SUSTAINABLE SANITATION
SYSTEMS THAT COMPLY WITH THE BUILDING CODES
for
Nanggroë Aceh Darussalam

November 2006
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Acronyms and Abbreviations

Atlas Atlas Logistique
BOD5 Biological Oxygen Demand (5 days)
BRR Aceh-Nias Reconstruction and Rehabilitation Agency
Building Code PU Building Code matrix of NAD Province, 2005
Cincin Concrete ring (Indonesian)
CRS Catholic Relief Services
CW Constructed Wetland for treatment of wastewater
ESP Environmental Services Program, USAID, Indonesia
FWS Free Water Surface (constructed wetland)
HAF Harapan (Hope) Aceh Foundation, local NGO
IPLT Municipal Sludge Treatment Facility (Indonesian)
HRT Hydraulic Retention Time (days or hours)
NAD Nanggroe Aceh Darussalam
O & M Operations and Maintenance
PU Public Works
P.E. Person Equivalent (number of persons)
SNI Standard National Indonesia
SFS Subsurface Flow System (constructed wetland)
USAID United States Agency for International Development
1. Introduction

This following was developed as a handbook to support the workshop “Sustainable Sanitation Systems” first conducted in Lhok Nga on 30 May, 2006. The goal of this collection is to provide useful guidelines and information for planners and engineers with building projects in Aceh and Nias.

Large housing construction projects are being implemented across Aceh. More than a hundred thousand homes will be constructed in only a few years time. This enormous building spree is challenged by an uncompetitive construction environment, poor construction and the use of poor quality materials. BRR is faced with trying to enforce the PU-BRR Building Codes, but lacks a “police force” to do so. Those implementing construction projects can support enforcement by setting good examples of ‘building back better’.

Sanitation and drainage works installed to this date often do not meet the Building Codes and this may be the last chance to promote better. Poor sanitation systems impact humans, the environment, related economic activities, are a waste of development resources and are unsustainable. Sustainable sanitation solutions must be adopted by the people of Aceh – not merely given. What we build now will simply work better if we more carefully consider how it fits in the lives of end-users, ultimately the managers.

If more and better systems are to be built in Aceh, then we must address what limits the implementation at the moment. The authors have necessarily taken a position on some of these issues to start the process, but we emphasize this is a ‘living document’ to be revised continuously in consultation with BRR and participating organizations over the coming months, perhaps years.

This handbook is a mix of technical and institutional issues without aiming to be thorough – in part because there is little time, but also because we don’t know everything yet. Everyone is welcome to contribute to this document, perhaps even adopt it when the authors are gone. More sharing of experiences, challenges, plans and designs must continue to take place. The “Sustainable Sanitation Systems” workshop was a first step, technical assistance was another. ESP will continue to facilitate a communications process in support of establishing sustainable sanitation systems in Aceh.

What is ESP? The Environmental Services Program of USAID takes a ‘Ridges to Reefs’ approach to linking water resources management with improved health. Integrated technical components include Watershed Management and Biodiversity Conservation, focusing on raw water resource conservation and rehabilitation as well as biodiversity conservation; Environmental Services Delivery, ensuring increased access to clean water and sanitation services; and Environmental Services Finance, leveraging necessary investment in infrastructure and environmental service rewards. In Aceh, ESP has a fourth technical component, Environmentally Sustainable Design and Implementation. The “Sustainable Sanitation Systems” workshop was part of this fourth technical component.

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USAID Environmental Services Program (ESP)

Banda Aceh, November 2006
2. Domestic Wastewater

2.1 Regulations

2.1.1 All wastewater

Domestic wastewater is described as “black-water” if it originates from toilets and “grey-water” if it originates from bathroom, kitchen, and clothes washing facilities. Grey-water, which constitutes about 80 percent of domestic wastewater, contains many pathogens and pollutants (Appendix 1) and should receive adequate treatment just like black-water. This is clearly stated in the PU Building Code matrix of NAD Province (2005).

Regulations mentioned in this chapter apply only if there is not a community wastewater treatment facility, which is the case for most of Aceh and Nias.

- ‘All wastewater must be processed before it is disposed in the city’s communal wastewater conduits or carried to a community wastewater processing plant if available.’
  
  PU Building Code matrix of NAD Province, 2005

- ‘Wastewater is all water originating from bathing, kitchen, washing and toilet.’

  SNI 03-2398/6379-2000

2.1.2 Combined or separate

SNI specifies two conflicting regulations for individual houses and small communities (max. 10 households) concerning black & grey-water treatment.

- ‘All wastewater must go to a septic tank followed by a soak-pit or leach-field.’

  Two conflicting regulations

- ‘The septic tank is used primarily for black-water’

  SNI 03-2398/6379-2000

The regulation does not specify how to handle grey-water separately. Perhaps for this reason grey-water is commonly allowed to flow to open drains (Chapter 2.2.1), even though this is in conflict with the Building Code. Most of the stagnant, foul smelling water in public drains is untreated grey-water, mixed with occasional septic overflows.
2.1.3 Details

- 'Disposal systems must be equipped with smell traps.' (air-vents, Ed.)
- ‘Processing is conducted in waterproof septic tank and equipped with absorbing well (soak-pit, leach-field, etc., Ed.).’
- ‘Minimal distance of septic tank and absorption (leach-field, Ed.) from the source of clean water is 10 meter.’
- ‘Site of septic tank might be in the front or back of the house, depending on the ease of flow from bath room and taking into account the minimum distance from clean water source.’
- ‘Procedures for planning of septic tank and absorption soak pit refer to the SNI-03-379-2000.’ (and SNI-03-2398-2000, Ed.)
- ‘For areas with shallow water table (less than 1 m), septic tank is made higher and effluent is made to flow horizontally.’

PU Building Code matrix of NAD Province, 2005

2.1.4 Brief discussion

**Septic tanks 10m from shallow well**

If septic tanks are waterproof then essentially it is not necessary to locate them 10 meters from a clean water source (shallow well). Especially in situations where the density of houses is high, it will be difficult to apply this regulation consistently and some leniency is practical if a sewer system is not optional. The regulation may partially stem from the fact that ‘septic tank’ is often synonymous with ‘soak-pit’ in Indonesia – and the latter has been the accepted local standard.

*Imagine the health impact with 700+ houses in a small area if all houses would have soak-pits and used shallow-wells. Surely waterproof septic tanks and post-treatment would be better*

Photo 1. Lam Pu'u, section of housing project for 700+ houses
‘Horizontal flow’ post-treatment in high groundwater

The ‘10 meter’ regulation as it applies to effluent disposal in leach-fields should be applied at all times, as should the regulation specifying the need for ‘horizontal flow’ (treatment of septic tank effluent = post-treatment) in situations with shallow groundwater. In the regulations, shallow groundwater is defined as ‘less than 1m’. Groundwater levels may fluctuate strongly between dry and wet seasons, and it is the latter that sets the limit. Post-treatment in high groundwater can be achieved amongst others with constructed wetlands (Chapter 2.6.4), but not with leach-fields (Chapter 2.6.2).

2.2 Current Situation

2.2.1 Grey-water disposal in open drains

Often, public drains in Indonesia and elsewhere, are de facto open, stagnant sewers which smell bad and attract disease carrying insects and rodents. The dengue fever carrying mosquito (Aedes aegypti), for example, thrives in stagnant drains because its predators (dragonflies, fish and frogs) cannot live in such polluted waters (DGLP 2006). During rainstorms, accumulated solids are flushed en masse to create problems elsewhere in waterways and finally in the sea.

Photo 2. Dengue fever is a man-made problem - mosquito larvae in a public drain, Ulee Kareng, Banda Aceh, May 2006

2.2.2 Black-water soak-pits

Concrete-ring (cincin) soak-pits are widely implemented in Aceh because they are easy and cheap to build, although they don’t comply with the building code. They lead to direct groundwater contamination in areas with high water tables. Health issues arise if they are near (10 – 30 m) shallow wells or environmentally sensitive areas (ponds, rivers, etc.). Apart
from the health risks, a major problem with soak-pits is nutrient pollution. When too many nutrients leach to the environment, they kill natural ecosystems like wetlands, rivers and coral reefs.

An additional problem, but only in Banda Aceh, is that concrete rings are constructed of poor-quality materials. Broken lids pose the risk of children falling in, and they provide mosquitoes with access to excellent breeding grounds close to the house. The use of poor quality cincins may even cause the whole pit to collapse in a few years.

Photo 3. Poor quality cincin used for soak-pits in Banda Aceh (right)

Figure 1. Diagram of cement-ring soak-pit (left) 4 or 5 stacked rings

Figure 2. Visualization of groundwater pollution caused by soak-pits
2.3 Design Principles

2.3.1 Sustainable development

The following are principles for the design of sustainable sanitation systems. Principles are hardly quantifiable, so we call this the software for design, which entails a mixture of social, cultural, political, economical, institutional and ideological preferences.

"Sustainable development is the management and conservation of the natural resources base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations." (FAO, 1988)

The authors are of the opinion that a sustainable design will thus:

**Comply with the Building Codes.**
The Building Codes are designed to protect public health and the environment.

**Have Minimal Operation and Maintenance Costs.**
The community or individual households must be willing and able to finance O&M.

**Use Local Skills and Materials as much as possible.**
The local government, community, or individual households, must be able to operate and maintain the systems using available resources. Imported resources are generally more expensive or not available in Aceh, certainly in some of the more remote areas like Meulaboh. Gaps in knowledge and skills can be addressed through training programs, local materials can be adapted to make sustainable designs.

**Have a Long-Term Vision.**
Future growth and spread of populations must be anticipated, meaning systems must be replicable or expandable. Sludge management must be planned now.

**Recycle.**
Recycle natural resources, water, carbon and nutrients, wherever possible – create opportunities for sustainable livelihoods (e.g. aqua- and agriculture).

**Address social sustainability in a wider context**
Does the project protect public health, locally and downstream? Does the project ‘fit’ in the local culture? Can local ownership be achieved? Are there education and awareness components in the project?

**Address environmental sustainability in a wider context.**
Does the project protect the immediate environment especially ground and surface waters? What are the downstream effects of the project? Poor water quality caused by nutrient-pollution for example. What is the intrinsic value of nature and biodiversity?

**Address economic sustainability in a wider context.**
How will operations and maintenance be paid for? Can livelihoods be integrated into management? What are the economic costs of poor sanitation? Such as declining fish stocks. What are the positive economic impacts of improved sanitation?
2.3.2 Centralised or decentralised

Centralized treatment systems are a desirable option in urban areas, or even in some of the denser reconstruction towns. However, concerns about slope and O&M requirements hinder implementation. Large-bore gravity sewers for raw wastewater are expensive and require adequate slope and base-flow, which is most often not available. Systems that require pumping are considered unsustainable (Chapter 2.3.1). Septic Tank Effluent Gravity (STEG) sewers (Chapter 2.5.1) are an alternative solution, but they keep the sludge issue decentralised. Topography, land availability, costs, budgets, etc. ultimately dictate which approach is more appropriate — centralized or decentralized.

The costs of municipal treatment wetlands are not necessarily lower than on-site CW systems, and may in fact be higher. Maxwell, C.F. (2006) estimates the costs at around 600 $US per household (5 P.E.), for projects between Banda Aceh and Meulaboh, most of which is attributable to sewers and not the CW itself.

Source: World Bank global analysis on sanitation investments, 2006

‘In Indonesia, for every $1 spent on improving sanitation infrastructure, there will be a $11.4 gained benefit valued from health cost saving, time saving and averted diseases’

‘In Indonesia, out of every 1000 live births, 50 children die before reaching the age of five due to diarrhea’

Source: World Bank global analysis on sanitation investments, 2006

Photo 4. Insufficient slope prohibit the use of gravity-fed centralized sanitation.
2.3.3 Integrating waste treatment with livelihoods

Nutrient flows through wetlands are a valuable resource. Potential livelihoods benefits include high-value feed for livestock, aquaculture, handicraft materials, building materials, fibres, food production (e.g. fruits; bananas, papaya, chilli) soil additives (compost) and energy from biogas. However, this only works if it is properly managed. If not, then waste merely turns to pollution and a destruction of natural resources, such as drinking water, fish stocks and ultimately those beautiful coral reefs.

Natural wetlands are a feature of Aceh’s coastal landscape. Many tsunami-affected settlements have natural wetlands nearby. People are returning here to live and make good use of the natural resources along this rich coast. If sanitation is to be a sustainable component of such redevelopment, then it must be integrated with the way people are building back their lives.

This involves a process of negotiation between polluters, farmers, fisherman, health educators, environmental advocates, engineers, businessmen, planners, government officials, donors, tourists and ultimately the villagers, who are the polluters themselves and beneficiaries of the reconstruction effort. Undoubtedly, this will take some time, and that is exactly what it needs. Sanitation takes time and effort to become part of people’s mindset and list of responsibilities. We can make it easier by showing the benefits.

Photo 5. Housing in natural wetlands - Calang (2006) what will this place look like in the future?
2.4 Grey-Water Primary Treatment

2.4.1 Design approaches

Things that are preferably removed from wastewater to make post-treatment systems function better are the fats, oils and greases (FOG), and course solids such as food scraps from the kitchen that contribute much to the BOD in grey-water. Strainers can be installed in the kitchen or bathroom sinks, but these are easily damaged or removed when they clog, thus cannot be relied upon to do the job alone, and they don’t remove FOG.

Photo 6. Bathroom strainer cut open to bypass clogging

Solids accumulating in a filter must be removed regularly and properly disposed as part of a solid waste program. A basic approach is to keep grey-water filters close to the house and easy to clean. Grey-water filters alone are not adequate to remove FOG, for which a grease-trap is required (Chapter 2.4.3).

Photo 7. Grey-water filter examples

2.4.2 Grey-water filter

Brick-masonry collection box (lined on the inside), with lid to keep mosquitoes out, and drain (perforated pipe) in the bottom. A simple kitchen strainer can be added to make it easier to remove solids (see Photo 7b).

Cost: 150,000 Rp. (material and labour)
**Case:** ESP-Meulaboh

![Diagram of grey-water interceptor](image)

Figure 3. ESP Meulaboh - Grey-water interceptor

**Case:** Atlas – Lam Kruet, Lhok Nga.

![Photo of grey-water filter](image)

Photo 6. Atlas Lhok Nga, grey-water filter
2.4.3 Grey-water grease trap

This is basically a ‘miniature septic tank’ of 225 litres (liquid volume) per household (Burns, 1999); for example using the low-cost and robust ESP design of 350 litres in Chapter 2.5.8.

2.5 Septic Tanks

2.5.1 Design approaches

Local conditions

Two to three times more water is consumed per capita in the West than in Aceh due to adequate water supply services and widespread usage of large-flush toilets, washing machines, showers, etc. Consequently, Western standards requiring fairly large septic tanks are not applicable here. Besides, the main contributors to sludge accumulation in septic tanks (toilet paper and washing-machine lint) are largely absent in Aceh.

Based on Burns (1999), Metcalf and Eddy (1995) and a general consensus that water consumption in Aceh is around 60-100 liters per person per day.

Sludge accumulation and safe handling

As mentioned in the former section, sludge accumulation in Aceh is expected to be lower than in the West. Unfortunately there is not much data available from tropical countries to determine exactly how much. Duncan Mara (1976) reports about 100 ml pppd (per person per day) in Zambia. Sludge accumulation in the West is reported to be 100-300 ml pppd.

Another complicating factor is that septic tanks mature with age, and within 3 years of operation the rate of sludge accumulation may be half the rate of a 1 year old tank. This is mainly something to keep in mind for performance monitoring; i.e. don’t judge the systems too soon, certainly not after only a few months. This maturation has to do with the growth of beneficial microorganisms in the tank, which can be maintained even when the tanks are emptied – as long as some sludge is left behind for inoculation and users ‘go easy on household chemicals’ (Appendix 4). This goes to show that sludge accumulation is closely related to O&M, and thus public awareness (Chapter 2.5.3).

The suggested approach is to consider sludge accumulation as a relatively unknown variable and to prepare for sludge removal, treatment and disposal or reuse facilities. These are necessary in any case, no matter how frequent septic tanks need to be emptied.

As a basis for design, 100 ml of sludge accumulation pppd is within range of what can be expected in Aceh, about half of which is attributable to black-water (Annex 1; Table A1.3).

Emptying of sludge from septic tanks is a combined responsibility of households and the local government (Chapter 2.5.3). Two basic approaches can be followed: 1) municipal sludge treatment facility (in Indonesia called ‘IPLT’), or, 2) on-site facilities for individual households or small communities. Stabilized and dried domestic sludge is an excellent soil conditioner which can be used in gardens or agriculture. Sludge stabilization can be achieved in properly functioning septic tanks, whereas sludge drying can be achieved in reed bed filters (Appendix 3), similar to constructed wetlands (Chapter 2.6).
Configurations for black- and grey-water

Grey-water constitutes the bulk of domestic wastewater; hence the combined treatment of black- and grey-water in a single septic tank requires relatively large tanks. Significant costs can be spared if grey-water receives separate primary treatment (Chapter 2.4).

Figure 4. Schematic presentation of on-site options for black- and grey-water

Central versus individual septic tanks

In accordance with the earlier mentioned principles, pumping is not considered a sustainable solution for transport of wastes in Aceh. This means that any centralised system will require gravity flow sewers.

Large-bore sewage pipes are required to convey raw household wastewater to central septic tanks by gravity, with adequate base-flow to transport solids (Chapter 2.5.2). The advantage is that sludge is accumulated and processed centrally, which might be more reliable and cost-effective than using sludge tanker trucks to empty individual septic tanks. It also allows for economics of scale in the beneficial use of sludge (biogas and compost). Lack of slope (Chapter 2.5.2) and high cost may be prohibitive however.

The advantage of having individual septic tanks for each house is that the effluent can be transported more easily under gravity for centralised post-treatment if so desired (Chapter 2.5.2). Individual septic tank effluent can also receive on-site post-treatment, which makes the system versatile. A mixture of on-site and clustered post-treatment is applied in Lam Krue, Lhok Nga (Appendix 5.2.3). A challenge with individual septic tanks is that it puts responsibility for O&M (namely sludge emptying) primarily with the households, who are not used to this in Aceh.

Post-treatment, reuse or disposal (Chapter 2.6)

- Constructed Wetland (on-site or communal)
- Standard leach-field (on-site)
- Vegetated leach-field (e.g. vetiver grass)
- Other (aqua-agriculture, municipal treatment plant, etc.)
- Not in drains with an open water surface!
**Anti Flootation**

Anti flotation measures are necessary for most tanks to prevent buoyancy in high groundwater when tanks are not full of water. Latter may happen after sludge pump-out or when reconstruction houses are not occupied yet and the contractor hasn’t filled the tanks with water as a precaution. Some people still think concrete or brick structures are heavy enough and won’t float, but it’s not just about the weight.

The average structure density must at least equal to that of water, which can be achieved by adding extra weight, or, the structure must be anchored. In most cases an anchor, or rim, will be easier and cheaper to implement than just adding extra weight., but the heavier the tank (brick/concrete), the easier anti flotation measures will be and vice versa.

When houses (including toilets, bathroom and kitchen) are elevated, the septic tanks could be placed above ground level, but care should still be taken against damage by flooding.

**2.5.2 Design ‘rules of thumb’**

**Gravity-flow sewer for central septic tank**

A large-bore sewage system is required if raw household wastewater is conveyed to central septic tanks by gravity, with adequate base-flow to transport solids. The flow velocity must be kept above 0.6 m/s to prevent deposition of solids (Crites and Tchobanoglous, 1998), which in many cases means minimum slopes of 2% are required.

- Conventional gravity raw wastewater sewer – 2% minimum slope + base-flow

**Wastewater quantity**

- 5 people per house
- 1 person uses 60 - 100 litres of water per day
- Safe assumption: 1 person produces 20 litres black-water and 80 litres grey-water/day
- Safe assumption: 1 house produces 100 litres black-water and 400 litres grey-water/day

**Sludge accumulation**

- Black- and grey-water
  - 100 ml per person per day (Chapter 2.5.1)
  - 183 litres per house per year
- Black-water
  - 50 ml per person per day (Chapter 2.5.1)
  - 92 litres per house per year
- Grey-water: same as black-water, but most of the accumulation can be prevented with a filter prior to the septic tank/grease trap (Chapter 2.4)
Tank liquid volume

1 day HRT is required for effective septic tank treatment; for the rest it depends on how often the tank needs to be emptied. For hot climates the design standard for sizing a septic tank is 3 days HRT, which allows extra volume for sludge accumulation and 1 day HRT at the time sludge needs to be removed (Duncan Mara, 1976). Tanks are generally emptied when they are 2/3rds full of sludge. This matches with data from the West, where the tank volume required ranges from 3.3-6.8 times the average flow corresponding to pump-out frequencies of 2-5 years (Crites and Tchobanoglous, 1998).

- Combined Black & grey-water septic tank: \(3 \times 500 = 1500 \) litres tank/house
  - Pump-out sludge every 6 years
- Black-water septic tank: \(3 \times 100 = 300 \) litres tank/house (minimal)
  - Pump-out sludge every 2 years
- Black-water septic tanks: two 350 litres tanks in series
  - reduce pump-out frequency to once every 4-5 years
- Grey-water: use filter and a ‘miniature septic tank’ (Chapter 2.4)

2.5.3 Public awareness

Home-owners need to be made aware of good practices regarding septic tanks in order for the tanks to function properly. Few houses in Aceh currently have (waterproof) septic tanks consequently public awareness is very low.

The main message to the public would be to ‘go easy on the household chemicals and leave some sludge behind in the tank after pump-out’ (Chapter 2.5.1).

If they don’t follow these recommendation (and others; see Appendix 4), the main effect will be a higher rate of sludge accumulation. Septic tank O&M capacity building should be integrated with programs for solid waste management; e.g. to develop feasible alternatives for safe disposal of chemicals (oils, paints, etc.).

Safe treatment, disposal or reuse of sludge is an issue that still needs to be addressed in Aceh. The local government sanitation service (Dinas Kebersihan) is responsible for emptying individual septic tanks at the request of home owners who pay a fee for the service. However, few homes actually have (waterproof) septic tanks and few regions in NAD actually have functioning sludge treatment facilities and tanker trucks. Disposal of sludge in rivers, overloaded stabilization ponds or landfills is not a sustainable solution. The public should be involved in developing mechanisms for sludge handling so that they are aware and willing to participate, either with self-managed on-site systems by paying for services provided by the local government (Chapter 2.5.2).
2.5.4 Conventional septic tank

**Material:** Brick or Concrete

**Costs:** 5 - 10 million per house

The national standard designs (SNI-03-2398-2000) are conventional systems as described in respected engineering books such as Metcalf and Eddy (1995). The SNI offers both a single and a double compartment system in reinforced concrete.

![Figure 5. Standard Two-Chamber Septic Tank](image)

![Figure 6. Government standard septic tanks - drawings by HAF (2006)](image)
Main Challenges with conventional septic tanks
- Waterproofing requires complete dewatering during construction
- Risk of damage from earthquakes
- Skilled labour required, takes time to install
- High costs

Main Advantages of conventional septic tanks
- Large size tank, less frequent sludge emptying
- The tanks heavy, less buoyancy problems

Case: UNHCR in Calang are building a few hundred septic tank systems from batako cement blocks. The design is quite similar to the SNI double compartment system. There were problems getting the tanks waterproof. BRR is taking the project over (November 2006) and will implement a different design for the remaining houses.

2.5.5 Fibreglass

Main Challenges with fibreglass tanks
- Can be damaged in transport
- Difficult for local vendors to produce large orders
- Structural integrity problems if material is not rigid/thick enough
- Flotation of the tank, large anchors required

Main Advantages of fibreglass tanks
- Easy and fast to install

Case: Atlas Logistique, Lam Kruet, Lhok Nga, based on a design from ASIA Fiberglass
- Size of septic tank: 1500 litres (1000 litres effective) for 1 household
- Treatment: black-and grey-water
- Cost of tank (factory price): Rp. 1.2 million
- Cost after transport and installation: (?) Rp. 3 million
- Issues: large diameter fibreglass lid is unsafe to stand on
- Issues: the inlet pipe is close to the outlet; short-circuit of inflow
- Issues: flotation in high-groundwater

Photo 9. Atlas Lhok Nga - two compartment fibreglass septic tank
Figure 7. Two compartment fibreglass septic tank dimensions (ASIA Fiberglass)
2.5.6 Plastic water tanks

Small plastic water tanks (350 litres) can be converted to single chamber septic tanks with the addition of inlet-, outlet-, and air-vent pipes. This system has been applied with success in Bali.

Figure 8. Plastic water tank modified as septic tank (HAF, 2006)
Figure 9. Plastic water tank with angled inlet pipe to stir sludge (Norm Van’t Hoff, 2006)

Main Challenges with small plastic tanks
- Flotation risks
- Structural integrity; soil may collapse on the tank if not compacted
- Pipe fittings may leak

Main Advantages of small plastic tanks
- Easy to install and guaranteed waterproof
- Water tanks are available on the shelf
- Screw-on lid provides easy and safe inspection

Case: BRR/ESP Mon Ikeun, Lhok Nga
- BRR reconstruction site: 7 houses
- ESP Pilot to test plastic water tanks of 350 litres
- Cost: 600.000 Rp. per tank
- the contractor installed 500 L instead of 350 litre tanks
- the soil was not properly compacted
- the tanks weren’t filled with water
- the rain season brought drainage and flooding problems
- Result: some tanks floated or collapsed under the weight of the soil
- Other tanks were fine
- See Appendix 5.2
2.5.7 Concrete rings in Banda Aceh

Concrete 'rings' (cincins) are commonly used to make soak-pits in Banda Aceh; which means no floors, no sealing between rings, no sealing of inlet and outlet pipes. It appears difficult to get builders in Banda Aceh to use this material and their skills, to build waterproof septic tanks. Concrete rings are not useless per definition; the situation in Meulaboh and Calang for example is completely different (Chapter 2.5.8). Perhaps the builders in Banda Aceh can learn from these experiences and develop sustainable skills for better sanitation.

Challenges with cincins in Banda Aceh

- Poor quality of materials used – dirty sand and gravel of random size
- Poor concrete ratio (too much sand)
- No steel reinforcement - final product breaks or cracks during transport
- Tank lids are not strong enough – standing on one is risky
- High water tables make in-situ construction of a floor in the tank difficult
- Difficult to make waterproof
- Builders are reluctant to follow CARE specifications (Appendix 2)
- Builders are not always willing or able to make necessary adjustments
  - Like cutting a groove on the ring edge for sealing (Figure XXX).

Benefits of cincins

- Many vendors
- Cheap material
- Local capacity to build concrete rings exists

Case: CARE Lhok Nga – concrete ring septic tank

- Made from Banda Aceh style rings; Ø 80cm, height 40cm, 5cm thick
  - Following CARE specifications (Appendix 2)
- Septic tank is made of four rings 1.6 m deep, 525 litres
- Cost of single cincin (not installed): 30.000 Rp.
- Cost of single improved (CARE) cincin (not installed): 50.000 Rp.
- Cost of four rings (525 litres): 200.000 Rp.
- Total cost of installed septic tank: (?) 400.000 Rp.
- Main challenge (CARE): 9 out of 10 contractors still don’t apply the technical specifications even when given to them – result: tanks are not waterproof

Solutions to make better cincin septic tanks in Banda Aceh

- Introduce the bigger and stronger rings made in Meulaboh, Calang and Sigli
  - 50cm high, 7cm thick, Ø 80cm, good mix of concrete
  - Import the moulds, or have them made in Banda Aceh
- Pe-cast the floor into the ring (Chapter 2.5.8)
- Training of the vendor for construction and installation of septic tanks
- Random inspection (e.g. kick-test final product)
Figure 9. CARE - concrete ring septic tank with waterproof joints

Photo 10. CARE – concrete ring septic tank with waterproof joints

A concrete floor is made on-site in the bottom, but this is often not waterproof.
2.5.8 Concrete rings - ESP

ESP developed a robust septic tank with 364 liters liquid volume for the low-cost of 500,000 Rp (fully installed on-site in Meulaboh). The design is based on good quality concrete rings that are available in most places outside of Banda Aceh; 50cm high, 7cm thick, Ø 80cm, and good mix of concrete.

The basic modification of what is locally available is a prefabricated, reinforced bottom, which makes the rings guaranteed waterproof, and inlet-outlet holes with plug-and-play 3inch pipe fittings. Another addition is the ‘anti-flotation-rim’. For little over 1 milion Rp. per household, black- and grey-water can receive adequate pre-treatment (1 tank for each); and more tanks can be added at a low incremental cost if more volume is desired.

Figure 10. ESP improved concrete ring septic tank design
Photo 11. Waterproof concrete ring

Photo 12. Prefabricated reinforced bottom (left)

Photo 13. Concrete ring with inlet/outlet holes – 3inch pipe fitting (right)

Cases in progress since October 2006:

- Pilot system at ESP guesthouse
- CARITAS Switzerland, Meulaboh
  - Desa Pasir 214 houses, Suak Inrah Puri 495 houses, Padang Seurahet 717 houses
- MEDAIR
  - Calang, Rigah 110 houses, various other locations: 390 houses
- CRS and Habitat for Humanity are developing their own versions of this system
  - Habitat for Humanity Resource Center in Meulaboh
2.5.9 Comparison of Septic Tanks

The following Table 1 presents a quick overview for comparison of different types of septic tanks. Two systems are included that were not discussed in the previous chapters (BioTech and Dusapan, see Appendix 2) because they haven’t been implemented yet but are being considered by some agencies.

The absolute costs below are estimates, but the relative costs are generally valid. Transport costs and different markets may be the largest cost variables. Other variables are related to details such as: does the cost include air vents and anti-flotation measures?

<table>
<thead>
<tr>
<th></th>
<th>BioTech</th>
<th>DUSAPUN</th>
<th>National Standard Concrete/Brick</th>
<th>Fibreglass</th>
<th>Plastic Water Tank</th>
<th>Concrete Ring ESP</th>
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<tr>
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<td>6</td>
<td>4</td>
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</tbody>
</table>

Table 1. Comparison of Septic Tanks
2.6 Post-Treatment, Reuse and Disposal

2.6.1 Design approaches

Need for post-treatment

Septic tanks used to be called 'liquefaction tanks' because in the absence of extraneous materials, essentially all the solids discharged to a septic tank were liquefied (Crites and Tchobanoglous, 1998). Most of the nutrients are derived from urine (Annex 1) and are thus already in a liquid or suspended solid phase. These are not removed at large in septic tanks (Annex 1). Removal of nitrogen, for example, requires both aerobic and anaerobic processes, whereas a septic tank is merely anaerobic. The Building Codes (Chapter 2.1) and septic tank effluent quality (Annex 1) make it clear that post-treatment is a must, not an option.

Leach-fields or constructed wetlands

Details of the building code (Chapter 2.1) state 'For areas with shallow water table (less than 1 m), septic tank is made higher and effluent is made to flow horizontally' (PU 2005). This means that leach-fields are not suitable for many locations in Aceh and Nias. Leach-fields are still discussed for those situations where the groundwater is deep enough. In these cases, vegetated leach-fields (e.g. papaya, banana or vetiver) are a more sustainable method to dispose and make beneficial use of effluent. For most high groundwater conditions along the coast of Aceh; 'Made to flow horizontally' is exactly what sub-surface flow constructed wetlands can do (Chapter 2.6.3). Aqua-agricultural use of treated wastewater is another alternative which can be integrated with municipal treatment wetlands (Chapter 2.3.3).

Food for thought – the resource value of domestic wastewater

Human excreta are comprised of two basic components, urine and faeces. Each has very different properties, they are produced in different quantities, and they require different care in processing. Published figures indicate that more than 1 litre of urine per day (500 litres/year) and less than 200 g of faeces (50 litres/year), including moisture, is produced daily, depending on the type of diet, location, age, activity and health status. Urine contains nearly 80% of the total nitrogen found in excreta and about two-thirds of the excreted phosphorus and potassium. The majority of the carbon excreted, up to 70%, is found in faeces.

Total excretion per person is 4.5 kg of nitrogen, more than half a kg of phosphorus, and 1.2 kg of potassium per year. This is the amount needed to grow a year's supply of grain for every person.

In a communal setting of 500 people, this equates to 2250 kg of nitrogen, nearly 300 kg of phosphorus, and 750 kg of potassium. If this was a commercial fertilizer, the economic value would be around Rp. 20 million.

Although using only urine is valuable, both urine and faeces should be recovered and recycled to avoid long term depletion of soils.

Stabilized sludge is an excellent soil-conditioner – source of carbon, improving moisture and nutrient retention capacity of the soil (cat-ion exchange capacity) and improving soil-structure (permeability and aeration).
2.6.2 Leach-fields

Leach-fields are described in SNI-03-2398-2000 and basically consist of a buried, perforated pipe, surrounded by gravel with a top-layer of palm tree fibre (ijuk). Although leach-fields are required by regulation, hardly any have been installed in Aceh thus far.

Figure 11. Example of a leach-field for on-site septic tank effluent disposal

Leach field cost estimate:
- Cost: mainly gravel @ 150,000 Rp./m³ (excl. transport costs) in Aceh
- Example for 1 house: 6 m trench, 50cm gravel depth, 0.75m wide = 2.25 m³ gravel = Rp. 337,500 (material only)
- perhaps Rp. 450,000 for total installation.

Challenges for standard leach-field
- Not suitable in high groundwater tables (many parts of Aceh)
- Nutrients are not removed in un-vegetated leach-fields
- Blocking of pipes may cause poor distribution uniformity over the field, or blockage of the entire system altogether
- Infiltration capacity of the underlying soil may diminish in time if the disposed effluent contains high loads of suspended solids

Advantages of standard leach-fields
- Relatively cheap compared to constructed wetlands
- Local skills and material available
2.6.3 Vetiver Grass

Vetiver grass has a high capacity for removing pollutants from wastewater. Nutrients and trace elements are absorbed by the plants through a very large root system which also acts as a living bio-filter. Well-designed vetiver plantings are cheaper than most engineering solutions and they require little or no maintenance once established. Vetiver is very hardy - it can handle wet and dry conditions, as well as various qualities of water. It is a very useful plant: (combined) uses range from animal feed, erosion control, wastewater treatment, essential oils and craft materials. Vetiver has been well studied in many different situations and no negative impacts are expected to result from its introduction: it sets sterile seeds and does not spread by stolons or rhizomes. Because the roots penetrate vertically downwards only, it does not compete with adjacent crop plants. Multiplication is established by splitting.

The only challenge with vetiver grass lies in its lack of availability. Large amounts of rootstock are needed for land management projects, and presently, the only source is the area around Garut in West-Java. The solution is to establish nurseries in Aceh. ESP recently began a 1 hectare vetiver grass nursery with 20 women in Lhok Nga.

Case: Mercy Corps Laqm Ujong - shelter
Drain water (grey-water, storm-water and some septic tank effluent) from a shelter flows into a basin on the edge of a wetland. Before it seeps into the wetland it has to pass through a planted root system of vetiver grass, which also keeps the embankment in place. The project suffered a setback because the pipes were blocked with grey-water solids, requiring installation of a grey-water filter.
2.6.4 Constructed Wetlands

Introduction

Wetlands are one of the least expensive treatment systems to operate and maintain - they are very sustainable (Kadlec and Knight, 1996).

 Constructed wetlands (CW) are an effective, natural and relatively low maintenance method of providing good treatment of effluent from septic tanks or other primary wastewater treatment facilities.

They are essentially manmade replicas of natural wetlands, suited for specific purposes. CW’s come in all shapes and sizes, depending on site evaluation and selection. Wetlands are adaptable to almost any location and they can be constructed in any configuration – from small single units of only a few m², to systems of hundreds of hectares integrated with aquaculture.

Two types of constructed wetland systems have been developed for wastewater treatment: (1) free water surface (FWS) systems and (2) subsurface flow systems (SFS) (Metcalf and Eddy, 1995). These may come in many shapes and sizes with combinations of FWS and SFS systems. For example, for a single house it could simply be a shallow waterproof-, or at least low-permeable pit, filled with a media and planted with evenly spaced wetland plants (Figure 13). The plants have a treatment function, add to beautification of the community (gardens), yield beneficial products (banana, papaya) – which altogether entices public awareness about the environment and a sense of ownership of the systems.

Figure 12. Wetlands can be constructed anywhere

Figure 13. Typical subsurface flow (SFS) constructed wetland (CW)
Design approaches

The extra costs and space associated with a CW rather than a leach-field is a must, not a choice (Chapter 2.6.1). Still, to make the systems more acceptable, those extra costs and space should be as low as possible. Downsizing the treatment surface area takes care of both – but when does the system become too small? Each case requires an adjustment based on expected outflow quality, available space, budget, and appropriate design information.

On-site CW’s are basically waterproof garden beds, which can easily be fitted in spatial plans – even in relatively dense housing projects. Waterproofing can be done using various materials: plastic liners, clay, brick, fiberglass, etc.

SFS is the preferred choice for on-site CW systems, since FWS systems are potentially attractive breeding grounds for mosquitoes (especially when not stocked with mosquito eating fish). SFS systems are covered by sand or soil, thus there are no direct health risks. Constructed wetlands are an unknown concept to local communities and socialization of these systems is a key to success. The ‘treatment gardens’ should also be clearly recognizable above ground by means of adding a border. This also keeps runoff rainwater out of the systems.

Municipal treatment wetlands can be integrated with livelihoods (Chapter 2.3.3).

Figure 14. Mai Po Marshes Nature Reserve, Hong Kong, constructed wetland 383 ha. (in Shutes, 2001)
**STEG sewer for communal wetland**

Municipal treatment wetlands or wetlands for clusters of houses require collection of primary treated wastewater to a central location. Septic Tank Effluent Gravity (STEG) sewers use small-bore pipes and require minimum slopes of merely 0.15 % (for 3 inch PVC pipes; Crites and Tchobanoglous, 1998). However, service laterals (septic tank to sewer pipe) are usually laid at a constant slope of 2%. Slopes of 0.5-1 % were used for the ESP pilot in Lam Kruet (Appendix 5.2.3).

**CW design calculations**

Metcalf and Eddy (1995)

- Primary pre-treatment of wastewater is required
  - Maximum BOD$_5$ loading rates on CW of 7-13 g/m$^2$/day
- SFS: wider and short is better than narrow and long
  - Flow velocities should be kept below 7m/day for effective treatment
- HRT 4-15 days
- depths of 10 – 75 cm
- hydraulic loading rates of 140 - 470 liters/m$^2$/day
- specific areas of 2 – 7 m$^2$/100 liters/day

There are indications that CW’s in the tropics can perform well on smaller areas because the biological treatment processes occur at higher rates throughout the year. Stewart Diemont (2005), for example, shows that CW pollutant removal rates in Honduras are higher than would be expected in temperate regions. Bigger to a certain degree is better, but cells are reported to function well with:

- HRT 1.1 – 2.6 days
- BOD$_5$ loadings of 18-25 g/m$^2$/day

Calculations

- Septic tank effluent contains 100 - 200 mg BOD$_5$/litre
- 1 house (5 P.E.) produces about 500 litres of domestic wastewater per day
- 1 house produces about 50 - 100 g BOD$_5$ per day
- The minimal CW surface area required is:
  - based on BOD$_5$ loading: 2-16 m$^2$
  - based on hydraulic loading: 1 - 4 m$^2$
  - based on 4 days HRT and assuming 75cm depth for a SFS: 2.7 m$^2$

‘Rule of thumb’

The minimal surface area required for a single house (5 P.E.) SFS CW is 3 m$^2$.

Municipal wetlands require much larger areas when they include shallower FWS cells and aquaculture (Figure 14).
Public awareness

Home-owners need to be made aware of good practices regarding treatment wetlands in order for them to function properly. Few houses in Aceh currently have constructed wetlands, consequently public awareness is very low.

Constructed treatment wetlands may yield many beneficial products if properly managed (Chapter 2.3.3). It should be made clear, however, that the principal removal mechanism of nutrients and organic matter in smaller on-site systems is not through the removal of plant biomass. The main removal mechanisms are filtration and mixed anaerobic/aerobic digestion. Plants may in fact be left to decay in the treatment wetlands, providing a source of carbon for denitrifying bacteria. This makes the system low maintenance, the gravel bed requires cleaning only once every 10 years or so (depending on the size of the system); in fact yielding a rich soil which can be used elsewhere in the garden or for farming.

Marsh-plants, such as cattail, which bring some oxygen in the gardens through their roots, are the preferred choice of plants. However, the public may prefer flowers, banana’s or papaya’s, and these choice should be left open if it encourages them to take ownership of the systems.

A golden rule, however, should be: don’t grow root crops used for human consumption.

![Figure 15. Example of a subsurface flow Constructed Wetland](image)

Cases

- CARE, Lhok Nga, 2 houses (Appendix 5.3.1)
- ESP Lam Kruet, Lhok Nga, 20 houses (Appendix 5.3.2)
- ESP Mon Ikeun, Lhok Nga, 7 houses (Appendix 5.3.3)
- In progress: pilot system at ESP guesthouse, Meulaboh
- In progress: CARITAS Switzerland, Meulaboh
  - Desa Pasir 214 houses, Suak Inrah Puri 495 houses, Padang Seurahet 717 houses
- In progress: MEDAIR Calang, Rigah 110 houses, various other locations: 390 houses
2.6.5 Filters

*Intermittent Sand Filters (ISF) - aerobic*

There are many different kinds of biofilters which mimic the action of wastewater degradation in unsaturated soil and are generally used where local soil conditions, high groundwater or development density, preclude disposal in conventional septic tile fields.

Effluent from the ISF is generally nitrified, with approximately 50 percent removal of total nitrogen. However, this removal of nitrites requires denitrification; which can be enhanced e.g. by recycling ISF effluent to a septic tank with an upflow filter for attached growth (anaerobic bacteria using carbon as a source of energy); see below. Nitrites (toxic to fishes) are relatively unstable and are easily oxidized into nitrates (Metcalf and Eddy, 1995).

Effluent from the ISF is nearly completely nitrified but some variability can be expected in nitrogen removal capability. Controlled studies generally find typical nitrogen removals of 18 to 33 percent with an ISF.

**Challenges with ISF in Aceh:**

- ISF must be properly maintained to function.
- ISF require a pump, thus a reliable source of power is required for this system.
  - Unless toilets/houses are raised and there is sufficient hydraulic head.
- Clogging of the surface of sand filters may occur.
- Necessary to periodically rake, remove and replace the upper few inches of media.
- The sand media removed must either disposed of at a sanitary landfill, or regenerated.

Studies of sand filters used for individual residences have shown that home owner neglect and/or their lack of knowledge about the system and its maintenance requirements, can result in problems with these systems.

*Upflow Filter (UF) - anaerobic*

Upflow filter systems intermittently dose septic tank effluent below a bed of media, allowing solids to settle and decompose below the bed, while liquids rise through the media and treated effluent overflows over the top.

Upflow filters mainly trap BOD and TSS. Anaerobic bacteria attached to the filter media can perform denitrification using organic carbon as an energy source. However, this process is limited by the low level of nitrification in septic tanks. Nitrification (aerobic process) most often appears to be the limiting step for nitrogen removal in domestic wastewater treatment processes. Hence, nitrogen removal with UF is enhanced when preceded by a nitrification process (e.g. an intermittent sand filter).

**Challenges with UF in Aceh:**

- Some means of back-flushing the upflow filter must be provided for in its design.
- The unit should be back-flushed periodically to remove accumulated microbiological films.
2.6.6 Comparison of post-treatment, reuse and disposal options

Constructed wetlands are the best choice altogether (see Tables 2 and 3 below). The current indication is that on-site sub-surface flow constructed treatment wetlands (3m²) will cost between 2.5-3.5 million Rp./house in Aceh. Once constructed, the O&M requirements are minimal and the systems can run independently for decades.

One of the reasons why these systems perform well for the removal of nitrogen (if designed properly) is because they have anaerobic and aerobic processes, with an adequate source of carbon for the anaerobic denitrifying bacteria (see picture below).

<table>
<thead>
<tr>
<th>Onsite Wastewater Disposal Practice</th>
<th>TSS (%)</th>
<th>BOD (%)</th>
<th>TN (%)</th>
<th>TP (%)</th>
<th>Pathogens (Logos)</th>
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Table 2. Average effectiveness of on-site disposal systems

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<tr>
<td>Mound System</td>
<td>8,300</td>
<td>180</td>
</tr>
<tr>
<td>Anaerobic Upflow Filter</td>
<td>5,500</td>
<td>NA</td>
</tr>
<tr>
<td>Intermittent Sand Filter</td>
<td>5,400</td>
<td>275</td>
</tr>
<tr>
<td>Recirculating Sand Filter</td>
<td>3,900</td>
<td>145</td>
</tr>
<tr>
<td>Water Separation System</td>
<td>8,000</td>
<td>300</td>
</tr>
<tr>
<td>Constructed Wetlands</td>
<td>710</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3. Cost of on-site disposal systems
3. White-water (storm-water) Drainage

Christoph Mor, May 2006

3.1 Regulations and Issues on the Ground

In dealing with storm water drainage (rain water runoff) the following regulations largely make use of best engineering practises.

A. Equipment in Building

• Any building and yard must be provided with rain water channelling system.
• Rain water must be channelled to absorbing wells. Only in areas where absorption wells are unlikely because of special conditions (such as: high ground water, landslide prone areas, very thick underground clay layer) the rain water may be siphoned to the network of city’s communal in accordance with prevailing regulations.
• If the city’s public network or other acceptable is not available yet or because of other acceptable reasons, then other ways approved by the authority must be sought.

   PU Building Code matrix of NAD Province, 2005

B. Equipment Around the Building

• Both sides of the road must be provided with drainage/sewers
• The drainage shall be a part of a bigger drainage system or drainage-collecting rivers
• Dimensions of ducts shall be in accordance with their service areas
• The drainage must be planned such that the functions of containing, distributing and disposing the water shall be efficient and effective
• Type and dimensions selected for the drainage system shall be based on economic as well as security factors
• Drainage mains include the following parts:
  (1) Lying along the roads to collect rain water from adjacent buildings and transport it to disposal areas;
  (2) Sufficiently sized to transport the maximum water flow from the catchment areas efficiently;
  (3) Materials used shall establish permanent mains

   PU Building Code matrix of NAD Province, 2005
The following comments underscore the positive aspects (things that should be done) of the code and the potential problems that arise if the code is implemented without giving careful attention to the existing conditions in which drainage is to be built.

**Positive aspects**
- Individual plots and larger settlement schemes shall be furnished with engineered storm water drainage systems (open channels, etc.).
- Un-polluted rain water shall be infiltrated into the ground whenever possible.
- Storm water drains shall follow both sides of roads
- The regulation explicitly calls for the periodic maintenance/cleaning of systems, and with that implicitly requests drainage engineers to design low- and easy-maintenance systems.

**Potential problem areas**
- Infiltration wells, as proposed in the regulation, could become a new source of ground water pollution, if they perforate directly into the ground water layer. This solution will simply not work:
  - in areas with very high ground water tables,
  - in areas with very clayish impervious top soils,
  - after strong pre-saturation of soils due to long-lasting rains (e.g. a series of several wet days).
- Draining the strong rainfall events of Aceh (both in intensity and duration) poses some engineering challenges. Systems designed to cope with peak flows, in particular in the very flat areas, tend to be large and therefore costly and they may still be ineffective to prevent water logging in low laying areas.
- During dry weather, these large and empty drains serve as 'neighbourhood garbage dumps', which leads to a sub-set of serious environmental health concerns (control of mosquito prone environment).

---

**C. Requirement for Conduit**
- Conduits for rain water can be open and/or closed
- In case of closed conduits, at every alteration of flow direction a manhole (examination hole) shall be provided
- The tilt of the conduit must be sufficient to allow the flow in the system
- The conduit shall be made of PVC, fibreglass, masonry, concrete, iron sheets, iron or steel.
- Details:
  - Holes are made with a distance of 25-100 m, in accordance with its diameter and prevailing standards.
  - Rain water should be able to flow properly under gravity so the drain is free from stagnant water
  - If flow under gravity is not possible, a pumped system shall be used
  - Iron sheet, iron and steel conducts shall provided with rustproof coating.

*PU Building Code matrix of NAD Province, 2005*

**D. Checking, Testing and Maintenance**
- Rain water drainage systems shall be maintained regularly to prevent sedimentation and obstructions.

*PU Building Code matrix of NAD Province, 2005*
3.2 Design Principles and Parameters

Periodic water logging in low laying sections of an individual plot is the current (and well accepted) reality in urban and peri-urban settings. We feel it is, however, important to properly engineer this phenomenon, in order to reduce environmental health hazards from water related vectors.

We propose a system in which a drainage area would be landscaped. A part of the area would be used for periodic storm-water retention. To facilitate easy drainage after a rainfall event, the system will be interconnected by sub-surface pipes. The system of retention areas will follow the boundaries of individual plots, and planted with garden bushes and trees (banana, papaya, etc.). It will provide privacy by forming some kind of natural fence to neighbouring plots. The system could potentially be so designed as to allow for grey-water disposal as well.

![Figure 17. Landscaped drainage areas with vegetated sub-surface retention areas](image)

![Figure 18. Pipes connecting vegetated sub-surface retention areas for storm-water](image)
2.3 ‘Rules of thumb’

Banda Aceh’s rainfall data and some basic calculations indicate the following:

- Rainfall of a 24 hours event, recurrence interval 1 year (the maximum rainfall during a 24 hour period encountered once a year): 70mm
- Required retention volume, to drain 24 hour, 1 year return period event within the following (dry) day: 40mm
- When 10% of the drainage area is used as retention area, the average water depth in the retention area will be less than 400mm for a maximum of 48 hours. The average outflow of the drainage area will be some 4l/s.ha.
**Examples:**

The average rainfall delivered by a rainfall event of 6 hours duration and recurrence interval of 2 years (happens on average once every two years) is some 55mm.

The average rainfall delivered by a rainfall event of 24 hours duration and recurrence interval of 1 year is some 70mm. This rainfall is used in the above ‘rule of the thumb’.

**3.4 Drainage Master plan for Lam Kruet, Atlas**

Master plan for Lam Kruet Housing Scheme, Atlas Logistique, work in progress:
Site: Lhok Nga – Lam Kruet
Type of Unit: contouring - storm-water retention areas connected by pipes
Size of unit: 10% - 20% of total area of housing scheme

With slight contouring of the land surface a system of retention areas (about 10% to 20% of the total area of the housing scheme) will be formed.

**Schematic:** 2-3 house plots; storm water flows to depressions (green-zones) which are connected by pipes (blue lines, see pictures on previous pages). The water infiltrates in the soil, evapo-transpires, and runoff eventually discharges into a natural wetland (not in picture).

![Gravel bed (unlined) and drain pipe](image)

Figure 21. Cross-section drainage green zone
References


DGLP Queensland (2003) Guidelines for the use and disposal of greywater in unsewered areas. Queensland Local Government and Planning, Australia


Duncan Mara (1976) Sewage Treatment in Hot Climates. John Wiley & Sons


Appendix 1: Domestic Wastewater Quality

The following information (from the West) only gives an indication of what black- and grey-water in Aceh may look like.

Little data is available specifically for Aceh. The quality of grey-water in Aceh is expected to be different due to differences in the amount of water consumed and household practices – hand-washing versus washing machines, food preparation, household industries, soaps with phosphates and boron, etc. The quality of black-water is also expected to be different, namely because people in Aceh generally don’t use toilet-paper, nor large-flush toilets.

Table A1.1 Microbiological Characteristics of Grey Water (Winneberger, J.H.T.)
Table A1.2 Chemical/Physical characteristics of grey-water (without garbage disposal solids)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>Tap Water</th>
<th>Low</th>
<th>High</th>
<th>Average</th>
</tr>
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<tbody>
<tr>
<td>Arsenic</td>
<td>mg/l</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Barium</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cadmium</td>
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<td>&lt;0.01</td>
<td>0.03</td>
<td>0.01</td>
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<tr>
<td>Chromium</td>
<td>mg/l</td>
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<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/l</td>
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<td>0.08</td>
<td>0.16</td>
<td>0.11</td>
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<tr>
<td>Iron</td>
<td>mg/l</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>0.20</td>
<td>0.11</td>
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<td>Lead</td>
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<td>&lt;0.01</td>
<td>0.10</td>
<td>0.04</td>
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<td>Magnesium</td>
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<td>2.8</td>
<td>2.0</td>
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<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
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<td>&lt;0.05</td>
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<td>Zinc</td>
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<td>Ammonia</td>
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<tr>
<td>Calcium</td>
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<td>17</td>
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<td>Chloride</td>
<td>mg/l</td>
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<td>20</td>
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<td>25</td>
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<td>Cyanide</td>
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<td>0.02</td>
<td>0.02</td>
<td>&lt;0.02</td>
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<td>Fluoride</td>
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<td>0.95</td>
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<td>Nitrate/Nitrite</td>
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<td>0.9</td>
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<td>Phosphates</td>
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<td>59</td>
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<tr>
<td>Sulfate</td>
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<td>40</td>
<td>83</td>
<td>160</td>
<td>117</td>
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<tr>
<td>BOD</td>
<td>mg/l</td>
<td>*</td>
<td>270</td>
<td>360</td>
<td>328</td>
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<tr>
<td>CCE</td>
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<td>11</td>
<td>41</td>
<td>20</td>
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<td>COD</td>
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<td>283</td>
<td>549</td>
<td>452</td>
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<tr>
<td>MBAS</td>
<td>mg/l</td>
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<td>16</td>
<td>39</td>
<td>22</td>
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<td>TOC</td>
<td>mg/l</td>
<td>&lt;5</td>
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<td>92</td>
<td>80</td>
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<tr>
<td>Color</td>
<td>PtCl\textsubscript{4} equiv. units</td>
<td>&lt;5</td>
<td>30</td>
<td>&gt;100</td>
<td>68</td>
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<tr>
<td>Conductivity</td>
<td>(\mu/min/cm)</td>
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<td>390</td>
<td>358</td>
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<tr>
<td>Odor</td>
<td>Threshold number</td>
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<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>pH</td>
<td>pH units</td>
<td>7.2</td>
<td>6.9</td>
<td>7.5</td>
<td>7.2</td>
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<tr>
<td>Suspended Solids</td>
<td>mg/l</td>
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<td>68</td>
<td>33</td>
</tr>
<tr>
<td>Total Solids</td>
<td>mg/l</td>
<td>108</td>
<td>113</td>
<td>451</td>
<td>382</td>
</tr>
<tr>
<td>Turbidity</td>
<td>mg/L, SiO\textsubscript{2} equiv.</td>
<td>1</td>
<td>30</td>
<td>68</td>
<td>49</td>
</tr>
</tbody>
</table>

*Not applicable
Table A1.3 Urine, faeces and grey-water per person per day, quality & quantity

*Above table does not include toilet paper*

**NITROGEN**

Figure 2. Nitrogen (g) produced in domestic wastewater per person per day

Figure A1.1 Nitrogen in Domestic Wastewater per person per day
Table A1.4 Untreated Domestic Wastewater and Septic Tank Effluent Quality

Fecal coliforms: (Metcalf and Eddy, 1995)
- raw domestic wastewater: $10^6$-$10^{10}$ (MPN/100ml)
- septic tank effluent: $10^5$-$10^7$ (MPN/100ml);
Appendix 2: Septic Tank Design
A2.1 CARE- ‘Cincin’ Construction Specifications

Patrick Lyons, CARE, May 2006

Vendor Fabrication Check List

1. Aggregate specifications
   Gravel - 3/4” crushed rock ASTM C-33
   Sand - clean sand ASTM C-33

2. Concrete specifications
   Concrete ratio meets specification - 1:2:3 - concrete strength should be 225 Kg/cm2
   Concrete should receive ad-mixture - Sika accelerate
   Groove cast in place during the Cincin construction
   Curing time is sufficient - 15 days
   Dry pack - 1:2 (cement to sand ratio) sand to have approximately 8% water for sealing of rings - rings to be spaced at 3 cm so grout is forced into the space between rings

Sample well ring and sealing between well rings testing for water tightness – during sealing of the rings a 3 – 4cm spacer is used, a dry pack is then used to fill the void.

Well ring being cast – note the groove being dug into the ring – this is intended to add connection strength to the rings being joined.

Example of poorly graded gravel for construction

Concrete mixture: commonly too wet, which reduces the composite strength of the product. Use of salt water also reduces quality.
A2.2 BioTech Septic Tank
A2.3 DUSASPUN Concrete Septic tank

**TANGKI SEPTIK HORIZONTAL**
Horizontal Septic Tank

---

**KAPASITAS**
Capacity

**VOLUME**
Volume

**TEBAL DINDING**
Wall Thickness

**DIAMETER DALAM**
Inner Diameter

**DIAMETER LUAR**
Outer Diameter

**TINGGI AIR**
Water Height

**PERKIRAAN BERAT**
Approx. Weight

**KODE PRODUK**
Product Code

<table>
<thead>
<tr>
<th>TYPE</th>
<th>KAPASITAS</th>
<th>VOLUME</th>
<th>TEBAL DINDING</th>
<th>DIAMETER DALAM</th>
<th>DIAMETER LUAR</th>
<th>TINGGI AIR</th>
<th>PANJANG ANGKUTAN</th>
<th>BERAT APPROX.</th>
<th>KODE PRODUK</th>
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<tr>
<td>ST-5</td>
<td>5</td>
<td>0.45</td>
<td>53</td>
<td>600</td>
<td>706</td>
<td>400</td>
<td>2462</td>
<td>750</td>
<td>5C.0005A01</td>
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</tbody>
</table>

---

1) A x B untuk ST-5 sampai ST-10 = 300 x 400 mm
A x B untuk ST-11 sampai ST-15 = 400 x 600 mm
A x B untuk ST-16 sampai ST-29 = 400 x 600 mm
Appendix 3: Post-Treatment Design

Figure 10.1 Reed Bed Design for Faecal Sludge Dewatering: SANDEC

Source: Heinss and Koottatep, 1998

Figure A2.1. SANDEC - reed bed design for faecal sludge dewatering
Appendix 4: Public Awareness, O&M

Things that should not go into a septic tank

- No cigarette butts, tissues, sanitary napkins, disposable diapers, cat-box litter, coffee grounds, or cotton swabs. If it is not biodegradable, it doesn’t belong in the system.

- No paints, oils, chemical drain cleaners, thinners, solvents, poisons, or pesticides. These toxic chemicals not only kill helpful bacteria, they may also contaminate the groundwater.

- No grease or cooking oils. Grease may harden in the septic tank’s scum layer and build up until it blocks the inlet or outlet. If you melt grease and pour it down the drain, it may run through the septic tank and then harden, clogging the soil pores.

- Go easy with your garbage disposal. To avoid frequent pump-outs, compost your garbage or put it in the trash.

- **Go easy with household chemicals.** Disinfectants, ammonia, bathroom cleaners, bleach, etc. can kill the bacteria your system needs in order to operate properly. Allow the system to dilute and neutralize them a little at a time.

  Infiltrator Systems Inc., 2002
Appendix 5: Cases
A5.1 CARE Fibreglass CW in Lhok Nga

This system has been used as a training tool (CARE staff and contractors), as well as an example of an improved septic system that could be implemented in the Aceh context. Only local materials and contractors have been used. It has increased awareness of CARE staff and the local community to these issues. It has also increased debate and inspired design teams to think of new ideas and system alternatives.

![Figure A6.1.1 CARE Lhok Nga - Fibreglass garden tank](image)

**Type of unit:** fiberglass garden tank for SFS constructed wetland  
**Developed by:** Patrick Lyons, CARE, with assistance from ESP  
**Implemented by:** CARE, early 2006  
**Site:** Lhok Nga, Aceh  
**Size of project:** 30 houses, 15 units  
**Size of each unit (households):** 2  
**Cost of each unit (CW only):** 2.5 million (1.25 M Rp./house; Banda Aceh prices, this was price of prototype, later units may be cheaper)

**Problem**
- High water tables – high likelihood of contamination  
- Close proximity of septic tanks and shallow wells (domestic water source)  
- Limited treatment capacities of conventional system to handle grey-water  
- Limited budgets  
- Small lot size limits sanitation infrastructure implementation  
- Grey water discharges directly to natural wetlands and rice fields

**Solution – combined septic tanks and SFS CW**
- 3 water tight septic tanks, using improved CARE specifications (Appendix 2)  
- 2 houses share one upgraded system, reduced cost and both families have an increased distance from their shallow wells.  
- Grey water can be handled by the larger system  
- Fibreglass tanks used for the SFS garden-wetland - easy installation.
Photo A5.1.1 CARE Lhok Nga - Fibreglass reservoir for constructed wetland – made in Banda Aceh.

Photo A5.1.2 CARE Lhok Nga - Improved well rings installed – Installation along the property line between the two houses connecting to the system.

Photo A5.1.3 CARE Lhok Nga - Sanitation system configuration – Houses on left and right connected to septic tanks – septic effluent then flows to constructed wetland.

Photo A5.1.4 CARE Lhok Nga - Constructed Wetland - filling with Gravel - Red box in background is a shallow well

Evaluation from CARE: pending
A5.2 BRR/ESP in Mon Ikeun, Lhok Nga

BRR/ESP Sanitation Pilot
Implementation: May 2006
System: plastic septic tanks (350 litres) + SFS CW (3m²) + vegetated leach-field
Site: Lhok Nga –Mon Ikeun
Size of system: 7 houses
Cost of system: Rp. 4 million /household (all-in)

A group of 7 houses were built by BRR in Mon Ikeun, Lhok Nga, where sanitation first consisted of soak-pits for toilet-water (poor quality cincins), 10m upstream from the water supply consisting of shallow wells. Groundwater in the dry-season is about 2m deep and the soils are sandy.

Photo A5.2.1 BRR/ESP Mon Ikeun single-house SFS CW (3m³) and septic tank (orange)

The household families were approached to engage in a pilot study and a conceptual plan was agreed upon during a meeting. The resulting layout for each house is a waterproof septic tank (PE plastic, 350 litres, for black-water), a grey-water interceptor, a constructed wetland garden of 3m² (3m² -1m deep) for black and grey-water, followed by a vegetated leach field.

<table>
<thead>
<tr>
<th>Sanitation Cost per House-Installed</th>
<th>Rp. (million)</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterproof septic tank (black-water only); 350 liter P.E.</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Vegetated Leach-field (with gravel)</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Grey-water filter (interceptor)</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Constructed Wetland</td>
<td>2.5</td>
<td>4</td>
</tr>
</tbody>
</table>

Table A5.2.1 BRR/ESP Mon Ikeun – Sanitation cost per house
A cheap plywood frame is used to keep the plastic liner (blue) in place. The box is filled with layers of limestone, gravel and sand. When that is finished, the tank will be filled with water and planted with wetland species.

The pipe from the house into the septic tank (orange) carries black-water. The pipe from the septic tank to vegetated leach field (blue) carries septic effluent. The second pipe going into the wetland carries filtered grey-water.

Current evaluation (November 2006):

The pilot in Mon Ikeun is facing problems because the plastic tanks have proven unreliable. Some of the tanks floated as a result of unexpected drainage and flooding problems around the houses. But the tanks were also poorly implemented by a local contractor, and some of the tanks imploded under the weight of shifting soil, also because the contractor decided on his own to implement 500 liter tanks instead of the specified 350 liter tanks. All in all the septic tank part of the pilot is considered a failure. It must be added, however, that a few of the tanks performed well; despite the fact that most of the houses are not consistently occupied by the same number and type of people. In one case, a house was occupied by 14 migrant workers, yet the septic tank seemed to function fine. Still, the overall poor performance has led ESP to develop a better solution using concrete rings (Chapter 2.5.8).
The constructed wetlands in Mon Ikeun seemed to have worked fine and remain waterproof. However, the inconsistent movement of people in and out of the houses, and most houses are abandoned now, have caused problems with socializing the system. Newcomers are not aware of the wetland system, because it is buried underground, the brick border was removed and wild pigs had eaten the banana’s and papaya’s. Subsequently, one man placed a tree nursery on top of four wetland units. The lesson learned from this is that more emphasis should be placed on the socialization. It would perhaps also be better if the treatment wetlands are more robustly added as a fixed feature in the garden, by adding a firm brick-masonry, lined and painted, border.
A5.3 ESP in Lam Kruet, Lhok Nga

Site: Lhok Nga – Lam Kruet  
System: fibreglass septic tanks (Atlas), SFS CW + vegetated leach-field (ESP)  
Implementation: early till mid 2006  
Gravity flow: no pumping  
Size of system (households): 18-20  
Cost of Complete Household System - around Rp. 6 million/house

The Lam Kruet pilot is ESP’s first treatment wetland in Aceh. This sub-surface flow wetland will be a living laboratory, which will provide valuable technical data on conversion rates in wet-tropical zones. ESP will monitor water quality through the system over 12 months – the results will be available on request. ESP aims to continue working with BRR towards developing standards for treatment wetlands. With ATLAS Logistique, ESP is working on more sustainable sanitation systems for all of their (200) Lam Kruet houses.

Figure A6.3.1 ESP Lam Kruet - Overview

Arrow points to sub-surface wetland outlet
Photo A6.3.1 ESP Lam Kruet - trench for the treatment wetland

Photo A6.3.2 ESP Lam Kruet - treatment wetland cells
Design notes

The SFS CW in Lam Kruet has a 2,000 litres septic tank in addition to septic tanks at the houses) and 6 garden compartments each 1m wide, 4.7m long, and 1.7m deep. The media consists of Layers: 30cm sand, 90cm gravel and 30cm limestone rocks at the bottom: 150cm total. The concrete tanks have a volume of (1.7m * 4.7m * 6 units) 50m³. To calculate the volume of wastewater that can go in there; subtract the free-board (20cm) and the layer of sand (30cm; because this will be above the water level; account for the porosity (gravel, about 30%). Hence (1.2m * 4.7m * 6 units * 0.3) we come to about 11m³. This means a HRT of about 1 day.

The wetland has an effective surface area of about 28 m². This comes down to about 1.5 m³/house equivalent; which is lower than recommended (Chapter 2.6.4), but has yielded good results in Bali and is therefore an interesting pilot study. Atlas has already implemented on-site individual wetland gardens for 40 houses which could not be connected to this central system. Should the central system appear overloaded at some point during the monitoring that ESP is planning; then a number of current connections can be disconnected and receive on-site systems also.

Figure A6.3.2 ESP Lam Kruet- constructed wetland cell

Black water - minimum 3 days detention time in household septic tank
Black water - minimum 4.2 days total detention time in total system
Grey water - minimum detention time of 1.2 days in the total system.
Secondary treated outflow from the wetland is disposed in a drain.
To facilitate an uninterrupted monitoring program (no leaks) the Lam Kruet system has been built to very high structural standards, this has made the system too expensive for wide application. Cheaper methods for creating watertight garden tanks are needed to make communal sub-surface flow wetlands more affordable.

The shape of the Lam Kruet garden tank is sub-optimal, preferably, it would be wider and shallower, but it was only possible to use the land if the system could be built in a long narrow strip along the boundary, because a long, narrow garden does not impinge on small land holdings.

**Current Evaluation (November 2006)**

The system has been in operation since September 2006 and is working fine. It will take a few months for the system to develop and meaningful water quality samples can be taken.

Getting the required slope to bring effluent from the house septic tanks to the central system has proved difficult. This resulted in a lowering of the inlet level, and correspondingly the outlet level. Thus the water level in the system is not as high as it could be. ESP is currently working to install a moveable outlet, to see if the water level can be raised 10-15cm without creating back-flow problems.
More cases to be added later