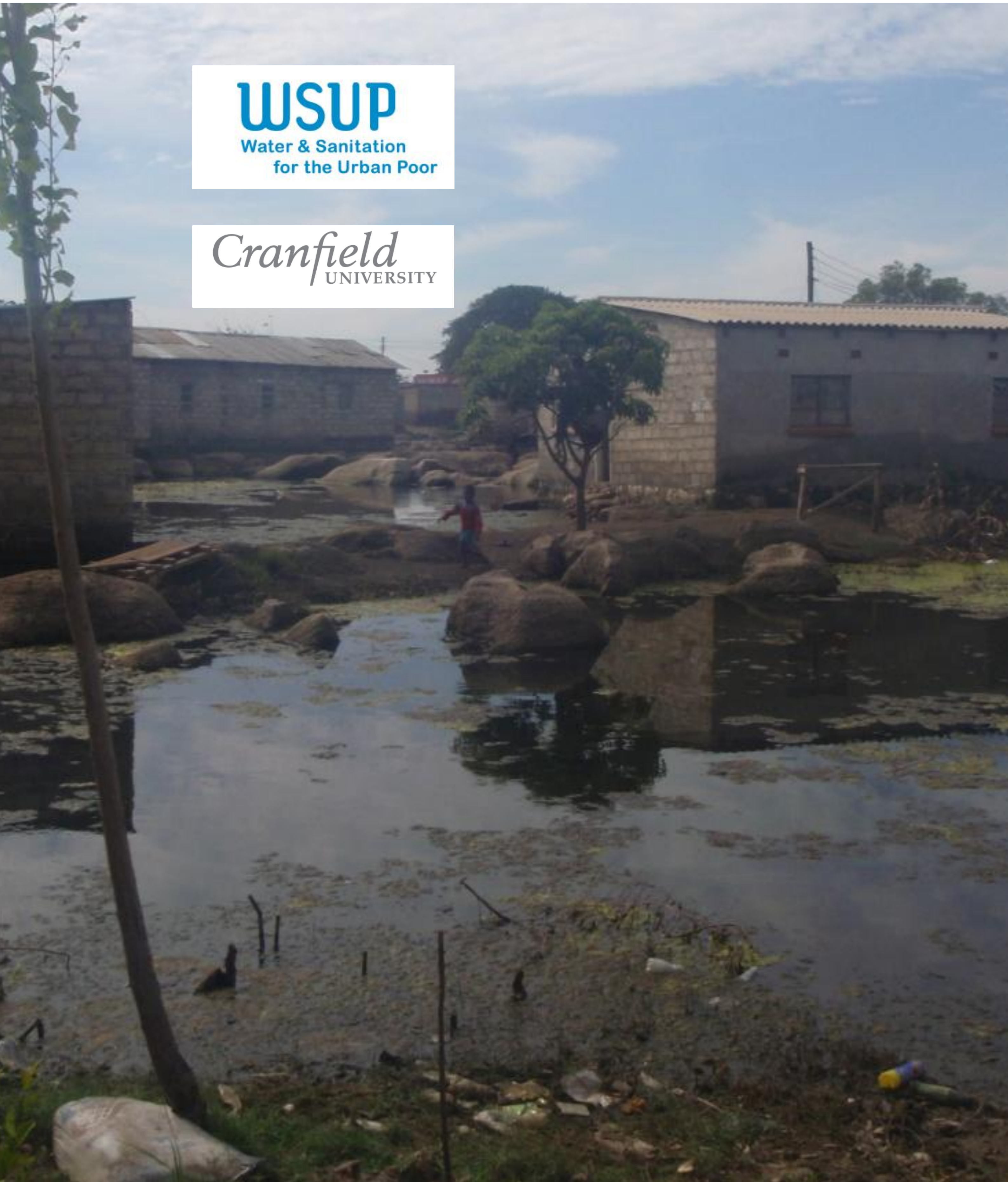
# How to Climate Proof Water and Sanitation Services in the Peri-Urban Areas in Lusaka



WSUP
Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY

# How to Climate Proof Water and Sanitation Services in the Peri-Urban Areas in Lusaka

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Work based on field visit to Lusaka undertaken in May 2010

Cover Photo: Tom Heath 2010

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**Reference**
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# Executive Summary

This report evaluates the impacts of climate change on water and sanitation technologies in two peri-urban areas in Lusaka, Chazanga and Kanyama, and the potential adaptations required to mitigate the impacts. Under current forecasts of climate change, the mean temperature in Zambia is predicted to increase. It is less certain how average precipitation will be affected, but both floods and droughts will occur more often.

- **Chazanga** is most at risk to a decrease in precipitation which will cause a lower water table. This will result in water scarcity, damage to infrastructure and drying up of shallow wells, all of which will increase the demand for new kiosks. In addition, decreased rainfall will affect hydroelectricity generation and cause power shortages. However, if precipitation (or its intensity) increases, there will be flood damage to boreholes, kiosks, septic tanks and pit latrines and poor drainage at kiosks.

- **Kanyama** is most at risk to an increase in precipitation, resulting in an increase in flooding (currently Kanyama's floods last for 3 months). Flooding causes kiosks and buildings to collapse, contaminates water supplies (particularly the shallow wells used in the unserved areas) and affects livelihoods, education and health. Flooded latrines and contaminated water will increase cholera and diarrhoea.

Potential short, medium and long term adaptations were identified for the Water Trusts, Lusaka Water and Sewage Company and the City Council. The adaptations were determined based upon a field visit, a vulnerability assessment and a literature review. The key recommendations are as follows and should be developed within a water safety plan:

Chazanga:

- In the short term acquiring a generator to mitigate the impact of power cuts, while on a longer time scale acquiring a direct line from LWSC
- Expanding the kiosk network into unserved areas
- The building standards of soakaways should be improved
- Vegetation should be planted next to the roads and the shallow wells protected from runoff
- ECOSAN should be encouraged, investing in the technology , education and market for sewage
- There should be enforcement against fly tipping of faeces and raising awareness of the health issues

Kanyama:

- Improving the drainage should be the main priority
- Developing emptying options for latrines, including those which have collapsed
- Ensure new latrines are sufficiently elevated to avoid sewage out flowing
- ECOSAN should be reviewed and in the longer term decentralised sewage promoted
- Expand the kiosk network into unserved areas
- Tighter enforcement against fly tipping

Lusaka Water and Sewage Company:

- Investigate link between groundwater recharge and rainfall intensity in Chazanga
- Construct new storage tanks for both settlements
- Rehabilitation of pipe network to improve pressure in systems
- Establish/expand peri-urban unit to provide technical and administrative assistance during flooding

Lusaka City Council:

- Implement land management activities to reduce severity of floods
- Improve drainage system in Kanyama and employ workforce to maintain and clean the drains
- Subsidise tanker/provider free removal of waste, improve solid waste disposal options
- Construct a deeper and wider main drain in Kanyama to accommodate the increased flooding water

# Contents

# Introduction

"Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly temperature increases" (IPCC, 2007). This report outlines the impacts (both direct and indirect) associated with the climate scenarios predicted (both increasing and decreasing rainfall) for two peri-urban compounds in Lusaka – Chazanga and Kanyama.

It starts by reviewing the impacts of the climate scenarios predicted for Lusaka, on Chazanga and Kanyama; the indirect impacts of climate change and the impact upon water resources in Lusaka. It then synthesises how the climate scenarios will affect the existing vulnerabilities, problems and technology in Chazanga and Kanyama. The report concludes by outlining the main adaptations required in the peri-urban areas by the Water Trusts, Lusaka Water and Sewage Company and Lusaka City Council, dividing them between short, medium and long-term adaptations. The key climate resources for Zambia and ongoing climatic research in Zambia are also summarised.

The report aims to provide pragmatic recommendations for adaptation; focusing upon what is known rather than the uncertainties. The document should be read alongside the Zambia Climate Briefing (Heath, 2010).

# Method

Prior to the fieldwork, key literature on the impacts of climate change on water and sanitation technologies was identified. The key document was a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010). This describes the vulnerabilities of various water and sanitation technologies to climate change, and proposes adaptations. From the field visit it was possible to select which technologies are being used in Chazanga and Kanyama and hence identify the vulnerabilities of the whole water and sanitation system to climate change. The adaptations required to mitigate these vulnerabilities were also selected from Charles et al (2010) and are listed in the appendix.

The field visit to Lusaka, was completed in May 2010 and entailed 41 semi-structured interviews with members of the community and representatives from the local service providers, water utility, City Council, government, the scientific community and NGOs (Table 3 in the appendix lists the interviewees). The interviews and observations assessed the impact of flooding and droughts on the existing environmental, social and economic vulnerabilities and the impact on technologies. The interviews also assessed the institutional awareness of climate risks. Further climate vulnerabilities were identified from the literature review. One focus group was undertaken to do a cause and effect analysis (i.e. what are the problems, what causes them and what impacts they have).

The information gathered from the interviews was used to prepare a vulnerability assessment. This involved listing the problems identified in the peri-urban area and identifying the linkages between them (e.g. vehicles driving over pipes leads to leaks, which results in ingress of water). Once the linkages between all of the problems had been identified, the expected changes in climate were added (e.g. increasing rainfall) and the factors they impacted were identified. In addition, the indirect impacts of climate change (e.g. reduction in *Miombo* woodland) were incorporated assessing which factors they affected. This made it possible to assess how climate change will affect the existing vulnerabilities in Chazanga and Kanyama (see Appendix). This diagram was then used to determine the adaptations required to mitigate the problems.

The adaptations from both the fieldwork and the literature review were then amalgamated and assigned to the Water Trusts, Utility and City Council, dividing them into short medium and long term adaptations.

# Impacts of Climate Change on the Peri-Urban Areas

Zambia has abundant water resources (40% of the SADC region's water) but a combination of seasonal and temporal rainfall patterns and limited investment in infrastructure means the country still experiences water scarcity as well as severe floods. The main climate change challenges facing Zambia are an expected increase in floods and droughts combined with a reduction in *Miombo* woodland and maize yields, which will exacerbate the high levels of poverty in the country. The main climate impacts expected are as follows (refer to the Zambia Climate Briefing (Heath, 2010) for a more comprehensive overview):

## Climate Changes

- Temperature: the mean temperature is predicted to increase in Zambia with a greater frequency of 'Hot' days[1] and nights and very few 'Cold'[2] days or nights
- Rainfall: changes in rainfall are less certain, but rainfall is expected to increase in the rainy season and the winter is expect to be even drier. Rainfall intensity is expected to increase
- Extreme events: an expected increase in the frequency and intensity of extreme events, primarily droughts and floods. Expect extreme events to occur in new locations and a shorter growing season in some regions

## Uncertainty

One thing is certain; under climate change uncertainty will increase. When making climate change impact assessments, a 'cascade' of uncertainty arises (e.g. uncertainty with modelling, scenarios and data) making it difficult to make reliable predictions. The impacts predicted need to be considered alongside current

[1] Hot' day or 'Hot' night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region (average)
[2] 'Cold' days or 'Cold' nights are defined as the temperature for the coldest 10% of days or nights (average)

population pressures and existing vulnerabilities - even without anthropogenic climate change, climate variability undermines food security, negatively affects the environment and significantly affects livelihoods. Therefore the most pragmatic approach is to develop the resilience of water and sanitation systems-– managing risks and building their capacity to deal with unpredictable events, prioritising no-regret measures (UNWATER, 2009).

## CLIMATE SCENARIOS

To assess the impacts of climate change on Chazanga and Kanyama, the issues resulting from two climate scenarios were reviewed - increasing and decreasing precipitation. Two scenarios were assessed due to the uncertainties predicting future precipitation. However, rainfall intensity (the rate at which rain falls) is expected to increase, so this was included in both scenarios (Table 1). Determining which of the issues may be significant for the settlements was assessed during the field visit to Lusaka.

**Table 1: Key issues resulting from climate changes in Kanyama and Chazanga (the appendix summarises the impacts of the key issues on water and sanitation technologies)**

| | Increase in precipitation, increase in rainfall intensity | Decrease in precipitation, increase in rainfall intensity |
|---|---|---|
| Kanyama | **Water Supply**<br>Flooding increases<br>Groundwater recharge increases<br>Increase in extreme rainfall events<br>Run-off increases | **Water Supply**<br>Localised flooding increases/flash floods<br>Increase in extreme rainfall events<br>Run-off increases |
| | **Sanitation**<br>Flooding increases; increase in extreme rainfall events<br>Groundwater tables rising | **Sanitation**<br>Localised flooding increases/flash floods; increase in extreme rainfall events |
| Chazanga | **Water Supply**<br>Increase in extreme rainfall events<br>Run-off increases | **Water Supply**<br>Increase in extreme rainfall events<br>Run-off increases<br>Water availability in shallow wells and boreholes decreases |
| | **Sanitation**<br>Flooding increases; increase in extreme rainfall events | **Sanitation**<br>Increase in extreme rainfall events<br>Water availability in shallow wells and boreholes decreases |

## IMPACT OF CLIMATE CHANGE NOT DIRECTLY RELATED TO WATER AND SANITATION

The following summarizes the main indirect impacts of climate change on Zambia; refer to the climate change briefing (Heath, 2010) for a comprehensive overview:

- **Food insecurity – principally maize**: Increasing temperatures and a shorter growing season will decrease the area suitable for maize production in the North and centre of Zambia by 80%, while maize yields may decrease by 66%. This will increase the price of maize, affecting poorer communities and reducing the number of meals taken. The GDP of Zambia is closely correlated with precipitation due to the importance of rain fed agriculture in the economy, this will decrease if there is less rainfall (Thurlow *et al*., 2009); This will lead to increased migration. The migrations will typically be to urban areas, where the migrants are often more rather than less vulnerable to certain climate-related impacts (DFID 2010). The increased populations in urban area will increase competition over natural resources.
- **Charcoal:** Increasing temperatures and decreasing rainfall will reduce the regeneration rate of *Miombo* woodland, increasing the price and scarcity of charcoal. *Miombo* woodland covers 60% of the land and provides fuel and charcoal for 80% of households (MEWR, 2008, UN-REDD, 2010);
- **Electricity**: A reduction in rainfall will decrease the availability of water for hydroelectric (90% of the electrical supply), leading to power shortages (MTENR, 2007).

## IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN LUSAKA

Before assessing the vulnerability of the peri-urban areas to the climate change, it is necessary to review how climate change will impact water resources in Lusaka. Lusaka relies on groundwater and water piped from the Kafue River. However, there is very little information publicly available on water resources in Lusaka or even Zambia. Some information is available in the IWRM national plan (MEWR, 2008) which overviews the water resource situation in Zambia. During interviews stakeholders mentioned a water balance has been completed by the Water Board, ZESCO and the Zambezi River Basin authority but this was not available; similarly, the WWF are currently modelling abstractions from the Kafue river. However, there is evidence available that Kafue River's water quality is continuously deteriorating (heightened eutrophic conditions, increased heavy metals and suspended solids, decreased fish catch and objections of taste, (Kambole, 2003)). The impact of the climate changes on water resources are outlined below:

- **Increasing precipitation** will increase the volume of water available from the Kafue River and groundwater; however there will be an increase in localized flooding (resulting from poor drainage). Any increase in intensity of rainfall will intensify flooding and soil erosion in Lusaka
- **Decreasing precipitation** will have a severe impact on groundwater resources in Lusaka. If the water available for abstractions is decreased there will be increased reliance on the Kafue River, which may also have a lower supply due to less rainfall and an increased concentration of contaminants. The predicted rise in temperature will increase evaporation from the river and the volume of water needed for irrigation. Decreasing rainfall will lower the river levels; therefore more water is likely to be retained by the hydroelectric dam at the Itezhi-tezhi (upstream of the abstraction point for Lusaka), further reducing volume of water in the river. This will be exacerbated by the proposed closure of the Nkana Copper mines, which were pumping 500 $m^3$ a day into the river supplementing the low flow. In addition, the Kafue water works (which treats 50% of Lusaka's water) is old and in need of repair making it more likely to fail to treat river water, which will have less water available for dilution

The sustainability of ground water was assessed qualitatively during the field visit to Lusaka. The stakeholders were asked if the current abstraction was sustainable. The majority believed it was not; the most notable exception was the Acting Deputy Director of Water Affairs and Energy who believed there was sufficient water. Figure 3 outlines the opinions of stakeholders from different organizations. The main reason abstraction was viewed as unsustainable was the lack of regulation; however, a Parliamentary Bill is being proposed requiring the registering of boreholes, which should improve the understanding of how much water is being extracted. Most informants believed there should be more water piped from the Kafue River.

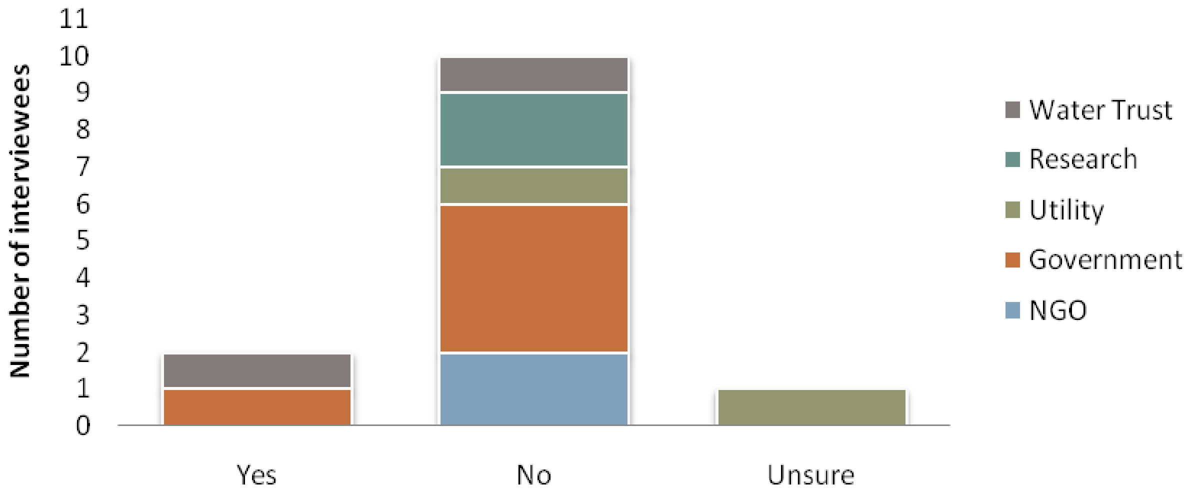


Figure 1 Results of interviewees' response to the question "Is ground water abstraction in Lusaka sustainable?"

## IMPACT OF CLIMATE CHANGE ON CHAZANGA

Climate change is likely to exacerbate or reduce existing vulnerabilities rather than create new problems (Figure 2 and 3 overviews the existing vulnerabilities). The following outlines the impact of climate change on water and sanitation in Chazanga.

### INCREASING PRECIPITATION

An increase in rainfall will have a positive impact upon Chazanga, as it will increase groundwater levels, which will decrease the risk of water shortages, the shallow wells drying up and equipment being over used (shortening its lifetime). Due to the area's topography flooding is unlikely to be a future problem. However, the increase in precipitation will intensify the poor drainage at the kiosks leading to more stagnant water and associated health risks. In addition increases in temperatures will likely reduce crops yields, increasing poverty and migration into the area, which will in turn increase the demand for land and associated pressures on sanitation (lack of space, open defecation, fly tipping of faeces).

### DECREASING PRECIPITATION

Decreasing precipitation will exacerbate most of the current environmental problems in Chazanga. The main risk is a lower water table, poor drainage at the kiosks, power shortages and damage to infrastructure; of these a lower water table has the largest number of impacts on Chazanga. Lower water tables cause water shortages, grit to get into the pipes and the drying up of shallow wells. This leads to insufficient water, long queues at the kiosk, an increase in vandalism/illegal connections and an increase in shallow well use (although if these dry up there will be an even greater demand from the kiosks). There will also be public health risks from an increase in inappropriate water saving in the home and potentially lower pressure in the system leading to ingress of contaminants and damage to infrastructure. Decreasing precipitation combined with increasing temperature will decrease the maize yields, the land available for farming and the *Miombo* woodland, increasing the risk of migration and poverty. This will exacerbate the Water Trusts' lack of finance, which undermines operations, limits maintenance, new infrastructure and the expansion of the kiosk network.

### INCREASING RAINFALL INTENSITY

An increase in rainfall intensity will result in the erosion of boreholes and kiosks leading to the loss of supply and contaminants entering the system. Latrines will be at greater risk of collapse and the erosion of soil around septic tank's absorption field will reduce its efficiency. The increase in intensity of rainfall will also increase the risk of the shallow wells being contaminated.

## Impact of climate change on Kanyama

Climate change is likely to exacerbate or reduce existing vulnerabilities rather than create new problems (Figure 4 and 5 overviews the existing vulnerabilities). The following outlines the impact of climate change on water and sanitation in Kanyama.

### Increasing Precipitation

In Kanyama increasing precipitation will exacerbate most of the current environmental problems. It will increase the risk of flooding, latrines being submerged and contamination of shallow wells. Kanyama is most at risk to flooding, which causes kiosks and buildings to be filled with water and collapse, contaminates the water supply, affects livelihoods, education, and health and makes standpipes inaccessible. Submerged latrines and contamination of shallow wells are linked and lead to annual outbreaks of cholera and diarrhoea disease. The lack of space (which will intensify due to climate induced migration) and the unplanned nature of Kanyama are putting pressure on the settlement's boundaries (land is being stolen from farmers). This in turn limits the drainage effectiveness, encourages the fly tipping of faeces and limits the options for latrine emptying all of which increase the health risks. In addition groundwater levels are likely to rise, which will exacerbate the problem of collapsing and overflowing latrines and may create pathways for rapid dispersal of contaminants.

### Decreasing Precipitation

Decreasing precipitation will have a positive impact on Kanyama, as it will reduce the risk of flooding, but there will still be a sufficient quantity of water available for domestic uses. Less rainfall will lower the water table (currently 2 m below ground level) lowering the risk of groundwater floods. But the increase in intensity will still cause problems for Kanyama and may lead to localised flooding, damage to infrastructure and contamination of the shallow wells. In addition increases in temperatures will likely reduce crop yields, increasing migration into the area. This will increase the demand for land, the construction of poor quality latrines and number of households with no access to safe water.

### Increasing Rainfall Intensity

An increase in rainfall intensity will increase the severity of the floods (and the speed of onset) resulting in the erosion of boreholes and kiosks leading to the loss of supply and contaminants entering the system. Latrines are more likely to collapse and erosion of the soil around septic tank's absorption field will reduce its efficiency.

## CLIMATE CHANGE AWARENESS

As well as increasing the resilience of water supply and sanitation systems, working with other organizations to build capacity and share knowledge is key for successful adaptations to climate change. Therefore an understanding of the current climate awareness and actions of the different stakeholders is needed. Table 2 gives a rough assessment of this information based on stakeholder interviews.

Table 2: Climate change awareness and actions of organizations in Lusaka

| Stakeholder | Awareness | Plans/Actions | No. Interviews |
|---|---|---|---|
| **Community** | Limited | None | 11 |
| **Water Trust** | Limited | None | 12 |
| **LWSC** | Low | Not assessed in work | 2 |
| **City Council** | Medium | • Disaster management unit, headed by town clerk, looks at flooding and drought | 3 |
| **Government** | Awareness at policy level but little implementation | • Large scale projects with SADC<br>• Incorporating climate change into 6th national development plan<br>• preparing 2nd communication to United Nation Framework Convention on Climate Change UNFCCC<br>• Climate Change Facilitation Unit<br>• Vulnerability Assessment Committee<br>• Reducing Emissions from Deforestation and forest Degradation Initiative | 8 |
| **Research** | High and advocates of Climate change | • Involved in 6 national development plan, trying to mainstream climate change<br>• Research projects (MSc and PhD) | 2 |
| **NGOs** | 2 involved in capacity building and awareness raising, 1 had limited knowledge | • Prepared reports on vulnerability<br>• Set up climate change civil sector partnership<br>• Tried to implement carbon capture project (WWF) but there is no national REDD framework so unable to | 3 |

# Recommendations

Adapting to climate change requires a combination of technological and structural measures, risk sharing and capacity building to increase the robustness of systems. Coping with climate change does not involve many entirely new processes or techniques. It should, however, be made clear that this is not an argument for 'business as usual'. Existing instruments, methods and measures may need to be introduced at a faster pace, and applied in different locations, at different scales, within different socio-economic context and in new combinations (CAPNET, 2009). Developing water safety plans should be a priority, to reduce the risks to water supply by establishing a framework for managing the risks to drinking water from catchment to consumer (refer to Bantram 2009).

This section reviews the key adaptations for Chazanga and Kanyama Water Trust, Lusaka Water and Sewage Company and Lusaka City Council. The adaptations were determined based on a field visit, a vulnerability assessment and selective literature review – refer to the appendix for further details. Some recommendations will be part of existing maintenance programmes; however, the priority of these actions may need increasing. The adaptations have been divided into three timescales (based on Venton, 2010):

- **Short term:** contingency adaptation for extreme events – e.g. Drought management Flood forecasting, focus on disaster management experience;
- **Medium term:** tactical adaptations regarding climate variability, linked with disaster risk reduction;
- **Long term:** adaptations necessary to respond to a predicted different climate.

The adaptations are then divided into four categories (based on Charles *et al*., 2010):

- **Capital expenditure**, which includes new investments and projects;
- **Operational expenditure**, which includes adaptations that can be made to existing systems;
- **Monitoring**, which includes programmes that can be implemented immediately to support planning decisions, or implemented in the long term to support continuing decisions;
- S**ocioeconomic,** tools such as community education, training and public awareness that can support short and long-term adaptations.

## Adaptations in Chazanga

The main impacts of climate change in Chazanga are water shortages and damage, in addition in the future the large growth will increase land pressure and exacerbate the problems associated with the limited latrine emptying options. The main adaptations to each of these issues are outlined below:

- **Water Scarcity**: the principle causes are a lower water table and power shortages. In the short term acquiring a generator will help reduce the problem. In the longer term drilling a new borehole and/or installing a direct line from Lusaka Water and Sewage Company will reduce the vulnerability. Deepening the borehole is an option (as long as the borehole is not at the base of the aquifer), but will require development to alleviate the problem of grit getting in to the borehole; otherwise a lower pumping rate should be used for a longer duration. In addition new boreholes and kiosks are needed to reach the unserved.
- **Damage to Infrastructure:** Protecting the water and sanitation infrastructure requires the stabilisation of the soil around the structures, planting, buffer strips, storm and erosion reduction measures should be implemented
- **Poor Drainage:** increased intensity of rainfall will exacerbate the poor drainage at the kiosks and increase the volume of standing water (increasing the risk from malaria and contamination). Therefore the building standards for soakaways need to be improved: firstly the soil filtration rate should be tested to determine the minimum size, the sides of the soak away should be checked for silt and the depth may need to be increased (refer to WHO, 1996, 3.9)

## Adaptations for Chazanga Water Trust

### Immediate/ Short term (0 – 6 months)

#### Capital Expenditure

- Buy generator for new borehole

#### Operation Expenditure

- Pipe maintenance programme to reduce leaks
- Adapt maintenance programme to identify breakages (refer to EPD 2007 and DOH 2008)
- Restrict water supplies during droughts
- Ensure high levels of maintenance on kiosks to avoid unnecessary wastage – ensure taps, valves and meter all working
- Ensure functioning water meters in all homes and on all kiosks

#### Monitoring

- Monitor the impact of droughts on water levels in the shallow wells
- Undertaken sanitary and water use surveys (refer to WHO 1996 2.1)
- Concentrate water quality monitoring of shallow wells during periods of droughts and after heavy rains
- Monitor the microbial quality of water at kiosks

#### Social Economic

- Implement education programme to improve efficiency of use
- Promote and raise awareness of the importance of hygiene
- Mount ropes and buckets at shallow wells and protect wells from runoff
- Raise awareness of the risks of siting latrines close to shallow wells
- Identify the most at risk shallow wells and develop communication procedures to notify the community which are not safe
- Educate communities about reliable water sources: how to select them, what makes them reliable
- Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system

## Medium Term (6 Months – 1 year)

### Capital Expenditure

- Use durable materials when constructing kiosks – use builders sand and ensure adequate cement used
- Ensure well heads are properly designed to prevent erosion damage that may increase infiltration (refer to WHO, 2003)
- Use compaction of soils and planting around infrastructure to increase durability of structures and maintain conditions which mitigate erosion, e.g. planting schemes, compaction of soils and plants in buffer strips
- Expand the kiosk network, prioritising unserved areas
- Encourage the development of double vault ECOSAN latrines to deal with lack of space expected with growth

### Operation Expenditure

- Prepare Water Safety Plan to manage risks to water supply (guidelines in Bantram, 2009)
- Replace old pipes
- Reduce illegal connections and leakage
- Maintain positive pressure in pipes or close kiosk before supply runs out (refer to Franceys, 2010)
- Repair erosion damage and sod (turf) or seed areas as necessary to provide turf grass cover

### Monitoring

- Monitor pipes for blockages and breaks
- Septic tank system inspections of pit (check no build up of silt) and absorbtion field (refer to WHO, 2003)
- Regularly check abandoned borehole is properly sealed to protect groundwater quality

### al Economic

- Education and awareness raising of lower-water use latrine options (refer to Scott 2005)
- Encourage reuse of water in community

## Long Term (1 year+)

- Consider deepening screen on old boreholes. Install relief boreholes that can be uncapped for easy use in dry periods to supplement existing wells
- Install pressure release valves
- Investigate direct connection from LWSC
- Investigate and if possible implement alternative and supplementary water sources and water harvesting methods
- Examine lower-water use approaches (plastic seals rather than water seals) and slabs that are easier to clean and use less water (refer to Scott 2005)
- Consider low-flush toilets. If no water available, septic tanks will not be a viable option. Investigate other systems for management of human excreta such as ECONSAN
- Investigate methods for the artificial recharge of groundwater/Investigate catchment management practices to promote infiltration (refer to GBR, 2009, WHO 1996, 2.5)
- Construct public toilets in wetland places where it is expensive to construct private toilets for individual homes
- Construct kiosks with shelters to protect vendor, protect equipment and allow for other income generating activities

# Adaptations in Kanyama

The main impacts of climate change in Kanyama are an increase in flooding due to poor drainage and the contamination of water due to overflowing latrines. In addition expanding the kiosk network needs to be prioritised to provide safe water to the community particularly during the floods. The main adaptation's to each of these issues is outlined below.

- **Flooding:** The main priority for Kanyama needs to be addressing the localised flooding which devastates the area. The council and various NGOs are improving the drainage, but this work needs to be expanded as climate change will increase the severity of the flooding. The key actions are clearing the drainage ditches of rubbish and the rock, develop and expand the drains which run into the main drains and moving houses which block the drains
- **Overflowing latrines:** Improving the drainage will reduce the flooding in Kanyama, however even with improved drainage there is likely to be localised flooding due to blocked drains or rising ground water, so the latrines will still overflow. There needs to be assistance with emptying latrines (current and those which have collapsed), and ensuring new latrines which are built high enough to avoid sewage overflowing. Encouraging regular emptying will also address the limited land issues. As flooding is still an issue ECOSAN should be reviewed as there is little market for the sewage and the latrines are not well adapted to the floods, in the longer term, a decentralised sewage system is the most sustainable options as long as it is well maintained
- **Kiosk network:** The network needs to be expanded to ensure every household has access to safe water during floods. This will require the sinking of additional boreholes and further investment and support to the water trust. It is also worth considering adjusting the design of the kiosks to the shelter structure as this will improve the lifetime of the valves, taps and enable the vendor to sell products and have shelter

## Kanyama Water Trust

### Immediate/ Short term (0 – 6 Months)

#### Capital Expenditure

- For deep boreholes ensure the casing extends below the level of shallow aquifers. Extend lining above flooding level

#### Operation Expenditure

- Regular programme of leak detection and repairs (refer to EPD 2007, WHO 2001 and DOH 2008)
- Flush out pipes and clean standpipes after floods (refer to WHO, 1996 2.27)
- Shock chlorinate borehole water after the floods have subsided (refer to WHO, 2005 & WHO 2.25)
- Develop response plan after flooding to assess damage to standpipes and to inform future improvements (refer to Reed 2006)
- Adapt water treatment to respond to changing water to ensure that water quality is not compromised during or after floods

#### Monitoring

- Monitor the response of groundwater levels and quality to increasing rainfall
- Monitor water quality and adapt treatment processes Sanitary inspection of standpipes (refer to WHO, 1996 2.27)
- Testing of shallow wells, raise awareness of high risk wells in community

#### Social Economic

- Advise the community to avoid using contaminated springs for drinking during and after floods, until quality has been verified
- Develop communication procedures to notify the community when the water is safe

- Raise awareness about potential health issues associated with sewage and dangers of emptying pits for floods to wash away
- Raise awareness of the dangers of latrines close to shallow wells (refer to Cave and Kolsky 1999)

## Medium term (6 Months – 1 year)

### Capital Expenditure

- Where possible, implement land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, reforestation (refer to BGT, 2009 & WHO, 1996 2.5)
- Improve borehole lining to prevent ingress of water from soil and shallow groundwater, ensure that borehole are sealed to several metres below the water table
- Site new boreholes well away from latrines and other sources of groundwater pollution
- Build bunds (banks, dykes or levees) to divert floods away from borehole, or raise the well head
- Ensure that wellheads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures
- Aim to site pipes in areas at low risk to flooding. Relocate water pipes away from open sewers and drainage channels
- Construct standpipes from durable materials (including mesh foundation) to reduce damage during floods , avoid using local material, use proper building sand
- Place kiosks on elevated platforms to allow access during floods
- Minimize erosion with planting schemes, buffer strips and storm water management
- Construct new kiosks and storage tanks to expand network to unserved areas

### Operation Expenditure

- Prepare Water Safety Plan to manage risks to water supply (guidelines in Bantram, 2009)
- Repair rendering of borehole wall when necessary (refer to WHO, 2003)
- Maintain well head protection areas (refer to WHO, 2003)
- Investigate increasing protection zones around boreholes (acquire land), minimum of 15 m to latrine, raise awareness in community, empty near latrines and close (refer to Cave and Kolsky, 1999)
- Protect pipes under road: signs to alert vehicles, deepen pipes
- Introduce a pipe maintenance programme to reduce leakage and potential for ingress (repeated check)
- Rehabilitation to improve pressure in system (refer to Franceys, 2010)
- Flush out flooded pipe network after waters have receded to remove sediments
- Pipe maintenance programme to fix leaks in pipes
- Reduce illegal connections and leakage
- Ensure functioning water meters in all homes and on all kiosks
- Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips Improve soakaways at kiosks

### Monitoring

- Monitor microbial quality of water after the well or borehole has been renovated
- Develop and implement reporting mechanism when areas above pipes are flooded. Review risks and need for refurbishment or replacement

### Social Economic

- Raise awareness about potential health issues associated with sewage (refer to Curtis 2005, Appleton and Sijbensema, 2005)
- Community education on latrines on the need to empty regularly, post flood rehabilitation to remove silt, to plant shrubs around latrines (reduce pit erosion), build smaller pits (less risk of collapse and less sewage to contaminate) and the importance of regular maintenance (limit vulnerability to collapse) (refer to Scott 2005)
- Raise awareness of need to the restart composting in ECOSAN latrines following flooding to redress moisture balance (refer to Smet and Sugdon 2006)
- Hygiene education at kiosks, train to keep area clean, avoid standing water and check containers

### Long term (1 year+)

- Develop back-up sources, such as linkages to other water sources or community water supply systems
- Provision of alternative water sources during inundation or household treatment (who sheet)
- Construct kiosks with shelters to protect vendor, protect equipment and allow for other income generating activities
- Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding
- Maintain hygiene education in community sewage (refer to Curtis 2005, Appleton and Sijbensema, 2005)
- Construct public toilets in slum areas in wetland places where it is expensive to construct private toilets for individual homes

### Sewers

- Build decentralised sewers (refer to Gate 2001)
- Local decentralized treatment will reduce pumping costs and enable local responsive management when system is vulnerable to damage
- Low-cost sewers can be more easily maintained or replaced when damaged, but are more vulnerable to erosion. Have spare parts available
- Ensure that sewers are gravity flow wherever possible. Low-cost and shallow sewers have much lower pumping requirements
- Do not locate sewers in soils which are regularly waterlogged. Low-cost and shallow sewers may be less susceptible and above groundwater levels
- Site sewers pipe away from drainage channel. Compaction of soil and planting above sewers, under paved roads etc. Clean sewers regularly. Clean drains regularly especially just before wet season
- Monitor silt levels, blockages, cross connections, in drains and sewers

## Other Stakeholders

The two other main stakeholders are Lusaka Water and Sewage Company (LWSC) and the Lusaka City Council. LWSC are responsible to NWASCO (regulator) for ensuring water and sanitation services meet the legal requirements. Their principle role is providing technical support (both staffing and equipment) and working with the peri-urban unit to secure new funding from the Devolution Trust Fund. The city council's role is providing local services in the peri-urban area areas: drainage, roads, waste collection, public health and planning. The city council also work with the Ward Development Committees (elected representatives from the community) who identify key areas of concern in the settlements. The urban poor are vulnerable to hazards induced by climate variability; however, they also have a certain level of built-in-resilience (preventative, impact minimizing and economic strategies, asset accumulations, and development of social support networks) which must be recognized and which can be better supported by planning initiatives from the City Council (Allen *et al*., 2010). A central role of the council should be addressing the issues of adaptation within their existing programmes and projects as an integral part of development plans rather than creating separate adaptation plans. The following identifies how LWSC and the city council should adapt to climate change and support the peri-urban areas. The adaptations for LWSC are split into the short, medium and long term, while those for the council are further dived into capital, operation, monitoring, policy changes and social economic adaptations.

### Lusaka Water and Sewage Company

### Short term (0 – 6 months )

- Install pressure release valves for both settlements
- Assist in improving well head protection areas and well head inspection (refer to WHO, 2003)
- Responsibility for ensuring water quality meets NWSACO standards

### Medium term (6 months – 1 year)

- Raise finances for new infrastructure from DTF in Chazanga and Kanyama
- Assist in deepening screen in borehole in Chazanga
- Investigate link between groundwater recharge and rainfall intensity in Chazanga
- Construct new storage tanks for both settlements
- Rehabilitation of pipe network to improve pressure in systems(new storage tanks, pressure release vales)(refer to Franceys, 2010)
- Establish/expand peri-urban unit to provide technical and administrative assistance during flooding
- Assist expanding the kiosk network
- Determine the degree of vulnerability through investigating linkages between rainfall and groundwater, e.g. residence times
- Raise awareness among water resource managers and water engineers about the potential for lateral transport of pathogens and subsequent contamination of water

### Long term (1 year+)

- Develop back up supplies for Chazanga, install main line connection for Chazanga
- Investigate methods for the artificial recharge of groundwater/Investigate catchment management practices to promote infiltration (refer to BGR, 2009 &WHO, 1996 2.5)
- Assist deepening boreholes. Install relief wells that can be uncapped for easy use in dry periods to supplement existing wells

## Municipality – Lusaka City Council

### Short term (0 – 6 months)

#### Operation Expenditure

- Repair plinths and clear ditches of rubbish and silt

#### Monitoring

- Identify most at risk shallow wells and make community aware which are high risk

#### Social Economic

- Develop communication procedures to communicate when water is safe
- Hygiene education at shallow wells, advise the mounting of rope and bucket and protecting shallow wells from runoff
- Raise awareness about potential contamination of drinking-water supply, the risk during floods, health issues associated with sewage and the risks of emptying the latrines for the flood to disperse
- Dissemination of public health messages with advice about dealing with the issues, including household treatment and boil water notices where appropriate
- Raise awareness on risk of latrines close to shallow wells and the need for regular emptying
- Raise awareness about the dangers of unstable pit latrines

### Medium term (6 months – 1 year)

#### Capital Expenditure

- Implement land management activities to reduce severity of floods, e.g. terracing, adequate drainage, reforestation, retention basins
- Increase size of ditch and plant trees on side of ditches
- Buy/move houses blocking drains
- Ensuring that local drains feeds effectively into the main drainage channel and construct new feeders if necessary
- Have a permanent workforce to maintain and clean the drainage system

#### Operation Expenditure

- Proper garbage and solid waste disposal together with increased awareness (repair garbage truck)
- Enforce no dumping of latrine matter, improved emptying options, make community aware of risks

- Regulate better quality construction of latrines/improve standards (refer to Scott, 2005)
- Subsidise tanker/provider free removal of waste

### Monitoring

- Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines
- Mapping most vulnerable sites in need of intervention

### Social Economic

- Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system
- Move away from composting - not appropriate for Kanyama in the longer term
- Site latrines at least 15 m away from drainage channel (Cave and Kolsky, 1999)
- Encourage users/enforce standards for pit latrine: superstructure at the same level as the houses; build round pits instead of square (increase stability); regular emptying and post-flood rehabilitation to remove silt; plant shrubs around latrines (reduce pit erosion); build smaller
- Advocate the importance of regular maintenance, proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits (refer to WHO, 2003)
- Raise awareness of need to restart composting following flooding event to redress moisture balance
- Raise standards for septic tanks: use durable materials in construction; design to prevent ingress of silt; secure pit to ground (prevent floating on flood) and install non return vales (shut during floods)
- Raise awareness of monitoring and maintenance requirements for septic tanks: empty tank post flood; dangers of waterlogged soakways; need to plant grasses and shrubs in the absorption area, and around the septic tanks (reduce erosion); check the vegetation over the septic tank and soil absorption field after flooding; build bunds (banks, dykes or levees); awareness of signs of failure of an absorption field, and how to fix it or construct a new one and the need to empty (refer to WHO, 2003)
- Ensure tank full of water during flood to prevent damage to the infrastructure. However, lids need to be properly fitted and secured to prevent sewage overflow

## - Long term (1 year+)

### Capital Expenditure

- Invest in market for composted sewage in Chazanga (refer to Scott and Read 2006)
- Construct a deeper and wider main drain in Kanyama to accommodate the increased flooding water
- Use sustainable urban drainage systems and separate sewers in Kanyama. Encourage decentralized systems

### Policy

- Facilitate security of tenure to allow residents to stay longer and develop stronger ties to the community and better networks
- Tighter planning and regulation of land tenure, working with farmers
- Support saving schemes of the urban poor facilitating access to financial institutions
- Adopting modifications practiced at the household level into housing, land use and infrastructure municipal plans and procedures
- Advocate ECOSAN latrines in Chazanga, set up with marketing, hygiene awareness on reuse and not putting rubbish in latrines
- Developing opportunities for communication and sharing experiences among local government and grassroots organizations about how to build better resistant housing and infrastructure
- Developing building codes that specify measures like increasing plinth height or window locations, allow families to share infrastructure; increase building standards for washrooms

### Social Economic

- Ensure that users know they should keep moisture out of ECOSAN latrines after flooding
- Support use of alternative building materials and appropriate technology look into quality of materials, raise awareness of which are not suitable (refer to ITDG, 2007)

# Response to Recommendations

A response to the following questions will be included from Chazanga, Kanyama, LWSC and Lusaka City Council:

1. How will [stakeholder] respond to the climate proofing recommendations?
    a. How will the adaptations be implemented?
    b. How do they impact long term plans?
2. What additional information do you require to apply the adaptations?

# Further Information

Climate modelling and climate change adaptation are both areas of continuing research. It is important to be aware of the ongoing work being undertaken which will inform future investments and adaptations. Table 5 illustrates that although climate change is recognised at the policy level, there is little work being implemented. As policy filters down it will have a greater impact on resource management and it is important to stay aware of changes to policy.

## Current Research

The following lists the key research currently being undertaken in Lusaka, detailing the principle organisation, and the purpose of the work.

### Principle Resources

- **Second National Communication to the United Nations Framework Convention on Climate Change.** A draft being prepared by the Climate Change Facilitation Unit (established by Ministry of Tourism, Environment and Natural Resources). The report includes a review of the major activities and an inventory of greenhouse gas emissions; assessment of potential impacts of climate change on the most vulnerable sectors; analysis of potential measures to abate increase of greenhouse gases; and capacity development for reporting on climate change. The project is supported by UNDP and the University of Zambia (www.ccfu.org.zm/)

### Secondary Resources

- **United Nations Environment Programme** have produced a vulnerability assessment and are working on an assessment of the climate change information gaps (www.undp.org.zm)
- **Integrated Water Resources Management and Water Efficiency planning process** is being implemented by the Ministry of Energy & Water Development (www.mewd.gov.zm)

- **Zambia Water Partnership** is a partnership comprising of stakeholders in the water sector and interested organisations. It has a mandate to promote the implementation of Integrated and sustainable Water Resources Management in Zambia. ZWP is currently hosted by the School of Mines, University of Zambia with Dr. Imasiku A. Nyambe as the coordinator (www.zwp.org.zm/index.html)
- **Zambia National Vulnerability Assessment Committee** part of the Disaster management Unit which is a special unit under the Office of the Vice-President of Zambia. They prepare assessments of vulnerability in Zambia (www.dmmu-ovp.gov.zm/)
- **WWF Zambia**. Trying to implement a carbon sequestration project, modelling the Kafue River flows/abstractions and involved in climate change advocacy

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# Appendix

Table 3 Overview of interviews undertaken in Lusaka

| Organisation | Number of Interviews |
|---|---|
| **City Council** | **3** |
| • Housing and Social Services | 1 |
| • Public Health | 2 |
| **Community** | **11** |
| • Chazanga | 6 |
| • Kanyama | 4 |
| • Community - Focus Group | 1 |
| **Water Trust** | **12** |
| • Chazanga | 5 |
| • Kanyama | 7 |
| **Government** | **8** |
| • Devolution Trust Fund | 1 |
| • Environment Council | 1 |
| • Ministry of Energy and Water Resources | 1 |
| • Ministry of Local Government and Housing | 2 |
| • Ministry of Tourism, Environment and Resources | 2 |
| • National Water Supply and Sanitation Council | 1 |
| **LWSC** | **2** |
| • LWSC | 1 |
| • Zulu Burrow | 1 |
| **NGO** | **3** |
| • CARE | 1 |
| • United Nations Environment Programme | 1 |
| • WWF | 1 |
| **Research** | **2** |
| • National Institute for Scientific and Industrial Research | 1 |
| • University of Zambia | 1 |
| **Total** | **41** |

## Vulnerability Assessment

Understanding the existing vulnerabilities is central to assessing the impacts of climate change. Figures 2 - 5 outline the environmental vulnerabilities and problems with the water supply systems in the settlements and impact of the climate scenarios predicted for Lusaka. There are two assessments for each settlement, one assessing the impacts of increasing precipitation, the other decreasing precipitation, both include increasing rainfall intensity. The factors directly impacted are highlighted red and subsequent impacts are shown in pink – the darker the colour, the greater the likelihood that the problem will be affected by climate change. The figures are as follows:

- Figure 2: Impact of increasing rainfall and increasing intensity on existing vulnerabilities in Chazanga
- Figure 3: Impact of decreasing rainfall and increasing intensity on existing vulnerabilities in Chazanga
- Figure 4: Impact of increasing rainfall and increasing intensity on existing vulnerabilities in Kanyama
- Figure 5: Impact of decreasing rainfall and increasing intensity on existing vulnerabilities in Kanyama


**Figure 2 Impact of increasing precipitation and rainfall intensity on existing vulnerabilities in Chazanga (red indicates direct impact of climate change, green no direct affect)**


**Figure 3 Impact of decreasing precipitation and rainfall intensity on existing vulnerabilities in Chazanga (red indicates direct impact of climate change, green no direct affect)**


**Figure 4: Impact of decreasing precipitation and rainfall intensity on existing vulnerabilities in Kanyama (red indicates direct impact of climate change, green no direct affect)**


**Figure 5: Impact of increasing precipitation and rainfall intensity on existing vulnerabilities in Kanyama (red indicates direct impact of climate change, green no direct affect**

## LITERATURE REVIEW

In addition to identifying the impacts of climate change on the existing vulnerabilities and problems in Chazanga and Kanyama the literature was reviewed to assess the impact of climate change on water and sanitation technologies. The following tables overview how the technologies (current and planned) are vulnerable to the key issues (outlined in Table 1) and the resulting impacts. The tables are based on observations during the field visit and literature, which assesses the impact of climate change on technology – principally a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010).

## Impact of Climate Change on Technology in Chazanga

### Community-managed drinking water systems (direct connections)

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Water availability decreases | Insufficient water for demand, or increased seasonality of water | Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home. Low pressure in system may allow ingress of contamination into the water distribution network. Intermittent water supplies and pressure changes in the distribution network lead to damage of the infrastructure | Restrict water supplies and switch pipes off. Increase water storage capacity to provide supply over extended dry periods Investigate alternative water sources and water harvesting methods | Pipe maintenance programme to reduce leaks. Prioritize allocation for domestic use. | Monitor for microbial quality of water. | Educate communities about reliable water sources: how to select them, what makes them reliable, etc. |
| **Run-off increases** | No threat | | | | | |

### Kiosk/ Standpipe

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Water availability decreases | Addressed in community managed supply | | | | | |
| Run-off increases | Erosion damaging standpipe. | Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe | Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction | Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips. | Sanitary survey. | Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system |

### Borehole

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Water availability decreases | Insufficient water for demand | Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home | Investigate alternative and supplementary water sources and water harvesting methods, such as rainwater collection and water reuse. Prioritize water use for drinking. Investigate methods for the artificial recharge of groundwater Investigate catchment management practices to promote infiltration. Consider deepening the wells and boreholes | Ensure high levels of maintenance on wells to avoid unnecessary losses of water at the point of use | Monitor water use at well for user pays scheme, and assist in demand management. Monitor the ability of wells to cope with current droughts | Implement education programme to reduce water demand. Promote the importance of hygiene |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Increased use of viable wells causes increased wear and tear, and increased water demand | Damage to well or borehole increases the risk of contamination entering water source. Public health risk from consumption of the water | Determine the degree of vulnerability through investigating linkages between climate and groundwater, e.g. residence times | Ensure high levels of maintenance on in demand wells | Sanitary survey. Monitor the ability of wells to cope with current droughts | |
| | Less water available for hygiene and cleaning | Public health risk from inappropriate water saving in the home | Research cleaning and hygiene methods that have low-water usage | | Water use surveys | Raise awareness of the importance of hygiene |
| | Groundwater levels dropping, especially during a dry period or season | Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home. Increased risk of contamination of the water at the end of the drought | If supply from the well is already variable, consider that the current well may need to be extended or new deeper wells may need to be installed. Install relief wells that can be uncapped for easy use in dry periods to supplement existing wells | Determine the degree of vulnerability | Concentrate water quality monitoring during periods of high risk at the end of the droughts | |
| Run-off increases | Erosion | Permanent loss of borehole or well. Damage to the structure of the borehole or well, leading to a temporary loss of supply. Public health risk from contaminants entering the standpipe | Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures | Maintain conditions which mitigate erosion e.g. compaction of soils and plants in buffer strips. | Monitor microbial quality of water after the well or borehole has been renovated | Raise awareness among the community about the damage that erosion can cause to wells and boreholes. Develop communication procedures to notify the community when the water is safe |

## SEPTIC TANKS

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Increase in extreme rainfall events; run-off increases | Erosion of soil around the tank and absorption field | Damage to infrastructure. Reduced efficacy of the absorption field | Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build bunds (banks, dykes or levees) to divert flow away from system | Check the vegetation over the septic tank and soil absorption field after flooding. | | |
| Water availability decreases | Less water available for flushing and cleaning | Toilet and discharge pipe becomes dirty or blocked | Examine lower-water use approaches (plastic seals rather than water seals, for example) and slabs that are easier to clean. Increase attention to construction quality and setting out of sewers. More rodding eyes. Steeper falls. Consider low-flush toilets. If no water available, septic tanks will not be a viable option. Investigate other systems for management of human excreta | Consider feasibility of households doing more regular cleaning, rodding etc. Improve solid waste management, especially for fat solids | Septic tank system inspections | Education and awareness of lower-water use latrine options |
| | Increased distance to groundwater tables | Reduced risk of groundwater pollution | Septic tanks become more viable option | | | |
| | Changing moisture levels in soils | Movement and infrastructure damage | Design for movement. | Adapt maintenance programme to identify breakages | Monitor performance for blockages and breaks | |

### Improved pit latrines

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Increase in extreme rainfall events; run-off increases | Erosion | Collapse of latrine | Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding | Regular maintenance essential to limit vulnerability to collapse | | Hygiene promotion. Education on regular maintenance requirements |
| Water availability decreases | Increased distance to GW tables | Reduced risk of groundwater pollution | Pit latrines become more viable option | | | |

### Planned: Composting/dry latrines

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Increase in extreme rainfall events; run-off increases | Erosion | Same as improved Pit Latrines | | | | |
| Water availability decreases | No issues | | | | | |

## Impact of Climate Change on Technology in Kanyama

### Community-managed drinking water systems (direct connections)

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases | Increased flooding reduces the availability of safe water resources | Flooding events increase the level of chemical and microbiological contamination in water sources, increasing the risk to public health. Increased suspended sediment loads carried by flood waters may exceed the treatment capacity of any small scale water treatment system that has been added to the supply | Adopt higher design standards for infrastructure Where possible, implement land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, reforestation | Establish centralized support unit to provide technical and administrative assistance in the event of flooding | Enhanced inspection of infrastructure | Raise awareness among the community of the risk of contamination during floods and reduction in drinking water availability. Dissemination of public health messages with advice about dealing with the issues, including household treatment and boil water notices where appropriate |
| | Groundwater quality deterioration during floods | Floodwaters contaminate shallow and deep groundwater sources through damaged or disused boreholes Shallow groundwater may also be affected by infiltration of floodwater through soil layers. Risk to public health from consuming the water | Improve source protection Relocate groundwater source where possible | Impose well head protection areas and well head inspection. Shock chlorination after flood | Sanitary inspection. Intensify water quality monitoring during flood | Develop communication procedures for when water is safe. Raise awareness about risks from water quality changes during flooding and the need for household water treatment |
| | Entry of contaminated flood water into water supply pipes | Widespread contamination of the water supply system. Risk to public health from consuming the water | Aim to site pipes in area of low risk of flooding. Relocate water pipes away from open sewers and drainage channels | Introduce a pipe maintenance programme to reduce leakage and potential for ingress, possibly with the aid of a central support system. Rehabilitation to improve hydrostatic pressure. Flush out flooded pipe network after waters have receded to remove sediments. Shock chlorination | Sanitary inspection. Develop and implement reporting mechanism when areas above pipes are flooded. Review risks and need for refurbishment or replacement | Issue boil water notices where appropriate. Develop communication procedures for when water is safe |
| | Contamination of drinking-water in supply affecting whole community | Severe risk to public health from consuming the water | Develop back-up sources, such as linkages to other water sources or community water supply systems. Develop emergency backup supplies | Regular programme of leak detection and repair | Sanitary inspection | Issue boil water notices where appropriate. Develop communication procedures for when water is safe |
| Groundwater recharge increases | Potential deterioration in the quality of groundwater sources as a result of more | Rising groundwater levels flood sanitation systems, creating pathways for the potentially rapid dispersal of contaminants into groundwater. Rising water level mobilizes microbial and chemical contaminants. Ingress of | Investigate increasing protection zones around wells, to reduce contamination sources. Adapt water treatment to respond to changing water quality. Develop, implement and update water safety plans. Investigate the benefits of placing increased reliance on | Maintain positive pressure in pipes wherever possible. Pipe maintenance programme to fix leaks in pipes | Design and implement a monitoring programme for groundwater sources based on | Raise awareness among the community of the risk of contamination from rising. Dissemination of public health messages with advice about dealing with the issues, including |

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| | rapid transport of water in subsurface, and potential compromising of sanitation systems | groundwater into treated water supply, potentially contaminating water. Significant public health risk from consuming the water | groundwater systems in areas of rising groundwater, provided appropriate treatment can be added. Increase the depth of well intakes, where possible. Move towards continuous positive pressure in system | | groundwater level. Monitor the response of groundwater levels and quality to increasing rainfall, to identify vulnerability. Sanitary inspection | the need for household treatment and boil water notices where appropriate. |
| | Increase vulnerability of flooding | See flooding | | | | |
| Increase in extreme rainfall events | Water quality, particularly at shallow depths, may deteriorate Increased lateral flow in soils may spread contamination. | Public health risk from contaminants entering the water distribution system. | Consider constructing deeper wells. | Ensure that wells are sealed to several metres below the water table | Monitor water quality and adapt treatment processes to ensure that water quality is not compromised. | Raise awareness among water resource managers and water engineers about the potential for lateral transport of pathogens and subsequent contamination of water. |
| **Run-off increases** | No threat | | | | | |

## Kiosk/ Standpipe

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases | Standpipes inundated with contaminated floodwater. | Standpipes become inaccessible or are damaged by the floodwater. Quality of the water at the standpipe deteriorates and there is potential for more widespread contamination of the distribution system. | Place on elevated platform to allow access during floods. Construct standpipes from durable materials to reduce damage during floods. Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding. | Adopt a standpipe maintenance programme to reduce potential for ingress (e.g. chambers are sealed). Develop response plan after flooding to assess damage to standpipes and to inform future improvement. Flush out pipes and clean standpipes after floods. | Sanitary inspection of standpipe. Increase water quality monitoring after floods have receded. | Issue boil water notices where appropriate. Develop communication procedures for when water is safe. |
| GW recharge increases | See community managed piped supply | | | | | |
| Increase in extreme rainfall | See community managed piped supply | | | | | |
| Run-off increases | Erosion damaging standpipe. | Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe. | Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction | Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips. | Sanitary survey. | Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system. |

## BOREHOLE

| Issue | Vulnerability | Impacts | Adaptations | | | |
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| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases | Increased contamination of groundwater and lateral flow in soil | Floodwaters introduce contamination into the groundwater by infiltration though the soil, by damaged or disused bore holes or dug wells. Lateral flow increases, transporting contaminants below the surface. Significant public health risks from consuming the water | Site well away from latrines and other sources of groundwater pollution | Repair rendering of well wall when necessary | Sanitary inspection. Monitor the response of groundwater levels and quality to flooding, to identify vulnerability | Prevent latrines being constructed nearby |
| | Well is inundated | Widespread contamination of the aquifer, causing long term problems with the quality of water in the well. Significant public health risks from consuming the water | Build bunds (banks, dykes or levees) to divert flow, or raise the well head. Site on embankments. For deep wells, ensure the casing extends below the level of shallow aquifers. Extend lining above ground. Convert dug wells to hand pumped tubewells with sanitary completion. Improve well lining to prevent ingress of water from soil and shallow groundwater, where appropriate. Implement land management activities to reduce severity of floods, e.g. terracing, adequate drainage, reforestation, retention basins | Repair and clear ditches. Increase size of ditch. Repair plinth. Shock chlorinate well water after the floods have subsided. Provision of alternative water sources during inundation or household treatment | Sanitary inspection. Increase water quality monitoring. Monitor conductivity if in coastal or estuarine areas | Issue boil water notices where appropriate. Develop communication procedures for when water is safe |
| Groundwater recharge increases | Potential deterioration in the quality of groundwater sources as a result of more rapid transport of water in subsurface, and potential compromising of sanitation systems | Significant risk to the health of consumers. Increase in groundwater level could also lead to a reduction in the vulnerability of protected wells and provide a more sustainable water supply than alternative water supply options | Investigate increasing protection zones around wells, to reduce contamination sources. Adapt water treatment to respond to changing water quality. Set intakes at greater depth or modify pumping regimes, where feasible. In the event of a decrease in the vulnerability of protected wells, an increase in the reliance on groundwater sources should be considered | Establish centralized support unit to provide technical and administrative assistance. Act upon sanitary risk inspections | Design and implement a monitoring programme for groundwater sources based on groundwater level. Monitor the response of groundwater levels and quality to increasing rainfall, to identify vulnerability Sanitary inspection | Prevent latrines being constructed nearby. Raise awareness among users of the wells about risks from water quality changes during flooding and the need for household water treatment. Issue boil water notices where appropriate. Develop communication procedures for when water is safe |
| Increase in extreme rainfall events | See Flooding | | | | | |
| | Groundwater quality, particularly at shallow depths may deteriorate. Increased lateral flow in soils may also spread | Quality of the water from the spring deteriorates. Water quality changes may be long term if the aquifer becomes contaminated | Investigate alternative sources, if appropriate and possible | Properly seal abandoned wells to protect groundwater quality. Maintain well head or spring head protection | Water quality monitoring after a flood to verify that water quality is not compromised | Advise the community to avoid using contaminated springs for drinking during and after floods, until quality has been verified |

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| | contamination | | | areas. | | |
| Run-off increases | Erosion | Permanent loss of borehole or well. Damage to the structure of the borehole or well, leading to a temporary loss of supply. Public health risk from contaminants entering the standpipe | Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures | Maintain conditions which mitigate erosion e.g. compaction of soils and plants in buffer strips | Monitor microbial quality of water after the well or borehole has been renovated | Raise awareness among the community about the damage that erosion can cause to wells and boreholes. Develop communication procedures to notify the community when the water is safe |

## Septic tanks

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases; Increase in extreme rainfall events; run-off increases | Back flow of sewage into the house | | Install non-return valve that can be shut in event of a flood; do not use the septic tank again until waters have receded | Regular emptying services to minimize faecal sludge build-up | | Raise awareness about potential health issues associated with sewage |
| | Inundation of the system, resulting in contamination of surrounding area with sewage | | Where possible, site tank away from water supply | | | Raise awareness about potential health issues associated with sewage |
| | Flooding of septic tank resulting in accumulation of silt | | Design to prevent ingress of silt | Septic tanks and pump chambers can fill with silt and debris, and must be pumped out and cleaned after a flood. Ensure adequate access to tanks so that they can be cleaned | | |
| | Flotation | Structural damage to tank, for example from movement | Use durable materials in construction of tanks | | | It is important that tanks are full of water during a flood to prevent damage to the infrastructure. However, lids need to be properly fitted and secured to prevent sewage overflow. Education and increased awareness of issues surrounding damage and when to replace |
| | Flooding of the absorption field with sewage sludge | | Install non-return valve that can prevent flow to the field in event of a flood | | | |
| | Inundation of the soakaway | | Delay using septic tank until flood waters and groundwaters have receded | | | Raise awareness of signs of failure of an absorption field, and how to fix it or construct a new one |
| | Erosion of soil around the tank and absorption field | Damage to infrastructure. Reduced efficacy of the absorption field | Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build | Check the vegetation over the septic tank and soil absorption field after flooding | | |

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| | | | bunds (banks, dykes or levees) to divert flow away from system | | | |
| Groundwater tables rising | Flotation of septic tank | Damage to infrastructure | | If groundwater rises above the bottom of the tank, the tank will need to be secured to prevent floating during pump out | | Education and increased awareness of issues surrounding damage and when to replace |
| | Inundation of soakaway | Increased potential for contamination of groundwater. Treatment of sewage by soil in soakaways may be reduced Septic tank fills and backs up | Use shallower infiltration trenches or introduce artificial wetlands or reedbed systems to improve effluent treatment. Where possible, site system away from water supply. Design septic tank systems in conjunction with drainage to lower the groundwater table. Introduce trees and other plants to improve drainage and increase water loss by transpiration | | Monitor water quality and groundwater levels | Education to increase awareness of the risks of sewage upwelling if soakaways are waterlogged. Ensure that septic tanks are emptied regularly |

## IMPROVED PIT LATRINES

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases; Increase in extreme rainfall events; run-off increases | Pit overflowing or inundated; very mobile contamination | Faeces leaving pit and causing pollution downstream. Silt and solids entering pit and filling it | Design pit to allow regular emptying and post-flood rehabilitation to remove silt. Proper pit covers to prevent material flowing out in a flood. Investigate overflow mechanisms to filter water to reduce pressure build-up. Where possible, site latrine away from water supply, and away from areas prone to flooding. Build pit latrine superstructure at the same level as the houses, as these usually are above normal flood level. In urban areas, consider small pits which need regular (monthly or less) emptying to minimize the amount of faecal matter exposed to flooding. Consider if dry or composting latrines or sewerage is appropriate | Regular pumping or emptying of pit latrine (particularly in urban setting) | Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines – to ensure that systems are in place | Raise awareness about potential contamination of drinking-water supply and need for regular emptying |
| | Increased intentional emptying of pits during floods | Widespread contamination with faeces | | Regular pumping or emptying of pit latrine (particularly in urban setting) | Monitoring and enforcement systems should focus on emptying and faecal sludge management, as well as construction of latrines – to ensure that systems are in place | Raise awareness about potential health issues associated with sewage. Raise awareness about potential contamination of drinking-water supply |
| | Inundation or erosion | Collapse of latrine | Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding damage. Small pits in urban areas to minimize risk of collapse. Build bunds (banks, dykes or levees) to divert flow away from latrine. Planting of shrubs around the pit to reduce erosion damage. Adopt more conservative design standards for infrastructure to take higher and more frequent events into | Regular maintenance essential to limit vulnerability to collapse | | Hygiene promotion. Education on regular maintenance requirements |

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| | | | consideration (more expensive), or have systems that can be quickly and cheaply replaced | | | |
| | Damage to the superstructure | | Make more durable, especially the bottom 30cm, or choose a cheaper temporary option that can be reinstalled rapidly | | | |
| | Latrine not accessible | | Find a new site, not subject to such frequent flooding, or construct temporary latrines in refuges | | | |
| | Erosion | Collapse of latrine | Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding | Regular maintenance essential to limit vulnerability to collapse | | Hygiene promotion. Education on regular maintenance requirements |
| Groundwater tables rising | Inundation of the pit from below | Contamination of groundwater and soil, potentially reaching drinking-water resource | Provide protected water supply. Consider options: shallower pits and more frequent emptying; dry composting latrines; sewerage. | Regular pumping or emptying of pit latrine (particularly in urban setting) – link to smaller pit sizing | Monitor drinking-water quality | Education to increase marketing and user education of alternatives |
| | Inundation of pit | Pit collapse. | Build round pits instead of square to increase stability. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to prevent collapse. Small pits in urban areas to minimize risk of collapse. Introduce trees and other plants to improve drainage and increase water loss by transpiration | | | Raise awareness about the dangers of unstable pit latrines, and under what conditions these might occur |

## COMPOSTING/DRY LATRINES

| **Issue** | **Vulnerability** | **Impacts** | **Adaptations** | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases; Increase in extreme rainfall events; run-off increases | Pit inundated | Faeces leaving chamber, leading to pollution in the environment | Design toilet to be appropriate to flooding levels (e.g. above ground chambers, rather than small pits) | Capacity to restart composting following event. Redress moisture balance | | Ensure that users know they should keep moisture out after flooding |
| | Increased intentional emptying of pits during floods | See Pit Latrine | | | | |
| | Inundation or erosion | See Pit Latrine | | | | |
| | Damage to the superstructure | See Pit Latrine | | | | |
| | Latrine not accessible | See Pit Latrine | | | | |
| Groundwater tables rising | Inundation of the pit from below | See Pit Latrine | | Capacity to restart composting following event. Redress moisture balance | | Ensure that users know they should keep moisture out after flooding |
| | Inundation of pit. | See Pit Latrine | | Capacity to restart composting following event. Redress moisture balance | | Ensure that users know they should keep moisture out after flooding |

## PLANNED: SEWERS

| Issue | Vulnerability | Impacts | Adaptations | | | |
|---|---|---|---|---|---|---|
| | | | Capital expenditure | Operational expenditure | Monitoring | Socioeconomic tools |
| Flooding increases; Increase in extreme rainfall events; run-off increases | Erosion | Same as improved Pit Latrines | | | | |
| | Infiltration of flood water into sewer, leading to plug flow of pollutants and resuspension | Overloading of treatment works. Pollution of water resources downstream. Ingress of silt | Use sustainable urban drainage systems and separate sewers. Encourage decentralized systems | Clean sewers regularly. Clean drains regularly especially just before wet season | Monitor silt levels, blockages, crossconnections and so on, in drains and sewers | Stop illegal connections to foul sewers |
| | Rising receiving water levels. | Overloading of sewers, leading to backing-up. | Shallow sewers. Flap valves. | | | |
| | High flows cause sewers to flood into environment and houses | Decrease diameter of pipes to attenuate and store water. Separate sewage and stormwater systems. Consider use of small bore or other low-cost sewerage options at local level to reduce costs of separate systems. Design decentralized systems to minimize impact of local flooding | | | | Education about hygiene and cleaning up after flooding |
| | Treatment and pumping systems cannot work if electricity is affected | | Ensure that sewers are gravity flow wherever possible. Low-cost and shallow sewers have much lower pumping requirements | Local decentralized treatment will reduce pumping costs and enable local responsive management when system is vulnerable to damage | | |
| | Erosion exposing and damaging pipe work, especially simplified sewerage | | Site pipe away from drainage channel. Compaction of soil and planting above sewers, under paved roads etc. Adopt more conservative design standards for infrastructure to take more severe and more frequent extreme weather events into consideration (the more expensive option), or have systems that can be quickly and cheaply replaced | Low-cost sewers can be more easily maintained or replaced when damaged, but are more vulnerable to erosion. Have spare parts available | | |
| Groundwater tables rising | Sewer surrounded by water | Overloading. Damage to sewer (scouring or washout of bedding, and flotation leading to cracking of the sewer pipes) | Do not locate sewers in soils which are regularly waterlogged. Low-cost and shallow sewers may be less susceptible and above groundwater levels | | | |