Sewage Treatment in India

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Abstract

Devikulam is a small village in rural south-east India, suffering from poverty, poor health standards and a lack of public infrastructure works. Through work done by this team—in conjunction with our tutors, unit coordinators and the cooperation of Engineers without Borders (EWB)—we propose a solution to Devikulam’s human waste management issues.

We have designed a toilet system, in which the effluent is collected and subsequently treated by sub-surface constructed wetlands. The system is solar powered, sourcing water from the village’s already established communal water tank. Current issues of water/soil contamination and pathogen proliferation would be considerably reduced or eliminated.

The size of the project is scalable depending on land availability and available capital resources. There is additional capacity for the constructed wetlands to be utilised in other greywater treatment projects, providing opportunities for future civil infrastructure expansion. The system is designed to be cost-effective, sustainable, and to accommodate Devikulam’s cultural profile.
Team Reflection

Introduction

As an important part of our first-year engineering study at the University of Western Australia, the unit ‘GENG1003: Introduction to Professional Engineering: Global Challenges in Engineering’ grouped the six members of our team together to work cooperatively towards a common objective. Despite being initially unfamiliar, the group soon got to know each other through both the work we did for our project and the team-oriented exercises we participated in during the weekly information and practical sessions.

GENG1003 was the perfect complement to the technical training we receive in our other classes, as it developed the professional, organisational and interpersonal skills that we will require in order to deploy our technical abilities effectively as practicing engineers. It gave us the opportunity to experience what it is like to engineer solutions in a group dynamic, progressively learning about the resulting benefits and difficulties. By working cooperatively, we were able to divide the workload, and harness the strengths of each of our group.

Tasked with designing in a global context, the project was an invaluable learning experience, requiring us to expand our understanding of foreign culture and acknowledge how as engineers, we must consider the implications of our work. We feel that altruistic projects of this nature are the most rewarding, and that as engineers we are equipped to make an appreciable difference in the world.

Working as a Team

Surprisingly useful were the team’s different backgrounds and areas of expertise. The initial inspiration for our solution came from a similar system operating at the rural home of our group leader, Jeremy Stark. Tina Bazargani’s Persian heritage gave her a familiarity with squat toilet systems which assisted us in the design of the individual toilets and our understanding of how they work. Some of the group had done prior tertiary study, and thus exhibited enhanced report writing and university study skills which helped the group collectively. Writing reports of this format and magnitude was certainly something that none of us had experience with, which made it a worthwhile process.
The process was not without its share of complications, which is to be expected when a diverse group of people with varied levels of experience, conflicting ideas and a range of personality types are placed in a working environment and expected to complete a task harmoniously. All things considered, the project went smoothly; aside from a few minor disagreements in practical sessions (no doubt a consequence of the flexibility in these sessions leading us to argue about the best path to the same result), our efforts were complementary.

It is difficult to assign leadership in these scenarios, as we are all peers on an equal footing, with few students wishing to compromise their individual integrity for the sake of agreement. Although Jeremy Stark was appointed a position in the first week of semester, this was in more of a ‘representative/spokesperson’ capacity than a leader per se, as we felt that all decisions should be made as a result of democratic collaboration.

**Time Management**

Time management was something we wrestled with throughout the semester. Figures A.1 and A.2 compare the first incarnation of our project schedule with an actual timeline of our progress. The group consensus was that we didn’t get enough work done during the middle of semester, which increased pressure on us late in the term. The main reasons for us falling behind were:

- The Easter break (a week without regular classes occurring around the middle of semester) had the potential of being one of the most productive; in fact the working schedule formulated in week 6 had planned on the team using this week to catch up on our work. However this didn’t go to plan as the majority of our group left Perth to visit family or go on holiday.
- An important item on the project schedule (Figure A.1) was a ‘preliminary design draft’, due week 9, which never came to fruition. We hadn’t actually decided on our final design until approximately week 10, due to technical uncertainties, which left us lagging behind schedule.

Our group’s lack of progress—something we had attributed to insufficient time spent working together—definitely improved when we began to meet several times a week in the library. While little in the way of writing or individual work took place in these sessions, they proved invaluable in their ability to focus the efforts of the team, giving us an opportunity to discuss different ideas and resolve misunderstandings or conflicts, and ensure that everyone’s time was spent most effectively. The meetings also brought the group closer together in a social sense, and there was a positive correlation observed between this camaraderie and the amount of work being produced.
Due to the scale of this report, it was imperative that we not only divided labour equitably, but that we were coordinated in our approach. In an effort to improve productivity, inspire the group dynamic and avoid pitfalls such as redundant or conflicting information, we set up a ‘Google Docs’ document; an online shared file that enabled us to contribute collectively to a dynamic version of our final report (Google, 2011). This proved especially useful when writing the summary, introduction and conclusion, as at any stage we could review the most recent work by the group, then consolidate and summarise the crucial elements.

**Workshop Sessions**

Practical sessions were initially problematic, as group members had differing opinions on the best way to achieve common goals. A balance had to be met between having each of the group working independently on a component of the prototype, and having everyone decide on each stage of construction—a trade-off between efficiency and efficacy. After a somewhat unsuccessful practical session in week 10, a list was created detailing every step of construction required for completion, so that the following week we were able to immediately perform the necessary work, and division of tasks was made easier once all the steps were outlined on paper. By visualising each stage of building, it also clarified which materials we still needed to purchase.

The building process was frustrating overall, with our prototype failing to perform its intended function. The main issue was with the flow of water through the 4mm reticulation pipe—at the scale we worked at (a thimble’s worth of water input into the system), there was not enough water pressure/force to make the water flow reliably through the mock wetland and out to a collecting reservoir. We attempted to change the gradient of the pipe and open up a bigger entry point for the water, the result being a leaking ‘toilet’. We don’t feel that the prototype design was too ambitious, but given the lack of resources at our disposal and workshop time constraints, we had to cut the troubleshooting process short and complete construction. The priority was to ensure that the model would be visually serviceable when conveying the basic mechanics of our design to our tutors and other teams.
Writing the Report

Aside from a potentially volatile group dynamic, we were also limited by our technical knowledge in the field of report writing. The unit assumed a certain competency in technical writing that only had a chance to develop in us over the course of the semester, something that we had to teach ourselves and each other. The lack of explicit instruction as to the nature of the report created some confusion amongst us. This was positive, as it required us to abandon the familiar passive learning style ingrained in us from high school, encouraging us to seek answers and help ourselves; but this metamorphosis was inherently difficult, and is something that will need to continue developing as we mature academically.

With the benefit of hindsight we understand how the information sessions and the weekly memos could have been utilised in forming a solid foundation upon which this report could have been built. Where appropriate, we have endeavoured to integrate some of the more abstract social science aspects of the information sessions into the report, by connecting our design decisions to the ubiquitous issues of:

- Sustainability.
- Equality.
- Diversity.
- Ethics.
- Globalisation.
- Modernisation.
Mission Statement

The objective of this project is to provide the villagers of Devikulam with the means to dispose of their bodily waste hygienically and efficiently, to protect the environment from further pollution and to improve their overall standard of living.

“Engineering needs to promote itself as relevant to solving contemporary problems, to becoming more socially responsible and to link to ethical issues related to development.”

(UNESCO, Engineering: Issues, Challenges and Opportunities for Development, 2010)

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1. Introduction

Presented with the challenge of designing a solution to Devikulam’s waste management problems, our team took this flexible task and immediately narrowed it to the human waste aspect, as we feel that addressing this particular situation is of paramount importance. In essence, the problem we are attempting to solve is the pollution and poor hygiene that has come about due to the prevailing practice of ‘open defecation’, which involves the villagers passing their waste anywhere that is convenient (generally in the surrounding environment), due to a complete lack of toilets in the village. As a result of this practice, the village’s waste matter is not treated or filtered in any way, which comes with serious health implications.

The treatment and disposal of waste is a universal issue, meaning that we had a range of systems on which to base our project during the early stages of development, leading to the exciting task of designing a unique solution specific to Devikulam. Examples of the waste treatment solutions investigated:

- Sewage plants.
- Anaerobic baffle reactors.
- Algal lagoons.
- Vertical sand-gravel filtered systems.
- The patented EcoSan composting toilet.

We also worked with different preliminary incarnations of our final design, which utilised things like rainwater, saltwater from the village’s saline bore and western-style toilets with flushing cisterns. While EWB is currently trialling a handful of EcoSan toilets in the village, we feel that our project is more suited to the context. A wetland will be easier to maintain and repair due to its simplicity and build materials, and by keeping Devikulam independent of expensive imported technologies we can avoid an unhealthy reliance on foreign products.

After weeks of research, comparative analysis and deliberation, we decided upon our solution to the problem in Devikulam: a toilet system connected to a constructed wetland that will filter the effluent. Water is provided by a solar-powered pump, which pumps from a large tank connected to an existing
bore. This water supplies tanks positioned above the blocks of toilets, which is then gravity-fed down through hoses into the individual toilet cubicles, which are used for filling the bucket for flushing. A sink and soap is provided for hand washing purposes.

The constructed treatment wetland as detailed in this report is essentially a man-made version of a very natural phenomenon; the processes of water filtration exhibited by naturally occurring wetlands can be considered a fine example of engineering in nature (Tanner, 2001). Similar wetlands to that in this project are employed worldwide, in places such as Australia, the United States, and most importantly for this project, India (Greenway, 2005; United States Environmental Protection Agency [EPA], 2010; Juwarkar et al, 1995). By tailoring the universally applied, generic technology of the constructed wetland to the context of Devikulam, we managed to work the constraints of the situation into an innovative design.

As is fundamental to all engineering projects, we have given great thought to sustainability and cost-effectiveness. Our design process was shaped by the constraints imposed by the unfortunate economic conditions of the area. Of the 85 households in Devikulam, almost all of them exist below the poverty line (EWB, 2011; Buzza, 2008). This has obvious implications when formulating design parameters; the lack of economic welfare in the village underpinned our entire decision making process.

Factors given consideration include:

- Minimising initial capital expenditure.
- Maintenance requirements (in terms of both material and labour resources).
- The availability of utilities and materials in Devikulam.
- Necessary education programs and community involvement.

The social implications of introducing technology or practices that are foreign to the people of Devikulam were central to our design. There is a vastly different social structure in Devikulam compared to that with which our group is familiar, and we have a responsibility not to disturb the cultural equilibrium. Data collected by EWB surveys and Buzza (2008) describe a systems of castes; similar in some ways to our divisions of upper and lower classes. In India however, the system is intensified; the castes have traditionally represented rigidly enforced segregations, the social reality of which being discrimination and prejudice towards those deemed ‘untouchables’. Our design process
has been shaped by our attempts to provide equal opportunities to those of either caste, not wanting to aggravate any inequality that may still exist in Devikulam.

India has a population of 1.21 billion, yet a staggering 665 million (59%) lack access to latrines (Census India, 2011; Wax, 2009). The World Toilet Organisation organizes the annual ‘World Toilet Summit’, where awareness is raised and solutions discussed for the 2.6 billion people worldwide who do not have access to appropriate sanitation facilities (WTO, 2011). The problem with idealised, broad spectrum movements such as the one promoted by the aforementioned World Toilet Summit, is that it is difficult to account for the variety of circumstances in which they wish to affect change. That is the benefit of small scale, structured engineering projects like the one we have been undertaken; we are focused on a single context and have a specific objective. By taking the time to understand the intricacies and constraints in Devikulam, we are better equipped to serve their needs.
2. Background

2.1 Cultural Background

India has a very diverse culture, differing from caste to caste, this includes differences from language, religion, food and climate. Nevertheless there are some fundamental values, tradition and beliefs that appear to be universal among the population of India.

The most dominant religion is the Hindu religion that is practiced by over 80% of the population (Central Intelligence Agency's [CIA], 2010). Various aspects of the Hindu religion are practised differently throughout the different castes, although birth, marriage and death rituals are kept typically the same. There are also festivals and ceremonies that do not only worship their gods but aspects of nature, such as the sun, river, animals etc.

From India’s census in 2001 the CIA record 15 alternative languages that are spoken. Although English is the most common second language, the most widely used language is Hindi, which employed by 41% of the population.

The climate in India has large variations throughout the country because of its large size and varying terrain. There is a monsoonal wet season and dry season. The monsoon starts at the south between May and June then a few weeks later it will hit the north between June to October. This brings a large burst of rain to the affected areas with varying amounts of rain throughout different regions of the country. The central north area receives as little as 13 cm and to the far northwest corner they have received us much 1141cm during the monsoon season. The dry season begins when the northern winds prevail, beginning in December. Until May the climate gets hotter and the drought continues. Then the monsoon season will begin again when the winds change back to the southwest (IMD, 2010).
Devikulam is a rural village by the coast in southern India. The local population is 375 villagers living in 85 households. There are three different castes in Devikulam that have a mutual understanding of each other, although they rarely associate. In India 25% of the population live below the poverty line with 75% living in rural areas; and the majority of Devikulam people living in impoverished conditions. Most villagers do not have full time employment only working a few days a month or not at all. The main source of employment is from the local farms (Engineers Without Borders [EWB], 2011).

The majority of the villagers in Devikulam live below the poverty line. Over half of the households only have walking as a form of transport and the next local village, Munnar which is 4km away, is the closet place to get food from a shop. Devikulam is a village which has very limited educational facilities, there is only one school, which struggles to maintain its teacher and is extremely poor with no water, toilets and terrible infrastructure, including, but not limited to: poor electricity network which encounters daily blackouts; poor transport routes, which is frequently reduced to rubble in the monsoonal season; no health care facility, which is greatly needed; and no sewerage system, resulting in hygiene problems and outbreaks of disease. Approximately half the households in the village have a mobile phone, which furthers an isolation that makes it difficult for people to communicate to nearby villagers. Half of the households have members that can only maintain work for twenty days or less from local farms and a nearby prawn industry. The average annual income per household is about 30 000 rupees a year which calculates to an approximate US$650. This data (EWB, 2010) illustrate how poor and impoverished the rural village of Devikulam is.

Pitchandikulam Forest for Devikulam is an organisation to help with improving the standard of living in this area, by developing ways for a better standard of living. This includes implementing new sustainable designs to their village, for example: installing a new source of renewable electricity;
improving water sanitation and industry development; or building a toilet block to improve sanitation. Some considerations for the new design consider the villagers preferred materials and the aspects of their everyday living practices, such as the mud houses they live in, mud being a building material preferred over concrete, which makes the houses very hot in the summer, although the quality of the mud houses (especially the thatched rooves) needs to improved for better protection from the rain. The literacy level in Devikulam is very poor and an education seminar will need to be developed for the villagers.

2.2 Toilet Availability Data

Devikulam is a poor village, therefore the local implementation of toilets is neither affordable and thus nor a priority. Therefore toilets will only become available if there is funding or initiative for such a design, and it must also be taken into consideration that the villagers like to go out to the open for their toilet functions. It is for this reason that the villagers in Devikulam would rather the funding to go towards improving their housing or to gain new ways to support an income.

In nearby villages there has been water refinement and dry toilets implemented which do not require water and are safe and easy to use. There has been varying success of these toilets depending on the cultural values of each village. For example, human waste being used as compost, which is produced in this dry toilet process, is frowned upon by the villager’s local belief (EWB, 2011) and can impede on the use of these toilets.

2.3 Social Scenario

2.3.1 Cultural Values

We have analysed many cultural values in relation to our design. The main source of information has come from the EWB website and forum. There have been a significant number of issues that have arisen that have been dealt with the context of the village being the main priority. These are the issues we have faced in relation to the cultural values of the villagers and a simple way to overcome them. Each caste in Devikulam rarely associates with one another (EWB, 2011). Therefore the toilet block will be designed for one cast. This will help avoid problems that could arise with such duties associated with the toilets including cleaning and maintenance of the toilets. The villagers of Devikulam prefer defecating out in the open (EWB, 2011), and it has been assumed that they squat, and therefore have replicated this to eliminate the transition and to increase the appeal to use our toilet system. The EWB has been contacted with concerns of using existing, but unused, bores. We found
It has been identified that the local electricity supply is very unreliable (EWB, 2011) and that the villagers would like a new source of consistent electricity supply. Therefore for the toilet have considered this and we are using renewable solar energy to pump the water.

The tribes in Devikulam have large gender equality difference (Idukk), with the males of the tribe restricting the actions of the females. Our toilet block is built for males and females and will hopefully add more equality to the village, taking into account that the villagers currently defecate in the same manner, out in the open, it is our hope that that the toilets will be shared in the same way. Results from the Pitchandikulam Bio Resource Centre have indicated that a similar toilet filtering method called the Reciprocating Vegetated Sand Filter would be in favour for the villagers in Devikulam. Therefore our wetland system will be accredited by the village.

The villagers’ way of defecating is currently unhygienic. There is only 53% of the population in India who wash their hands after defecating (UNICEF, 2008), which can cause disease and the villagers want to stop the spread the disease to become a healthier community. Therefore it was a vital decision to provide soap in the toilet that the sanitation standard is as high as possible. Building the toilet block in Devikulam is a way to produce a short term income for the villagers. As most villagers are unemployed the significance of getting extra work will be a great benefit. Our design will support the labour of the villagers as local materials and building practices will be used.

### 2.3.2 Current Methods

In Devikulam there is only the most basic way of defection and that is out in the open. In India over 50% of the population defecate in the open and only 53% who use soap after defecating (UNICEF, 2008). This statistic follows through to Devikulam with the preferred way to defecate is out in the open (EWB, 2011). This causes pathogenic infections that can result in various sicknesses, among which include diarrhoea, which in the most severe cases is deadly.

### 2.3.3 Overseas Programs

Wetlands systems that are used for water treatment has been used for over 40 years require a lot of land, have low running costs and have small operational requirements. It is a reliable alternative to
other conventional water treatment systems particularly in small and remote communities (Vymazal et al., 2006). In Staten Island, New York there is a horizontal storm water filter which manages one third of the Staten Island storm water. The horizontal wetland consists of streams and ponds which filter the water and store the filtered water for future use. It is a cost effective design that is sustainable and is environmentally positive. “The Bluebelt is an award-winning program that is enhancing the natural resources of Staten Island while providing Island residents with cost-effective stormwater management,” (Ward, 2007). This program has won the United States Environmental Protection Agency’s (EPA) environmental quality award in 2005, exhibiting how successful these wetland systems can be.

### 2.4 Economic Scenario

India’s GDP is US $1.53 trillion which is the tenth largest in the world. However since India has a population of 1.2 billion people their GDP per capita is US $3400 which is ranked 163rd in the world (CIA, 2010). 54% of India’s GDP is from services and transportation with over US $164 from national exports. There is a large dependence from the agricultural sector to maintain jobs. India has a very large amount of its population who live below the poverty line with 700 million people living on only $2 a day. This also represents the income of the villagers in Devikulam as the average annual household income is US $650. Although a large number of people in India are being well educated in computer software and engineering etc. and can speak the English language, which accelerates the exports of computer software. The economy is currently growing at 9% and this has resulted with a large shift of the population becoming middle class, who earn between US $4 000 to $20 000 (US Department of State, 2010).
3. Technologies Investigated

3.1 Introduction

Various ideas were researched in order to find the most suitable waste treatment option for Devikulam. The climate, environmental impact, location, maintenance, social effect and cost of all the different options were taken into account to find the best solution for the sanitation problems faced by the village.

A flushing or dry toilet had to be decided on, taking into account how the water would be obtained if a flush was required. The Ecosan and the pit and compost toilets all used no water, while all other investigated ideas needed a flush so the waste could be filtered and recycled in another form.

Options have to be looked at in deciding the different ways the waste could be recycled, disposed or even reused. Choices ranged in cost and productivity whether it was an expansive wastewater treatment plant or a simpler gravel filtering system. All had their own advantages and disadvantages which had to be investigated in order to make the right decision for the project.

3.2 Water Supply

If flushing toilets were decided to be the best option, we would require a reliable source of water to ensure their continued operation. Several methods of obtaining a reliable source of non-potable water were investigated.

3.2.1 Bore

One major option for water supply is a bore. Bores are already used locally, with some bores abandoned by the villagers due to the water quality deteriorating (EWB, 2011). This is very favourable as no financial outlay is required to construct a bore, as well as water being available year round. However, a pump is required to convey water to the toilet blocks. Three major pump options were investigated, a diesel powered pump, a grid powered electric pump, and a solar powered electric pump.
The diesel powered pump was quickly eliminated, as ongoing running costs are extremely high, diesel is not widely available in Devikulam, and no-one would be willing to pay such ongoing costs.

Likewise, the grid powered electric pump was also eliminated due to the fact that mains supply is extremely unreliable in Devikulam (EWB 2011), and again some-one would have to pay the ongoing costs of running such a pump, making this option hostage to the money-men of the village.

Therefore the only viable option would be a solar-powered electric pump. This configuration is superior to other options in that these is no on-going costs, (though initial outlay is higher) and that the system is independent of a village member contributing to running costs. In order for the system to be functional at night, (when there is no power available from the solar panels), an elevated water tank must be used to store the potential energy available to run the sanitation system.

3.2.2 Rainwater Tank

If rainwater tanks were installed in Devikulam there would have to be approximately 50 rainwater tanks to collect water from the gutters located on the roofs of the toilet blocks. The houses of Devikulam would be unable to hold a series of gutters as they are made of mostly weak thatched materials. This means limited water is able to be gained than usually is in a town, as only the toilet blocks are collecting the water. Water tanks throughout Devikulam would eliminate the need for several bore pumps to be built or borrowed from the town, which can potentially be harmful for the environment or have a bad influence on the people in the community. An extensive amount of research was gone into the climate conditions and water tank sizes to see if placing water tanks around the town would be able to provide enough water for the toilets all year round.

Devikulam has predominantly three seasons, summer, winter and monsoon. The monsoon season is when the majority of the rainfall occurs throughout the year, overall receiving approximately 600mm of rainfall annually. Rainfall from the monsoon months would be enough to sustain the 150L of water needed to flush the toilets, but during the summer months there wouldn’t be enough, making the rainwater system redundant. This is why bore pumps were a necessary option if flushing toilets were to be provided.
### 3.3 Toilet Design

#### 3.3.1 Composting Toilets

Composting toilets use a ventilated, closed environment to turn waste into a product helpful in providing soil nutrients and other preservatives. The waste goes into a ventilated chamber that gets completely dried out. As human waste is only 10% solid, just a small portion is left in the chamber which can be used as an effective fertiliser for soil.

It is a simple and sustainable way of managing waste, while also being a valuable resource for the people of Devikulam as most of the community are in the agriculture business in need for rich compost to use. Turning the waste problem into a valuable resource is a major gain from installing compost toilets. The typical issue of obtaining water for toilets is eliminated as no water is needed for compost toilets. By not needing to acquire or install water pipes reduces costs, although compost toilets do have relatively high costs at around a thousand dollars for the toilet itself not including installation. Transport and disposal of the waste isn’t needed as it is a recurring cycle which would save a lot of money on employment and equipment.

The issue with the composting toilets is the constant maintenance needed and the problems that arise without proper care for them. Compost toilets need a very precise amount of organic materials at the right temperature and moisture levels to work effectively. This would mean constant maintenance and routine checks would be needed for them. Due to there being no one already trained on how to look after compost toilets it was not the best option to choose. Proper maintenance is vital as in the wrong environment waste can maintain their harmful viruses and pathogens which are dangerous for the health of the community. This would also create unpleasant odours, which could turn the community off the toilets, defeating the purpose of the project.
3.3.2 Pit Toilets

A pit toilet is a cheap, easy way of collecting the waste into one single area where it can be vacuumed out or backfilled and buried over when full. It is effectively just a large concrete lined hole where the waste can fall straight into. Often this waste is transported to some wastewater treatment plant nearby. Pit toilets are usually found in rural areas where there is no sewage piping or electricity.

The great affordability and simplicity of the pit toilet is what makes it such an appealing option for managing the waste in Devikulam. Building them involves digging a hole and lining it with concrete which would only take a couple of weeks per toilet. There are no pipes or electricity needed for the toilets to be able to function. Little maintenance is needed, which is valuable for such an isolated town that has no real expertise in this field. The gravel toilets are a simple way of eliminating issues associated with people going to the toilet everywhere around the town, but it is not a sustainable option for the city.

While the pit toilet is easy to install and can last a long while, it doesn’t provide a sustainable solution to waste management. If the waste was to be vacuumed out it would need to be taken by truck to a sewage plant. This would be costly as Devikulam is so isolated, plus large trucks may have difficulty driving around the town to the different pits due to the lack of functioning roads. Just disposing the waste is an unwanted outcome for managing waste in Devikulam as it is harmful to the environment and won’t be able to last forever. Recycling and reusing are much more ideal options that the pit toilet doesn’t provide.

3.3.3 Flushing Toilets

Flushing toilets are by far the most modern, clean, and easy to use toilets available today. The huge advantage of a flushing toilet system is the fact that the system can be upgraded later with more toilets, creating equity amongst the villagers, ensuring that the advantage of the toilet is evenly spread. Also, the centralised treatment of waste allows for easier disposal, as well as shared management. However, the disadvantages of this system are the larger initial outlay, and the requirement to construct a sewer to dispose of the effluent.
3.4 Waste Disposal Methods

3.4.1 EcoSan Toilet

The EcoSan system is a patented design that turns waste into a valuable product used in making rich compost and certain fuels. Waste is passed through a screw conveyor that is continually screwed every time the toilet lid is lifted. The liquid from the waste is evaporated over the 25 day process, leaving only a small amount of solid, odourless matter that is deposited through the end of the screw like chamber. This can then be given to farmers for compost or factories using it in the process of making fuel.

The EcoSan requires no drains, piping, water or chemicals. This would be ideal for the small, remote community of Devikulam as these things are hard to obtain and creates a certain level of maintenance needed. The waste can be recycled for 6-10 families per toilet into an important resource for the community. This is an efficient way of battling Devikulam’s current waste management issues.

The EcoSan has local and international patents on its design, meaning it would cost a lot for them to be installed, as well as being a rather complex system to install in the first place. This high cost, tough installation and the villagers’ adverse reactions to human compost led to it not being the best option for Devikulam.

3.4.2 Anaerobic Baffle Reactor

An anaerobic baffled reactor is an extremely effective septic tank that filters waste from the toilet by passing it through a series of chambers. Waste falls down into a ventilated chamber where it slowly passes over active biomass. It takes about two days for the slightly angled water and waste to reach the outlet where it is has been digested and is now safe to go back into the lake. Every 2-3 years the resultant waste at the bottom of the tank needs to be emptied.
The anaerobic baffled reactor is a good concept for reusing the waste of Devikulam as it requires no electricity and is relatively easy to build from local materials. It also lasts for a long period of time, meaning it is a long term solution for the waste management problems in Devikulam.

The main issue with the design was the need for a constant volume of around 2000 to 200 000L of water needed which we found would be difficult to achieve, especially in the summer months. The lake in Devikulam is already used for bathing and cleaning by the community so using water from this in the Baffle Reactor may not be readily accepted. Constant maintenance is also needed for checking the sludge balance every few months. This sludge also needs to be removed every 2-3 years with some kind of vacuum which creates maintenance issues that would be difficult to follow through with due to the isolation and lack of expertise in Devikulam.

3.4.3 Gravel and Sand Filter

A gravel filtered pit toilet is a sustainable way of filtering the waste from a flushing toilet. Layers of gravel and sand can slowly filter the waste through biological processes once the toilet has been flushed. This water is then fine for drinking after about 3-4 years.

Waste goes through a toilet as it normally would, but instead of going to a sewerage plant or wetland it seeps through layers of gravel and sand where it is filtered and returned to the underground which can then be pumped using a bore pump. Gravel and sand filtration toilets are often uses in remote areas all over the world due as it is relatively low cost and is a good replacement if a town doesn’t have a sewerage system or another type of wastewater treatment place.

Although the gravel filtered toilets is a sustainable option, it needs a lot of water per flush to make sure it will go all the way down.

3.4.4 Algal Lagoon

An algal lagoon can treat waste water through a series of complex chemical reactions that effectively break down the harmful components of the waste. Algae grow best in high temperatures, along with low flows and temperatures. This is a close representation of the climate in Devikulam, meaning this process should be effective.

Algal lagoons work best in small communities like Devikulam as there are less amounts of waste, meaning the process will be more effective. Using the pre-existing lakes as algal lagoons would have
been most efficient, although this may have had negative repercussions on the community as it can tend to release unpleasant odours. The people of Devikulam already used the lakes for washing themselves, so an acceptance of this new algal lagoon would seem unlikely. It would also need constant regulation as very often there is an algae overgrowth which must be controlled for the system to keep working efficiently. This would be difficult to follow as there is a lack of people capable to fulfil this job currently living in Devikulam.

3.4.5 Wastewater Treatment Plant

Sewage plants are the predominant way waste is disposed in western society. Advanced technology is used to turn waste into a less harmful product.

The technology used in wastewater treatment plants is continually progressing, increasing the performance and sustainability. The best option would be to build a small scale treatment plant at a larger city nearby that the waste could be transferred to. This would be more effective than a large plant that is too hard to maintain and provide power to. A large scale sewerage plant would be best in a very large city far away such as (). This would be very costly and difficult to transport their waste to.

There are only 17 working wastewater sewage plants in India. These are much too small to treat any marginal amount of India’s wastewater. There are only so few plants as they lack proper maintenance and pumping, therefore causing overflowing or blocking to occur. The idea for a sewage plant is much more suited for a larger city with the recommended maintenance and electricity needed for pumping. The cost associated with building and running the treatment plant is a large issue, being a minimum of one million dollars. The large cost, along with the sewage plant having to be located in another larger city to be effective, makes it a flawed, complex option for dealing with waste in Devikulam.

3.4.6 Rice Paddy

Rice paddy fields are used in growing monocots that contain seeds known as rice. The use of paddy fields has been around for thousands of years and to date over 100 countries including China, India and Japan are currently using them. They work by flooding a large area, creating an ideal environment for the growth of monocots.
India currently has the second largest export of rice in the world, with China being number one. This means there would most likely be a lot of knowledge of how to grow it throughout the country, including surrounding cities of Devikulam. If the rice paddy was effective it could provide a reliable food source for the Devikulam, as well as filtering their waste.

The main issue is trying to use the rice paddy as a sort of filtration for their waste. It may become a tough job getting the community to eat this rice being filtered by their waste. Rice paddies require a great deal of maintenance all year round in keeping a healthy growth of monocots. A great deal of education would be needed for the Devikulam farmers before they could start using paddy fields without assistance.

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Figure 3.4: Treatment Feasibility Chart
4. Design Solution

4.1 Structure

The final design chosen is a multi-stage system capable of providing Devikulam with appropriate sanitation technology and non-potable water supply. The final system configuration chosen is capable of effectively removing human wastes and treating it in accordance with Australian government standards of 30mg/L BOD5 (Australian Guidelines for Sewerage Systems: Effluent Management, 1997) The system is designed to be built in stages and fully upgradable, allowing it to cater for an increasing population, given the upwards trend of population growth in India (National Informatics Center. 2006). The system also has the twofold benefit of providing on-demand non-potable water for the people of the Colony quarter.

The construction of the system is designed to be basic and cheap, and in its basic version requires no specialised materials and no machinery to construct or operate, keeping it within the means of the villagers. Only basic construction and plumbing knowledge is required to build the initial system and subsequent upgrades.

The system is also designed to be minimal maintenance and have a long useful life. Similar systems worldwide have been in operation for over 20 years with no major problems, as well as operating in a variety of contexts. (Wood, 1995)

4.2 Stage 1: Toilet Block

The system has several blocks of toilets, with each block having four toilets. The toilets are a typical eastern squat design, and are raised approximately 300mm above floor level. The raise has been chosen to simplify construction allowing the bowl to remain above ground, simplifying plumbing, while also providing moderate flood resistance in the monsoon season. The construction of the toilet block buildings can be any construction method which is available to the villagers, whether it be Bamboo Reinforced Concrete, or basic Mud Thatch. Flushing is intended to be a gravity fed system, utilising the optional overhead water tank, however can be bucket flushed if funding constraints do not allow overhead water tank.
The optional overhead water tank can be implemented using two different methods. Method One is the most cost-effective and involves constructing a toilet block directly below an existing overhead water tank. Devikulam has one such tank which is not currently in use. It is proposed that a toilet block be constructed underneath this tank in order to minimise extra costs involved with the project.

Option two involves installing a new overhead water tank. In order to achieve appropriate elevation, and to minimise cost, it is recommended that either the tank be incorporated into the construction of the toilet block (ie roof mounted) or by utilising an off-the-shelf aftermarket tank stand. The nominal capacity of the tank should be in the order of 1000L to be able to provide enough water for functional operation of the toilets for daily operation, with a safety margin included in the event of pump failure or misuse of the water supply.

The other requirement for the water tank option is a pump. It has been identified that a solar powered electric pump would be the best option for the community, as solar requires no grid connection, and hence no-one is required to pay for the on-going costs for general operation.

**4.3 Stage 2: Sewer System**

![Figure 4.1: Proposed sewerage system diagram](image)
The sewer system is again a basic design, with heavy-duty PVC piping chosen in accordance with WHO standards. One pipe connects each toilet block, and each block connection runs into a junction connecting with other blocks. This pipe then runs into the first stage of the constructed wetland. PVC piping was chosen as a compromise between cost and durability over pre-cast concrete piping, as PVC is far more cost-effective than concrete, but lacks the durability of concrete. However, PVC meets the WHO standards for piping, and is therefore acceptable for our needs. [World Health Organisation (2006)]

4.4 Stage 3: Treatment Wetland

The wetland treatment system is the final stage of the Devikulam sanitation system. The system is a hybrid of two different wetland designs, with a Free-Water Surface Constructed Wetland the initial stage, with a Horizontal Subsurface Flow Constructed Wetland the final stage.

Figure 4.2: Wetland Treatment System

Figure 4.3: Free-Water Surface Flow Wetland
The first stage, the Free-Water Surface Constructed Wetland is responsible for breaking down solids and neutralising some pathogens. The wetland is constructed in an excavation 12x50x1m, with a level gradient. Such a size was calculated to allow for future capacity. The wetland is kept watertight through the use of a clay lining around the edges of the pit. Clay was chosen over expensive geotextiles due to the fact that clay is locally available and cheap compared to specialised materials. The pit is partially filled with sand, in which the *Phragmites karka* reeds are planted in. The spoil from the excavation is placed in an embankment approximately 1m high around the wetland. This embankment is designed to prevent excess water from escaping, and also to prevent monsoon rains flooding the wetland.

The first stage works to treat the blackwater in several ways. The slow motion of the water acts as a settling pond for any solid waste, breaking it down. The nutrients from the waste are then absorbed by the reeds through their underground rhizome (root) network. In addition, the open nature of the pond allows the intrusion of UV radiation, contributing to the destruction of pathogens (de J. Quinonez-Díaz *et al.*, 2001).

![Figure 4.4: Sub-surface Flow wetland](image)

The second stage for the waste treatment is a Horizontal Subsurface Flow Constructed Wetland. This stage is responsible for the final treatment of the blackwater. This stage is constructed similarly to the first, however there are some differences. The wetland is constructed in an excavation approximately 12x50x1m, with a 1% gradient falling away from the inlet. The wetland is kept watertight through the use of a clay lining around the edges of the pit, with the clay lining discontinued for the last quarter to allow the treated water to flow back into the water table. The pit is completely filled with sand, again
in which the *Phragmites karka* reeds are planted in. The spoil from excavation is placed in the embankment in Stage One, helping reinforce the wall.

Blackwater treatment is performed in this stage is mainly performed through filtration by the sand. Despite the fact that relatively large sizes of sand particles can be used, it is capable of filtering physical masses of sizes greater than 0.01mm and constricting bacteria with sizes as small as 1μm. Nutrient removal is also performed by the *Phragmites* reeds. (Shaw, 1999)
Figure 4.5: Sub-surface Flow Wetland after construction

Figure 4.6: The same wetland two years later.
5. Implementation

5.1 Human Capital

There is human capital that is needed for the completion of our project. This includes the construction workers to construct the system, engineers to oversee the process as well as the end users input during the process.

We have identified that it is crucial to involve the village people of Devikulam as much as possible during the commissioning stage of the project (Waylen et al., 2010). This is to ensure that the context in which the project is taking place is accounted for. This includes placement of the toilet system, environmentally sustainable construction process and also for the villagers to have an understanding of how everything works.

We are using local villagers to help with construction and they will receive a small payment for their work. This is to ensure that any money being spent on the project will benefit Devikulam and its villagers as much as possible. The use of local construction personnel also ensures that again, the context of Devikulam is appreciated as much as possible (Waylen et al., 2010). These local workers from within the village can be used because not many villagers have constant ongoing work. They can be paid on their days off for the work they contribute. The local construction workers will also be educated in construction of the toilet systems (See section 5.2 for more details).

However some higher skilled construction personnel will have to be sourced from outside Devikulam for the more complex construction stages. These will be construction workers with experience in: plumbing, brick laying, concrete work and general construction. These workers will be sourced from as close as possible to Devikulam. Along with the engineers these workers will educated the local workers (See section 5.2 for more details). Along each step of the construction process the engineers and skilled construction workers will be receiving feedback from the local village people. This is to ensure that the social and environmental factors of Devikulam and its surrounding areas will be taken into account.

The engineers will be responsible for overseeing the process and will have to be obtained from outside of Devikulam, with the help of EWB. Preferably these engineers will be from within Indian and from within the state of Tamil Nadu in which Devikulam is located. These engineers will assist in
the safe and efficient construction of the project. The engineers will work closely with the higher skilled construction personnel and the local workers to ensure the process of construction and commissioning goes as smoothly as possible.

As well as human capital for the construction phase, there is also a small amount of ongoing maintenance (see section 5.4). The toilets need to be kept clean and the users of the toilets will do this (See section 5.2). If there is any unscheduled maintenance such as repairs this can be carried out by the local workers who have been educated and involved with the construction process. This prevents the need for outsourcing workers and allows the full operation and maintenance of the system to be carried out as much as possible by the locals of Devikulam.

### 5.2 Education

For the success of our project to be realised, education will be essential (Cairncrossa et al., 2005). The villagers of Devikulam will need to know how to use our toilet system and the maintenance procedures associated with it. The workers constructing the building will also need to be educated.

The commissioning stage of the project does not require exceptional skill but does require basic knowledge of some plumbing and construction process and hence some education. The external engineers and skilled workers will provide this expertise to the local construction workers during the construction of the first system. Having had the local villagers educated on and helped with the construction of the systems will mean that in the future if a problem was to arise then help can be found locally.

The first toilet block and system will be constructed with the complete team of workers and engineers. During this stage engineers and skilled workers will detail specific steps and stages in the construction. From connecting the plumbing, erecting the building, constructing the reed system and initiating the operation of the whole system, the engineers will work with the skilled workers to make sure each local worker is competent in constructing the toilet system until each one is able to work in a team without assistance. These skilled workers and engineers will continue assisting with and overseeing the project. It is crucial that each local worker is marked competent as being able to safely assist in construction. The local workers have the most knowledge of how the village operates and as mentioned having their input will allow for the construction and implementation to take this into account.

Once construction is complete, education is needed on the ongoing use of the toilet. The toilet is a traditional squat style toilet so the basic use of it should be familiar to the village people because
when they are going to the toilet they are currently squatting. There are some differences however. Our toilet has a hose for cleaning the body after using the toilet and a bucket for flushing. This hose is to ensure the hygienic operation of our toilet system. We have also put in place a sink for washing hands as another way to ensure hygienic operation. The basic steps to use the toilet are:

1. Fill the bucket next to the toilet with the hose by turning the tap and filling
2. Position feet on sides of toilet and manoeuvre into a squatting position over the bowl
3. Do what you need to do
4. Then use the hose again, this time to clean your body parts
5. Then use the bucket of water to pour down the toilet to flush
6. If there are any debris on the bowl use the brush and scrub off
7. Wash your hands with soap at the sink

The idea is that if everyone follows this same procedure that the toilet will be kept in a clean and sanitary condition, ready for continued use and its users will be living are more hygienic life. There is similar hygiene education happening in this area of India (Snel et al., 2002) and studies have shown that hygiene education have been successful (Biran et al., 2009). To ensure that everyone knows and follows these procedures we will be doing two things; inside every toilet there will be a poster so that the user knows what to do, secondly upon the completion of the construction of the system, the local village workers who were involved in the process, will give the other villagers who were not, a tour of the toilets and further push the correct procedure.

Due to the nature of our reed filtration system, raw sewage will be in open areas. It is essential that no one enters the reed area unless necessary and following the correct procedure. To ensure that this doesn’t happen there will be signage around the reed beds (See appendix). If it is absolutely necessary for a person to enter the reed area for repairs to the system then they must do it following procedure. This includes wearing waders and other personal protection equipment. If someone was to fall in the reed are they could become very sick (UK Health and Safety Executive, 2009).

It is through the education that our system is more likely to be a success (Waylen et al., 2010). From the initial education of the engineers and skilled workers on the context of Devikualm to the education of the people of Devikulam themselves, education is a key part and needs to be provided from beginning to end (Waylen et al., 2010).
5.3 Construction/Installation

Our project consisting of a toilet system and vertical reed system will involve a number of construction stages. From surveying the proposed construction area, preparing the land, constructing the buildings, constructing the wetlands and the final plumbing fit out and testing. As noted section 5.1 and 5.2 there is various human capital and education that is needed for the construction of the project. You will see below that local workers can complete many parts of the construction with little construction knowledge. However the experienced construction support team and the engineers will oversee and assist with the whole process. Note that the following construction process is for one toilet block and one reed filtration system. The same process will be applied multiple times for the full construction of our waste solution.

The first stage of the project will be to identify and prepare the land area for construction. There is a number of sites around the village of Devikulam where the toilet blocks will be placed, there is then going to be separate reed filtration systems for a group of toilet blocks. Having separate reed filtration systems in different parts of the village will allow for less piping and therefore a more economical construction. There areas for the toilet blocks will be situated between different clusters of housing. In order to minimise cost, the land that is selected will be as flat as possible and as clear as possible, that is with minimal trees and other growth (Scutella & Heberle, 2005). The three spots of land for each toilet block will also need a clear path for piping to the reed filtering system and this will be taken into account when selecting the site. When selecting the sites for the toilet blocks, the engineers as well as the workers from Devikulam will be involved. The engineer’s input is needed to make sure the land is technically suited and the local worker’s input is need to ensure that the land is suited for the village. It cannot be too close to any busy areas of the village or on ground that already has uses planned in the future.

Once the sites for each toilet have been selected, the land will need to be prepared for construction (Scutella & Heberle, 2005). Firstly any obstructions on the selected site will need to be removed; this includes trees, plants and any large boulders or other objects. Once this has been completed the land will need to be made flat and even. Excavation equipment may be needed to move dirt and sand to flatten the area and make it perfectly flat, this does depend on the gradient of the land and how much it needs to be altered. The next stage is to compact the earth on the site. Motorised compactors will be used for this. This is done to prepare for the concrete slab that will be placed on top. That completes the site preparation. Local workers will be able to complete this stage excluding the use of an excavator which will need to be done by trained personnel.
The next stage is to prepare for the concrete slab. This involves two parts: constructing the concrete footings and to pre-install necessary plumbing. Any plumbing required before the footing is constructed will have to be placed down (Scutella & Heberle, 2005). The sewage outlet pipe coming from the toilets and the water inlet pipe coming from the tank may be needed. The footings will be constructed around the edge of the slab. The standard size of footing that we will use is a 400mm wide by 400mm deep reinforced concrete footing (Garcia 2010). Steel reinforced concrete is the standard for footing construction (Scutella & Heberle, 2005). This size does depend however on the selected site. Firstly a trench for the footings will have to be dug and secondly the steel reinforcing will have to be placed in these trenches. Concrete will then be poured into the trench and allowed to cure. This completes construction of the footing. Any additional plumbing that needs to be done before the slab is installed will be done now. This includes the pipe from the toilets to the edge of the site. The continued plumbing to the reed filtration system will be constructed at a later stage. This can all be completed by the local workers with the help of the skilled workers.

The next stage is to construct the concrete slab. The slab will have to take into account the weight of the walls, the weight of the concrete flat roof and the weight of a full water tank. The slab is constructed of steel reinforced concrete. It will take some time for the footings to fully cure before the slab can be constructed. Firstly a wooden mould for the slab will be constructed, the steel reinforcing is then put in place and then the concrete is poured into the mould (Scutella & Heberle, 2005). It is essential, especially in a hot climate that the concrete does not dry out. Water will be needed to ensure during the curing process that the slab does not dry out and crack (Dee Concrete, 2010). This stage can be completed mostly by local workers.

The next stage, after the slab has cured, is to construct the exterior and interior walls. The walls will be made from bricks. Bricks have been chosen for the construction material because they are cheap (see section 5.5) and can be sourced close by. Bricks can also be used in the event that our system is decommissioned (Gregory et al, 2004). The walls have to be able to carry a concrete slab roof and a full water tank on top of that and this will have to be considered before construction. Local workers will be trained and then carry out this part of construction.

The next stage after the completion of the walls is to continue with plumbing. This is done before the concrete roof is installed. Plumbing of piping from the roof tank will need to be put in place. This piping will be standard copper piping used for residential plumbing (Scutella & Heberle, 2005). A pipe with a tap on the end will need to be placed inside each cubical. This piping will come from the roof tank and down the wall in each cubical. There are standards for plumbing that need to be met and the local workers will be trained on these and then allowed to proceed with it themselves (World
After the completion of the plumbing the roof will be constructed. The roof will be constructed of steel reinforced concrete. This is necessary to be able to support the water tank that will be placed above. The exterior walls will support the concrete slab roof. As with the foundation for the building, a wooden mould will need to be constructed into which the concrete will be poured. The mould for this part is a little more involved. Wooden sides for the mould and a wooden base will have to be constructed. Supports will be placed inside the building to support the wooden mould and concrete from underneath. After the completion of the mould the steel reinforcing will be placed in the mould.

To pour the concrete into this mould will be harder than for the foundation of the building because it is above the ground. A standard cement truck will not be able to pour concrete into this mould. However with a simple ramp system and some wheelbarrows the cement can be poured into the wheelbarrows and taken up the ramp and dumped in the mould (Scutella & Heberle, 2005). The slab is then left to cure, again it is critical to ensure that the slab does not dry out and crack (Dee Concrete, 2010).

The construction of the above mentioned mould and concrete roof is more complex than any of the previous stages and will require greater assistance form the skilled workers. The construction and support of the mould must meet safe standards and thus will be carried out by the skilled workers to ensure this. The pouring of the concrete into the mould can be completed by the local workers.

The main construction stage of the toilet block has been completed. It is just further fitting and installation that needs to be completed. The next stage is to install the polyethylene water tank. This will have to be fastened to the roof. The piping and taps that were previously installed need to be fitted to the tank. The copper piping to the taps needs to be extended and joined to the tank. The pipe from the pump can also be linked to the top of the tank. The toilets themselves will then need to be installed; there will be 12 of these in each toilet block. The plumbing for the toilets was completed prior to the foundation being constructed so the toilets can simply be placed in their associated cubicles, lined up with the piping and then glued and fastened in place. Doors will need to be fitted to the building to complete this process. There will be a door on each cubical.

The process for constructing the wetland does not take such an involved process however is even more crucial. Once again a suitable area for the wetland will have to be found. This land will be as much as possible; central to the toilet blocks it services. The area will need to be as clear as possible: this includes trees and plants. Again the local people of Devikulam will be involved in this process to
ensure suitable land is selected, away from busy areas and areas already planned for development. After the area has been found it will need to be cleared.

Firstly any obstructions on the selected site will need to be removed; this includes trees, plants and any large boulders or other objects. The areas need to be marked up and dug out to the correct size and they will be sloping to allow the flow of the waste. The bed of the reed area will be compacted, to ensure that sewage does not seep into the water table (Kadlec & Brix, 1995). To stop the walls of the reed area collapsing in, a clay wall will be built around the inside of the reed area. That completes the initial preparation of the area.

The next stage is to fit the inlet pipes. The piping from the toilets will be divided up as it comes into the vertical reed system. The vertical reed system allows the waste to be spread evenly over the reed area so that the whole reed area is utilised as opposed to horizontal wetlands. This piping will be fitted across the red bed and held in place by the walls. The piping from the toilet blocks to the reed area does not have to be completed at this stage. The outlet piping from the reed area will be put in place. This is a large diameter pipe that acts as an exit at the end of the read area once the waste has been broken down by the reeds. This will pass through the clay wall. These stages can be completed by the local workers with the assistance of the skilled workers.

The bed of the reed area is going to comprise of course sand and gravel. The layer of sand will be along the base of the reed area with the gravel placed on top of that. Once these materials are in place, the reeds need to be planted. The reeds that are being used are native to the area (Billore et al., 1999). The reeds will be planted throughout the reed area. They are to be spaced quiet close together so that the reed system can be effective immediately after construction. The placement of sand and gravel as well as the planting of the reeds can be done by local workers. Any excavation equipment needed to move sand or gravel will need to be operated by trained personnel.

The next stage is to complete the plumbing and the instillation of the pump and solar panel. Currently the villagers have a bore feeding into a 30,000 litre water tank and this is used for a variety of things, these include: farming, washing and drinking (Engineers Without Borders, 2011). Our system will also use water from this tank. The pump for our system will be located next to this tank. The solar panel will be mounted high on a pole out of reach so that it can’t be tampered with or stolen and a second solar panel will also be mounted on the pole as a backup power source for the bore pump that feeds into the tank. A steel pole is to be put in place next to the tank with two mounting brackets, one for each panel. The panels will be tilted slightly to the south to obtain maximum possible sunlight.
The next stage is to complete the final piping. The piping from the pump next to the tank to the toilet blocks needs to be completed and the piping from the toilet blocks to the reed filtration areas. These pipes will be buried underground. After the piping and electrical for the pump has been installed, that stage is completed. The trenches in which the piping is buried should not yet be filled in.

The construction is now complete. To finish off the implementation the system needs to be commissioned. Now that the pumps are connected they will be constantly topping up the tank. The whole system should be monitored at this stage. The pipes need to be monitored for leaks, as well as the tank and the taps in the toilet block. The engineers and skilled workers will okay this if it is deemed to be working correctly. The trenches can then be filled in on the tank side. To test the plumbing on the toilet side the hoses will be temporarily placed in the toilet to direct feed water into the toilet. This is done to make sure that water satisfactorily reaches the reed system. Once this is given the okay by engineers and the skilled workers then these trenches can also be filled in.

There are a few things left to ready the toilet system for use:

- Buckets and toilet brushes need to be placed in each cubical
- Wall posters need to be placed in each cubical
- Signage needs to be placed around the reed areas

That is the completion of the construction and implementation process. After this process is complete the education process needs to be swiftly implemented. This is to ensure that the toilet system is a success and fits in with the social context and lifestyle of the village of Devikulam (Waylen et al., 2010).

### 5.4 Monitoring and Maintenance

One of the benefits of a solar powered pump is that it is easily maintained (Bahadori, 1978). The more complex a system is, i.e. the more moving parts, the more likely it is that a component could fail and would need to be attended to by a qualified person. Therefore a less complex system is likely to work for a longer period of time without any problems, and as a result would require less maintenance. The system should also be regularly monitored to ensure that the pressure of the system has not changed. This can be done by recording the operating pressures on the pressure gauges, and noting any difference (Solar Pumps, 2010).
The water tank needs very little maintenance. Samples of water should be tested every year or more frequently if possible, to ensure levels of chemicals such as sulphur and iron oxide are not at harmful levels (Solar Pumps, 2010). The fittings should also be checked for scale build ups. Mosquito breeding is also something that should be checked, and stopped by adding domestic kerosene. Once every 2-3 years, the bottom of the tank should also be checked for any signs of sludge, which should be cleaned off. Although it is not necessary, if the water in the tank is thought to be contaminated, it is possible to disinfect it by adding 40ml of liquid sodium hypochlorite or 28 grams of granular calcium hypochlorite (Department of Health, Government of South Australia, 2008).

For the toilets to stay in good condition over their useful life, they should be cleaned at least once or twice a week with water and a toilet brush and at least once every two weeks with cleaning detergents. Each family should be responsible for cleaning their own toilets. To know how much water has been used, and the changes in demand, a water flow metre and data loggers can be installed on the discharge pipe. This will help to identify faults with either pipes or valves, as a decrease in demand can mean a blockage in pipes or even in vales. An increase in the water flow can be the cause of a valve that is faulty and won’t close (Solar Pumps, 2010). Any problems with the toilets or pipes would require a professional plumber to fix it.

The final part of the design is the reed bed filtration system. The Phragmites karka reeds require no maintenance after initially being planted (Kivaisi, 2001).

5.5 Project Costing

To estimate the cost of this project, we must consider the different costs associated with each toilet block, and the costs of fittings that make each toilet function. These can be further categorised into one-off costs and ongoing costs. The major costs to be considered in our project are:

- Water tank.
- Solar powered pump.
- Toilet block (building, with squat toilets, hoses, sinks, soap, and plumbing).

The SHURflo 2088 Series Diaphragm Pump and 120W solar panel were chosen not only because they are ecological, and a renewable energy source, but also because of the cost savings (Paoli et al., 2008). Solar powered pumps may initially cost more, but the electricity savings over the useful life of the pump, will save money (Thirugnanasambandam et al., 2010). To estimate the ‘cost of ownership’
of a solar powered pump, the initial cost of the pump as well as ongoing operating costs must be added. The ongoing costs would include the cost of maintenance, system monitoring, repairs, and manpower (Solar Pumps, 2010).

As mentioned above, a simpler system has less moving parts, and hence there is less chance that a component will fail to work and as a result requires less maintenance. The pumps would need to be maintained by staff that have experience with the systems, and are able to identify problems with the system and know how to fix them. These staff members would be paid an hourly rate, and since less maintenance is needed for simple systems, the cost of maintenance is reduced. If the system was checked and monitored for two hours in a month, at a labour rate of approximately $16, in a year this would cost $384 in a year (Kumar & Tiwari, 2009).

The SHURflo 2088 Series Diaphragm 12 VDC Pump will cost $95.58 AU. The 120W Mono-crystalline solar panel will cost approximately $639 AU (Wholesale Pump Agents, 2010; Volt Electronics Superstore, 2009). Due to the lower manufacturing cost in India, it is expected that if the pump and solar panel were purchased there, they would cost less. (Clark, 2009)

The water tank will store the water needed to flush the toilets. We have estimated that in order to provide sufficient amounts of water for the 12 toilets in the block, an 1100L water tank is needed per block. This 1100 L polyethylene water tank will cost $545 including GST in Australia. The tank has a 20 year warranty, so there are no other ongoing costs, but the tank may need to be replaced after 30 or so years (Irrigation Warehouse Group Pty Ltd, 2010). It is expected to cost less if it was purchased from wholesalers, or purchased in India.

The cost of the toilet block will be made up of the cost of purchase and installation of 12 squat toilets, the actual building that the toilets will be in, and plumbing them to the wetlands. The squat toilet used, will be a white ceramic one that can be purchased from an Indian wholesaler company that sells them for approximately $2.70 each for a minimum purchase of 2000 toilets (Alibaba, 2011). For our project we will not be requiring all of the 2000 toilets. The remaining toilets could be sold to retailers in India, or could be used to develop other small towns in India where they currently don’t have access to toilets. The total cost of purchasing the 12 toilets in one block will be $32.40. The cost of installation will depend on the labour rates in India, and the number of hours required for installing them.
The cost of the building that the toilet blocks will be in can be calculated by calculating the cost of the materials, and calculating how much you will need. The dimensions of the building are 4m x 6m x 2.4m. The steps that should be taken to calculate costs are:

1. Calculate the total area of the wall.
2. Find out how many bricks are needed.
3. Find out the cost per brick and multiply this by the number of bricks required.

The following calculations were made with the assumptions that:

- One toilet cubicle will have dimensions 1m x 1.5m x 2.4m.
- A standard size brick has dimensions: 76mm x 230mm x 110mm (Boral, 2002).
- The standard cost of one brick in India is 2.5 Rupees (The Hindu, 2005).

The total area of the 4 walls and the 10 small cubicle walls inside the building are;

\[2(6\times2.4) + 2(4\times2.4) + 10(1.5\times2.4) = 84m^2.\]

Therefore the total area = 84m\(^2\) ≈ 4116 standard size bricks (Boral, 2002).

The total cost of purchasing the bricks is 4116 x 2.5 = 10 290 Rs ≈ $217 AU

The cost of concreting the building as quoted by an Australian company would be roughly $1300. (Mick Taylor Concreting, 2011) This is expected to be higher than the cost of the cementing in India, because of the cheaper labour rates (Lerche, 1995). The cost of 13 doors at a wholesale price of 400 Rs each would total 5200 Rs ≈ $110 (Alibaba, 2011).

The 6m x 4m slab and the flat concrete roof will approximately cost $3000 AU, including labour costs. (Wendy, 2011)

The cost of 100mm diameter PVC pipe is approximately $19 for a 3m long pipe (Bunnings Warehouse, 2011). The maximum amount required is estimated to be around 300m, bringing the one off cost to $1900. An alternative to the PVC pipe is the SA sewer concrete pipe, with a diameter of 675 mm. This type of pipe is larger, and costs $145 p.m (Rocla, 2011). Therefore the total cost of $43500 is substantially higher than the cost of the PVC pipe.

Personal hygiene is being promoted as part of the education system. The design consists of one or two wash basins per toilet block and soap to wash hands with. Basins can be purchased from
wholesalers at a cost of $35 each for a minimum purchase of 10 basins. (Alibaba, 2011) A 25L antibacterial liquid hand soap can be purchased for $79, and a 25L toilet bowl cleaner can be purchased for $69. (Bulkwholesale, 2011) As mentioned in 5.1, there will be a hose in each cubicle for personal cleaning, and a bucket to flush the toilet with. The ‘Shower and Toilet’ hose can be purchased from wholesalers at a cost of $0.75 for a minimum purchase of 500. (Alibaba, 2011) The cost of 12 hoses for each toilet block sum up to $9.

The cost of the reed bed filtering system would include the costs of the *Phragmites karka*, and the cost of the gravel sand filter. The cost of construction and maintenance of the *Phragmites karka* are negligible (Trivedy, 2007). The cost of sand in India is approximately Rs.3,000 for two units of sand (inclusive of freight charges) (The Hindu, 2010).

### 5.6 Economic Events

To know the possible future costs of the system, we must consider all possible future events. An event that could potentially cost more is the growth of the population. This could require more toilets to be built in the village, and in return increase the demand of the water pumps, tanks, and the reed bed filtering system. There are also unlikely events such as natural disasters that should also be considered. There is likelihood for damage to be done on local reeds by strong winds, or storms during monsoon season, as well as damage to the water tanks and the toilet blocks. The costs that might arise from this, range from costs associated with adding a toilet or two to a block or increasing the size of the water tank, to building a whole new toilet block that would also require additional plumbing to the reed bed filtration system and even potentially increasing the size of the reed beds. Other factors that affect the cost of such repairs or replacements are inflation. Inflation rates are increasing throughout the world, and this could alter the future costs of the different parts if they are to be replaced. The organisation or company funding this project could set up a deal with the manufacturers, whereby the manufacturers are under contract for particular parts if they agree to supply the products at a certain price for the period of the contract thus eliminating the inflation cost risks. This also benefits the manufacturing company as they have work for the time of the contract.
6. Impact Assessment

6.1 Introduction

Given the context in which we are engineering, it has been of chief importance throughout the designing process to ensure that the proposed solution will not only have a positive impact on the Devikulam village and its community, but that it will also be sustainable and efficient. By identifying the implications of each of our preliminary designs, both positive and negative, we were not only better equipped to decide on our final strategy, but it also allowed us to qualify the benefits of our design, and pre-emptively solve issues that could arise from the implementation of our ideas.

As highlighted by Denny (1997), the implementation of wetlands in developing countries has been a slow process, this being attributed to a shortage of individuals involved in tailoring designs. Most alarming was Denny’s observation that humanitarian projects are often engineered with commercial interests in mind (as might be the case with the EcoSan toilets being trialled):

“...aid programmes from developed countries tend to favour the more overt technologies which have commercial spin-off for the donors...”

Sharing the sentiment that “assistance and support must be foremost” when implementing projects of this nature, our goal has been to empower the village to develop—but at its own pace.

We will analyse the impact of our project from three main perspectives of Devikulam; the economy, the social dynamic, and the environment encompassing the village. We cannot underestimate our influence on Devikulam—despite our project having noble aspirations, without truly understanding the wants and needs of the recipients, it is impossible to predict the success of changes that are made.

6.2 Economic Impact

Due to the economic constraints in Devikulam (in terms of poverty, minimal technological development and lack of commercial industry), we have to ensure that we are providing a human waste management alternative that is not going to impose a financial burden which outweighs the benefits of our solution (EWB, 2011). Ongoing expenses would manifest in the form of maintenance (cleaning products) and utility usage (water, electricity).
As the reed beds are essentially self-sufficient (although Denny (1997) implies that efficacy of the system is improved when the growth is cropped regularly), there would be no need to employ someone to maintain them. It would be necessary for those responsible for each toilet to use the chemicals made available to the village for cleaning purposes at regular intervals; depending on project funding these chemicals would either be provided by government/private entities, or each family in the village would pay a small fee for these cheap supplies. Another necessary expense is hand sanitizer/soap. These chemical products have the advantage of being versatile and could be used to improve hygiene conditions in any area of the village, for example maintaining sterile kitchen surfaces and cookware.

In regards to repairs, the design is very simple and would require no trade expertise to make repairs to the toilet block. Problems could arise should the piping running from the toilets to the wetlands become blocked or broken—if there is no one capable of doing plumbing work, someone may need to be called in from a larger city such as Kadapakkam (22km away) or assistance requested from Pitchandikulam Forest (see Section 2). It is conceivable that assistance would be provided by the same entity that installs or maintains the bores, as they would have the necessary skills to perform repairs.

Our design is ‘low-tech’; the requisite components for construction (i.e. clay, concrete, wood—for a comprehensive list, refer to Section 5) are widely available in the region, something that is vital to the project’s viability. The shipment of manufactured materials to rural regions such as Devikulam is costly even for developed countries, so it is essential that the toilets and wetland are comprised of readily available materials. Aside from the initial capital outlay, the main inputs into the system are water, (sourced from bores already installed in the village) and sunlight (to power the solar powered pump). The village bore currently runs on mains power, and according to EWB (2011) there are problems with intermittent supply. Not only would the recommended solar panel increase the continuity of the village’s water supply, but it would eliminate the bore’s reliance on mains power, meaning reduced electricity expenditure.
A simple design means that there will be little expertise required to do construction and maintenance work, thus minimal need to source labour or parts from outside the village. By not importing patented and/or sophisticated systems (such as the EcoSan toilets currently being trialled), there are less problems with acquiring specialty items (i.e. replacement mechanisms or workmen who are qualified/trained to do the repairs). This enables the village to modify, enhance or perform makeshift repairs on the system. Should the local government see value in the project, this could potentially lead to the provision of specific maintenance/cleaning jobs to Devikulam citizens. By rejecting the assimilation of foreign products such as the EcoSan, Devikulam is impeding the proliferation of globalisation (yet is inherently globalised through its facilitation of international aid services).

Another effective use of the wetlands would be to reach an agreement with the local private prawn farming companies. Revenue and employment could be arranged for Devikulam in exchange for the use of the wetlands. Filtering the water output of the prawn farms (at the moment there is no effluent treatment program) to remove industrial and animal wastes would decrease the ecological footprint of the prawn industry, improving its sustainability. It is important for areas such as Devikulam who have very few marketable industries to exercise sustainable business practices, so that these industries may serve them well into the future (EWB, 2011).

Compared with the current practice of open defecation, there are additional costs inherent in the application of any project. After acknowledging the capital required to undertake construction, consideration must be given to the opportunity costs involved in using land in the village for the wetlands. It is possible that in the future this land could be used for farming, other infrastructure projects or development. This may be negated somewhat by the capacity of the wetlands to be utilised in other water treatment processes—which safeguards the project from redundancy—and could in fact assist the village in developing a structured plumbing system, something which is universally adopted by developed nations (WHO, 2006).

### 6.3 Social Impact

It is imperative that any assistance provided to Devikulam is welcomed, as it is unethical for us to inappropriately interfere with the village and its traditional values. Ideally, a balance can be met between technological sophistication and the maintenance of traditions and cultural identity.
According to the 2011 EWB survey of Devikulam, 80-90% of the households in Devikulam have televisions or mobile phones; yet none have their own toilet. It is the priority of this project to improve health and health education in the village, which we believe to be of cardinal importance.

The development and implementation of technological or civil innovations can be seen as a vehicle for transforming engineers into ‘engineer-sociologists’ (Bijker et al, 1987, p. 83). This applies to engineering in any context, but is perhaps most pronounced when interfacing with markedly different societies such as that in Devikulam. In particular, it is interesting to note the changes in the rights and roles of minorities or societal subdivisions that can be catalysed by the introduction of new technologies—in this case, the liberation of women in modern Indian society—from a traditional system of arranged marriage to a more equitable process afforded them through the criterion of toilet ownership (Mukhopadhyay & Seymour, 1994; Wax, 2009). Similar benefits may be afforded to those facing discrimination due to caste; if inter-caste sharing of the toilet resources were to succeed, there could be an equalising effect in the community.

There are increasing social pressures in Indian society for households to own or have access to developed sanitation resources, in fact a ‘No Toilet, No Bride!’ campaign in the northern Indian state of Haryana has resulted in 1.4 million toilets being constructed in the area (Bhowmick, 2011). Women have banded together and refused to marry men who do not possess a latrine, realising the importance of good health practices (Wax, 2009). We take this as a reasonable gauge of the villagers’ priorities, supporting our decision to design a human waste management solution.

The wetland system provides infrastructure that can be used in the future to further develop the village, thus improving the quality of life in Devikulam. The capacity of the wetlands to be adapted to filter other systems’ effluent—such as a plumbing network from the houses and communal washing areas—ensures that the village has the opportunity to expand to meet the requirements of its residents (Greenway, 2005). This augmentation can have positive social implications (assuming it is in concordance with the villagers’ wishes), as improved municipal infrastructure can lay the foundations for greater healthcare and education projects in the future.

Depending on the number of toilets installed, and the exact location(s) of installation, some inequity may arise in regards to who is responsible for the resources provided. Cleaning of the toilets could
become an issue; if western society is any indication, the people of Devikulam may not be inclined to selflessly contribute to the maintenance of a communal resource. Our strategy to minimise issues would be designating each family a toilet, or if necessary one toilet per 2-3 families, which would encourage the villagers to take care of that which belongs to them. A correlation has been observed between community involvement and the success of conservation and intervention projects (Manikutty, S., 1997; Waylen et al., 2010); it would be no different in Devikulam—if we can motivate the villagers to collectively contribute in some way to the upkeep of the toilets/wetlands, the project would be far more likely to be a success, in terms of sustainability and/or improvements to the overall hygiene. Refer to Section 5.2 regarding possible education programs.

The distribution of the toilets would need to take the class/caste system into account, as it would be unfair to unevenly cater for either group. There is definitely the potential for friction arising between these castes as a result of the toilets being available—inequitable distribution of resources is the cause of many of the world’s conflicts (Homer-Dixon, 1994). Although we may wish to promote unity in the village amongst castes, and avoid segregating the groups further with our design, it may be an unrealistic expectation of the project as the caste system has been around for centuries (Dutt, 1986). While the caste system has officially been abolished under the Indian Constitution (Part III – Fundamental Rights, 2007), we must consider the possibility that there is still discrimination in Devikulam, such as has been discussed in a report by Center for Human Rights and Global Justice [CHRGJ] (2007). The CHRGJ observed,

“Discrimination violating Dalits’ rights to education, health, housing, property, freedom of religion, free choice of employment, and equal treatment before the law.”

Whether or not this is happening to the same extent in the rural setting of Devikulam has not been determined. We submit that international rights movements such as the CHRGJ represent many of the benefits of globalisation; by promoting awareness of issues, providing aid services and attempting to bridge the gap in living standards with the ‘third-world’. Buzza (2008) did note that in Devikulam, the two castes interact cordially, and that some “caste mingling occurs at certain functions”.

Our system was designed with cultural sensitivity in mind; we didn’t want to introduce typically western methods and ideals to the Devikulam culture, without consideration given to how it may affect them. We understand that whether or not they are comfortable with the current system of open defecation, we are offering them a unique alternative, and our decision to focus on a human waste
treatment solution is reinforced by the knowledge that toilet systems are universally adopted by the affluent regions of the world (World Toilet Organisation [WTO], 2011).

6.4 Environmental Impact

It is positive in an environmental sense that many of the materials used in the project’s construction could be recycled, salvaged or even manufactured by the villagers in Devikulam. The majority of what is used in the construction and daily operation is naturally occurring (sand, reeds, water). This contributes to the sustainability of the design, and lessens the environmental impact of the project as minimal non-biodegradable debris and unusable refuse will be left behind when alterations or repairs are made (or in the unlikely event that the project or village is abandoned).

As mentioned, the primary resources input into the proposed wetland waste management system are water (renewable) and sunlight (perpetual). By using solar power, reliance on fossil fuels or expensive batteries is eliminated. Sunlight is effectively an infinite source of energy that can be harnessed by the project, due to the low power requirements of the bore’s pump. The output of the system is again water, and also breathable oxygen if you consider the photosynthetic work done by the wetland’s reed bed (Luo et al, 2006). This water would be of a drinkable purity, which would be feeding directly back into the water table, for redistribution in the future—for drinking, bathing, washing, farming etc. This is a fundamental aspect of the project—recycling contaminated water through natural processes to produce clean, reusable water. A lack of clean drinking water has been identified as an issue for the village; our system not only replaces some of what is uses directly back into the water table, but it reduces the amount of water contamination that is caused by open defecation.

Water analyses performed by Pitchandikulam Forest (2010) exposed undesirable levels of bacteria in the water, their primary solution being to quarantine the bore area from human contamination. This will be achieved (in part) by the implementation of this project, as toilets effectively divert the stream of human waste from the ground into the appropriate treatment wetlands. Open defecation by cattle will still remain an issue for further investigation (EWB, 2011).
The wetland system will of course not output the same volume of clean water that is put in, as some will be consumed by the transpiratory processes of the reed bed, as well as evaporative forces acting on the surface of the wetland (Luo et al., 2006). It is for this reason that we have not integrated a method of collecting the water output of the wetlands—the rate at which water exits the system would be insufficient for any practical uses, and would require another pump/tank combination to make it harvestable. Although this falls outside the scope of this project, and releasing the water deep into the ground will effectively resupply the bores it was originally pumped from (Figure A.3), there is potential for recycling of this water output (Section 8 – Recommendations).

The materials used in the project are predominantly biodegradable, for example the clay, wood, concrete, sand and gravel which make up the bulk of the construction are not harmful to the environment in the way that substances such as plastics are (Laist, 1987). The water tank we suggest would be made of polyurethane, however these tanks are items that will always be in demand (especially in Devikulam where 100-150cm rainfall per annum (Figure A.4) means effective rainwater collection systems could be engineered—they currently utilise a 30,000L tank in the village (EWB, 2009)).

It has been shown that constructed wetlands cultivate a natural habitat ideal for native flora and fauna to flourish, which provide myriad benefits to the human population (Tanner, 2001).

Some of those mentioned include:

- Climate regulation
- Flood protection
- Recreational opportunities
- Tourism
- Plants are important in the manufacture of medicines etc.
- Soil formation and nutrient cycling

By redirecting the human waste into the filtration system, there will no longer be the contamination of the soil and water used for their crops due to open defecation—especially important to Devikulam as these crops are their primary source of income and nutrition (EWB, 2011).
One of the initial concerns with the constructed wetland design was the possibility that an open body of water would provide a breeding ground for mosquitoes, this being problematic due to mosquitoes’ propensity for transmitting disease. This remains a point of contention, as opinions on the matter are divided;

- The Environmental Protection Authority of South Australia [EPA] (2002) determined mosquitoes to be of minimal risk due to permanent wetlands providing an opportunity for all manner of organisms to flourish, including natural predators of the mosquito.

- Reports by Dale (2008) and Russell (1999) have stated that it is vital to manage mosquito populations in wetlands—something viable in a developed nation such as Australia, where these articles were published—but unlikely in Devikulam.

Our determination is that due to the severity of the diseases prevalent in India (e.g. malaria), and the lack of supervised maintenance intended, that mosquitoes are definitely a problematic factor. We would initially address this by ensuring that wetlands are constructed only on the outskirts of Devikulam, and a certain distance from already established buildings.

Due to the somewhat volatile weather conditions in Devikulam, there may be a risk of flood damage to the reed bed of the surface wetland. According to the Indian Meteorological Department (IMD, 2010), approximately 75% of India’s annual rainfall comes in the space of only 4 months, over two events known as the monsoon seasons. We have confirmation however that similar wetland systems are used effectively in other parts of India (with similarly seasonal weather) (Juwarkar et al, 1995), so we expect that there will typically be no issues. Were the project not implemented, flooding of the ground used as an open toilet would have comparable ill effects on the soil and water table. Refer to Section 4 regarding the weather-resistant measures taken.

In the Water Innovations report published by EWB (2011), it is noted that one of the three bores utilized by the village is turning brackish (reaching unacceptable salinity levels), supposedly due to the excessive water usage in the village. Utilisation of this saline bore (currently used for washing and other non-drinking purposes) was discussed as a potential water source for our wetlands project; however this caused the following complications over time:
Saltwater causes undue corrosion on all components of the toilet(s). This potentially means that more expensive/specialized corrosion resistant materials may be required for construction.

While there are certainly reed/plant varieties (including the Phragmites family) that can exist in saltwater (Windham & Lathrop 1999), due to the filtering nature of the wetland, we suspect that salt would gradually collect in the reed bed to levels where even these species would be unable to survive.

Attempts to address these factors would increase costs and maintenance requirements on top of that which we had planned, negatively affecting the overall sustainability of the project. Thus we recommend that the water is sourced from either of the freshwater bores available in the village.

### 6.5 Impact in terms of stakeholders’ interests

<table>
<thead>
<tr>
<th>Stakeholder*</th>
<th>Social</th>
<th>Economic</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devikulam villagers</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Government bodies</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.1: Stakeholders’ interests table

In Figure 6.1 above, we analyse the interests of the two main stakeholders in the project: the people of Devikulam and the various Governments (Local, State (Tamil Nadu) and Central) presiding over them.

- A ‘+’ in the table represents positive interests; there will be positive repercussions from that perspective.
- A ‘-’ in the table represents undesirable consequences from that perspective.
- Blank means negligible interest in the outcome.

**Brief summary of stakeholders’ interests**

- The one ‘negative’ value in the table represents the small financial costs that could affect the villagers if they are required to pay for soap and cleaning chemicals.
- Positive social implications for:
Residents: See Section 6.3 on “No toilet, no bride!” campaign.

Government: A cleaner, more developed village gives a good impression to other areas.

- Positive economic impact on the Government (Gale, 2009):
  - Less expenditure on healthcare due to poor hygiene.
  - Less ‘sick days’ taken by workers.

- Positive environmental effects for:
  - Residents: They will live in a cleaner village, and will have cleaner water over time.

*Prawn farmers and neighbouring villages have not been included as stakeholders, because this project will not have any great effect on them.

6.6 Risk Assessment

Here we define risks to be the factors that could contribute to the project being unsuccessful to varying degrees. While we have considered most of these concerns, and made attempts to nullify the issues in question, some questions still remain—predominantly due to the difficulties in obtaining information and understanding the cultural dynamics of Devikulam.

Outline of the major risks to the project’s success:
- Extended cloud cover during the monsoon season resulting in solar power outages.
- Issues with male/female sharing of the toilets.
- Members of different castes refusing to share sanitation resources.
- Damage or wear to the system requiring skilled labour not present in Devikulam.
- Village water supply running low/brackish.
- Mosquito infestation.

Responses are discussed in Section 8 – Project Recommendations.
7. Conclusions

- The villagers of Devikulam will be able to dispose of their bodily waste hygienically and efficiently.
- The toilet and wetland system was contrasted with numerous other human waste treatment processes, and deemed most suitable for Devikulam.
- Initial capital expenditure has been minimised by the use of locally available resources.
- Use of the toilets and wetlands is provided at negligible cost to the villagers.
- The configuration of the toilets will take into account the gender inequalities and caste system present in Devikulam.
- Constructed treatment wetlands are a natural, adaptable, environmentally friendly and effective manner of treating contaminated water.
- Given the innumerable benefits provided by the wetlands, the capacity to replenish the ground water supply and considering the proposed water requirements relative to that of the village’s agricultural use, the overall negative environmental impact of the project is negligible.
- Devikulam may use the wetlands in other water treatment processes in the future, meaning the opportunity for expansion of industry and infrastructure.
- The wetlands have the potential to generate income for Devikulam, through joint ventures with the prawn farming industry, cropping of biomass or harvesting medicinal/ornamental plant species.
8. Recommendations

8.1 Introduction

Although we are committed to a final design, the more we scrutinise the logistics of our solution, the more we are presented with new directions that the project could take. Exposing potential flaws or inefficiencies in our work is not necessarily a setback, however. It is our professional and ethical responsibility to our client (and to ourselves) to submit the most thorough report possible, so that any shortfalls in the design can be taken into account before it is considered for implementation. By identifying problematic elements, we are provided with the opportunity to minimise or eliminate the issues, resulting in a more comprehensive design and report.

While it is vital that we submit work of the highest standard, it is equally important to critically analyse every step of the process, to both elucidate any errors or weaknesses, and to provide structured problems for us to solve. Our proposed implementation method is outlined in Sections 4&5. The following recommendations will assist those wishing to continue our work or implement the preferred aspects of our design, with additional consideration given to the alternatives provided.

8.2 Separation of toilet blocks by caste

Devikulam is split into two distinct sections: the colony, which is the area densely populated by the lower-class Scheduled Caste (SC) (formerly known as Dalits/’untouchables’), and the village*, where the (marginally) less impoverished Most Backward Class (MBC) reside (Buzza, 2008). Figure 4.1 illustrates the locations of these areas (the colony is inset). The rough geographical division of the groups would make it easier to designate toilets to families of the same caste. It is recommended that a number of toilet blocks are installed in specific areas, considering the logistics of all 375 villagers commuting to one central toilet block; but this must be contrasted with the potential costs of plumbing water to the extremities of the village.

*Note that in this report, the terms ‘village’ and ‘villagers’ generally refer to the whole of Devikulam and its entire population, respectively.
8.3 Division of toilet blocks into male/female sections

OR build separate blocks for men and women

The toilets are unisex—the members of a family share a toilet between them, both male and female. We have made the assumption that this will be acceptable to the people of Devikulam, quite possibly a flawed methodology. Although the introduction of toilets will be an improvement over the current situation, and the trial of four EcoSan toilets more than likely involves a unisex arrangement, this is not necessarily the best configuration. We did consider having the blocks split into male/female, or having separate blocks for both sexes, but this would detract from the benefits of having a family unit responsible for their own toilet.

As each toilet block would be based on the same build specifications regardless of designation, the decided configuration could be an afterthought; a trial in the village or a preference survey would be a good method of determining the best allocation of toilets.

8.4 Implementation of a seasonally alternating rainwater and solar powered pump combination

By installing a hybrid system that takes advantage of the rainfall during the monsoon season and the sunlight during the dry season, the reliance on sunlight would be diminished. Using otherwise neglected rainwater as a supplement to the water supply would be an environmentally friendly option, but this may not be feasible until a suitable guttering network is constructed; the thatched roofs currently in operation will not act as a suitable surface for rainwater collection (EWB, 2011).

8.5 Connection of the pump system to the mains energy

It would be prudent to have the pump that channels water from the 30,000L tank by the bore to the tank above the toilet block(s) connected to the mains (grid power), in case of poor sunlight conditions, so that the effective running time of the pumps can be optimised. If the power supply from the solar panel ceased functioning, the toilets would run dry within 24 hours. Other renewable energy sources such as wind generators could be looked into, and combinations are possible (Chedid & Rahman, 1997).
8.6 Refining agricultural processes

We have considered the possibility that we would be depleting the limited water resources of the region. Agricultural processes (especially rice and coconut (EWB, 2011)) are responsible for the majority of the village’s consumptive water usage. It is estimated that agriculture is responsible for ~75% of the world’s water use, and that 15-35% of all farming practices are unsustainable (Wallace, 2000) (note that these figures may not apply to Devikulam, due to the rudimentary farming techniques used).

If water resources continue to diminish at unacceptable rates, then thought might be given to modifying the farming techniques currently in place. Possible solutions proposed by Wallace (2000) are the reduction and recycling of runoff/drainage, or a reduction in soil evaporation. Fortunately in Devikulam there are high levels of rainfall (IMD, 2010).

8.7 Recycling of the water output of the wetlands

Rather than have the purified water output of the wetlands flow back into the ground supply, it is possible that some immediate use could be found. If the grazing areas in Devikulam become over-cultivated and nutrient-poor, the wetlands could be stripped back to reduce nutrient removal, and the effluent used as a fertiliser to rehabilitate the land (Denny, 1997).

Some form of collection reservoir could be installed at the end of the cycle, so that this water could be reused for drinking/washing/farming etc. As outlined in Section 6.4, the volume and rate of water output would likely be insufficient for direct application to irrigation, but if a tank similar to that on the toilet blocks collected the water output, it could be hand pumped up for drinking, or another grid powered pump could direct the effluent over farmland. The minor risk of water taken directly from the wetland becoming pathogenic is something the villagers would not be capable of monitoring themselves, so another water filtration process at the end of the cycle would be appropriate.

8.8 Cropping the reed-beds for bio-mass or planting ornamental/medicinal varieties

Denny (1997) suggests that with adequate nutrient supply, a reed variety such as papyrus can create 100 tonnes hectare\(^{-1}\) year\(^{-1}\) of biomass that could be sold as renewable fuel or utilised in some biomass powered process in Devikulam. This would require community involvement, but the potential income could be beneficial to the villagers.
It is also possible at this scale to plant non-wetland plants, such as those with an aesthetic, cultural or medicinal value, as another means to provide income to the villagers. This has been shown not to reduce efficiency of the wetlands systems (Zurita et al, 2011).
9. Appendix

<table>
<thead>
<tr>
<th>Phase of development</th>
<th>Time period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research for primary design(s)</td>
<td>Week 6-Week 7 (6th April-13th April)</td>
</tr>
<tr>
<td>Primary design draft</td>
<td>Week 7-Week 9 (13th April-2nd May)</td>
</tr>
<tr>
<td>Final report draft</td>
<td>Week 9-Week 12 (2nd May-23rd May)</td>
</tr>
<tr>
<td>Edit and finalise final report</td>
<td>Week 12-Week 13 (23rd May-30th May)</td>
</tr>
<tr>
<td>Construct prototype</td>
<td>Week 9-Week 13 (2nd May-30th May)</td>
</tr>
<tr>
<td>Prepare and deliver presentation</td>
<td>Week 12-Week 13 (23rd May-30th May)</td>
</tr>
</tbody>
</table>

**Figure A.1:** Project schedule 6/4/11

<table>
<thead>
<tr>
<th>Phase of development</th>
<th>Time period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research for primary design</td>
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<td>Final report draft</td>
<td>Week 11-Week 12 (16th May-23rd May)</td>
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<tr>
<td>Edit and finalise final report</td>
<td>Week 12 (23rd May-30th May)</td>
</tr>
<tr>
<td>Construct prototype</td>
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</tr>
<tr>
<td>Prepare and deliver presentation</td>
<td>Week 13 (30th May)</td>
</tr>
</tbody>
</table>

**Figure A.2:** Final timeline 24/5/11

**Figure A.3:** Groundwater Flow (USGS Circular 1139)
Figure A.4: India: Annual rainfall (Compare Infobase Ltd., 2008)
10. References


Sewage Treatment in India


Wendy (2011, Februray 7) Cost of a Concrete Lab [Msg 9] Message Posted to