Securing the Natural Freshwater Systems of the Bhutan Himalayas

Climate Change and Adaptation measures on Water Resources in Bhutan

November, 2011
1.0 Introduction:
Water resources are essential component of the earth's hydrosphere and indispensable part of the terrestrial ecosystem. Water is needed in all aspects of life. The presence of a safe and reliable source of water is an essential prerequisite for social well-being and economic productivity.

Climate change is currently taking place at an unprecedented rate and is projected to compound the pressures on natural resources and the environment. The world's rivers and wetlands are degrading at an alarming rate, more than other ecosystems (Millennium Ecosystem Assessment 2005), seriously affecting biodiversity (Dudgeon et al. 2006; Vörösmarty et al. 2010) and human-subsistence communities dependent on river flows (Lemly et al. 2000). The consequences are widespread threats, including habitat loss and degradation, invasive species, overharvesting and pollution (Allan and Flecker 1993; Dudgeon et al. 2006), whose impacts may be altered by climate change, which is predicted to change flow regimes to rivers and wetlands (Milly et al. 2005; Bates et al. 2008; Palmer et al. 2008). Such phenomena will potentially have profound and widespread effects on the availability of, and access to, water resources. By the 2050s, access to freshwater in Asia, particularly in large basins, is projected to decrease, as well as increasing extremes of dry and wet periods (IPCC 2007).

This will particularly affect wetlands and rivers predicted to become drier and may also offer opportunities where runoff and water availability are predicted to increase. Regulated river basins are predicted to be affected more than free-flowing river basins (Palmer et al. 2008).

Climate change and water resources are closely linked. Climate change is likely to lead to increase the magnitude and frequency of precipitation related disasters, such as floods, landslides, typhoons and cyclones. Flows in rivers are likely to decrease at low flow periods, as a result of increased evaporation, and runoff increase with high rainfall events and waste overflows, both of which will degrade water quality. Increased temperatures and changes in precipitation are projected to accelerate the retreat and loss of glaciers, impacting on the timing of stream flow regimes and thereby downstream agriculture. Heavily populated low
lying areas, glacial fed river basins and the semi-arid regions of the developing world, which are already poor and face major water resource management and food security problems, are likely to be the most severely impacted by the ongoing climate change.

Freshwater is mainly utilized for household use, water supply, agriculture and in industries. About 67% of the water is used in irrigation for the production of food grains worldwide. The comprehensive assessment of water management in agriculture revealed that one in three people are already facing water shortages (IPCC, 2007). Around 1.2 billion people, or almost one-fifth of the world’s population, live in areas of physical scarcity. Another 1.6 billion people, or almost one quarter of the world’s population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers); nearly all of which are in the developing countries. To make it worse, while resources are limited, the demand of water in such countries is ever increasing with the growth in population. This situation will be further compounded by the impacts of oncoming climate change.

2.0 Climate in Bhutan:

Bhutan lies in the middle of the Eastern Himalayas where the climate is driven by the westerly winds originating in the Bay of Bengal. Monsoon is intense from June up to early September. During pre-monsoon (April, May), light showers tend to occur, often accompanied by thunderstorm activity. The post monsoon period (October, November) can witness occasional downpours. The rest of the year remains pretty dry but also under influence of some westerly disturbances that would occasionally bring light showers.

From a climatic point of view, Bhutan can be divided in three parts: subtropical in the southern foothills, temperate in the middle valleys or inner hills, and alpine in the northern part of the country. Southern foothills are commonly hot and humid during monsoon and chilly during winter and their yearly precipitation range from 2500 to more than 5000 mm. Inner foothills are cold in winter, pleasant in spring, hot in summer and mild in fall; precipitation would range between 1000 to 2500
mm a year. The Northern area is cold throughout the whole year; precipitations are limited to 500 to 1000 mm.

2.1 Climate Modeling:

IPCC’s Fourth Assessment Report (IPCC 2007a; 2007b) concludes that there is more than 90% probability that the observed warming since the 1950s is due to the emission of greenhouse gases from anthropogenic activity. Temperature projections for the 21st Century suggest a significant acceleration of warming over that observed in the 20th Century (Ruosteenoja et al. 2003). In Asia, it is very likely that all areas will warm during this century. Based on regional climate models, it is predicted that the temperatures in the Indian sub-continent will rise between 3.5 and 5.5ºC by 2100, and on the Tibetan Plateau by 2.5ºC by 2050 and 5ºC by 2100 (Rupa Kumar et al. 2006). In early 2011, downscaling on Bhutan specifically performed with PRECIS by START / ADPC under an ADB consultancy predicts +3ºC by 2050 (less than 0.1/decade). Because of the extreme topography and complex reactions to the greenhouse effect, even high resolution climatic models cannot give reliable projections of climate change in the Himalayas. Various studies suggest that warming in the Himalayas has been much greater than the global average of 0.74ºC over the last 100 years (IPCC 2007a). Warming will be significant in arid regions of Asia and the Himalayan highlands, including the Tibetan Plateau (Gao et al. 2003; Yao et al. 2006). Warming in Nepal and on the Tibetan Plateau has been progressively greater with elevation (Figure 1).
3. Water Resources:

3.1: Major river basins:

Being landlocked, Bhutan’s water resources are mainly in the form of rivers. There are four major river basins, viz. the Amo Chhu (Toorsa), the Wang Chhu (Raidak), the Punatsang Chhu (Sunkosh) and the Drangme Chhu (Manas) (Figure 2), all of which drains into the Indian plains. Nyera Ama Chu, Jomotshangkha Chhu and Shaar Chhu form smaller river basins. All the river systems originate within the country except three rivers viz. Amo Chhu, Gongri and Kuri Chhu all of which originate in the southern part of the Tibetan Plateau.

The north-south rivers are the larger rivers running from the highest mountains of the country down to the lowlands near the Indian border. These rivers have steep longitudinal gradients and narrow steep-sided valleys, which occasionally open up and provide broader valleys with small areas of flat land for cultivation.

The second main category of rivers, designated as the east-west tributaries, include all the minor streams that flow as tributaries into the north-south rivers. These minor streams are mainly rain-fed. In terms of water supplies to both the rural and urban areas, the east-west tributaries are of greater importance.
There are 2,674 glacial lakes (Table 1), but they are mostly small and are mainly located in the remote high altitude alpine areas. The outburst of some of these lakes from time to time has resulted in enormous flash floods and damages downstream. Understanding of dynamics between climate, glaciology and hydrology is vital but the in depth research and analysis has not been conducted except for the following inventory of glaciers and lakes conducted in 2001:

Table 1: Summary of glaciers and glacial lakes of Bhutan.

<table>
<thead>
<tr>
<th>Sl#</th>
<th>Sub basins</th>
<th>Glaciers Number</th>
<th>Area (Km²)</th>
<th>Ice reserves (Km³)</th>
<th>Glacial Lakes Number</th>
<th>Area (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amo chhu*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>71</td>
<td>1.83</td>
</tr>
<tr>
<td>2</td>
<td>Ha chhu*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>53</td>
<td>1.83</td>
</tr>
<tr>
<td>3</td>
<td>Pa chhu</td>
<td>21</td>
<td>40.51</td>
<td>3.22</td>
<td>94</td>
<td>1.82</td>
</tr>
<tr>
<td>4</td>
<td>Thim chhu</td>
<td>15</td>
<td>8.41</td>
<td>0.33</td>
<td>74</td>
<td>2.82</td>
</tr>
<tr>
<td>5</td>
<td>Mo chhu</td>
<td>118</td>
<td>169.55</td>
<td>11.34</td>
<td>380</td>
<td>9.78</td>
</tr>
<tr>
<td>6</td>
<td>Pho chhu</td>
<td>154</td>
<td>333.56</td>
<td>31.87</td>
<td>549</td>
<td>23.49</td>
</tr>
<tr>
<td>7</td>
<td>Dang (Tang) chhu*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51</td>
<td>1.81</td>
</tr>
<tr>
<td>8</td>
<td>Mangde chhu</td>
<td>140</td>
<td>146.69</td>
<td>11.92</td>
<td>521</td>
<td>17.59</td>
</tr>
</tbody>
</table>
The majority of the valleys are narrow V-shaped valleys indicating that water erosion has been the main cause in their formation. Due to the existence of distinct rainy and dry seasons, there are large seasonal variations in the river flows. They carry large volumes of flow and sediment during the monsoon season, whereas the flow is relatively low during the dry season due to the limited base flow from insufficient groundwater recharge. Snowmelt from the high altitude alpine areas in the north contributes to the flow at the end of the dry season. Apart from the major north-south flowing rivers, Bhutan consists of a dense network of small - mainly rain-fed tributaries that flow down the steep slopes and side valleys to join the major rivers.

### 3.1.1: IWRM for holistic water management

The current scenario of abundant water resource might be challenged by the new, complex and pervasive dynamics caused by population growth and socio-economic development. These challenges will have to be effectively addressed through appropriate policies, Acts and regulations. Further public education and awareness, stakeholder participation and well designed developmental programmes with efficient and coordinated management institutions are important. These are all envisaged and carried out under Integrated Water Resources Management (IWRM). The IWRM is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. In the Bhutan Water Vision, IWRM has been defined as a process “Promoting coordinated development and management of water resources to maximize the economic
and social welfare in an equitable manner without compromising the sustainability of the vital ecosystems”.

3.2: Wetlands

Bhutan has number of wetlands viz. glacial lakes, marshes, swamps, ponds etc.). In Bhutan, wetlands also enjoy particular biological, spiritual and socio-cultural functions. From a hydrologic point of view, wetlands have an important buffering function, as temporary water storage eco-service. Wetlands in Bhutan are under increasing pressure from unplanned development, disturbances and lack of awareness among the general public leading to the loss of integrity of the wetland ecosystem. Even though there are no aggregated data to make an unambiguous demonstration, there is a strong perception, backed by number of informal reporting that Bhutan experiences a drying up of streams and creeks with the disappearance of their associated marshes and swamps. This change, to be further confirmed, could already be an impact of climate change.

Wetlands support high biological diversity including migratory birds and other flora and fauna. Wetlands are also important for water storage and release which sustains the perpetual flow in our rivers that is crucial for our hydropower generation. Culturally these wetlands and lakes are revered as sacred sites and are associated strongly with the traditional belief systems and lifestyles. It is reported that 104 bird species uses freshwater ecosystems in Bhutan and many other aquatic plant and animal species such as *Rununculus trichophyllus*, *Hydrilla verticillata*, *Potamogeton crispus*, *R. Tricuspis*, *Acorus calamus*, *Acorus gramineus*, *Shoenoplectus juncoides*, *Typhus spp.*, *Phragmites spp.*, *Equisetum spp.*, *Aconogonum alpinum*, *Carex spp.*, *Juncus spp.* and *Salix sp.* Similarly large predators such as *Panthera tigris*, *Panthera pardus*, *Panthera uncia*, and smaller predators such as *Neofelis nebulosa*, *Cuon alpinus*, and *Felix bengalensis* come for water and stalk prey species at water sources. Other mammals associated with wetland ecosystems include *Platanista gangetica Lutra lutra*, *Lutrogale perspicillata*, *Bubalus arnee*, *Felis viverrinus*, *Herpestes urva*, *Nectogale elegans*, *Chimarrogale himalayica*, etc.
The Coleoptera species *Hydraena karmai* (Figure 3) was newly discovered from a puddle in a place called Zomyuethang behind Punakha Dzong. Several new species of Ephemeroptera (may flies), Plecoptera (stone flies) and Trichoptera (caddis flies) EPT taxa were also discovered from the water bodies in Bhutan in two weeks of sampling and assessment from Paro, Thimphu, Tsirang and Sarpang Dzongkhags. The impacts of climate change compounded by the ad hoc developmental activities will wipe these new species and others even before they are discovered signaling the importance and the need to address the impacts of climate change and ad hoc developmental activities with great urgency.

The relict species of dragon fly larvae, *Epiophlebia laidlawi* (Figure 3) was found in the headwater of DreyChhu stream above Dechencholing, Thimphu and in LamchelaChhu stream in Chendebji, Trongsa (Chhopel, G.K, 2005). This species is categorized as rare and highly threatened and only other places where it is found to this day is in eastern Japan and Nepal. This species is an indicator of the pristine water quality.

![Figure 3: Hydraena Karmai (left picture) found only in Bhutan; Epiophlebia laidlawi (right) indicator of pristine water quality.](image)

**3.3: Water Availability:**

Bhutan has a very rich water resource with long term average annual flows of 73,000 million cubic meters per year which gives rise to perhaps one of the highest per capita mean annual flow availability of water at 109,000 cubic meters.
**Table 2: Gross National land Area, Runoff and Minimum Flow**

<table>
<thead>
<tr>
<th>Sl.#</th>
<th>Characteristics National Features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land Area for entire Country</td>
<td>38,394 Km²</td>
</tr>
<tr>
<td>2</td>
<td>National Population</td>
<td>634,982</td>
</tr>
<tr>
<td>3</td>
<td>Long term mean annual flow entire country</td>
<td>2,325 m³/sec = 73,000 million m³/year</td>
</tr>
<tr>
<td>4</td>
<td>Per capita mean annual flow availability</td>
<td>109,000 m³</td>
</tr>
<tr>
<td>5</td>
<td>Minimum 7 days flow of 10 year period</td>
<td>427 m³/sec = 13,500 million m³/year</td>
</tr>
<tr>
<td>6</td>
<td>Per capita minimum flow availability</td>
<td>21207 m³</td>
</tr>
</tbody>
</table>

Source: Adapted from WRMP, DOE/ Norconsult, 2003

Erratic rainfall patterns and the associated hydrological flows will have a huge impact on the overall water resource system in the country. The major rivers provide water for hydropower and tourism/recreation. Tributaries and streams provide for all other uses with emphasis on water supply and irrigation. Sub-surface sources, in the form of springs and aquifers, provide water for domestic water supply and small scale irrigation.

According to the 2010 land cover assessment study based on the satellite images of 2006 to 2009, forest cover has increased from 64.36% in 1995 to 70.46% in 2010 and shrub cover from 8.13% to 10.43%. The overall forest cover (forest plus shrub) has increased from 72.5% to 81.27% (State of Nation Report 2011). Perhaps due to this rich vegetative cover, Bhutan’s rivers have far less silt content compared to rivers in the region. Even in the peak monsoon period, the silt content recorded in the Wangchhu is between 500 to 800 ppm. This also means lower maintenance costs for the repair of turbines. The turbines in Bhutanese hydropower projects achieve an average life-span of over 50,000 hours before any rework is necessary compared to about 10,000 hours in the region.
The Hydrology Section, Department of Energy, has been recording river sediment data at six locations along three major rivers, namely Punatsang Chhu, Kuri Chhu and Mangde Chhu. Analysis of the available data showed that river sediment load was generally low with the exception of Kuri Chhu where data recorded at Kurizampa location showed relatively high sediment load (Figure 4). This can perhaps be attributed to intensive agricultural practices, forest degradation as a result of over-grazing and excessive fuel wood collection, and construction of feeder roads in the upstream areas of Kuri Chhu.

3.4: Water Demand

The proportion of population without access to safe drinking water declined from 55% in 1990 to less than 12% in 2008. The MDG target of reducing those without access to safe drinking water by half by 2015 has thus already been achieved (MDG progress report 2005). However, the sustainability of the urban water supply system and functionality of existing rural water supply schemes is one of the main challenges. 88% of the rural population and 98 % of urban population in the country now has access to piped drinking water supply (PHCB 2005). Analysis of the comprehensive rural water supply scheme (RWSS) inventory report in 2009 revealed that 31% of the rural schemes are non-functional due to various factors. Sources for drinking water are mainly from streams/rivers, protected springs and alternatively from rainwater. Water from these sources is of good physico-
chemical and biological quality which could be directly tapped for drinking purposes with minimal treatment. Despite the availability of surface water sources in abundance at national level, there are localized water shortages. Further, while there is lack of information on the yield of spring sources, many springs are said to be drying up.

The water demand projection is focused on the consumptive use of surface sources. For the purposes of analysis the users have been categorized into irrigation, municipal, rural and large industries. Municipal use comprises the requirement for domestic, institutional, commercial, Government and public uses, as well as small cottage industries that are supplied through the Municipal system.

**Table 3: Worst case gross national consumptive and non-consumptive water demand**

<table>
<thead>
<tr>
<th>Demand Category</th>
<th>2002 (million m³/year)</th>
<th>2012 (million m³/year)</th>
<th>2022 (million m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal Demand</td>
<td>10</td>
<td>19</td>
<td>37</td>
</tr>
<tr>
<td>Irrigation Demand</td>
<td>393</td>
<td>472</td>
<td>472</td>
</tr>
<tr>
<td>Rural Demand</td>
<td>11</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Industrial Demand</td>
<td>0.6</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Livestock Demand</td>
<td>7.5</td>
<td>8.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Sum of maximum consumptive demand</td>
<td>422</td>
<td>516</td>
<td>541</td>
</tr>
<tr>
<td>Sum of water supply (excl.irri) demands</td>
<td>29.1</td>
<td>43.7</td>
<td>68.7</td>
</tr>
<tr>
<td>Add-on irrigation demand</td>
<td>15</td>
<td>-</td>
<td>26</td>
</tr>
<tr>
<td>Non-consumptive hydropower demand</td>
<td>6,700</td>
<td>16,600</td>
<td>26,900</td>
</tr>
</tbody>
</table>


A detailed water demand forecast exercise carried out by the Department of Energy with expertise from Norconsult for the preparation of Bhutan’s Water Resources Management Plan (WRMP) had estimated 422 million m³ of gross consumptive demand in 2002 and forecasted this demand to grow to 516 million m³ by 2012 and to 541 million m³ by 2022 (Table 3).
Non-consumptive water demand exists in the form of hydropower demand. The hydropower demand has been estimated at 6,700 million m$^3$ for 2002, and is forecasted to grow exponentially to 26,900 million m$^3$ by 2022, keeping in view the upcoming and potential hydropower projects in the future.

The result of the water balance assessment carried out by Norconsult indicates that at the national level there is a large surplus of available and firm flow in the main north/south rivers. The Gross National Water Balance extracted from WRMP report is given below, which illustrates that Bhutan does not have an overall annual water balance problem on a national scale.
### Table 4: Gross National Water Balance (Source WRMP 2003)

<table>
<thead>
<tr>
<th>Water Balance Indicator</th>
<th>2002</th>
<th>2012</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of maximum total consumptive annual demand for all sectors as % of mean annual runoff</td>
<td>0.58%</td>
<td>0.70%</td>
<td>0.74%</td>
</tr>
<tr>
<td>Sum of maximum total consumptive annual demand for all sectors as % of minimum 7-day flows with 10 year recurrence</td>
<td>3.20%</td>
<td>3.80%</td>
<td>4.00%</td>
</tr>
<tr>
<td>Sum of maximum water supply (excluding irrigation) demands as % of minimum 7-day flow with 10 year recurrence</td>
<td>0.22%</td>
<td>0.33%</td>
<td>0.51%</td>
</tr>
</tbody>
</table>

Although water balance issues are not critical on a national scale in Bhutan, the picture may be different as one move to sub-basin levels or further down into smaller sub-catchments with heavy population concentrations. Considering that the main consumptive use of water for irrigation and drinking are extracted from the tributaries, the water balance study needs focus beyond sub-basins into catchments and sub-catchment levels to fully understand water balance status.

### 4.0 Institutional set up

The National Environment Commission (NEC) is entrusted with the responsibility of coordinating water resources management in the Country as an apex body on water resources. For this, the Water Resources Coordination Division has been established under the NEC Secretariat, with the mandates of water quality monitoring, development of appropriate standards and coordination of the management of water resources.

However, the actual implementation is the responsibility of the following Agencies (Water Act 2011):

(a) The Ministry of Works and Human Settlements and Municipal Bodies for ensuring safe, adequate and potable water supply in the Thromdes.
(b) The Dzongkhag Tshogdu and Gewog Tshogde supported by the Dzongkhag, Dungkhag and Gewog Administration in collaboration with the Ministry of Health for ensuring safe, adequate and potable water supply at Dzongkhag, Dungkhag and Gewog level.

(c) The Ministry of Health for ensuring safe and potable water supply through regular water quality monitoring in both urban and rural areas.

(d) The Ministry of Agriculture and Forests, for land-use and irrigation, watershed management, water resources in forests, wetlands and protection of catchment areas.

(e) The Ministry of Economic Affairs for hydro-power development, the collection, analyses and dissemination of water resources data and monitoring of water flows (discharge level) and sediment for the purposes of the National Integrated Water Resources Management Plan, planning and design of water resource infrastructure and flood issues.

(f) The Ministry of Home and Cultural Affairs for coordination of Disaster Preparedness and mitigation related to water resources.

(g) The Ministry of Education for including water resource issues in the curriculum of schools and institutions and awareness creation.

(h) Civil Society Organizations and the Media for assisting in prevention of water pollution and sustainable use of water resources through education, public awareness and promoting public-private partnerships.

The coordination and management of water resources at policy and programming level needs a major overhaul. For e.g the drinking water is being looked after by two different Ministries; viz. Ministry of Health for the rural water supply and Ministry of Works and Human Settlement for urban water. These two ministries do not have mechanism to coordinate and carry out their works in independently. There are avenues for them to build on collaborative synergy and avoid duplication and waste of resources.

The holistic principles of IWRM have been reflected as a cornerstone in the Water Act 2011, and the reality of implementing and translating this into action
can materialize only if our limited resources are pooled for collective effort and action.

5.0 Issues:
5.1 Glacial retreat:
Himalayan glaciers are receding faster today than the world average (Dyurgerov and Meier 2005) (Figure 7). The IPCC Fourth Assessment Report (IPCC, 2007a; 2007b) states that there is a high measure of confidence that in the coming decades many glaciers in the region will retreat, while smaller glaciers may disappear altogether. Various attempts to model changes in the ice cover and discharge of glacial melt have been made by assuming different climate change scenarios. One concludes that with a 2ºC increase by 2050, 35% of the present glaciers will disappear and runoff will increase, peaking between 2030 and 2050 (Qin, 2002).

![Figure 7: Rapid retreat of greater Himalayan glaciers in comparison to the global average.](image)

Glaciers in Bhutan Himalaya are less well studied than those in other countries; however there are evidences that the glaciers in Bhutan are also retreating (Karma et al., 2003). Ageta and the team studied rate of retreat of some selected large debris-covered glaciers associated with large lakes by comparing archived photographs, satellite images, and maps of previous years. Using lake expansion rates up-valley to calculate retreat rates for the related glaciers, the authors
reported retreat rates in the range of 30–35m per year. The Tarina Glacier retreat rate was 35m per year from 1967 to 1988 (Ageta et al. 2000). However, the rates were found to be variable with time, a phenomenon attributed to irregular calving at the tongue of the mother glacier, which is in contact with the lake water (Ageta et al. 2001).

Debris free or ‘clean’ glaciers (C-type) are considered more sensitive to climate change than debris covered (D-type) ones. Karma et al. (2003) examined terminus variation for 103 debris-free glaciers in the Bhutan Himalaya over a period of 30 years (from 1963 to 1993). Retreat rates (on the horizontal projection) as high as 26.6 m/year were reported for these glaciers.

A ground survey of the C-type, Jichu Dramo glacier was conducted in the Bhutan Himalaya as part of fieldwork in 1998; the glacier was resurveyed in 1999 to assess the changes. Naito et al. (2000) recorded a 12m retreat (from 1998-1999) and estimate that the surface was lowered by 2 to 3m.

The retreat rates for C-type glaciers in the Bhutan Himalaya were compared with retreat rates for some glaciers in eastern Nepal. Karma et al. (2003) report that the retreat rates were higher for glaciers in the Bhutan Himalaya than for glaciers in eastern Nepal; attributing the sensitivity of these glaciers to the intensity of the monsoon. These glaciers and glacial lakes are located in the northern fringes on the country, of which 24 of them are categorized as potentially dangerous (Figure 8).
Increase in temperature as a result of Climate Change will lead to retreat of glaciers and increase the risk of Glacial Lake Outburst Flood (GLOF), hence it is necessary to monitor the flow regimes. GLOFs occurred in 1957, 1960, 1968 and 1994 (Figure 9) with varying intensity and damage to life and property in the downstream valleys. A recent study warns that Raphstreng and Thorthormi glaciers and lakes in Lunana could become dangerous unless mitigation measures are taken.

Field assessments by the DGM and the Institute of Geology, University of Vienna, have predicted probability of outburst of Thorthormi and Raphstreng Tsho, yet again in the headwaters of Pho Chhu Sub Basin, in the next ten years or so.

**Figure 8:** Number of potentially dangerous lakes in Bhutan

**Figure 9:** Chronology of the occurrence of GLOF in Bhutan.
Based on the monitoring results using satellite imagery pictures of the Department of Geology and Mines, Bhutan’s glaciers are observed to be receding at a rate of 20-30 meters per annum (Figure 10). Unless some measures are undertaken it is possible that all the glaciers in Bhutan Himalaya could disappear within few decades. This is definitely a serious concern for a country like Bhutan whose economy is dependent on the glacial lakes which act as natural reservoirs and also help to regulate seasonal flows in the rivers.

**Figure 10**: Increased glacier retreat since the early 1990s; ICIMOD, 2001.

Bhutan’s accelerated development of hydropower projects has set a target of 10,000 MW by 2020. Out of this, more than 6000 MW is planned in the Punatsangchhu Basin which is located downstream of Lunana. As per the study conducted by the Department of Geology and Mines in conjunction with the University of Vienna, on account of the receding glaciers caused by global warming, it is predicted that a major GLOF leading to discharge of about 53 million cubic meters could occur by 2015. This is about three times the intensity of the 1994 floods.

Proper hazard zonation and an effective early warning system are being implemented with support from the hydropower projects. The Department of Geology and Mines is also carrying out mitigation measures to reduce the water levels in the Thorthormi glacial lake. This task is physically very demanding, as access to the glacial lakes is only possible by foot for about six months of the year and logistically very challenging.
5.2 GLOF

The most significant impact of climate change in Bhutan is the formation of supra-glacial lakes due to the accelerated retreat of glaciers with increasing temperatures. The risk of potential disasters inflicted by Glacial Lakes Outburst Floods (GLOFs), which pose new threats to lives, livelihoods and development, is mounting as the water levels in several glacier lakes approach critical geostatic thresholds. Although current disaster management policies, risk reduction, and preparedness plans in Bhutan are able to address recurrent natural hazards in the country, they are not yet prepared to deal with the new GLOF apparently caused by the impacts of climate change.

Rising mean temperatures, attributed to climate change, are the main cause of glacial retreat and are correlated with faster rates of glacier melt. Analysis of the available meteorological data from the Department of Energy (Figure 11) show greater increase at higher altitudes. This may be the reason for accelerated melting of glaciers receding at a rate of almost 20-30 meters per year. The melting ice from these receding glaciers is increasing the volume of water in glacial lakes, and the melting of ice-cored dams is destabilizing them, pushing the hazard risk for GLOFs to critical levels.

**Figure 11:** Minimum and maximum temperatures of various places in Bhutan.
The only GLOF event properly documented in Bhutan is the one that occurred on 7 October 1994. From a survey conducted on 20–23 October 1994, it was found that 17 lives were lost, 96 households were affected, 12 houses damaged, 5 water mills washed away, 816 acres of dry land and 965 acres of pasture land were either washed away or covered with sand and silt, 16 yaks were carried away, 36 cowsheds and a full year’s manure washed away, 16 tonnes of food grains lost, 2838 pieces of wooden shingles and 68 wooden beams washed away, 4 bridges washed away, 2 chhortens destroyed and the temple at Tsojug was badly damaged.

5.3 Runoff over time and space:
Mountain regions provide more than 50% of the global river runoff, and more than one-sixth of the Earth’s population relies on glaciers and seasonal snow for their water supply (Eriksson et al, 2009). In Asia, climate change induced glacial melt could seriously affect half a billion people in the Himalayan region who depend on glacial melt for their water supply (Stern 2007). In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra – all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers. The current trends in glacial melt suggest that the low flow will become substantially reduced as a consequence of climate change (IPCC 2007a). The effect of this on, for example, food production and economic growth is likely to be unfavorable. The situation may appear to be normal in the region for several decades to come, and even with increased amounts of water available to satisfy dry season demands. However, when the shortage arrives, it may happen abruptly, with water systems going from plenty to scarce in perhaps a few decades or less. Some of the most populated areas of the world may “run out of water during the dry season if the current warming and glacial melting trends continue for several more decades” (Barnett et al. 2005). Flooding may also arise as a major development issue. It is projected that more variable, and increasingly direct, rainfall runoff will also lead to more downstream flooding.
5.4 Decrease in capacity of Hydropower generation:

Climate change will impact the temporal and spatial variation in flow, mainly affecting electricity generation due to disruption of average flows for optimum hydropower generation. One may also see increased sediment load in rivers and reservoirs. Due to more erratic and unpredictable rainfall patterns, there would be reduced ability for catchments areas to retain water, leading to increased runoffs and enhanced soil erosion. Average generation at the Chhukha hydropower plant on an annual basis has not changed but in recent years, the low flows are beginning to show a sign of decrease. The overall glacier retreat observed in most of the Himalayas including Bhutan, (Karma, 2003, Bajracharya, 2008) could result in a decreased availability of snow in the region. It has now become a common sight during the winter months to see Mount Everest, the highest mountain in the world, with only sparse snow cover.

Entire hydropower generation systems established on many rivers will be in jeopardy if landslides and flash floods increase, and hydropower generation will be affected if there is a decrease in the already low flows during the dry season. Engineers will have to consider how to respond to these challenges (OECD 2003). Specific hazards related to glacier retreat are the formation of pro-glacial lakes and in some cases the events of glacial lake outburst floods (GLOFs). These can have a devastating effect on important and vulnerable infrastructure downstream such as hydropower stations. Equally important, the operations of hydroelectric power stations will become more complex. With climate change, the complexity and variability of river flow generation will both rise (Renoj et al. 2007) and become increasingly difficult to predict. This could have serious implications on river flows and water availability for power plants for about several months per year.

The most critical impacts of climate change to water resources in Bhutan will be on the hydropower generation. The impacts may include the following:

- Increased risk of Glacial Lake Outburst Flooding (GLOF);
- Increased run-off variability’s of glacier retreat, more intense precipitation during monsoon and potentially decreased precipitation in winter;
- Increased sediment loading as a result of landsides, GLOF as a result of intense rainfall events;
- Increased evaporation losses from reservoirs (in future) as a result of rising temperature;
- Current domestic water supply is predominantly met from the springs and small tributaries. However, by taking into account the current pace of development activities inside the river basins, the need for tapping the main rivers to increase water supply has already been studied and planned for Thimphu city. This will have implications downstream particularly on hydropower projects during the lean flow period, in the long run.

5.5 Reduction in water source yield and quality deterioration:
The prominent negative impacts of climate change on Water, Sanitation and Hygiene from the national perspective are:
- Damage of water supply and sanitation infrastructures from increased flooding or landslide, debris flow, GLOF etc.
- Increased O&M costs for water treatment due to degradation of water quality input.
- Pollution induced by overwhelming capacity of low cost surface water protection system, including pathogen loading, water borne diseases propagation,
- Water borne diseases Increased by dry spells / droughts and degradation of quality of shallow water, ponds and marshes,
- Possible drying up of spring and stream sources in remote areas.

5.6 Landslide Dam Bursts
In the mid-mountains a landslide triggered by cloudburst often falls into a river, damming it temporarily and creating an impoundment in the upstream reach. The
steeper the slope, the greater the possibility of the formation of a landslide dam. In narrow valleys, massive slope landslides can completely block the path of a river, impounding a huge quantity of water. When the dam breaks after it is overtopped or when it fails to withstand water pressure, a sudden flood is created. Such events occur randomly and cannot be predicted precisely. Such a flood gouges out beds and banks, thereby increasing the sediment load of river substantially. It also brings devastation to lives and properties.

Figure 12: Temporary landslide dam on a river. Source: Ajaya Dixit, basic water science 2002.

Due to the v-shaped valleys and steep gradients landslide dam bursts occur very frequently during monsoon in several locations especially in the upper watersheds.

In September 2003 a large rockslide occurred along the Tsatichhu river, close to Ladrong village, Lhuentse Dzongkhag, in east Bhutan. The slide mass blocked the valley and, soon thereafter, a lake was formed that filled progressively. Because of the proximity of the Kurichhu Hydropower Project (about 35 km downstream) and the scale of the event, serious concerns arose about the potential downstream hazard. The dam finally burst on 10 July 2004, after incessant rain for several days. A large volume of water and debris was released and the flood wave traveled down the Wabragchhu and the Kurichhu, seriously impacting on all low lying areas.

In May 2009, such an incident in the upper catchment area of Wangchhu river caused major destruction in the Thimphu valley.
5.7 Water induced health hazards

Climate change has more subtle and sustained impacts on human health by affecting the three basic elements of life namely air, water and food (Bhutan’s Natural Heritage, 2010). The impact of climate change on health conditions can be broken into three main categories: (i) direct impacts of for example, drought, heat waves, and flash floods, (ii) indirect effects due to climate-induced economic dislocation, decline, conflict, crop failure, and associated malnutrition and hunger, and (iii) indirect effects due to the spread and aggravated intensity of infectious diseases due to changing environmental conditions (WHO 2005). The latter effect includes the expansion of vector-borne diseases such as malaria and dengue and water-related diseases such as diarrhoea. Regions such as the Hindu Kush-Himalayas, located at the fringe of the current geographic distribution of these and many other diseases, are particularity susceptible to the negative effect of rising temperatures. It is projected that the spread of malaria, Bartonellosis, tick-borne diseases and infectious diseases linked to the rate of pathogen replication will all be enhanced. Malaria mosquitoes have recently been observed at high altitudes in the region (Eriksson et al. 2008).

Endemic morbidity and mortality due to diarrhoeal disease associated with floods and droughts are expected to rise in East, South and Southeast Asia due to projected changes in the hydrological cycle (IPCC 2007a). This will be in addition to an already very high global burden of climate change attributable diarrhoea.

Heavy rainfall can lead to flooding, which can increase incidence of waterborne diseases. The sanitation and cleanliness of the water and the surrounding environment are challenged as the downpour triggers sewage overflows, contaminating drinking water causing diarrhoea, cholera, etc. Diarrhoeal disease has remained one of the top three causes of morbidity in the last one decade and contributes to about 10-15 % of the morbidity cases.

Figure 13: Occurrence of Water-borne Diseases, 2000-05
However, there are also expected to be positive climate change induced effects on the health status of certain populations in the Himalayan region. High altitude areas will open up to new types of agricultural production and new livelihood opportunities, people will find their homes and villages more comfortable due to less cold conditions, and the risks associated with cold and respiratory diseases will be reduced as the use of fuel wood for heating is reduced.

5.8 Reduction in agriculture productivity

The productivity of agricultural systems is dependent on the availability of water resources for irrigation. Due to climatic vulnerability and associated risks, agricultural production systems especially in marginal areas are prone to degradation of land resources through land and soil erosion, and over-extraction of groundwater (National Water Mission, Government of India, 2010). Subsistence and smallholder farmers are particularly vulnerable to climate variability and socio-economic stresses that further complicate their livelihood systems (Bates et al. 2008). It is paradoxical that too much water (floods, land slips) and too little water (droughts) both adversely affect agriculture leading to food insecurity. Extremes in temperatures (high/low) and shifts in rainfall patterns (early/late) lead to adjustments in planting and harvesting times, often resulting in lower crop productivity and food production.

In recent years the observed and visible impacts on agriculture possibly due to climate change in Bhutan have been the loss of arable lands, damage to crops and loss in production, changes in temperature and rainfall patterns affecting production and food security and increasing water conflicts amongst farmers and communities as water becomes increasingly scarce for crop production, particularly rice. Several acres of paddy fields were lost to flash floods in Trashiyangtse in 2009 and Sarpang in 2010. Exact figures are unavailable but each year cultivated lands are lost to landslides and soil erosion. This is particularly true in areas in the east and south which receive heavy rainfall averaging over 4000 mm per annum.
Possibly due to changing climate and associated effects such as fluctuating temperatures, droughts and windstorms, there is a heavy toll on crop production. In April 2010, a strong windstorm swept 10 districts of Trashigang, Pemagatshel, Mongar, Samdrupjongkhar, Lhuentse, Gasas, Trongsan, Chukha, Paro and Zhemgang damaging standing crops of maize, houses, lhakhangs, chhortens, schools, BHUs and RNR centres. A total of 263 households were affected and two human injuries were reported. The estimated damage to crops and loss of property amounted to Nu 2 million. In 2009, the occurrence of windstorm, hailstorm, heavy rains and landslides affected 344 acres of cropped maize and rice area and caused an estimated production loss of 140 MT of food grains (Ghimiray, M, unpublished report). Conflicts arising over access to water and use for rice production are on the rise. A case in point is the unresolved conflict among the villagers of Limuteychhu watershed in Punakha over inequity in traditional water use rights and practices between upstream and downstream communities. Interventions by development workers and court of law have not satisfied the warring communities. Due to changing weather patterns, humidity and temperatures, there has been a dramatic rise in pest and disease outbreaks in many crops. In maize, two devastating fungal diseases, Turcicum Leaf Blight (TLB) and Grey Leaf Spot (GLS) have caused huge losses in maize production. The diseases occurred in epidemic scale throughout the country in 2006. Likewise in rice, a major epidemic outbreak of blast disease occurred in 1995 leading to a loss of 1099MT of rice or Nu.11 million. The outbreak was associated with high rainfall and overcast conditions.

5.9 Sustainability of water intensive industries
Most of the industries are located in the young, fragile and geologically unstable southern foothills that are prone to natural soil erosion and landslides. The industries that are heavily dependent on water are distilleries, agro industries, breweries, beverage industries, food industries and metallurgical industries that require a continuous flow of water for the cooling process (Table 5). Water
supplies for most of the existing industries are currently met from the local tributaries, but some are served from the associated municipal water supply. The water need for these water intensive industries are tapped from the springs and streams. The reported cases of drying up of water sources and dwindling of water yield in the headwater, if true, will jeopardize the sustainability of these industries. This is even more frightening since the availability of an alternate source was never ascertained. The exploration of groundwater reserve in the southern plains is being initiated by the Ministry of Agriculture and Forests.

Table 5: Water dependent industries. Adapted from WRMP 2003.

<table>
<thead>
<tr>
<th>Industry Name</th>
<th>Location</th>
<th>Estimated Consumption, 000 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drangchu Beverages</td>
<td>Phuntsholing</td>
<td>500</td>
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<tr>
<td>Jimina Paper Manufacturing Co.</td>
<td>Jimina</td>
<td>4</td>
</tr>
<tr>
<td>Penden Cement Authority Ltd.</td>
<td>Gomtu</td>
<td>99</td>
</tr>
<tr>
<td>Army Welfare Project; Distillery</td>
<td>Gelephu</td>
<td>329</td>
</tr>
</tbody>
</table>

6.0 Existing gaps in understanding and addressing climate change impacts on water resources.

6.1 Lack of comprehensive data and inventory on water resources
The data and information on water resources in Bhutan are very basic. No comprehensive inventories of water resources were ever conducted. The only source of data currently available is the publication of the Department of Energy and Norconsult on the Water Resources Management Plan, 2003.

The EU funded project ASSESS-HKH, discovered a new aquatic species within a few weeks of sampling and assessment. No comprehensive and systematic monitoring and studies were ever conducted on the aquatic biodiversity in Bhutan.

As mentioned above, the information on the surface water especially the minor tributaries and the associated streams and springs are not documented comprehensively. The work on ground water resources is at its infancy and the
information on this resource is almost non-existent except for a few tube wells and hand-dug wells in the southern part of the country.

6.2 Education and awareness on the impacts of climate change on water resources
The possible reason could be the lack of education and awareness of the impacts of climate change on water resources that led to the implementation of projects with adverse effects on the environment in the recent past. Such developmental activities have resulted in the loss of a wide expanse of wetlands. Even though some of the legislations recognize the importance of wetlands, and the need to maintain buffer areas for the ecological sanctity of the riverine ecosystems, the actual implementation has been lacking. A case in point is the construction of the Chhumey vocational training institute in Bumthang and the loss of several hectares of wetlands in Changangkha in Thimphu to the construction of youth hostel facilities. The loss of these valuable wetlands would mean the permanent loss of the water “reservoir” that retains water for gradual release into the river for sustained flow overtime.
People also needs to be further educated on the urgency to safeguard the headwater catchments and watersheds from excessive exploitation through forest degradation and overgrazing.

6.3 Lack of convergence of policy and practice
Although, there are a number of legislations and policies addressing the management of water resources, these efforts are in piecemeal rendering implementation ineffective. The Water Bill, 2011 is under legislation and is expected to be enacted in the summer session of 2011 parliament. Following this the rules and regulations pertaining to relevant sectors will be formulated to make the implementation of the provisions more effective.
However the specific concerns of climate change and its impact on water is lacking. With the threats from the impacts of climate change, it has become necessary for the country to address climate change concerns through
implementation of ecosystem-based approaches to safeguard the integrity of the ecosystems in general and riverine ecology in particular.
Bearing in mind the expected accelerated hydropower development, it is imperative to ensure the sanctity of the riverine ecosystems through enforcement of minimum ecological flow reserve and the mandatory provisions on the migratory pathways for aquatic fauna such as fish ladders.

6.4 Lack of capacity
There is a lack of national capacity in terms of institutional, human and financial resources to deal with climate change and its impacts on water resources. There is a lack of sufficient fund to carry out the environmental management activities and to conduct requisite adaptation and mitigation activities. Therefore capacity building needs special attention parallel to the institutional building, technology transfer, technical expertise and infrastructure strengthening.

6.5 Weak linkages and coordination amongst stakeholders
There are a number of institutions working on water related fields in the country. Often these agencies work in isolation with no coordination with the other stakeholders. For instance, the Ministry of Works and Human Settlement oversees the urban water while the Ministry of Health is responsible for the rural water. They work in isolation and lack proper coordination. This has resulted in a lack of synergy, duplication and waste of resources. The coordination of information sharing and dissemination is a cross-sectoral issue which is crucial for an integrated and holistic response to climate change at national and regional levels. In view of the limited human and financial resources to ensure the optimal utilization of these resources as well as progressive advancements in areas of water and climate change, it is important to identify the most effective mechanisms of collaboration and minimize duplication.
7.0 Adaptation to Climate change: “Climate adaptation is water adaptation”

Climate change adaptation is mainly about water; water is one of the main, if not the primary, medium through which climate change influences the Earth’s ecosystems and therefore people’s livelihoods and well-being (Adapting to climate change-risks and resilience, Theme 4). Water resources and how they are managed impact almost all aspects of society and the economy, in particular health, food production and security, domestic water supply and sanitation, energy, industry, and the functioning of ecosystems. A changing climate is directly felt in the water sector; consequently, much work on adaptation and building resilience needs to be done through the water sector.

Already, water-related climate change impacts are being experienced in the form of more severe and more frequent droughts and floods. Higher average temperatures and changes in precipitation and temperature extremes are projected to affect the availability of water resources through changes in rainfall distribution, soil moisture, glacier and ice/snow melt, and river and groundwater flows; these factors are expected to lead to further deterioration of water quality as well.

Water resources have always varied in time and space. The core business of water resources management is about coping with variability: storing excess water from wet periods to bridge dry spells, protecting low lying areas from floods, balancing withdrawal between upstream and downstream areas and between different uses etc. Under present climate variability, water stress is already high, particularly in the developing countries, and climate change adds even more urgency for action. Without improved water resources management, the progress towards poverty reduction targets, the Millennium Development Goals, and sustainable development in all its economic, social and environmental dimensions, will be jeopardized. The poor, who are the most vulnerable, are likely to be affected the most.
7.1 Adaptation Mechanisms

Water is the medium through which climate change expresses itself, therefore adaptation to climate change can be achieved mainly through better water management. Recognizing this and responding to it appropriately present development opportunities. Appropriate adaptation measures build upon known land and water management practices to foster resilience to future climate change, thereby enhancing water security. Innovative technologies and integrated solutions are needed at the appropriate scales, for adaptation as well as mitigation.

Climate Change will likely increase the frequency and duration of droughts. More extreme weather conditions are a possibility. For example, regions where an increase in rainfall is predicted might experience less precipitation during the dry season and more rainfall during the monsoon. Scientists predict that the seasonal pattern of water demand and supply will change and notably there can be mismatch between the peak supply (runoff of melt water) and the peak demand for irrigation water or hydropower. To cope with these possible future changes, it is imperative to implement adaptation measures to climate change especially in the field of water-related disasters, such as floods, sediment-related disasters, storm surges and droughts.

Agenda 21, chapter 18 of the Rio Declaration clearly indicated the need to understand and quantify the threat of the impact of climate change on fresh water resources and facilitate the implementation of effective counter-measures. Developing adaptation mechanisms to the impact of climate change will be necessary even though it may be expensive.

8.0 National Action Plan:

As we adapt, we must maintain a holistic view of the continuity between climate change adaptation, environmentally sustainable development and enhanced resilience as development themes that enhance our progress toward the Millennium Development Goals. And in doing so, it is critical to enable closer cooperation among policy-makers, scientists, engineers, economists, water
managers, decision-makers, local communities and other stakeholders. Climate change is a profound challenge, but it also presents us with opportunities to invent strategies and action plans to address the pertinent issues for the well-being of our societies. Making use of accumulated knowledge, developed capacity of the society as a whole and comprehensive approaches would go a long way in combating the impacts of changing climate.

The action plan is developed through a series of multi-stakeholder consultative meetings with all the key stakeholder agencies in Bhutan, and also with separate meetings with representatives from regional and international organizations. The primary goal and the objective of this action plan are to strongly recommend realistic, practical and far-sighted measures and actions to adapt to the impending impacts of climate change.

The key goals that will guide the realization of the proposed action plans are as below:

1. To improve understanding and increase awareness of the impacts of climate change on water resources.
2. To increase resilience to respond to the impacts of climate change on water resources.
3. Water Resources Management through adoption and implementation of IWRM and eco-efficiency
4. Mainstream climate change and water resources in national plans and programmes.
### 8.1 Log framework:

<table>
<thead>
<tr>
<th>Goals</th>
<th>Objectives</th>
<th>Activities</th>
<th>Budget in USD (million)</th>
<th>Time line – 2012 to 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.1</td>
<td>Carry out comprehensive water resources inventory; mapping, assessment of the quality and quantity of the major water sources for various uses</td>
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<td>Develop database on the amount of water resources (rainfall, snowfall, reservoir storage, river discharges, groundwater potential, groundwater levels, water quality, etc.) and on water allocations (water intakes, water demand, and related seasonal changes, etc.)</td>
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<td>Monitoring of glacial and seasonal snow covers to assess the contribution of snow melt to water flow of Bhutanese rivers</td>
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<td>Establish permanent water quality and quantity monitoring stations in all 20 Dzongkhags</td>
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<td>Institute a Multisectoral Task Force including NGOs, CSOs, and Private to provide a platform for holistic advice on issues related to water resources and its development</td>
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<td>Translate technical and scientific findings into a language understandable by decision-makers, planners and other non-scientists; and encourage decision-makers and other non-specialists to increase their scientific literacy with respect to water and climate change.</td>
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<td>Promote the networking of educational institutes, especially the higher education sector, to share research and data related to climate change and its impacts on water resources</td>
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<td>Identify the human resource gap and build technical and managerial capacity at all levels</td>
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<td>Develop long-term monitoring and analysis of indicators of climate change on water resources</td>
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<td></td>
<td>Quantify and value the environmental services of forests as a source for water</td>
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<td></td>
<td>Strengthen technology transfer, sharing of best practices and researches within the institutions in the region on understanding the impacts of climate change on water resources</td>
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</table>
To increase resilience to respond to the impacts of climate change on water resources.

### 2.1 Improve preparedness to water related natural disasters and emergencies

<table>
<thead>
<tr>
<th>Action</th>
<th>Priority</th>
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</thead>
<tbody>
<tr>
<td>Develop and facilitate cost effective, socially acceptable, and sustainable disaster-preparedness and risk-minimisation through improved assessment and socio-economic vulnerability analysis</td>
<td>5.0</td>
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<tr>
<td>Develop and implement policy for the protection of natural water course.</td>
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<tr>
<td>Ensure the minimum ecological flow reserve particularly in the downstream of the dam</td>
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<td>Installation of GLOF technical early warning systems with associated awareness-raising</td>
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<td>Regular monitoring of lake levels, both manually and through the satellite.</td>
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<td>Creation of speed arresting/ controlling meandering pathways for the overflow of GLOF to delay the impact on the downstream infrastructure</td>
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<tr>
<td>Improve land use planning in degraded catchment/ watersheds areas through afforestation</td>
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<tr>
<td>Strengthen transboundary collaboration on the exchange of flood forecasting and information.</td>
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</table>

### 2.2 Enhance knowledge & preparedness of the local community, schools and institutes on the impacts of climate change on water

<table>
<thead>
<tr>
<th>Action</th>
<th>Priority</th>
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<tbody>
<tr>
<td>Develop awareness, advocacy and outreach programme on water resources management including water legislations and policies, at all levels</td>
<td>1.0</td>
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<tr>
<td>Promote community involvement in watershed/ catchment protection and in decision making processes</td>
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<tr>
<td>Incorporate traditional knowledge and local perspectives in adapting to the changing climate</td>
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<tr>
<td>Integrate into the school curriculum on the awareness and preparedness on water - induced natural disasters.</td>
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<tr>
<td>Training local communities to respond to water- induced disasters.</td>
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### 2.3 Implementation of multipurpose projects with carry-over storages & rainwater harvesting

<table>
<thead>
<tr>
<th>Action</th>
<th>Priority</th>
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</thead>
<tbody>
<tr>
<td>Impounding reservoirs for drinking water supply in both urban and rural areas</td>
<td>15.0</td>
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<tr>
<td>Development of multipurpose mini hydropower schemes and use of the water from the reservoir/ tail race for municipal use</td>
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<tr>
<td>Rain Water harvesting to prevent water shortages during dry periods and irregularities during the monsoons</td>
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<tr>
<td>2.4 Enhance ecological management practices</td>
<td>Conserve wetlands in the headwater catchment areas as continual source of pure water, habitat for biodiversity, spiritual and cultural asset and for other ecosystem services</td>
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<td>Encourage the spread of green belt to increase local resilience to sediment-related disasters, recharging of groundwater and create aesthetic green landscapes in the urban environment</td>
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<td>Mandate the requirement of buffer area (30m) on the banks of rivers, and installation of minimal river training works</td>
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<td></td>
<td>Develop and implement stringent rules and regulations to protect water sheds and catchment areas</td>
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</table>

| 3.1 Institutional arrangement and harmonizing the functions of various stakeholders on water | Promote integrated water resources management (IWRM) and use the river basin as the framework for planning and investments | 2.0 |
| | Creation of an independent authority/commission on water for effective coordination and holistic management of water resources |  |
| | Strengthen coordination and linkages among Agencies (including NGOs, CSOs, private) on water issues |  |
| | Water use and control practices required to secure the quantity and quality of water resources, particularly optimal water allocation to different water users through cooperation and coordination |  |
| | Harmonize Policies and Legislations to avoid overlapping and conflicting provisions |  |

<p>| 3.2 Implementation of Eco-efficiency for effective management of water resources | Promotion of Water Safety Plan as a tool to consistently ensure the adequacy and safety of a drinking water supply through comprehensive risk assessment and management approach from catchment to consumers | 10.0 |
| | Prevention of water loss in the system due to breakage of old pipes, leakages and illegal tapping of water |  |
| | Promotion of water efficient fixtures such as water saving sanitary fittings |  |
| | Improving on-farm water management to enhance productivity of water i.e. ‘more crop per drop’. |  |
| | Reconstruction of irrigation systems (lining, better maintenance) to reduce water loss (by as much as 50%) and apply advanced water-saving methods of irrigation |  |
| | Promoting the rational use of industrial water through reuse, cascade use, water saving processes and equipment |  |
| | Reducing water use through metered charging, progressive charging, fair water pricing, water saving equipment |  |</p>
<table>
<thead>
<tr>
<th>4. Mainstream Climate Change and Water Resources into national plans and programmes</th>
<th>4.1 Developing water and climate change mainstreaming tools and guidelines</th>
<th>Develop tools and guidelines to address water and climate change in national and local development plans and programmes</th>
<th>1.0</th>
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<tr>
<td></td>
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<td>Review, assess and realign institutional set up and mandates of water agencies for effective coordination, synergy, and service delivery</td>
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<td>Strengthen local capacity and community engagement in incorporating and implementing water and climate change adaptation activities</td>
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<td>Integrate existing and emerging knowledge on water and climate change into water management plans and development programs to ensure climate proofing</td>
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<td>Plan for incremental adaptation actions in tandem with improving climate projections</td>
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</table>

**TOTAL 44 million USD**

### 9.0 Regional Action plan

As per the discussion during the Expert group regional consultative meeting in Dhaka, Bangladesh, 2-3 July, 2011, on developing a 10 year regional roadmap beginning 2012 on securing natural freshwater systems of the eastern Himalayas, the following actions have been considered for regional collaboration: The identified areas of cooperation are divided into two broad headings: Climate Change and its impact on regional water resources and sharing of knowledge and capacity building, as detailed below:

#### A. Climate change and its impact on regional water resources

1) Assessment of existing hydro-meteorological network and enhancement of data collection process;

2) Review of state-of-art in climate modeling in the form of GCM/RCMs and selection of appropriate modeling tools for development of hydrological scenarios at different scales in the region;

3) Enhance ecosystem management practices to minimize the impacts of climate change induced disasters;
4) Develop effective approaches and actions concerning disaster management;
5) Building resilience to climate change impacts through conservation of mountain, coastal and wetland ecosystems; and
6) Promote traditional water conservation techniques coupled with modern methods to increase water use efficiency.

B. Sharing of knowledge and capacity building
1) Lessons, good practices and appropriate technologies shared in the region to improve water use efficiency for effective adaptation;
2) Quantify and value the environmental services of Eastern Himalayan ecosystems as a source of water;
3) Networking of national centers of learning and institutes for related capacity building and carrying out necessary studies;
4) Dissemination of success stories and best practices on climate change adaptation; and
5) Sharing of related knowledge products for improving the understanding of climate change impacts on water resources in the region.

Bibliographical references:

1. Adapting to climate change: risks and resilience. Theme 4 – Basin level management: How can IWRM deliver solutions?


47. Rupa Kumar, K; Sahai, AK; Krishna Kumar, K; Patwardhan, SK; Mishra, PK; Revadkar, JV; Kamala, K; Pant, GB (2006) ‘High resolution climate change scenario for India for the 21st Century’. Current Science 90: 334-345.

48. Rural Water Supply and Sanitation Scheme, Public Health Engineering Division, Department of Public Health, MoH, Bhutan.


51. UWICE, WWF Bhutan program office, Inventory of high altitude wetlands in Bhutan, 2010.


57. Yao, TD; Guo, XJ; Lonnie, T; Duan, KQ; Wang, NL; Pu, JC; Xu, BQ; Yang, XX; Sun, WZ (2006) ‘δ18O Record and Temperature Change over the Past 100 years in Ice Cores on the Tibetan Plateau’. Science in China: Series D Earth Science 49(1): 1-9.

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