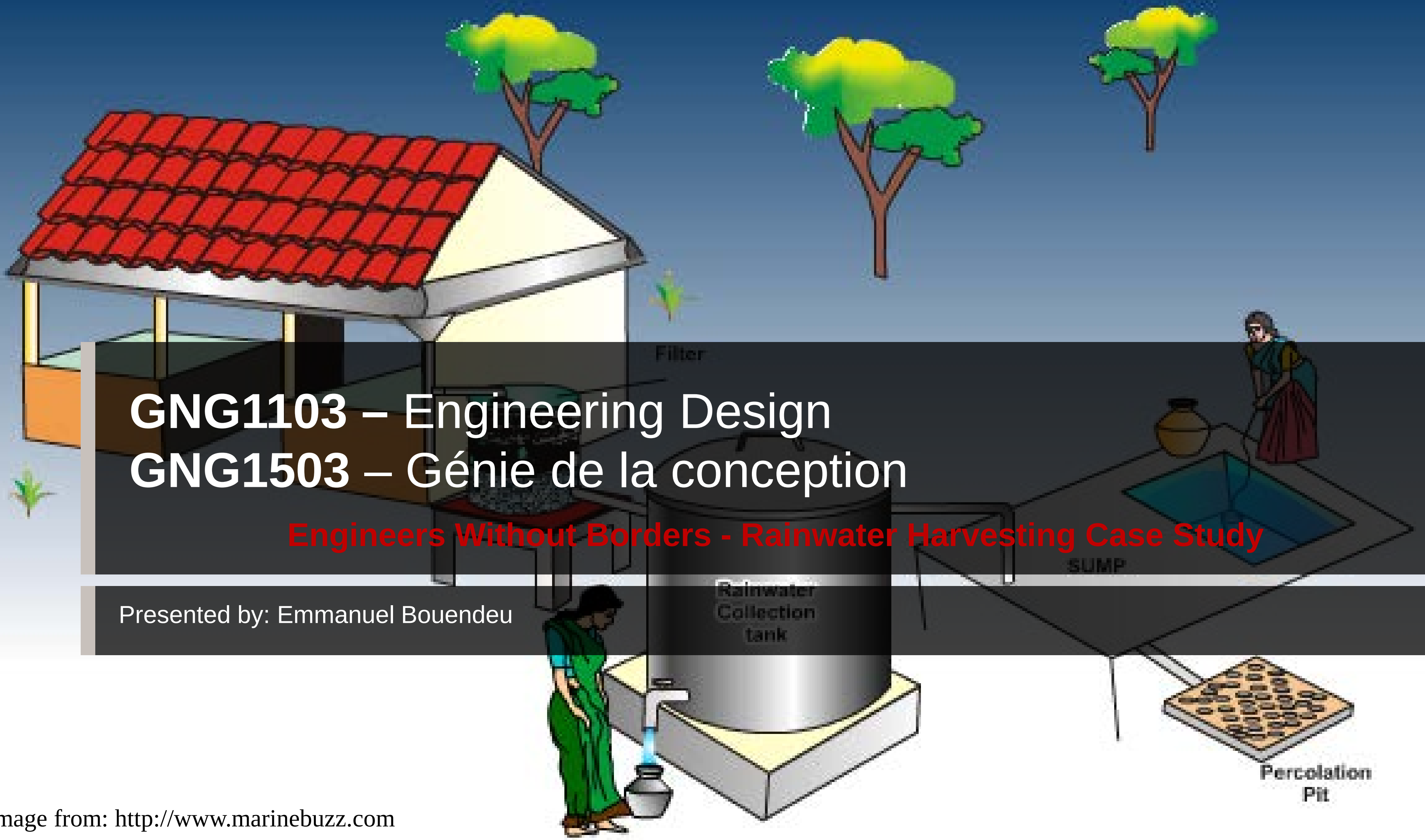


GNG1103 – Engineering Design
GNG1503 – Génie de la conception

Engineers Without Borders - Rainwater Harvesting Case Study

Presented by: Emmanuel Bouendeu

Image from: http://www.marinebuzz.com

Agenda

- **Reminders**
- **Review Questions**
- **Design Case Study**
  - Exercise
  - Needs Identification & Problem Definition
  - Conceptual Design
  - Preliminary Design
  - Detailed Design
  - Cost Estimation
  - Others Issues
  - Lessons Learnt

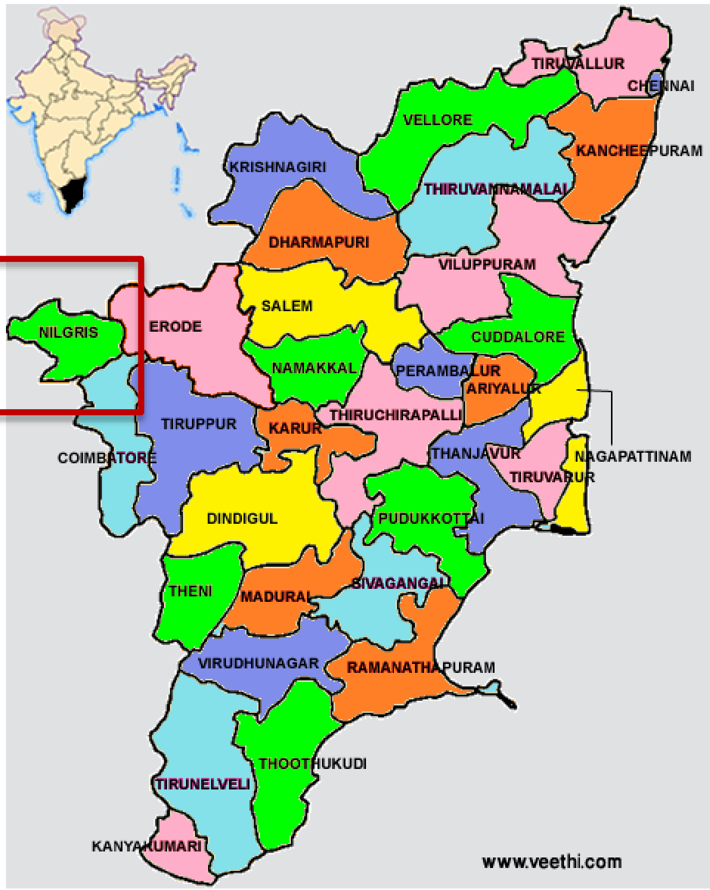
Reminders

- Due date of **Assignment 1** (Personality): Jan. 13th
- Due date of **Deliverable A** (Team Contract) : Jan. 19th
- Due date of **Report of Lab 1** (Computer Tools) : Lab 2
- What is your summary of **Lecture 1**?
  - Definition of Engineering design
  - Engineering design process
  - High performing team
  - Effective leadership in team
  - Energies in team

Review Questions

1. What are the **key steps** you can suggest for solving an engineering design problem?
2. **Apply the suggested steps to the design problem** of your GNG1103 course project (before you begin, list your **assumptions** or **special considerations** that apply to your project).
3. Apart from the technical and economic issues, what **other issues** can influence a product design?

EWB Rainwater Harvesting



http://www.veethi.com/places/tamil-nadu-state-24.htm

Based on a thesis by Dan Olsen at the University of Waterloo for Engineers Without Borders

Case Study – Individual Work

Exercise:

1. What is the problem?
2. What is proposed to solve it?
3. What key data is available?

- ***You have 5 minutes!***

WATERLOO CASES IN DESIGN ENGINEERING

WCDE-00003-01
Revision 100911

ENGINEERS WITHOUT BORDERS - RAINWATER HARVESTING

Dan Olsen[1] (EWB) and Colin Campbell (WCDE)

Introduction

Mavukall is a rural village in the Nilgiris District of the Indian state of Tamil Nadu. Like many other parts of southern India, a majority of the rural population does not have access to an adequate supply of drinking water for domestic use. Groundwater resources (streams, lakes, wells, springs, etc.) are showing signs of depletion, as well as pollution in the case of a nearby river, so a reliable and affordable alternative is required.

Figure 1: Small-scale rainwater harvesting system.

One alternative source of potable water is Rainwater Harvesting (RWH). As indicated in Figure 1, rainwater flows off the roof into gutters, then through a down-pipe, and into a storage tank. This has no adverse effect on groundwater. Tamil Nadu has gone so far as to make RWH installation on houses mandatory [1]. Unfortunately, most rural households have difficulty affording a RWH system, and this imposes a significant constraint on the design.

The Rural Development Organization (RDO) in the Nilgiris District works to improve access to an adequate supply of water in rural areas. Engineers Without Borders (EWB) has worked with RDO on similar rainwater harvesting projects, to develop the design requirements for implementing RWH systems for all houses in a village.

engineers without borders
ingénieurs sans frontières

[1] Dan Olsen wrote the original version of this case study for Engineers Without Borders.

WATERLOO CASES IN DESIGN ENGINEERING

What is the Problem?

What is Proposed to Solve It?

What Key Data is Available?

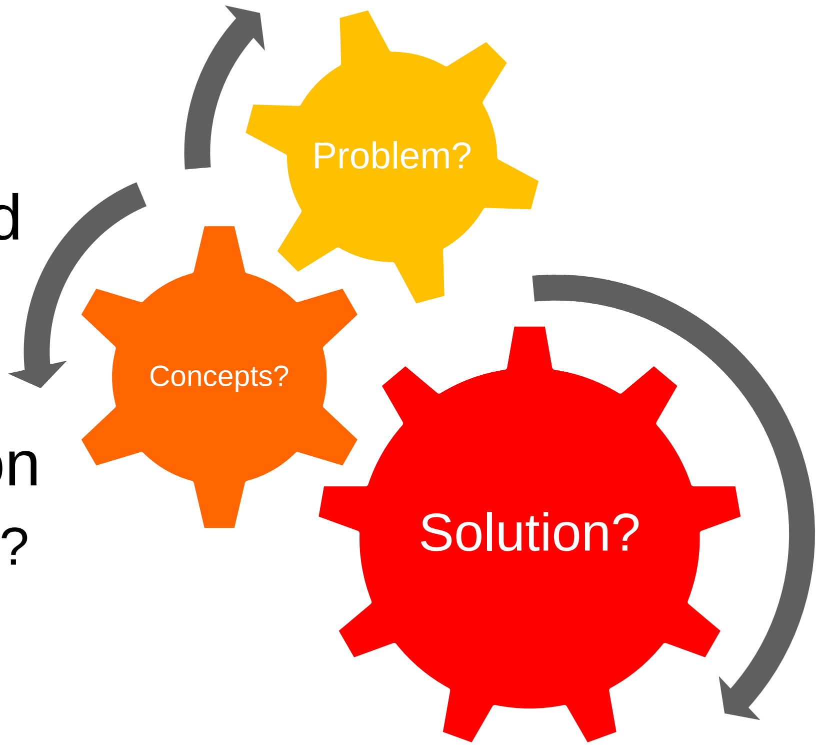
Case Study – Group Work

- Get into small groups of 3-5 people
- Plan how to solve this problem
  - What steps would you take
  - Outline your approach on a piece of paper
- ***You have 5 minutes!***

Solution Steps?

Suggested Solution Steps

- First, understand the problem
  - What is required?
- Identify potential concepts and pick a solution
  - Is it feasible?
- Develop and refine the solution
  - What are the key characteristics?
  - How good will this solution be?
- Complete the solution
  - How much will it cost?
- In lecture 3 we will show you "**Design Thinking**", which is a standard approach to engineering design



First, Understand the Problem

NEEDS IDENTIFICATION

Understand the Problem

- What is the real need?
  - To provide an adequate supply of potable (drinking) water to each household
- How much water is required each year per household?
- In your groups, calculate this amount (5 min)

Water Demand

- Requirement: What is the annual water demand?
  - Each household uses 240 koodahms per month at 12 litres/koodahm = 2,880 litres/month
  - 2,880 L/month x 12 months/year = 34,560 L/year

- Must supply: 2,880 L/month, or 34,560 L/year

Is this "Reasonable"

- Always do a "sanity check" on your results
- How can you check if your results are reasonable in this case?

Water Demand in Canada

139 L/day/person is
12,510 L/month/household
(3 people)
vs. 2880 L/month for case

Always check results with previous experience or literature – "sanity check"

Identify Potential Concepts and Pick a Solution

CONCEPTUAL DESIGN

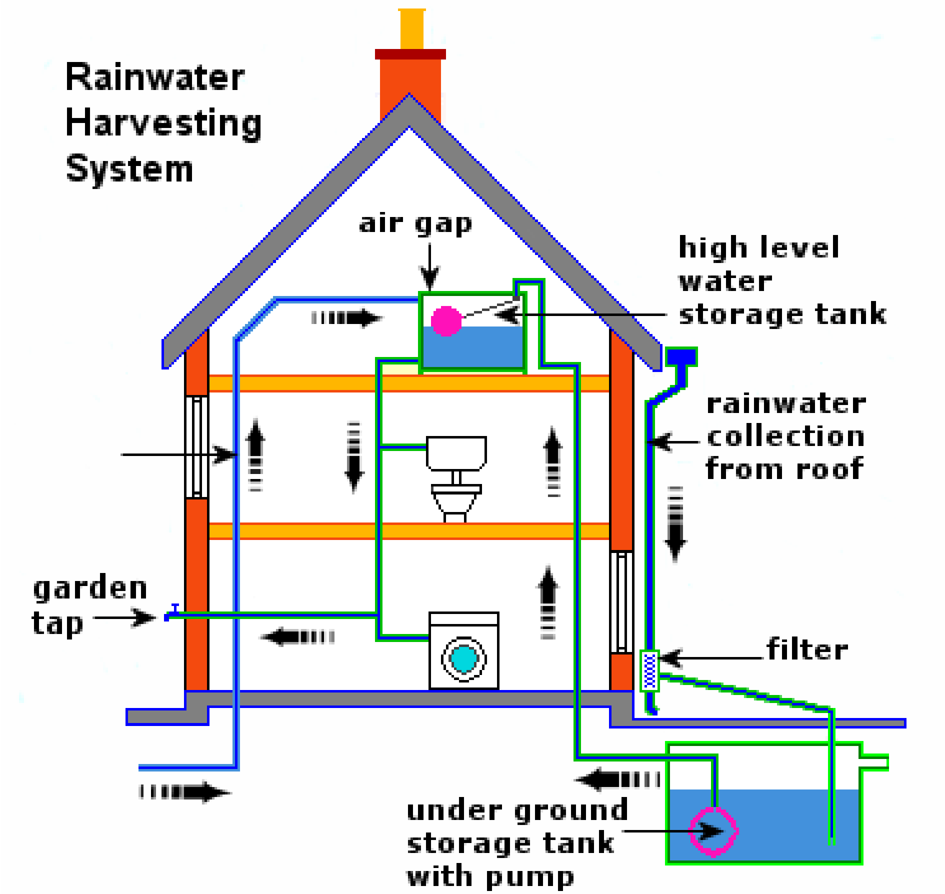
Design Criteria

- First, determine criteria you can use to judge the quality of the solution.
- In this case:
  - Ability to supply water when needed
  - Cost
  - Ease of obtaining materials
  - Ease of construction
  - Ability to provide ***clean*** (drinking) water

- These can help you choose the ***best*** solution!

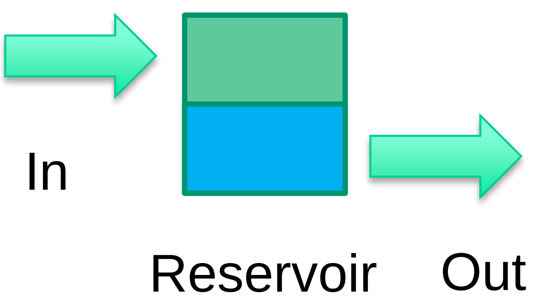
Solution – Rainwater Harvesting

Schematic Model (Configuration)



http://www.lowenergyhouse.com/rainwater-harvesting.html

Conceptual Model



Is This Feasible?

- In your groups, determine whether this will work based on the first design criteria (5 min):

"Ability to supply water when needed"

Check Feasibility – Rainwater Harvesting

- Is it feasible?
- How much water can be collected in the worst year?

Rainfall by Year

- Historical rainfall data – mm

1985 – the driest year on record

835 mm of rain

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1984	16	37	113	27	44	204	281	44	115	233	25	179	**1318**
1985	10	0	15	94	32	182	34	85	153	57	73	100	**835**
1986	36	58	15	9	99	177	86	172	204	75	73	60	**1064**
1987	12	0	16	33	99	97	80	123	161	229	113	108	**1071**
1988	0	0	96	143	98	93	293	188	212	79	29	16	**1247**
1989	0	0	11	43	82	98	486	68	205	193	49	5	**1240**
1990	47	0	4	57	217	66	89	129	73	227	85	40	**1034**
1991	8	0	5	111	85	153	300	142	123	243	72	3	**1245**
1992	5	0	0	57	157	387	230	119	127	113	281	2	**1478**
1993	0	2	19	27	92	163	110	78	149	212	200	99	**1151**
1994	8	18	9	102	66	169	291	70	148	266	137	4	**1288**
1995	13	0	1	56	124	117	147	128	119	196	127	0	**1028**
1996	22	8	25	158	72	477	180	89	318	175	27	161	**1712**
1997	18	0	53	47	83	144	253	173	95	270	156	40	**1332**
1998	0	0	0	16	32	200	289	151	103	149	92	142	**1174**
1999	0	2	17	78	64	43	173	72	101	293	95	15	**953**
2000	5	17	0	42	218	273	165	324	263	109	164	84	**1664**
2001	2	2	15	228	24	167	111	90	187	72	84	26	**1008**
2002	1	20	3	150	204	148	46	154	52	293	90	10	**1171**
2003	0	16	22	88	41	161	121	70	46	181	102	2	**848**
AVG:	**10**	**9**	**22**	**78**	**97**	**176**	**188**	**123**	**148**	**183**	**104**	**55**	**1193**

Rainfall Collected

- Minimum annual rainfall = 835 mm *(worst case year from data provided)*
- Household roof area = 6 m x 10 m = 60 m^2
- Harvesting efficiency = 75%
- Available water:

  0.835 m x 60 m^2 x 0.75 = 37.575 m^3 x 1000 L/m^3

  = **37,575 L**

- This is greater than the demand (34,560 L)
  - **So this concept is feasible (just)**

Proposed concept is acceptable

Course Attendance: Registration

- Use your smartphone or laptop to **register/notify** your attendance in this lecture
- Allow **geo location** in the attendance site
- Accept **cookies** from third parties applications
- Log in using only your **Uottawa** account at the link below

https://attendance.azarm.ca/attendancerecord/gng1103f

- Your attendance must be registered only **during the lecture** and at the **time specified by the professor**

- You can also use the **QR code** below, to register quickly

Develop and Refine the Solution

PRELIMINARY DESIGN

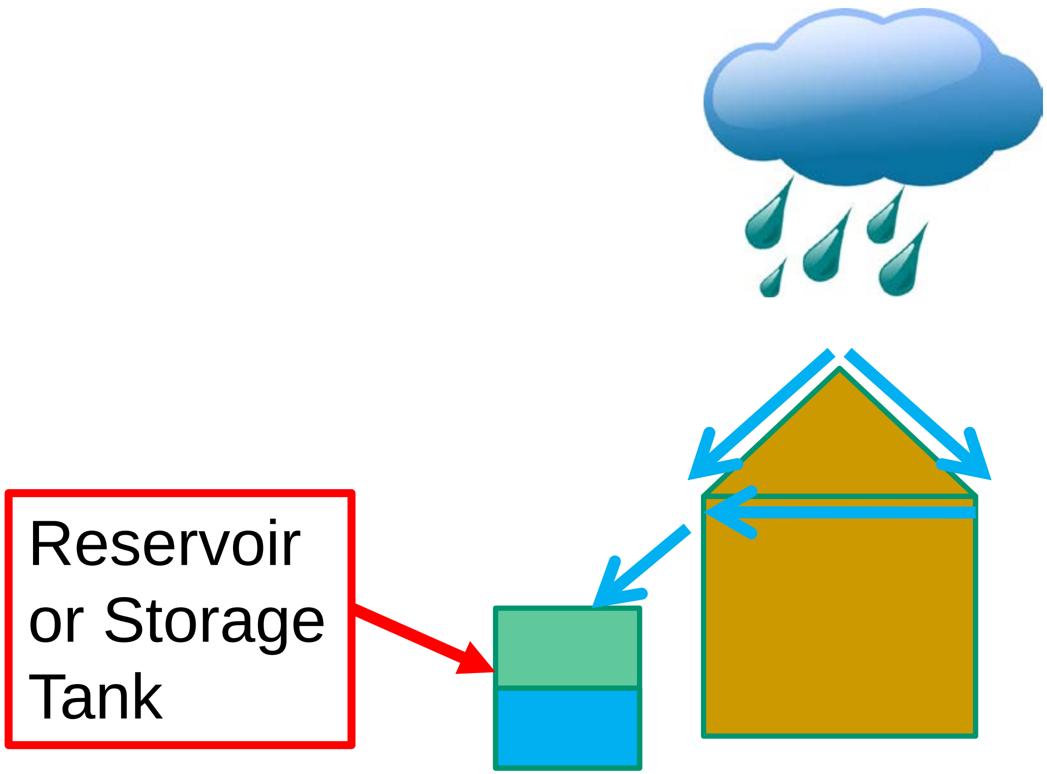
Configuration

- What is the general configuration
- What are the key components in terms of design?
  - What do we have control over?
  - What affects reliability of the system?

Illustration by Chris Gash

Develop a Detailed Solution

- The key component is the reservoir or storage tank



How to Determine the Right Reservoir Size?

- In your groups, determine a **method/algorithm** for picking a 'reasonable' reservoir size, based on the data below (5 mins)

1985 – the driest year on record

835 mm of rain

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1984	16	37	113	27	44	204	281	44	115	233	25	179	**1318**
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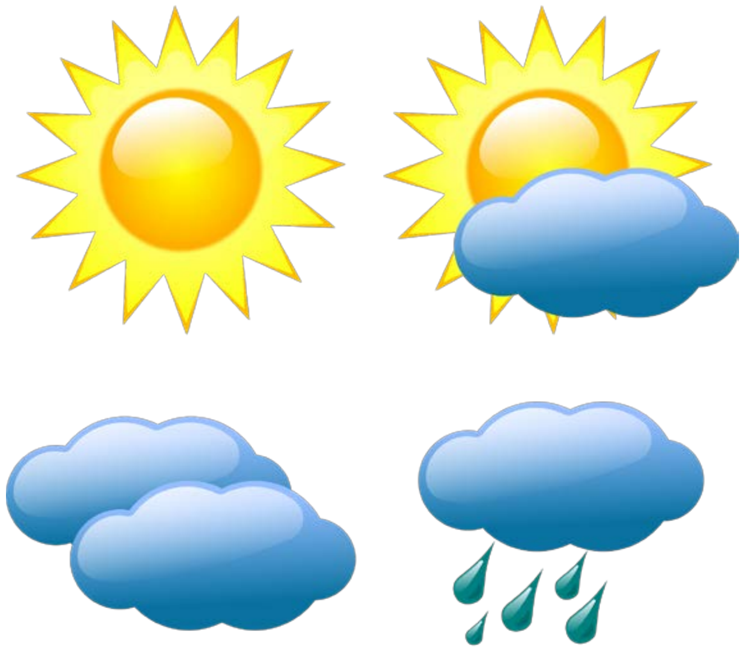
AVG:	**10**	**9**	**22**	**78**	**97**	**176**	**188**	**123**	**148**	**183**	**104**	**55**	**1193**

Reservoir Size?

- Estimate a reasonable reservoir size based on the monthly precipitation in the ***worst year***

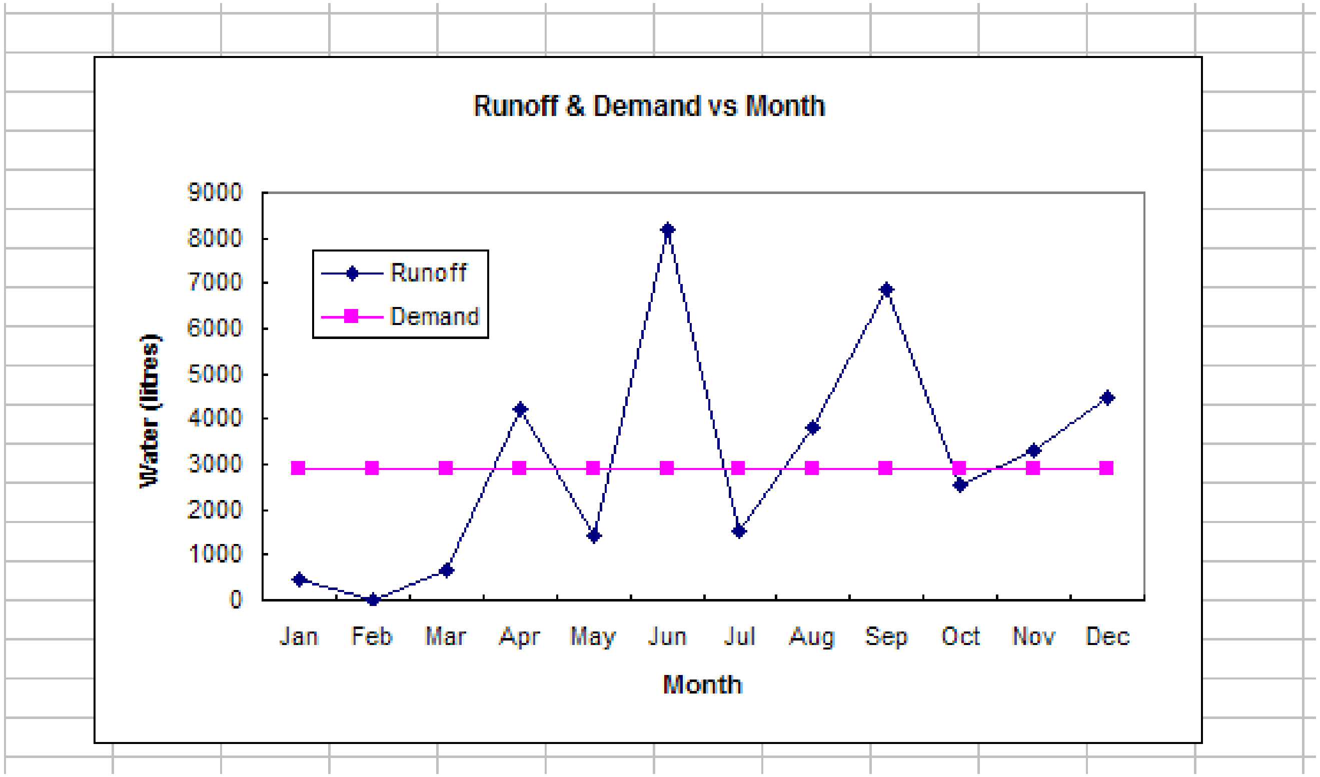
Monthly Precipitation (mm)		
1985	J	10
	F	0
	M	15
	A	94
	M	32
	J	182
	J	34
	A	85
	S	153
	O	57
	N	73
	D	100



Initial Design

- How big should the reservoir be?

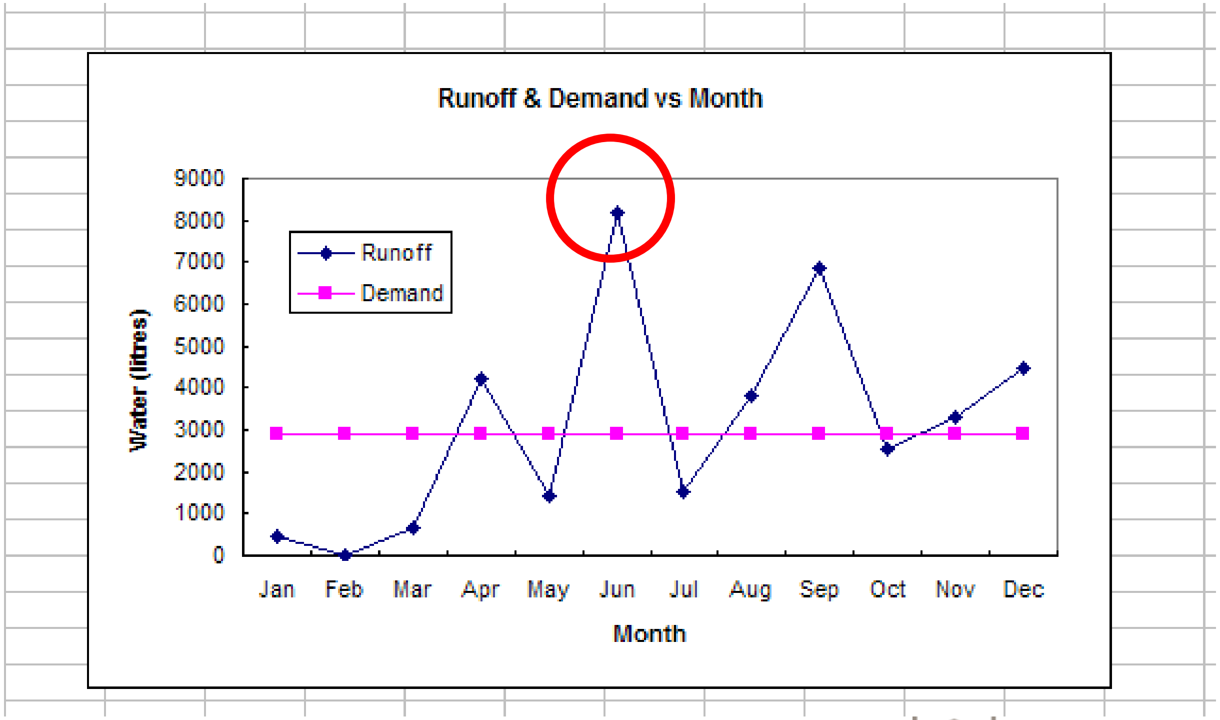
<u>Plot</u> available water (runoff) per month for ***worst year***



Preliminary Design

- How big should the reservoir be?
  - Monthly demand = 2,880 L
  - 3 month demand ~ 9000 L

First Estimate

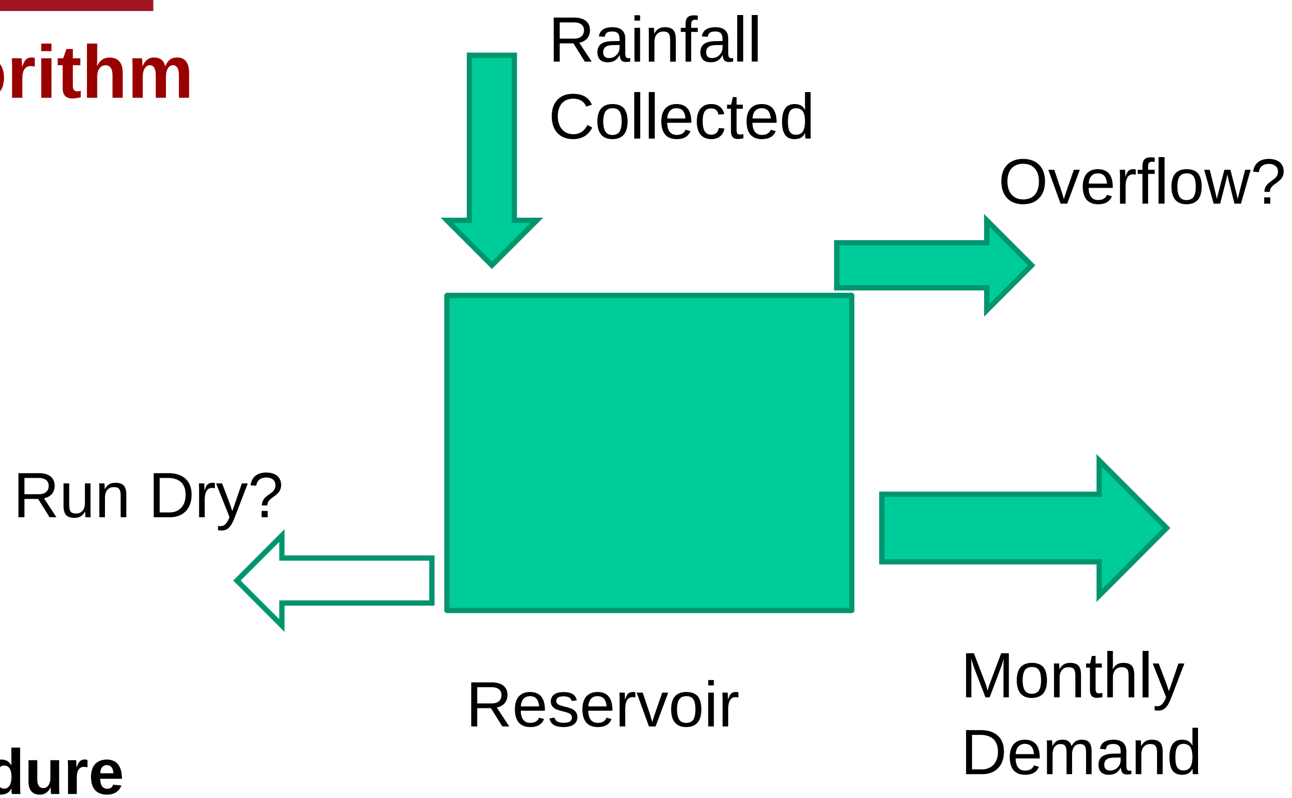


Develop solution through successive refinement

How Do We Improve the Estimate?

- Refine the solution by performing analytical simulations
  - Try different reservoir sizes to determine the reliability
- Reliability = % months with adequate water

Simulation Algorithm



Simulation Procedure

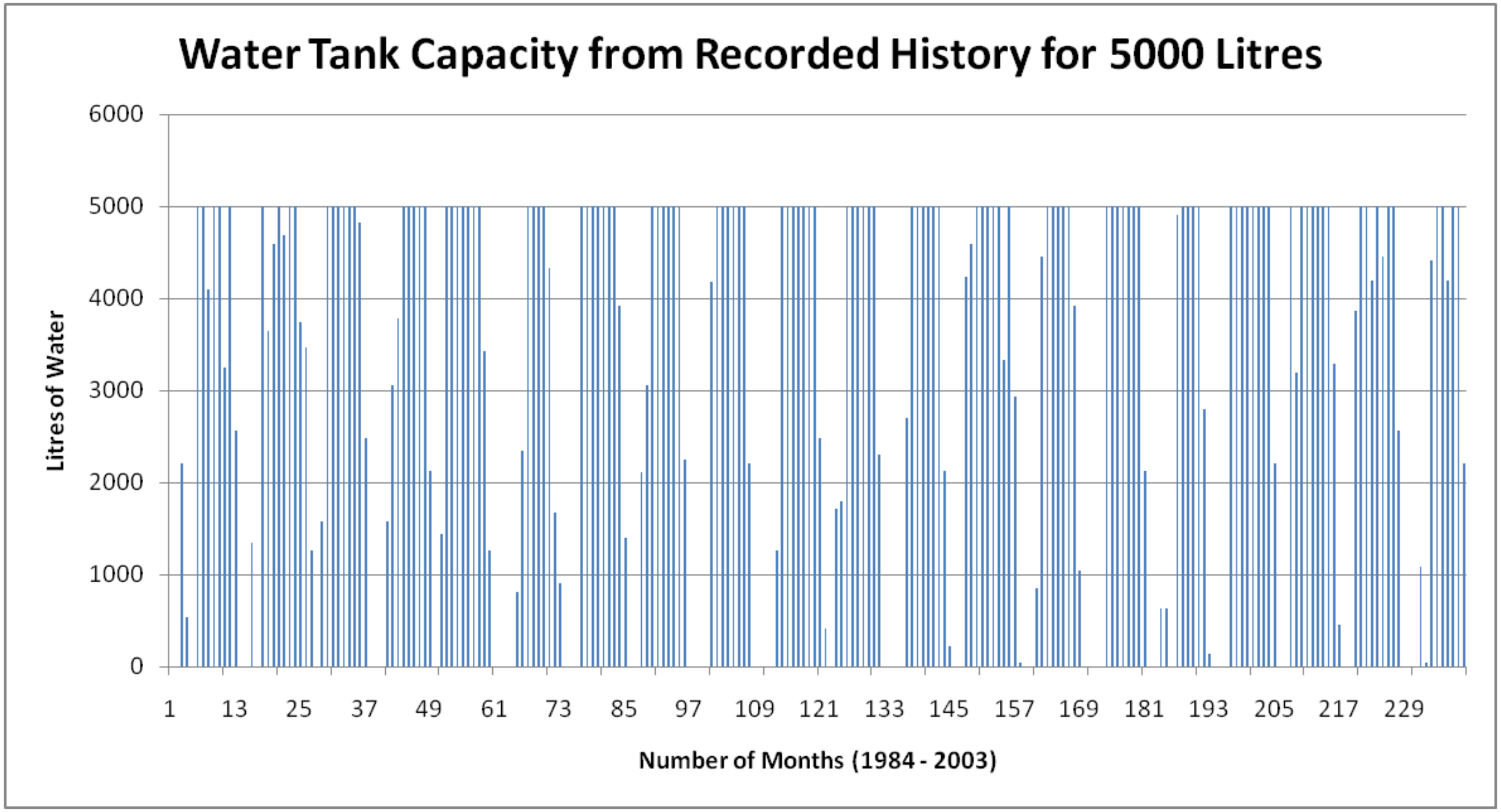
- Starting Balance
- Balance = Previous Balance – Monthly Demand + Rainfall Collected
- Check if dry (no negative balance!)
- Check if Overflow
- Repeat for 20 years (240 months)

Excel Simulation

Design Parameters									
Tank Size	20000	l				Reliability:	0.9875		
Roof Size	60	m^2							
Efficiency	0.75								
Demand	2880	l							
Year	**Month**	**Precipitation**	**Rainfall Collected**	**Monthly Demand**	**Raw Balance**	**Balance (empty)**	**Balance (full)**	**Empty Flag**	
1983	**D**						**0**		
1984	J	16	720	2880	-2160	0	0	0	
	F	37	1665	2880	-1215	0	0	0	
	M	113	5085	2880	2205	2205	2205	1	
	A	27	1215	2880	540	540	540	1	
	M	44	1980	2880	-360	0	0	0	
	J	204	9180	2880	6300	6300	6300	1	
	J	281	12645	2880	16065	16065	16065	1	
	A	44	1980	2880	15165	15165	15165	1	
	S	115	5175	2880	17460	17460	17460	1	

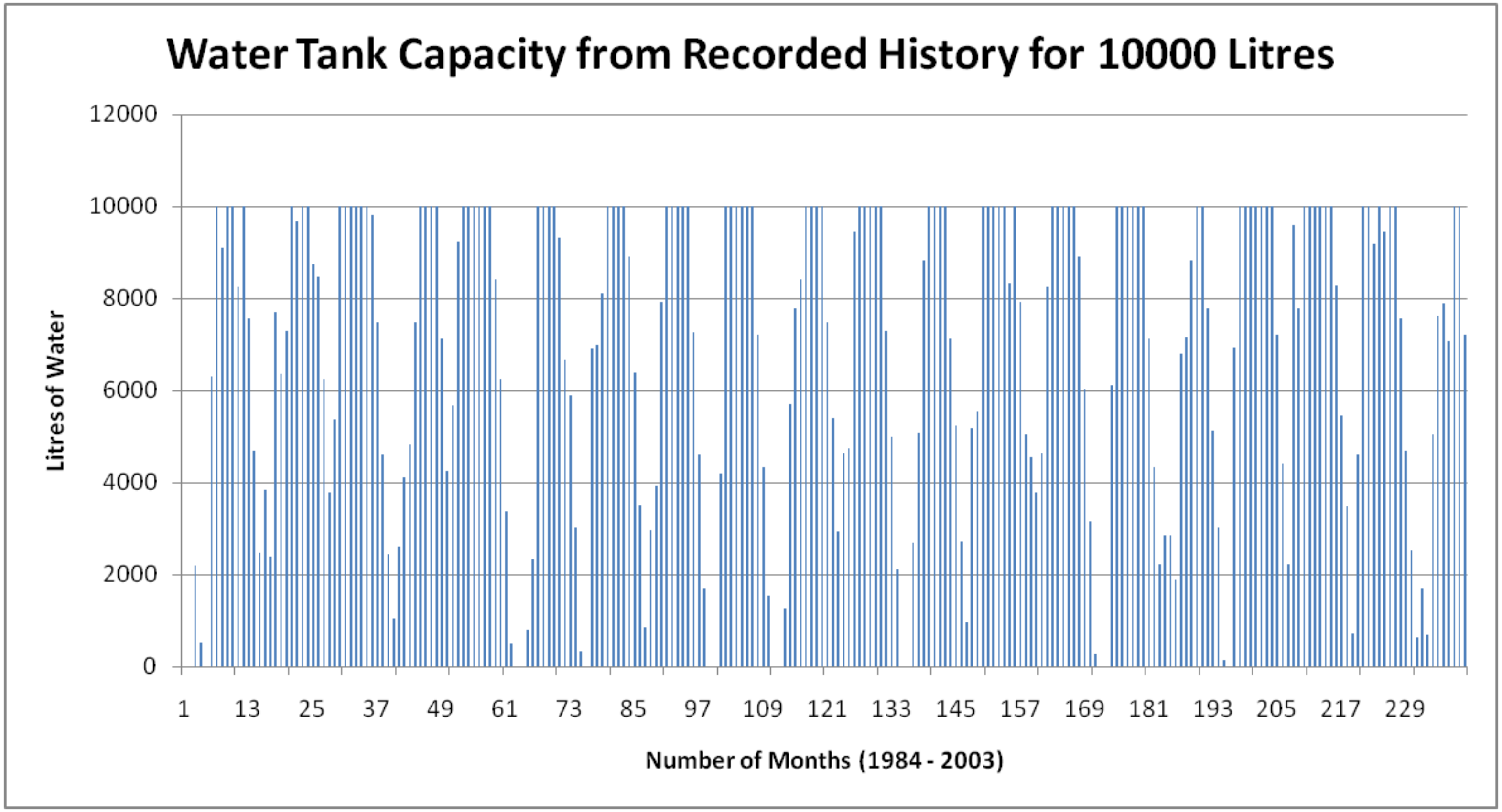
Calculate reliability for any tank size. That is, what percentage of the time do you have adequate water?

Simulation Results – 5,000 L



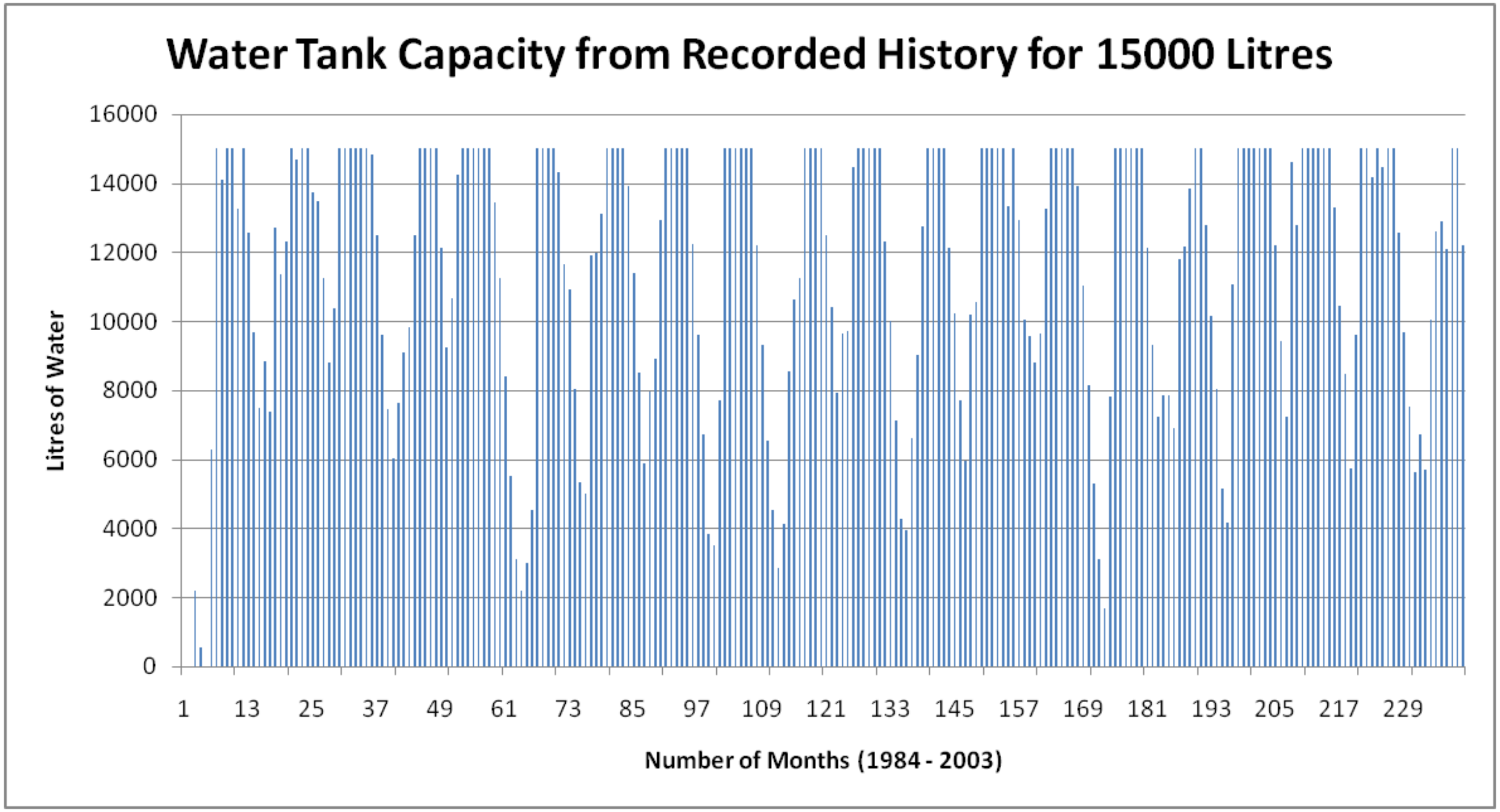
Using the Excel Simulation

Simulation Results – 10,000 L



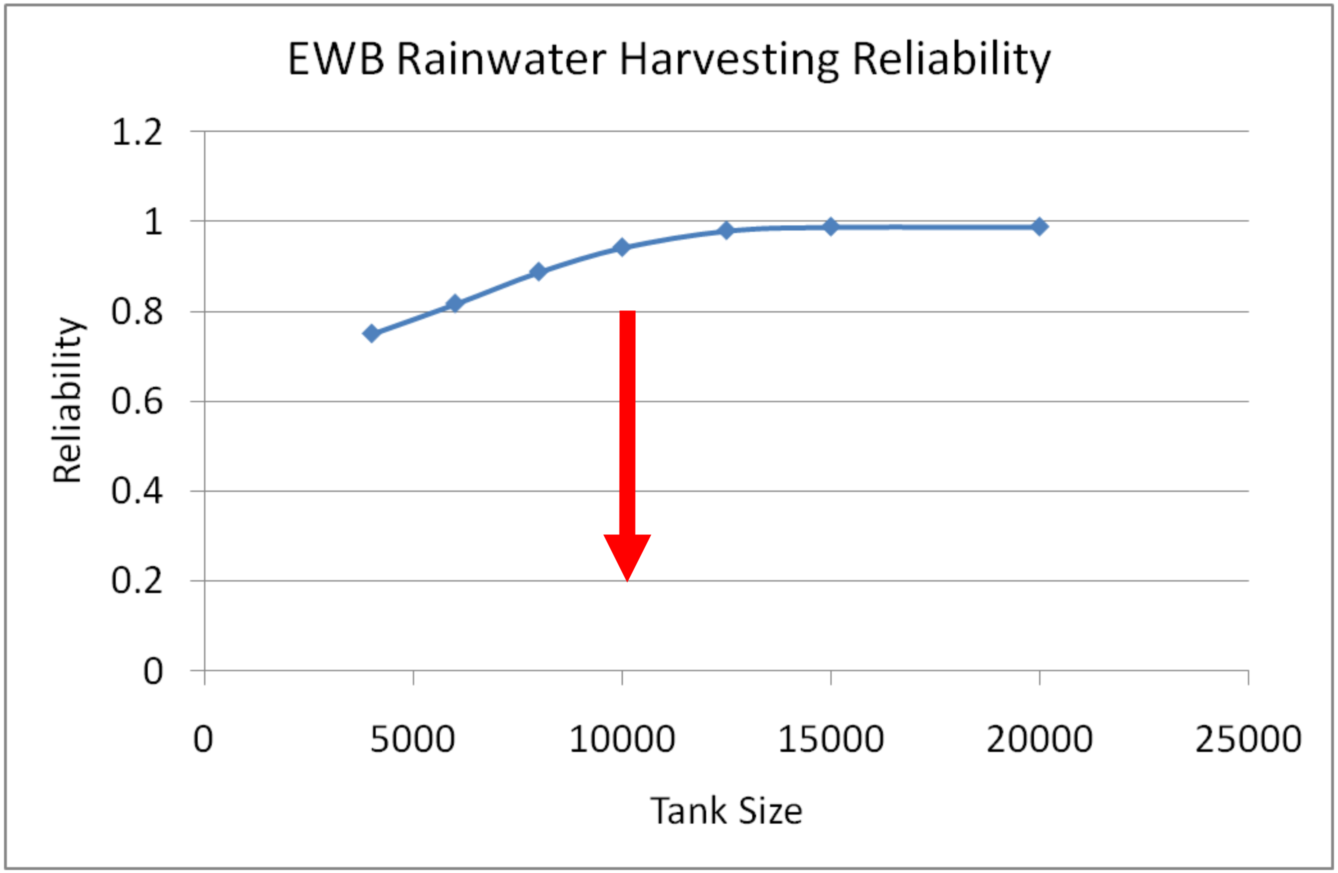
Using the Excel Simulation

Simulation Results – 15,000 L



Using the Excel Simulation

Simulation Results – Reliability



Choose a suitable tank size to maximize reliability while minimizing cost

Complete the Solution

DETAILED DESIGN

How Much Will It Cost?

Select material based on lowest cost

Quantity	Item	Cost (Rupees)
varies	Gutters	300 per m
1	Filter Unit	450 each
1	Down pipe and gate valve	750 each
1	Construction Labour Costs	300 total

Building Material	Typical Capacity Range	(Rupees/litre)
Reinforced Concrete	> 50,000 litres	2.5
Brick/Stone Masonry	15,000 to 50,000 litres	4.0
Ferrocement	4,000 to 15,000 litres	1.5 – 2.0
Plastic	< 4,000 litres	3.0

Given Data:

Tank Size 10,000 litres

Eaves: 20 M*
(Assume 10m long x 2)

Revised	Total (Rupees)	Costs
Gutters	6,000	for 20 m
Filter Unit	450	each
Down pipe and valve	750	each
Labour	300	Total
Total	**7,500**	**Rupees**

Storage Tank:

Unit Cost	2	per litre
Total Cost	**20,000**	Rupees

Total Estimate	**27,500**	**Rupees**
Exchange	$0.024	/Rupee
Total $CDN	**$660**	

Is This Cost Feasible?

- $660 per unit – is this reasonable based on what we know?
- Average salaries of villagers
  - Women: 50 Rupees/day
  - Men: 75-80 Rupees/day

  (no comment on fairness…)
- Economic instability
  - Season dependent

Worker Earnings

Income	**50**	**per day**
Weeks (seasonal)	**16**	
Days/Week	**6**	
Total Days	**96**	**days**
Total Income (Rupees)	**4,800**	**per year**

A Storage tank costs about 27,500 Rupees, versus an estimated annual income of 4,800 Rupees!!

Social and Cultural Issues

https://youtu.be/cHnwD0VCnTc

Social Issues

- Power structures
- Daily rituals of the villagers
- Who will have ownership over the water
- How women & men relate
- Community's previous experience with Non-Governmental Organizations

Cultural Issues

- Local acceptance/familiarity of the technology
- Taste of the water
- Distance/time required to extract water
- Manpower required for implementation
- Religious/spiritual beliefs
- Are people displaced during building process?

'Other' Issues?

- Such systems are not just used in "far away" places like India or even only for collecting rainwater; they are needed in Canada!
  - First Nations communities like Garden Hill, Manitoba, now use such storage tanks (or "cisterns") to store drinking water from water treatment plants in their houses… such usage is not without issues… (https://www.cbc.ca/news/indigenous/garden-hill-first-nations-drinking-water-1.4907864)
  - Problems (e.g. "sticky water") can arise with cleanliness and drinkability for such water storage systems and they need to be cleaned once or twice a year (e.g. https://www.canadianhomeinspection.com/real-estate-resources/plumbing/cisterns/ has some interesting typical Canadian cost and volume numbers as well as the basic cleaning requirements for water storage tanks being used for drinking water)

Image of Garden Hill's community water fountain from CBC link above

Lessons Learned

- First, understand the problem
- Establish feasibility
  - Physical, technical, economic
  - Check your results at each step of the process
- Establish topology and size components
- Perform appropriate analyses
- Refine solution using successive approximation
  - Increasingly complex analyses, properly verified
- Keep in mind other factors
  - Cost, manufacturability, environmental, cultural, …