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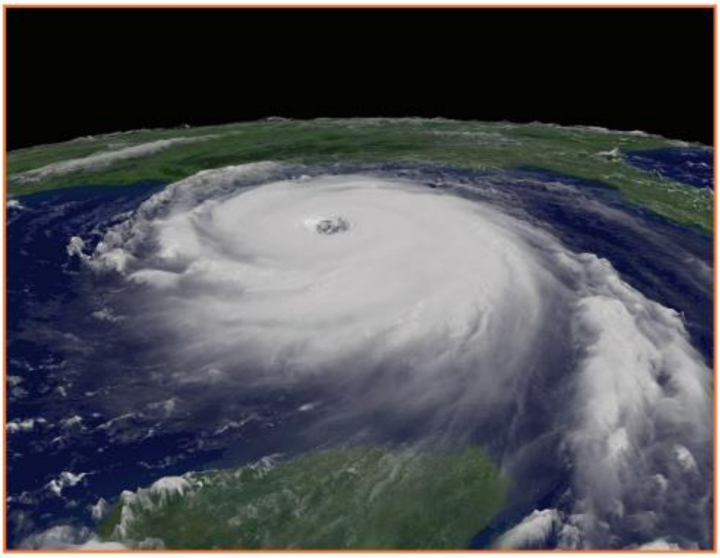

Promotion, 2014-2015

DEDICATION

TO:

ALMIGHTY GOD

MY BROTHERS AND SISTERS

MY WIFE FRANCINE NYIRARUKUNDO

MY SON RYAN FRANKLIN HIRWA

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ABSTRACT

In most of the areas of the earth's planet climate change becomes a big issue to the ecosystem, in this document we outlined the impact of climate change in relation to WASH and gives the examples to some country affected by climate change like Latin America, California, Haiti, India Kenya, Etc.

Global warming was as one which contribute to the temperature rise and causes the earth warmer due to the greenhouse gases emission. Ozone layer in the stratosphere above us which acts as a shield to protect Earth's surface from the sun's harmful ultraviolet radiation, this layer plays a major rule to protect earth from hit. Climate change impact on water resources and water program has been discussed on it and its relative impact to WASH, because it can cause flooding, deforestation, drought, sea water rise, disaster from strong wind or storm.

Furthermore, flood can cause damage to infrastructure (Roads, houses, sanitation), human and animal death, Surface and water pollution, waterborne disease like diarrhea, cholera, malaria and others. The deforestation lead to drought which causes the lack of water in quality and in quantity (Either surface water or ground water); this drought also push the people to be displaced from their local region to another which becomes more dangerous to them. Suddenly, Strong wind or storm happens and destroy many infrastructure and mix different things which pollute water.

In Water Sanitation and Hygiene (WASH), there is a need of water sources for supplying where is needed, there is also need of sanitation for excreta disposal and also there is a need for hygiene practice in order to have safe life and beautiful environment. Analysis and discussion of different documents related to impact of climate change shows us that according to the instability of climate, WASH is also affected by that climate instability.

Key word:

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1. Climate Change
2. Water, sanitation and hygiene
3. Flooding
4. Drought
5. Water pollution

RESUME

Dans la plupart des zones de la planète, le changement climatique représente un problème important pour l'écosystème. Dans le présent document, nous avons dressé un aperçu des impacts du changement climatique en reliés au WASH et donné des exemples de pays affectés par le changement climatique tels que l'Amerique Latine, California, Haiti, l'Inde, le Kenya…

L'effet de serre est l'un des éléments qui contribue à l'augmentation de la température provoquant le réchauffement de la planète dû au rejet des gaz à effet de serre. La couche d'Ozone située dans la stratosphère au-dessus de la terre agit comme un bouclier protégeant la surface de la planète de radiations ultraviolettes nocives. Cette couche joue un rôle important dans la protection de la Terre contre la chaleur. Le changement climatique a un impact sur les ressources en eaux et les programmes en eaux ont entamé des discussions en rapport avec cela et son impact relatif au WASH parce qu'il peut causer des inondations, la déforestation, la sècheresse, la montée du niveau d'eau dans la mer et des catastrophes provenant de vents forts ou tempêtes.

En outre, l'inondation peut provoquer des dégâts aux infrastructures (Routes, Habitations, Ouvrages d'assainissement), Aux Hommes et la mort des animaux, la pollution du sol et de l'eau, des maladies hydriques tels que la diarrhée, le choléra et la malaria etc. La déforestation entraine la sécheresse qui cause le manque d'eau en qualité et en quantité (de l'eau de surface aussi bien que de l'eau souterraine). Cette sécheresse entraine aussi les populations à se déplacer de leurs régions locales pour une autre qui peut devenir plus dangereux pour eux. Soudainement, un vent fort ou une tempête survient et détruit plusieurs infrastructures et crée un mélange de plusieurs éléments qui polluent l'eau.

Dans le WASH (Water, Sanitation and Hygiene), il y'a un besoin de ressources en eau pour approvisionner les zones en besoin, il y'a aussi un besoin d'assainissement pour le traitement des rejets et il y'a aussi un besoin de pratiques d'hygiène afin d'avoir une existence paisible et un bel environnement. L'analyse et les discussions des différents documents concernant l'impact du changement climatique nous montrent qu'en relation avec l'instabilité climatique, Le WASH est aussi affecté par cette instabilité climatique.

Mots clés: Changement climatique, WASH, Inondation, Sécheresse, Pollution de l'eau

ACRONYMS AND ABBREVIATIONS

1. 2iE : Institut International d'Ingénierie de l'Eau et de l'Environnement

2. ADB: African Development Bank

3. ALNAP: Active Learning Network for Accountability and Performance

4. DOC: Dissolved Organic Carbon

5. EPA: Environmental Protection Authority

6. GDP: Gross Domestic Product

7. GHGs: Greenhouse gases

8. IPCC: International Panel on Climate change

9. LAC: Latin America and the Caribbean

10. MDGs: Millennium Development Goals

11. NCDC: National Climatic Data Center

12. NGOs: Non-Governmental Organizations

13. NOAA's: National Oceanographic and Atmospheric Administration's

14. O&M: Operation and Maintenance

15. PDSI: Palmer Drought Severity Index

16. SAGE: Stratospheric Aerosol and Gas Experiment

17. TMDL: Total Maximum Daily Load

18. UNEP: United Nations Environment Programme

19. UNICEF: United Nation Children's Fund

20. UV: ultraviolet

21. UW: University of Washington

22. WASH: Water, Sanitation and Hygiene

23. WHO: World Health Organization

24. WMO: Established by the World Meteorological Organization

25. WYI: World Youth International

TABLE OF CONTENT

LIST OF FIGURE

CHAPITER I: INTRODUCTION

Climate change is when the average long-term weather patterns of a region are altered for an extended period of time, typically decades or longer. Examples include shifts in wind patterns, the average temperature or the amount of precipitation. These changes can affect one region, many regions or the whole planet. Climate changes are caused by changes in the total amount of energy that is kept within the Earth's atmosphere. This change in energy is then spread out around the globe mainly by ocean currents as well as wind and weather patterns to affect the climates of different regions. In that, the causes of climate change is natural processes such as volcanic eruptions, variations in Earth's orbit or changes in the sun's intensity are possible causes. However, human activities can also cause changes to the climate for example by creating greenhouse gases emissions or cutting down forests causing negative impact. The Earth's climate has never been completely static and in the past the planet's climate has changed due to natural causes (WYI, 2014).

In Washington State for example, it is predicted that the next 50 years, climate change will have a dramatic impact on due to snowpack decrease, water shortages and wildfires, and more people may die. The report from the Climate Impacts Group at the University of Washington paints a bleak picture of the impact of climate change on human health, agriculture, energy supply and demand, stream-flow, water storage and infrastructure (DONNA GORDON BLANKINSHIP, 2009). A 2012 study found that climate change is already costing us more than $1.2 trillion a year and reduced global GDP 1.6 percent within that same time period (Mindy S. Lubber, 2014).

Water and sanitation play a crucial role in the transmission of diarrheal disease. These environmental factors contribute to approximately 94 percent of the 4 billion cases of diarrhea that the World Health Organization (WHO) estimates to occur globally each year. Children under the age of 5 in developing countries bear the greatest burden and account for the majority of the 1.5 million deaths attributed to diarrhea annually. In Latin America and the Caribbean (LAC), roughly 77,600 children under the age of 5, over 200 children every day, die each year from diarrhea and its complications (UNICEF /WHO, 2005).

1.1. Background

Water, as basic for human life is particularly threatened by climate change. The irrefutable evidence of global climate change and new evidence of its far-reaching ramifications on water security and water related disease (especially in poorer water stressed countries) is also fueling increasing interest in the sector (UNICEF, 2006). In Nepal, as in many other parts of the world, the urban poor are more particularly vulnerable, living in informal settlements and marginal land often not legally acknowledged by the authorities and therefore not served with basic water supply or sanitation. Many do not have land tenure, and lack rights or incentive to invest in infrastructure improvement.

Therefore fluctuation in availability of water due to climate change can directly affect their health and availability to be economic active, the main reason that the majority of informal residents migrate to the city. The evidence shows that the most important form of city adaptation to climate change is to push for progress to the Millennium Development Goals, especially provided potable water and sanitation and reducing the number of people living in slum (Danilenko and et. Al, 2010). In Kathmandu valley there are 40 squatter settlements and 137 slum communities on which 40,237 population live in 8,846 households. Of these, 22% had no access to piped water supply and none had adequate sanitation (ADB, 2010). Due to climate change impact, the quality of water supply will be much lower during dry days which lead the inadequate sanitation and hygiene practice and flood causing damages the water infrastructures lead to shortage of water in rainy days.

1.2. OBJECTIVES

1.2.1. Global objective

To review the impact of climate change in WASH, in a view to address its related consequences on the environment and populations.

1.2.2. Specific objectives

- ✓ To outline the impact of climate change in relation to WASH.
- ✓ To be aware of linkage between climate change and WASH.

1.3. Scope of the dissertation

This dissertation is limited on impact of climate change in WASH Sector, as it affects the globe in different forms. In this work, some example of countries affected by climate change will be highlighted in relation to impact to WASH.

1.4. Structure of the study

The dissertation is made of four chapters. The first chapter gives the Introduction, background of the study, objectives of the study, Scope and methodology. The second chapter discusses different aspects to impact of climate change in WASH according to different authors. The third chapter deals with analysis and discussions. The fourth chapter presents conclusion and recommendation.

1.5. Methodology

This dissertation consists of exploration of available documents on impact of climate change in WASH in order to gather information which guides us to fulfill the study. All of my dissertation has been done by bibliographical, web graphical references and other sources such as previous studies on the topic as well as reports from different Non-Governmental Organizations (NGOs) and other related documents. For design, AutoCAD software has been used.

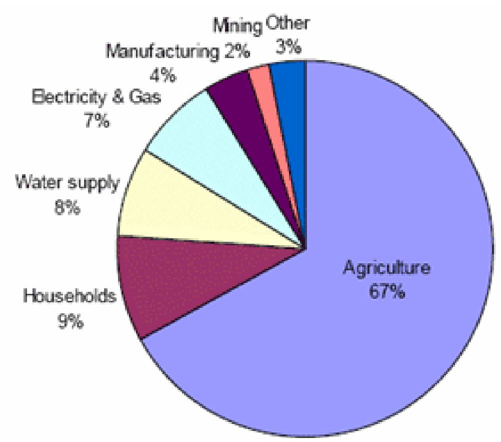
CHAPITER II: LITERATURE REVIEW

2.1.Climate Change Impacts on WASH

Africa is no exception to climate change variability, a problem further exacerbated by low capacities to address and adapt to the phenomenon. The continent has become increasingly susceptible to wind storms, droughts, floods, rainfall variability, coastal erosion, and sea-level rise. When coupled with existing socio-economic challenges, these adverse impacts stunt progressive national development and augment vulnerabilities and low number of infrastructural constraints and human capacity limitations. The current situation will continue to persist unless sustainable and urgent measures are taken (through the intervention of such timely and worthwhile project/grogram initiatives)".

According to the Comprehensive Assessment of Water Management in Agriculture, one in three people are already facing water shortages (2007). Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, while another 1.6 billion people, or almost one quarter of the world's population, live in a developing country that lacks the necessary infrastructure to take water from rivers and aquifers (known as an economic water shortage).

Figure 1: Water use in the world



Source: **UNEP, 2005**

However, the first step in understanding how the National Water Program should respond to climate change is to understand the basic science of climate change and the consequences of climate change for water resources. Some of the primary effects of climate change for water resources include but not limited to: Air and Water Temperature Increases; Changes in Levels and Distribution of Rainfall and Snowfall; Storm Intensity Increases; Sea Level Rise; and Changes in Coastal/Ocean Characteristics (http://www.epa.gov/climatechange/).

Furthermore, it is increasingly likely that one response to climate change will be a shift in methods of producing energy (e.g., increased demand for biofuels). Some of these changes in the methods of energy production may affect water resources and water protection programs. Some of the impacts on water resources due to shifts in energy production are described in this section (IPCC 1988).

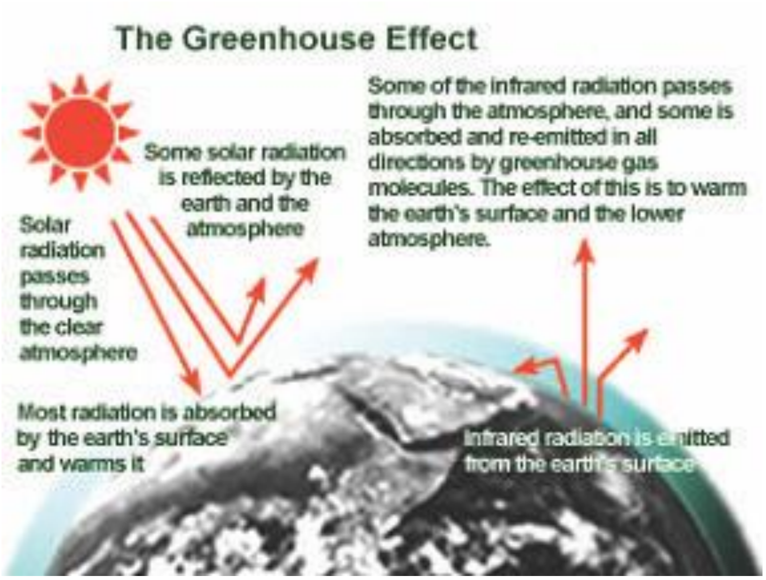
Climate change is having serious and unpredictable impacts on the world's water systems through more flooding and droughts. It's impacting on rivers and lakes - which supply drinking water for people and animals - and are a vital resource for farming and industry. We're facing the biggest environmental challenge our generation has ever seen. If we don't pay attention, something we care about will be affected by climate change.

2.1.1. Climate Change Basic

Climate change refers to significant change in measures of climate (such as temperature or precipitation) lasting for an extended period (decades or longer).Energy from the Sun drives the Earth's weather, climate and physical processes at the surface. The Earth absorbs energy from the Sun and also radiates energy back into space. However, much of this energy going back to space is absorbed by "greenhouse gases" in the atmosphere. Because much of this energy is retained in the surface-atmosphere system, the planet is warmer than it would be if the atmosphere did not contain these gases. Without this natural "greenhouse effect" temperatures would be about 60ºF (about 33ºC) lower than they are now, and life as we know it today would not be possible (EPA 2007a).

Climate change may result from cosmic factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; natural processes within the climate system (e.g., changes in ocean circulation); and human activities that change the atmosphere's composition (e.g., through burning fossil fuels) and the land surface (e.g., deforestation, reforestation, urbanization, desertification).

Figure 2: The Greenhouse Effect



Source: **EPA 2007a.**

During the past century, humans have substantially added to the amount of greenhouse gases in the atmosphere by burning fossil fuels such as coal, natural gas, oil and gasoline to power cars, factories, utilities and appliances. The added gases, primarily carbon dioxide and methane, are enhancing the natural greenhouse effect and likely contributing to an increase in global average temperature and related climate changes (EPA 2007a).

2.1.2. Air and Water Temperature Increases

As the earth's temperature continues to rise, we can expect a significant impact on our fresh water supplies with the potential for devastating effects on these resources. As temperatures increase, evaporation increases, sometimes resulting in droughts. The US is currently in one of the most severe, multi-state, multi-year droughts in decades.

Temperatures are changing in the lower atmosphere, from the Earth's surface all the way through the stratosphere (9 to 14 miles above the Earth's surface) (EPA 2007b). Most climate change scenarios project that greenhouse gas concentrations will increase through 2100 with a continued increase in average global temperatures (IPCC 2007a, and EPA 2007c).

The average surface temperature of the Earth is likely to increase by 2 to 11.5°F (1.1 to 6.4°C) by the end of the 21st century, relative to 1980-1990, with a best estimate of 3.2 to 7.2°F (1.8 to 4.0°C). The average rate of warming over each inhabited continent is very likely to be at least twice as large as that experienced during the 20th century (EPA 2007c and IPCC 2007a).

2.1.2.1. Impacts of Air and Temperature on Water Resources

Warmer air temperatures are expected to have several impacts on water resources including diminishing snow pack and increasing evaporation, which affects the seasonal availability of water (Field et al. 2007, p. 619).

A key impact of warmer air temperatures is warmer water temperatures. Some impacts of warmer water temperatures are: a shift in aquatic species distribution and population (Field et al. 2007, p. 631); "the rise in global temperature will tend to extend polewards the ranges of many invasive aquatic plants …" (IPCC 2008, p. 56); "higher stream temperatures affect fish access, survival and spawning (e.g., west coast salmon) (Field et al. 2007, p. 629); higher temperatures reduce dissolved oxygen levels, which can have an effect on aquatic life (EPA 2007h), and according to the IPCC, "warming is likely to extend and intensify summer thermal stratification, contributing to oxygen depletion" in lakes and reservoirs (Field et al. 2007, p. 629); increased concentrations of some pollutants (e.g., simulations in the Bay of Quinte in Lake Ontario indicated that 3 to 4°C (5.4 to 7.2° F) warmer water temperatures contribute 77 to 98 percent increases in summer phosphorus concentrations (Field et al. 2007, p. 629)); "higher surface water temperatures will promote algal blooms and increase the bacteria and fungi content", which "… may lead to a bad odor and taste in chlorinated drinking water and the occurrence of toxins" (Kundzewicz et al. 2007, p. 188). "Because warmer waters support more production of algae, many lakes may become more eutrophic due to increased temperature alone, even if nutrient supply from the watershed remains unchanged" (U.S. CCSP 2008, p. 142); and "actual evaporation over open water is projected to increase, e.g., over much of the ocean and lakes, with the spatial variations tending to relate to spatial variations in surface warming" (IPCC 2008, p. 29).

Some aquatic organisms are particularly sensitive to temperature. For example, the breeding cycle of many amphibians is closely related to temperature and moisture, and reproductive failure can occur when breeding phenology, periodic biological phenomena correlated with climate, and pond-drying conditions are misaligned (Field et al. 2007, p. 630). Further, many coral reefs are surviving at or close to their temperature tolerance levels, so rising sea surface temperatures are creating more hostile conditions for the corals (EPA 2007k). Saltwater and freshwater fisheries are also affected by climate change; in 2001, the IPCC stated that "projected climate changes have the potential to affect coastal and marine ecosystems, with impacts on the abundance and spatial distribution of species that are important to commercial and recreational fisheries" (Cohen et al. 2001, as referenced in Field et al. 2007, p. 620).

Further, "cold-water fisheries will likely be negatively affected by climate change; warm-water fisheries will generally gain; and the results for cool-water fisheries will be mixed, with gains in the northern and losses in the southern portions of ranges" (Field et al. 2007, p. 631). Although temperature increases may favor warm-water fishes, such as smallmouth bass, "changes in water supply and flow regimes seem likely to have negative effects" on these fishes (Field et al. 2007, p. 632).

2.1.2.2. Impacts of Air and Temperature on Water Programs

As air and water temperatures warm, water resource managers will likely face significant challenges. First, increased pollutant concentrations and lower dissolved oxygen levels will result in additional waterbodies not meeting water quality standards and, therefore, being listed as impaired waters requiring a Total Maximum Daily Load (TMDL). Secondly, increased growth of algae and microbes will affect drinking water quality. Thirdly, increased water use will put stress on water infrastructure and demands on the clean water and drinking water State Revolving Funds;

and finally, drinking water and wetlands managers will need to account for water losses due to increased evapotranspiration rates resulting from temperature increases.

2.1.3. Rainfall/Snowfall Levels and Distribution

According to the IPCC, an increase in the average global temperature is very likely to lead to changes in precipitation and atmospheric moisture because of changes in atmospheric circulation and increases in evaporation and water vapor (EPA 2007e). The effects of increases in temperature and radiative forcing, a measure of irradiation in the tropopause, "alter the hydrological cycle, especially characteristics of precipitation (amount, frequency, intensity, duration, type) and extremes" (Trenberth et al. 2007, p. 254).

Climate models suggest an increase in global average annual precipitation during the 21st century, although changes in precipitation will vary from region to region (IPCC 2007a, as found in EPA 2007e). Regional precipitation projections from climate models, however, must be considered with caution since their reliability at small spatial scales is limited (EPA 2007e).

2.1.3.1. Impacts of rainfall on Water Resources

Changing precipitation patterns are expected to have several impacts on water resources including: increased frequency and intensity of rainfall in some areas will produce more; pollution and erosion and sedimentation due to runoff (EPA 2007h); "water-borne diseases and degraded water quality are very likely to increase with more heavy precipitation" (IPCC 2008, p. 103); potential increases in heavy precipitation, with expanding impervious surfaces, could increase urban flood risks and create additional design challenges and costs for stormwater management" (Field et al. 2007, p. 633); flooding can affect water quality, as large volumes of water can transport contaminants into waterbodies and also overload storm and wastewater systems (EPA 2007h); in general, in areas where precipitation increases sufficiently, net water supplies may increase while in other areas where precipitation decreases, net water supplies may decrease (EPA 2007i); "increased occurrence of low flows will lead to decreased contaminant dilution capacity, and thus higher pollutant concentrations, including pathogens. In areas with overall decreased runoff (e.g., in many semiarid areas), water quality deterioration will be even worse" (IPCC 2008, p. 43); "a wide range of species and biomes could be affected by the projected changes in rainfall, soil moisture, surface water levels, and stream flow in North America during the coming decades. The lowering of lake and pond water levels, for example, can lead to reproductive failure in amphibians and fish, and differential responses among species can alter aquatic community composition and nutrient flows" (IPCC 2008, p. 104); changes in rainfall patterns and drought regimes can facilitate other types of ecosystem disturbances, including fire and biological invasion" (IPCC 2008, p. 104).

Some of the greatest potential impacts of climate change on estuaries may result from changes in physical mixing characteristics caused by changes in freshwater runoff....Changes in river discharges into shallow near-shore marine environments will lead to changes in turbidity, salinity, stratification, and nutrient availability" (IPCC 2008, p. 58); and "greater rainfall variability is likely to compromise wetlands through shifts in the timing, duration and depth of water levels" (IPCC 2008, p. 128).

Due in parts to their limited capacity for adaptation, wetlands are considered among the most vulnerable ecosystems to climate change (IPCC 2008, p. 56).
Although impact assessment studies often focus on negative consequences of changes in precipitation and flow, it is important to note that there are water quality benefits to increased precipitation (e.g. increased drinking water supply) and of decreased precipitation (e.g. reduced frequency of flooding).

2.1.3.2. Impacts of rainfall on Water Programs

Changing precipitation patterns pose several challenges for water program managers: increased rainfall can enhance surface and ground water supplies of drinking water; increased rainfall, especially more intense rainfall, will result in increased stormwater runoff and may make overflows of sanitary sewers and combined sewers more frequent, putting increased demands on discharge permit programs and nonpoint pollution control programs; increased stormwater runoff will wash sediment and other contaminants into drinking water sources, requiring additional treatment; additional investments in water infrastructure may be needed to manage both decreases in rainfall (e.g., expanded water supply retention facilities) and increases in rainfall (e.g., increases in pipe and stormwater management facilities), and these demands could strain water financing generally, including the State Revolving Funds; limited water availability and drought in some regions will require drinking water providers to reassess supply facility plans and consider alternative pricing, allocation, and water conservation options; in areas with less precipitation, demand for water may shift to underground aquifers and prompt water recycling and reuse, development of new reservoirs, or underground injection of treated water for storage; in areas with less precipitation, limited groundwater recharge combined with increasing use will have adverse impacts on stream flow and make meeting water quality goals more challenging; and increased incidence of wildfire as a result of reduced precipitation can reduce the amount of water retained on the land, increase soil erosion, increase water pollution, increase risk of flooding, and pose a threat to water infrastructure.

2.1.4. Storm Intensity

According to the IPCC, "the frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor" (IPCC 2007a, Working Group I Summary for Policymakers, p. 8). Further, "based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures" (IPCC 2007a, , p. 15).

2.1.4.1. Impacts of storm on Water Resources

The primary impacts of increasing storm intensity on water resources is coastal and inland flooding, complicated in the case of coastal storms by storm surges. Many of these impacts will vary regionally and can be influenced by other factors such as the level of development in the watershed. Some of the key water impacts of this flooding are the following: water quality changes may be observed in the future as a result of "water infrastructure malfunctioning during floods" (Kundzewicz et al. 2007, p. 189); and flood magnitudes and frequencies will very likely increase in most regions, mainly a result of increased precipitation intensity and variability, and increasing temperatures are expected to intensify the climate's hydrologic cycle and melt snowpacks more rapidly (IPCC 2007b, as found in EPA 2007h).

In addition to flooding, increased storm frequency and intensity may result in the following: Adverse effects in surface and ground water quality and contamination of water supply (IPCC 2007b, Working Group II Summary for Policymakers, p. 18); water quality changes may be observed in the future as a result of "overloading the capacity of water and wastewater treatment plants during extreme rainfall" (Kundzewicz et al. 2007, p. 189);"water-borne diseases will rise with increases in extreme rainfall" (Kundzewicz et al. 2007, p. 189); and "all studies on soil erosion have suggested that increased rainfall amounts and intensities will lead to greater rates of erosion unless protection measures are taken" (Kundzewicz et al. 2007, p. 189).

2.1.4.2. Impacts of storm on Water Programs

Water resource managers will face significant challenges as storm intensity increases: although there is some uncertainty with respect to climate models addressing storm intensity and frequency, emergency plans for drinking water and wastewater infrastructure need to recognize the possibility of increased risk of high flow and high velocity events due to intense storms as well as potential low flow periods; damage from intense storms may increase the demand for public infrastructure funding and may require reprioritizing of infrastructure projects; floodplains may expand along major rivers requiring relocation of some water infrastructure facilities and coordination with local planning efforts; in urban areas, stormwater collection and management systems may need to be redesigned to increase capacity; combined storm and sanitary sewer systems may need to be redesigned because an increase in storm event frequency and intensity can result in more combined sewer overflows causing increased pollutant and pathogen loading; greater use of biological monitoring and assessment techniques will help water resource managers assess system impacts of higher velocities from more intense storms and other climate change impacts; the demand for watershed management techniques that mitigate the impacts of intense storms and build resilience into water management through increased water retention (e.g., green roofs, smart growth) is likely to increase; and the management of wetlands for stormwater control purposes and to buffer the impacts of intense storms will be increasingly important.

2.1.5. Sea Level Rise

"Global mean sea level has been rising", according to the IPCC. "From 1961 to 2003, the average rate of sea level rise was 1.8 ± 0.5 mm per year. For the 20th century, the average rate was 1.7 ± 0.5 mm per year. There is high confidence that the rate of sea level rise has increased between the mid-19th and the mid-20th centuries" (Bindoff et al. 2007, p. 387). Further, "there are uncertainties in the estimates of the contributions to sea level change but understanding has significantly improved for recent periods (Bindoff et al. 2007, p. 387)." For example, "… for the period 1993 to 2003, … the contributions from thermal expansion (1.6 ± 0.5 mm per year) and loss of mass from glaciers, ice caps, and the Greenland and Antarctic Ice Sheets together give 2.8 ± 0.7 mm per year" (Bindoff et al. 2007, p. 387).

2.1.5.1. Impacts of sea level rise on Water Resources

The primary impact of sea level rise on water resources is the gradual inundation of natural systems and human infrastructure in coastal and estuarine areas. Inundation impacts include: wetland displacement (Burkett et al. 2001, p. 348); accelerated coastal erosion (Burkett et al. 2001, p. 345); water quality modifications may also be observed in the future as a result of stormwater drainage operation and sewage disposal disturbances in coastal areas due to sea level rise (Kundzewicz et al. 2007, p. 189); "low lying coastal areas such as deltas, coastal plains, and atoll islands are regarded as particularly vulnerable to small shifts in sea level" (Burkett et al. 2001, p. 348). "Coastal areas also include complex ecosystems such as coral reefs, mangrove forests, and salt marshes. In such environments, the impact of accelerated sea level rise will depend on vertical accretion rates and space for horizontal migration, which may be limited by the presence of infrastructure" (Burkett et al. 2001, p. 345); and sea level rise increases the vulnerability of coastal areas to flooding during storms (EPA 2007l).

Impacts of sea level rise other than inundation include: rising sea level increases the salinity of both surface water and ground water through salt water intrusion (EPA 2007l); if sea level rise pushes salty water upstream, then the existing water intakes might draw on salty water during dry periods (EPA 2007l); and salinity increases in estuaries can harm aquatic plants and animals that do not tolerate high salinity (EPA 2007l).

2.1.5.2. Impacts of sea level rise on Water Programs

Sea level rise will affect a range of water programs and pose significant challenges for water program managers. Firstly, emergency plans for drinking water and wastewater infrastructure need to recognize long-term projections for rising sea levels; secondly, drinking water systems will need to consider relocating facilities or intakes as sea levels rise and salt water intrudes into freshwater aquifers used for drinking water supply; thirdly, sewage treatment plants will need to consider relocation of some treatment facilities and discharge outfalls; and finally, watershed-level planning will need to incorporate an integrated approach to coastal management in light of sea level rise including land use planning, building codes, land acquisition and easements, shoreline protection structures (e.g., seawalls and channels), beach nourishment, wetlands management, underground injection to control salt water intrusion to fresh water supplies, and related programs.

2.1.6. Coastal/Ocean Characteristics

The IPCC states that the oceans are warming, ocean biogeochemistry is changing, and global mean sea level has been rising (Bindoff et al. 2007, p. 387). “The increase in atmospheric CO2 causes additional CO2 to dissolve in the ocean.… The increase in surface ocean CO2 has consequences for the chemical equilibrium of the ocean. As CO2 increases, surface waters become more acidic …; however, the response of marine organisms to ocean acidification is poorly known and could cause further changes in the marine carbon cycle with consequences that are difficult to estimate” (Bindoff et al. 2007, p. 403).

2.1.6.1. Impacts of coastal on Water Resources

Changes in ocean characteristics are expected to have several impacts on coastal and ocean resources including: “the biological production of corals, as well as calcifying photoplankton and zooplankton within the water column, may be inhibited or slowed down” as a result of ocean acidification (Denman et al. 2007, p. 529); “ecological changes due to expected ocean acidification may be severe for corals in tropical and cold waters … and for pelagic or oceanic ecosystems” (Denman et al. 2007, p. 529); “acidification can influence the marine food web at higher trophic levels” (Denman et al. 2007, p. 529); and salinity increases in estuaries can harm aquatic plants and animals that do not tolerate high salinity (EPA 2007l)

2.1.6.2. Impacts of coastal on Water Programs

Changes in ocean characteristics pose several challenges for water program managers including: watershed level protection programs may need to be revised to account for changes in natural systems as salinity and pH levels change; programs to protect coral reefs, including temperate and cold water corals, from land-based pollution and impacts may need to be reassessed to provide enhanced protection; and wetlands programs may need to be adjusted to account for changing salinity levels and impacts on wetlands health.

For coastal populations, water quality is likely to be affected by salinization, or increased quantities of salt in water supplies. This will result from a rise in sea levels, which will increase salt concentrations in groundwater and estuaries. Sea-level rise will not only extend areas of salinity, but will also decrease freshwater availability in coastal areas. Saline intrusion is also a result of increased demand due in part to growing coastal populations that leave groundwater reserves increasingly vulnerable to contamination and diminishing water reserves (IPCC 2007).

2.1.7. Changes in Energy Generation

Likely responses to climate change include development of alternative methods of energy production that reduce emissions of greenhouse gases and “sequester” carbon generated by energy production. Alternative methods of energy generation can have impacts on water resources, as can the sequestering of carbon from conventional energy generation processes.

2.1.7.1. Impacts of changes in Energy Generation on Water Resources

Regarding the geologic storage of carbon, according to the IPCC, "Groundwater can be affected both by CO_2 leaking directly into an aquifer and by brines that enter the aquifer as a result of being displaced by CO_2 during the injection process" (IPCC 2005, p. 31).
Another "… potential CO2storage option is to inject captured CO_2 directly into the deep ocean (at depths greater than 1,000 m), where most of it would be isolated from the atmosphere for centuries. This can be achieved by transporting CO_2 via pipelines or ships to an ocean storage site, where it is injected into the water column of the ocean or at the sea floor. The dissolved and dispersed CO_2 would subsequently become part of the global carbon cycle…. Ocean storage has not yet been deployed or demonstrated at a pilot scale, and is still in the research phase" (IPCC 2005, p. 34). IPCC also states that "experiments show that adding CO_2 can harm marine organisms" (IPCC 2005, p. 35) and that "studies are needed of the response of biological systems in the deep sea to added CO_2, including studies that are longer in duration and larger in scale than those that have been performed until now" (IPCC 2005, p. 45).

At the same time, sequestration of carbon in "biological" forms, (i.e., preserving forests, no-till agriculture, and related land management practices) may have water quality benefits by encouraging practices that reduce the amount of stormwater runoff and the pollution levels in the runoff. "Stopping or slowing deforestation and forest degradation (loss of carbon density) and sustainable forest management may significantly contribute to avoided emissions, conserve water resources and prevent flooding, reduce run-off, control erosion, reduce river siltation, and protect fisheries and investments in hydroelectric power facilities; and at the same time, preserve biodiversity" (Nabuurs et al. 2007, p. 574).
On the subject of agriculture, according to the IPCC, "a mix of horticulture with optimal crop rotations would promote carbon sequestration and could also improve agro-ecosystem function" (Smith et al. 2007, p. 521). Minimal tillage (reduced tillage) or without tillage (no-till) "… practices, which result in the maintenance of crop residues on the soil surface, thus avoiding water losses by evaporation, are now being used increasingly throughout the world.

Since soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion, reduced, or no-till agriculture often results in soil carbon gain, though not always. Adopting reduced- or no-till may also affect emissions of N_2O, but the net effects are inconsistent and not well quantified globally. Furthermore, no-tillage systems can reduce carbon dioxide emissions from energy use. Systems that retain crop residues also tend to increase soil carbon because these residues are the precursors for soil organic matter, the main store of carbon in soil" (IPCC 2008, p. 123).

However, "while the environmental benefits of tillage/residue management are clear, other impacts are less certain. Land restoration will have positive environmental impacts, but conversion of floodplains and wetlands to agriculture could hamper ecological function (reduced water recharge, bioremediation, nutrient cycling, etc.) and therefore, could have an adverse impact on sustainable development goals" (Smith et al. 2007, p. 522).

The IPCC Technical Paper on Climate Change and Water states that "…large-scale biofuel production raises questions on several issues including fertilizer and pesticide requirements, nutrient cycling, energy balance, biodiversity impacts, hydrology and erosion, conflicts with food production, and the level of financial subsidies required" (IPCC 2008, p. 66). The energy production and greenhouse gas mitigation potentials of dedicated energy crops depends on availability of land, which must also meet demands for food as well as for nature protection, sustainable management of soils and water reserves, and other sustainability criteria" (IPCC 2008, p. 117).

"Implementing important mitigation options such as afforestation, hydropower and bio-fuels may have positive and negative impacts on freshwater resources, depending on site-specific situations (IPCC 2008, p. 130).

2.1.7.2. Impacts of changes in Energy Generation on Water Programs

Changing energy generation methods poses several challenges for water program managers including: increased water use and withdrawals requiring expanded efforts to assure water supply availability; need for increased attention to potential nonpoint pollution impacts of expanded agricultural production; need for increased attention to discharge permit conditions to address increased temperature and concentration of pollutants due to low flows; increased interest in more efficient use of electrical energy at water facilities and production of power from methane at some wastewater treatment facilities; need for new capability to assess effects of ocean sequestration activities; and effective market-based practices that have water quality benefits could be a source of revenue for these practices.

2.2. Global warming

Global warming is defined as an increase in the average temperature of the Earth's atmosphere, especially a sustained increase great enough to cause changes in the global climate (Theodore C. Sorense, 2012).

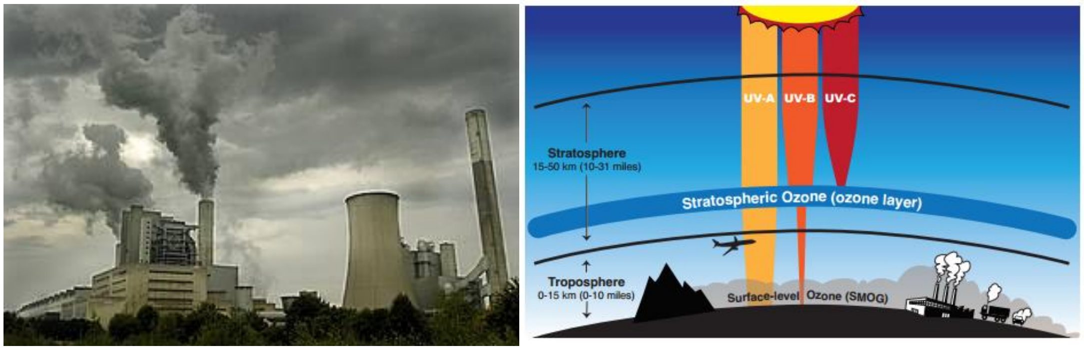
2.2.1. Greenhouse effect

Green House effect is the phenomenon whereby the earth's atmosphere traps solar radiation, and is mediated by the presence in the atmosphere of gases such as carbon dioxide, water vapor, and methane that allow incoming sunlight to pass through, but absorb the heat radiated back from the earth's surface. Thus the Greenhouse gases (GHGs) provide a blanketing effect in the lower strata of the earth’s atmosphere, and this blanketing effect is being enhanced because of the human activities like burning of fossil fuels etc (Theodore C. Sorense, 2012).

When fossil fuels coal, oil and natural gas are burnt they release CO_2 into the atmosphere. Because of this, the layer of greenhouse gas is getting thicker, which is in turn making the Earth warmer. Thus the ongoing unlimited burning of fossil fuels is the cause of climate change.

In terms of fuels, the main problem is coal. The other key reason is waste – inefficient use of energy. And in terms of industries, the main culprit is electricity production – the power industry.

Figure 3: The average coal-fired power plant wastes twice as much energy heating up the planet as it converts to useful electricity



Source: NASA's Earth Observatory: http://earthobservatory.nasa.gov

The biggest climate polluter is the global power sector which generates around 40% of all global electricity from coal.

According to the International Energy Agency the power sector is responsible for 37% of all man-made Carbon Dioxide (CO2) emissions. It creates about 23 billion tonnes of CO2 emissions per year, in excess of 700 tonnes a second. In turn, this CO2 continues to heat up our planet which poses an unprecedented threat to us and the environment (McCuen, Richard H, 1998).

2.2.2. Ozone

Ozone (O3) is a molecule made up of three atoms of oxygen (O), and is mostly found in the stratosphere, where it protects us from the Sun's harmful ultraviolet (UV) radiation. Although it represents only a tiny fraction of the atmosphere, ozone is crucial for life on Earth.

Ozone in the stratosphere: a layer of the atmosphere between 15 and 50 kilometers (10 and 31 miles) above us acts as a shield to protect Earth's surface from the sun's harmful ultraviolet radiation. Without ozone, the Sun's intense UV radiation would sterilize the Earth's surface. With a weakening of this shield, more intense UV-B and UV-A radiation exposure at the surface would lead to quicker sunburns, skin cancer, and even reduced crop yields in plants (http://ozonewatch.gsfc.nasa.gov).

2.3. Changes in Precipitation and Drought Patterns

Projections of changes in total annual precipitation indicate that increases are likely in the tropics and at high latitudes, while decreases are likely in the sub-tropics, especially along its poleward edge. Thus, latitudinal variation is likely to affect the distribution of water resources. In general, there has been a decrease in precipitation between 10°S and 30°N since the 1980s (IPCC 2007). With the population of these sub-tropical regions increasing, water resources are likely to become more stressed in these areas, especially as climate change intensifies.

While some areas will likely experience a decrease in precipitation, others (such as the tropics and high latitudes) are expected to see increasing amounts of precipitation. More precipitation will increase a region's susceptibility to a variety of factors, including:

- Flooding
- Rate of soil erosion
- Mass movement of land
- Soil moisture availability

These factors are likely to affect key economic components of the GDP such as agricultural productivity, land values, and an area's habitability (IPCC 2007). In addition, warming accelerates the rate of surface drying, leaving less water moving in near-surface layers of soil. Less soil moisture leads to reduced downward movement of water and so less replenishment of groundwater supplies (Nearing et al 2005). In locations where both precipitation and soil moisture decrease, land surface drying is magnified, and areas are left increasingly susceptible to reduced water supplies.

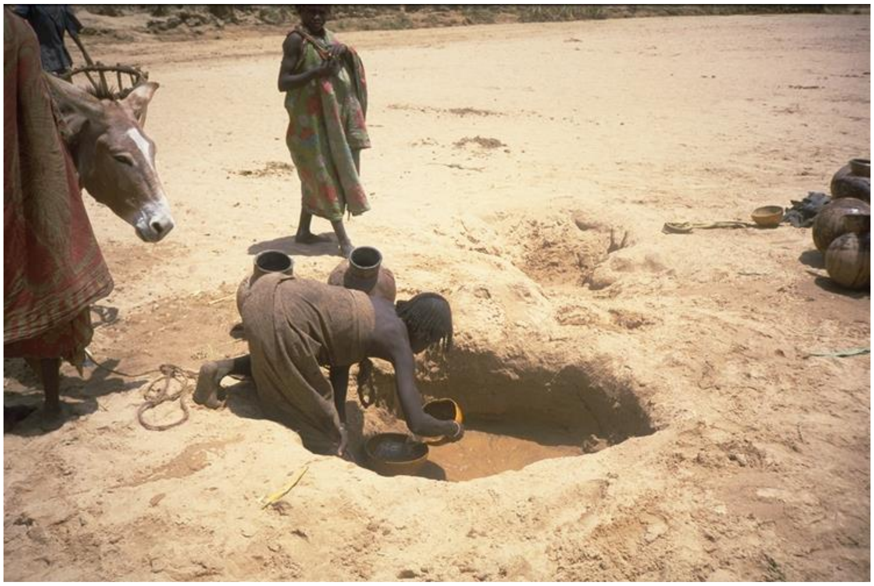
Although projecting how changed precipitation patterns will affect runoff is not yet a precise science, historical discharge records indicate it is likely that for each 1°C rise in temperature, global runoff will increase by 4%. Applying this projection to changes in evapotranspiration and precipitation leads to the conclusion that global runoff is likely to increase 7.8% globally by the end of the century (Oki and Kanae 2006). Thus, a region that experiences higher annual precipitation and more runoff increases the likelihood for flooding.

Furthermore, in areas that are already vulnerable due to their limited groundwater storage availability, this cycle intensifies with increased warming and diminishing water supplies. In water stressed regions, variability of precipitation patterns is likely to further reduce groundwater recharge ability. Water availability is likely to be further exacerbated by poor management, elevated water tables, overuse from increasing populations, and an increase in water demand primarily from increased agricultural production (IPCC 2007).

A recent global analysis of variations in the Palmer Drought Severity Index (PDSI) indicated that the area of land characterized as very dry has more than doubled since the 1970s, while the area of land characterized as very wet has slightly declined during the same time period. In certain susceptible regions, increased temperatures have already resulted in diminished water availability. Precipitations in both western Africa and southern Asia have decreased by 7.5% between 1900 and 2005 (Dai et al 2004).

Most of the major deserts in the world including the Namib, Kalahari, Australian, Thar, Arabian, Patagonian and North Saharan are likely to experience decreased amounts of precipitation and runoff with increased warming. In addition, both semiarid and arid areas are expected to experience a decrease and seasonal shift in flow patterns. If increased temperatures cause an intensification of the water cycle there will be more extreme variations in weather events, as droughts will become prolonged and floods will increase in force (Huntington 2005).

Figure 4: Shortage of water in desert



Source: Hygiene promotion Madam Schrustine, July 2015

When no rain or only a very small amount of rain falls, soils can dry out and plants can die. When rain fall is less than normal for several weeks, months, or years, the flow of streams and rivers declines, water levels in lakes and reservoirs fall, and the depth to water in wells increases. If dry weather persists and water supply problems develop, the dry period can become a drought.

The process of global warming has such an impact on the climate that it increases the severity of precipitation at one time, and minimizes it in the other. Therefore, this process has resulted in severe drought like conditions in India, with tens of millions of deaths resulting from it in the past few centuries. India depends heavily on prolonged and optimum monsoons for its agricultural productivity, failure of which results in the decreased crop productivity, leading to droughts. The World Record Of Drought Was In 2000 in Rajasthan, India (Theodore C. Sorensen, 2012).

Figure 5: People parched for water are ready to injure each other as they struggle to get water from a well in the drought affected areas of India.

Source: Global warming and its impacts on climate of India, 2000.

The beginning of a drought is difficult to determine. Several weeks, months, or even years may pass before people know that a drought is occurring. The end of a drought can occur as gradually as it began. Dry periods can last for 10 years or more. For example during the 1930's, most of the United States was much drier than normal. In California, the drought extended from 1928 to 1937. In Missouri, the drought lasted from 1930 to 1941. That extended dry period produced the "Dust Bowl" of the 1930's when dust storms destroyed crops and farms (Joe A. Moreland, 1993). The appendix 5 shows the impact of flood in India.

2.4. Flooding

Flooding is an expected and regular occurrence in many places, and in rural areas it may be welcomed as the floodwaters carry sediments that improve the fertility of the soil. Residents may use different terms to distinguish between beneficial and harmful floods. In urban areas, floods are less welcome. They often affect the poorer urban residents, who cannot afford to build in areas above flood level. Few (2003) includes a quote from IPCC (2001) that “squatter and other informal settlements with high population density, poor shelter, little or no access to resources such as safe water and public health services, and low adaptive capacity are highly vulnerable." Poorer residents also suffer more, because they have fewer resources to assist in dealing with floods.

Floods can be dangerous to humans, and can destroy houses including water and sanitation infrastructure, either by the force of the floodwaters or because materials are weakened when wet. Damage can be more severe when flooding is associated with strong winds.

Figure 6: Photo showing flooding in urban area Haiti

Source: Flooding, the Global WASH Cluster, Haiti in March, 2009

Various different circumstances may cause flooding, or increase the likelihood of serious flooding. Deforestation, construction in flood-prone areas, obstruction of drainage channels are a few examples of human activities that may contribute to severe flooding (Global WASH Cluster 2009). Harvey (2007) identifies three principal types of flood: rapid-onset, slow-onset and annual seasonal flooding

A very useful document published by the Active Learning Network for Accountability and Performance in Humanitarian Action (ALNAP) (Alam, 2008) provides a detailed review of key lessons learned from evaluations of emergency responses to flooding over a 20 year period. The study considered flooding in Africa, Asia and the Americas, but does not draw separate lessons for urban and rural floods. Some of the characteristics of urban flooding are identified, such as that natural resources may not be readily available in urban areas, and that people living in urban areas are often dependent on single sources of income for their livelihoods.

Participants attending the workshop in Haiti identified four categories of people who may be affected directly by urban floods:

- those who stay in their homes,

- those who relocate to official shelters,
- those who relocate to unofficial
- those who stay with host families.

Priority responses for those affected by urban flooding and Options for supplying water during floods (See appendix 1 and 2)

2.4.1. Rainfall return period

Most people have heard the terms, 100 year flood, 50 year storm, or 200 year flood, as a description of the magnitude of a storm or flood. We understand that the larger the number before 'year flood', the greater will be the effect on river levels and on anything out on the river's flood plain. Also, we understand from the words '100 year flood' that it has a flood return period of 100 years, or in other words, it should only happen every 100 years on the average, but questions remaining are 'Could a 100 year flood occur the next year after one has just occurred?' and 'What is the likelihood of its occurring within any given time period?'

Frequency Analysis provides a systematic approach for using historical data to relate the magnitude of a naturally occurring event (e.g. river levels at 5 ft above flood stage) to the probability of its occurring in a given time period or to its recurrence interval (McCuen, Richard H., 1998).

2.4.2. Diarrhea disease

Water and Sanitation and Their Effects on Diarrheal Illnesses

Diarrhea can cause severe dehydration and poor absorption of nutrients, which in turn make affected individuals more susceptible to infectious diseases. Diarrhea in early childhood is associated with impaired growth, physical fitness, and cognitive development, which can lead to diminished future school performance and lower economic earning power. Severe diarrhea that is not cared for appropriately can also lead to death. Safe drinking water and improved sanitation play a significant role in reducing the risk of diarrheal diseases.

Unimproved water sources are vulnerable to contamination and are a major source of disease transmission; unimproved sanitation is a major source of contamination for clean water sources. According to WHO, diarrhea morbidity could decrease by 32 percent with improved sanitation such as pit latrines, septic tanks, and composting toilets; and by 6 percent to 25 percent with improved water supply such as protected dug wells, public taps, and tube wells.

Climate Change and Its Effects on Diarrheal Illnesses

Climate encompasses the weather patterns in a geographic area over long periods of time, typically measured in years, whereas weather consists of the fluctuations in the atmosphere, like temperature, precipitation, and wind, over a period of hours or days. Between 1970 and 1999, 30 natural disasters involved hurricanes, floods, droughts, or tsunamis, all of which potentially contribute to increases in waterborne illnesses from their varied effects. Jonathan Patz’s conjecture that "human impacts occur when climate hazards and population vulnerability converge" Furthermore, increased weather extremes are one consequence forecasted to follow from climate changes predicted by the Intergovernmental Panel on Climate Change.

In addition, the creation of safe water sources and effective sanitation systems does not guarantee protection from contamination or destruction from natural disasters. UNICEF calculated that in LAC "between 1994 and 2003 the economic losses in water and sanitation were about $650 million, as a result of at least 2,100 urban systems damaged, 4,500 rural aqueducts affected, and 28,000 wells and 173,000 latrines destroyed" due to natural disasters including floods, hurricanes, and earthquakes. These figures illustrate the impact of natural disasters on established water systems. Extend these figures to include the impact on unimproved water and sanitation sources, such as a community that gets its water from surface sources and the effects on health are even more distressing. These factors are reflected in Table (Appendix 3), which displays the physical and economic damages to water and sanitation systems in LAC as a result of Hurricane Mitch in 1998.

During floods especially those related to El-Niño events, environmental diseases such as typhoid, amoeba, cholera and bilharzia normally associated with contaminated water and poor sanitation reach epidemic levels in such places (National Climate Change Response Strategy. KENYA, April, 2010).

Figure 7: Submerged huts in Western Kenya

Source: Floods caused by El-Niño events, 2006

2.5. Water, Sanitation and Hygiene (WASH)

Key preparedness and response lessons identified by Alam (2008) specifically for „Water, sanitation and health ‟are:

- "Good understanding of water and sanitation conditions, disease surveillance, speedy response to warning and above all, preparedness of health agencies are the preconditions to reduce the spread of diseases and preserve the quality of the environment during and after flooding."
- "Initiatives to improve water supply or water systems should incorporate long-term sustainability." "Water and sanitation interventions need to be locally appropriate and take into consideration possible problems regarding the availability of water, local perceptions regarding water quality and purity, testing water purity regularly and prevalent sanitation practices and needs."
- "Water-borne diseases are preventable through provision of clean water and sanitation."

2.5.1. Water quality

Freshwater bodies have a limited capacity to process the pollution stemming from expanding urban, industrial and agricultural uses. Water quality degradation can be a major source of water scarcity.
Although the IPCC projects that an increase in average temperatures of several degrees as a result of climate change will lead to an increase in average global precipitation over the course of the 21st century, this amount does not necessarily relate to an increase in the amount of potable water available.

A decline in water quality can result from the increase in runoff and precipitation- and while the water will carry higher levels of nutrients, it will also contain more pathogens and pollutants. These contaminants were originally stored in the groundwater reserves but the increase in precipitation will flush them out in the discharged water (IPCC 2007).

Similarly, when drought conditions persist and groundwater reserves are depleted, the residual water that remains is often of inferior quality. This is a result of the leakage of saline or contaminated water from the land surface, the confining layers, or the adjacent water bodies that have highly concentrated quantities of contaminants. This occurs because decreased precipitation and runoff results in a concentration of pollution in the water, which leads to an increased load of microbes in waterways and drinking-water reservoirs (IPCC 2007).

One of the most significant sources of water degradation results from an increase in water temperature. The increase in water temperatures can lead to a bloom in microbial populations, which can have a negative impact on human health. Additionally, the rise in water temperature can adversely affect different inhabitants of the ecosystem due to a species' sensitivity to temperature. The health of a body of water, such as a river, is dependent upon its ability to effectively self-purify through biodegradation, which is hindered when there is a reduced amount of dissolved oxygen. This occurs when water warms and its ability to hold oxygen decreases. Consequently, when precipitation events do occur, the contaminants are flushed into waterways and drinking reservoirs, leading to significant health implications (IPCC 2007).

2.5.2. Water supply

Water commonly is not present at the locations and times where and when it is most needed. As a result, engineering works of all sizes have been constructed to distribute water from places of abundance to places of need. Regardless of the scale of the water supply system, development of either ground water or surface water can eventually affect the other. For example, whether the source of irrigation water is ground water or surface water, return flows from irrigated fields will eventually reach surface water either through ditches or through groundwater discharge.

Building dams to store surface water or diverting water from a stream changes the hydraulic connection and the hydraulic gradient between that body of surface water and the adjacent ground water, which in turn results in gains or losses of ground water. In some landscapes, development of ground water at even a great distance from surface water can reduce the amount of ground-water inflow to surface water or cause surface water to recharge ground water.

The hydrologic system is complex, from the climate system that drives it, to the earth materials that the water flows across and through, to the modifications of the system by human activities. Much research and engineering has been devoted to the development of water resources for water supply. However, most past work has concentrated on either surface water or ground water without much concern about their interrelations. The need to understand better how development of one water resource affects the other is universal and will surely increase as development intensifies (Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley, 1998).

Figure 8: A standpipe installation supplying about 1000 inhabitants

Source: McCluskey, 2001 (Global WASH Cluster 2009)

Potential impacts of climate change on WASH service delivery

According to the World Health Organization (WHO) and UNICEF Joint Monitoring Programme, the state of water-supply and sanitation services worldwide is a source of concern in several respects (WHO-UNICEF, 2009). Globally, 1 billion people are currently without access to improved water supply and 2.6 billion have no form of improved sanitation services. Most of these people live in Asia and Africa. In Africa, for example, 2 out of 5 people lack an improved water supply

Significant disparities exist between rural and urban services, which continue to contribute to the burden of life in rural areas. People who live in the informal, overcrowded per urban settlements spawned by urbanization, also have especially low coverage. Increasingly, surface and groundwater sources are being polluted by pesticides, and by industry and untreated household waste water. The over extraction of water for agriculture and manufacturing, which causes the water table to decline, is another bad practice, which threatens the sustainability of these resources in many parts of the world.

Placing the potential impacts of climate change within this undeniable context supports the argument that climate change has not been a major contributory factor to the unacceptable WASH service levels that currently exist in many parts of the world. The fundamental causes of current WASH sector challenges are more closely linked to factors that include: poor governance, lack of capacity, urbanization, increasing population, increasing competition for limited safe water resources, lack of accountability and insufficient expenditure on, for example, O&M.

2.5.3. Sanitation

During flooding, Harvey (2007) says that local people may be able to identify solutions that are more creative and cheaper than solutions proposed by NGOs; and that "to ensure an environment free from faecal contamination, three main areas must be addressed:

1. promotion of good excreta disposal practices by the affected population through the involvement of the community in the design and siting of the latrines;
2. prevention of overflowing of raw sewage from pits and septic tanks during flooding which would result in a very serious environmental health hazard; and
3. Provision of adequate excreta disposal facilities for displaced people during flooding."

Various practical and cultural difficulties experienced during urban Women and girls also threw menstrual cloths into the flood water, or washed them in dirty water. Some women went together to use latrines located on higher ground, but were embarrassed at having to use latrines in the presence of men whom they did not know, and feeling inappropriately dressed in wet saris that clung to their bodies. Not everyone was able to obtain free safe water, or to afford safe water where it was sold. Some therefore drank the dirty floodwater floods in Dhaka are identified by Rashid (2000). Those most severely affected were women living in poor areas. Basic sanitation was not readily available; so many women urinated or defecated in their homes, wrapped faeces in paper or plastic bags, and threw them into the flood waters.

WASH professionals emphasize the importance of water supply and sanitation during floods, but a paper by Rashid et al. (2007) provides a ranking of the perceived adverse impacts of flooding, illustrating the importance of WASH interventions for those affected by floods in Dhaka, Bangladesh. Waterborne diseases are ranked third, contamination of water by sewage and wastes is ranked fourth, and contamination of drinking water is ranked sixth. Respondents in the two districts surveyed relied on tube-wells and municipal taps as their sources of drinking water. The major perceived adverse impacts, and their rankings, are:

i. Damaged property/house
ii. Undesirable odours
iii. Water-borne diseases
iv. Contamination of water by sewage and wastes
v. Mosquito infestation
vi. Contamination of drinking water
vii. Stagnant water in depressions
viii. Growth of aquatic weeds.

A paper by Few (2003) considers both the positive and negative impacts of flooding. Floods may provide increased work opportunities for labourers. Negative impacts include increased risk to health from waterborne pathogens, insect-borne infections and snakebite. The paper also draws attention to the potential negative health effects of flooding in the longer term: mental health impacts resulting from stress, and effects of malnutrition resulting from disruption to food supplies and incomes.

CHAPITER III: ANALYSIS AND DISCUSSION

Based on differences impact of climate change in WASH as it was seen in different areas all over the world, and due to some examples seen in some countries, it seems that climate change has a very big impact in WASH Sector. In this dissertation, as Water, Sanitation and Hygiene (WASH) is like a system which cannot be separated; when the climate is changing, it cause a great impact to WASH like damage of water supply system, pollution of surface and ground water, shortage of water and others. In that, during the implementation of WASH the impact of climate change must be taken into consideration. The analysis and discussions are being outlined below based on some of the important cases which happen on the earth, and which cause positive or negative impact of climate change in WASH.

3.1. Global warming and WASH

The concentration of gases, such as carbon dioxide (CO2) and methane, in the atmosphere has a significant effect on the heat budget of the Earth's surface and the lower atmosphere. The increase in concentration of CO2 in the atmosphere of about 25 percent since the late 1700s generally is thought to be caused by the increase in burning of fossil fuels. At present, the analysis and prediction of "global warming" and its possible effects on the hydrologic cycle can be described only with great uncertainty. Although the physical behavior of CO2 and other greenhouse gases is well understood, climate systems are exceedingly complex, and long-term changes in climate are embedded in the natural variability of the present global climate regime.

Shallow aquifers, which supply much of the stream flow nationwide and which contribute flow to lakes, wetlands, and estuaries, are the aquifers most sensitive to seasonal and longer term climatic variation. As a result, the interaction of ground water and surface water also will be sensitive to variability of climate or to changes in climate (See appendix 6). However, little attention has been directed at determining the effects of climate change on shallow aquifers and their interaction with surface water, or on planning how this combined resource will be managed if climate changes significantly (Thomas C. et al. 1998).

Linking this global warming to WASH, it is understandable that global warming causes the variation of surface water and ground water which are the main sources of water supply and hygiene promotion. It means that global warming causes the reduction of ground water table and dries wells and borehole installed in some different areas to allow population to have access to potable water.

The practice of WASH goes with different parameters like food security, shelter, culture and others which help the activities to be well implemented. But as the climate change due to global warming has negative impact on ecosystem, here we can say the disappearance of forest, reduction of crop production, reduction of animal production and the death of the human being who can't resist on heat. These also lead to the displacement of people, lack of food which cause malnutrition and other related diseases; and all of these become a big challenge to WASH activities.

3.2. Impact of Rainfall / Storm in WASH

As mentioned earlier, the rainfall return period is 50 years, 100 years or 200 years, by linking this with water cycle (see appendix 6), in this regard, there is the need for a drainage channel to be constructed and maintained so as to accommodate the heavy run-off water. However, this is not always the case as seen in the Zogona gully passing through University of Ouagadougou (see figure 9 and 10) which shows the grass growing in gully and stagnant water mixed by lots of sediments and shows that the real level of this gully has reduced. Considering also the figure 11 which shows the damage of the embankment of a gully due to water deviated from nearby household; all of those situation show us that when there is a rainfall return period or storm, it can cause a big disaster which can destroy roads, houses, latrines, water supply connection, dams burst, surface and ground water pollution, human and animal deaths and other related consequences. When this disaster happens, it causes a negative impact to the implementation of WASH. So, "Prevention is better than cure".

Figure 9: Grass growing, water stagnation and sediments in gully of Zogona, 2015

Source: Photo gully taken October 29, 2015

Figure 10: Water stagnation mixed by lots of sediments in Zogona gully, 2015

Source: Photo of gully taken October 29, 2015

Figure 11: Damage of embankment of gully due to water from nearby household, 2015

Source: Photo of gully taken October 29, 2015

3.3. Impact of drought in WASH

Drought is a period of drier than normal conditions that results in water related problems. If dry weather persists and water supply problems develop, the dry period can become a drought (Joe A. Moreland, 1993). In the period of drought the Water, Sanitation and Hygiene (WASH) implementation activities are highly affected. The following are discussion on the issue.

When there is a drought in region, a high number of populations are displaced in mass from their local place to another place to look if they can find water. Everywhere they pass, they do open defecation due to lack of sufficient latrines. In that case, due to lack of water in that place, that open defecation causes to them the disease like diarrhea, cholera and other diseases which lead to death. And some of the displaced people dies from thirst and hunger; where the most vulnerable are old men, pregnant women and the children under five years old.

Figure 4 shows the people who need water to feed themselves and their cattle. But due to lack of water the practice of hygiene is very poor. Looking well to the picture, the created well is not protected; it means that during rainfall, water can wash out all excreta defecated openly and other refuses into the well. This well shows also the land sliding into water, woman who is fetching water is inside the well putting her foot inside water before drawing it, and all of those lead to water pollution. As water is seems to be untreated, even the drawer is contaminating water before getting it. Those people can get diseases caused by climate change.

Taking the example of drought in India (see figure 5), People parched for water are ready to injure each other as they struggle to get water from a well in the drought affected areas. Relating this to hygiene promotion, in hygiene promotion practice, before fetching water, it is better to clean a container properly and fetch water in the well without any contamination to well water, and after getting water, it is advised to cover the container with clean cover and properly. But looking very well to the above figure 5, it seems that every one didn't find water anywhere to clean they container, and are all struggling putting their container at once in the well. As the containers are dirty, arriving in the well, the containers pollute well water and during the use of that water, they are also going to be contaminated. This is the real proof of the negative impact of climate change in WASH.

3.4. Impact of flood in WASH

Taking the example of figure 6 showing flood in Haiti and figure 7 showing flooding in Kenya as mentioned earlier, it seems that flooding can cause big problem in the area where it happened.

Quoted to IPCC (2001) saying that Flooding is an expected and regular occurrence in many places, and in rural areas it may be welcomed as the floodwaters carry sediments that improve the fertility of the soil. According to this, the sediments carried by flood water are used in field as fertilizers and the population who use these sediments as fertilizers, one way, they see it is as opportunity to them, but in another way it is not because it creates other problems related to the sediments washed out by flood water. Some of those sediments are there to create another soil layer where it is dumped, it can also cause soil scaring in the way where water come from and create big disordered gully, which in its turn it will cause land sliding, soil erosion, human and animal death. And also in the way coming, the flood water brought the cultivable soil from the upper party which in turn will cause a famine in that area.

Relating this to WASH Sector, the sediments dumped by flood water will cause a negative impact in the region where it is dumped. In that include: increasing of aquifer depth, burying water pipe network system, Surface water polluted by human and animal dead bodies and also feces or dungs defecated openly in the way where water has come from. All of those issues cause a reduction of water sources and water quality which affect the implementation of WASH. However, the practice of Water sanitation and Hygiene (WASH) needs the source of water, either surface or ground water, to distribute to the vulnerable people; it needs also sanitation (Latrines, Septic tank) to prevent open defecation and the hygiene of the population is needed in order to have safe life and sustainable. But because of that situation created by flood water, they will need to supply water from other region, which will be very expensive. Figure 8 shows standpipe installation supplying about 1000 inhabitants which cost more after flooding disaster.

“Floods can be dangerous to humans, and can destroy houses including water and sanitation infrastructure, either by the force of the floodwaters or because materials are weakened when wet. Damage can be more severe when flooding is associated with strong winds” (IPCC, 2001).

According to the above paragraph, the flood is frequently happens in some different area of the earth. The figure 6 shows flood problem in urban area and the figure 7 shows the flooding problem in rural area. Starting by figure 6, the left picture shows the flooding in household Which gives the image that everything are mixed with dirty water, even inside the house water is there, the sanitation infrastructure has been damaged and being mixed by flood water, it means that the cooking materials, the food inside house, beds, clothes and other household materials all are mixed with polluted water.

The right figure shows the flood water in urban settlement where there is a high risk for the people to lose their life, house collapsing, road infrastructure damage. If this flood last long time and the water sources are damaged, the vulnerable people will prefer to use that flood water for cooking, drinking, wash clothes and feeding their cattle. In that case, this situation will bring negative impact to the vulnerable population like diarrhea disease, cholera and other water borne disease. This situation becomes also a big challenge to WASH implementers, because the area is inaccessible. The practice of hygiene is difficult due to lack of water quality in the flooded area.

The following are various practical and cultural difficulties experienced during urban floods in Dhaka identified by Rashid (2000). Those most severely affected were women living in poor areas.

Basic sanitation was not readily available; so many women urinated or defecated in their homes, wrapped faeces in paper or plastic bags, and threw them into the flood waters. Women and girls also threw menstrual cloths into the flood water, or washed them in dirty water. Some women went together to use latrines located on higher ground, but were embarrassed at having to use latrines in the presence of men whom they did not know, and feeling inappropriately dressed in wet saris that clung to their bodies. Not everyone was able to obtain free safe water, or to afford safe water where it was sold. Some therefore drank the dirty floodwater.

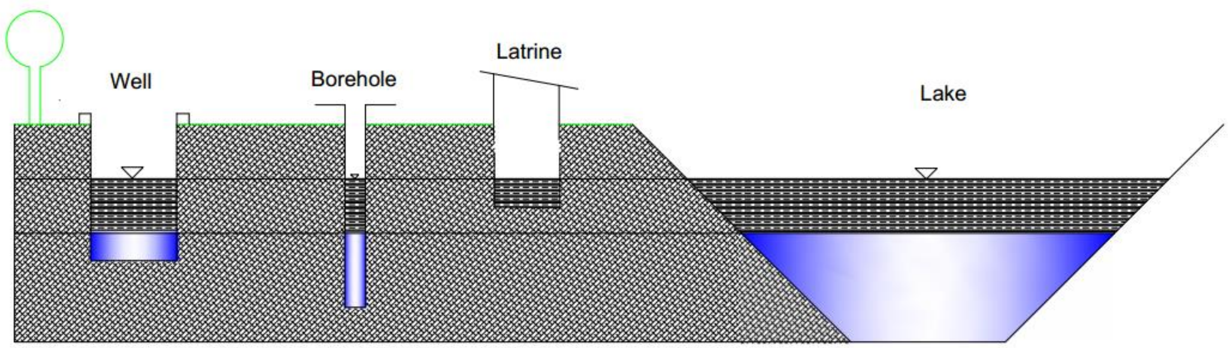
During floods especially those related to El-Niño events, environmental diseases such as typhoid, amoeba, cholera and bilharzia normally associated with contaminated water and poor sanitation reach epidemic levels in such places (National Climate Change Response Strategy. KENYA, April, 2010).

The above paragraph explains clearly the risk caused by flood in rural areas, and as it is seen in figure 7, it is clear that there, the population have displaced from the flood area to other place. And when the people are displaced in mass from their local area to another, they meat different problems like lack of food, potable water and latrines which lead them to bad practice of the hygiene. This situation provoke them to do open defecation and use dirty water for cooking, drinking and washing their clothes which make them sick from the disease cited earlier.

3.5. Surface and ground water recharge and its pollution in relation to WASH

Impacts of sea level rise other than flooding include: rising sea level increases the salinity of both surface water and ground water through salt water intrusion (EPA 2007l); if sea level rise pushes salty water upstream, then the existing water intakes might draw on salty water during dry periods (EPA 2007); and salinity increases in estuaries can harm aquatic plants and animals that do not tolerate high salinity (EPA 2007). Water commonly is not present at the locations and times where and when it is most needed. As a result, to distribute water from places of abundance to places of need. Regardless of the scale of the water supply system, development of either ground water or surface water can eventually affect the other (Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley, 1998).

Figure 12: Ground water pollution due the aquifer rise



Source: Design of ground water pollution

If we link the previous paragraph by sea level rise caused by snow melt or other circumstances and considering the recharge of ground water from surface water or vice versa; the bad or good development of either ground water or surface water can eventually affect the other.

To proof this phenomenon, let us consider the Sketch in figure 12. This sketch is designed in form where ground water aquifer is charged by surface water. In WASH, during the implementation and installation of water supply and sanitation infrastructures; ground water aquifer is taken into consideration before the installation. The sketch illustrates that there are the area where there are borehole, well and latrine constructed and equipped. And during the installation of each well, borehole and latrine, the standards norms were respected referring to water table. The sketch is showing the impact of huge surface water level rise due to sudden climate change; and that caused tremendous rise of underground aquifer level.

As is it is appearing on the appendix 8, the initial surface water level has raised and charged the aquifer, aquifer level increased and reached the bottom of latrine, after that water is contaminated by excreta (feces) and continue to pollute water in borehole and water in wells. In that case, as people use to come to fetch water on those both sources borehole and well, and they are immediately contaminated through that polluted water. It means that climate change has either positive or negative impact in WASH.

5.6. Hygiene Promotion

Hygiene promotion is seen as an optional add on to a programme and a limited understanding of the term means that it is seen only as the dissemination of messages about hand washing. Hygiene promotion should ensure the optimal use, care and maintenance of water and sanitation facilities and can also be a mechanism to involve affected populations in the design and delivery of an effective and appropriate response.

Hygiene promotion approaches used during the dialogue with the affected population together with the hardware aspects of the response; It is an important thing which helps to motivated them and making them participating in each hygiene promotion activities. Demonstrating cultural sensitivity and providing responses that demonstrate awareness of social and cultural beliefs and practices. The most vulnerable people in communities are at greatest risk from floods. Priority should be given to vulnerable groups, in terms of both responses to flooding and Disaster Risk Reduction activities (Global WASH Cluster 2009).

As outlined above, the hygiene promotion is a long process which can consider different parameters in order to be very successful. Some of the essential things to be considered when doing hygiene promotion are: participatory of beneficiaries, availability of water source, availability of excreta disposal system and availability of hygiene kits. When climate change causes a hazard or disaster and disturbs or destroys one of the hygiene promotion chains component; the implementation of hygiene becomes difficult and the population is more vulnerable.

Figure 13: Hand washing installation

Source: UNICEF WASH Annual report, 2013

CHAPITER IV: CONCLUSION AND RECOMMENDATION

4.1. CONCLUSION

Water, Sanitation and Hygiene (WASH) to the sentence "the Earth's climate has never been completely static and in the past the planet's climate has changed due to natural causes" (WYI, 2014), we can conclude that even in the future, the earth's climate will never be completely static.

This dissertation has outlined lots of problems caused by climate change and its effect to WASH like Global warming, air pollution, drought, flooding and deforestation. As water is one of the main part of WASH, the problem of water pollution or shortage of water either surface water or ground water which is the primarily need during WASH implementation; based on that, the problem will lead to the greater impact in WASH. Flood causes a death to human and animals and bring different disease related to water like Diarrhea, Cholera, Malaria and others. As seen in this dissertation the vulnerable people are obliged to use dirty water to fulfill their needs and these bring to them negative impact created by climate change. Drought brings the problem of lack of water due to increase in depth of ground water aquifer, reduction of surface water and soil compaction. This situation leads to the displacement of population and provoke uncontrollable open defecation which will be washed out during flood time and pollute water. The impacts of water and sanitation on diarrheal disease and the actions needed to minimize this impact are well known. Less well known are the potential human health effects of climate change.

Finally, in ecosystem, when one sector is not in normal condition or is missing, it affects others (see appendix 6). In that, comparing the all things affected by climate change and the necessary to WASH implementation, we conclude that climate change has an impact in WASH.

4.2. RECOMMENDATIONS

We are addressing our recommendations for:

- Policymakers to emphasize the capacity building for citizens participatory on awareness of climate change and its impact.
- The destruction of a water or sanitation system in the wake of a natural disaster is unfortunate, governments can use such failures as models to test and design new ideas for improved systems that might resist damage or contamination.
- WASH to consider different parameters like rainfall return period, and be sure that the drainage channel are well maintained in order to drain water during flooding, so that the infrastructures like latrines, borehole and wells can sustain.
- Policymakers concerned with the impacts on diarrheal diseases from meteorological changes should focus surveillance and monitoring, and infrastructure and development.

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APPENDIXES

Appendix 1: Options for supplying water during floods

Options for supplying water during floods	Where the option might be appropriate/used	Advantages	Disadvantages
For those Living in the Flooded Area			
Boiling	Often promoted, but not usually realistic.	Can provide acceptable quality of drinking water.	Requires fuel which may be unavailable or expensive; can be easily recontaminated when stored.
Bleaching Powder	On a household level; either distributed, or used with instructions for purchased chlorine; can be locally prepositioned for	Usually easily available in country; safe active % of chlorine.	Difficulties for users in understanding instructions; different products of different active % available; often unreliable potency and
Water purifying tablets	Distribution for household level use.	Set amount of chlorine for a set amount of water; can be locally pre-positioned in predictable flooding.	Varying strengths with same sizes of tablet can cause confusion; because they have to be able to cope with the highest chlorine demands, they can leave a strong smell and taste.
Chloro-flocculants sachets	Distribution for household use where waters are turbid and chlorination is either not completely effective or acceptable to the user.	Can produce clear water which has a residual chlorine level; ensures effective disinfection of turbid waters; can be locally pre-positioned in predictable flooding.	More expensive; can suffer from same disadvantages as water purifying tablets.
Transport of chlorinated water in sealed plastic bags	Transported and distributed to affected amilies; Half volume of water half air to ensure	Gets some clean water to families where there are few options.	High logistics demand and cost; bags can be perforated; difficult to store in the house.
Raising level of tubewell above water level (pre/post flood)	Where regular floods with predictable water levels.	Allows access all year round to existing protected water sources; can be very cost effective; can be a preparedness mechanism done at	Need to ensure access during floods (eg near building); can"t cope with unpredictable bigger floods.
For those Displaced by Floods			
Access to free water from existing paid-for sources	Where free or maintenance-cost only water sources are unavailable due to flooding (usually the choice of the poor).	Gives access to clean water for all; can increase availability of water; can be useful in urban settings.	Difficult to target the poor, requires blanket access; using existing suppliers of water (eg tanker suppliers) will not always increase the total availability of water. *Oxfam Public Health Assessment of Floods, Haiti, November 2000, unpublished*
Provision of protected water supplies at special shelters on high ground	Sites or specially designated „flood shelters" can serve large numbers of families for extended periods of time.	Provides clean water for the displaced in the area in which they are sheltered. Water is nearby and boats are not needed for collecting water.	Space is often limited in such shelters; sanitary seals are therefore important; shelters are often located in areas which will not be used at other times of the year - maintenance can therefore be a problem.

Source: Global WASH Cluster, UNICEF New York, 3 UN Plaza, New York, USA, 2009

Appendix 2: Priority responses for those affected by urban flooding

Those who stay in their homes	Those who relocate to official shelters	Those who relocate to unofficial shelters	Those who stay with host families
Arrange distribution of safe water during the flood phase (from regular distribution system, rainwater collection or compact water treatment unit). Provide safe excreta disposal. Arrange distribution of appropriate NFIs. Provide water quality testing services, or advice and information on water quality. Communicate appropriate hygiene messages to those remaining in their homes based on ongoing dialogue to understand barriers to change and feasible actions. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)	Arrange distribution of adequate quantities of safe water. Provide or procure additional latrines with handwashing facilities and ensure care and maintenance. Encourage local people to assist with clearing debris, possibly under cash for work programmes, as part of hygiene promotion response. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea. Rehabilitate infrastructure, including electromechanical plant, as soon as possible.	Provide emergency/ temporary water supplies, and emergency/temporary sanitation (chemical toilets, for example.) but without permanent infrastructure. Provide containers for water storage. Provide advocacy assistance to obtain permissions for people to remain in unofficial locations. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea.	Arrange distribution of adequate quantities of safe water, with increased supplies to meet additional demands. Identify host families, and provide assistance to both hosts and guests, to encourage people to continue staying. Arrange distribution of essential and appropriate NFIs Ensure those affected are aware of how to reduce hygiene risks. Provide additional, tools, materials and support to host families for water supply and sanitation (e.g. containers for storage of water). Provide tools and facilities for collection of flood debris and household wastes. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)

Appendix 3: Summary of Damage to Water and Sanitation Systems Caused by Hurricane Mitch (October 1998)

Country	**Damage to water and sanitation systems damages (US$)**
Honduras	90% or more of population without access to water service in early November; 40% without access by late November $58.0 million
Nicaragua	32% of water service infrastructure damaged $19.8 million
Guatemala	396 communities with damaged systems; 20,000 latrines destroyed $16.1 million
El Salvador	32% of water service infrastructure damaged $2.4 million

Source: Pan American Health Organization, Emergencies and Disasters in Drinking Water Supply and Sewerage Systems: (Washington, DC: PAHO, 2002).

Appendix 4: The effect of storm in the desert leading to disaster

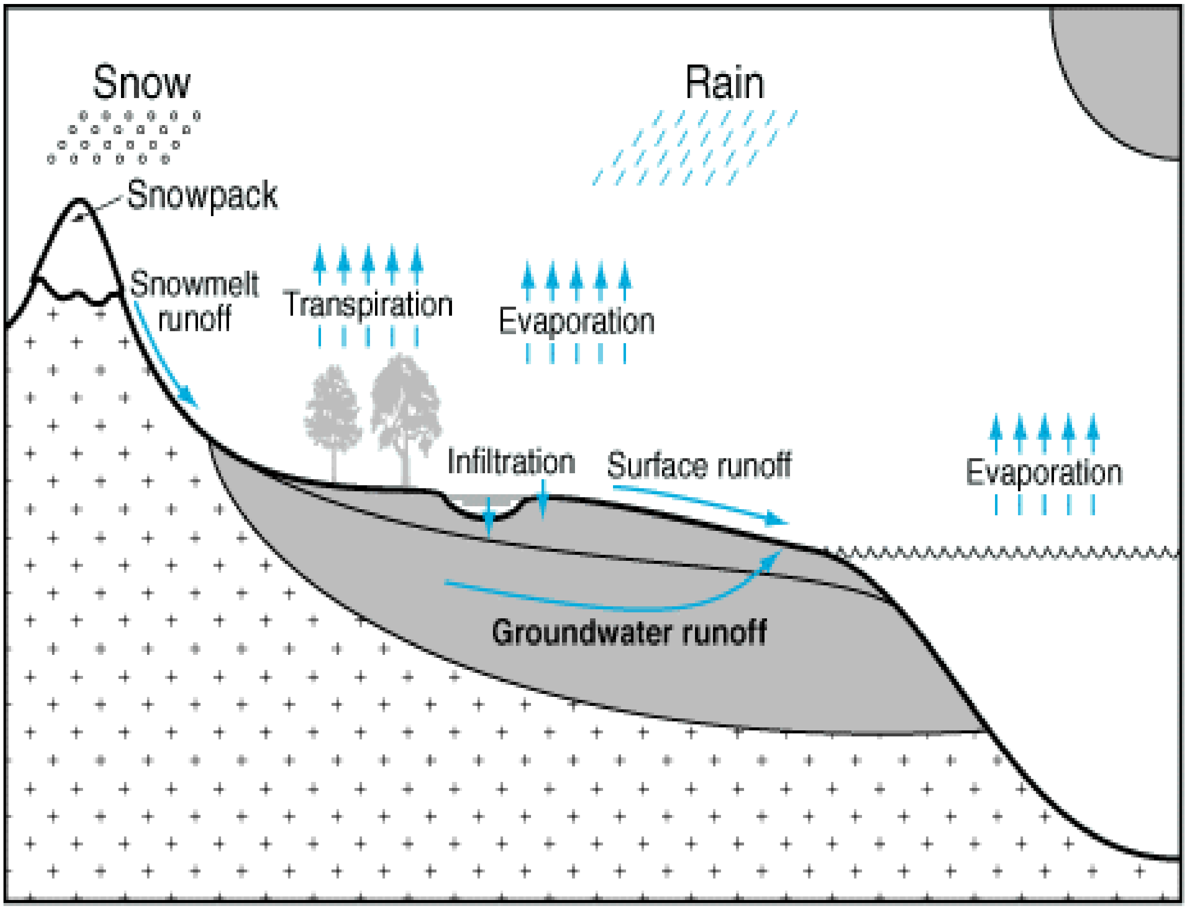
Source: The risk of disaster; Hygiene promotion note: By Schristine, 2015

Appendix 5: The top floods in India's history

Impact of Flood in India (1953-2006)

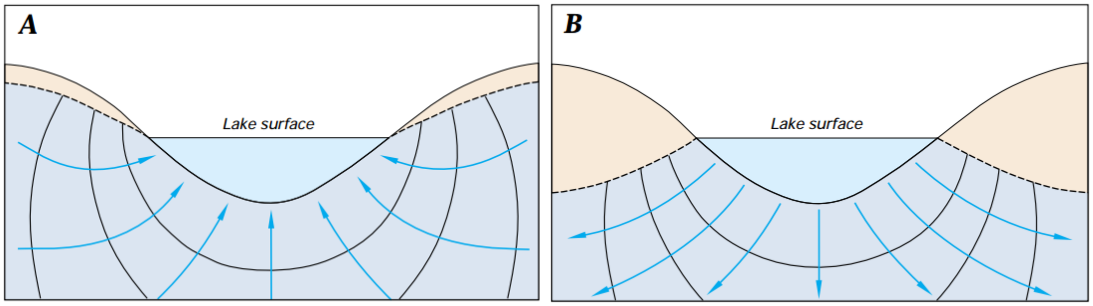
Years in group	Average area affected in '000 hectares	Average population Affected in million	Average human loss in '000	Average cattle loss in '000	Average economic loss in million rupees
1953-57	6664	16.76	399	33	140
1958-62	6448	11.714	648	31.8	148
1963-67	4342	12.636	347.2	6.4	98
1968-72	7832	34.53	1503.8	98	1162
1973-77	9606	44.956	3022.2	186.2	2542
1978-82	9588	46.518	2379	249	6382
1983-87	9162	55.80	1775.6	105.2	17540
1988-92	8531	37.42	2109	96	14928
1993-97	6821.4	33.66	1992.2	73	16090
1998-2002	5382.5	26.89	2143.25	59.03	16863.3
2003-06	2867.5	23.864	1563.75	34.14	NA

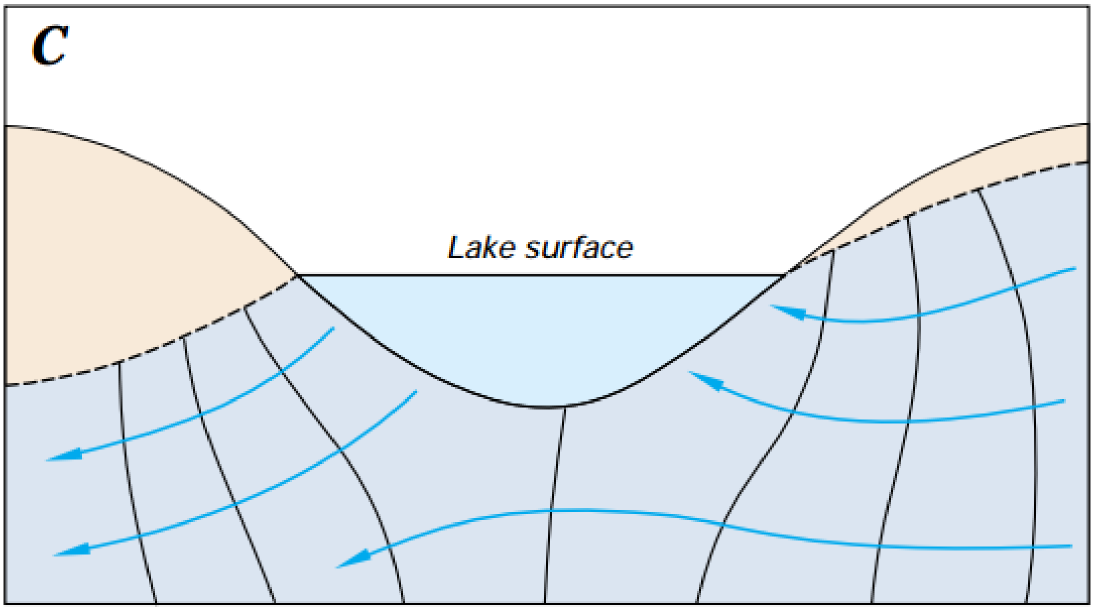
Appendix 6: Water cycle



Source: Health, 1980. Hydrologic water cycle Notes, 2015

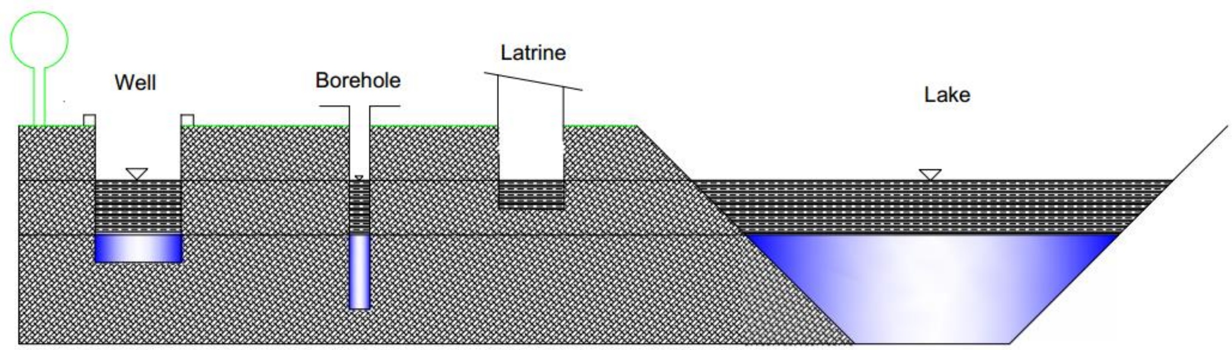
Appendix 7: Surface water and Ground water recharge

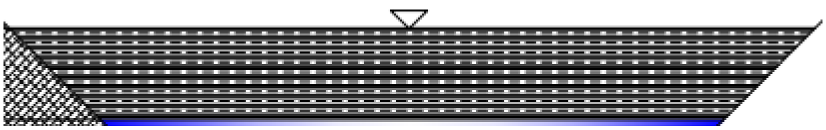




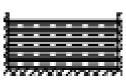
Lakes can receive ground water inflow (A), lose water as seepage to ground water (B), or both

Appendix 8: Ground water recharge




: Dirty water


: Fresh water


: Ground water table mixed by feces