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INTERNATIONAL EXPERIENCE REVIEW:

Climate Change Impacts and Adaptation Responses for the WATSAN Sector

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1 INTRODUCTION

Climate change presents additional obstacles to ending poverty and achieving social justice. Rising temperatures, increasingly erratic rainfall, and more frequent and severe floods, cyclones and droughts all have significant consequences for the livelihood security of general public in particular poor people.

It is now widely accepted that some degree of future climate change is inevitable and that significant impacts will be felt via water (Bates et al., 2008). The impacts of climate change on water supply and sanitation are very likely to directly affect the public health and environment. Access to safe water supplies and hygienic sanitation are likely threatened by future climate change. If any of the predicted consequences of climate change, such as higher average temperatures, increased rainfall, or floods, were to affect the viability of drinking-water supply and sanitation facilities, two critical problems for the future will arise:

a) The cost of achieving the safe drinking water and healthy sanitation will increase, because higher-cost technologies will be required to deliver services.
b) Households and communities currently with access to improved facilities might see that access removed by the destruction of water or sanitation infrastructure, or by the deterioration of water supplies, resulting in the reversal of progress towards the better living conditions, and potentially leading to the displacement of populations.

The impact of climate change on access to drinking-water supply and sanitation facilities will vary both by region (in terms of the specifics of the change in climate expected) and by facilities (in relation to the vulnerability of the facility to the expected change in climate). To date, although such problems have been highlighted as serious and likely consequences of climate change by the Intergovernmental Panel on Climate Change (IPCC, 2007), there has been very little systematic assessment of the potential impacts. Where studies have been done, the conclusions are often quite broad (for example, that increased flooding increases the risks of contamination of water supplies) or based on limited evidence. Furthermore, the recommendations from these studies tend to make general statements about the need for research, rather than identifying needs for more targeted research on key regions and facilities most likely to be affected by climate change. This highlights the need for further research to improve water and sanitation provision.

Regarding climate, the report focuses on changing rainfall patterns. While there will be impacts from other changes in climate (temperature, sea level, and so on), changes in rainfall, and their consequences for water resources, are considered to have the greatest potential impact on water supply and sanitation facilities.

An improved drinking-water source is one that is likely to provide “safe” water. Sanitation systems are considered adequate if they are private and if they separate human excreta from human contact.

We recognize that a number of possible, specific impacts of climate change have not been included in the present review work; for example: vectors of disease; emergency responses; and indirect effects of climate change. However, the significant impacts on drinking water supply and sanitation identified within the scope of the present report provide sufficient reason for policy development within the water and sanitation sector. Future studies into more specific impacts of climate change will be important in order the refine these policies. The present document draws clear lines between the impact of changing rainfall patterns and the sustainability of different drinking-water supply and sanitation facilities.

2 CLIMATE CHANGE IMPACTS

In terms of climate change observations, numerous long-term changes in climate have already been observed that will affect water and sanitation, including widespread changes in precipitation amounts and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. These observations were reported by the IPCC (2007) and represent confident findings and predictions based on, and limited by, the available data. Predictions from global climate models are gradually converging indicating that weather patterns will become more variable and will include more extreme events[1].

While there are predictions on the long-term impacts of climate change on water resources (Campbell-Lendrum & Corvalan, 2007; Kundzewicz et al., 2007; Bates et al., 2008), the long-term impacts on public health are less well known, primarily because of the uncertainty in prediction of local effects of global changes in climate. However, all populations are likely to be affected to some extent by changing climate, the risks being particularly high in the poorest countries of the world, primarily because these countries have a high incidence of climate-sensitive diseases, and lack resources and institutional capacity to control them. Direct health impacts will be caused by death or injury in floods; indirect health impacts will arise though decreases in availability of safe water, resulting in increasing reliance on poor quality water sources.

In 2004, climate change was estimated to be responsible for approximately 3% of worldwide diarrhoea cases (WHO, 2009). Almost 90 % of the burden of diarrhoeal disease is attributable to lack of access to safe water and sanitation (WHO, 2009). Reductions in the availability and reliability of freshwater supplies caused by climate change are expected to increase this hazard. The impacts will fall disproportionately upon developing countries and low-income groups within all countries.

Geographical patterns of warming in the 21st century are projected to be similar to those observed over the past decades, with warming expected to be greatest over land and most high northern latitudes. The IPCC (2007) consider it very likely that hot extremes, heatwaves and heavy precipitation events will continue to become more frequent. It is also likely that tropical cyclones will increase in intensity, with increases in wind speed and more heavy precipitation. Climate change is also expected to affect water quality (Bates et al., 2008). Higher water temperatures and increasing runoff from more intense rainfall are predicted to contribute to deterioration in water quality, including increasing algal blooms and higher turbidity.

2.1 Climate Change Impacts on Water Supply System

The impacts of climate changes on water resources, and hence on water supply system, are likely to be further compounded by increasing water demand from population growth, increasing affluence and changes in other water demands (Bates et al., 2008).

The continuing impact of climate change on drinking-water supply facilities is predicted to result in significant infrastructure costs and potential fatalities from the inability of facilities to cope with extreme events or even multiple events in a season. It was estimated that between 1994 and 2003 in Latin America and the Caribbean, natural disasters including floods and hurricanes caused economic losses in water and sanitation of approximately US$ 650 million from the destruction of urban systems, rural aqueducts, wells and latrines (Charveriat, 2000). This does not include the damage to unimproved water and sanitation sources.

As well as direct health impacts associated with contamination of drinking-water sources, climate events can severely affect the water delivery infrastructure. Flash or high-velocity floods can do damage to water systems because their physical force can knock out key components such as water treatment works and pumping stations (McCluskey, 2001). Water treatment works can be inundated

[1] Source Climate Adaptation –Modelling Water Scenarios and Sectoral Impacts, CESR 2009

by flood water, as in the United Kingdom experience described through Figure 2-1, potentially causing major disruption. In addition, extreme stormwater events may result in the degradation of materials used to construct water supply pipelines though impacts caused by increased ground movement and changes in groundwater (CSIRO, 2007).

Figure 2-1: Impact of flooding on Mythe Water Works, United Kingdom

A key example of the impact is from the Mythe water treatment works, which supplies water to 350,000 people (EA, 2007). At the height of the floods, the treatment works was inundated with up to half a metre of flood water (see above Figure). For operational reasons and to protect the distribution system from contamination, the treatment works was closed for 17 days, leaving 140,000 households without water. Severn Trent Water, the operators of the treatment works, have since increased the security of the site by building a 1.5 metre high flood barrier around the treatment works and installing an extra pumping equipment to remove flood water (BBC, 2007; EA, 2007).

Already by the 2020s, water temperature increases in the majority of the rivers across the globe could exceed 65 per cent. Summer months (especially August) are the most vulnerable to DO level change. The expected diminishing of the DO level could be about 10 per cent by the 2020s. Such a change in these indicators will require additional treatment of water for drinking purposes[2].

Reduced water flows from shrinking spring water and longer and more frequent dry seasons; decreased summer precipitation, leading to a reduction of stored water in reservoirs fed by seasonal rivers; precipitation variability and seasonal shifts in stream flow; reduction in inland groundwater levels; an increase in evapotranspiration as a result of higher temperatures; the lengthening of the growing season; and increased irrigation water usage. Increased household water demand in the hot season, water scarcity and drought, impairing raw water sources' reliability, as it is altered by changes in the quantity and quality of river flow and groundwater recharge.

As the average annual average temperature gradually is increasing and droughts will become more frequent and severe, heavy effects on drinking-water quality as a consequence of the decrease in pollutants being diluted (resulting from increasing water temperatures, and water scarcity/flow) will

[2] UNDP Human Development Report 2009/2010. Climate Change and Socio Economic Impact and Policy Options for Adaptation

be observed; As a result of climate variability, frequency of heavy rains is increasing at the same time; as a result, increased water flows will displace and transport different components from the soil to the water through fluvial erosion[3].

2.2 Climate Change Impacts on Sanitation System

The climate change risks such as increased precipitation, temperature and the flow will have huge impact on urban sanitation system. Increased rainfall triggers floods and increased temperature results in drought will deteriorate existing sanitation infrastructure. Where long-term rainfall increases, groundwater levels may rise, decreasing the efficiency of natural purification processes, increasing risks of infectious disease and of exposure to toxic chemicals. Potential indirect effects of climate change on the sanitation situation include the impacts of energy interruptions, increasing the unreliability of piped sewerage services.

Physical accessibility of water sources and sanitation facilities can be affected by climate change, for example where extreme weather events render it is impossible to arrive at the water source or sanitation facility, especially women, children, persons with disabilities, and elderly persons. In developing and under-develop countries, where sanitation facilities are flooded, there may not only be a break in services, but the flooding may distribute human excreta and its attendant health risks across entire neighbourhoods and communities.

Within the categories of improved sanitation, the evidence for vulnerability to storms and other extreme rainfall events relates mainly to the performance of sewers, wastewater treatment works, septic tanks and pits. The consequences of these events for toilets and latrines have not been recorded, but are likely to involve physical damage at the level of the household. The broader effect on environmental health of damaging toilets connected to sewers and other wastewater storage and treatment systems will be less than the consequences of flooded pit latrines and significantly less than the effects resulting from the damage to infrastructure.

One of the key risks from extreme rainfall events to sewers is to combined sewer systems. The combination of sanitary wastewater and storm water makes the combined sewer systems particularly vulnerable to storms and extreme rainfall events because once the input exceeds a certain value, the excess wastewater is discharged untreated into the environment from the combined sewer overflow, contributing to increased contamination of surface water (potentially including drinking-water supplies and recreational waters). The magnitude of the problem created by rainfall in areas served by combined sewer systems can be very significant. During 2006, in the province of Ontario, Canada, 1544 releases of sewage were reported, of which 1256 (81%) were caused by wet weather (Podolsky & MacDonald, 2008). To avoid combined sewer overflows discharging too frequently, the systems are designed with additional reserve capacity to deal with particular extreme events; for example, a one in five-year or a one in ten-year storm event.

During storms and other extreme events, serious consequences arise when sewers overflow into houses and other built up areas, leading to major disruption of services, severe damage to buildings, and immediately threatening the health of the population exposed to the floods. After the floods have receded the contamination of household furnishings and the fabric of the house may continue to represent a risk to the health of the occupants for a considerable length of time.

In addition to sewer overflows occurring during floods, sewer systems and supporting infrastructure can suffer physical damage if the force of the flood causes land movement or erosion around buried sewer pipes, or if sewer pipes above ground are washed away by the flood waters (CSIRO, 2007). Physical damage to the sewers may also occur as a result of differential ground settlement, which can occur after floods or heavy rainfall, or during periods of drought (Fehnel, Dorward & Mansour, 2005).

[3] WHO Guidance on water supplies and sanitation in extreme weather events, 2010.

The immediate response following physical damage to the sewer system is to undertake repairs to the damaged section of pipe to bring the system back into operation.

In many countries where sewer outfalls discharge into the rivers, either as short or long outfalls, as river levels rise in the future, water levels in the sewers may rise in response, causing wastewater to back up and flood through manholes in roads and the toilets and washbasins of homes and buildings (PAHO, 1998; Caribbean Environmental Health Institute, 2003). In April 1997, the Grand Forks floods in North Dakota and Minnesota, United States inundated sewer pumping stations, causing sewers to flood and overflow in residential areas. Shut-off valves can prevent such back-flow, but in many cases in developing countries these have not been installed (Few et al., 2004).

The infrastructure and the operational components of a wastewater treatment works can be damaged or taken out of service by flood waters, resulting in the discharge of untreated sewage and sewerage overflows. During the summer of 2007, the United Kingdom experienced several periods of extreme levels of rainfall compressed into relatively short periods of time (EA, 2007; Pitt, 2008). In Yorkshire, 136 sewage treatment works were flooded, affecting the services to two million people (EA, 2007), and in Gloucestershire 11 sewage treatment works, including the Sedgeberrow sewage treatment works (see below Figure), and 40 sewage pumping stations needed replacement equipment (Worcestershire County Council, 2008).

Figure 2-2: Impact of increased rainfall on sewage pumping station, United Kingdom

Droughts and water shortages may act as a barrier to sanitation coverage, depending on the

technology chosen (Fry, Mihelcic & Watkins, 2008). Waterborne sanitation systems are the traditional technologies used in urban developments, but may not be suitable for water scarce areas. There is no evidence of significant damage to sanitation infrastructure from periods of low rainfall and drought, apart from the potential for pipes and other infrastructure to be damaged by differential ground settlement (Fehnel, Dorward & Mansour, 2005). Nevertheless, droughts will have some effect on the operation and maintenance of these sanitation systems. Sewer systems receive a variety of gross solids, in addition to faecal stools, from domestic and commercial properties (Littlewood & Butler, 2003). The potential for reduced water flows in sewer systems, as a result of water conservation measures implemented to mitigate the effect of drought, has raised concerns about the transport of gross solids and the prospect of blockages.

Septic Tanks

Septic tanks and cesspits are vulnerable to the effects of increased rainfall and storms. Cairncross & Alvarinho (2006) have shown that septic tanks can represent a significant hazard for environmental contamination. In 2000, major floods affected the cities of Chokwi and Xai-xai in Mozambique, causing approximately 3000 septic tanks to overflow. Although the international response to these floods was swift and effective, Cairncross & Alvarinho (2006) note that donors were less willing to support future programmes of work to mitigate the problems and increase preparedness for future flooding events.

Pit Latrines

The problems of maintaining low cost on-site sanitation principally pit latrines, in flood prone areas have been reported by several authors (Kazi & Rahman, 1999; Chaggu et al., 2002; Parry- Jones & Scott, 2005; IFRC, 2008). The nature of the problem is self-evident from the simple design of these systems, which separate the waste from human contact by containing it in a pit. When the pit floods, either as a result of rising groundwater or by inundation of surface water, or both, the excreta may readily dissipate into the groundwater or be discharged into the surface flood waters.

In areas where pit latrines are present in high numbers, often the low-income suburbs of cities in developing countries, the contamination of surface water can be particularly severe (UN-Habitat, 2008). This is a significant problem that has been observed in many locations, on many occasions under present climate variability (Kazi & Rahman, 1999; Chaggu et al., 2002; Cairncross & Alvarinho, 2006; IFRC, 2008).

In many areas the problems created by the natural inundation of pit latrines have been aggravated by the actions of the residents. Studies by Chaggu et al. (2002) in Dar es Salaam have shown that residents take advantage of floodwater to flush out their latrines. While these releases may be deliberate and add to the problem created by natural inundation of pit latrines, the residents do not have any cheap and accessible alternative means of extending the life of their latrines. The only intervention to prevent this problem and to reduce the widespread contamination of flood waters from pit latrines is to introduce pit-emptying services.

Pit latrines can be rendered inoperable when groundwater levels rise and intersect at some level of the pit adding to its total volume, to the point where it completely fills. Not only does this hinder the use of the latrine but also presents a risk of contamination of water sources downstream from the latrine. In loose soils, this has caused the pit to collapse.

In general, reduced rainfall and developing drought conditions will favour pit latrines and other forms of on-site sanitation. Although there is no published evidence to support this supposition, the recommendations in design manuals related to the sitting of latrines in relation to water sources would suggest that it is accurate. The appropriate separation distance between on-site sanitation and sources of untreated drinking-water has been the subject of several studies (see Lawrence et al., 2001). Guidelines for separation distances aim to protect the source of drinking-water, for example a protected well, from pathogens that may be transported through the subsurface from a pit latrine.

2.3 Summary of the Impact on Water Supply and Sanitation System

Evidences discussed in previous sections of this report support the assumption that climate change has impact on the quality, quantity and availability of water. However, climate change is only one of several drivers impacting in this regard and cannot always be seen as an isolated factor but in many aspects as an exacerbating factor for other drivers. The poor general situation in the wastewater disposal is one of other major drivers which negatively impact the water resources qualities through discharge of untreated water to surface water and the infiltration into the underground.

One of the main aspects in terms of climate change and the impact on water supply and sanitation is the precipitation. Due to climate change the precipitation can increase or decrease and/or the intensity of rainfall can change. Key impacts on water resources and WSS facilities are shown in the following table:

Table 2-1: Summary Table of Key Impacts of Climate Change on Water Supply & Sanitation

Climate Scenario	Impacts on Water Resources	Impact on Water Supply & Sanitation
Increased amount of rainfall	Increased frequency of flooding Deterioration of water quality Increased groundwater recharge and rising groundwater levels.	Damage to both water supply and sanitation facilities, Flooding of sanitation systems resulting in contaminated flood waters which further contaminate the water supply and distribution system. Increased transport of contamination in soil and groundwater
Decreased amount of rainfall	Falling groundwater levels Low flows in surface waters Deterioration of water quality. Changes compounded by increased temperatures and evapotranspiration.	Low water availability causes problems for hygiene and cleaning. Salinity of groundwater affects water supplies. Sewerage in rivers becomes less diluted causing contamination issues. Increased algal growth Insufficient water makes flush-sanitation systems redundant.
Increased intensity of rainfall	Changes in groundwater recharge More run-off resulting in more erosion and greater transport of contaminants to surface waters Flash flooding Deterioration of water quality	Increased turbidity resulting in requirement for better sedimentation and filtration in surface water treatment plants. Damage to both water supply and sanitation infrastructure from flash flooding

3 IMPORTANT TRENDS IN WATSAN DEVELOPMENT

Safe drinking water and basic sanitation are like no other commodity, excepting food, in that it is essential to human life. The greatest challenges facing us relate to the conditions in which we live, how we are nourished and sheltered. Water is a central issue in a world that is increasingly urbanised and has a rising population to feed and seemingly ever increasing risks.

The 20th century saw global population triple and the development of megacities. Water consumption rose and need for better sanitation facilities is going at rocket speed, both in total amount needed and in per capita demand. Increasing pollution loads and abstractions have outstripped the assimilative capacity of ecosystems. Across the world, urbanisation has progressed through stages of ever denser habitation. Water service and infrastructure are meant to keep pace with these changes in developed countries: typically, there is an assumption that the services will follow the newest needs in terms of how people work and live. Ironically, in many of the countries, water and better sanitation facilities are undervalued by the citizens who live in towns and cities because water is readily available from the tap and open defecate is widely practised.

Once the water is used, it is then flushed away down the toilet or the sink and is never seen or thought of again. Up to one-third of the water supplied to domestic properties is used for toilet flushing and a further significant proportion is used for purposes other than drinking. Worldwide, the demand for water for irrigation is now consuming some 75% of the total abstracted. In anticipation of this explosion in water use there was significant investment in the past in the provision and operation of water infrastructure, much of it in informal and low-technology groundwater pumping, some of which helps grow cheap crops exported from the developing countries to the developed world. Worryingly, much of this water use is unsustainable (New Scientist, 2006).

Figure 3-1: Recent trends in drinking water sector

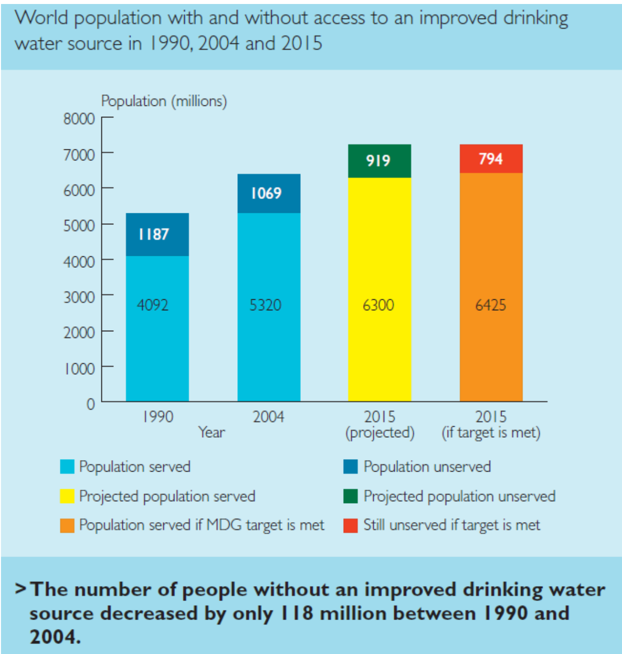
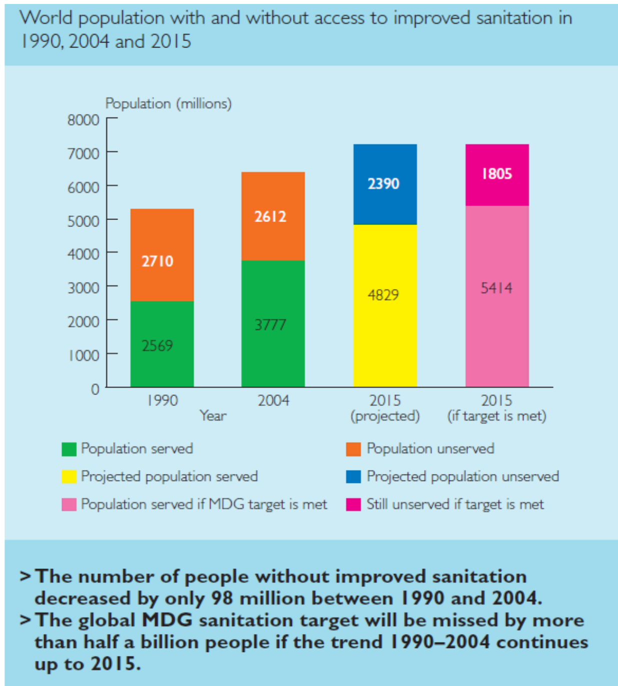


Figure 3-2 Recent trends in sanitation sector



The challenge for the *Water for Life* decade is threefold: to maintain the gains already made; to push ahead quickly to provide drinking water and sanitation services to the billions of people living in rural areas who have no such services; and to accelerate the successful efforts in urban areas to keep pace with the rising urban population, particularly by focusing on low income and disadvantaged groups.

Figure 3-1 and Figure 3-2[4] shows while 1.2 billion people gained access to both improved drinking water sources and improved sanitation from 1990 to 2004, another 1.6 billion need to gain access from 2005 to 2015 to reach the MDG sanitation target and 1.1 billion need to gain access to meet the drinking water target.

3.1 Recent Changes in WATSAN Sector

The change from the integrated approach of community participation and health education to community management of the water and sanitation sector was signalled in many parts of the developing and under-developed countries. Developments in community management can be seen in many projects run by the UNDP-World Bank Regional Water and Sanitation Groups in many developing countries including in Africa, Asia and other South American countries. The key elements of community management of the water and sanitation sector are:

- effective control of water resources vested in the local communities;
- decentralized, district-level support of community management with government promoting service provision;
- the encouragement of an active role in the process by the formal and informal private sector; an adherence to the demand-driven approach; the consideration of water as an economic commodity; and
- a special focus on women.

Other approaches have changed as well:

- from a project to a programmatic approach;
- from the water agency as provider of free water to facilitator to achieve paid services;
- from a predetermined technology to a demand-driven choice; and
- an increase in the importance of information, education and communication.

The underlying reasons for these changes are that users must be responsible for maintenance to ensure sustainability that agencies are no longer able to carry the cost of operation and maintenance, and that former concepts could not keep pace with population growth.

The new approaches are seen as more sustainable, cost-effective and having a wider reach. The central assumption in the new market- oriented concept is that people are able to manage and finance the operation and maintenance of the water facility when they themselves have made the choice for the technology they want, and which is in line with their capacity to pay. Willingness and ability to pay will determine the selection of communities for programmes and also the level of sanitation technology proposed.

In this market-oriented approach users are trained to be good clients making good choices for the needs they have and the money they want to spend; users accept the consequences of their choice for future costs, operation and maintenance, and dependency on other agencies; and users are trained to manage the operation and maintenance and to finance it. Agencies (government and NGOs) are trained to be facilitators who train users to be clients; who protect clients by guaranteeing the functioning of other agencies and their supply of spares and services; and who give good after sales service. This paper stresses the need to separate the role of agencies as facilitators from their role as

[4] Source based on World Health Organization and UNICEF Organization Data

suppliers of technology. Governments, by providing guidelines, quality control and subsidies, and user associations both have a role to play in this free-marketing process.

It has been observed that the emphasis on cost aspects and the need for cost recovery will lead donors to prefer projects which have the highest chance of a good turnover of revenue, which may favour the rich in the urban fringe or rural areas and may even empower men who commonly have control over money rather than increasing the participation of women in water supply and its management.

In describing a pilot project in twelve urban centres of northern Ghana, it has been observed that in four the concept is well implemented, in three full community management is expected in the coming years, but in five there is less enthusiasm due to the complexity of technology and the resistance of the community to take over responsibility for a utility for which they cannot foresee the consequences. The conclusion is that community management is an approach, not a formula and should never be forced on a community. The findings of pilot projects in West Africa are that the external input of external support agencies is a requirement and that community management of the sanitation component can never be a solution for the coverage of the investment costs, except for simple sanitary services like latrines. Pilot projects in rural areas of Ghana show that information, education and communication are key elements in achieving a community-managed water facility through a demand-driven approach and that in a rural setting interventions have to adapt in speed to the decision procedures within the village.

4 DIFFERENT TYPES OF WATER SUPPLY SYSTEMS

Water for human consumption comes from one of two basic sources:

1) Water from a well to supply an individual residence, well water for farmstead properties, and well water for small public sector properties that include schools, public buildings, and small commercial enterprises.
2) Municipal water systems that provide potable water to a wide array of commercial property and domestic use buildings including apartments, condominiums, duplex housing, and single family dwellings.

Water supply for drinking and domestic uses is an essential basic requirement for households and communities. Unlike in large urban settlements, for small communities in rural and outback areas conventional methods of water sourcing, extraction, and supply are not cost effective. Especially so in the rural areas of developing countries which need simple, alternative methods to satisfy their domestic water needs. The below sections summarises the different types of water supply system that are available in rural and urban sectors and how they are related to Nepal.

4.1 Rural Water Supply System

Water supply to rural communities can be sourced from rainwater, groundwater or spring/surface water. Through simple rainwater harvesting techniques, household as well as community needs for water in arid and semi-arid regions, where no other water sources are available or feasible, can be met. Groundwater is, by far, the most practicable choice for safe water supply. There is a wide range of low-cost groundwater extraction techniques available. In areas where groundwater is not available in adequate quantities, the next best available option for water supply is from surface water sources. Often, surface water sources are more contaminated than groundwater, which necessitates treatment of water and hence increases the costs of water supply projects. There are simple treatment methods available to provide minimal levels of treatment to produce safe water free of microbial contamination.

4.1.1 Groundwater System

Open wells are the major groundwater extraction structures and traditionally, most of the rural people have been depending on homestead open wells for domestic purposes. Water stored in aquifers is almost protected naturally from evaporation, and well yields are in many cases adequate, offering water security in regions prone to protracted droughts as experienced in the African and Middle Eastern Countries. With aquifer protection, groundwater has excellent microbiological and chemical quality which require minimal or no treatment.

Groundwater has been found to be sufficient both in quantity and quality for most rural communities across the globe. It is therefore not surprising that the percentage of the rural communities which depend on boreholes and wells has increased substantially since 1984 as the Government and the Non-Governmental Organisations (NGOs) have embarked on large scale drilling of more boreholes and wells. However, it has to be emphasized that the drilling rigs and the pumps are expensive and require foreign currency which is usually scarce in the Third World countries. In general, these boreholes and wells which provide good quality drinking water are rapidly replacing the usually polluted traditional surface water sources.

There are several community driven schemes are in place in different parts of the developing countries where the local communities are largely promoting the usage of groundwater sources.

4.1.2 Surface Water System

Surface water sources are derived directly from stream and river flow, or are stored prior to use, usually from behind high- or low-level dams that form water retention lakes anywhere from a few acres to many square miles in size. Factors such as chemical and bacterial quality greatly influence the economics of water treatment and the physical quality of the water.

Surface water supplies are divided into two distinct classifications, filtered and unfiltered. These classifications are based upon the type of treatment necessary to produce potable water, and upon the quality of such water prior to any required treatment process. Most of the more convenient source of water for small communities is frequently a natural stream or river close by. A river intake should be sited where there is an adequate flow and the level allows gravity supply to minimize pumping costs. The quality of the water is also important so the water intake should be up-flow of density populated or farming areas or of cattle watering places.

In recent times, loss of forest cover, indiscriminate removal of sand from river bed, clay mining from valley floors and soil erosion in the high land has caused serious threats to surface water availability.

4.1.3 Community Managed Rural Water Supply System

There is a growing trend in most countries to encourage rural communities to manage their own water supply schemes. International and local non-governmental organizations (NGOs) are active in the water supply sector, particularly in their support for small, community-based schemes.

Several funding agencies and NGO's have come forward to identify the various community based water supply management programs and all the agencies have their own selection criteria, but often a project is selected because it was asked for by the community or village development committee, because political pressure was used, or because the agency wanted to meet a set target for the area. Programmes normally last two to three years and provide water for human consumption and watering of cattle. The choice of technology is usually dependent on the topography and water resources available. The different technologies are:

- piped gravity schemes
- shallow wells with handpumps
- dug wells
- spring protection

- Artesian boring.

Of these technologies, piped gravity schemes, shallow handpumps and dug wells are the most commonly used techniques. Maintenance of completed systems, whether undertaken by Water User Committees (WUCs) or any other agencies, usually consists of making only minor repairs and replacements, leaving major repairs and system replacement to be included in a new development project. WUCs have been formed to help in constructing water supply systems, but sometimes do not continue their activities after completion of the systems. The central problem is that the communities in many cases have not viewed the systems as their own.

4.1.4 Rural Water Harvesting System

Rainwater harvesting is an accepted freshwater augmentation technology. While the bacteriological quality of rainwater collected from ground catchments is poor, that from properly maintained rooftop catchment systems, equipped with storage tanks having good covers and taps, is generally suitable for drinking, and frequently meets WHO drinking water standards. Notwithstanding, such water generally is of higher quality than most traditional, and many of improved, water sources found in the developing world. Contrary to popular beliefs, rather than becoming stale with extended storage, rainwater quality often improves as bacteria and pathogens gradually die off.

Rooftop catchment, rainwater storage tanks can provide good quality water, clean enough for drinking, as long as the rooftop is clean, impervious, and made from non-toxic materials and located away from over-hanging trees. Rainwater harvesting will make an important contribution to resolving water shortages in the future. For at least three millennia, people across the world have harvested rainwater for household, livestock and agricultural uses, but rainwater harvesting has become more and more neglected since the advent of large centralized water supply systems, in spite of their high energy input and serious environmental problems. Rainwater harvesting can be as simple as a small dam to stop water flooding off a slope or as technically advanced as a reservoir that catch rainwater for drinking and agriculture purposes in rural parts of the developing countries.

4.1.5 Public Water Supply System

Public water supply refers to water withdrawn by public and private water suppliers and delivered to users. Public water suppliers provide water to domestic, commercial, and industrial users, to facilities generating thermoelectric power, for public use, and occasionally for mining and irrigation. A public water supply is a public or private water system that provides water to at least 25 people or has a minimum of 15 service connections.

The water-use activities in the public water-supply category include water withdrawal from ground and surface water; stream conveyance to and from reservoirs and canals; consumptive use, as evaporation during open storage or conveyance; raw and finished water storage; purchases from other public water suppliers; treatment; and distribution to other public water suppliers and to various users.

Small public water-supply systems have water from a few wells pumped to an elevated tank from which water flows by gravity through a distribution system to users. As the population served by the public water-supply system increases, or as local ground-water supplies prove inadequate to meet the needs of the population served, surface water is used, either in place of or in addition to, the wells. Treatment plants are used much more frequently when surface water is a source of supply. Increasing average daily demand (ADD) on the public water supply system necessitates the development of larger sources, storage facilities, and distribution systems. Large public water-supply systems can be complex and incorporate many reservoirs from which withdrawals are made from one reservoir (or from several independent reservoir systems), from wells, well fields, or even springs.

4.2 Urban Water Supply System

Rapid urbanization in the World imposes a major challenge for the expansion of improved water supply sources. Despite increasing access rates to improved water supply since the middle of the 90's, urban population growth has outpaced the rate of expansion of improved services, in particular in those countries with the highest rate of urban population growth. As a consequence today more than 87 million people rely on unimproved sources of water supply. The United Nations Millennium Development Goals' initiative aims to cut this figure in half by 2015. Major infrastructure developments, specifically in urban areas, are needed to make this vision a reality.

The development and operation of urban water supply systems, and infrastructure in general, has largely been the responsibility of the public sector in both developing and developed countries alike. In many countries, service provision has been hampered by public sector financial and capacity constraints.

There are several urban water supply systems that are currently available in developing and developed countries. Some of them are summarised in the below sections.

4.2.1 Impounding Reservoir System

Reservoirs created by placing dams across rivers, streams, or at the neck of a valley to capture runoff have been a source of many countries municipal water supplies since the mid-1600s. The reservoirs provide water not only to municipal water systems but also to irrigation systems. Reservoir systems are especially common in North America, India, Europe and other parts of Asia. In majority of the cases, the reservoirs are designed in such a way that the water from reservoirs flow through the lower portion of the dam to the treatment plant without any pumping requirements.

Impounding reservoir systems without a mechanical interface are considered the most reliable and economical source of municipal water supply. More recently constructed water supply systems use this concept through the use of standpipe tanks or gravity tanks on water systems when there is a minimum demand on the system. When there is a higher demand, the water flows by gravity feed from these holding tanks to meet the system demand.

4.2.2 Freshwater Lakes

The best examples of fresh-water lakes for supplying water come from communities surrounding the great lakes. These lakes are supplied by countless streams and rivers that, in turn, are supplied from water runoff from hills, especially during the winter and spring seasons. This is generally considered a functionally, inexhaustible supply of water. Manmade lakes may be an important solution for coping with increasing water demand.

Without question, rivers across the country provide the most primary sources of water for municipal and irrigation water systems. Side water damming is one approach to retaining water during dry spells. Other approaches to this problem include cross-connecting rivers and lakes with aqueducts that could be opened on demand to move water from one region to another.

4.2.3 Wells

Driven or bored wells are excavated to the level of the water table. Artesian or flow wells are a special classification of wells in which the water is trapped below a rock formation, which causes the water to be under pressure of varying intensity. When a tap is made through the bedrock, the water flows to the surface under pressure. This pressure may be sufficient to move the water to the treatment plant. All other types of well require low-lift or high-lift pumps depending on the depth of the water or the distance of the water from the surface.

Wells are the primary source of water for both urban and rural areas with populations up to around 5,000. Larger communities may use a series of well fields, and usually pump up to gravity tanks to provide the required flow and pressure to the distribution system.

In many parts of the developed and developing countries, especially on the Asian part, the underground supply of water is not being replenished as quickly as it is being consumed. At the end of 2005, this was a special problem in South Asian countries such as India, Pakistan, Sri Lanka, Nepal and Bangladesh. In some cases, water is being transported by tanker trucks to meet the minimum needs for domestic consumption. Alternative water sources such as streams, rivers, ponds, and lakes are the only source of water supplies for mobile tankers to provide fire protection.

4.2.4 Oceans & Bays

Until recently, the salinity of the water has made this source unacceptable for human consumption and therefore, not a source for municipal water supplies. New technology is now making desalination cost-effective. Water systems using ocean and bay water for fire protection have been used in several countries in recent years. Pumping stations provide both low-pressure and high-pressure water supplies to specially marked fire hydrants, primarily in the commercial and industrial districts of large cities across the globe. Some coastal communities in the USA make use of limited coverage fire protection systems that take water from the Atlantic Ocean or the Gulf of Mexico.

4.2.5 Composite Water Supply Systems

While the descriptions and configurations reviewed above cover the basic types of community water supply systems, specific conditions of areas served by the water system and, most importantly, the topography, may require a “composite system” that uses components from more than one of the “typical water systems.” Some examples:

- Adding pumping stations to a gravity reservoir system to increase pressure and volume during peak demand periods including a fire flow requirement
- Gravity tank supplies often have more than one storage tank to meet daily consumption requirements. On smaller water systems, gravity tanks may be needed to meet both volume and pressure requirements in case of a "working structure fire."
- Booster pumping stations may be installed where there is a need for more than one service level based on pressure demand.
- Well fields may have a number of different lift pumps that transport water to a filtration plant instead of localized purification.
- Direct pumping into the distribution system may be supplemented by gravity tanks that "float" on the system to maintain pressure and flow characteristics during different demand periods through the day and night.
- Gravity tanks are especially useful for improving the reliability of any water system.

4.2.6 Urban Municipal Water Supply System

The purpose of municipal water delivery systems is to transport potable water from a water treatment facility to residential consumers, for use as drinking water, water for cooking, water for sanitary conditions, and other water use in a domestic environment. Water supply also is essential for business and industry to operate in a municipal environment. Of no less importance is the need to supply water to properly located fire hydrants to provide the public with an effective level of fire protection. Municipal water systems also may need to provide water for special services that include street cleaning, the selling of water to contractors for erecting buildings, parks and recreation, and miscellaneous uses.

5 DIFFERENT TYPES OF SANITATION SYSTEMS

Providing adequate sanitation facilities is one of the major challenges in developing and under-developed countries. In addition, there has been a disturbing increase in the number of poorly designed and poorly operated water-borne on-site sewerage systems, especially in urban areas.

When sanitation systems fail - or are inadequate - the impacts on the health of the community, on the health of others and on the environment can be extremely serious.

Sanitation includes both the 'software' of understanding why health problems exist and what steps people can take to address these problems, and 'hardware' such as toilets, sewers and hand-washing facilities. Together, they combine to break the cycle of diseases that spread when human excreta and waste are not managed properly. Good sanitation refers to the appropriate behaviour and practices of the people living in a specific environment.

- The people know to avoid contact with human excreta and to hygienically dispose of human waste;
- The people's behaviour displays a responsible attitude towards the hygiene of their families, the community, and the environment. By being a responsible and hygienic individual you make sure that you do not spread diseases.

Good sanitation is achieved when everyone in a community understands the health importance of safe excreta disposal, and takes the necessary practical steps to promote good personal hygiene and public health. This includes access to, and consistent use of, a safe and hygienic toilet.

From the Municipality's point of view, a sanitation improvement programme starts with a strong local health team that can identify local sanitation-related health problems and work with residents to remedy them. Key issues are poor hygiene practices, such as open defecation; contamination of water sources; malnutrition caused by worms or on-going diarrhoea, lack of safe and hygienic toilet facilities, lack of facilities for hand washing and inadequate refuse removal. It is crucial to promote understanding of the linkages between water, sanitation, hygiene and health.

The slow progress in sanitation facilities is not unique to developing countries only. Experience in developed countries shows that, in these countries too, it took a long time to achieve the current high levels of sewerage coverage. This is attributed to, among others, the low priority traditionally given to sanitation and the relatively high cost of providing sanitation compared to water supply. Sewerage provision in developing countries is even a much bigger task, given the high poverty and governance problems that generally prevail in these countries.

5.1 Rural Sanitation System

The word sanitation refers to civic life; the term rural sanitation refers to rural civic life. There are several rural sanitation programs were identified and implemented in several developing countries through various funding arrangements. Though conventional sewer systems offer convenience and public health benefits to the users, it is often not feasible to operate these systems in rural and sparsely populated areas due to the following reasons:

- Wastewater collection network in sparsely populated areas become expensive;
- Capital and operation costs of treatment systems for such area become prohibitively high because of the smaller scale of operation

In view of the above, majority of the rural communities rely on simple and community driven systems and the following are the best examples of such rural sanitation facilities:

5.1.1 Open Defecate

Over a billion people worldwide defecate in the open. This amounts to almost one in five people in developing countries not using or not have an access to any toilet or latrine. Nearly 73% households in rural India practice open defecation despite sanitation drives launched by the government, according to an independent evaluation by the Planning Commission, India.

In recent years, it became a national pride for majority of the developing countries to put an end to open defecation. Community-Led Total Sanitation (CLTS) is an innovative approach for mobilising communities to build their own toilets and stop open defecation. First pioneered in Bangladesh in 2000 it has now spread across Asia, Africa, Latin America and the Middle East.

5.1.2 Pour Flush Toilet

A pour-flush toilet is like a regular flush toilet, except that instead of the water coming from the cistern above, it is poured in by the user. When the water supply is not continuous, any cistern-flush toilet can become a pour-flush toilet. Just like traditional flush toilets, there is a water seal that prevents odours and flies from coming back up the pipe. This type is most widely used in areas where piped water system is not available to use the septic tanks.

Water is poured into the bowl to flush the toilet of excreta; approximately 2 to 3 L is usually sufficient. Both pedestals and squatting pans can be used in the pour flush mode. Due to demand, local manufacturers have become increasingly efficient at mass-producing affordable pour-flush toilets and pans. The S-shape of the water seal determines how much water is needed for flushing. To reduce water requirements, it is advisable to collect toilet paper or other dry cleansing materials separately.

Pour-flush toilet pans are most commonly used in combination with a single- or twin pit pour flush latrine and therefore installed outside the house. However, due to the water seal that effectively prevents odours and flies from coming back up the pipe, pour flush pans can also be installed inside the house. Since there are no mechanical parts, pour-flush toilets are quite robust and rarely require repair. Despite the fact that water is used continuously in the toilet, it should be cleaned regularly to prevent the build-up of organics and or/stains. To prevent clogging of the pour-flush toilet, it is recommended that dry cleansing materials be collected separately and not flushed down the toilet.

5.1.3 Pit Latrine System

Many international reports confirmed that pit latrine facilities are most widely used in rural parts of developing countries. The type of pit latrine used is usually just a hand dug hole in the ground covered with a concrete slab fitted with a riser and seat surrounded by a superstructure around it.

Pit latrine designs range from simple unimproved pit latrines, through Ventilated Improved Pit latrines (VIPs) to alternating twin pit systems. In a twin pit system, the second pit is only used when the first pit is filled. The first pit is left sealed for a year or more before emptying during which time disease-causing organisms are destroyed by natural processes. After such storage, without the addition of fresh wastes, the contents become safe to handle, and may be used as compost.

The basic components of a pit latrine are the pit, ideally 4-5 meters deep, a cover slab with a hole through which users defecate into the pit and a superstructure, sufficient to ensure privacy and provide protection from the weather. It must be possible to clean the slab. Partly for this reason, most slabs are made of concrete but it is possible to use a smaller concrete or plastic ‘SanPlat’ laid on top of a latrine cover made from wood and other ‘natural’ materials. VIPs are pit latrines incorporating a vent pipe, designed to draw flies and smells away from the pit and cabin. The flies are trapped by a screen located at the top of the vent pipe and eventually die.

5.1.4 Composting Toilets

In composting toilets, faeces or excreta fall into a composting chamber together with cleansing material. Dry organic material such as sawdust is added to adjust moisture content and C/N ratio in order to obtain optimum conditions for thermophilic composting. Organic household waste can also be added. Depending on the process, shorter or longer maturation periods and maybe also secondary treatment are required. Urine might be diverted to decrease humidity of the compost and to be reused separately. The final product is a humus-like soil (humanure), which is valuable as soil amendment improving its fertility, structure and water retention capacity. These facilities are environmental stable method of human waste disposal. Since there is no water flushing is involved, so, there are no spreading of waterborne diseases and groundwater contamination.

5.2 Urban Sanitation System

On-site household sanitation systems are currently in use in urban areas which are insufficient to protect public health and ecosystems now and will be exacerbated due to continued rapid increases in urbanisation and population densities. Although residents are responsible for managing their on-site sanitation systems, in general they lack understanding and have low willingness to address sanitation problems, because of low incomes and lack of assistance from Government. Introduction of the regulations will help, but there will also be a need for behavioural change, which may be tackled through a promotional program linking water supply and sanitation in many ways.

5.2.1 Septic Tanks (Onsite Systems)

Septic tanks are a most widely used and common means of disposal for majority of the urban residential households and commercial premises across the globe. It has been noticed in several environmental campaigns that majority of the septic tanks installed in developing countries do not comply with international design and construction standards. Since there are no standards set for septic tank designers and contractors in majority of the developing countries, often the sizes are not in line with the size of the household. Majority of the existing septic tanks are made of concrete structure that is equipped with single compartment that are not efficient in complete removal of solids, organic matter and the pathogenic bacteria.

In many developing countries, the local Ministry of Health works closely with the communities for better provision of healthy septic tanks. To achieve the best public health results, they often conducted and prepared septic tank management matrices that are widely used in several countries. A sample of the matrix is shown in Annex A.

Septic system failure is unpleasant, unsanitary, could become a source of serious disease and cost thousands of dollars to resolve. Septic failure can result in contamination of the groundwater and nearby drinking water wells or in some cases septic tanks sludge backed up into house or on the surface of backyard. These are routine failures that are easily predicted and prevented. Less predictable is the catastrophic failure of a septic system component. The potential risks of septic tanks include:

- Poor Design, Installation and Maintenance
- Groundwater contamination as a result of sewage seepage through ground and illegal connections from low lying and low income group areas
- Sludge Removal

5.2.2 Community Sewerage Treatment System (CSTS)

Community sewage treatment systems (CSTS) are often referred to as either in India as DEWATS (Decentralised Wastewater Treatment Systems) or in Indonesia as SANIMAS (Sanitation by Communities). The later successful programme was started on a pilot scale in 2003. The concept has been adopted in many developing countries, including Brazil and many on the African continent.

A Community sewage treatment system is a low capital, low operating and maintenance system purposely designed for populations less able to afford traditional sewerage and treatment. The systems are usually operated by an NGO or members of the community.

From a technical standpoint a CSTS relies on processes that require a low energy input and relatively simple capital works. There are up to four treatment stages:

1) Settlement of solids: This is a physical process and the least expensive way of removing up to 30% of the incoming BOD. Settlement is usually accomplished with a multi-chamber septic tank or purpose built volume like an Imhoff tank.
2) Biological treatment: This is accomplished in an anaerobic environment (low redox), where the metabolic pathways consist of converting carbon into mostly carbon dioxide, methane and about 5% biomass. This typically occurs within the multi chambers referred to above.
3) Filtration: This process often includes more anaerobic biological degradation but the main aim is again to physically remove solids. Often an anaerobic filter is employed.
4) Redox or Eh Increase: An anaerobic system typically operates less than – 200 mV. Effluent from this treatment system will be "hungry" for oxygen due the large concentration of residuals in a reduced state, e.g. sulphides, carbonic acid, etc. This redox increase (typically to >10 mV or higher) is typically accomplished with a phyto-based system (plants) that use sunlight to create oxygen. Examples include wetlands, planted gravity filters, reed beds.

The performance of CSTS is always a source of questions. The DEWATS handbook indicates that treatment quality depends on the nature of influent and temperature, but can basically be defined in the following approximate BOD removal rates:

- 25 to 50 % for septic tanks and Imhoff tanks
- 70 to 90 % for anaerobic filters and baffled septic tanks
- 70 to 95 % for constructed wetland and pond systems.

Many publications write that DEWATS and SANIMAS systems achieve a 90% removal of BOD.

5.2.3 Comprehensive Piped Sewerage System

A sewage system may convey the wastewater by gravity to a sewage treatment plant. Where pipeline excavation is difficult because of rock or there is limited topographic relief (i.e., due to flat terrain), gravity collection systems may not be practical and the sewage must be pumped through a pipeline to the treatment plant. In low-lying communities, wastewater may be conveyed by vacuum. Pipelines range in size from pipes of 150 mm in diameter to concrete-lined tunnels of up to 3 - 4 m in diameter.

- Community sewage can also be collected by an effluent sewer system, also known as a STEP system (Septic Tank Effluent Pumping). At each home, a buried collection tank is used to separate solids from the liquid effluent portion. Only the liquid portion is then pumped through small diameter pipe (typically 60mm to 100mm) to downstream treatment. Because the waste stream is pressurized, the pipes can be laid just below the ground surface along the land's contour.
- Sewage can also be collected by low pressure pumps and vacuum systems. A low pressure system uses a small grinder pump located at each point of connection, typically a house or business. Vacuum sewer systems use differential atmospheric pressure to move the liquid to a central vacuum station. Typically a vacuum sewer station can service approximately 1,200 homes before it becomes more cost-effective to build another station.

The comprehensive sewerage system where all sewage is pumped out of the residential area to a wastewater plant for treatment and further discharged into sea is the best solution to remove all current public health, groundwater contamination and any pollution to the streams or rivers.

However, this system has major risks in laying, operating and maintaining it as a long-term scheme. There potential risks associated with the piped sewerage system in developing countries including:

- Land Issues: piped sewerage system requires significant amount of land for pumping stations and wastewater treatment plant
- Operation & Maintenance: Improper allocation of annual operation and maintenance funding would damage and deteriorate the system and impose great public health, contamination of soil and groundwater resources
- Energy: The impact of raise in electricity costs would make this sewerage alternative non-viable due to the very high operating and maintenance costs of pumping stations
- Qualified Technicians and Staff: lacking qualified and experienced technical staff to run the sewerage system, pumping stations and the wastewater treatment plants
- Spare Parts: not be equipped with adequate mechanical workshops that can fix the equipment on site due to unavailability of the right tools and spare parts
- Overflow from Wet well

6 CLIMATE CHANGE EXTREMES - PRECIPITATION

Climate change can impose common threats to all of the above mentioned water and sanitation systems both in rural and urban areas. However, every threat has two extremes such as threat of having not enough water to a threat from having too much. Both these extremities are discussed in the below sections.

6.1 Impact of Decreased Rainfall on WATSAN

Climate modeling projections for 2050 indicates that more seasonal climate of hot, dry summers and mild, wet winters can be foreseen across the globe. This would result in reduced rainfall. Approximately 80 per cent of the rainfall and most of the stream flow and recharge to groundwater occur in the ‘wet’ season between May and October in majority of the cases.

The term drought may refer to a meteorological drought (precipitation well below average), hydrological drought (low river flows and low water levels in rivers, lakes and groundwater), agricultural drought (low soil moisture), and environmental drought (a combination of the above). The socioeconomic impacts of droughts may arise from the interaction between natural conditions and human factors such as changes in land use, land cover, and the demand for and use of water.

Excessive water withdrawals can exacerbate the impact of drought. Droughts have become more common, especially in the tropics and sub-tropics, since the 1970s. Decreased precipitation and increased temperatures, which enhance evapotranspiration and reduce soil moisture, are important factors that have contributed to more regions experiencing droughts.

The regions where droughts have occurred seem to be determined largely by changes in sea surface temperatures, especially in the tropics, through associated changes in the atmospheric circulation and precipitation. In Australia and Europe, direct links to global warming have been inferred through the extreme nature of high temperatures and heatwaves accompanying recent droughts.

Groundwater is the major water resource in many developing countries. With climate change, the groundwater available for consumptive use by 2050 may decrease drastically for the ‘median’ and ‘dry’ climate seasons. The reduced rainfall also impacts the surface-water availability.

6.1.1 Impact of decreased rainfall on water supply

With the potential reduction in water supplies from the effects of climate change there will be basically less water available at the intake or source points of water supply systems. This reduction could also be associated with over abstraction through tubewells at higher levels in the catchment and/or population pressure increases. The worse scenario is that the water supply is so drastically reduced that a drought situation arises. To adapt to these threats there is a need to save water for drinking and other daily needs which can be considered under the general headings of storage, improving efficiency of use and reuse of water. Reducing rainfall results in falling groundwater levels, low flows in the surface waters, deterioration of water quality and changes compounded by increased temperatures and evapotranspiration. These will affect water supply as:

- Low water availability causes problems for hygiene and cleaning.
- Salinity of groundwater affects water supplies.
- Sewerage in rivers becomes less diluted causing contamination issues.
- Increased algal growth
- Insufficient water makes flush-sanitation systems redundant.

6.1.2 Impact of decreased rainfall on sanitation system

In general, reduced rainfall and developing drought conditions will favour pit latrines and other forms of on-site sanitation. Although there is no published evidence to support this supposition, the recommendations in design manuals related to the siting of latrines in relation to water sources would suggest that it is accurate. The appropriate separation distance between on-site sanitation and sources of untreated drinking-water has been the subject of several studies (see Lawrence et al., 2001). Guidelines for separation distances aim to protect the source of drinking-water, for example a protected well, from pathogens that may be transported through the subsurface from a pit latrine.

Appropriate guidelines to address this issue are difficult to construct because the distances travelled by pathogens are influenced by many different factors that combine to create circumstances that are very specific to a particular site. However, a general principle that emerges from the guidelines is that the greater the distance between the base of the latrine and the water table, the lower the risk of pathogens reaching the groundwater. Applying this principle to reduced rainfall and drought conditions provides the rationale for the supposition that pit latrines are suitable for use in drought conditions, depending also on cultural and socioeconomic factors.

6.2 Impact of Increased Rainfall on WATSAN

6.2.1 Impact of increased rainfall on water supply

Heavy rainfall events, and the resulting surface runoff, affect surface water quality through washing in increased loads of sediments and pathogens, as well as other pollutants. More intense rainfall and extreme events, such as cyclones, will lead to an increase in suspended solids (turbidity) in lakes and reservoirs as a result of erosion by raindrops and runoff (Leemans & Kleidon, 2002), with the potential for pollutants to be introduced into the water source (Brouyere, Carabin & Dassargues, 2004).

Increased turbidity can lead to additional stress on water treatment systems (Hunter & Syed, 2001; Hunter, 2003), increasing coagulant demand, reducing the working period of the multi-stage filters and increasing the chlorine demand, which will all contribute to reduced efficacy of the treatment process. Studies have shown a correlation between increases in turbidity and illness in communities (Schwartz, Levin & Hodge, 1997), which may reflect either the increased contaminant loading during storm events or efficacy reductions in the treatment.

Cyclones can also contribute to increased sediment loads in water supplies. Brouyere, Carabin & Dassargues (2004) showed that the observed increase in precipitation and temperature in southern Finland was responsible for an increase in winter runoff, which resulted in an increase in modelled suspended sediment loads. Kostaschuk et al. (2002) measured suspended sediment loads associated with tropical cyclones in Fiji, which generated very high (around 5% by volume) concentrations of sediment in the measured flows.

Increased erosion resulting from increased precipitation intensities would exacerbate sediment transport (Kundzewicz et al., 2007). Examples of vulnerable areas can be found in north-eastern Brazil, where the sedimentation of reservoirs is significantly decreasing water storage and thus water supply (De Araujo, Guntner & Bronstert, 2006). Evidence of heavy rainfall leading to contaminated storm water runoff into surface water sources is not new and has been shown by a number of workers since the 1970s (see for example Doran & Linn, 1979; O'Shea & Field, 1992). An outbreak of Acanthamoeba keratitis was reported in Iowa, United States, following flooding which inundated a treatment works. In Walkerton, Ontario, Canada, in May 2000, heavy precipitation combined with reduced disinfection contaminated drinking-water with E. coli and Campylobacter jejuni, resulting in an estimated 2300 illnesses and seven deaths (Hrudey et al., 2003).

The Great Lakes, in the United States, which serve as a drinking-water source for more than 40 million people, are particularly susceptible to faecal pollution and can become reservoirs for waterborne diseases. On-going studies and past events illustrate a strong connection between rain events and the amount of pollutants entering the Great Lakes. The 1993 Cryptosporidium outbreak in Milwaukee, which affected the health of more than 400 000 people, coincided with record high flows in the Milwaukee River, a reflection of the amount of rainfall in the watershed (Curriero et al., 2001). Recognizing these vulnerabilities, utilities in some developed countries have adapted by implementing an additional filtration step in drinking-water plants, increasing operating costs by around 30% (AWWA, 2006). An alternative approach is to undertake protection and restoration of the ecosystems that naturally capture, filter, and store and release water, such as rivers, wetlands, forests and soils, increasing the availability of good quality water. This approach was taken by the New York City Department for Environmental Protection, which saved several billion dollars by investing in catchment management, enabling them to avoid upgrading filtration.

Large-scale contamination of drinking-water has been described as the most serious disease hazard from floods (Parker & Thompson, 2000). Contamination may arise from: high turbidity, making purification difficult; floodwater entering well heads; flood levels higher than well head walls or water flowing directly over wells and other intakes; fuel or chemical pollution; physical damage to water treatment plants; and animal cadavers near water intakes (PAHO, 1998; Caribbean Environmental Health Institute, 2003). Nutrient contamination can lead to additional problems of water quality in piped water supplies. Studies by LeChevallier, Schulz & Lee (1991) have shown that nutrients in water supplies can promote the re-growth of coliform bacteria in the distribution system, leading to a further deterioration in water quality.

There can also be cross-contamination from damaged sewage systems. In Bangladesh in 1998, Dhaka city's waste disposal system became almost completely ineffective (Nishat et al., 2000): many streets became flooded with water mixed with waste and sewage, the leakage of sewage contaminated most water supply lines, and the reserve water tanks of many houses became submerged and contaminated.

6.2.2 Impact of increased rainfall on sanitation system

One of the key risks from extreme rainfall events to sewers is to combined sewer systems. The combination of sanitary wastewater and storm water makes the combined sewer systems particularly vulnerable to storms and extreme rainfall events because once the input exceeds a certain value, the excess wastewater is discharged untreated into the environment from the combined sewer overflow, contributing to increased contamination of surface water (potentially including drinking-water supplies and recreational waters). The magnitude of the problem created by rainfall in areas served by combined sewer systems can be very significant. During 2006, in the province of Ontario, Canada, 1544 releases of sewage were reported, of which 1256 (81%) were caused by wet weather (Podolsky & MacDonald, 2008).

To avoid combined sewer overflows discharging too frequently, combined sewer systems are designed to manage a certain flow of wastewater that has been calculated using a range of environmental, social and economic factors, with additional reserve capacity to deal with particular extreme events; for example, a one in five-year or a one in ten-year storm event. However, the magnitude and frequency of these extreme events are identified from historical records, which Adger and others have argued may not be reliable in the face of climate change. Combined sewer overflows are just one issue associated with the flooding of sewers during storms and other extreme events. Serious consequences also arise when sewers overflow into houses and other built up areas, leading to major disruption of services, severe damage to buildings, and immediately threatening the health of the population exposed to the floods. After the floods have receded the contamination of household furnishings and the fabric of the house may continue to represent a risk to the health of the occupants for a considerable length of time.

In addition to sewer overflows occurring during floods, sewer systems and supporting infrastructure can suffer physical damage if the force of the flood causes land movement or erosion around buried sewer pipes, or if sewer pipes above ground are washed away by the flood waters (CSIRO, 2007).

Physical damage to the sewers may also occur as a result of differential ground settlement, which can occur after floods or heavy rainfall, or during periods of drought (Fehnel, Dorward & Mansour, 2005). The immediate response following physical damage to the sewer system is to undertake repairs to the damaged section of pipe to bring the system back into operation. However, we can find no examples in the literature of adaptations to sewer systems that will increase their resilience to the potential effects of climate change. The implication of this is that repairs made to damaged pipework will not affect the overall ability of the system to withstand future extreme events. In addition to the physical damage to infrastructure, the loss of electricity supplies, as discussed for piped water networks, is also a significant risk, especially to major sewer pumping stations during a flood.

In many coastal areas, sewer outfalls discharge into the sea, either as short or long sea outfalls. As sea levels rise in the future, water levels in the sewers may rise in response, causing wastewater to back up and flood through manholes in roads and the toilets and washbasins of homes and buildings (PAHO, 1998; Caribbean Environmental Health Institute, 2003). In April 1997, the Grand Forks floods in North Dakota and Minnesota, United States inundated sewer pumping stations, causing sewers to flood and overflow in residential areas. Shut-off valves can prevent such back-flow, but in many cases in developing countries these have not been installed (Few et al., 2004).

In developing and under-developed countries, residents rely on onsite sanitation systems such as pit latrines, but consist primarily of flush toilets with septic tanks and vertical soakaways. In majority of the developing countries, the sanitation system such as septic tanks are poorly designed and constructed without following minimum design requirements and standards. In low income group areas, the residents cannot afford to have soakaway systems that separate grey water and sewage, so, they drain the grey water directly into the septic tank soakaway system which is purely either designed for sewage or poorly designed system. By doing so, the residents will push the flows to a soakaway which has very limited capacity. When rain hits these areas, then, they bring more rainfall runoff into the soakaway and the sludge and sewage resurfaces due to incapacity issues. This impacts largely the public health and hygiene since the residents come in contact with the sewage whenever there is a storm.

7 CLIMATE CHANGE EXTREMES – TEMPERATURE

The increased temperature poses a serious and additional threat to poor farmers and rural communities in the region who live in remote, marginal areas such as mountains, dry-lands and deserts; areas with limited natural resources, communication and transportation networks and weak institutions.

In particular, climate models indicate temperature increases in the Asia/Pacific region on the order of 0.5-2°C by 2030 and 1-7°C by 2070. Temperatures are expected to increase more rapidly in the arid areas of northern Pakistan, India and western China. Additionally, models indicate rising rainfall concentration throughout much of the region, including greater rainfall during the summer monsoon. Furthermore, winter rainfall is likely to decline in South and Southeast Asia, suggesting increased aridity from the winter monsoon.

7.1 Impact of increased temperature on Water Supply System

As temperatures rise, people and animals need more water to maintain their health and thrive. Many important economic activities, like producing energy at power plants, raising livestock, and growing food crops, also require water. The amount of water available for these activities may be reduced as Earth warms, and if competition for water resources increases.

Managing water resources to ensure a secure supply to growing populations is already a major challenge in many areas. In particular, maintaining water security is a key priority for the poor rural people any developing country. Climate change impacts to water resources may have a wide array of subsequent negative consequences. Climate change is in fact expected to further modify the availability of water resources, driven by seasonal decreases in rainfall and runoff in South and Southeast Asia and increases in runoff in other areas, particularly the Pacific Islands.

Freshwater availability in Central, South, East and South-East Asia, particularly in large river basin, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion of people by the 2050s. Expansion of areas under severe water stress will be one of the most pressing and urgent environmental problems in the region, especially in South and South East Asia, as the number of poor rural people living under serious water stress is expected to increase substantially in absolute terms.

7.2 Impact of increased temperature on Sanitation System

The increased temperate has positive and negative impacts on the urban and rural sanitation system. The bacterial growth rate is temperature dependant and the rate of biological reactions is also temperature dependant. Minor temperature changes can have significant effects on biological reactions. Due to the increased temperature, many gases evolve from wastewater treatment plant or contained septic tanks that contribute to the green house effect. These gases will have a huge impact on the equipment as they are of corrosive nature.

Temperature has a considerable effect on anaerobic degradation of organic matter with influence on the growth and survival of micro-organisms. When temperature increases erratically, chemical and enzymatic reactions as well as growth is affected with complete cease of growth at the highest temperatures possible for survival. Minimum growth temperature is probably met when cell membrane loses its proper functioning with subsequent disturbances in uptake and excretion compounds. On the other hand, as temperature rises, chemical and enzymatic reactions as well as growth are accelerated up to the temperature optimum, above which proteins, nucleic acids and other cellular components may be irreversibly damaged. Thus, temperature rise within the optimal range is beneficial to anaerobic degradation of organic matter, but becomes damaging at temperatures above optimum (Madigan et al. 1997).

8 CLIMATE CHANGE EXTREMES – FLOODING

With a warming climate comes increased variability in rainfall, resulting in a greater risk of droughts and floods (UNDP, 2006). Floods include river floods, flash floods, urban floods or sewer floods, and can be caused by intense or long-lasting precipitation, snowmelt, dam break, or blockages to the water system.

Floods are predicted to increase in severity, with 15 of 16 large river basins worldwide predicted to exceed the 100-year peak volumes more frequently if CO_2 levels quadruple (Kundzewicz et al., 2007). In some areas, the current 100-year flood is predicted (with large uncertainty) to have a return period of as little as two to five years. In Bangladesh, an area already subject to severe floods, the flooded area is projected to increase by 23% – 29% with a 2°C increase in temperature (Mirza, 2003). River basins that are likely to be affected by flood are currently home to up to 20% of the world population (Kundzewicz et al., 2007).

8.1 Impact of Floods on Water Supply System

The increased likelihood of future flooding, together with the recent events experienced in New Orleans, Austria, the Czech Republic, Germany, Hungary and the Russian Federation, raises the issue of how floods affect human health. Besides the "tangible" effects of flooding, such as damage to property and infrastructure, there is a growing awareness of the significance of the "intangible" effects, both physical and psychological, that have traditionally been underestimated in assessing the consequences of flooding.

Floods affect water quality and water infrastructure integrity, and increase fluvial erosion, which introduce different kinds of pollutants to water resources. Flood events in rivers also bring with them sediment ranging in form from suspended solids to bed load. If the suspended solids can be kept in suspense until they reach the field then there is a benefit. However all other forms of sediment entering the intake structure may damage the treatment system, transmission system and distribution system severely restrict the reservoirs storage capacity and increases maintenance costs.

Increased flow in the rivers due to increased rainfall often causes flooding in low-lying areas which causes uncontrolled surcharges that may introduce microbial and chemical pollutants to water resources that are difficult to handle through the use of conventional drinking water treatment processes. Several studies have shown that the transmission of enteric pathogens resistant to chlorination, such as Cryptosporidium, is high during any flood event (Nchito et al., 1998; Kang et al., 2001). This is a situation that could be magnified in developing countries, where health levels are lower and the pathogen content in polluted flood waters is higher (Jiménez, 2003). In addition, extreme precipitation leading to floods puts water infrastructure at risk. During floods, water treatment facilities are often out of service, leaving the population with no sanitary protection.

8.2 Impact of Floods on Sanitation System

Similarly, increase in flood water levels along the river banks that may often cause flooding within the wastewater treatment facilities (majority of the treatment facilities are adjacent to water courses for easy disposal of effluent) which leaves the facilities to shut down temporarily. If the flooding remains for prolonged period, the population that are connected with the sewer system cannot flush their water closets due to the surcharge in the sewer system.

In late 1982 and early 1983, intense, prolonged rainfall brought severe floods and landslides to many coastal regions of Ecuador. The floods caused extensive damage to infrastructure across Ecuador, affecting drinking water and sewage facilities. In the city of Babahoyo, Ecuador, discharges from the sewerage system (via inspection wells) directly into the standing floodwaters that lay across much of the city created a level of coliform contamination that "corresponds to raw wastewater" (Hederra, 1987). The following are the consequences of flood events:

- Serious consequences also arise when sewers overflow into houses and other built up areas, leading to major disruption of services, severe damage to buildings, and immediately threatening the health of the population exposed to the floods.
- After the floods have receded the contamination of household furnishings and the fabric of the house may continue to represent a risk to the health of the occupants for a considerable length of time.

- In addition to sewer overflows occurring during floods, sewer systems and supporting infrastructure can suffer physical damage if the force of the flood causes land movement or erosion around buried sewer pipes, or if sewer pipes above ground are washed away by the flood waters (CSIRO, 2007).
- Physical damage to the sewers may also occur as a result of differential ground settlement, which can occur after floods or heavy rainfall, or during periods of drought (Fehnel, Dorward & Mansour, 2005).
- In addition to the physical damage to infrastructure, the loss of electricity supplies, as discussed for piped water networks in the previous sections, is also a significant risk, especially to major sewer pumping stations during a flood.
- The infrastructure and the operational components of a wastewater treatment works can be damaged or taken out of service by flood waters, resulting in the discharge of untreated sewage and sewerage overflows.

9 FUTURE TRENDS AFFECTING WATSAN

For the next decade, five challenges have emerged that need to be taken into account for the sustainability of water supply and sanitation services in rural areas:

Challenge 1: Seeking the sustainability of basic rural water and sanitation

Challenge 2: The demand-based approach: thinking beyond the project cycle

Challenge 3: Decentralization in municipalities

Challenge 4: Sector policy and financial policy for rural water and sanitation: pending issues

Challenge 5: Long-term sustainability of the services and monitoring systems

The diversified demand and the need to propose options: The introduction of the demand-based approach represented an important step forward in acknowledging the importance of designing projects according to the needs and preferences of each community. This differentiation of the demand also applies for the rural beneficiary households, and is seen most clearly in the options available in terms of sanitation solutions. This recognition on the part of the sector can catalyse a paradigm change where the solutions offered in the way of services are increasingly aligned on the preferences expressed by the future beneficiaries. In the decade ahead, mechanisms will be needed to facilitate greater flexibility in responding to user preferences with appropriately tailored projects and programs for basic services.

Management of water resources: There is mounting concern regarding the care of these resources, their management and their importance for sustainable rural drinking water supply and healthy sanitation facilities. There is greater sensitivity about this need and recognition that water resources require integral management, something that can be done through greater coordination with other users of the sources and with other community institutions (irrigators) and municipal authorities (municipal governments and other water boards).

Although the contexts and conditions vary in different parts of developing countries, care of water resources is now acknowledged to be an intrinsic element in the management of rural systems and in the debate on sector policies.

Inter-sector coordination contributes to sustainability: The opportunities and contributions that can be generated by the players and mechanisms of other sectors (education, health, and environment) are demonstrated by an improvement in the sustainability of the services. From the creation of a new water culture to behaviour changes resulting in better hygiene practices, examples in the South Asia region can be cited where inter-sector coordination has produced an impact. The promotion of broader inter-sector initiatives during the coming decade will depend on the capacities for coordination among the community, municipal and sector institutions and on their ability to look clearly ahead without losing sight of present-day realities.

Financial management of the services over the medium and long term: Financial management of the drinking water supply and sanitation boards or committees already forms a component of the efforts being made in the developing countries to generate capacities and sustainability. The fact is, though, that financial management is often limited to operation and maintenance, or to a short-term view of the system.

However, financial management based on a medium or long-term horizon, in which replacement or expansion requirements must also be taken into account, is something that is yet to be undertaken in the national or subnational context. It is not known, for example, how to anticipate these needs and how to finance them (with own funds, counterpart funds, or a combination of the two). Greater attention to this question will help the sector to anticipate future needs likely to arise beyond the next decade.

Public-private-social partnerships as a tool for improving synergies: Participation by the private sector (in the broadest sense of the term, which includes both private entities run for profit and non-profits) continues to take place in various aspects of the WATSAN sector. Not only does this present opportunities for participation during the same period as is covered by the contract for construction and technical advisory services for the systems, but it also opens possibilities for provision of innovative basic sanitation solutions, which can be negotiated and agreed upon with the community and the users. In order to channel a larger contribution by the private sector during the next decade, it will be necessary to set up coordination mechanisms at the municipal level that will identify opportunities for added value, while maintaining alignment with the strategic objectives of expanding the coverage of sustainable services, with special emphasis on the poorest and least privileged households.

10 REASONS FOR CONTINUING TO INVEST IN WATSAN

In majority of the developing countries, 100-150 children die every day because of diarrhoeal related illnesses – many of these deaths can be prevented by adequate sanitation, safe drinking water and improved hygiene. In countries like India, Sri Lanka, Bangladesh, Pakistan, Nepal and other African countries, half of the rural population is without adequate sanitation and safe drinking water facilities.

The main bottlenecks in the water and sanitation sector are as identified below include:

- institutional arrangements with overlapping of roles and responsibilities and weak coordination mechanisms;
- high non-revenue water;
- dysfunctional water supply schemes;
- ageing infrastructure;
- water and sanitation driven by political interests which may not match equity and inclusion priorities;
- poor water quality from polluted and contaminated sources;
- inadequate waste water treatment;
- high dependency on ground water which is depleting; and
- inadequate solid waste management.

The following are the key reasons for continuing to invest in water and sanitation sector:

1) To ensure the availability of basic safe, accessible and adequate water supply and sanitation facilities in both rural and urban populations.
2) To completely remove the incidences of water and sanitation related diseases and child mortality rates in rural and urban populations.
3) To enhance and stimulate the socio-economic development both in rural and urban centres through the effective and efficient usage of safe water supplies and responsible sanitation management.
4) To ensure that the basic water supply and sanitation facilities are provided for poor and marginalised communities, and especially women which eventually reduces a huge burden on fetching for water walking for several miles and completely removes the fear of going out in dark for toilets.
5) To build sufficient institutional and operational capacity to ensure that new and existing schemes are efficiently and transparently managed and maintained in order to operate at required service levels for their full design periods.
6) To strengthen and enhance the existing assets condition to cope with any future climate change impacts. In addition this, any new assets shall be designed in consideration with climate change threats. This means, investment is required in strengthening the institutional capacity towards climate change, amendments to the existing policies & regulations in line with the climate change threats.
7) The majority of the developing countries in South Asia South East Asia and Africa, due to the absence of urban water supply and sanitation master plans, the authorities have no clue about the existing coverage due to which they were unable to plan for the uncovered areas. So, there is an immediate need for investment to produce master plans in water supply and sanitation sectors.

The term investment in WATSAN sector means capital investment, institutional investment, and operational & maintenance investments.

Majority of Asia, Pacific and African countries falls within the highly vulnerable zones of climate change and its inextricable link and need to develop its adaptive capacity, resilient water and sanitation systems and disaster risk reduction. Resilience of water and sanitation systems and disaster risk reduction is critical to build adaptive capacity. There is lot to do in this sector and require continuing investment both in education and technology enhancement.

11 TECHNOLGY ADVANCEMENTS TO ENSURE RESILIENCE TO CLIMATE CHANGE IN WATSAN SECTOR

Technology advancement is an essential element of human response to climate change. The adverse impacts of climate change on the water and sanitation sector will be experienced worldwide and are often projected to be most severe in resource-poor countries. Therefore, it is necessary to have access to a diverse array of adaptation technologies and practices that are appropriate and affordable in various contexts. The scale of these adaptation technologies/practices should range from the individual household level (e.g. household water treatment), to the community scale (e.g. rainwater collection in small reservoirs), to large facilities that can benefit a city or region (e.g. a desalination plant).

11.1 Resilience to Climate Change in Water Supply Sector

Six typologies are discussed here to define the adaptive function to which that these technologies and practices contribute. Most technologies/practices fit into more than one typology because they can contribute to more than one aspect of climate change adaptation. The six typologies are:

- Diversification of Water Supply
- Groundwater Recharge
- Preparation for Extreme Weather Events
- Resilience to Water Quality Degradation
- Stormwater Control and Capture
- Water Conservation

Table 11-1: Adaptation technologies in water supply sector

	Diversification of water supply	Groundwater recharge	Preparation for extreme weather events	Resilience to water quality degradation	Stormwater control and capture	Water conservation
Boreholes/tubewells as drought intervention for domestic water supply			√			
Desalination	√			√		
Household water treatment & safe storage				√		
Improving resilience of protected wells to flooding			√	√		
Increase the water-efficient fixtures and appliances						√
Leakage management, detection and repair in piped system				√		√
Post construction support to community managed water systems	√		√	√		
Rainwater Collection from Ground Surfaces - Small Reservoirs and Micro-catchments	√	√			√	
Rainwater Harvesting from Roofs	√	√		√	√	
Water Reclamation and Reuse	√	√		√		
Water Safety Plans (WSPs)			√	√		

Diversification of Water Supply: Precipitation patterns are projected to become more variable under most climate change scenarios. The response of water resources to precipitation events varies widely. For example, groundwater systems typically show a much slower and more muted response to drought and heavy precipitation than surface water. Therefore, diversification of the resources used for water supply can reduce vulnerability to climate change. In addition, exploring alternatives to freshwater resources (e.g. water reuse or desalination) can further bolster resilience.

Diversification of water supply can occur at different scales, from massive dam projects that may serve an entire country to interventions at the household level. Additionally, it should not be assumed that every water source must be of sufficient quality for all uses (e.g. drinking and cooking). For example, non-potable treated wastewater can often be safely used for irrigation. The technologies and practices included under diversification of water supply are:

- Desalination
- Post-construction Support for Community-managed Water Systems
- Rainwater Collection from Ground Surfaces—Small Reservoirs and Micro-catchments
- Rainwater harvesting from Roofs
- Water Reclamation and Reuse

Groundwater Recharge: Groundwater tables are declining in many areas around the world due to unsustainable rates of abstraction. Intentional recharge of groundwater is becoming increasingly popular. Innovative schemes for groundwater recharge using harvested rainwater, reclaimed wastewater and other methods have demonstrated success in elevating or preventing the depletion of groundwater tables.

Such technologies and practices include:

- Rainwater Collection from Ground Surfaces—Small Reservoirs and Micro-catchments
- Rainwater Harvesting from Roofs
- Water Reclamation and Reuse

Preparation for Extreme Events: The intensification of the global hydrological cycle is projected to increase risk of extreme wet and dry events in many areas. These adaptation technologies and practices can decrease vulnerability to extreme events:

- Boreholes/Tubewells as a Drought Intervention for Domestic Water Supply
- Improving Resilience of Protected Wells to Flooding
- Post-construction Support for Community-managed Water Systems
- Water Safety Plans

Resilience to Water Quality Degradation: Climate change is projected to have adverse impacts on water quality. Higher water temperatures, extreme precipitation events, and periods of low flow exacerbate many forms of water pollution. The following adaptation technologies can improve resilience to water quality degradation:

- Desalination
- Household Water Treatment and Safe Storage
- Post-construction Support for Community-managed Water Systems
- Water Reclamation and Reuse
- Water Safety Plans

Stormwater Control and Capture: Most urban areas are designed so that stormwater and other runoff are channelled from drainage systems into waterways and away from the city to prevent flooding. Capture of stormwater with detention basins, porous asphalt, green roofs, infiltration galleries and cisterns can be used to turn stormwater from a possible hazard into resource. Technologies that contribute to stormwater capture and control include:

- Rainwater Collection from Ground Surfaces—Small Reservoirs and Micro-catchments
- Rainwater harvesting from Roofs

Water Conservation: Water consumption per capita generally increases as a country experiences economic development. However, conservation measures in some of the most developed countries have led to a levelling off and eventual decline in per capita water use. Conservation increases resilience to drought, prevents groundwater depletion, and can postpone significantly the need for expansion of water reservoirs and treatment facilities. Technologies and practices that contribute to conservation include:

- Increasing the Use of Water-efficient Fixtures and Appliances
- Leakage Management, Detection and Repair in Piped Systems

Other Adaptation Technologies / Practices in the Water Sector: Some alternative technologies/adaptation options can be controversial, require legal frameworks or infrastructure unavailable in many settings or their implementation is very context specific. Integrated Water Resource Management (IWRM) (see below) can provide a framework for decision-making under each of these approaches:

- **Artificial reservoirs**: Typically created by construction of a dam in a valley, artificial reservoirs have the potential to yield massive increases in available water supply. However, there are numerous adverse environmental and social impacts associated with dam construction, flooding and displacement of populations. Among the environmental impacts is the counter-intuitive finding that construction of some dams can potentially increase greenhouse gas emissions due to the decay of vegetation as the valley is flooded.
- **Cross-sectoral collaboration**: Approaches to water resources management in many countries are dominated by sectoral divisions. Agriculture, municipal water supply, industry, energy and other sectors utilize and are dependent on access to water resources. When these competing interests are pursuing their goals independently the result can be incoherent and fragmented development and management.
- **Improved knowledge of water resources and water demand**: Understanding available water resources and anticipating demand are essential to any water management strategy. IPCC states: "*Information, including basic geophysical, hydrometeorological, and environmental data as well as information about social, cultural and economic values and ecosystem needs, is also critically important for effective adaptation*." Examples include understanding: groundwater systems, surface hydrology, and the dynamics of salinization in coastal systems, and detailed domestic, industrial and agricultural water use.
- **Water markets**: The Dublin Statement Principle No. 4 reads "*Water has an economic value in all its competing uses and should be recognised as an economic good*." The question of who has the right to use a given water source is handled very differently depending on the local legal framework. The use of markets on which the right to extract water can be traded as an economic good has been explored and implemented in the USA, Chile, Australia and elsewhere.

11.2 Resilience to Climate Change in Sanitation Sector

Sanitation facilities means the collection, containment or treatment, and disposal of excreta, can be delivered through on-site or off-site means. On-site sanitation includes a range of options, from very simple non-water using pit latrines to septic tanks connected to flush toilets and which take household greywater. Off-site systems are forms of sewerage where part or all of the excreta are transported away from the household for treatment or disposal at a central point. Sewerage may be conventional (typically, connected to flush toilets and household greywater, and in many cases stormwater) or modified – where only liquid matter is piped away (small-bore sewerage) or where sewerage works on a non-constant flow principle (shallow sewers) and does not take stormwater.

Table 11-2: Adaptation technologies in sanitation sector

Technology	Resilience	Issues

Pit Latrines	High	Many adaptations possible; flooding represents a particular challenge
Septic Tanks	Low – Medium	Vulnerable to flooding and drying environments
Modified Sewerage	Medium	Less vulnerable than conventional sewerage to reduced water quantity, but flooding a threat
Conventional Sewerage	Low – Medium	Risk from reduced water availability and flooding of combined sewers
Sewage Treatment	Low – Medium	Vulnerable to increases and decreases in water; treatment requirements may increase as carrying capacity is reduced

Pit Latrines: based on the research and evidence suggests that dry and low-flush pit latrines have high climate resilience because there is significant adaptive capacity through changes in design. In environments that are getting drier and where groundwater levels decline, pit latrines will be highly resilient because of the increasing potential for the attenuation or death of pathogens. There may be increases in nitrate concentrations, but the overall burden of disease associated with nitrate is much lower than other threats to the health of households only able to afford a pit latrine. Soil stability and hence pit stability could decrease in drying environments, but relatively simple adaptations exist to reduce this risk, by lining pits using local materials. Where pits are regularly emptied, for instance in high density peri-urban areas, pit stability could be affected and in such situations more permanent linings may be warranted to avoid pit collapse.

In environments where flooding may be an increasing risk, pit latrines may be more vulnerable. In the past, flooding of pit latrines has been responsible for widespread environmental contamination and public health risks. Where increased rainfall (even seasonally) leads to rising groundwater levels, this can lead to flooding of the pit and contamination of shallow groundwater. This has often been given as a justification for not installing latrines where groundwater is used as a drinking-water source. The risks might increase in an environment that is getting wetter, but changes in design (for example, to vault latrines) and the implementation of simple risk-based approaches to defining separation distances and the selection of appropriate groundwater technology may all reduce these risks (MacDonald et al., 1999; ARGOSS, 2001; Chave et al., 2006).

Pour–flush latrines have a slightly lower resilience than dry pit latrines, although their level of resilience is similar. In environments that are getting wetter, low-flush systems are more likely than dry latrines to cause groundwater contamination because use of water, even in small quantities, can significantly increase pathogen breakthrough (Pedley et al., 2006). This risk may be compounded in situations where groundwater levels are also rising. In environments that are drying, the requirement for any water at all will reduce resilience, although the typical volume associated with pour–flush latrines (1–3 litres at most) means that the impact would be relatively limited. Extreme rainfall events would not be likely to have any greater impact on pit latrines that use low volumes of water, for instance pour–flush latrines, than on dry pit latrines.

Septic tanks: Septic tanks, which tend to be linked to toilets that use large volumes of water, are likely to be less resilient than latrines. In drying environments, the volumes of water required to keep a septic tank functioning may be difficult to sustain. In environments where groundwater level rises or extreme events increase, managing drain field operation and preventing tank flotation present particular problems. There is evidence that flooding of septic tanks and drain fields can represent a very significant source of environmental contamination as a consequence of flooding.

Conventional and modified sewerage and wastewater treatment: Sewers have more limited climate resilience and in particular face threats from significantly decreasing rainfall and water flows, and from heavy rainfall events, which can result in widespread environmental contamination and public health risks. The following technologies shall be considered to make the system resilient to climate change:

- There are adaptations that build greater resilience into sewer systems, but these are often expensive and technically demanding. Adaptations include deep tunnel conveyance and storage systems that intercept and store the combined sewer overflow water until it can be conveyed to the wastewater treatment works.
- Sustainable urban drainage systems or providing additional storage for stormwater will increase resilience of sewers.
- Small-bore and shallow sewers may be more resilient in drying environments, as they typically use less water than conventional sewerage. As a consequence they are less vulnerable to decreasing water availability.

12 ENVIRONMENTAL IMPACTS MITIGATION

Climate change adaptation programs are rightly differentiated from those focused on mitigation. However, the potential impacts of adaptation strategies on greenhouse gas emissions and their effects on mitigation goals should not be neglected.

The following are the key impacts of climate change adaptations on the environment;

- Construction of a dam in a valley, artificial reservoirs have the potential to yield massive increases in available water supply. However, there are numerous adverse environmental and social impacts associated with dam construction, flooding and displacement of populations.
- In addition to the environmental and social impacts, construction of some dams can potentially increase greenhouse gas emissions due to the decay of vegetation as the valley is flooded.
- Installation of desalination plant has many environmental impacts. These include: effects of the concentrated waste stream on ecosystems; the impact of seawater intakes on aquatic life; and greenhouse gas emissions.
- Deep bore tubewells will have an impact on the soil strata above it and may cause differential settlement along the road system. This issue has been recently identified in Thailand and several research works are underway to understand the root causes and strategies to combat with the damage.
- Construction of small reservoirs affects the hydrological impacts downstream and also has huge impacts on the irrigation system that might trigger food scarcity.
- Surface storage options can lead to parasite/vector breeding, algal blooms and poor water quality, particularly in small reservoirs fed by agricultural runoff.
- In sanitation sector, majority of the communities are moving towards the more comprehensive sewerage system which involves pumping stations and advanced treatment technologies. These techniques consume more energy and produce greenhouse gases that in-turn affects the climate.

13 INSTITUTIONAL REFORM REQUIREMENTS

Sustainable service delivery improvements are not achievable unless technical and financial inputs are driven by effective and accountable institutions – clearly accountable to legitimate political authority and consumers, and with full responsibility for operational management. The water and sanitation sector facing a crisis rooted in a lack of formal accountability mechanisms/regulation, transparency and operational autonomy, technical inadequacy, tariff imbalances and financial instability. The institutional reforms and capacity building within the water and sanitation sector plays a vital role for effective and efficient operation of the system with minimal public health and hygiene issues.

A Strength, Weakness, Opportunity, Threat (SWOT) analysis is carried out for a range of water and sanitation institutes within the developing countries to scan the internal and external environment as an important part of the strategic planning process and normally applies to firms working in a competitive environment say at the time of launching an institutional reform or introducing a new product.

Table 13-1: SWOT Analysis

STRENGTHS	WEAKNESSES
• Monopoly Service Provider (in terms of ownership/access/use of infrastructure/ facilities, collection of revenue) • Availability of basic infrastructure and facilities	• Certain ambiguities in governance framework that open the organization to multiple and at times uncoordinated controls • Not ring fenced from political interference • Financial instability – Running a deficit • Technical inefficiency – lack of trained and qualified staff • Decaying infrastructure and facilities and lack of regulatory controls resulting in rapid decline in performance standards
OPPORTUNITITIES	**THREATS**
• An internal commitment to institutional and governance reforms • Strong donor support and technical assistance in implementing the reform process • A number of urban planning exercises underway that could be integrated with the reform process • Upcoming elections that could provide the time and political space for finalizing and implementing politically feasible and sustainable reforms	• Lack of board political consensus on the shape of reforms • A loss of donor support and interest in facilitating the reform process • Internal incapacity to manage the reform process • Resistance from civil society on the selected reform options

Figure 13-1: A crisis of Governance

The Governance Crisis			
Ambiguity in Role Definition	Lack of Accountability - Regulation	Non viable Financial Management	Technical Inefficiency

Impact			
Inappropriate financing/resource and work distribution Duplication of work/loss of resources Lack of institutional coordination Political tensions	Deteriorating financial and technical performance standards Growing public distrust and dissatisfaction	Lack of investment in maintenance of facilities/services Unsatisfactory human resource development Growing debt portfolio	Inappropriate infrastructure planning/development Inefficient maintenance of facilities/services

To effectively tackle any institutional reform challenges, mobilization and support for change is desirable not only within the institutions itself but amongst the widest possible range of stakeholders. Building mutual understanding in a heavily contested institutional environment is always a difficult and risky process. As a first step, documenting the defected situation in regards to 'who has access to what services' and identifying 'who plays what roles' can be a very useful step in promoting the understanding of 'why certain stakeholders behave in the way that they do'.

For instance, the local communities might have done remarkable work in improving the water and sanitation infrastructure in the informal settlements however the problem of harmonizing these systems within a network must be recognized. At the same time, the significant contribution of local water and sanitation board in developing bulk water and wastewater resources must be recognized, especially in the context of the genuine constraints under which the organization operates. Similarly, the role of local government representatives in representing their constituency and the associated roles assigned and executed by the different tiers of local government needs to be given due priority. The general thrust of such an assessment being to move from the reality, to the incentives that lie behind this reality – that sustain the current status quo.

Without a viable governance framework that identifies the appropriate roles and responsibilities of relevant stakeholders in policy making, service delivery and regulation, the long term effects of technical, financial or internal management changes cannot be secured.

The goal of the broader reform package should be to reform the water and sanitation sector in terms of ensuring the institutional and financial viability of the sector and enhancing customer orientation and accountability and therefore improve the quality of life of the people. A viable reform initiative would have to be based on the following important considerations:

- Achieving political commitment
- Building mutual understanding in a heavily contested institutional environment
- Identification of approaches for maximizing the capacity of all contributing stakeholders
- Avoiding the implantation of 'Models' that are not based on a thorough assessment of the ground realities and lack the legitimacy of stakeholder consensus.
- Ensuring the sustainability of actions through achieving public legitimacy

One needs to analyse the current situation of policy formulation and implementation.

- How adequate are the policies in terms of the involvement of relevant and appropriate stakeholders in the formulation process?

- What is their relevance to the existing ground realities?
- How have the policies been translated into programs and how effective have these programs been in improving services?
- Do all the relevant stakeholders agree with the policies?
- Do the policies accurately reflect a focus on the underserved populations?
- What kind of political support is there for the policy framework?
- How important is this support and how is it influenced by local politics?

Policy based review has to be linked with an analysis of the institutional roles and responsibilities.

- What are the gaps in carrying out functions?
- What are the legal, technical and financial constraints faced in service delivery and linkages with cross cutting social and environmental concerns?
- Is there an adequate supply of human resources to carry out the projects and programs? What are the main gaps?
- Is there a plan to build capacity to fill the gaps?
- How effective are these institutions and organizations in carrying out their roles?
- Is there any mechanism for coordination among the different actors?

A public expenditure review and analysis is critical requirement.

- Are priorities in funding appropriate?
- Is the payment program customer oriented?
- What are the causes hindering proper enforcement of payments?
- Are the financial controls inadequate to control corruption?
- Is the billing system properly managed?
- What is the status of the management information and financial information system? What is the level of theft and illegal domestic connections?
- What is the relevance of the tariff structure?

Issues related with the assessment of the physical infrastructure development, the level of technological advancement available at the local level, technical manpower, organizational strengths and capacities within the sector based entities are critical in framing the right policies that find resonance with the existing ground realties.

Assessment and Evaluation of Ownership/Management Options for Improved Service Delivery in the Water Supply Sector

The key focus of the reform process initiated by the External Support Agencies is to develop new ownership and management options for improved service delivery. Effective utility reform involves an interaction between the utility and its direct institutional environment. The reforms that can be undertaken by a utility are thus dependent on the reforms that the environment supports. Similarly, improvements in the environment in which the utility operates are likely to have a limited impact if the utility has insufficient internal capacity to make the most of this favourable development. Within a particular institutional framework, types of ownership and management systems and their level of appropriateness within the existing political and governance framework have a critical bearing on the performance of a utility. In case of the water supply and sanitation sector, a wide range of organizational models exist, most of which involve some mix of public and private involvement. The number and types of organizational models and ownership structures have increased substantially over the years since the introduction of private and public-private hybrid models. However, within South Asia, South East Asia and Africa, water utilities have operated almost entirely within the public sector with water related services commonly provided by state-owned monolithic water organizations in the larger cities and by a mix of provincial/local government authorities in the smaller towns. The recently notified water and sanitation policies in many developing countries at the national and provincial levels have very clearly indicated a significant political shift towards transforming utilities into more modern service delivery organizations that emphasize operational and financial sustainability by more actively participating with the civil society and through engaging private sector involvement.

If a general consensus of all stakeholders is obtained on moving from the model of a 'public sector monopoly utility' to a decentralized mix of public-private involvement, the need would arise of carefully assessing, evaluating and analysing the various options available (their potential of enhancing 'sustainable operationalization of water supply' with emphasis on cost recovery) and their relevance and comparable feasibility in terms of the existing political, technical, institutional and financial ground realties. Highlighted as following are some key factors that such an assessment would have to take into account:

- Examination of where the private sector can add value and comparing modes of participation (financing, service management) within the backdrop of discussion on issues related with asset ownership, capital investment, commercial risk, types of contractual arrangements etc.
- Evaluate the capacity and interest of the private sector in developing countries to play a more significant role in enhancing the efficiency, coverage, reliability and sustainability of water services
- Identification of consequences of choice (notably for different users/public private stakeholders) in advance would allow the balancing of different interests Identification of the best model for achieving 'sustainable' cost recovery (at least operations & maintenance) within the context of the present project area where there is low tariff affordability, political interference, weak regulation, local sensitivities and large infrastructure needs.
- There is a critical need for developing of risk allocation factors by governments that are attractive to the private sector while fulfilling their development agenda. Identification of the model that offers the least 'risk factor' would be extremely important. Inadequate risk sharing arrangements are at the heart of past failures. It also needs to be stressed that with regards to risk sharing in public-private partnerships, the responsibility of changes are not only with the public authority, instead there should be clear guidance on investor obligations, breaches, penalties and compensations linked to contractual requirements.
- Evaluating the comparable future costs of the various models of private sector involvement if any so that they may be incorporated by the governments in their medium term budgetary allocations
- Discussion on issues related with capacity, transparency and accountability of sub-sovereign entities and what would be the best model for achieving them
- Examination of the key elements of business environment that bear on water supply and sanitation: local governance, overall institutional setting, policies and political will and within that context identify the model that suits best the ground realities
- The comparable analysis for new 'ownership and management' option/s for improved service delivery need to focus on the respective capacities of the various models in addressing corruption explicitly in the PPP framework, clear definition of performance targets and outputs and allowing the private sector to benefit from the contract (rather than by perverting it). Reducing incidences of transaction, gain from each transaction and increase probability of detection and penalty

- The selected new 'ownership and management' option/s for improved service delivery need to have mechanisms for participation by all stakeholders, notably through the creation of capacity and space for dialogue (incl. public and private sector, communities, NGO's, users)
- Enhancing 'sustainable operationalization of water supply and sanitation' would require the public sector to remain the enabler. However, it needs to be assessed as to how political role can be separated from the role of administration and operation of service delivery so that the new model/s for service delivery can be effectively 'ring fenced' and sustained in the long run
- Enhancing 'sustainable operationalization of water supply and sanitation' would require a degree of consistency across federal, provincial and local governments and also institutional continuity. This requirement needs to be assessed with reference to the discussion on the potential 'ownership and management' option/s for improved service delivery
- Enhancing 'sustainable operationalization of water supply and sanitation' would require the development of some regulatory elements/dispute settlement mechanisms to frame the activities of the new service delivery entities having private sector involvement. This is a critical of area for discussion and assessment while deciding upon new 'ownership and management' option/s for improved service delivery and would require, prior to the selection of a 'model' a thorough review of the legal and regulatory environment governing the role of public/private sector in the delivery of municipal services in any developing country.

14 KEY LESSONS FOR ADAPTATION IN NEPAL

Nepal is in the heart of the Great Himalayan region.

- the 15th poorest country in the world
- over 55% of the population live under the international poverty line of $1.25 a day
- over 10 million of its population are at greater risk of natural disasters including floods, drought, disease outbreaks and forest fires
- emerging from a 10-year civil war with a fragile peace process

Nepal's temperature is rising faster than the global average, and rainfall is becoming unpredictable. Water resource is projected to become one of the most pressing environmental problems with high impacts from climate change in hills and mountains of Nepal. Drying water sources, ground water depletion is likely due to long dry seasons, irregular rains, and high intensity rainfall leading to high run-off and less infiltration. Rural communities in hills and mountains of Nepal are experiencing the impact on water resource due to climate change.

Observations of recent climatic trends include increases in temperature, an upward shift of agro-ecological zones, increasingly variable precipitation patterns, and changes in snowfall patterns (less snow and changes in timing). Communities also perceive a shift in wind, frost and dew patterns, as well as increases in extreme weather events (droughts and floods) and avalanches. The Himalayan glaciers, an important renewable water source, are retreating as temperatures increase. All of this entails risks for a poor country like Nepal with an economy very dependent on natural resources, notably in terms of agricultural productivity and food security, availability of water, nutrition, health and sanitation. Glacial lake outburst floods are also a threat to population and infrastructure.

The Government of Nepal has initiated processes whereby climatic threats to development are being addressed. Priority climate adaptation measures have been identified across a range of sectors through a highly consultative process, which is an exemplar for other developing countries. In preparation for the role of coordination of climate change response measures, the Ministry of Environment has developed an implementation framework that will be used to coordinate national through to local adaptation initiatives. Nepal's National Adaptation Plan of Action (NAPA) provides a clear guideline for the disbursement of at least 80 per cent of adaptation funds on implementation at the local level. To support implementation the government of Nepal has recently developed a national framework for a Local Adaptation Plan for Action (LAPA). However, the biggest challenge to achieving these aims will be the quality of governance at all levels. The following challenges and barriers can be seen in Nepal in implementing any climate change adaptation plans:

14.1 Role of Nepali Women in WATSAN

Women and children generally carry the burden of water collection and it is now widely accepted by everyone in the WATSAN sector that gender issues must be integrated into project development and adaptation plans. However, the practicalities of balancing the roles of women and men in water and sanitation projects still present many difficulties to agencies. For example, inclusion of women on water committees does not necessarily guarantee that they will get involved in decision making but conversely, additional responsibilities may only serve to increase women's already heavy daily workload. Especially in Nepal they were seeking ways to reintroduce men into management committees because they had become totally excluded from planning and decision-making.

14.2 Targeting the Poor

The full potential of health benefits to communities will only be achieved if the provision of water is accompanied by hygiene promotion and sanitation. Majority of the programs and schemes were not reaching the very poor in the community. They will always tend to hold back whilst more vocal and confident people will step forward to claim the benefits. In the water context, Nepal shall take a firm stand at the planning stage to ensure that low-caste groups (Dalits) were adequately served. The message here is that it is not enough to classify an entire community as 'poor', since every community will tend to subdivide itself and marginalise sub-groups within it. In every WASH programmes, the staff will take a proactive role in identifying and working specifically with marginalised groups.

14.3 Gaps in Nepal

There are some of the notable gaps in this lesson-learning exercise are in:

- Integrated community water resource management
- Promotion of healthy sanitation practices through public awareness programmes
- Management and conservation of the environment
- Collaboration with the private sector
- Innovations e.g. community financing mechanisms for sustainable O&M
- Social marketing techniques.

14.4 Water Resources Management

Changes in precipitation patterns had affected the sources of water supply systems in Nepal. Landslides and flash floods caused by the increase in the events of intensive rains had destroyed the intake structures and affected the water discharge in the streams and to the downstream reservoirs. The streambeds had risen because of deposition of debris, which had covered up the stream water, making it inaccessible for water resource management. Wherever possible, water committees had tried to use alternative techniques, such as deep bore tube wells or traditional springs for domestic water usage. According to the local communities, rehabilitation of water resources and channels was one of their priority demands.

Based on the needs of the communities, water intake and supporting components were rehabilitated. In some parts of Nepal, communities were provided with high density polythene pipes and plastered concrete cement for the rehabilitation of transmission pipelines and the reservoir structures. Some communities now could get reliable water sources, in areas where previously they could hardly get 1 hour of water supply per day. This in turn helped the irrigation sector in rural areas. This helped the beneficiary households to increase the total crop production in the area, thereby helping in food security and income generation. Increased food security and household income had strengthened their resilience to the impact of climate change and likely disasters.

14.5 Promoting Integrated Water Resource Management (IWRM)

Nepal shall work towards increasing IWRM and its principles still need to be stressed and advocated if sustainable adaptation strategies to climate change are to be realised. In many parts of Nepal, water issues are divided among numerous government departments and are dealt with in a segregated manner. Strong sectoral linkages are prerequisites for meeting the enormous challenge of climate change and its vast array of effects in all facets of life, health, environment, transport, energy, and food security. Mechanisms must be put in place to cut across sectors and link programmes and strategies dealing with water and climate issues in concrete ways. IWRM can provide this framework, but priority must be given to its planning and implementation. This, in some countries, including Nepal, would require a radically new way of thinking, cutting across sectors to address water management in a holistic manner.

Yet the climate change challenge requires just that: radical new thinking. Even acknowledging the principles of IWRM but only implementing parts of it would still be a significant leap forward for water management.

14.6 Forest, Land and Soil Conservation

In the past, increased frequency and intensity of floods used to destroy large areas of cultivated land in the area. In 2006 alone, over 8 ha of land were destroyed by landslides and floods. One of the demands of the communities was, therefore, protection of their land from future floods and landslides. In some cases, the houses located close to streams where floods occur frequently needed to be protected.

The destruction of forest has a huge impact on the water and sanitation sector. Majority of the water resources are located in the dense forests that are helping the recharge of groundwater and the local streams. Due to the absence of forest and helpful soil around within the catchment would retard the groundwater recharge and eventually triggers the drought.

Based on the needs of the communities, gabion wire boxes shall be filled with rocks and on the riverbanks to divert the stream flow during flood periods. It helps to protect the intakes of water supply system and irrigation channels, lands and houses located at vulnerable sites. However, the flood of 2006 was several times bigger than the communities had anticipated. Most of the gabion wire boxes were destroyed and buried under the debris. There was, of course, need for some technical improvements. There could be further larger and intensive events of landslides and floods, for which the communities must be prepared and protected.

The investment shall be increased for protection against CC threats and to enable the riverbanks to withstand the impact of intensive rainfall and flash floods. Interventions had now to be made to erect check dams in upstream micro-catchments, together with afforestation and forest management, to reduce the deepening of gullies, occurrence of landslides and debris flow to minimize damage in downstream areas.

14.7 Rehabilitation of WATSAN Infrastructure

Destruction of important local infrastructures such as intake structures, transmission pipelines, reservoirs, sanitation facilities as a result of landslides and floods is also an impact of extreme rains and floods. More of such infrastructures are likely to be affected in the future from erratic rains, floods and landslides. The communities are to be prepared for such events. There is a need for projecting and predicting future climate change and its impact and incorporate such factors in the planning, construction and rehabilitation of infrastructures. Although the communities across Nepal are in need of help, including rehabilitation of infrastructures and provision of new facilities that are more resilient to CC threats.

14.8 Awareness & Education to Local People & School Students

Awareness of local communities and stakeholders about climate change and its expected impact was very low. Their views on climate change were only related to their geographic boundaries. However, the area of coverage of climate is wide and beyond the local environment (Gurung 2005). A number of awareness activities, such as slide shows, interactions, educational visits, visual documentaries, etc., are required to increase the awareness of the communities and local stakeholders.

The local people, especially school students, need to be aware of local weather and climate. In order to make them aware of local weather and climate, a meteorological station shall be established in communities that are vulnerable to CC threats so school students can participate and take records of temperature and rainfall. Information materials such as booklets and posters on climate change and its global and local impact were also produced and disseminated.

14.9 Knowledge Bias

There continues to be a great need to recognise knowledge held by local people. Although in the face of a changing climate it is not certain that present adaptation strategies will be sufficient in the future, yet they must be the starting point on which to begin. Local technologies that aid communities to well on the ground and may even lead to violations of basic human rights. Time-after-time it is discovered that the communities who share their best practice techniques and methods are those that can increase their resilience to change and challenges.

14.10 Institutional Issues

Alongside the numerous socioeconomic, environmental and geophysical constraints to adaptation facing Nepal, there is a long history of institutional failures that currently complicate the development process and will severely hinder any effective adaptation, either strategic or autonomous. From constantly changing governments, including vacillation between pure royal control to constitutional monarchy and the republic in 2006, and frequent turnover of administrations, Nepal has a long history of political upheaval and impermanent stability. The following are the most relevant failures that will be the most difficult, but essential, to overcome if the most severe effects of the imminent impacts of CC are to be avoided.

- Constantly changing organizational structures
- High turnover of government personal
- Failure of public institutions
- Ineffective coordination within the sector
- Deficient capacity
- No clear defined roles and responsibilities

15 CONCLUSIONS

Some concluding thoughts are as follows:

- Clean Water and safe sanitation is not the privilege; it is the RIGHT of any community. Water scarcity and its related sanitation issues are the fast-growing problems in developing and also in some parts of developed countries. Wasteful use of water continues due to poor policy, mismanagement, and wrong incentives.
- Opportunities exist to improve safe drinking water supplies and healthy sanitation facilities, but usually require a holistic approach by combining community awareness with apt management and policies.
- Highlighting Nepal in particular, climate change has several local-level impacts. In Nepal, the most studied subject on the impact of climate change is retreating of glacier and snowline and

its subsequent impact on the formation of glacial lakes. There is inadequate information on the relationship of climate change with droughts, landslides, floods, and cold and heat waves. Studies are also lacking on the impact of climate change on water and sanitation sector. Nevertheless, poor local communities are the ones most affected by the impact of climate change.

- Poor communities have low awareness of global climate change and its impact. There is inadequate awareness even among the professionals working in governmental and non-governmental organizations, both at grass roots and at national level. There is a need to raise the awareness of climate change and its impact among all types of stakeholders. The communities have experienced the impact of climate change and are adopting different survival strategies.
- Nevertheless, most of such practices are focused on short-term coping strategies. The long-term adaptation strategies are lacking because of lack of understanding of climate change and its impact in addition to the lack of resources in the communities' control and hand. The impact of climate change is very much localized; therefore, it has to be systematically understood and subsequent coping and adaptation strategies developed and implemented locally. Although climate change has multiple effects in a given locality, the most affected sector such as water and sanitation should be taken as the entry point for developing and promoting an integrated programme.
- The international experience suggests that the climate change adaptation approach should include a diverse range of conservation and development activities, including strategies for disaster risk reduction. The approaches might be promoted as 'Integrated Conservation and Development Approach' with ultimate goal to achieve sustainable development. The impact of climate change has already become severe, with more severe impact likely to come. The adaptation to any climate change programme should keep the future projection in mind. If the likely future impact not taken into account, any investment in coping strategies will be a waste of resources, as they are likely to be destroyed by bigger disasters in the future. Therefore, disaster risk reduction should be an integral part of all climate change adaptation programmes.

ANNEX A- SEPTIC TANK MANAGEMENT MATRIX

PROGRAM ELEMENT	RESPONSIBLE PARTY	ACTIVITY
PUBLIC EDUCATION AND PARTICIPATION	Regulatory Authority	• Educate Owner/User on purpose, use, and care of treatment system. • Provide public review and comment periods of any proposed program or rule changes.
	Service Provider	• Be informed of existing rules and review and comment on any proposed program and/or rule changes. • Participate in advisory committees established by the Regulatory Authority.
	Owner/User	• Be informed of purpose, use, and care of treatment system. • Be informed of existing rules and review and comment on any proposed program and/or rule changes. • Participate in advisory committees established by the Regulatory Authority.
PLANNING	Regulatory Authority	• Coordinate program rules and regulations with local planning and zoning and other water-related programs. • Evaluate potential risks of wastewater discharges to limit environmental impacts on receiving environments during the rule making process. • Inform local planning authority of rule changes and recommend its evaluation of potential impacts on land use.
PERFORMANCE	Regulatory Authority	• Establish system failure criteria to protect public health, e.g., wastewater backups in building, wastewater ponding on ground surface, insufficient separation from ground water or wells.
	Owner/User	• Regularly maintain system in proper working order
TRAINING AND CERTIFICATION/ LICENSING	Regulatory Authority	• Maintain a current certified/licensed Service Provider listing.
	Service Provider	• Obtain training from the manufacturer or vendor regarding appropriate use, installation requirements, and O&M procedures of any proprietary equipment to be installed.
	Owner/User	• When using third-party services, contract with only the appropriate certified/licensed Service Providers.
SITE EVALUATION	Regulatory Authority	• Codify prescriptive requirements for site evaluation procedures.
	Site Evaluator	• Obtain certification/license to practice.
	Owner	• Hire a certified/licensed site evaluator to perform site evaluation.
DESIGN	Regulatory Authority	• Codify prescriptive, pre-engineered designs that are suitable for treatment sites that meet the appropriate prescriptive site criteria.
	Designer	• Obtain a certification/license to practice.
	Owner	• Hire a certified/licensed designer to prepare system design.
CONSTRUCTION	Regulatory Authority	• Administer a permitting program for system construction, including Regulatory Authority review of proposed system siting and design plans. • Require that record drawings of constructed system be submitted to the Regulatory Authority by Owner.
	Contractor/ Installer	• Comply with local requirements in the design and construction of dispersal systems.
	Designer of Record	• Comply with applicable local requirements in the design and construction dispersal systems.
	Owner	• Hire a certified/licensed contractor/installer to construct system. • Submit final record drawings of constructed system to Regulatory Authority.
OPERATION & MAINTENANCE	Regulatory Authority	• Provide Owner/User with educational materials regarding system use and care. • Send timely reminder to Owner of when scheduled preventive maintenance is due.
	Pumper/Hauler	• Obtain certification/license to practice.
	Owner	• Perform recommended routine maintenance or hire a certified/licensed pumper/hauler to perform maintenance.

PROGRAM ELEMENT	RESPONSIBLE PARTY	ACTIVITY
		• Hire a certified/licensed pumper/hauler to periodically inspect, service, and remove septage for proper treatment and disposal.
	User	• Follow recommendations provided by Regulatory Authority, Service Providers, and/or Owner to ensure that undesirable or prohibited materials are not discharged to system.
RESIDUALS MANAGEMENT	Regulatory Authority	• Inventory available residuals handling/treatment capacities and develop contingency plans to ensure that sufficient capacities are always available.
	Pumper/Hauler	• Obtain certification/license to practice
COMPLIANCE INSPECTIONS/ MONITORING	Regulatory Authority	• Perform compliance inspections at point-of-sale, change-in-use of properties, "targeted areas," and systems reported to be in violation. • Conduct compliance inspections of residuals hauling, treatment, and disposal.
	Pumper/Hauler	• Inform Owner of any noncompliant items observed during routine servicing of system.
	Owner	• Periodically perform a "walk-over" inspection of the system and correct any deficiencies.
CORRECTIVE ACTIONS	Regulatory Authority	• Negotiate compliance schedule with Owner for correcting documented noncompliance items. • Administer enforcement program, including fines and/or penalties for failure to comply with compliance requirements. • Obtain necessary authority to enter property to correct imminent threats to public health if the Owner/User fails to comply.
	Designer	• Provide Owner with documents (drawings, Specifications, modifications, etc.) that may be required by Regulatory Authority prior to corrective action.
	Contractor/ Installer	• Perform required repairs, modifications, and upgrades as necessary.
	Owner	• Comply with terms and conditions of the negotiated compliance schedule. • Hire appropriate certified/licensed Service Providers to perform required corrective actions.
RECORD KEEPING, INVENTORY & REPORTING	Regulatory Authority	• Administer a database inventory (locations, site evaluations, record drawings, permits, performed maintenance, inspection reports) of all systems. • Maintain a residuals treatment and disposal tracking system. • Maintain a current certified/licensed Service Provider listing that is available to the public.
	Pumper/Hauler	• Prepare and submit records of residuals handling as required.
	Owner	• Provide drawings, Specifications, and maintenance records to new property owner at time of property transfer.
FINANCIAL ASSISTANCE & FUNDING	Regulatory Authority	• Provide the legal and financial support to sustain the management program. • Provide a listing of financial assistance programs available to Owner and the qualifying criteria for each program. • Consider implementing a state or local financing program to assist Owners in upgrading their systems.