National Environment Commission

Royal Government of Bhutan

Report on Community Level Water Resources
Pema Gatshel Dzongkhag

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Analysis of Water Source Survey Data and Hydrological Analysis of Water Availability Projections under Different Climate Scenarios in Pema Gatshel Dzongkhag

National Environment Commission

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Foreword

Water is a trans-boundary element that is essential to support life and livelihoods. Conservation and possible improvement of water resources in terms of quality and quantity as well as availability is crucial to ensure a healthy water system that can meet both current and future demands. Global issues of water scarcity and pollution are increasing, with many communities facing water related problems. In Bhutan, the current water availability exceeds the demand but issues in terms of spatial and temporal distributions are present, leading to water shortages reported in some areas. The main challenges Bhutan faces in terms of water are that of unpredictable climate, drying up of water resources, accelerated glacier melting, increasing population and urbanization, accessibility and management issues, and stakeholder participation and multi-sectoral coordination issues.

Quantification of water resources is essential for developing management strategies to maintain or improve our resources and to address any existing issues. Projections of availability of the water resources under different climate scenarios and time periods can help us develop plans to ensure that future demands are met. Public opinions on the water resources available should also be taken into consideration in order to recognize critical areas that require support or interventions. This report aims at meeting the above conditions by providing details on the water resources including measured and observed flows, projected future demands and availability for two climate change scenarios and time periods, and household survey data on water resources.

The current assignment is in line with the second outcome of the National Adaptation Program of Action II (NAPA II) project "Addressing the Risks of Climate-induced Disasters through Enhanced National and Local Capacity for Effective Actions", coordinated by the Climate Change Division of the NECS along with eight implementing partners (IPs). It is linked to Outcome 2.2 "Community level water resources inventory completed and maintained by the Dzongkhag administrations". This report analyzes water source survey data and water availability projections under different climate scenarios in the Dzongkhags of Mongar, Pema Gatshel, Samtse and Tsirang. With this inventory, we hope to help secure Bhutan's current and future water supply.

Karma C. Nyedrup
Officiating Secretary
National Environment Commission Secretariat

Acknowledgement

The National Environment Commission Secretariat would like to thank the Global Environment Facility - Least Developed Countries Fund for the financial support provided to the National Adaptation Programme of Action II and the United Nations Development Programme, under which this inventory was carried out. The NECS would like to express its gratitude to the Dzongkhag officials of Mongar, Pema Gatshel, Samtse and Tsirang for their assistance in data collection as well as feedback provision after the data analysis. The NECS would also like to thank the Department of Forests and Park Services as well as the Renewable Natural Resources sectors of the concerned Gewogs for their support in making this document possible.

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Abbreviations and Acronyms

ADB	Asian Development Bank
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DGM	Department of Geology and Mines
DHPS	Department of Hydropower & Power Systems
DOA	Department of Agriculture
DOFPS	Department of Forest & Park Services
DHMS/NCMH	Department of Hydro-Met Services/ National Center for Hydrology and Meteorology
EIA	Environmental Impact Analysis
EMP	Environmental Management Plan
FEMD	Flood Engineering Management Division (MOWHS)
FNCA	Forest and Nature Conservation Act
GHG	Greenhouse Gas

GI	Galvanized Iron
GLOF	Glacial Lake Outburst Flood
GRF	Government Reserved Forest
HDPE	High Density Polyethylene
HEC HMS	The Hydrologic Engineering Center, Hydrological Modeling System
HEC RAS	The Hydrologic Engineering Center, River Analysis System
HH	Households
ICIMOD	International Center for Integrated Mountain Development
IEE	Initial Environmental Examination
LAP	Local Area Plan
masl	Meters above mean sea level
OHS	Occupational Health and Safety
NECS	National Environmental Commission Secretariat
NAPA	National Adapation Programme of Action
NLCS	National Land Commission Secretariat
O&M	Operation and Maintenance
RGoB	Royal Government of Bhutan
TDS	Total Dissolved Solids
TNA	Training Needs Assessment
ToR	Terms of Reference
WMD	Watershed Management Division, DOFPs, MOAF
WRCD	Water Resources Coordination Division, NECS

Local Names

Kholsa	–	Stream in Lhotshamkha/ Nepali
Kuwa	–	Pond in Lhotshamkha/ Nepali
Pani	–	Water in Lhotshamkha/ Nepali
Khola	–	River in Lhotshamkha/ Nepali
Nala	–	Drain in Lhotshamkha/ Nepali
Dara	–	Hill in Lhotshamkha/ Nepali
Doban	–	Confulence in Lhotshamkha/ Nepali
Chhu/Chu	–	River/Water in Dzongkha
Ri	–	River/Water in Tsangla

Executive Summary

This assignment is based on the water resource and household survey previously conducted in the target districts as part of the NAPA II Project. The main objective of the project is to evaluate the present water availability and to analyze the climate change impacts on the water resources. Initially, an in-depth information on the district including hydrological modelling results, climate change scenarios and their impacts on respective river basins was collected which was then analyzed to come up with a water resource availability report for the district on a Gewog-wise scale.

Pemagatshel Dzongkhag has an area of 1022 sq. km with 11 Gewogs and a total population of 22,287 consisting of 4,881 households. The district is located in South Eastern Bhutan at an altitude range of 1000-3500 masl. The district has a sub-tropical climatic condition in its lower regions and temperate climatic condition in its higher regions. The average yearly temperature of the district is 17 degree centigrade and average annual rainfall is estimated at about 1867 mm/year. The forest cover of the Dzongkhag is about 87% while agriculture covers only about 7%.

The water available in each Gewog of Pemagatshel was calculated by downscaling the flows of the sub-basins of Drangmechhu. The hydrological modelling results for Drangmechhu basin were used for Pemagatshel as the district falls within the Drangmechhu basin. These hydrological modelling results were from the ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management, 2016 – Stand Alone Report on "Hydrological Modelling and Water Resource Assessment of Bhutan." The flows generated for each of the sub-basins of the Drangmechhu from the model were downscaled to the Gewogs using the Area Ratio method. The Gewog areas falling inside the sub-basins were delineated in GIS and subsequently their flows were calculated based on their respective sub-basin flows. The model calibration for Drangmechhu Basin was done using observed data at sub-basin level and the model was run for the period from 2000 to 2013. The available water at each Gewog was then calculated from the model results.

As per the downscaled flow results, the maximum flow generated was 101.48 MCM/month in July for Norbugang and minimum flow of 0.55 MCM/month in December for Yurung Gewog.Water available per capita per month for each Gewog was also calculated with the current and estimated future population figures and compared with demand for water. The available water for each Gewog was found to be comparatively higher than the actual demand for all the months but their distribution and timely occurrence may lead to deficiencies in some areas. Shumar Gewog had the highest water demand but the available water was lower than most of the Gewogs in the Dzongkhag. The high water demand may further affect the demand and supplybalance in the Gewog in the future and could possibly lead to severe shortage in some areas.

In Pemagatshel, the demand for water is anticipated to increase in the future with increase in population. Currently, the water requirement is not met in a few areas and some areas in the Dzongkhag face severe water shortages. The availability of water in the future under climate change is uncertain which necessitates quantification of the available water resources. In this assignment, the impacts of climate change on water resources of the Gewogs were assessed from the projected future temperature and precipitation which were used in the HEC-HMS models of the respective basins.

Two scenarios to represent GHG emissions, RCP 4.5 and RCP 8.5 were used to find the available water in the future for the Gewogs. The changes in flows were calculated for two future time periods (2016 to 2046) which represents the future climatic conditions for the year 2030s and (2046 to 2075) for the year 2060s with respect to the historical time period (1970-2010). The flows for the Gewogs show an overall increase in the mean annual flow for both the future scenarios and time periods but with discrepancies in their monthly trends. An increase in the mean yearly flow may be favourable for the farmers in the district but uneven or high increases in some months may be problematic. A decrease in the month of December is prominent in all of the scenarios and time periods and also for most of the winter months which may indicate further decrease in flows in the future. The increase in water demand in the Gewogs and increasing population coinciding with decrease in flows for some months may cause an imbalance in terms of the demand and supply in the future.

An attempt was made to compare the observed and the modelled flows from the water survey location points. A total of 687 points were surveyed during the Community Level Water Resources Inventory of 2017 for both dry and wet seasons. These points were overlaid on the Gewog map of Pemagatshel and the catchments of the points were delineated with watershed analysis tool in GIS using DEMs of 25 m resolution. In some cases, these points did not fall on a streamline generated from the 25m resolution DEM and few points were found outside the designated Gewogs. These errors could be due to faulty DEM, GPS or also due to springs and ponds which do not have a contributing catchment. Some of these points were verified in the recent field visit conducted by the NECS. It was found that most of these points fell on water bodies or ponds whose catchments cannot be identified in GIS. The household survey results also reveal high dependence of households on spring water and ponds in some cases. Out of 687 measurement points, catchments of only 36 water source location points could be identified and delineated in GIS. The daily average flow for those points whose catchments could be identified was calculated from the total Gewog flow using the Area Ratio method.

Most of the observed flow data falls within the monthly flow availability of their corresponding catchment flows delineated in GIS. This makes us believe that the point measurements are reliable and so is the modelled data. However, it may be noted that these figures should not be used to design structures or for practical decision making purposes. These figures are only indicative of where the possible problems may arise and could be used for prioritization and planning of projects and activities to further investigate the areas.

Individual household survey was also carried out in the Gewogs of Pemagatshel to comprehend the status of the available water in terms of quality and quantity. This survey was done for a sample size of 263 households in 9 Gewogs of Pemagatshel. From the Water Resource Inventory, a set of 22 questions were found relevant and accordingly used for the analysis. It was found that there is a high dependence on spring water sources followed by streams in the Dzongkhag. The results on year long water availability also revealed majority of the Gewogs to have adequate water throughout the year.

The maximum percentage of water source abandoned was found in Dechhenling and Dungmaed Gewogs. Most of the Gewogs have functional RWSS systems. Comparisons were also made based on water adequacy results and RWSS functionality results to check for consistency. The RWSS functionality results and the water adequacy results showed a good match for most of the Gewogs. Out of 111 respondents in the Dzongkhag, only 23.85% found the irrigation water abundant whereas majority found it inadequate. Majority of the respondents were satisfied with the water quality of their locality. It is noted that for some questions the number of respondents were less than 50% of the surveyed population and conclusions could not be drawn directly. Nevertheless, the Gewog-wise results on individual questions have also been analysed and interpreted where possible.

Chapter 1 : Introduction

Water resource is crucial to humans and all other forms of life. It plays an important role in a country's economy contributing significantly to increasing production and productivity. Water scarcity is prominent in most parts of the world with increasing demands that exceed the supply thereby causing an imbalance. On an average, 4 out of every 10 people are affected by water scarcity globally[1].

Bhutan has abundant water resources having the highest per capita water availability of 94,500 m^3/capita/annum[2] but imbalance in terms of spatial and temporal distributions have led to experience of shortages in local areas[3]. The major challenges and threats the country faces presently on its water resources are due to unpredictable climate, drying up of water sources, increasing population and urbanization, accelerated glacier melting, accessibility and management issues and stakeholder participation/multi-sectorial coordination issues. The Water Act of Bhutan 2011 and the Water Regulation of 2014 recognize increasing threats on the quality and quantity of water resources under rapid socio-economic development and also the need for stakeholders' coordination in managing Bhutan's water resources. The Act mandates the National Environment Commission Secretariat (NECS) to prepare and periodically update, in consultation with competent authorities, a National Integrated Water Resources Management Plan for the management of water resources. Consecutively the NECS in compliance with the Water Act and the 11th FYP initiated the National Integrated Water Resource Management Plan (NIWRMP), 2016 under the ADB-funded technical assistance.

Bhutan has five major river basins *Amo Chhu, Wang Chhu, Punatsang Chhu, Mangde Chhu and Drangme Chhu*.. The rivers are mostly fed by rainfall supplemented by an estimated 2-12% glacial melt and another 2% from snow melt (GWP). Climate change brought about by global warming is the biggest threat to the available water in the country. As per the climate assessment report of NIWRMP, the temperature is expected to rise with higher increases in the northern parts of the country under RCP 4.5. The rainfall shows an increasing trend with spatial and temporal variations. Increasing temperature is presumed to increase the evapotranspiration rate thereby increasing the crop-water demand, which in turn would reduce the river flow.

The current Assignment is in line with the second outcome of the project "Addressing the Risks of Climate-induced Disasters through Enhanced National and Local Capacity for Effective Actions", coordinated by the Climate Change Division of NECS along with eight implementing partners (IPs). It is funded by the Least Developed Countries Fund to address

[1] World Health Organization, 2012, http://www.who.int/en/
[2] Water – Securing Bhutans Future - Asian Development Bank/National Environment Commission
[3] Bhutan State of the Art of the Environment - National Environmental Commission Secretariat, 2016

some of the climatic vulnerabilities in Bhutan. The second outcome aims at enhancing community resilience to climate-induced risks by addressing problems on water. The current assignment is linked to the outcome 2.2 “Community-level water resources inventory completed and maintained by Dzongkhag administrations”. This assignment is for “conducting analysis of water source survey data and hydrological analysis of water availability projections under different climate scenarios in Samtse, Tsirang, Pemagatshel and Mongar.” It is part of the NAPA II project in the above four targeted Dzongkhags to provide the present status of water resources and the future water availability projections in these targeted Dzongkhags. According to the NAPA II project document[4], the districts of Mongar, Tsirang, Pemagatshel and Samtse are selected for the community-level water resources inventory (Output 2.2) because of its linkage with output 2.1 in water harvesting, storage and distribution system in the four Dzongkhags and the opportunity for complementing the efforts and synergy between the two outputs. The reason for selecting the above four Dzongkhags for the water harvesting project in Output 2.1 is due to high level of poverty incidences; Tarayana Foundation’s involvement in these Dzongkhags for local community development; and to address water scarcity within the overall context of poverty reduction and sustainable livelihoods at the grassroot level.

A National Water Resources Inventory (NWRI) was carried out in 2014 and 2015 which provided a general assessment of the water resources in all 20 Dzongkhags of Bhutan. The report provided information on the water flow measured at a number of water sources in each of the Dzongkhags and focused on establishing the maximum and minimum flow of the selected sites. However, the report was a primary assessment and a need for more detailed inventory with possible inclusion of hydrological modeling, climate change projections and household survey data was recommended. Thus, this document is intended to provide a more detailed inventory on a larger number of water resources in each of the selected Dzongkhags with additional information such as hydrological modeling and basin delineation through GIS, water availability and demand for both current and future climate change scenarios, and a compilation of household survey data to assess the public views on the existing water resources.

1.1 Methodology

The methodology for the current project involved acquiring in-depth information on each of the districts, analyzed and reported in individual reports. Analysis included compilation of previous surveys, studies, hydrological modelling results, climate change scenarios and their impacts on the respective basins. The method adopted for implementation is best represented by the following flow chart Figure 1-1.

[4]PROJECT DOCUMENT, *Addressing the Risks of Climate-induced Disasters through Enhanced National and Local Capacity for Effective Actions,* UNDP, NECS and GNHC Bhutan. April 2014.

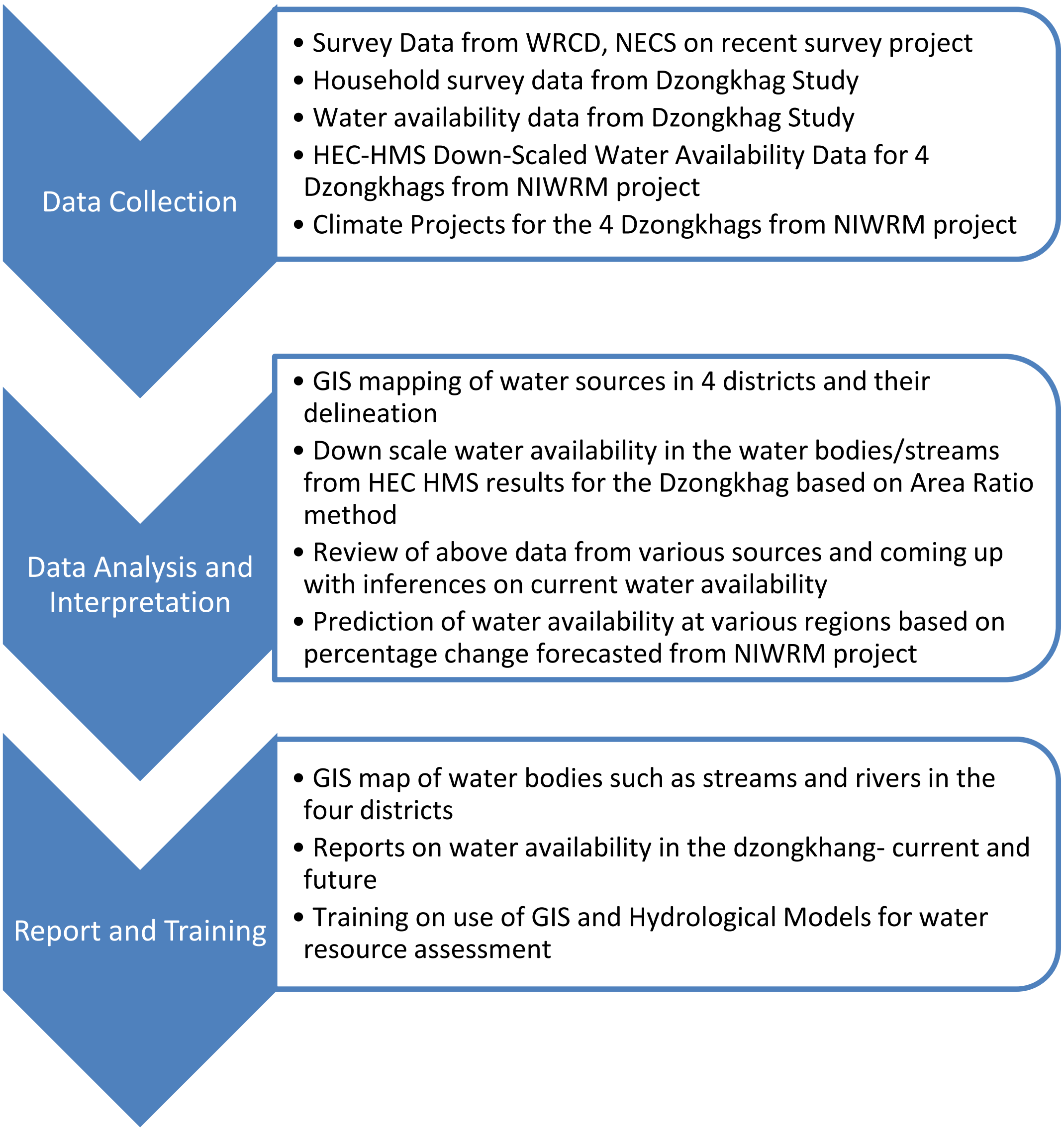


Figure 1-1: Methodology Chart

1.1.1 Data

The data used for the current study are Water Availability Data from Dzongkhag study and data from NWRI Project, HEC HMS down-scaled Water Availability Data for 4 Dzongkhags and Climate Projections for the 4 Dzongkhags from NIWRM project which were compared with the water flow data from the recent survey.

1.1.2 Hydrological Modelling

Hydrological model is an important tool in water resources planning, development and management. The Hydrological models for the basins were developed using HEC-GeoHMS (version 10) in Arc-GIS environment and HEC-HMS (version 4.0). The watershed delineation, hydrological modeling of the basins in HEC HMS, sub-basins and determination of the flows were done to determine the availability of the water resources from different streams in the project areas.

i. Watershed Delineation

The contributing areas for a particular stream were delineated in Arc GIS 10.3 using 25 meters resolution Digital Elevation Model (DEM). The DEM represents a topographic surface in terms of grids of elevation values derived at a finite number of points. HEC-GeoHMS an extension on ArcGIS processes the elevation and spatial information to develop river networks, basin boundaries and other hydrological inputs for developing the HEC-HMS model. HEC-GeoHMS was used to make the divisions based on the river network configuration.

ii. HEC-HMS

HEC-HMS is a hydrological modelling software designed to simulate precipitation-runoff processes for watershed systems in a wide range of geographical areas. It has three main components, the Basin Model, the Precipitation Model and Control Specification. Among the nine different loss methods available in HEC HMS to simulate precipitation losses, the Initial/Constant method and the SCS Curve number method were applied appropriately in modeling the basins. Transform model was selected and either Clark method or SCS unit hydrograph was used in the modelling the basins. The constant monthly method was used for base flow modeling. The catchment average rainfall was calculated using Thiessen polygon method. Once the model is developed, efficiency of the model depends on its parameters. For calibrating the model, observed rainfall and runoff data for selected periods were used.

1.2 Climate Change Impacts on Water Resources

Bhutan has rich perennial water resources with most of its rivers fed by permanent glaciers & glacier lakes. The long-term mean annual flow for the entire country is about 73,000 MCM. There are five major river basins in the country namely *Amo Chhu, Wang Chhu, Punatsang Chhu, Drangme Chhu and Manas.* The basin locations along with their areas are shown in Figure 1-2 and Table 1-1 respectively.

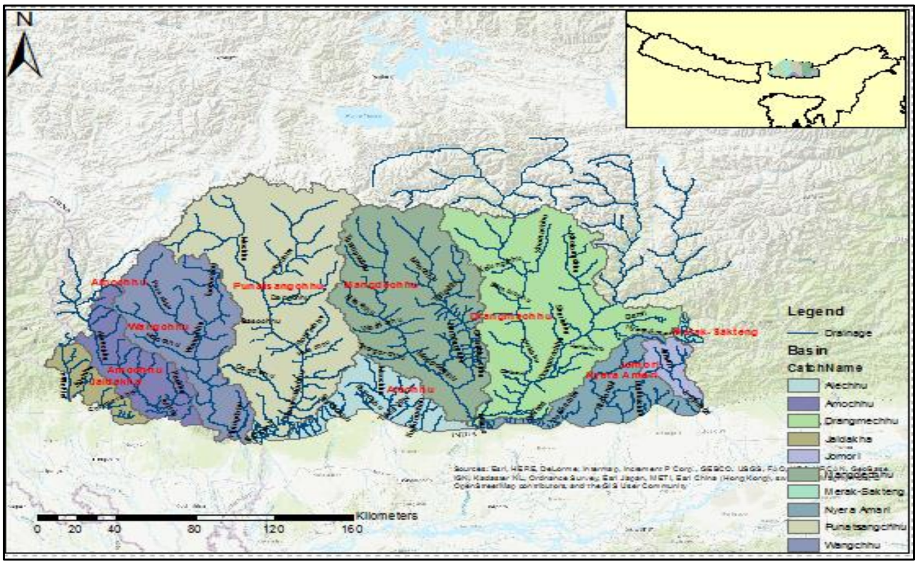


Figure 1-2: Basins

Table 1-1: River Basin Area

<table>
<tr><th>Management</th><th>Area (km²)</th><th>River Basins</th><th>Area</th><th>Annual flow</th></tr>
<tr><td rowspan="2">Amo Chhu</td><td rowspan="2">3,252</td><td>Jaldakha</td><td>942</td><td>2,715.64</td></tr>
<tr><td>Amo Chhu</td><td>2,310</td><td>6,659.36</td></tr>
<tr><td>Wang Chhu</td><td>4,596</td><td>Wang Chhu</td><td>4,596</td><td>5,209.06</td></tr>
<tr><td rowspan="2">Punatsang Chhu</td><td rowspan="2">11,582</td><td>Punatsang Chhu</td><td>9,645</td><td>19,129.79</td></tr>
<tr><td>Aie Chhu</td><td>1,937</td><td>6,989.14</td></tr>
<tr><td>Mangde Chhu</td><td>7,380</td><td>Mangde Chhu</td><td>7,380</td><td>11,797.24</td></tr>
<tr><td rowspan="4">Drangme Chhu</td><td rowspan="4">11,584</td><td>Drangme Chhu</td><td>8,457</td><td>13,569.14</td></tr>
<tr><td>Nyera Amari</td><td>2,348</td><td>3,383.89</td></tr>
<tr><td>Jomori</td><td>642</td><td>925.24</td></tr>
<tr><td>Merak - Sakteng</td><td>137</td><td>197.44</td></tr>
<tr><td>Total</td><td>38,394</td><td>Total</td><td>38,394</td><td>70,576.01</td></tr>
<tr><td rowspan="3" colspan="2"></td><td colspan="2">Population</td><td>746,773</td></tr>
<tr><td colspan="2">Per Capita Water Available</td><td>94,508.04</td></tr>
<tr><td>Flow</td><td></td><td>2,238.0 m³/s</td></tr>
</table>

Source: ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management, 2016- Standalone Report on "Hydrological Modelling and Water Resource Assessment of Bhutan."

Climate Change is expected to be a major driver of change to the fragile natural ecosystem in the country. The glaciers in the Himalayas are reported to retreat faster than other parts of the world, putting mountainous countries such as Bhutan lying in the region at greater risk in the future. Bhutan has already experienced partial outburst of its glacier lakes in some parts of the country and it has been experiencing an increase in frequency of intense monsoon rains causing flash floods and landslides.

1.2.1 Meteorological Parameters

The following rainfall, temperature and streamflow data and their trends are based on Historical Hydrological and Climatic Data collected by the National Center for Hydrology and Meteorology (NCHM) since 1985. However, reliable and consistent data were available only from mid 1990s. The key information about the climate and water are given in the sub-headings below.

i. Temperature

The monthly average temperature averaged for 17 years for the twenty Dzongkhags is shown in Figure 1-3. The average temperature for the entire country is shown in dotted yellow line in the figure below. The highest temperature recorded was 28.3°C in the month of August for Chukha and the lowest of 2.7°C in Haa in the month of January. The highest monthly average temperature for the entire country is about 22.22°C for the month of August and lowest of 10.14°C for January. Overall, Chukha Dzongkhag has the highest monthly temperature from the twenty Dzongkhags and Haa Dzongkhag has the lowest temperature.

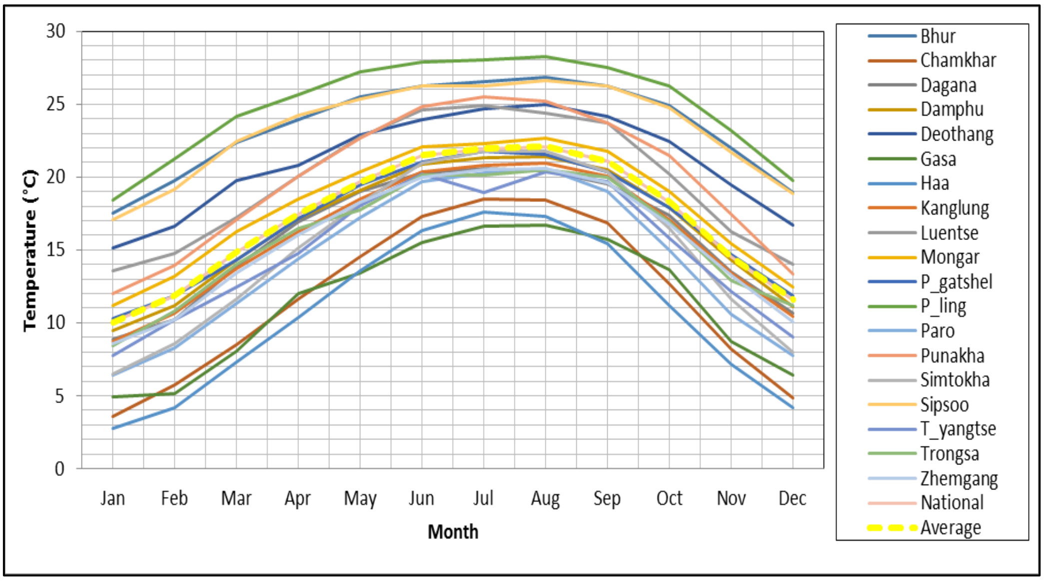


Figure 1-3: Monthly Temperature Variation

ii. Rainfall

Figure 1-4 shows the average rainfall of the twenty Dzongkhags averaged over 17 years. The total annual rainfall averaged over the country is 1,797.6 mm. The lowest total annual rainfall was recorded for Thimphu (602 mm), while the highest was recorded for Samtse (5461 mm). The trend of total annual rainfall across Bhutan is shown in Figure 1-5.

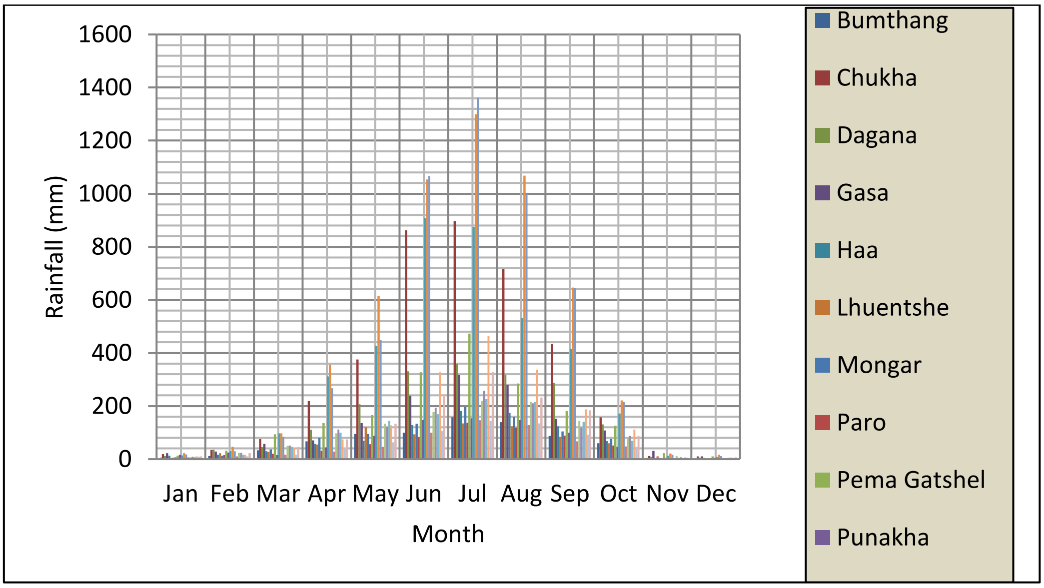


Figure 1-4: Monthly Rainfall across Bhutan (1996-2013)

Generally a decrease in trend in the total annual rainfall can be observed. This decrease was found to be insignificant considering that the decrease was less than 1% of the annual average values and the root mean square error (R2) value close to zero indicating that the decrease is not significant and consistent. The only stations that are showing positive slope are Gasa, Trongsa and Mongar which is only 4 from the 20 stations.

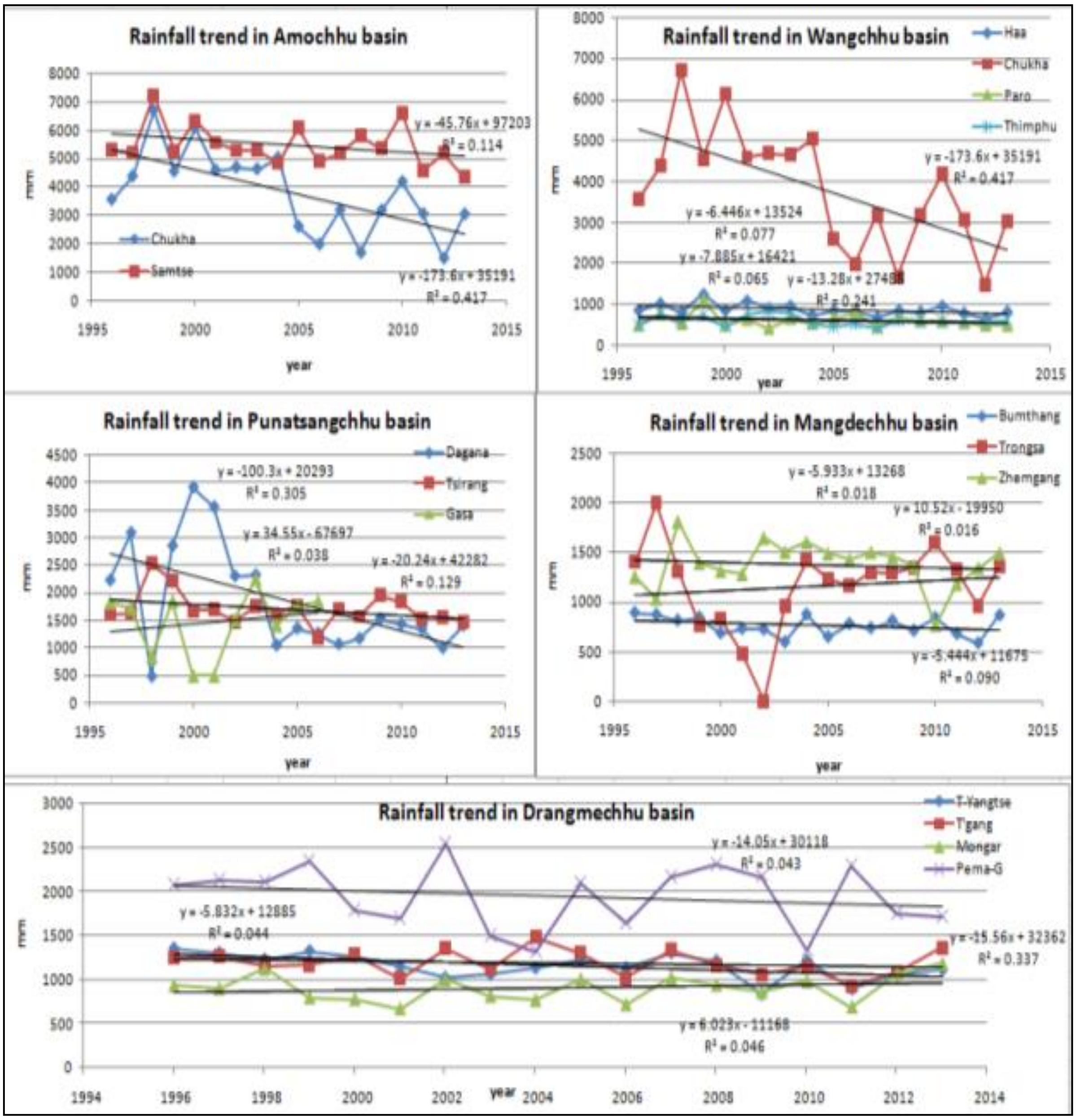


Figure 1-5: Annual Trends in Rainfall

iii. Hydrological Data.

The flows for various stations around the country are shown in Figure 1-6. The highest flows were recorded in the months of June to September, which contributed to about 76.3% of the total annual flow out of which the month of July contributed the highest percentage (21.3%) while the least was recorded in the month of February (1.8%). The main rivers were observed to have higher variations compared to smaller rivers. These seasonal variations in the flows are shown in Figure 1-6. There is no major flow variation between the months of

January to March but a gradual increase in the flow was seen starting from April till July and there after a decrease.

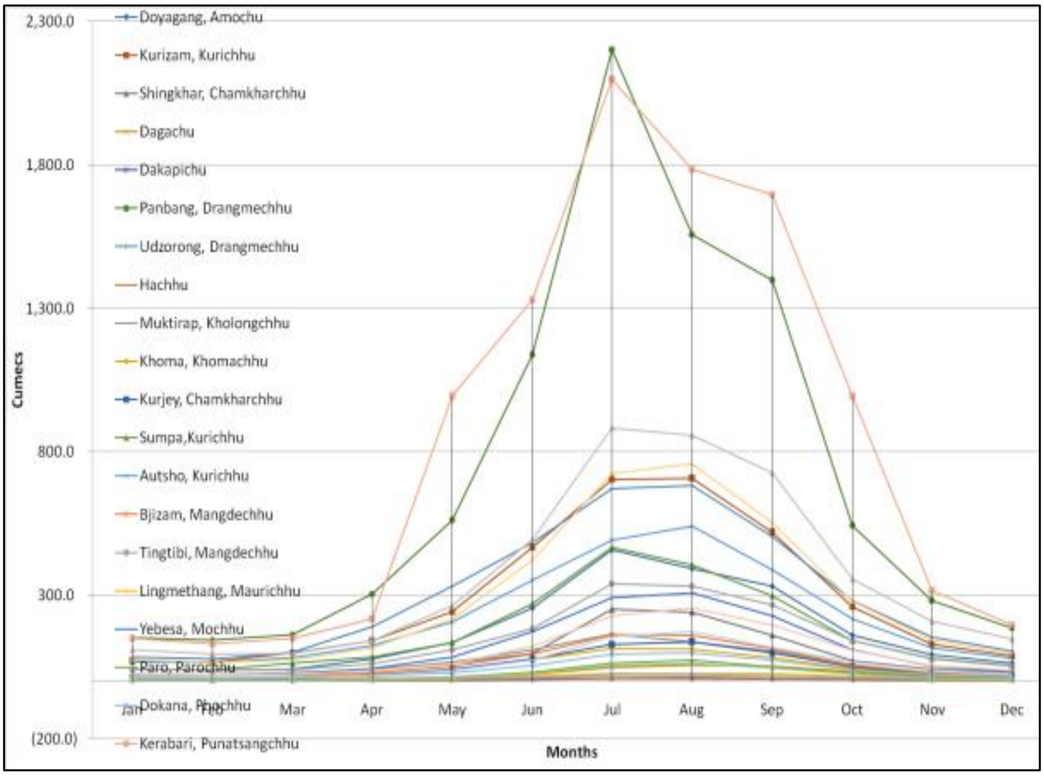


Figure 1-6: Seasonal Variation of River Flows

1.3 Glaciers and Climate Change

Bhutan has a total of 642 + 16.1 km^2 area under glacier cover (2010) that is about 1.6% of Bhutan's total land area as shown in Figure 1-5. As per the IPCC (Intergovernmental Panel on Climate Change) many glaciers are likely to disappear completely due to an increase in the equilibrium-line altitude. A volume loss of 60% of glaciers is projected by 2050 based on simulations of 11 glaciers in various regions. Bajracharya and team in 2014[5]confirmed that the glacier area in Bhutan was decreasing and that the changes were rapid. Bhutan is at a high risk of frequent Glacial Lake Outburst Flood (GLOF) in the future. Till date there had been 21 GLOF outburst cases in the Bhutan. Therefore, it is essential that glaciological studies are done extensively as there is very limited information about them.

[5]Bajracharya et al. 2014: The status and decadal change of glaciers in Bhutan from the 1980s to 2010 based on satellite data. Samjwal Ratna BAJRACHARYA, Sudan Bikash MAHARJAN, and Finu SHRESTHA. Annals of Glaciology 55(66) 2014 doi: 10.3189/2014AoG66A125.

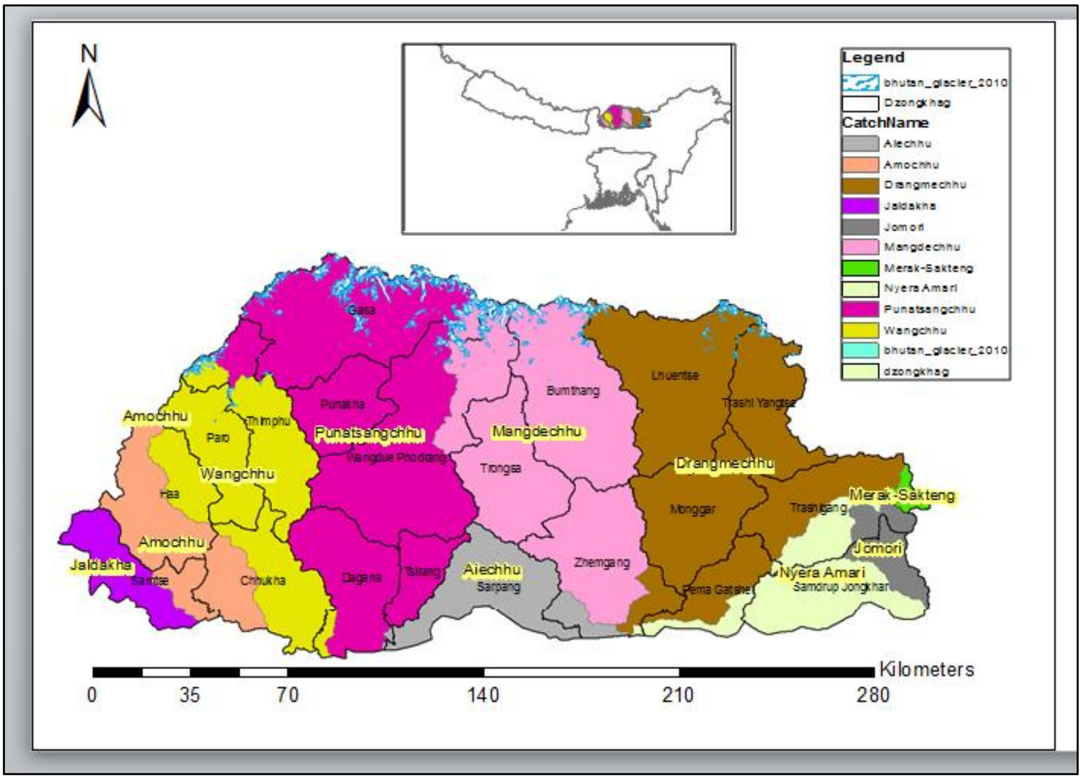


Figure 1-7: Glaciers of Bhutan

Chapter 2 : Pemagatshel Dzongkhag

Pemagatshel is located in South Eastern Bhutan at an altitude range of 500 to 3,000 meters above sea level. It has area of 1022 sq. km. with 11 Gewogs with a total of 4881 households. The topography of the district is characterized by steep slopes and narrow valleys with about 53% of the total area under broadleaf and coniferous forests cover and nearly 43% cultivable land. There are only negligible wetland farming activities and majority is dominated by Tseri Cultivation (shifting cultivation) despite its ban in 1995, leading to degraded land in the district. Cultivation in dry land is also a dominant agricultural practice with maize grown as the main cereal crop. The Dzongkhag forms a part of the Drangmechhu basin and the Nyera Amari basin. The Nyera Amari basin is also considered as a part of the Drangmechhu basin and it joins the Drangmechhu River outside the country. The major problems faced by most farmers currently in the district include lack of water sources for irrigation, extensive wildlife crop depredation and problems regarding accessibility.

2.1 Demographical Characteristics

Pemagatshel Dzongkhag has a population of 25426 (2015)[6]. It has 11 Gewogs as shown in Figure 2-1, the areas of which are mentioned in Table 2-1. The details of the population in each Gewog by gender are mentioned in Table 2-2 and the household size and numbers per Gewog are mentioned in Table 2-1. The district has a total of 4881 households.

Table 2-1: Gewog Areas

Sl. No.	Gewog Name	Dzo_Name	Area (Sq.Km)
1	Norbugang	Pemagatshel	181.65
2	Choekhorling	Pemagatshel	126.47
3	Dechhenling	Pemagatshel	137.02
4	Dungmaed	Pemagatshel	109.98
5	Chhimoong	Pemagatshel	52.83
6	Yurung	Pemagatshel	28.2
7	Chongshing	Pemagatshel	31.03
8	Khar	Pemagatshel	114.08
9	Shumar	Pemagatshel	92.16
10	Zobel	Pemagatshel	67
11	Nanong	Pemagatshel	81.69
		Total	**1,022.10**

Source: National Statistic Bureau, 2008

[6] –Statistical Year Book, 2016, National Statistics Bureau

Table 2-2: Gewog Population (2005)

Sl. No.	Dzongkhag/ Gewog/Town	Persons			Percent			Sex ratio (males per 100 females)
		Male	Female	Total	Male	Female	Total	
1	Chhimoong	347	402	749	3.12	3.6	3.36	86.32
2	Chongshing	416	518	934	3.74	4.63	4.19	80.31
3	Dungmin	680	790	1,470	6.12	7.07	6.6	86.08
4	Khar	923	923	1,846	8.31	8.26	8.28	100
5	Shumar	1,710	1,858	3,568	15.39	16.62	16.01	92.03
6	Yurung	601	712	1,313	5.41	6.37	5.89	84.41
7	Zobel	875	822	1,697	7.88	7.36	7.61	106.45
8	Nanong	1,144	1,207	2,351	10.3	10.8	10.55	94.78
9	Dechheling	973	1,099	2,072	8.76	9.83	9.3	88.54
10	Norbugang	1,070	953	2,023	9.63	8.53	9.08	112.28
11	Choekhorling	447	512	959	4.02	4.58	4.3	87.3
12	Kaynadang town	34	35	69	0.31	0.31	0.31	97.14
13	Kherigonpa town	95	46	141	0.86	0.41	0.63	206.52
14	Mongling town	46	20	66	0.41	0.18	0.3	230
15	Nangkor town	408	264	672	3.67	2.36	3.02	154.55
16	Pemagatsel town	570	496	1,066	5.13	4.44	4.78	114.92
17	Yalang town	23	12	35	0.21	0.11	0.16	191.67
18	Khothakpa town	128	110	238	1.15	0.98	1.07	116.36
	Total			**22287**				

Source: Population and Housing Census of Bhutan – 2005

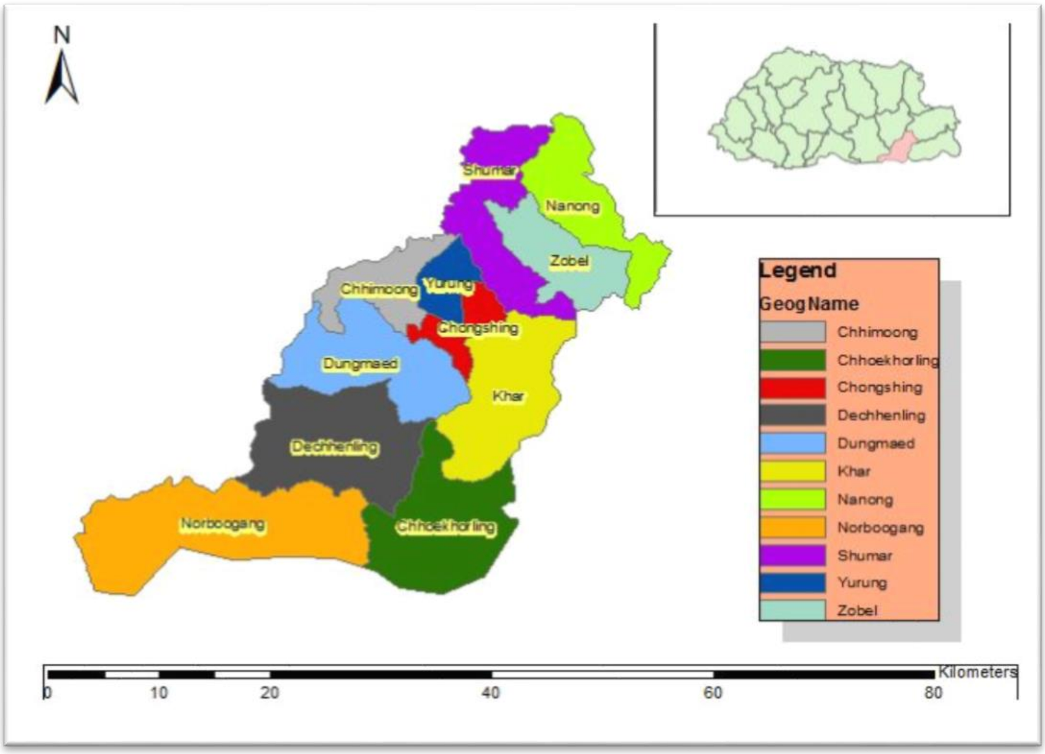


Figure 2-1: Gewogs in Pemagatshel

The topography of the Dzongkhag is characterized by steep slopes and narrow valleys, shown in Figure 2-2.

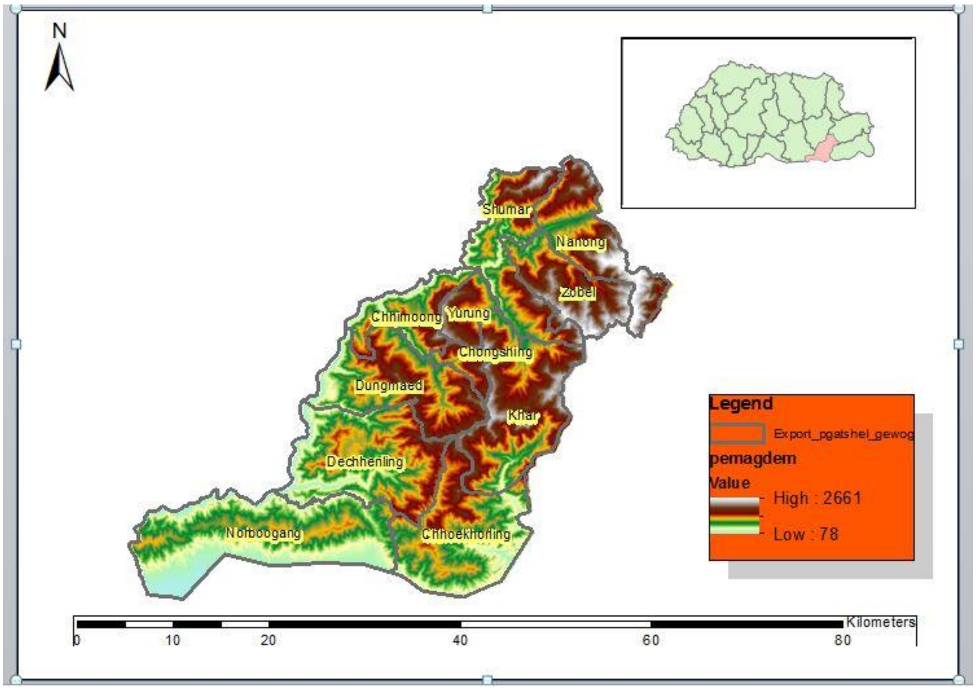


Figure 2-2: Topography by Gewog Pemagatshel

Table 2-3: Household Numbers

Dzongkhag/ Gewog/ Town	Size of Household														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 +	All mem-bers
PEMA GATSHEL	**506**	**777**	**774**	**830**	**780**	**545**	**312**	**181**	**107**	**42**	**10**	**6**	**6**	**1**	**4**	**4,881**
Chhimong	12	34	22	37	25	21	13	4	4	1	2	0	1	0	0	176
Chongshing	28	47	28	35	31	22	12	15	6	3	0	0	1	0	0	228
Dungmaed	26	74	61	63	65	27	21	9	6	3	0	0	0	0	0	355
Khar	58	65	58	57	53	44	30	26	16	3	0	0	0	0	1	411
Shumar	45	82	100	109	101	108	67	43	31	19	5	5	2	1	2	720
Yurung	42	59	45	58	44	34	16	12	7	1	0	0	0	0	0	318
Zobel	54	60	58	55	61	33	25	9	6	3	3	0	0	0	0	367
Nanong	48	72	94	93	94	61	31	25	8	4	0	0	1	0	1	532
Dechhenling	44	92	76	85	95	70	23	8	8	1	0	0	0	0	0	502
Norbugang	41	81	71	68	73	48	34	7	8	1	0	0	0	0	0	432
Choekhor-ling	55	60	61	62	32	16	8	4	1	0	0	0	0	0	0	299

Dzongkhag/ Gewog/ Town	Size of Household															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 +	All mem-bers
Kaynadang town	0	1	2	2	4	2	3	0	0	0	0	0	0	0	0	14
Kherigonpa town	5	0	0	1	6	2	1	2	1	0	0	0	0	0	0	18
Mongling town	0	0	0	0	3	1	1	1	0	0	0	0	0	0	0	6
Nangkor town	10	4	9	5	16	3	4	0	0	0	0	1	0	0	0	52
Pemagatsel town	21	20	35	38	40	26	14	6	5	0	0	0	0	0	0	205
Yalang town	0	1	0	2	0	0	1	1	0	1	0	0	0	0	0	6
Khothakpa Town	9	7	8	17	7	7	2	4	0	0	0	0	0	0	0	61
Nanglam Town	8	18	46	43	30	20	6	5	0	2	0	0	1	0	0	179

Source: Population and Housing Census of Bhutan – 200

2.2 Climate

Pemagatshel has a sub-tropical climate in its lower and southern parts with temperate climatic condition at its higher region. The average annual rainfall in the district is about 1867 mm/year and the average temperature is about 17°C. The average monthly variations from 1996 to 2013 for temperature and rainfall are shown in

and Figure 2-4 respectively.

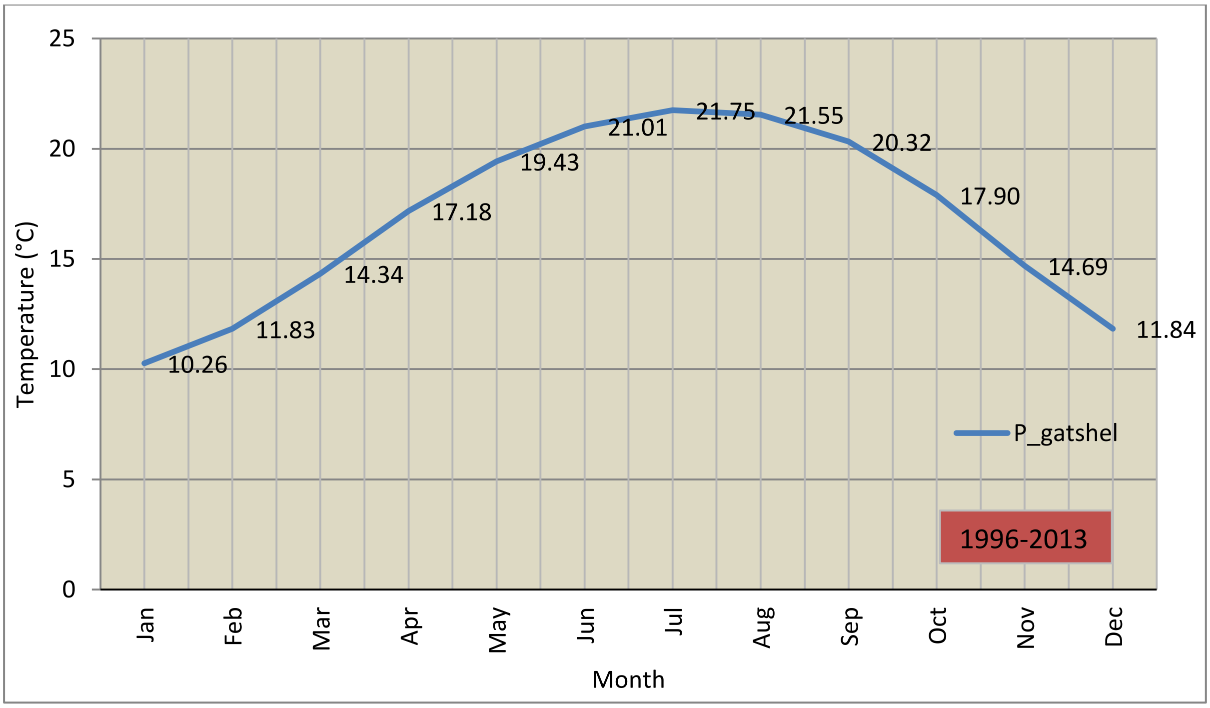


Figure 2-3: Average Temperature for Pemagatshel (1996-2013)

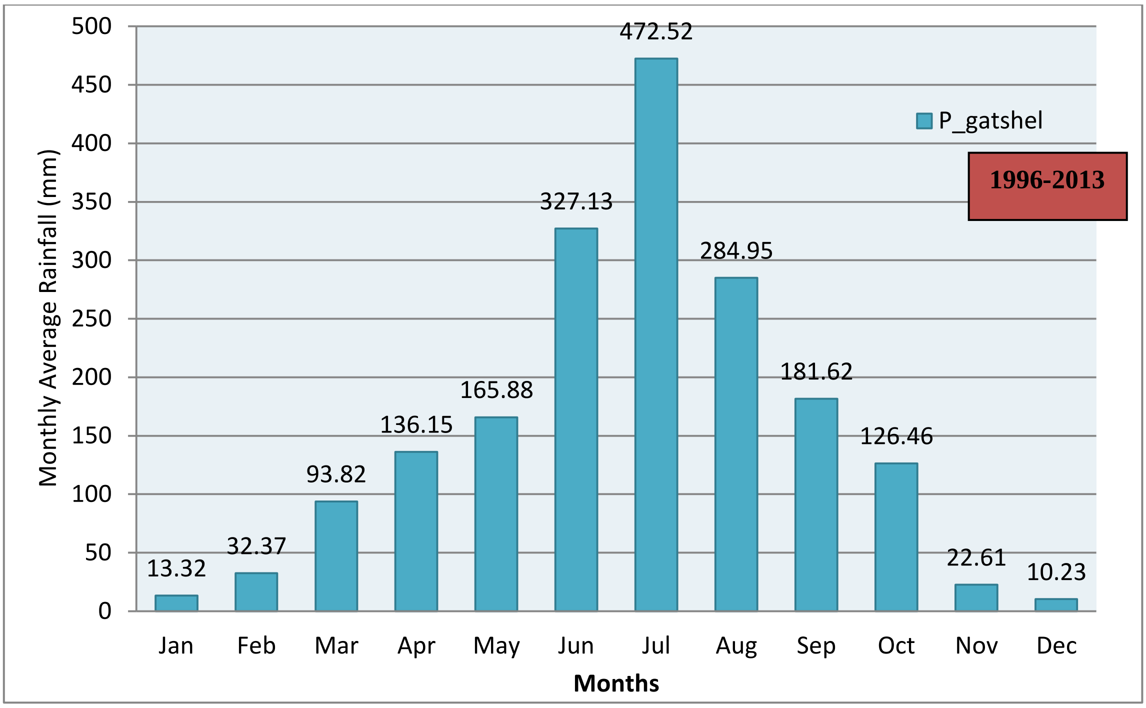
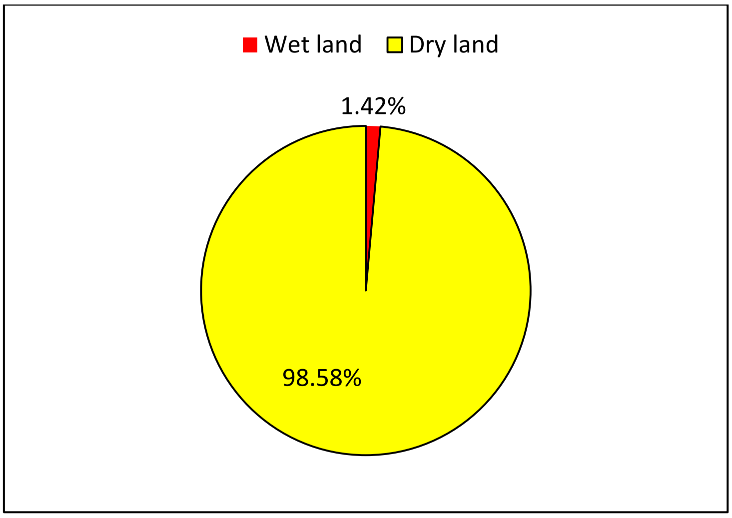


Figure 2-4: Average Annual Rainfall for Pemagatshel (1996-2013)

2.3 Land Use

The district has 87.7% of its area covered in forest followed by agriculture land holdings at 7.37%. The details of the types of agriculture land holdings in the district are shown in Figure **2-5**.

Figure 2-5: Agriculture Land-holdings (%)



Source: Agriculture Statistics 2013, MoAF

2.4 Basin

Drangme Chhu and *Mangde Chh*u Basins together have an area of 28,090.73 sq. km, that covers central and Eastern parts of the country. *Drangme Chhu* has two trans-boundary tributaries with India and China and a total of 5,510 km^2 and 6,676.9 km^2 international areas contributing to Kurichhu and Gongri. *Kuri Chhu* is the longest river in the *Drangme Chhu* basin with a length of 187 km. The districts of Monggar, Lhuentse, Trashi Yangtse, Trashigang and parts of Pemagatshel fall inside the *Drangme Chhu* basin. The Nyera Amari basin is also considered as part of the *Drangme Chhu* management unit, joining the *Drangme Chhu* at the later stages of exiting the country. The *Drangme Chhu* basin and the *Mangde Chhu* basins together are known as the Manas River Basin. The areas of the sub-basins of the *Mangde Chhu* and the *Drangme Chhu* are mentioned in Table 2-4. The Gewog areas of Pemagatshel falling inside the sub-basins of the *Drangme Chhu* and Nyera Amari basin are shown in Figure 2-6and their areas are given in Table 2-5. .Most parts of the districts falls inside the sub-basin W5700 of the *Drangme Chhu* basin and the rest fall inside the Nyera Amari basin. The present per capita average water requirement and the projected increases in the district is mentioned in table 2-6.

Table 2-4: Sub-basins area of Drangmechhu and Mangdechhu Basin

Sl. No.	Sub-basin name	Area sq. km.	Sl. No.	Sub-basin name	Area sq. km.
1	W4490	1,405.65	13	W6310	287.60
2	W4930	1,362.26	14	W5700	2,022.88
3	W4200	889.87	15	W5590	1,394.20
4	W5370	447.58	16	W6160	134.25
5	W4700	658.45	17	W5480	1,387.97
6	W5620	337.53	18	W5670	384.16
7	W3500	5,510.88	19	W6140	24.02
8	W4130	3,585.30	20	W6210	811.40
9	W5580	1,002.09	21	W4910	556.85
10	W4350	54.74	22	W5020	579.05
11	W4780	1,377.20	23	W4270	3,091.59
12	W5130	785.22	2.1.1	**Total**	**28,090.73**

Source: ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management, 2016

Table 2-5: Gewog Areas Inside Drangmechhu Basin and Nyera Amari Basin

Sl. No.	Gewog Name	Dzo_Name	Area (Sq.Km)	Area inside Drangmechhu Basin	Nyera Amari
				Sub-basin W5700	
1	Norbugang	Pemagatshel	181.65	73.60	108.05
2	Choekhorling	Pemagatshel	126.47	126.47	-
3	Dechhenling	Pemagatshel	137.02	125.02	12
4	Dungmaed	Pemagatshel	109.98	109.98	-
5	Chhimoong	Pemagatshel	52.83	52.83	-
6	Yurung	Pemagatshel	28.20	28.20	-
7	Chongshing	Pemagatshel	31.03	31.03	-
8	Khar	Pemagatshel	114.08	45.19	68.89
9	Shumar	Pemagatshel	92.16	92.16	-
10	Zobel	Pemagatshel	67.00	67.00	-
11	Nanong	Pemagatshel	81.69	65.27	16.42
		Total	**1,022.10**	**816.75**	**205.36**

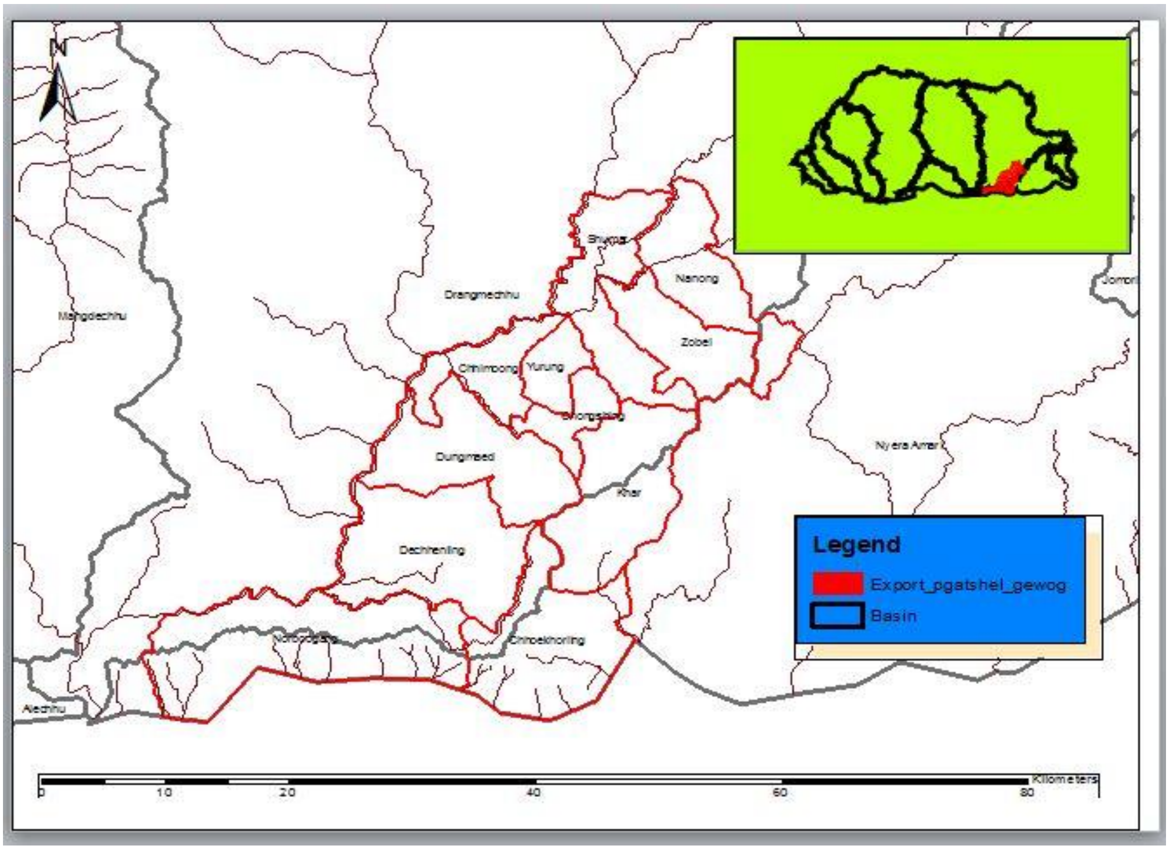


Figure 2-6: Gewogs Areas Falling Inside the Basins of Drangmechhu and Nyera Amari

Table 2-6: Water Demand in Pemagatshel Dzongkhag

Popula -tion in 2005	Populati -on in 2015	Water Demand 2015 - (M3/ Day)	Water Required 2015 (MCM/ Yr)	Water Require d (MCM/ Month)	Populat -ion in 2030	Water Demand 2030 - (M3/ Day)	Water Required (MCM/ Yr)	Water Required (MCM/ Month)
22,287	24,961	2,995	1.09	0.09	31,202	7,800	2.85	0.24

Source: National Statistical Bureau, Royal Government of Bhutan, 2008

In Pemagatshel Dzongkhag, the demand for water in the future is projected to increase by almost 2.6 times the current water requirement by 2030. This increment in water demand is projected for an assumed increase in population of 25% by 2030. Under these assumptions proper water resources management and utilization are crucial for the future.

Chapter 3 : Development of the Rainfall-runoff Model for *Mangde Chhu* and *Drangme Chhu* Basin

3.1 Methodology

The Thiessen polygons for the respective rainfall stations were developed and the weights were checked with the WMO standards. Digital Elevation Model (DEM) of the area was used to generate basin boundary, sub basins and many basin characteristics. The HEC-GeoHMS software was used to make this division and it was made based on the river network configuration. The software develops river network and other information/parameters needed to model the HEC-HMS based rainfall runoff model. The catchment characteristics, viz., river length, river slope, basin slope, longest flowpath, basin centroid, centroidal elevation, centroidal longest flow path were determined at this step. Finally, HEC-HMS rainfall runoff model components, viz., basin model file, meteorological model file, background shape file, etc., were also created at this step. These details could be imported to HEC-HMS for developing the rainfall-runoff model for the basin.

3.1.1 Data

Daily rainfalls at gauging stations were used in the study along with streamflow gauging stations which were used in the calibration and verification of the rainfall-runoff model. The Thiessen polygons for the respective rainfall stations were developed and the weights were checked with the WMO standards. Digital Elevation Model (DEM) of the area was used to generate basin boundary, sub basins and many basin characteristics.

3.1.2 Model Development

The rainfall-runoff model was developed for *Mangde Chhu* and *Drangme Chhu* basin using HEC-HMS software. The total area of the basin (28091 km^2) was divided into 23 sub-basins as shown in Figure 3-1and areas of these sub basins are given in Table 3-1.

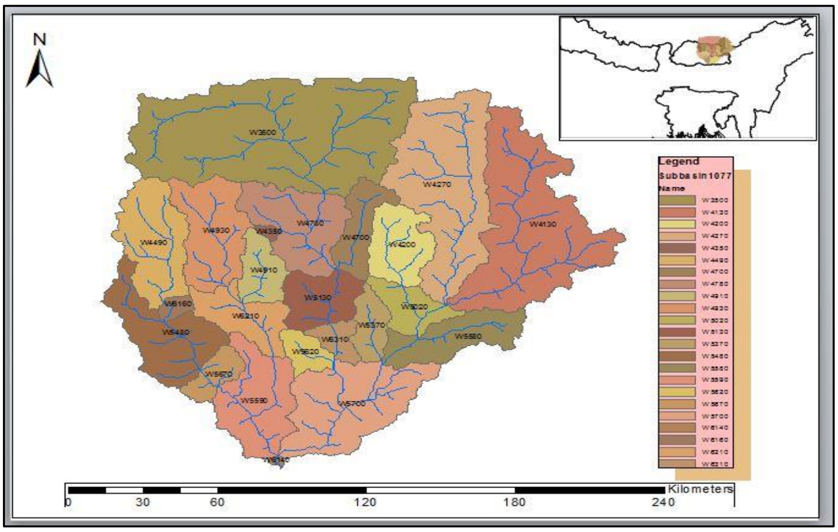


Figure 3-1: Sub-basins of Drangmechhu and Mangdechhu Basins

Table 3-1: Sub-basins of Mangdrechhu and Drangmechhu Basins

Sl. No.	Sub-basin name	Area sq. km.	Sl. No.	Sub-basin name	Area sq. km.
1	W4490	1,405.65	13	W6310	287.60
2	W4930	1,362.26	14	W5700	2,022.88
3	W4200	889.87	15	W5590	1,394.20
4	W5370	447.58	16	W6160	134.25
5	W4700	658.45	17	W5480	1,387.97
6	W5620	337.53	18	W5670	384.16
7	W3500	5,510.88	19	W6140	24.02
8	W4130	3,585.30	20	W6210	811.40
9	W5580	1,002.09	21	W4910	556.85
10	W4350	54.74	22	W5020	579.05
11	W4780	1,377.20	23	W4270	3,091.59
12	W5130	785.22	**24**	**Total**	**28,090.73**

The calibration and validation of the model was done based on observed rainfall and runoff data and the model was simulated for the period 2000 to 2013. The observed and simulated flow for the stations in *Drangme Chhu* and *Mangde Chhu* is shown in Figure 3-2 to Figure 3-5.

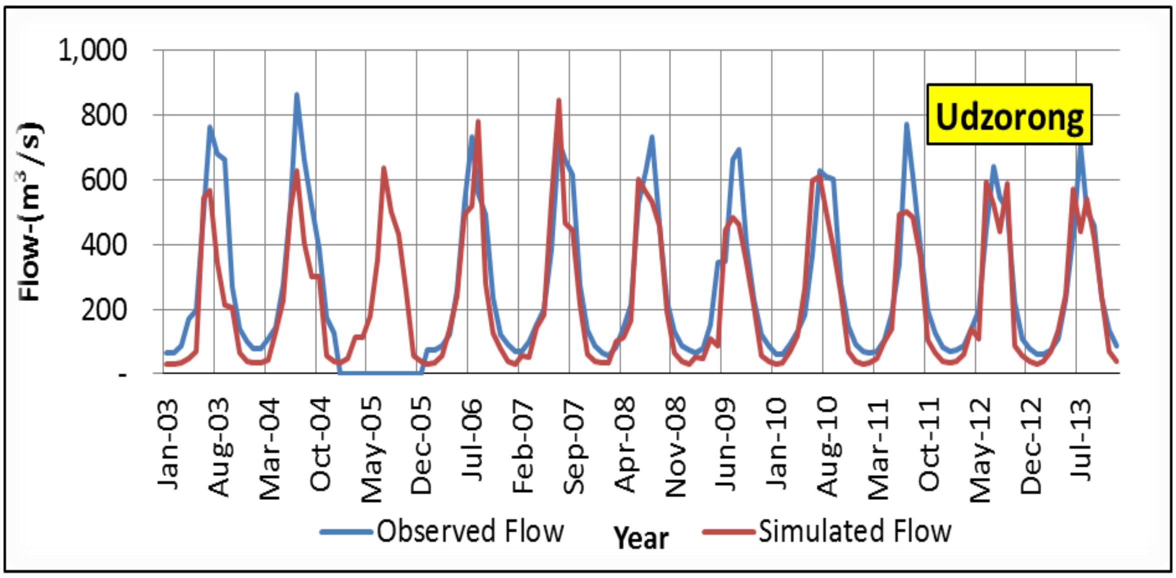


Figure 3-2: Observed and Simulated Flows at Udzorong Station

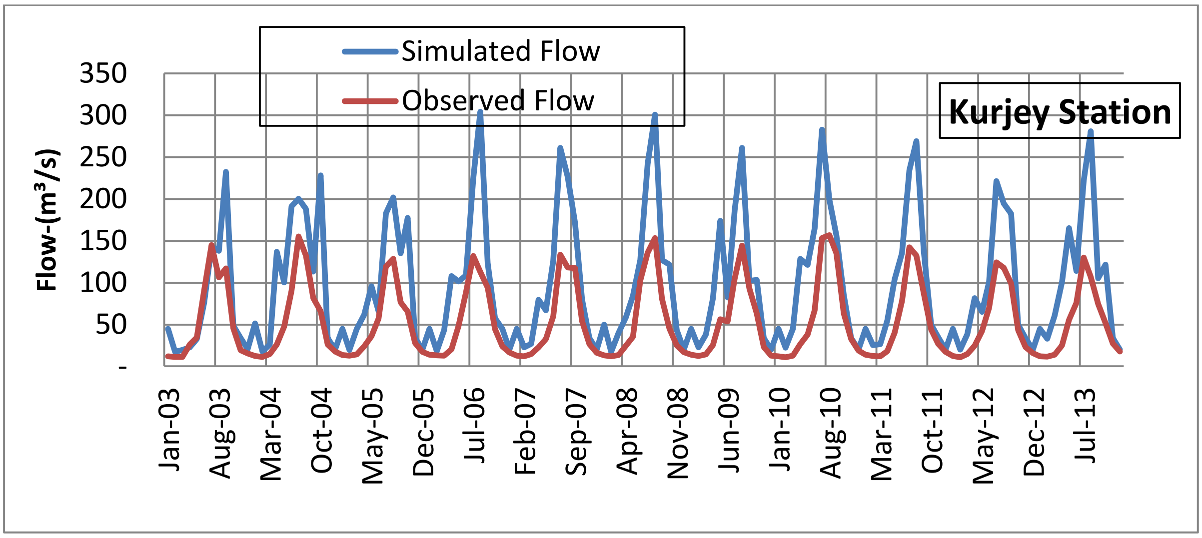


Figure 3-3: Observed and Simulated Flows at Kurjey Station

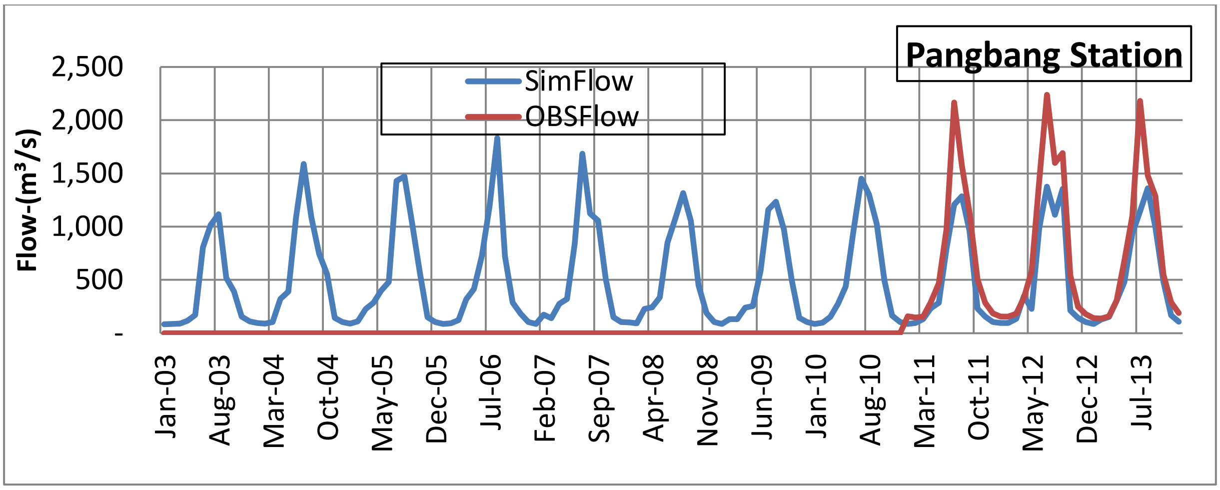


Figure 3-4: Observed and Simulated Flows at Pangbang Station

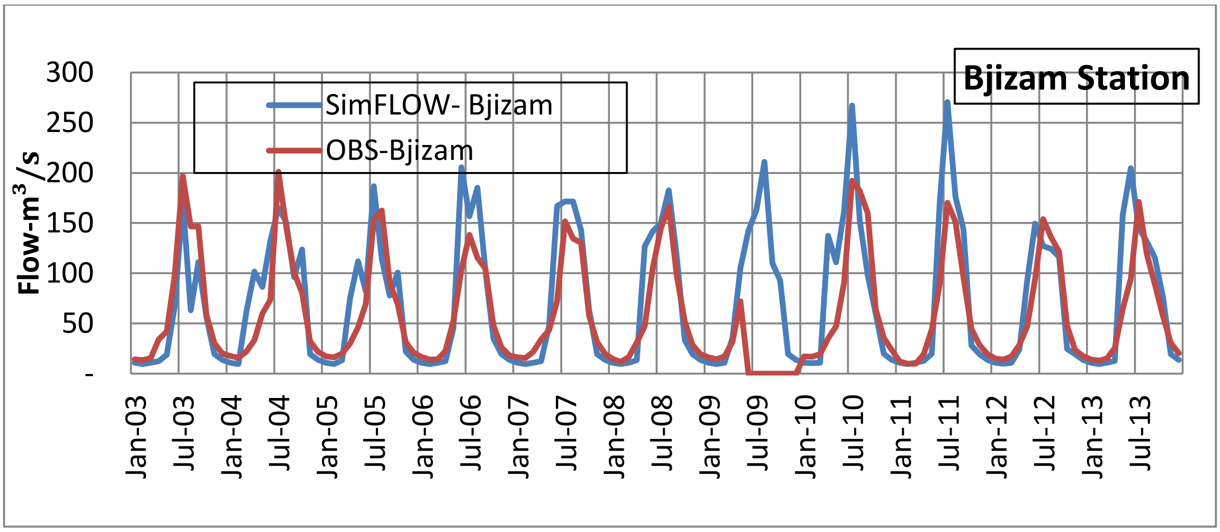


Figure 3-5: Observed and Simulated Flows at Bjizam Station

Figure 3-6 shows the rainfall-runoff model developed for the *Drangme Chhu* and *Mangde Chhu* basin using HEC-HMS.

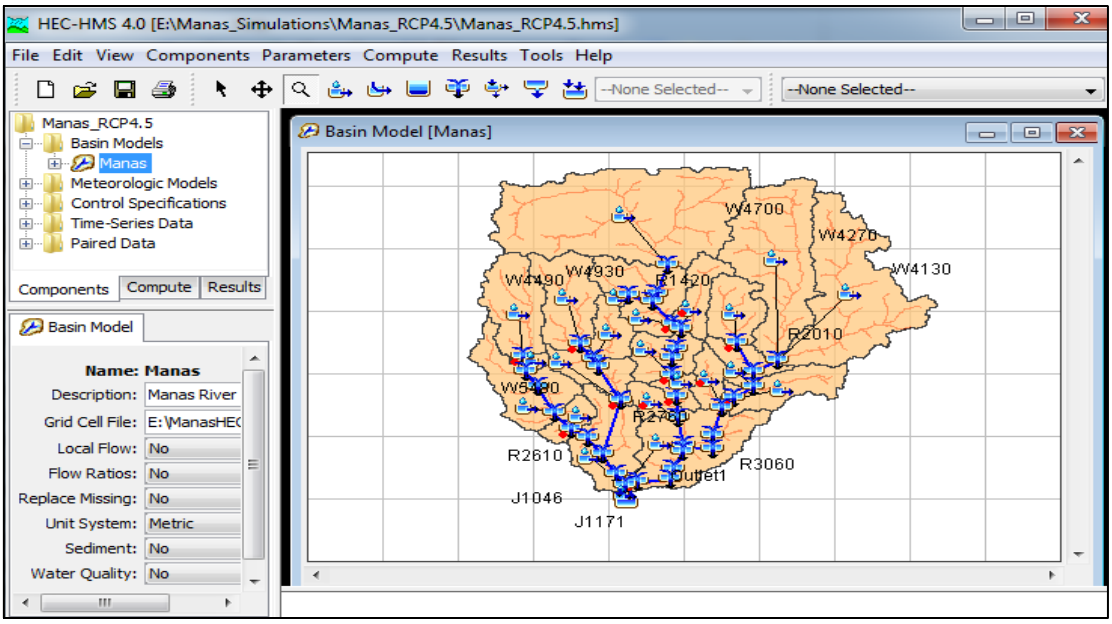


Figure 3-6: Rainfall Runoff Model Mangdechhu and Drangmechhu Basins

3.2 Water Availability at Sub-basin Level

Based on the calibrated and verified model, the water availability at sub basin level were determined. The Thiessen Polygon for observed rainfall gauging stations was modified to include rainfalls estimated at grid points as shown in Figure 3-7. The new climate data was incorporated in the model and the rainfall-runoff model developed for Mangdechhu and Drangmechhu basin was modified and the streamflow was generated. The water availability at sub basin level was determined from the modified model.

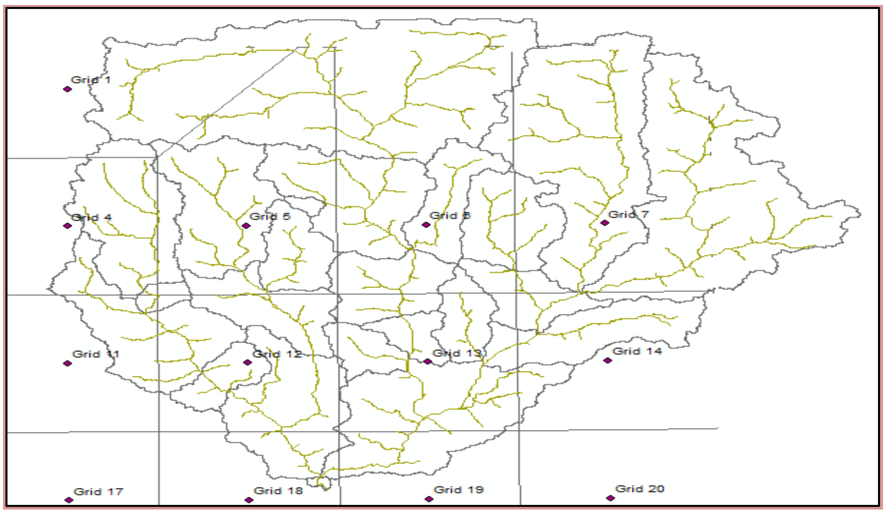


Figure 3-7: Rainfall Grid Points and Thiessen Polygon Network for Mangdechhu and Drangmechhu Basins

The total volume of water leaving the basin is estimated to be about 29,439 MCM/year. The flow generated at each of the sub-basins is given in 3-2 and the monthly flows of the basin are shown inFigure 3-8. The flows generated in the Dzongkhags falling inside the Drangmechhu and Mangdechhu basin are given in 3-2. The flow generated within Pemagatshel Dzongkhag and incoming flow from Mongar into the Dzongkhag is also mentioned in 3-2.The source of this analysis and downscaling is the hydrological modelling under the ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management, 2016- Standalone Report on *"Hydrological Modelling and Water Resource Assessment of Bhutan."*

Figure 3-8 depicts the monthly average water availability for the 23 sub basins based on simulations over the period from 2000to 2013.

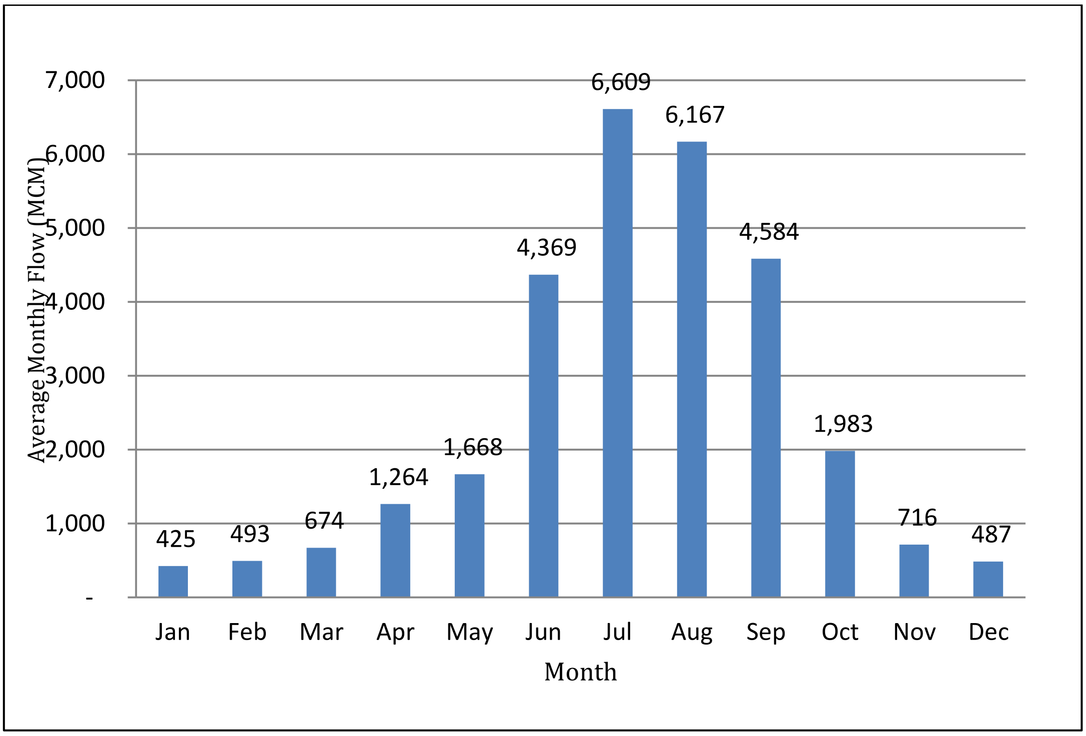


Figure 3-8: Average Monthly Flow

3-2: Flows Generated in Dzongkhags Falling Inside *Drangme Chhu* and *Mangde Chhu* Basins

	Trongsa			**Bumthang**	**Zhemgang**					**Lhuentshe**		
M^3/s	**From Wangdue-Sephu**	**Within**	**Total**	**Within**	**From Trongsa**	**From Bumthang**	**From Drangme**	**Within**	**Total**	**From China**	**With-in**	**Total**
Jan	8	11	19	24	19	24	88	25	156	30	20	50
Feb	7	18	25	24	25	24	108	32	189	31	25	56
Mar	12	29	40	42	40	42	146	39	268	30	56	86
Apr	30	73	103	94	103	94	269	85	551	20	128	148
May	62	97	158	113	158	113	338	119	729	120	138	258
Jun	109	153	262	134	262	134	821	198	1,416	681	223	904
Jul	132	242	374	246	374	246	1,303	346	2,269	611	311	922
Aug	111	193	304	262	304	262	1,295	269	2,130	479	303	782
Sep	82	147	229	161	229	161	948	205	1,544	374	229	603
Oct	47	133	179	115	179	115	426	109	830	164	129	293
Nov	14	19	34	40	34	40	158	30	262	55	39	93
Dec	10	10	20	23	20	23	106	16	165	38	21	59
Aver-age Annual =M3/s	52	94	146	106	146	106	501	123	876	219	135	354

Mongar				**Trashiyangtse**			**Trashigang**			**Pemagatshel**		
From Lhuentse	**From Trashigang**	**Within**	**Total**	**From India**	**Within**	**Total**	**From Trashiyangtse**	**Within**	**Total**	**From Mongar**	**Within**	**Total**
50	81	19	151	58	14	71	71	10	81	151	8	159
56	95	25	176	62	17	78	78	17	95	176	8	184
86	119	33	238	63	33	96	96	23	119	238	14	252
148	201	82	431	62	75	136	136	64	201	431	41	472
258	228	91	577	70	96	166	166	62	228	577	45	623
904	482	153	1,539	216	158	374	374	109	482	1,539	92	1,631
922	1,147	252	2,320	777	199	976	976	171	1,147	2,320	148	2,467
782	1,252	179	2,213	944	186	1,130	1,130	122	1,252	2,213	89	2,302
603	867	159	1,629	627	146	774	774	93	867	1,629	83	1,712
293	312	96	701	173	77	251	251	61	312	701	40	741
93	137	28	259	97	29	127	127	11	137	259	8	267
59	101	17	177	76	18	95	95	7	101	177	5	182
354	**418**	**95**	**868**	**269**	**87**	**356**	**356**	**62**	**418**	**868**	**48**	**916**

Source: ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management.- Standalone Report on *"Hydrological Modelling and Water Resource Assessment of Bhutan."*

Table 3-3: MCM/Month of Water Available at Sub-basins

MCM/Mont	W4490	W4930	W4200	W5370	W4700	W5620	W3500	W4130	W5580	W4350	W4780	W5130
Jan	28.93	23.03	27.86	6.74	32.81	15.08	80.62	68.43	16.93	0.27	11.12	9.76
Feb	25.54	23.69	27.57	10.04	34.43	19.44	81.94	66.46	35.56	0.41	12.21	20.46
Mar	42.22	54.54	61.78	15.97	53.41	19.13	80.62	64.42	46.65	1.38	57.17	38.11
Apr	109.39	129.51	132.09	42.21	94.24	33.16	53.30	70.84	128.85	4.73	160.95	83.29
May	224.70	148.41	187.02	45.15	113.58	37.89	321.41	85.84	117.96	5.01	156.18	94.31
Jun	395.88	211.55	309.63	59.84	189.64	46.08	1,823.2	171.94	192.67	5.96	243.97	157.51
Jul	480.91	343.63	370.34	101.87	273.93	77.41	1,635.2	857.10	298.45	9.56	329.50	220.47
Aug	404.94	342.75	362.50	85.11	267.45	72.23	1,282.6	1,390.49	231.26	9.00	318.51	216.79
Sep	299.64	204.12	289.97	72.05	206.23	64.60	1,001.5	910.45	160.98	5.82	239.90	161.07
Oct	169.02	158.09	143.16	47.07	136.46	53.04	439.30	211.71	122.08	3.93	114.11	89.96
Nov	52.37	56.52	65.93	14.17	53.44	21.79	146.77	130.04	20.27	0.54	25.70	23.81
Dec	36.69	32.15	39.12	7.43	32.44	15.83	102.31	103.79	12.08	0.40	13.39	8.85
Annual -	**2,270.24**	**1,728.00**	**2,016.96**	**507.65**	**1,488.05**	**475.67**	**7,048.9**	**4,131.51**	**1,383.73**	**46.99**	**1,682.71**	**1,124.3**

MCM/Month	W6310	W5700	W5590	W6160	W5480	W5670	W6140	W6210	W4910	W502	W4270
Jan	7.01	62.39	51.69	1.64	19.63	6.24	0.87	18.88	21.43	8.92	85.98
Feb	13.83	63.78	62.6	3.32	39.1	13.15	1.12	24.6	15.08	17.1	98.28
Mar	15.82	103.89	71.21	5.86	59.8	15.43	2.58	33.2	24.64	26.55	103.52
Apr	28.61	312.36	139.78	16.69	150.26	33.66	6.87	71.93	49.35	68.06	94.28
May	32.36	347.47	208.65	16.98	182.74	50.18	8.7	91.79	63.58	71.34	100.84
Jun	42.71	704.82	320.92	23.45	281.75	85.15	19.13	87.48	60.19	112.99	406.16
Jul	75.15	1,130.15	580.13	41.64	478.78	147.52	28.45	187.27	128.55	163.29	1,223.53
Aug	69.77	680.58	493.91	36.93	372.92	105.75	17.82	201.39	156.97	136.43	1,138.33
Sep	55.22	632.5	354.84	26.07	288.25	81.33	16.33	135.04	92.87	101.99	769.75
Oct	45.47	303.23	196.25	13.21	298.27	44.38	6.03	88.76	60.96	63.66	252.45
Nov	17.66	60.83	59.96	3.29	34.11	9.7	0.91	30.48	20.99	12.95	130.17
Dec	7.86	39.12	31.75	1.68	16.37	4.65	0.68	17.08	11.52	9.31	100.98
Annual -Total (MCM)/Year	**411.48**	**4,441.11**	**2,571.69**	**190.75**	**2,221.97**	**597.15**	**109.49**	**987.9**	**706.12**	**792.58**	**4,504.27**

Source: ADB CDTA 8623 BHU: Adapting to Climate Change through Integrated Water Resources Management.- Standalone Report on *"Hydrological Modelling and Water Resource Assessment of Bhutan."*

3.3 Water Availability at Gewog Level

The available water in each of the Gewogs of Pemagatshel was estimated using the Drainage-Area Ratio method. The Drainage-Area Ratio method is based on the assumption that the streamflow for a site of interest can be estimated by multiplying the ratio of the drainage area for the site of interest and the drainage area for a nearby streamflow-gauging station by the streamflow (Douglas et al 2005)[7]. Thus, the drainage-Area Ratio method, as analyzed by the USGS is given by:

$$Q_{ij} = \left(\frac{A_y}{A_x}\right) X_{ij}$$

Where:

Q_{ij} Estimated streamflow in cubic meters per second for month i and year j for the site of interest.

A_y : Drainage area in square kilometers for the site of interest.

A_x: Drainage area in square kilometers for the streamflow gauging station.

X_{ij} : Stream flow in cubic meters per second for month i and year j for the streamflow gauging station.

The flows generated for each sub-basin of *Drangme Chhu* and *Mangde Chhu* basin were further downscaled to the Gewogs using the Area-Ratio method explained above. The portions of Gewogs falling inside the sub-basins of *Drangme Chhu* and *Mangde Chhu* basin were identified and the available water was determined in these Gewogs. The monthly flow of each Gewog is computed based on the ratio of the area of the Gewog to the area of sub-basin and the corresponding monthly average flows for each of the Sub-basins. The Monthly Average Daily flows of the Gewogs are mentioned in Table 3.4.

Figure 3-6 shows the monthly flow variations of the Gewogs in Pemagatshel. The highest flow was identified for Norbugang Gewog in the month of July of 101.48 MCM and the lowest for Yurung Gewog in December of 0.55 MCM.

[7] Douglas et al, 2005: Douglas G. Emerson, Aldo V. Vecchia, and Ann L. Dahl; Evaluation of Drainage-Area Ratio Method Used to Estimate Streamflow for the Red River of the North Basin, North Dakota and Minnesota. http://pubs.usgs.gov/sir/2005/5017/pdf/sir20055017.pdf.

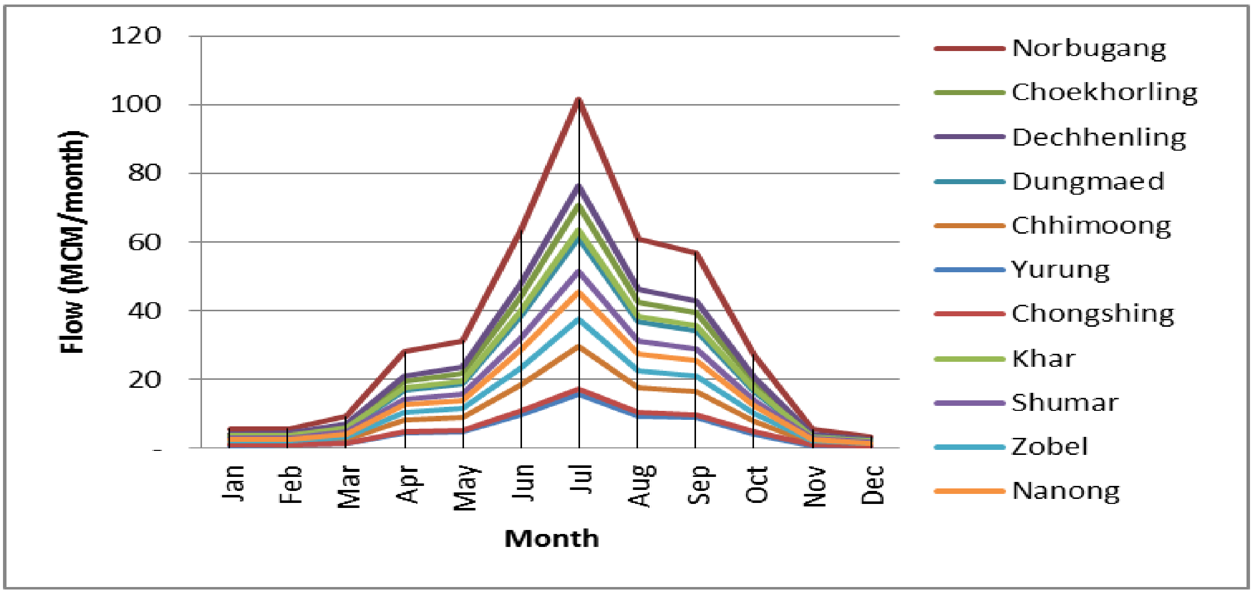


Figure 3-9: Monthly Flow Variation of Gewogs

Table 3-4: Monthly & Daily Average Flows at Gewogs

MCM/ Month	Sub-basin W5700	Norbu -gang	Choekh-orling	Dechh-enling	Dung-maed	Chhim -oong	Yur-ung	Chong -shing	Khar	Shu-mar	Zobel	Nan-ong
Jan	62.39	5.60	3.90	4.23	3.39	1.63	0.87	0.96	3.52	2.84	2.07	2.52
Feb	63.78	5.73	3.99	4.32	3.47	1.67	0.89	0.98	3.60	2.91	2.11	2.58
Mar	103.89	9.33	6.50	7.04	5.65	2.71	1.45	1.59	5.86	4.73	3.44	4.20
Apr	312.36	28.05	19.53	21.16	16.98	8.16	4.35	4.79	17.62	14.23	10.35	12.61
May	347.47	31.20	21.72	23.53	18.89	9.07	4.84	5.33	19.60	15.83	11.51	14.03
Jun	704.82	63.29	44.07	47.74	38.32	18.41	9.83	10.81	39.75	32.11	23.34	28.46
Jul	1,130.15	101.48	70.66	76.55	61.44	29.51	15.75	17.34	63.74	51.49	37.43	45.64
Aug	680.58	61.11	42.55	46.10	37.00	17.77	9.49	10.44	38.38	31.01	22.54	27.49
Sep	632.50	56.80	39.54	42.84	34.39	16.52	8.82	9.70	35.67	28.82	20.95	25.54
Oct	303.23	27.23	18.96	20.54	16.49	7.92	4.23	4.65	17.10	13.81	10.04	12.25
Nov	60.83	5.46	3.80	4.12	3.31	1.59	0.85	0.93	3.43	2.77	2.01	2.46
Dec	39.12	3.51	2.45	2.65	2.13	1.02	0.55	0.60	2.21	1.78	1.30	1.58
Annual - Total (MCM)/ Yr	**4,441.11**	**398.80**	**277.66**	**300.81**	**241.45**	**115.98**	**61.91**	**68.12**	**250.47**	**202.33**	**147.10**	**179.35**

3.4 Water Demand and Availability

The flows computed for each of the Gewogs were compared with the water demand in each Gewog. The yearly water requirement and the available water variations are presented in Figure 3-10. The water availble in the Gewog is represented on the primary axis (bar graph) and the water demand on the secondary axis (MCM/yr) (line graph). The available water was found to be comparatively higher than the actual demand in each of the Gewog on a yearly basis.

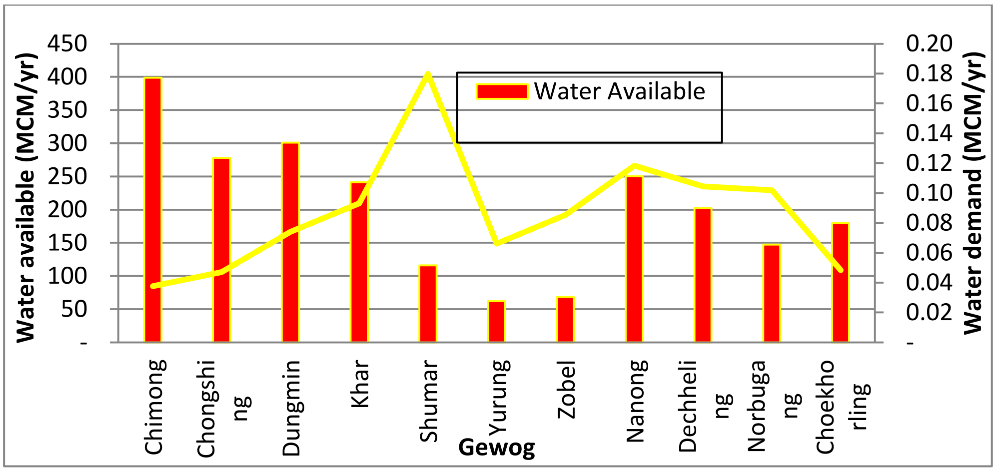


Figure 3-10: Water Demand and Available Water Variations in Gewogs

Also a comparison of the future and the present water demand pattern was also done. Figure 3-11 shows the comparison of the water demand for the year 2015 and 2030. The water demand was calculated for a population increment of 25% and increase in water demand of 250 l/c/d by 2030. The increase in demand in the future along with increase in population may adversely impact the available water in the district in the future.

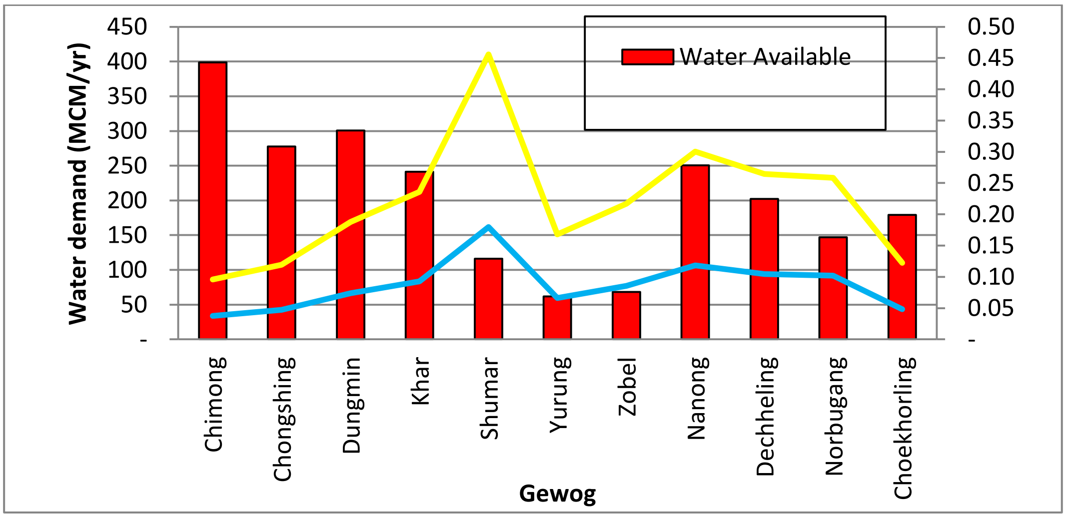


Figure 3-11: Water Demand Pattern and Availability Comparison

From Figure 3-11 it can be observed that Shumur has the highest water demand of 0.18MCM per year which is projected to increase up to 0.46 MCM/year by 2030 but the available water is much lesser compared to other Gewogs. Though the available water is about 115.98 MCM/year, due to accessibility issues some of the areas are already facing severe water shortages. Additionally, the downscaled flows maynot be an accurate representation of the actual available water for each of the households in the Gewog which are scattered throughout the Gewog. Further, the monthly flows and the demand were also analyzed for each Gewog. The per capita water demand was calculated for each month for all the Gewogs shown in Figure 3-12. The available water was found to be much more than the requirement for all the months but the distribution of the flow on both spatial and temporal scales may lead to insufficiencies in some areas.

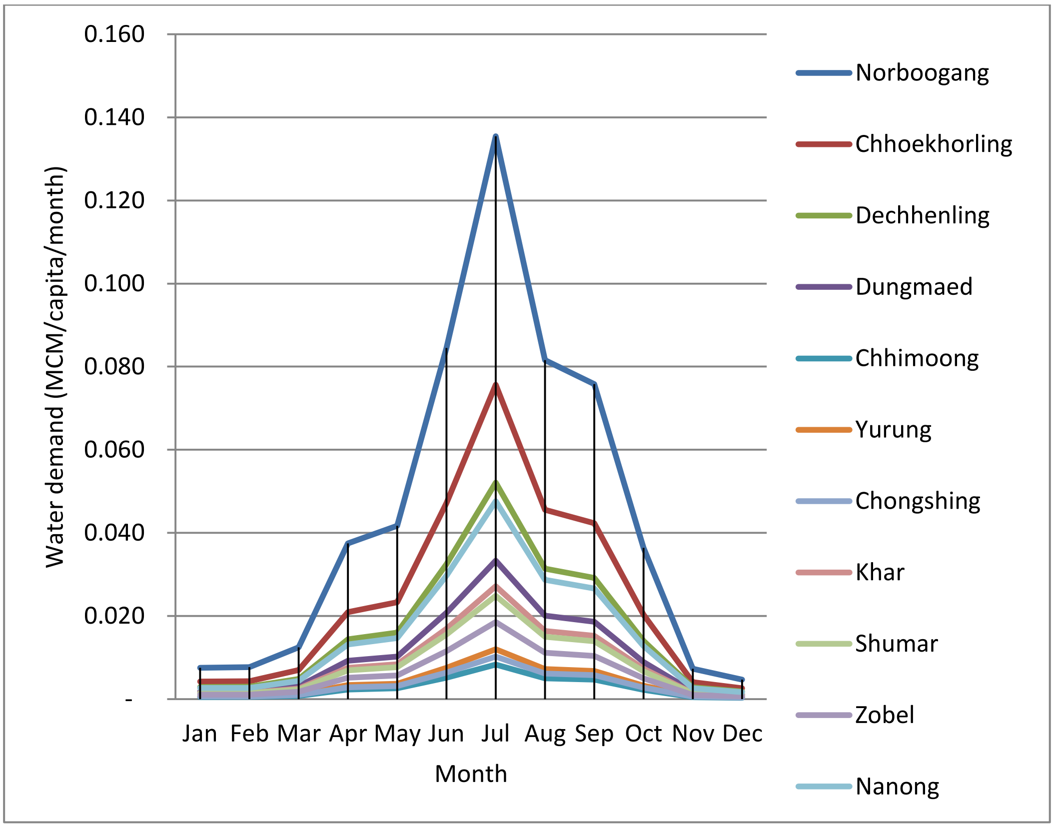


Figure 3-12: Per Capita Water Availability (MCM/month)

Table 3-5 shows the available water per Gewog in the district and the water demand for 2015 and 2030. It can be observed that for each month the available water is much higher than the monthly demand and the annual demand of 0.00004 MCM/capita/year in the district.

Table 3-5: Monthly and Yearly Flow and Water Demand Comparison (MCM)

	Norbugang			**Choekhorling**			**Dechhenling**				
Month	**Model**	**Demand in 2015 MCM/month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**
Jan	5.60	0.004	0.008	3.90	0.006	0.013	4.23	0.006	0.012	0.007	0.015
Feb	5.73	0.004	0.008	3.99	0.006	0.013	4.32	0.006	0.012	0.007	0.015
Mar	9.33	0.004	0.008	6.50	0.006	0.013	7.04	0.006	0.012	0.007	0.015
Apr	28.05	0.004	0.008	19.53	0.006	0.013	21.16	0.006	0.012	0.007	0.015
May	31.20	0.004	0.008	21.72	0.006	0.013	23.53	0.006	0.012	0.007	0.015
Jun	63.29	0.004	0.008	44.07	0.006	0.013	47.74	0.006	0.012	0.007	0.015
Jul	101.48	0.004	0.008	70.66	0.006	0.013	76.55	0.006	0.012	0.007	0.015
Aug	61.11	0.004	0.008	42.55	0.006	0.013	46.10	0.006	0.012	0.007	0.015
Sep	56.80	0.004	0.008	39.54	0.006	0.013	42.84	0.006	0.012	0.007	0.015
Oct	27.23	0.004	0.008	18.96	0.006	0.013	20.54	0.006	0.012	0.007	0.015
Nov	5.46	0.004	0.008	3.80	0.006	0.013	4.12	0.006	0.012	0.007	0.015
Dec	3.51	0.004	0.008	2.45	0.006	0.013	2.65	0.006	0.012	0.007	0.015
Annual	398.80	**0.047**	**0.097**	277.66	**0.074**	**0.154**	300.81	**0.070**	**0.145**	0.088	0.182
	Chhimoong			**Yurung**			**Chongshing**				
Month	**Model**	**Dmand in 2015 MCM/month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Demand in 2030 MCM/ month**	
Jan	1.63	0.015	0.031	0.87	0.008	0.016	0.96	0.007	0.014	0.012	
Feb	1.67	0.015	0.031	0.89	0.008	0.016	0.98	0.007	0.014	0.012	
Mar	2.71	0.015	0.031	1.45	0.008	0.016	1.59	0.007	0.014	0.012	
Apr	8.16	0.015	0.031	4.35	0.008	0.016	4.79	0.007	0.014	0.012	
May	9.07	0.015	0.031	4.84	0.008	0.016	5.33	0.007	0.014	0.012	
Jun	18.41	0.015	0.031	9.83	0.008	0.016	10.81	0.007	0.014	0.012	
Jul	29.51	0.015	0.031	15.75	0.008	0.016	17.34	0.007	0.014	0.012	

Aug	17.77	0.015	0.031	9.49	0.008	0.016	10.44	0.007	0.014	0.012
Sep	16.52	0.015	0.031	8.82	0.008	0.016	9.70	0.007	0.014	0.012
Oct	7.92	0.015	0.031	4.23	0.008	0.016	4.65	0.007	0.014	0.012
Nov	1.59	0.015	0.031	0.85	0.008	0.016	0.93	0.007	0.014	0.012
Dec	1.02	0.015	0.031	0.55	0.008	0.016	0.60	0.007	0.014	0.012
Annual	115.98	0.176	0.367	61.91	0.093	0.193	68.12	0.083	0.173	0.148

	Shumar			**Zobel**			**Nanong**		
Month	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**	**Model**	**Demand in 2015 MCM/ month**	**Demand in 2030 MCM/ month**
Jan	2.84	0.007	0.015	2.07	0.007	0.014	2.52	0.009	0.018
Feb	2.91	0.007	0.015	2.11	0.007	0.014	2.58	0.009	0.018
Mar	4.73	0.007	0.015	3.44	0.007	0.014	4.20	0.009	0.018
Apr	14.23	0.007	0.015	10.35	0.007	0.014	12.61	0.009	0.018
May	15.83	0.007	0.015	11.51	0.007	0.014	14.03	0.009	0.018
Jun	32.11	0.007	0.015	23.34	0.007	0.014	28.46	0.009	0.018
Jul	51.49	0.007	0.015	37.43	0.007	0.014	45.64	0.009	0.018
Aug	31.01	0.007	0.015	22.54	0.007	0.014	27.49	0.009	0.018
Sep	28.82	0.007	0.015	20.95	0.007	0.014	25.54	0.009	0.018
Oct	13.81	0.007	0.015	10.04	0.007	0.014	12.25	0.009	0.018
Nov	2.77	0.007	0.015	2.01	0.007	0.014	2.46	0.009	0.018
Dec	1.78	0.007	0.015	1.30	0.007	0.014	1.58	0.009	0.018
Annual	202.33	0.089	0.185	147.10	0.081	0.168	179.35	0.102	0.213

3.5 Water Availability and Demand During Dry Months

The availability of water during different months of the year and possibility of shortages in dry months were checked based on the demand calculated for each month. The available water is least in the month of December ranging from values as low as 0.55 MCM /month for Yurung to 3.51 MCM/month for Norbugang. However, the demand is much lesser than the low flow values ranging from 0.004 MCM/month to 0.02 MCM/month. Similarly, the flows for other dry months are comparatively lesser than rest of the months but as mentioned earlier major shortage may arise in some places especially during the low flow periods or during the dry season due to disproportionate spatial distribution of water.

3.6 Climate and Water

Globally, temperature is predicted to rise with increase in evaporation and change in rainfall along with changes to many other climate parameters. The change in rainfall quantity or shift of pattern due to climate change has a possibility to cause droughts and floods or create problems with storage which would be a great threat to water and food security. Hence, identification of climate change impacts on water resources is vital. The impact of climate on water resources of Bhutan was carried out as part of the ADB TA BHU: 8623 on Adaption to climate change through Integrated Water Resources Management (IWRM) for National Environment Commission of Bhutan. Two Representative Concentration Pathways[8](RCP) scenarios were used in the climate modeling conducted under the TA, and specifically two scenarios to represent GHG emission stabilization (middle of the line and somewhat optimistic RCP 4.5) and business-as-usual (pessimistic) RCP 8.5 cases. The RCP 4.5 is a stabilization scenario where total radiative forcing is stabilized before 2100 through a range of technology and strategies for reducing GHG emissions whereas in RCP 8.5 increasing GHG emissions over time that is representative of "business-as-usual" practices leading to high GHG concentration levels. The two GCMs, MRI-CGCM39 and CCSM410, were selected for the climate projection after downscaling it with APHRODITE database for bias correction.

APHRODITE refers to the Asian Precipitation Highly Resolved Observational Data Integration towards Evaluation of Water Resources project that created daily gridded precipitation at high resolution covering the whole of Asia. The APHRODITE database provided gridded rainfall and temperature data from 1976 to 2005 at roughly 50 km grid spacing, with 21 grid points covering Bhutan. This historical database was used for the statistical downscaling (with bias correction) of two selected GCMs. Proper biased corrections

[8]Representative Concentration Pathways (RCPs), were developed by the IPCC and are identified by their *total radiative forcing*, measured in watts per square meter (W/m^2) in year 2100 relative to 1750. Radiative forcing is defined as the difference of the solar energy absorbed by the Earth and the energy radiated back to space. Essentially, these scenarios describe the degree in which greenhouse gas emissions are actively mitigated, stabilized, or increased.

[9]MRI-CGCM3: Meteorological Research Institute, Tsukuba, Japan, 1.125 x 1.125(LonXLat).

[10]Community Climate System Model (CCSM4): NCAR (National Center for Atmospheric Research) Boulder, CO, USA. 0.90 x 1.25 (LonXLat).

were made to check the Aphrodite data and used them to represent the actual data for Bhutan. The results from the climate modelling were used to determine the flow in the respective basins as described below.

3.6.1 Water Availability under Climate Change in Drangme Chhu basin

In the *Drangme Chhu* basin, the annual flow is projected to increase in both RCP 4.5 and RCP 8.5 climate scenarios as per the model outputs. These flows were estimated using the new climate data in HEC-HMS. The data from 1976 to 2005 was used as representative of the past or the historical condition. The future climatic condition of the year 2030 is based on the period from 2016 to 2046 while the period from 2046 to 2075 was used for the year 2060. The percentage change in the direction and magnitude of the flow under the future climate change (up to 2075) with reference to the historical period (1970-2010) were calculated as shownin Figure 3-6. For the year 2030 in RCP scenario 4.5, the total annual flow is expected to increase by about 4.6 % whereas for RCP 8.5 scenario, the increase would be around 8.8 %. These totals would further increase in the year 2060 with an increase of 7.2% and 15% respectively for RCP 4.5 and 8.5 respectively. The starting months of the year all show high increasing trends in their flow but for the last four months of the year, a decline in the flow can be seen for the future scenarios and these changes are higher and similar for the month of December in all the future scenarios. Figure 3-13 shows the average monthly flows at the outlet of the *Drangme Chhu* basin for both RCP 4.5 and RCP 8.5 scenarios in comparison with the historical flow.

Table 3-6: Percentage Change in Flows under Different Climate Scenario

Month	Historica	RCP 4.5				RCP 8.5			
	1976-2005	**2016-2045**	**% Change**	**2046-2075**	**% Change**	**2016-2045**	**% Change**	**2046-2075**	**% Change**
Jan	116.4	122.9	5.6%	112	-3.8%	124.4	6.9%	117.5	0.9%
Feb	127.4	151.2	18.7%	147.3	15.6%	153.6	20.6%	151.9	19.2%
Mar	187.4	202.9	8.3%	214.2	14.3%	222.9	18.9%	222	18.5%
Apr	327	356.9	9.1%	340.1	4.0%	382.4	16.9%	409	25.1%
May	503.8	579.7	15.1%	574.2	14.0%	623.3	23.7%	605.2	20.1%
Jun	780.1	868.8	11.4%	685.7	-12.1%	833.8	6.9%	841.9	7.9%
Jul	1187.2	1198.8	1.0%	1340.6	12.9%	1,246.4	5.0%	1356.8	14.3%
Aug	946.5	1010.9	6.8%	1070.2	13.1%	996.9	5.3%	1213	28.2%
Sep	721.1	688.3	-4.5%	810	12.3%	786.7	9.1%	829.8	15.1%
Oct	395.6	389.2	-1.6%	391.4	-1.1%	426.4	7.8%	417.6	5.6%
Nov	189.1	181	-4.3%	208.2	10.1%	187.8	-0.7%	189.2	0.1%
Dec	132.2	123.2	-6.8%	123.5	-6.6%	125.2	-5.3%	120.7	-8.7%
Total	**5613.8**	**5873.8**	**4.6%**	**6017.4**	**7.2%**	**6,109.8**	**8.8%**	**6474.6**	**15.3%**

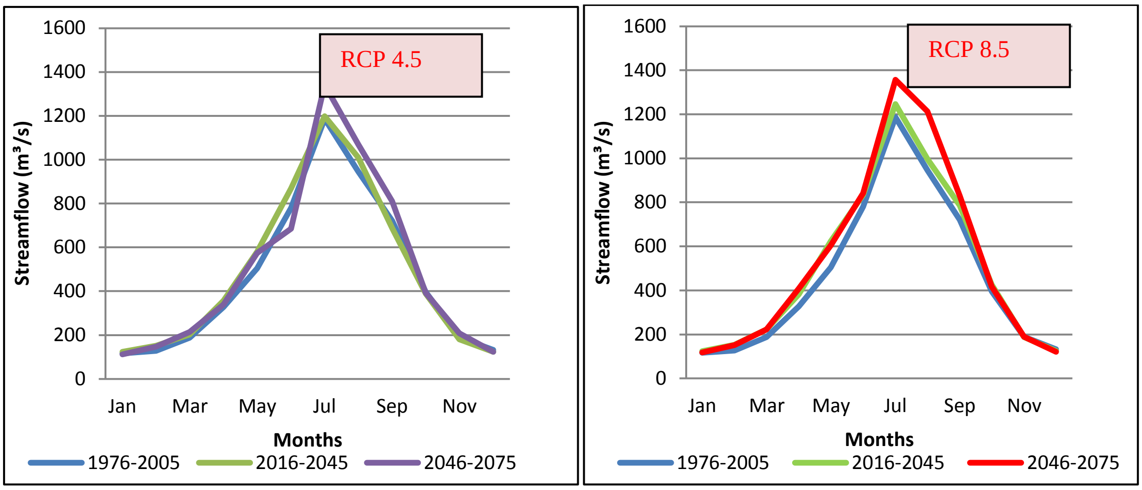


Figure 3-13: Change in Flow for Different Scenarios

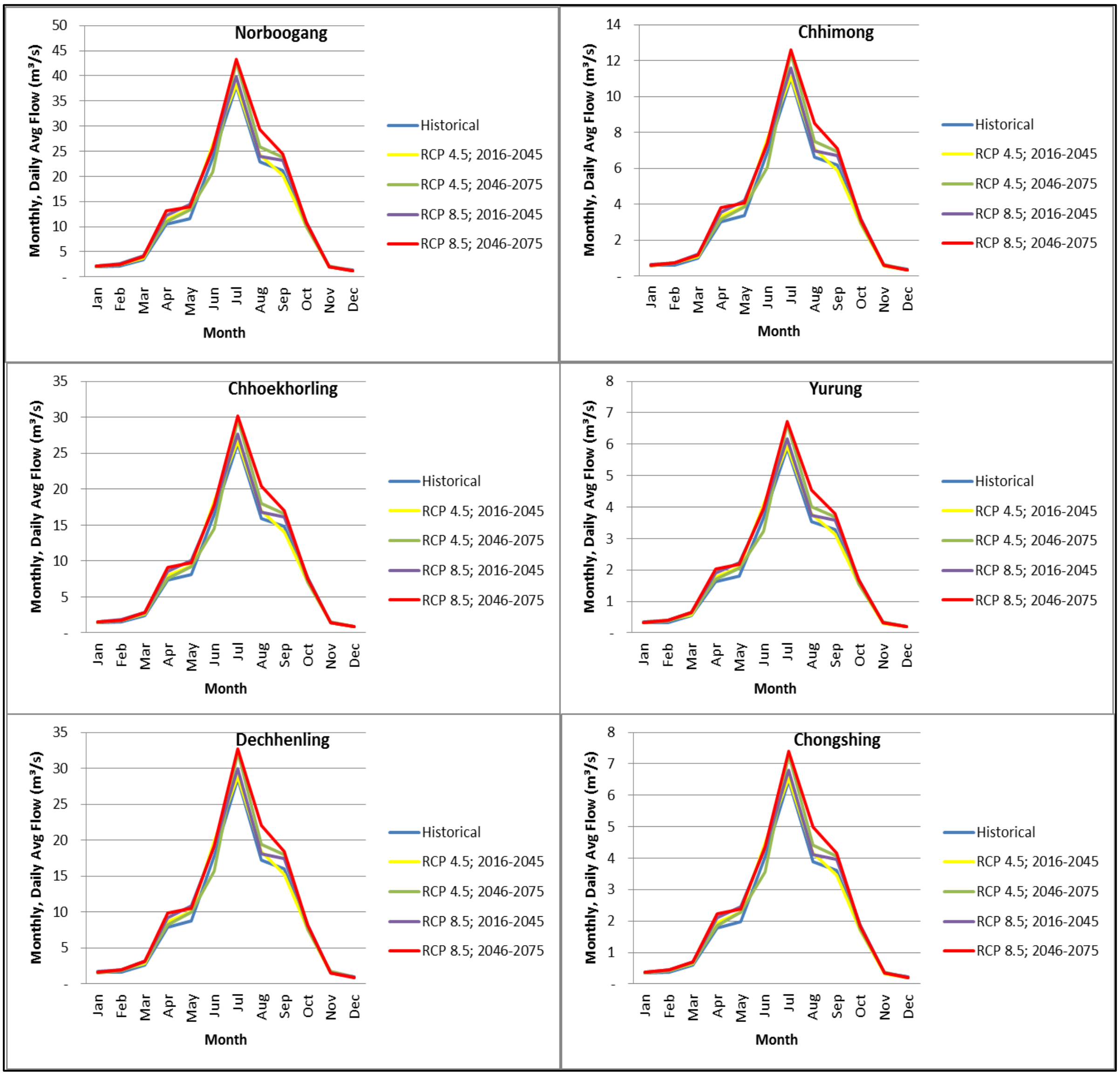
The change in the average monthly flows under different scenarios is shown in Figure 3-13and the percentage changes in flow under these scenarios are mentioned in Table 3-7. For RCP 4.5, year 2030, the months from September to December show constant decline in their future flows whereas the other months show an increment. The highest increase can be observed in the month of May, an increase of 15% and the lowest or the highest decrease in the month of December, a decrease of -6.8%. Similarly, for all the scenarios and all time periods a decline in the month of December was found to be common, which maybe an indication that the low flows are expected to further decrease in the future. For RCP 8.5, change in flow in the future for November seems to be minimal for both the time periods, whereas the other months show a much higher change. Except for the month of November and December, the other months show an increase in their monthly average flows for 2030 but for 2060 November month there is a minimal increment. Overall, these changes reflect an inconsistent change in monthly average flows for the basin although the annual changes reflect an increasing trend.

3.6.2 Water Availability under Climate Change at Gewog level

The available water for the Gewogs of Pemagatshel under future scenarios were computed form the percentage change in the flows obtained under different scenarios from the model. Consecutively, the flow under each scenario for every Gewog was calculated as shown in Table 3-7 and the flow under each scenario was examined. Figure 3-14 shows the flow variation in the Gewogs of Pemagatshel for different future scenarios and time scale. The annual average flow estimated for the Gewogs under different scenarios shows an increasing trend in all the Gewogs and for all scenarios but on a monthly basis these trends are likely to vary. A decrease in flow in the month of December was found to be recurring in all the scenarios and time periods for all the Gewogs.

The future flows for the Gewogs show an overall increase in their average annual flow but a rather inconsistent trend in their monthly average flows. The future flow in the month of December shows a decline for all the Gewogs under both the scenarios and time periods. The month of January, June October, and December shows a decline in their flow for 2060 under RCP 4.5 reflected in each Gewog. The months from September to December show a decline for all Gewogs under RCP 4.5, year 2030. The months of November and December show a decline for RCP 8.5, 2030, whereas only December shows a decline for 2060, under the same scenario. The changes in the flow reveal an unpredictable pattern of change interms of monthly changes, showing varying increasing and decreasing flows for the future years.

Generally, the annual flow for each Gewog shows an increase which may benefit the farmers in the district but these increases are uneven, having high increases in some months and a decrease in the other months. With these unexpected monthly shortages, the Gewogs of Shumur and Chhimoong that already have problems of water may have more problems in the future. Further the decline in flow in the winter months which is prominent in most of the cases may cause further reduction in low flows of the future which may be problematic for the people in the district.



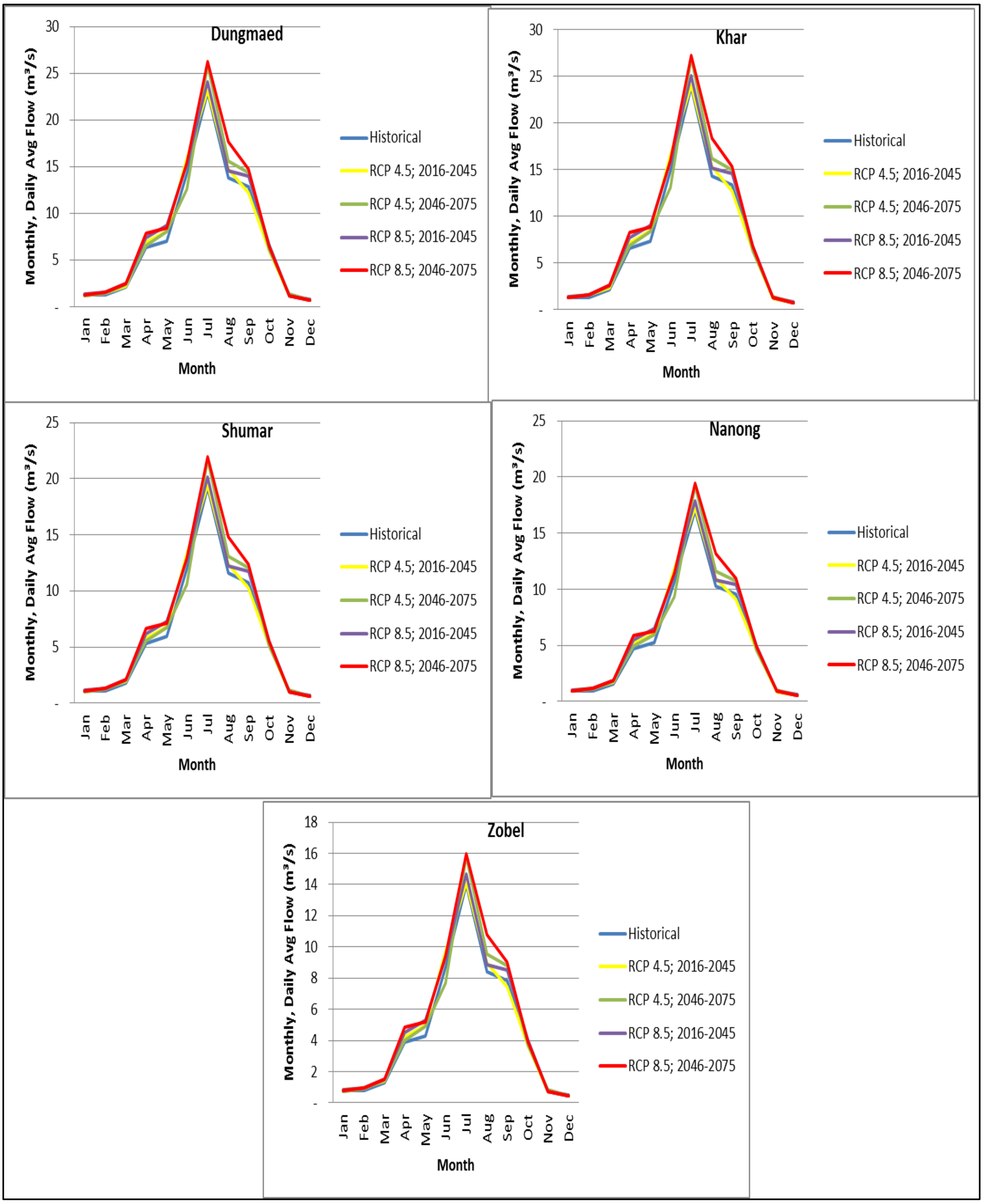


Figure 3-14: Water Available at Gewogs under Future Scenarios

Table 3-7: Water Availability at Gewog Level under Different Climate Scenarios

Months Basin	Scenario & Time Step	Ja	Fe	Ma	Ap	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Overall % Change of flow in the basin under different IPCC Scenario	RCP 4.5; 2016-2045	6%	19%	8%	9%	15%	11%	1%	7%	-5%	-2%	-4%	-7%	5%
	RCP 4.5; 2046-2075	-4%	16%	14%	4%	14%	-12%	13%	13%	12%	-1%	10%	-7%	7%
	RCP 8.5; 2016-2045	7%	21%	19%	17%	24%	7%	5%	5%	9%	8%	-1%	-5%	9%
	RCP 8.5; 2046-2075	1%	19%	18%	25%	20%	8%	14%	28%	15%	6%	0%	-9%	15%
Norbugang	**Historical**	**2.09**	**2.14**	**3.48**	**10.47**	**11.65**	**23.63**	**37.89**	**22.82**	**21.21**	**10.17**	**2.04**	**1.31**	**12.41**
	RCP 4.5; 2016-2045	2.21	2.54	3.77	11.43	13.40	26.32	38.26	24.37	20.24	10.00	1.95	1.22	12.98
	RCP 4.5; 2046-2075	2.01	2.47	3.98	10.89	13.28	20.77	42.79	25.80	23.82	10.06	2.25	1.23	13.30
	RCP 8.5; 2016-2045	2.24	2.58	4.14	12.25	14.41	25.26	39.78	24.03	23.13	10.96	2.03	1.24	13.50
	RCP 8.5; 2046-2075	2.11	2.55	4.13	13.10	13.99	25.50	43.30	29.24	24.40	10.73	2.04	1.20	14.31
Choekhorling	**Historical**	**1.46**	**1.49**	**2.43**	**7.29**	**8.11**	**16.45**	**26.38**	**15.89**	**14.76**	**7.08**	**1.42**	**0.91**	**8.64**
	RCP 4.5; 2016-2045	1.54	1.77	2.63	7.96	9.33	18.32	26.64	16.97	14.09	6.96	1.36	0.85	9.03
	RCP 4.5; 2046-2075	1.40	1.72	2.77	7.58	9.24	14.46	29.79	17.96	16.58	7.00	1.56	0.85	9.24
	RCP 8.5; 2016-2045	1.56	1.79	2.88	8.53	10.03	17.58	27.70	16.73	16.11	7.63	1.41	0.86	9.40
	RCP 8.5; 2046-2075	1.47	1.78	2.87	9.12	9.74	17.76	30.15	20.36	16.99	7.47	1.42	0.83	10.00
Dechhenling	**Historical**	**1.58**	**1.61**	**2.63**	**7.90**	**8.79**	**17.82**	**28.58**	**17.21**	**16.00**	**7.67**	**1.54**	**0.99**	**9.36**
	RCP 4.5; 2016-2045	1.67	1.91	2.84	8.62	10.11	19.85	28.86	18.38	15.27	7.54	1.47	0.92	9.79
	RCP 4.5; 2046-2075	1.52	1.86	3.00	8.22	10.01	15.67	32.27	19.46	17.97	7.59	1.69	0.92	10.02
	RCP 8.5; 2016-2045	1.69	1.94	3.13	9.24	10.87	19.05	30.01	18.13	17.45	8.27	1.53	0.94	10.19
	RCP 8.5; 2046-2075	1.59	1.92	3.11	9.88	10.56	19.24	32.66	22.06	18.41	8.09	1.54	0.90	10.83
Dungmaed	**Historical**	**1.27**	**1.29**	**2.11**	**6.34**	**7.05**	**14.31**	**22.94**	**13.81**	**12.84**	**6.15**	**1.23**	**0.79**	**7.51**
	RCP 4.5; 2016-2045	1.34	1.54	2.28	6.92	8.12	15.93	23.16	14.75	12.25	6.06	1.18	0.74	7.86
	RCP 4.5; 2046-2075	1.22	1.50	2.41	6.59	8.04	12.58	25.90	15.62	14.42	6.09	1.36	0.74	8.04
	RCP 8.5; 2016-2045	1.35	1.56	2.51	7.41	8.73	15.29	24.08	14.55	14.01	6.63	1.23	0.75	8.18
	RCP 8.5; 2046-2075	1.28	1.54	2.50	7.93	8.47	15.44	26.22	17.70	14.77	6.50	1.24	0.72	8.69
Chhimoong	**Historical**	**0.61**	**0.62**	**1.01**	**3.05**	**3.39**	**6.87**	**11.02**	**6.64**	**6.17**	**2.96**	**0.59**	**0.38**	**3.61**
	RCP 4.5; 2016-2045	0.64	0.74	1.10	3.32	3.90	7.65	11.13	7.09	5.89	2.91	0.57	0.36	3.77
	RCP 4.5; 2046-2075	0.59	0.72	1.16	3.17	3.86	6.04	12.44	7.50	6.93	2.93	0.65	0.36	3.86
	RCP 8.5; 2016-2045	0.65	0.75	1.20	3.56	4.19	7.35	11.57	6.99	6.73	3.19	0.59	0.36	3.93
	RCP 8.5; 2046-2075	0.61	0.74	1.20	3.81	4.07	7.42	12.59	8.50	7.10	3.12	0.59	0.35	4.18
Yurung	**Historical**	**0.32**	**0.33**	**0.54**	**1.63**	**1.81**	**3.67**	**5.88**	**3.54**	**3.29**	**1.58**	**0.32**	**0.20**	**1.93**

Months Basin	Scenario & Time Step	Ja	Fe	Ma	Ap	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
	RCP 4.5; 2016-2045	0.34	0.39	0.59	1.77	2.08	4.09	5.94	3.78	3.14	1.55	0.30	0.19	2.01
	RCP 4.5; 2046-2075	0.31	0.38	0.62	1.69	2.06	3.22	6.64	4.01	3.70	1.56	0.35	0.19	2.06
	RCP 8.5; 2016-2045	0.35	0.40	0.64	1.90	2.24	3.92	6.18	3.73	3.59	1.70	0.31	0.19	2.10
	RCP 8.5; 2046-2075	0.33	0.40	0.64	2.03	2.17	3.96	6.72	4.54	3.79	1.67	0.32	0.19	2.23
Chongshing	**Historical**	**0.36**	**0.37**	**0.60**	**1.79**	**1.99**	**4.04**	**6.47**	**3.90**	**3.62**	**1.74**	**0.35**	**0.22**	**2.12**
	RCP 4.5; 2016-2045	0.38	0.43	0.64	1.95	2.29	4.50	6.54	4.16	3.46	1.71	0.33	0.21	2.22
	RCP 4.5; 2046-2075	0.34	0.42	0.68	1.86	2.27	3.55	7.31	4.41	4.07	1.72	0.38	0.21	2.27
	RCP 8.5; 2016-2045	0.38	0.44	0.71	2.09	2.46	4.31	6.80	4.11	3.95	1.87	0.35	0.21	2.31
	RCP 8.5; 2046-2075	0.36	0.44	0.70	2.24	2.39	4.36	7.40	5.00	4.17	1.83	0.35	0.20	2.45
Khar	**Historical**	**1.31**	**1.34**	**2.19**	**6.58**	**7.32**	**14.84**	**23.80**	**14.33**	**13.32**	**6.38**	**1.28**	**0.82**	**7.79**
	RCP 4.5; 2016-2045	1.39	1.59	2.37	7.18	8.42	16.53	24.03	15.31	12.71	6.28	1.23	0.77	8.15
	RCP 4.5; 2046-2075	1.26	1.55	2.50	6.84	8.34	13.04	26.87	16.20	14.96	6.32	1.41	0.77	8.34
	RCP 8.5; 2016-2045	1.40	1.62	2.60	7.69	9.05	15.86	24.98	15.09	14.53	6.88	1.27	0.78	8.48
	RCP 8.5; 2046-2075	1.33	1.60	2.59	8.23	8.79	16.02	27.20	18.37	15.33	6.74	1.28	0.75	9.02
Shumar	**Historical**	**1.06**	**1.08**	**1.77**	**5.31**	**5.91**	**11.99**	**19.22**	**11.58**	**10.76**	**5.16**	**1.03**	**0.67**	**6.30**
	RCP 4.5; 2016-2045	1.12	1.29	1.91	5.80	6.80	13.35	19.41	12.36	10.27	5.07	0.99	0.62	6.58
	RCP 4.5; 2046-2075	1.02	1.25	2.02	5.53	6.74	10.54	21.71	13.09	12.08	5.10	1.14	0.62	6.74
	RCP 8.5; 2016-2045	1.13	1.31	2.10	6.21	7.31	12.81	20.18	12.19	11.74	5.56	1.03	0.63	6.85
	RCP 8.5; 2046-2075	1.07	1.29	2.09	6.65	7.10	12.94	21.97	14.84	12.38	5.44	1.04	0.61	7.28
Zobel	**Historical**	**0.77**	**0.79**	**1.28**	**3.86**	**4.30**	**8.72**	**13.98**	**8.42**	**7.82**	**3.75**	**0.75**	**0.48**	**4.58**
	RCP 4.5; 2016-2045	0.81	0.94	1.39	4.22	4.94	9.71	14.11	8.99	7.47	3.69	0.72	0.45	4.79
	RCP 4.5; 2046-2075	0.74	0.91	1.47	4.02	4.90	7.66	15.78	9.52	8.79	3.71	0.83	0.45	4.91
	RCP 8.5; 2016-2045	0.82	0.95	1.53	4.52	5.32	9.32	14.67	8.86	8.53	4.04	0.75	0.46	4.98
	RCP 8.5; 2046-2075	0.78	0.94	1.52	4.83	5.16	9.41	15.97	10.79	9.00	3.96	0.75	0.44	5.28
Nanong	**Historical**	**0.94**	**0.96**	**1.57**	**4.71**	**5.24**	**10.63**	**17.04**	**10.26**	**9.54**	**4.57**	**0.92**	**0.59**	**5.58**
	RCP 4.5; 2016-2045	0.99	1.14	1.70	5.14	6.03	11.84	17.21	10.96	9.10	4.50	0.88	0.55	5.84
	RCP 4.5; 2046-2075	0.91	1.11	1.79	4.90	5.97	9.34	19.24	11.60	10.71	4.52	1.01	0.55	5.98
	RCP 8.5; 2016-2045	1.01	1.16	1.86	5.51	6.48	11.36	17.89	10.81	10.40	4.93	0.91	0.56	6.07
	RCP 8.5; 2046-2075	0.95	1.15	1.86	5.89	6.29	11.47	19.47	13.15	10.97	4.83	0.92	0.54	6.44

Chapter 4 : Field Surveys and Comparisons with Model Results

4.1 Results from National Water Resources Inventory (NWRI) Survey

During the NWRI survey in Pemagatshel Dzongkhag, 19 measurements were taken at various locations spread across the minor and major streams of *Drangme Chhu* in nine Gewogs of Pemagatshel as shown in Figure 4-1. The points of measurement along with their location and measurement values are mentioned in Table 4-1. The highest flow was observed in June, a flow of 2826.25 lps (liters per second) at Nanong Gewog in Tsala ri and the lowest discharge was recorded for *Cherang Chhu* in Shumur Gewog with 0.03 lps in November.

A comparison based on measurements of various points on several streams from the NWRI field survey report and the recent Dzongkhag survey was also done. The Dzongkhag survey measured 678 points from various Gewogs under Pemagatshel Dzongkhag. The common streams that were measured in both the field surveys were compared and results are as below.

Peling chhu under Dechhenling Gewog showed a discharge value of 47.9 l/s in June and 13.3 l/s in May as per the results from the Dzongkhag field survey while the NWRI field survey results showed a value of 31 l/s for December. Since December month flow is higher than May and the flow in December has values closer to the summer flow measured in June, the measurement values may be questionable. However, the flow measurement values were taken only once and it may not be accurate to categorize it as an incorrect reading. In addition, readings may vary if taken at different locations and depdens on the type of measurement methods adopted.

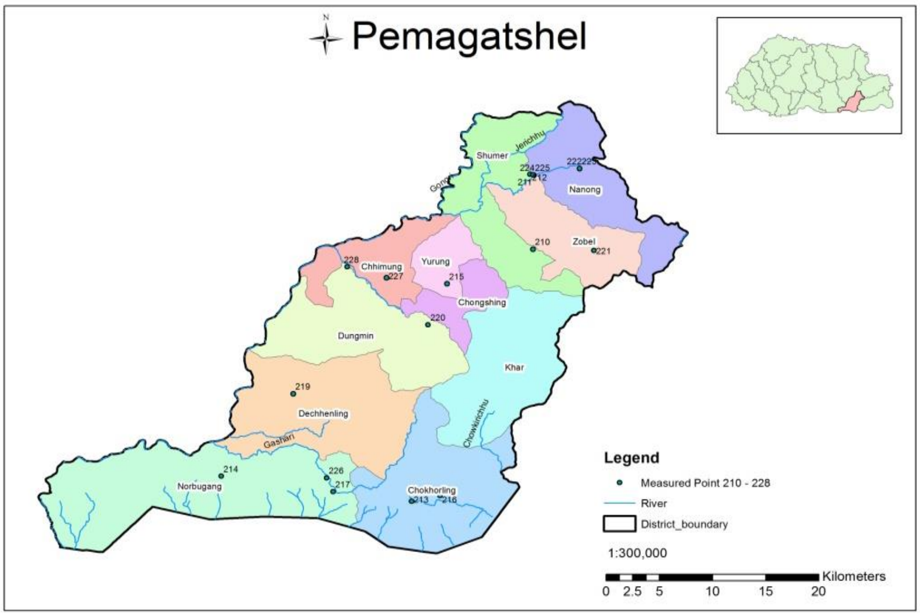


Figure 4-1: Map of Pemagatshel Dzongkhag Showing the Locations of NWRI Sites

Table 4-1: NWRI Data for Pemagatshel Dzongkhag

Gewog	Stream Name	Latitude	Longitude	Discharge (lps)	Month measured
Chhimoong	Tshobari Chhu	27.02381	91.29794	0.53	November
Chhimoong	Ure chu	27.03336	91.26481	853.25	June
Chhoekhorling	Lhungkhung- mu ree	26.82667	91.31936	55.00	December
Chhoekhorling	Menchey dopri	26.83186	91.34331	257.60	December
Chhoekhorling	Pagala drang	26.80583	90.39972	2457.30	June
Chhoekhorling	Tshetshegang chhu	26.84722	91.24756	1.49	December
Dechhenling	Peling chhu	26.92147	91.21928	31.00	December
Dungmaed	Plaitheughi Ri	26.98225	91.33331	8.50	November
Nanong	Demri uper stream	27.11419	91.42244	2465.68	June
Nanong	Shinang gongri	27.12003	91.46142	441.76	November
Nanong	Shinang gongri	27.12014	91.46139	2024.00	June
Nanong	Tsala ri	27.11442	91.42183	2826.25	June
Nanong	Tsala ri	27.11442	91.42183	71.60	November
Norboogang	Lucuri	26.84864	91.15844	98.00	December
Norboogang	Nganglam chhu	26.83511	91.25308	1323.00	June
Shumar	Cherang Chhu	27.04897	91.42192	0.03	November
Shumar	Joktang re	27.11478	91.41942	91.22	November
Yurung	Lungtenri Chhu	27.01844	91.34922	20.40	November
Zobel	Resena Chhu	27.04761	91.47356	112.00	November

4.2 Determination of Contributing Catchment Areas to All the Water Survey Locations from Dzongkhag Study

The water survey location points from the Dzongkhag surveywere mapped on GIS with a resolution of 25m x25m DEM single grid cells.

The catchment areas or the drainage area contributing to the flow at the point where discharge was measured were determined by mapping each point on a DEM as specified above.

The method of measurement adopted for these water resource points were either the conductivity method using SalinoMADD or in some cases when the flow was low; the bucket method for measurement.

For this project, cooking salt was used as a tracer as it is easily available, cheap and not harmful to the ecosystem at such concentrations. A known mass of salt say “M” is diluted in a volume of water of the river and at the downstream, a conductivity probe is placed, that measures the electrical conductivity of water throughout the duration say “T” of passage of the cloud of salt. A linear relationship is derived between the conductivity of water and dissolved salt concentration and the concentration curve is then deduced in function of time Ct. The flow rate (Q) is then obtained by integrating the concentration over time. This is shown in the following equation;

$$Q = \frac{M}{_{o}\int^{t}(Ct - Co)dt}$$

The bucket method[11] for flow measurement is a simple and fast volumetric technique to measure the flow rate in small streams or springs. It is a direct method of measurement where the flow is diverted into a bucket of known volume and the time to fill the bucket is measured with a stopwatch.

The catchment areas of the contributing points from the previous studies were determined using the watershed delineation tool in GIS and their daily average flows were estimated using the Area Ratio method from the flows calculated at the Gewog level.

Out of the 687flow measurement points in the Dzongkhag, the catchment areas of only 36 points could be determined. Some of the water source points that were measured were found to be scattered and not actually falling on a streamline delineated from the DEM. These errors could be due to inaccurate GPS measurements, faulty DEM or springs and pond water sources that do not have any contributing catchments. Some of these points were verified during the recent field visit by the NECS, most points were actually falling on small water bodies or ponds whose flows or catchments cannot be determined in GIS.

The number of survey points carried out for the Community Level Water Resources Inventory, 2017 for each Gewog is mentioned in Table 4-2 and their locations are shown in Figure 4-2. Only those points falling on a water body can actually be used for watershed delineation and comparison with hydrological modelling. The points that fall on the water body were selected and their watershed areas were mapped and the total flow for these watershed areas were calculated using the Area Ratio method. The average flow for every point in each Gewog was calculated and compared with the observed flows.

The water sources and their catchment areas that could be identified in the current study with their daily flows are mentioned in Table 4-3 and their respective watersheds delineated in GIS are shown in Figure 4-3. The average flow for every point in each Gewog was calculated and compared with the observed flows. Most of the measurement points showed comparable results with the modelled flow except for someobserved measurements that are comparatively high. The recent field survey results also had problems validating the measurements of the dry and wet months from the previous survey in some cases.

The details of the measurement point of the previous survey and their observed flows are given in Table 4-2. The area of each watershed is in Table 4-3.

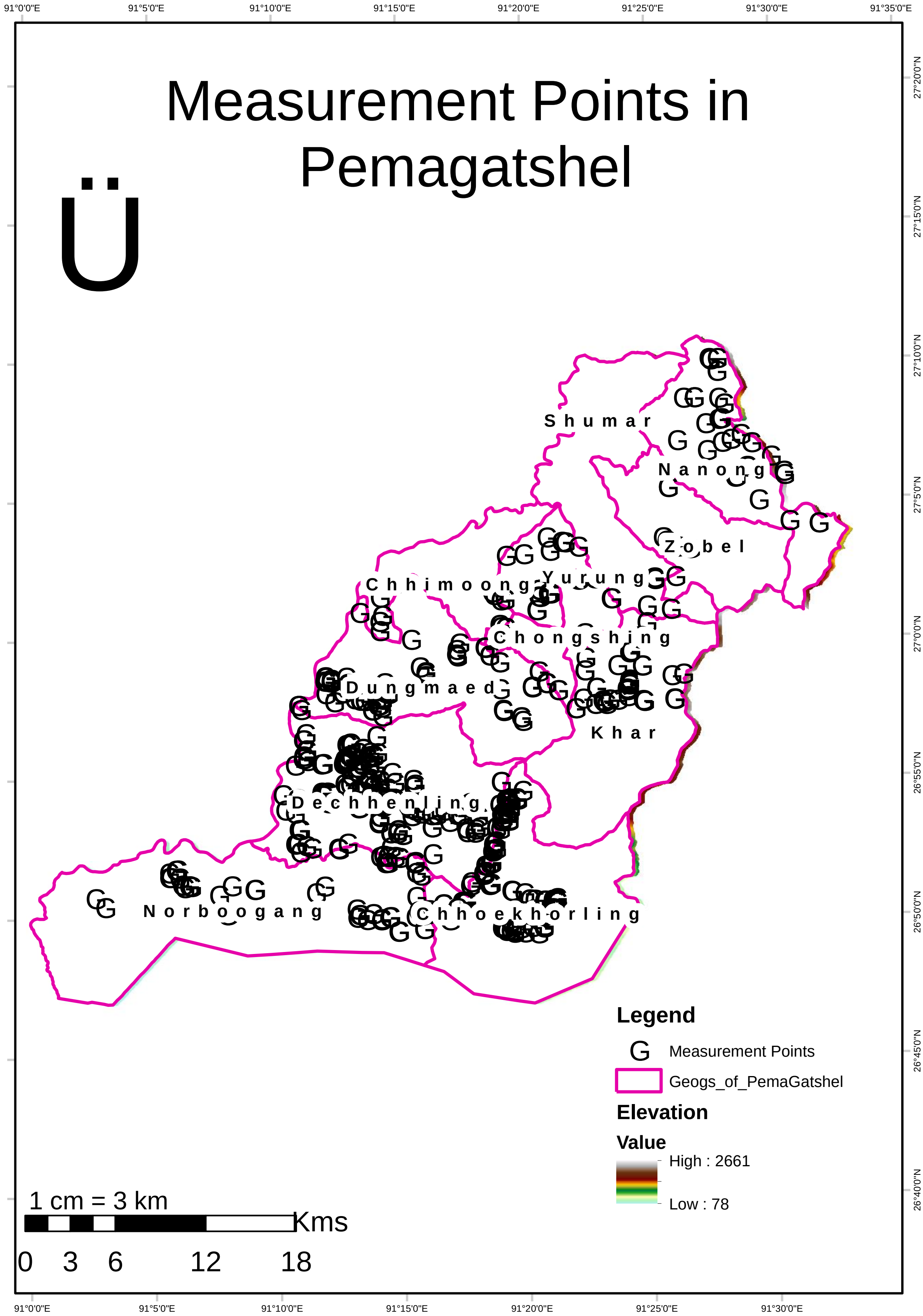


Figure 4-2: Water Survey Locations in Pemagatshel

Table 4-2: Number of Sources Available by Gewogs & Chiwogs under Pemagatshel

Sl. No.	Gewog	Chiwog/Place	No. of Sources
1	Choekhorling	4.1.1	4.1.2
	Sub-total	**4**	**135**
1	Dechhenling	Gonpawoong	14
2		Gonpawoong-Shingchongri	1
3		Kholomri	8
4		Namdaling	7
5		Ridzommo	7
6		Shingchongri	19
7		Shingchongri-Gongpawoong	1
	Sub-total	**10**	**57**
5	Dungmaed	Mikuree	29
	Sub-total	**1**	**29**
1	Khar	Khar	1
2		Khar-Yajur	8
3		Labar-Khangzor	21
4		Bongman	3
5		Naktseri-Tsebar	14
6		Zordung-Shinangri	4
	Sub-total	**6**	**51**
1	Shumar	Batsri	10
2		Dagor	4
3		Denchi-Yalang	14
4		Nangkor	28
5		Shali-Gamung	12
	Sub-total	**5**	**68**
1	Nanong	Nanong	21
2		Raling	13
3		Tokarey	8
4		Tshatsi	21
5		Wongchiloo	15
	Sub-total	**5**	**78**
1	Nganglam Thromde	Nganglam (Thromde)	6
2		Gashari-Bali	5
3		B/t Khalakhang ri and Dezama	2
4		Pagaladrang	1
5		Tsenkari	2
	Sub-total	**5**	**16**
1	Norbugang	Gashari	10
2		Menchhu	8
3		Norbugang-Rinchhenzor	9

4		Nyingshing borang	8
5		Tshaelshingzor	6
Sub-total		**5**	**41**
1	Yurung	Bangdala	16
2		Chhorgangzor to Mangarna	6
3		Dungsingma	6
4		Khangma	16
5		Khominang	10
6		Thungo	8
Sub-total		**6**	**62**
1	Zobel	Pangthang Daza	29
2		Zobel	17
3		Ngangmalang	13
		Resinang	21
Sub-total		**1**	**80**
1	Chongshing	Chongshing	9
2		Lanangzor	9
3		Mandi	4
4		Thongsa	9
5		Yomzor	8
Sub-total		5	39
4.2	Chimmong	chhimoong chiwong	6
4.3		Lungkholom	10
4.4		Nyasikhar	6
4.5		Chiphoong	9
Sub Total		**4**	**31**
Grand Total		**52**	**687**

Table 4-3 shows the flows calculated from the catchments of the survey points with their respective observed flows. The observed wet and dry month measurements for the Gewogs fall within the average monthly flow values from their catchments except for few points which should slightly higher flow measurement value then their modelled value, which is acceptable. Similarly, some points showed a very low observed value compared to their modelled value such as Phalamphu Ri water source location point at Nanong which showed a very low wet measurement value of 0.0097 l/s compared to its modelled average annual value of 19 l/s and minimum monthly average value of 0.3 l/s in the month of January. In addition, some measurement points showed discharge values higher in the dry months than the wet months' flows. These results maybe debated since only one time measurement was taken and these measurements may have been taken during or after a very dry or wet week or month.

Overall, the observed and the modelled flow values show a good match with both dry and wet months falling within the monthly water availability derived from their respective catchments.

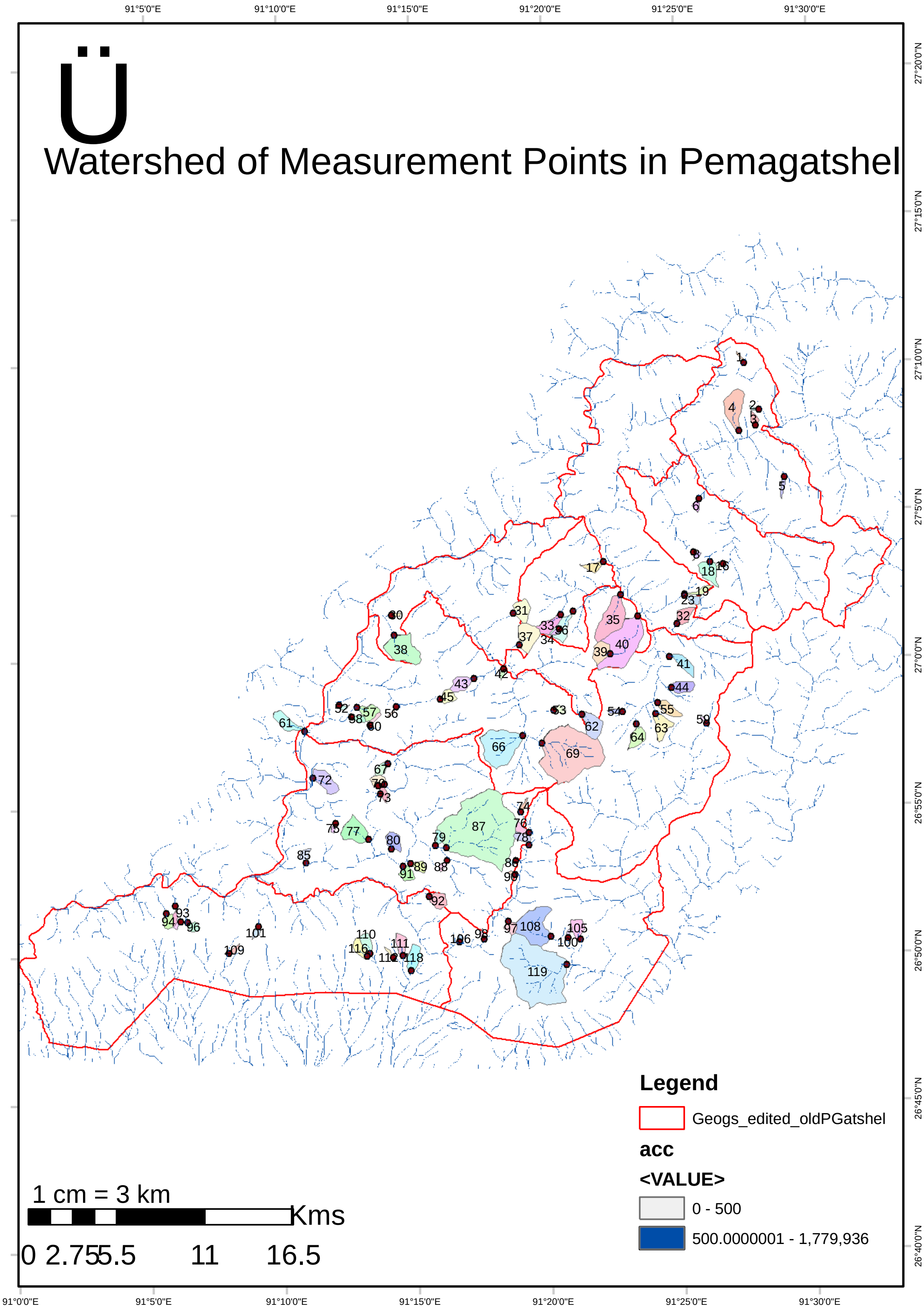


Figure 4-3: Watershed Area of Measurent Points in Pemagatshel

Table 4-3: Monthly Average Flows and Catchment Areas of Survey Points

Chiwog	Water Source	Area (km²)	Monthly Daily average flow (l/s)													Observed flow (l/s)			
			Jan	Feb	Mar	Ap	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual avg	Discharge 1		Discharge 2	
1. Norbugang Gewog																			
																Disch-arge 1	Month	Discharge 2	Month
Nyingshing boring	Hop ri	0.2	0.3	0.3	0.4	0.6	1	2.5	4.3	3.6	3.1	1.6	0.4	0.3	1.5	0.8	May	0.4	Feb
Nyingshing boring	Menchu ri	0.5	0.8	0.9	1.2	1.9	2.9	7.4	12.9	10.6	9.2	4.7	1.2	0.9	4.5	0.11	May	3.8	Mar
Nyingshing boring	Moyoma ri	0.1	0.2	0.2	0.3	0.4	0.7	1.7	2.9	2.4	2.1	1.1	0.3	0.2	1	0.17	May	0.44	Ma
Norbugang_Rinchhenzor	Kalakpar-shing ri	0.3	0.6	0.7	0.9	1.4	2.1	5.5	9.5	7.9	6.8	3.5	0.9	0.6	3.4	1.02	May	0.08	Feb
Norbugang_Rinchhenzor	Rinchen-zor ri (b)	0.2	0.3	0.4	0.5	0.8	1.2	3.2	5.5	4.6	3.9	2	0.5	0.4	1.9	0.09	May	0.02	Feb
Tshaelshingzor	Delokmin ri	0.2	0.3	0.4	0.5	0.8	1.3	3.2	5.6	4.6	4	2	0.5	0.4	2	4.09	May	0.064	Feb
Gashari	Lungtshe-ring drang	0.1	0.1	0.2	0.2	0.3	0.5	1.2	2.2	1.8	1.5	0.8	0.2	0.1	0.8	1.1	June	14.6	May
Gashari	Truelku ri	0.6	1	1.2	1.5	2.5	3.8	9.7	17	14	12.1	6.2	1.5	1.1	6	0.36	June	1.8	May
Menchhu	stream near junction	0.6	1.1	1.2	1.6	2.6	4	10.3	17.9	14.8	12.7	6.5	1.6	1.2	6.3	0.22	Aug	1.34	Apr
2. Choekhorling Gewog																			
-	Zangkho-lomri	12.4	143.1	146.3	238.2	716.3	796.8	1,616.30	2,591.60	1,560.70	1,450.40	695.4	139.5	89.7	848.7	8.31	June	156	Jan
-	Brong-shingre	3.6	41.2	42.1	68.6	206.1	229.3	465.1	745.8	449.1	417.4	200.1	40.1	25.8	244.2	0.8	June	9.7	Jan
-	Brong-shingre	3.6	41.2	42.1	68.6	206.1	229.3	465.1	745.8	449.1	417.4	200.1	40.1	25.8	244.2	0.7	June	232	Jan
-	Tharpare	0.1	0.9	1	1.6	4.7	5.2	10.6	17.1	10.3	9.6	4.6	0.9	0.6	5.6	0.2	June	7.45	Jan
-	Koknangre	0.8	8.7	8.9	14.6	43.8	48.7	98.8	158.4	95.4	88.6	42.5	8.5	5.5	51.9	0.01	July	18.7	Jan
3. Dechhenling Gewog																			
-	Tralire	15.7	180.6	184.7	300.8	904.4	1,006.00	2,040.60	3,272.10	1,970.50	1,831.20	877.9	176.1	113.2	1,071.50	-		161	Dec
-	Agurtsongre (1)	0.3	3.5	3.5	5.8	17.3	19.2	39	62.6	37.7	35	16.8	3.4	2.2	20.5	-		1.1	Nov
-	Bangre	0.2	1.8	1.9	3.1	9.2	10.2	20.7	33.3	20	18.6	8.9	1.8	1.2	16.9	-		76.7	De
-	Kulaphanre (5)	0.6	7.1	7.3	11.8	35.6	39.6	80.3	128.7	77.5	72.1	34.5	6.9	4.5	42.2	0.45	May	1.23	Nov
-	Choekhorli	1.8	0.02	0.02	0.03	0.1	0.1	0.2	0.4	0.2	0.2	0.1	0.02	0.01	0.1	0.23	July	12.4	Jan

	ngzampare																		
-	Goyongjab ree	0.3	4	4.1	6.6	19.9	22.2	45	72.1	43.4	40.3	19.3	3.9	2.5	23.6	0.001	July	7.35	Jan
4. Dungmaed Gewog																			
Mikuree	Yoebey ree	0.9	10.3	10.6	17.2	51.7	57.6	116.7	187.2	112.7	104.8	50.2	10.1	6.5	61.3	0.9	Jan	-	July
Mikuree	Phadiri	0.6	6.7	6.9	11.2	33.7	37.5	76	121.9	73.4	68.2	32.7	6.6	4.2	39.9	0.3	Jan	45	July
Mikuree	Bumpari	0.9	9.8	10.1	16.4	49.2	54.8	111.1	178.1	107.3	99.7	47	9.6	6.2	58.3	0.7	Jan	0.4	July
Mikuree	Yangshaw-ari	0.1	1.4	1.4	2.3	6.8	7.6	15.4	24.8	14.9	13.9	6.6	1.3	0.9	8.1	-	Jan	2.1	July
5. Chhimong Gewog																			
Lungkholom	Demri	1.8	20.3	20.8	33.8	101.6	113	229.3	367.7	221.4	205.8	98.7	19.8	12.7	120.4	0.4	May	0.7	Dec
6. Yurung Gewog																			
Dungsingma	Denang - khoi ri	1.1	13.1	13.3	21.7	65.4	72.7	147.5	236.5	142.4	132.4	63.5	12.7	8.2	77.4	0.2	May	65.8	Feb
Khominang	Nyokho ri	0.9	10.7	10.9	17.8	53.5	59.5	120.7	193.5	116.5	108.3	51.9	10.4	6.7	63.4	0.1	May	1.33	Feb
7. Chongshing Gewog																			
Thongsa	Tsab ri	5.2	59.5	60.8	99.1	297.9	331.3	672.1	1,077.70	649	603.1	289.2	58	37.3	352.9	16.01	May	4.64	Nov
8. Khar Gewog																			
Labar-Khengzor	Kunzim Ri (C)	0.9	10.6	10.8	17.7	53.1	59.1	119.8	192.1	115.7	107.5	51.5	10.3	6.6	62.9	0.9	Aug	1.3	Jan
Labar-Khengzor	Dorji Ri	1.2	13.3	13.6	22.1	66.4	73.9	149.9	240.3	144.7	134.5	64.5	12.9	8.3	78.7	3	May	38.7	July
Khar-Yajur	Lame Ri	0.9	9.9	10.1	16.5	49.7	55.3	112.2	179.8	108.3	100.6	48.3	9.7	6.2	58.9	0.8	May	21.3	Feb
Khar-Yajur	Manidrang Ri	0.9	10.1	10.3	16.7	50.3	56	113.6	182.1	109.7	101.9	48.9	9.8	6.3	59.6	5	July	36.8	Aug
Labar-Khengzor	Kunzim Ri (B)	0.1	0.9	0.9	1.5	4.5	5	10.2	16.3	9.8	9.1	4.4	0.9	0.6	5.3	2	May	61.1	Feb
Naktseri-Tsebar	Manchung-rang Ri A	0.2	2.1	2.1	3.4	10.3	11.4	23.2	37.2	22.4	20.8	10	2	1.3	12.2	0.1	May	0.5	Feb
9. Zobel Gewog																			
Pangthang Daza	Laipo Rii	0.2	2.5	2.5	4.1	12.4	13.8	28	44.8	27	25.1	12	2.4	1.6	14.7	0.4	April	2.5	Jan
10. Nanong Gewog																			
Raling	Tsengd-ongri	0.2	2.5	2.6	4.2	12.7	14.1	28.5	45.8	27.6	25.6	12.3	2.5	1.6	15	0.4	July	25.9	May
Nanong	Phalamphu Ri	0.3	3.2	3.3	5.3	16	17.8	36.2	58	35	32.5	15.6	3.1	2	19	0.344	Aug	0.0097	May
Tshatsi	Chumani (Muna)	0.1	1	1	1.7	5.1	5.6	11.4	18.3	11	10.3	4.9	1	0.6	6	0.45	Aug	60	May

Chapter 5 : Household Survey Report

5.1 Sampling Design and Questionnaire

Household survey for Pemagatshel Dzongkhag was conducted using single - stage stratified simple random sampling with the sample size of 263 households in seven Gewogs. The maximum nuber of respondents was from Norbugang with 75 households, while the least is from Choekhorling with 14 households as shown in Table 5-1. From the Water Resource Inventory, a set of 22 questions were found relevant and accordingly used for the analysis. The detail of the questionnaire is in Annex 2.Survey Questionnaire.

Table 5-1: Summary of Household Surveys Carried Out by Gewogs in Pemagatshel

Gewog	No- of respondents
Chhimong	16
Choekhorling	14
Decheenling	73
Dungmaed	34
Nanong	28
Norbugang	75
Yurung	23
Total	**263**

5.2 Data Storage and Analysis

The data from the household survey were all punched into MS Excel and then transferred to STATA for analysis. Analysis of the data was conducted with STATA 15 version - and relevant inferences made from the analysis.

5.3 Dzongkhag Level Information

The household survey data at Gewog level were analysed. The information for the Dzongkhag and Gewogs are inferred below in the subsequent sections.

5.3.1 Water Resources in Pemagatshel

The most common water resources identified in Pemagatshel are spring water resources (66.54%), followed by 32.32% streams and 1.14% ponds as shown in Figure 5-1.

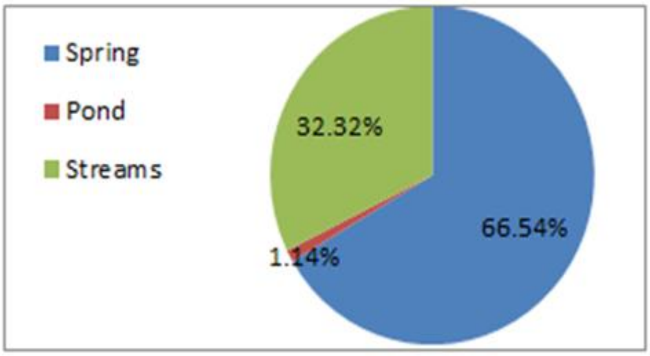


Figure 5-1: Water Source in Pemagatshel (N=1032)

While comparing the common water resources types in the Gewogs of Pemagatshel, we find that Nanong, Norbugang, Dechhenling, Yurung and Chhimong are more dependent on spring water, while Choekhorling and Dungmaed (Dungmin) are highly dependent on streams. Chhimoong has highest number of households depending on ponds (18.7% dependency on ponds). Details are shown in Table 5-2.

Table 5-2: Water Resources by Gewogs

Water source	Chhi-mong	Choekhor-ling	Dechhenling	Dungmin	Nanong	Norbugang	Yurung
Spring	43.75	28.57	82.19	38.24	89.29	60	91.3
Stream	37.5	71.43	8.7	61.76	10.71	40	8.7
Pond	18.75	0	0	0	0	0	0
Total	**100**	**100**	**90.89**	**100**	**100**	**100**	**100**

5.3.2 Water Uses in Pemagatshel

The most common use of water in Pemagatshel Dzongkhag is for drinking (62.6%), followed by livestock and others (5.04%). The details of water uses in the Dzongkhag are mentioned in Table 5-3.

Table 5-3: Water Uses in Pemagatshel

Main use of water	Frequency	Percent
Hydropower	1	0.41%
Irrigation	1	0.41%
Drinking	154	62.60%
Livestock	1	0.41%
Drinking+Livestock	2	0.81%
Drinking+Others	24	9.76%
Drinking+Livestock+Others	10	4.07%
Livestock+Others	51	20.73%
Irrigation+Others	2	0.81%

5.3.3 *Water Adequacy*

Respondents were also asked if they believe that the present water is adequate. Around 69% of the respondents claimed that their water resource is adequate all year round, while 25.66% mentioned there were seasonal shortage and 4.87% said that it was never sufficient as shown in Figure 5-2.

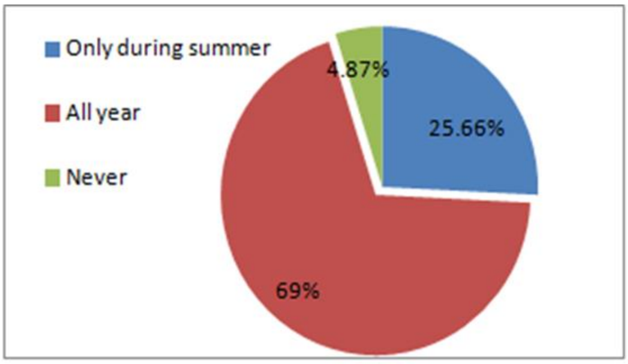


Figure 5-2: Water Adequacy in Pemagatshel (N=226)

Nanong Gewog had the highest percentage of households (96.15%) stating that they have adequate water throughout the year, while Norbugang had the least (38.89%) stating they have adequate water throughout the year. Chhimong had the maximum number of respondents stating (25%) that the water is never adequate. The details are in Table 5-4.

Table 5-4: Water Adequacy by Gewogs in Pemagatshel

Adequacy of water	Chhimong	Choekhor -ling	Dechhen-ling	Dung-min	Nanong	Norbu -gang	Yurung
All year	50	84.62	91.94	93.75	96.15	38.89	61.9
Only during summer	25	15.38	8.06	6.25	3.85	51.39	38.1
Never	25	0	0	0		9.72	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

5.3.4 *Water Source Abandoned, Reason and Potential for New Source*

During the survey, people were also asked if they have abandoned any water sources and to provide reasons for doing so. It was found that from 214 respondents; only 30.84% reported having abandoned a water source as shown in Figure 5-3. The maximum percentage of water source abandoned cases was found in Dechenling (74.24 %) as shown in table 5.5.

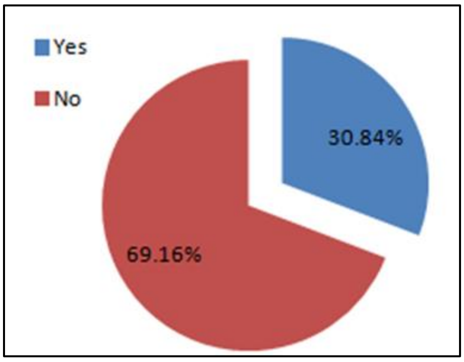


Figure 5-3: Water Source Abandoned in the Last 5 Years in Pemagatshel (N=214)

Table 5-5: Water Source Abandoned by Gewogs in Pemagatshel.

Abondoned source	Chhimong	Choekhor -ling	Dechhen-ling	Dung-min	Nanong	Norbu-gang	Yurung
Yes	14.29	8.33	74.24	63.16	0	0	9.09
No	85.71	91.67	25.76	36.84	100	100	90.91
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

From the 50 respondents, 18% reported drying of water resources as a reason for abandoning their water source whereas 72% said it was due to other reasons. From the 200 households who answered the question on new water sources availability, around 74% mentioned that there is no new source potential, while 26% mentioned that there are potential water sources available. The maximum respondents with possible new source citation are in Nanong (66.67%), followed by 52.17% in Yurung, 25% each in Chokhorling and Chhimong as shown in Table 5-6.

Table 5-6: Potential New Water Sources by Gewogs in Pemagatshel.

Potential for new source	Chhimong	Choekhor -ling	Dechhen-ling	Dungmin	Nanong	Norbu-gang	Yurung
Yes	25	25	20	43.75	66.67	17.14	52.17
No	75	75	80	56.25	33.33	82.86	47.83
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

5.3.5 Rural Water Supply Scheme (RWSS)

Out of the six Gewogs that responded to the question on RWSS coverage, Dungmaed (Dungmin), Nanongand Chhimong reported tohave 100% RWSS coverage while Choekhorling had the highest (38.46%) stating that there is no RWSS coverage. The details of RWSS coverage in the Gewogs of Pemagatshel is shown in Table 5-7.

Table 5-7: RWSS Coverage by Gewogs in Pemagatshel

Covered under RWSS?	Chhimong	Choekhorling	Dechhenling	Dungmin	Nanong	Norbu-gang	Yurung
Yes	100	61.54	77.46	100	100	NA	95.45
No	0	38.46	22.54	0	0	NA	4.55
Total	**100**	**100**	**100**	**100**	**100**	**NA**	**100**

Questions were also asked on the functionality of the RWSS.Out of 144 respondents, it was found that 88.19% have fully functional schemes and only 4.17% responded to have semi-functionalschemes in the Dzongkhag. This is shown in Figure 5-4.

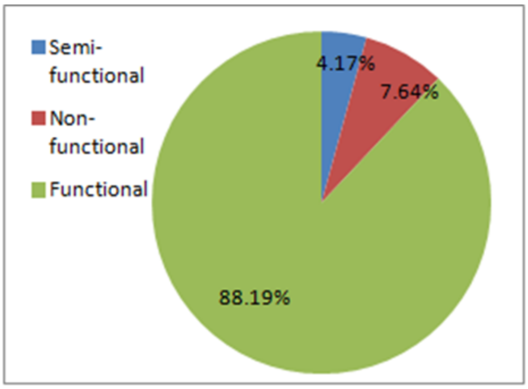


Figure 5-4: Functionality of RWSS in Pemagatshel (N=144)

Out of the six Gewogs who responded to RWSS functionality question, Choekhorling reported only 22.22% fully functional systems whereas the other Gewogs had more than 50% of the households stating that theyhave fully functional RWSS. This is shown in Table 5-8.

Table 5-8: RWSS Functionality by Gewogs in Pemagatshel

Functionality of RWSS	Chhimong	Choekhor -ling	Dechhen -ling	Dungmin	Nanong	Norbu -gang	Yurung
Functional	100	22.22	92.86	100	100	NA	70
Non-functional	0	77.78	7.14	0	0	NA	0
Semi-functional	0	0	0	0	0	NA	30
Total	**100**	**100**	**100**	**100**	**100**	**NA**	**100**

5.3.6 Comparison of Adequacy and RWSS Functionality Results

Comparisons between water adequacy results and RWSS functionality results were made to check the results consistency. If the match was a 100% it was marked as perfect while less than 100% and up to 50% was marked as reasonable and a match lower than 40% was marked as poor. Nanong, Dungmin (Dungmaed) and Dechenling Gewogs show a reasonable match with almost equal percentages of households claiming that water is adequate and that their RWSS is fully functional. This could indicate that the results of the survey are somehwhat reliable. The result for Chhimong Gewog is rather opposing. For Chhimong Gewog, 50% say the water is adequate all year long while 25% say they face seasonal shortages and 25% say they face year long shortages whereas RWSS functionality shows a 100% fully functional result.

5.3.7 Cropping and Irrigation

From the survey sample, only 111 have responded to this question and majority of the Gewogs have not responded to this question (details shown in Table 5-9). From the 111 households, 15.32% said that they practise cropping once in a year, while 84.68% practises cropping twice a year. Their satisfaction level on the availability of irrigation water was also evaluated as shown in Figure 5-5. It was found that only 23.85% find irrigation water abundant, 21.1% adequate, while majority (54.13%) said that the water for irrigation is inadequate. Only 0.92% has severe shortage out of 41.4 % that responded to this question.

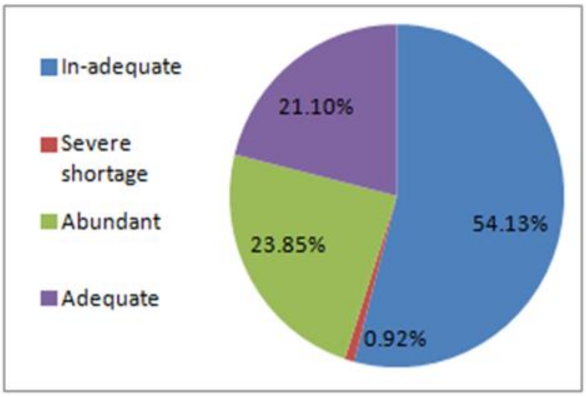


Figure 5-5: Perception on Irrigation Water Availability in Pemagatshel (N=111)

Table 5-9: Annual Cropping by Gewogs in Pemagatshel

Annual Cropping	Chhimong	Choekhor -ling	Dechhen -ling	Dung-min	Na-nong	Norbu-gang	Yurung
Yes	NA	NA	8.06	5.88	40	NA	NA
No	NA	NA	91.94	94.12	60	NA	NA
Total	**NA**	**NA**	**100**	**100**	**100**	**NA**	**NA**

5.3.8 Water Quality and Diseases

Majority of households interviewed seem to be satisfied with the water quality of their locality. 56.05 % of the households are very satisfied with their water quality, and 38.31 %

somewhat satisfied. Only 2.02% are dissatisfied and 0.40% very dissatisfied as shown in Figure 5-6.

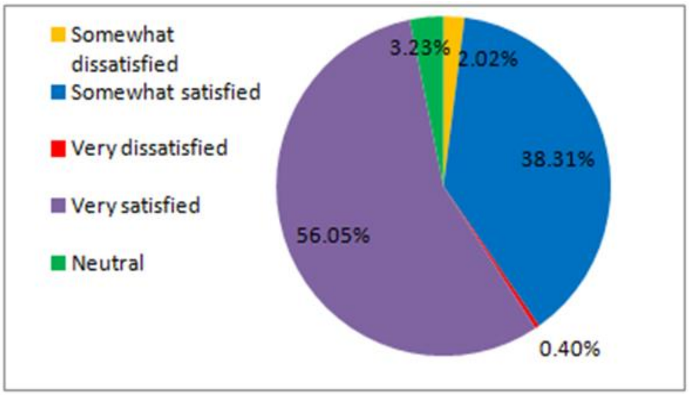


Figure 5-6: Satisfaction with Water Quality in Pemagatshel (N=248)

Based on the survey, majority of the households in the Gewogs of Nanong, Choekhorling, Dungmin (Dungmaed) and Dechhenling (100 %, 75 %, 72.73 % and 84.29 %, respectively) are very satisfied with the water quality. Households in Norbugang, Yurung and Chhimong seem to be only somewhat satisfied with the water quality (80.28 %, 61.9% and 42.86 % respectively). The details are in Table 5-10.

Table 5-10: Water Quality Perceptions by Gewogs in Pemagatshel

Satisfaction with water quality	Chhi-mong	Choekhor-ling	Dechhen-ling	Dung-min	Na-nong	Norbu-gang	Yurung
Very satisfied	21.43	75	84.29	72.73	100	19.72	14.29
Somewhat satisfied	42.86	25	11.43	24.24	0	80.28	61.9
Neutral	35.71	0	0	0	0	0	14.29
Somewhat dissatisfied	0	0	4.29	0	0	0	9.52
Very dissatisfied	0	0	0	3.03	0	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Only 30 households have cited a reason for their dissatisfaction with water quality in the neighbourhood. Most households had no idea about their water quality (50 %), and 30% said they have other reasons of dissatisfaction. Only 10% said it was either due to dirty or murky water.

Out of 68.44% respondents, most households have not reported any common diseases (65.78 % of households). The common diseases in the Gewogs are shown in Table 5-11.

Table 5-11: Common Diseases in Pemagatshel

Common Diseases	Chhi-mong	Choekhor-ling	Dechhen-ling	Dungmin	Nanong	Norbu-gang	Yurung
None	NA	91.67	100	88.89	NA	97.26	NA
Diarrhoea	NA	0	0	0	NA	0	NA
Cholera	NA	0	0	0	NA	0	NA
Malaria	NA	0	0	5.56	NA	0	NA
Eye infections	NA	0	0	0	NA	1.37	NA
Others	NA	0	0	5.56	NA	0	NA
Diarrhoea+ Typhoid	NA	8.33	0	0	NA	1.37	NA
Total	**NA**	**100**	**100**	**100**	**NA**	**100**	**NA**

5.3.9 *Gewog Wise Results*

While most of the results for the Dzongkhag have been presented in the previous sections through respective Gewogs, an effort was also made to look into the details of the data at Gewog level. Few important and interesting findings at the Gewog level are mentioned below.

i. Nanong Gewog

Out of 532 households, 28 households were interviewed in Nanong Gewog. From the 28, 89.29 % of the households depend on spring water resources and 10.71% on streams as shown in Figure 5-7. All 28 households use water for drinking only and none have abandoned a water source. All the households are covered by functional rural water supply scheme (RWSS).

Only 40% of the households' practice cropping once a year and the rest 60% practice cropping twice a year. Out of 89.29% dependent on spring, 91.67 % reported that water is abundant for irrigation, 4.17% said it was adequate and another 4.17% said it was inadequate as shown in Figure 5-8. All households who responded as having abundant water depend on streams for irrigation.

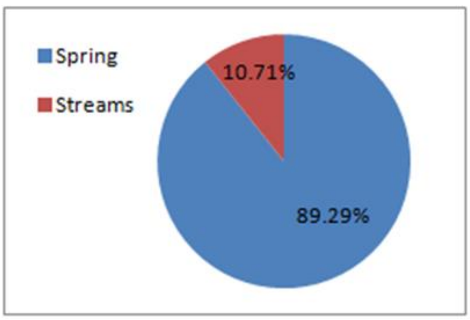


Figure 5-7 Water Source in Nanong

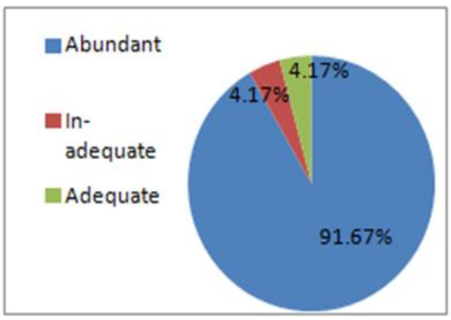


Figure 5-8 Perception on Irrigation Availability in Nanong

All of the households are very satisfied with the drinking water quality.

The RWSS functionality result and the adequacy result for Nanong Gewog shows a good match with about 96% water adequacy while 4% have seasonal shortages. The Gewog has 100% functional RWSS.

ii. Norbugang Gewog

Under Norbugang, 75 households were interviewed out of 502 households in the Gewog. From the 75, 60% of the households depend on spring water resources and the rest (40%) depend on streams as shown in Figure 5-9. 98.65% of the households use the water source for drinking purpose only and 1.35% use it for irrigation, drinking and others. All of the households surveyed said that they have not abandoned any water source and 17.14% reported that there are potential new sources available whereas, 82.86% reported of having no potential for new sources.

23.85% of the households said that there is abundant irrigation water, 21.1% said it is adequate, 54.13% said it is inadequate and 0.92% reported of severe shortages of irrigation water.

9.72 % of the households surveyed are very satisfied with drinking water quality and 80.28% somewhat satisfied as shown in Figure 5-10. A small percentage of the households (1.37%) reported presence of water borne diseases such as diarrhoea and typhoid and another 1.37% reported of eye infection.

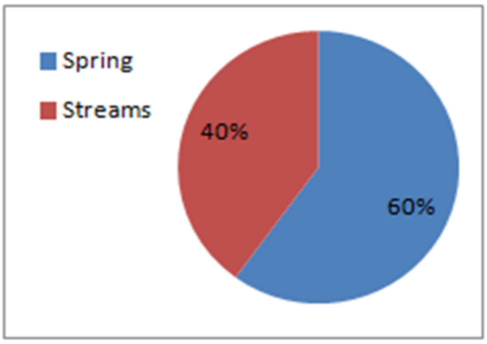


Figure 5-9: Water Source in Norbugang Gewog

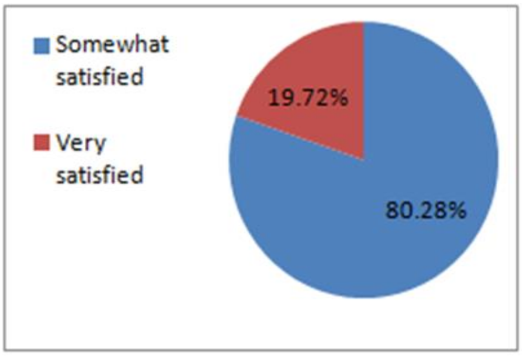


Figure 5-10: Satisfaction with Water Quality in Norbugang Gewog

iii. Choekhorling Gewog

From 229 households in Choekhorling, 14 households were interviewed. Out of the 14, 28.57% of the households depend on spring water resources and 71.43% depend on streams as shown in fFigure 5-11. 16.67% use water sources for drinking and livestock, 8.33% for drinking and others and 75% for drinking, livestock and others.

8.33% of the households have abandoned their water sources and 25% believed that there are potential new water sources available whereas 75% reported of having no potential for new sources.

Only 61.54% of households are covered under RWSS from which 22.22% of the households have functional RWSS.

Majority (75%) are satisfied with the drinking water quality and 25% somewhat satisfied. About 91.67% reported no incidences of water borne diseases and malaria and 8.33% reported of other diseases.

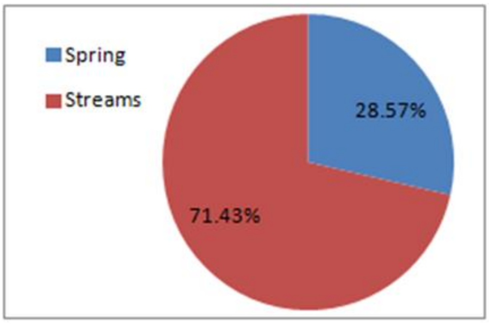


Figure 5-11: Water Source in Chokhorling Gewog

The RWSS functionality result and the adequacy result for Choekhorling Gewog shows a conflicting match with 85% water adequacy, 15% seasonal shortage and only 22% RWSS functionality and 78% non-functional RWSS.

iv. Dungmaed Gewog

Out of 355 households, 35 households were surveyed in Dungmaed. From the survey population about 38.24% of the households depend on spring water resources and 61.76% depend on streams as shown in Figure 5-12.

About 50% of the households use the water sources for drinking while 17.65% use for drinking and livestock and 29.41% for drinking.

From the surveyed households, 93.75% of households said that their current water source is adequate all round the year and only 6.25% said it is adequate only during summer. 100% of spring water dependents and 90.91% of stream water dependents reported that their present water source is adequate all year round.

Around 63.16% of the households reported to have changed their water source. 43.75% of the households said there are potentials for new water sources wheras 56.25% reported of having no possible new water sources. All of the households surveyed are under functional RWSS.

78.57% reported water to be adequate for irrigation and only 21.43% said it was inadequate. Around 94.12% of the households practice cropping twice a year.

72.73% are very satisfied with drinking water quality, 24.24% somewhat satisfied and 3.03% very dissatisfied (Figure 5-13). Around 88.89% reported that there are no cases of water borne diseases. 5.56% complained of malaria and remaining 5.56% complained of other diseases.

The RWSS functionality result and the adequacy result for Dungmaed Gewog shows a comparable match with about 93% water adequacy, 7% seasonal shortage and 100% RWSS functionality.

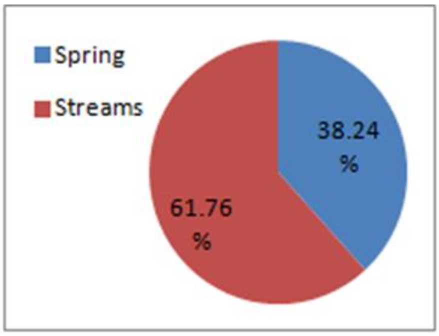


Figure 5-12: Water Source in Dungmaed Gewog

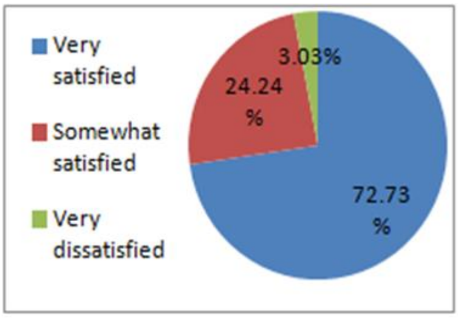


Figure 5-13: Satisfaction with Water Quality in Dungmaed Gewog

v. Dechhenling

Out of 502 households in Dechhenling, 73 households were surveyed. From the 73, around 82% of the households depend on spring water resources and 18% on streams as shown in Figure 5-14. 7.46 % of the households use the water source for drinking only, 23.88% for drinking and livestock and 46.27% for drinking, livestock and others.

Out of the 82.19% dependent on spring water sources, 92% reported the present water sources to be adequate all year round and only 8% reported of seasonal shortages. Out of the 17.81% dependent on streams, 91.67% said the sources are adequate all year round and only 8.33% reported of seasonal shortages.

Around 74.24% of the households reported to have changed their water source and 20% said there are potentials for new water sources in the Gewog.

77.46% of the households surveyed reported to have RWSS coverage and 92.86% out of the 77.46% have fully functional RWSS. Almost 91.94% of the households practice cropping twice a year.

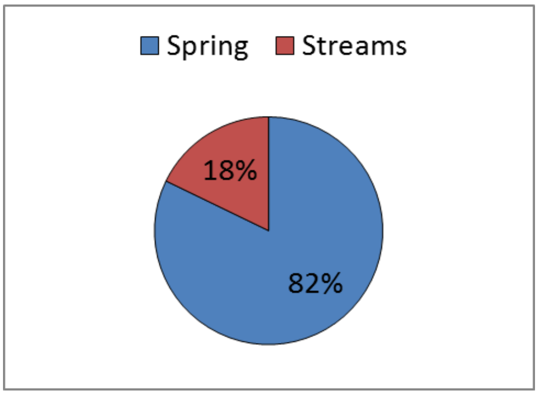


Figure 5-14: Water Source in Dechenling Gewog

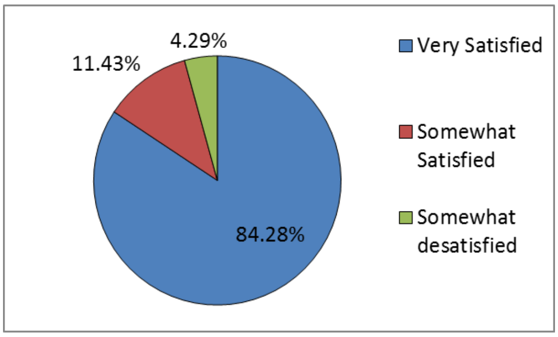


Figure 5-15: Satisfaction with Water Quality in Dechenling Gewog

Out of the 73 households surveyed, 84.29% of the households were very satisfied with their drinking water quality, 11.43% somewhat satisfied and 4.29% somewhat dissatisfied as shown in Figure 5-15. All the households reported that there are no cases of water borne diseases in the Gewog.

The RWSS functionality result and the adequacy result for Dechenling Gewog shows a comparable match with about 91.94% water adequacy, 8% seasonal shortage and 92.86% RWSS functionality and 7.14 non-functional RWSS.

vi. Yurung Gewog

Out of 318 households in Yurung, 23 households were surveyed. From the 23, 91.3% of the households depend on spring water resources and 8.7 % depend on Streams as shown in Figure 5-16. All the households surveyed use the source for drinking.

Out of 91.3 % dependent on spring water resources, 61.9 % reported the source to beadequate all year round whereas 38.1 % mentioned it to be adequate only during summer.

Only 9.09 % of the households have changed their water source and52.17 % said there are potential new water sources available. 95.45 % of the households are under RWSS, out of which70% are fully functional and 30% semi-functional.

14.29 % of the households are very satisfied with the drinking water quality, 61.9 % reported somewhat satisfied and 9.52 % somewhat dissatisfied as shown in Figure 5-17.

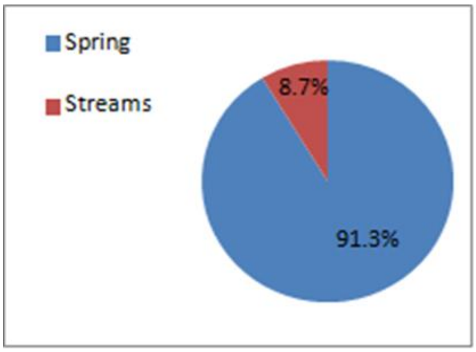


Figure 5-16: Water Source in Yurung Gewog

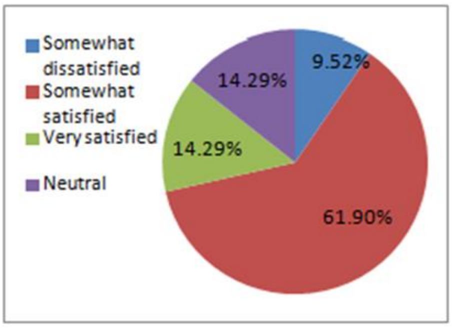


Figure 5-17: Satisfaction with Water Quality in Yurung Gewog

The RWSS functionality result and the adequacy result for Yurung Gewog shows a comparable match with about 61.9% water adequacy, 38% seasonal shortages and 70% RWSS functionality.

vii. Chhimong Gewog

Out of 176 households in Chhimong, 16 households were surveyed. From the 16, 43.75% of the households depend on spring water resources, 37.5 % on streams and 18.75 % on ponds as shown in Figure 5-18.

Among the total households surveyed, 81.82 % of the households use their water source for drinking only, 9.09 % for livestock and another 9.09 % for drinking, livestock and others (31% missing). 50 % of the households reported the current water source to be adequate all round the year, 25 % only during summer and 25% complained that it is never adequate. 14.29% have changed their water source. Only 25 % of the households reported the potential for new water resources in the Gewog. All the households surveyed are covered by RWSS and all are functional.

The Figure 5-19 shows the water quality satisfaction in the Gewog. 21.43% of the households are very satisfied with the drinking water quality and 42.86% reported to be somewhat satisfied.

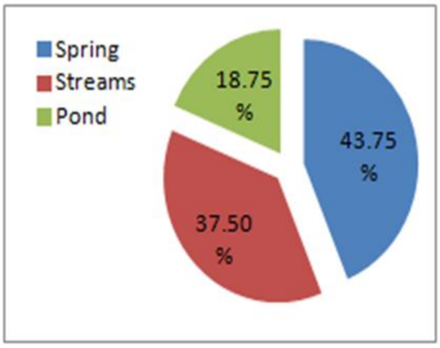


Figure 5-18: Water Source in Chhimong Gewog

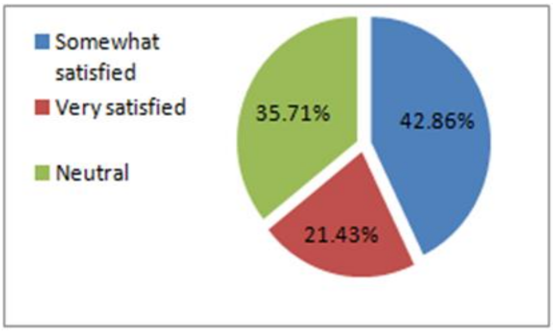


Figure 5-19: Satisfaction with Water Quality in Chhimong Gewog

The RWSS functionality result and the adequacy result for Chhimong Gewog shows an incompatible match with 50% water adequacy, 25 seasonal shortage and 25% yearlong shortages and 100% RWSS is functionality.

5.4 Summary of Gewog Household Survey Results

Norbugang Gewog had the highest number of respondents (17.36% of the households) with 75 households from a total of 432 households compared to other Gewogs while the least representation was from Choekhorling Gewog with only 4.68% respondents that is 14 households from a total of 299 households. The most common water source was found to be springs and streams. As per the survey results most of the Gewogs reported of having adequate water throughout the year. Gewogs that had high percentage of households with seasonal and year long shortages were Chhimong and Norbugang. Chhimong and Norbugang have 25% and 10% said that the water is never adequate. Most of the Gewogs have good RWSS coverage and functional RWSS. Choekhorling had the highest percentage (77.78%) who stated that RWSS is non-functional. A comparison of the survey results of RWSS functionality and water adequacy was done for each Gewog as can be seen in Table 5-12. Nanong, Dungmaed, Yurung and Chimmong showed a reasonable match which could indicate that the results are reliable. Choekhorling showed a poor match, which may make us question the reliability of the survey results. Since Choekhorling had the least representation of the households, it may have affected the result representation. Majority of the households in all the Gewogs seem to be content with their water quality with only 9% and less stating the water quality is not satisfactory. Nanong had the highest percentage who stated water quality was very good. From the Gewogs, 54.13% of the total households surveyed reported of irrigation water shortage.

Table 5-12: RWSS Functionality and Water Adequacy Comparison

Gewog	Source	Adequacy	RWSS full functionality	Match
Nanong	Streams and springs	96.15%	100%	Reasonable
Norbugang	Streams and springs	38.89%	NA	NA
Choekhorling	Streams and springs	84.62%	22.22%	Poor
Dungmaed	Streams and springs	93.75%	100%	Reasonable
Dechhenling	Streams and springs	91.94%	92.86%	Perfect
Yurung	Streams and springs	61.9%	70%	Reasonable
Chhimong	Streams, ponds and springs	50%	100%	Reasonable

Chapter 6 : Discussion and Conclusion

Pemagatshel is located in South Eastern Bhutan with an area of 1022 sq. km consisting of 11 Gewogs, 4,881 households and a population of 24,961. The flows for the Gewogs of Pemagatshel were calculated by down-scaling the flows from the model output of the Drangmechhu sub-basin. As per the downscaled results, the lowest flow is 0.55 MCM /month for Yurung in December and highest is 101.48 MCM/month in July for Norbugang. The water demand in each Gewog was also computed and compared with the available water for the Gewogs. Shumur had the highest water demand of 0.18 MCM with a water availability of 115.98 MCM/year.The water available is higher than the actual requirement in the Gewog but it is much lesser compared to the other Gewogs. Although the demand was much lower than the water availability results for the Gewogs, their distribution could cause problems or deficiencies in some areas.The climate change effect on the available water was also calculated for each Gewog. Under climate projections for RCP 4.5, the flow in Pemagatshel is likely to increase from January to August and decrease from September to December in 2030, while in 2060 the months of January, June, October and December are the only ones likely to see a decrease in flow. Under RCP 8.5 scenario, flows are likely to decrease in November and December for 2030 and only in December for 2060, while all other months may experience increase in stream flows. The decline of flow in the later months (winter) of the year may cause further reduction in low flows in the future. The unpredictable increase and decrease in the pattern of flow throughout the year may be problematic for the people in the district and especially for the farmers in the villages. The Gewogs of Shumur and Chhimoong already have water shortage problems and they may have higher risks of shortages in the future if water resources are not managed properly.

The water source points and their measured values collected from the Dzongkhag survey results were also assessed and compared with the modelled flows from this study. In some cases, the observed flows were found to be slightly higher than the modelled flows. The recent field visit conducted by the NECS also tried to validate the location of some points whose watersheds could not be mapped in this study. Some of these points were actually found to be small water bodies or ponds which do not have any contributing catchment and therefore couldn't be identified in GIS. The household survey results also showed a high dependence of the households on spring water and also on ponds in some cases.

The household survey was done for 263 households in Pemagatshel Dzongkhag. For some questions, the number of respondents was less than 50% of the surveyed population. It was found that there is a high dependence on spring water (66.5%) followed by streams (32.32%) which is similar in all Gewogs except for Chhimong which has 18.75% dependence on ponds. Generally, there is no water adequacy issue in the Dzongkhag with 69% of the respondents saying that they have adequate water all year round but 38.1% of respondents in Yurung and 15.38% in Chhimong mentioned of having high seasonal shortages. Major respondents in Dechhenling and Dungmaed have also abandoned their previous water sources. RWSS systems seem to have very good coverage and functionality with 88.19% having functional systems. Water quality is also generally considered to be good with 56% saying that they are very satisfied with the quality of the drinking water. From the Gewogs, 54.13% of the households in total reported of irrigation water shortages.

Chapter 7 : Issues, Challenges and Reccomendations

This assignment attempted to provide the overall status of available water resources in the Pemagatshel Dzongkhag and the possible areas for prioritization based on the availability of water resources. The available water in the Gewogs of the Dzongkhag was downscaled from a hydrological model, comparisons were made based on the actual field measurements, and the model flows wherever applicable. Apart from the actual field measurements, an attempt to compare results of water resources status based on individual household surveys was also done. The available water and the demand were also compared for each Gewog both for the present and the future time periods along with the impacts of climate change on the water resources of the Dzongkhag. The issues, limitations and challenges confronted in the current project are highlighted in this section and recommendations for improvement for future studies are mentioned in the following paragraphs.

The accuracy of the GPS locations of the field measurement points was said to be of concern by the Dzongkhag Environment Officers. Some of the point measurements in this study showed their measurement readings in far-off places from where they were actually measured. This makes it hard to locate the points in GIS and identify their contributing catchment areas. Since this was an extensive field survey, the DEOs also mentioned that the task interfered with their daily responsibilities, leading to prolonged completion time.

Some of the technical hitches from the field survey results were the water resources point locations and their validation. Although some points were verified during the recent field survey conducted by the NECS, these measured points were mostly found to be either small springs or ponds whose catchments cannot be identified in GIS. Furthermore, the points of measurements in this study revealed that several measurements were taken throughout the same stream. This may be avoided in the future by mapping and identifying stream lines on GIS or Google Earth and selecting a common outlet point for measurement. In addition, a field visit to verify these points and demarcation for future measurements may be valuable and time efficient. The points that have been measured and identified in this study can be prioritized and highlighted. These water source measurement points can be consulted with relevant stakeholders and marked for constant monitoring and measurement.

The method of flow measurement adopted was the conductivity method where SalinoMADD was used for measuring the flow. The instrument required a lot of salt for its operation and longer time for readings. Additionally, due to frequent equipment failure, limited manpower and resources, the officials had to use the bucket method of measurement in some cases. This use of two different methods could result in varying readings. In addition, comparisons based on one time measurement may not be accurate. Coordination and cooperation between relevant agencies was raised as an issue that led to conflicting measurement methods and values. In the future, coordination and management between relevant stakeholders and also constant monitoring of the progress may need to be prioritized for more efficient results.

A set of 22 questions were asked to the households of the Gewogs. The household survey results reveal the state of the water resources based on individual households but their coverage and reliability may be questionable. In some cases the questions answered may not represent the actual status of the available water since individual households may answer according to their needs. In some cases, the household survey results were contradictory to what the Gup had reported. In the future, organization and collaboration between relevant agencies may help in getting more precise results.

One of the limitations was also the lack of account for groundwater users in the region. The status of the water resources in the Gewog and their uses were based on surface water alone. It would be valuable to study the groundwater users in the districts to get a specific measure of their role in the water balance system in the district.

The findings from this study give a general idea of the status of water resources in the Dzongkhag. Although priority areas cannot be directly pinpointed due to limited evidence, an indication of the current water resources status based on household surveys and model outputs, as well as projections on future demands and availability could be presented.

Chapter 8: Appendix I: Water Source Inventory Results

Table 8-1 shows the water sources in Dechhenling Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 57 water sources. The highest dry discharge was recorded for Kurungri water source under Shingchongri-Gonpawoong Chiwog with 200 l/s and wet discharge from Sokporongri water source under Kholomri Chiwog with 280 l/s.

Table 8-1: Water Sources for Dechhenling Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Namdaling	Shingthangri	26.92591667	91.19675	1031	0.66	June	0.967	May
Namdaling	Leburi	26.93244444	91.22000	967	0.123	June	0.27	May
Shingchongri	Yangkuri							
Shingchongri	Phungi	26.91750000	91.22233333	970	0.01	June		
Ridzommo	Dongtshongri	26.90383333	91.24402778	645	0.565	June	1.42	May
Ridzommo	Namzongri 1	26.89388889	91.23438889	480	0.23	June	0.215	May
Ridzommo	Namzongri 2	26.89388889	91.23438889	480	0.23	June		
Shingchongri	Leburi 2nd						0.197	May
Shingchongri	Leburi 1st	26.91877778	91.22275000	1020	0.812	June	0.107	May
Namdaling	Maniri	26.90866667	91.19905556	1041	0.77	June	0.312	May
Shingchongri	Pheshingri	26.92086111	91.22302778	1075	0.631	June		
Shingchongri	Phungri	26.92086111	91.22302778	1075	0.63	June		
Shingchongri	Hawaishingri	26.91938889	91.22175000	982	0.02	June		
Shingchongri	Tshongpaphungri							
Shingchongri	Charchari	26.92188889	91.23011111	1018	0.342	June		

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Shingchongri	Sebegonpari	26.92711111	91.21158333	1031	0.811	June		
Shingchongri	Garzatpuri	26.92563889	91.21011111	1032	0.231	June	0.126	May
Shingchongri	Charchari	26.92880556					0.171	May
Shingchongri	Tshampari			229	0.32	June	0.241	May
Shingchongri	Momnangri	26.93033333	91.23077778	1015	0.678	June	0.405	May
Shingchongri	Manidogorbari	26.92947222	91.21558333	1187	0.78	June	0.0096	May
Gonpawoong	Khochiri	26.923222222	91.22013889	961	5	June	1.04	May
Gonpawoong-Shingchongri	Pelingchhu	26.92508333	91.22291667	938	47.91	June	13.3	May
Gonpawoong	Rebalingmori	26.91908333	91.22805556	977	0.32	June		
Gonpawoong	Poskari							
Gonpawoong	Gurbori	26.94177778	91.23297222	955	0.45	June	0.569	May
Gonpawoong	Baptari	26.90947222	91.21911111	956	6.425	June		
Gonpawoong	Zangrushingri 2nd	26.90883333	91.22355556	1021	0.522	June		
Gonpawoong	Zangrushingri 1st	26.90772222	91.22869444	1020	0.63	June	0.43	May
Gonpawoong	Martshallari	26.92644444	91.24050000	853	1.26	June		
Gonpawoong	Khemzere	26.91333333	91.21475000	958	0.783	June		
Gonpawoong	Bazagururi	26.87477778	91.21630556	956	0.362	June	25.2	May
Shingchongri	Leburi						0.0037	May
	Soinari	26.91877778	91.22275000	1020	0.812	June		
Kholomri	Pudungri						0.143	May
Shingchongri	Zhingri	26.93236111	91.22813889	973	0.323	June	0.0026	May

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Kholomri	Zaiphuri	26.92994444	91.22655556	899	0.55	June		
Namdaling	Namdaling CF water	26.90494444	91.17936111	431	0.05	June		
Kholomri	Sokporongri	26.96083333	91.18066667	257	280	Jan	143	May
Kholomri	Sunmari				Source dried up	Jan	8.93	May
Kholomri	Telungre	26.94011111	91.18352778	308	1.01	Jan		
Kholomri	Laishingrejugre	26.93383333	91.18583333	319	1.32	June	9.83	May
Kholomri	Changchangmari	26.92777778	91.18613889	290	0.98	June	0.796	May
Kholomri	Laishingree	26.93058333	91.18361111	276	9.01	June		
Namdaling	Khakhari	26.92502778	91.17808333	256	0.121	June	33.7	May
Namdaling	Boddawoongri	26.92088889	91.17830556	407	5	June		
Namdaling	Domling	26.91752778	91.17297222	379	5.4	June	3.95	May
Shingchongri	Amshingwoong1	26.89813889	91.17133333	392	67.1	June	0.716	May
Shingchongri-Gonpawoong	Kurungri	26.88641667	91.18011111	250	197	July	200	May
Gonpawoong	Amshingwoong2	26.8835000	91.19130556	295	0.31	June		
Gonpawoong	Yangkholomri3	26.89625000	91.17777778	452	0.222	June	4.96	May
Gonpawoong	Yangkholom2	26.87780556	91.17775000	450	0.21	June		
Gonpawoong	Yangkholom1	26.87808333	91.17919444	517	0.42	June		
Ridzommo	Donorburi	26.87308333	91.18108333	528	0.44	June	0.107	May
Ridzommo	Kerongri	26.87794444	91.21280556	378	191	July	195	May
Ridzommo	Namtongri	26.87669444	91.18516667	518	0.66	June		
Ridzommo	Prengkoongmari	26.87533333	91.18886111	464	0.72	June		

Table 8-2 shows the final water sources in Khar Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 51 water sources showing highest dry discharge from Marung Ri water source under Khar Chiwog with 2170 l/s and wet discharge from Marung Ri water source under Khar Chiwog with 280 l/s.

Table 8-2: Water Sources for Khar Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Bongman	Kheri	26.97688889	91.43055556	2028	0.962	May	0.082	Feb
	Yeyong RI	26.98333333	91.43086111	1990	1.011	May	0.713	Feb
	Gangtori	26.97777778	91.43833333	1799	0.639	May	0.08	Feb
Khar	Marung Ri	27.01666667	91.43055556	1320	280	July	2170	Aug
Khar-Yajur	Ribor	27.00891667	91.41419444	1326	4	July	40.5	Aug
	ManidrangRi	26.99919444	91.40952778	1033	5	July	36.8	Aug
Khar-Yajur	Jetsham Ri(A)	56.99216667	91.40577778	1094	0.2	July	21.9	Aug
	Jetsham Ri (B)					July	0.26	Aug
	Prabula Ri (A)	26.99177778	91.40322222	1114	0.2	July	0.33	Aug
	Prabula Ri (B)	26.99152778	91.40308333	1111	0.01	July	3.98	Aug
	Prabula Ri (C)	26.99102778	91.40227778	1117	0.02	July	0.721	Feb
	Lame Ri	26.98288889	92.09250000	1179	0.8	May	21.3	Feb
Labar-Khengzor	Nagphodrang Ri	27.47888889	91.41016667	1174	2.1	July	260	Feb
	Labar Ri (A)	27.47805556	91.40002778	1260	1.2	July	8.73	Feb
	Labar Ri (B)	26.97416667	91.40225000	1319	0.2	July	20.2	Feb
	Labar Ri (C)	26.97336111	91.40197222	1322	0.1	July	7.32	Feb
	Labar Ri (D)	26.97283333	91.40197222	1333	0.5	July	0.892	Feb

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Labar Ri (E)	26.97222222	91.40183333	1341	0.6	July	2.6	Feb
	Labar Ri (F)	26.97166667	91.40230556	1339	0.71	July	20.7	Feb
	Labar Ri (G)	26.96919444	91.40038889	1363	0.81	July	3.418	Feb
	Dorji Ri	26.96836111	91.40061111	1367	3	July	38.7	Feb
	Kunzim Ri (A)	26.96475000	91.40113889	1330	5	July	48.5	Feb
	Kunzim Ri (B)	26.96308333	91.43225000	1328	2	July	61.1	Feb
	Kunzim Ri (C)	26.96280556	91.38897222	1382	0.91	July	1.326	Feb
	GyalpoborangRi	26.96022222	91.38661111	1423	0.01	July	65.4	Feb
	Khengzor Ri A)	26.96147222	91.38500000	1424	1.2	July	48.5	Feb
	Khengzor Ri (B)	26.96172222	91.41202778	1444	1.12	July	102	Feb
	Khengzor Ri (C)	26.96225000	91.38416667	1372	0.3	July	11.3	Feb
	Gongdang Ri	26.96019444	91.37930556	1356	25	July	34	Feb
	Rangthang Ri				Source dried up	July	48.5	Feb
	Gomtsang Ri	26.96227778	91.41113889	1348	0.01	July	74.9	Feb
	Langzor Ri	26.96263889	91.39422222	1345	0.6	July	39.8	Feb
	Nagpholadrang Ri	27.47836111	91.41011111	1176	186	July	260	Feb
Naktseri-Tsebar	Manchungrang Ri A	26.96983333	91.38005556	1471	0.063	May	0.511	Feb
	Manchungrang Ri B	26.96983333	91.38005556	1471	0.063	May	0.6	Feb
	Rapksbrangsari ‘A’					May	1.1	Feb
	Rapksbrangsari ‘B’	26.96355556	91.37113889	1621	0.056	May	1.36	Feb
	Drupchu Ri	26.97238889	91.37405556	1935	0.0012	May	0.02	Feb
	Khawa Ri	26.97344444	91.37586111	2013	0.0032	May	0.024	Feb

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Kaptar Ri A	26.95777778	91.36613889	1880	0.006	May	0.013	Feb
	Kaptar Ri B	26.95777778	91.36613889	1880	0.006	May	0.06	Feb
	Omsha Ri						0.05	Feb
	Rotpaborang Ri 'A'						0.014	Feb
	Rotpaborang Ri 'B"							
	Rotpaborang Ri 'C'						0.1	Feb
	Rotpaborang Ri 'D'						0.48	Feb
	Khawa Ri B						0.0047	Feb
Zordung-Shinangri	Bokar Ri						0.05	Feb
	Konang Ri	26.98044444	91.37236111	1592	0.01	May	0.06	Feb
	Gyemcharoborang Ri	26.98044444	91.37236111	1592	0.01	May	0.28	Feb
	Laydung Ri	26.98330556	91.39447222	1450	0.043	May	20.8	Feb

Table 8-3 shows the final water sources in Nanong Gewog under Pemagatshel Dzongkhag with different water source name, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 78 water sources. The highest dry discharge was recorded for Dem Ri water source under Nanong chiwog with 40000 l/s and the wet discharge from Dem Ri water source under Nanong chiwog was 93.86 l/s.

Table 8-3: Water Sources for Nanong Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Raling	Khochungri (B)	27.11291667	91.46919444	1236	0.532	July	10	May
Raling	Drangtsiri	27.11652778	91.46600000	1238	2.341	July	22	May
Raling	Lautari						98.8	May
Raling	Tsengdongri	27.10183333	91.48250000	1622	0.411	July	25.9	May
Raling	Rowshingri	27.11797222	91.46197222	1237	0.49	July	0.0081	May
Raling	Redaza	27.11672222	91.45977778	1225	0.266	July	0.0081	May
Raling	Khangmari	27.11169444	91.45588889	1270	0.273	July	0.0078	May
Raling	Rowshingri (A) Branphu	27.11797222	91.46197222	1237	0.49	July	0.0075	May
Raling	Rowshingri (B) Branphu	27.11797222	91.46197222	1237	0.49	July	0.0075	May
Raling	Naktseri	27.10966667	91.46411111	1683	0.11	July	0.0059	May
Raling	Sengdong Ri	27.10100000	91.49302778	1596	46.71	August	0.0064	May
Raling	Dangtey Shing Ri (Sengdong)	27.10100000	91.49302778	1596	46.71	August	0.006	May
Raling	Pemari	27.11611111	91.47502778	1228			0.0068	
Wongchi- loo	Prengjari	27.08169444	91.49036111	2159	0.266	July	0.0044	May
Wongchi- loo	Gopasingmari	27.09577778	91.47516667	2064	0.094	July	0.0049	May
Wongchi- loo	Lebari	26.99977778	91.25647222	1705	0.663	July	0.0051	May
Wongchi - loo	Phugari	27.09547222	91.47455556	2047	0.08	July	0.0049	May
Wongchi- loo	Rabungri	27.09344444	91.47966667	1954	0.173	July	0.0051	May
Wongchi- loo	Megamri	27.09344444	91.47997222	1959	0.064	July	0.0051	May
Wongchi- loo	Zhimpori	27.09219444	91.49155556	2226	0.865	July	0.0045	May

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Wongchi- loo	Zhimpori Lamtag	27.09394444	91.49138889	2237	0.56	July	0.0045	May
Wongchi- loo	Rashiri	27.09380556	91.48411111	2132	0.124	July	0.0041	May
Wongchi- loo	Shangzori	27.10072222	91.50452778	2204	0.15	July	0.0044	May
Wongchi- loo	Wogombrakri	27.06913889	91.51069444	2291	0.77	July	30	May
Wongchi- loo	Tashiborang (A) Walicktang	27.06752778	91.53025000	1850	1.21	July	0.0054	May
Wongchi- loo	Tashiborang (B) Walicktang	27.06752778	91.53025	1850	1.21	July	0.0054	May
Wongchi- loo	Ngangshing Woongri (A)	27.09225	91.49161111	2235	0.548	August	0.0045	May
Wongchi- loo	Ngangshing Woongri (B)	27.09377778	91.48411111	2133	0.171	August	0.0044	May
Tokarey	Sangzor Ri	27.10072222	91.50452778	2204	0.15	August	28.6	May
Tokarey	Mukazor Ri	27.09866667	91.50719444	2259	0.061	August	28.6	May
Tokarey	Lemshing Ri	27.10027778	91.50825000	2205	0.05	August	0.0048	May
Tokarey	Shinang Rimung (Bargonpa)	27.09677778	91.50750000	2306	0.07	August	0.0045	May
Tokarey	Gay Ri (Tokari)	27.10786111	91.49877778	1938	0.09	August	0.0051	May
Tokarey	Moyong Ri (A)						0.006	May
Tokarey	Moyong Ri (B)						0.0061	May
Tokarey	Rashigonpa Remung	27.11594444	91.48566667	1813	0.75	August	0.0057	May
Nanong	Rilung Ri	27.11825000	91.47180556	1269	0.2	August	0.0079	May
Nanong	Dongshing Ri	27.12105556	91.47863889	1119	0.428	August	0.009	May
Nanong	Leba Ri						0.007	May
Nanong	Monphu Ri	27.13369444	91.47783333	912	39.8	August	1010	May

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Nanong	Walaktang Ri	27.13369444	91.47783333	912	39.8	August	460	May
Nanong	Phalamphu Ri	27.13025000	91.46388889	1040	0.344	August	0.0097	May
Nanong	Thongki Ri						0.0133	May
Nanong	Phogchi Ri						0.0128	May
Nanong	Yampha Ri (A)	27.11772222	91.43608333	761	0.21	August	0.0132	May
Nanong	Yampha Ri (B)						0.0133	May
Nanong	Kheyang Ri (Kulung)						0.0118	May
Nanong	Joktari	27.12647222	91.42094444	648	52.81	August	28.7	May
Nanong	Pam Ri	27.12455556	91.41886111	635	42.61	August	22.7	May
Nanong	Dem Ri	27.12427778	91.87211111	628	93.86	August	40000	May
Nanong	Tsala Ri	27.12427778	91.42369444	634	78.36	August	15000.0000	May
Nanong	Damstang Ri						20.8	May
Nanong	Tsanda Ri	27.12772222	91.45502778	849	50.61	August	449	May
Nanong	Roksha Ri	27.12672222	91.43147222	674	2.17	August	0.0152	May
Nanong	Lunggang Ri	27.12500000	91.42436111	637	0.948	August	0.0154	May
Nanong	Tsang Ri						0.0149	May
Nanong	Yelchen Ri	27.11808333	91.46797222	957	0.57	August	0.0102	May
Tshatsi	Phashi Ri (A)	27.06030556	91.34808333	1467	0.63	August	0.0068	May
Tshatsi	Phashi Ri (B)	27.14294444	91.46391667	1467	0.345	August	15.5	May
Tshatsi	Remung	27.14488889	91.45408333	1396	0.248	August	22.7	May
Tshatsi	Phokchi Ri	27.15711111	91.45269444	1788	0.01	August	0.0056	May

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)	Month	Discharge 2 (l/s)	Month
Tshatsi	Khesing Ri	27.15519444	91.47183333	1720	0.231	August	0.0058	May
Tshatsi	Khorapha Ri	27.15588889	91.47130556	1744	0.124	August	0.0058	May
Tshatsi	Gazang Ri						0.0058	May
Tshatsi	Throktsang Ri	27.15522222	91.47183333	1716	0.194	August	0.0058	May
Tshatsi	Chumani (Muna)	27.16672222	91.45777778	1700	0.45	August	60	May
Tshatsi	Rejok (Muna)	27.16672222	91.46333333	1769	0.77	August	15	May
Tshatsi	Yechilo (A)	27.16850000	91.47347222	1788	0.125	August	5	May
Tshatsi	Yechilo (B)	27.16850000	91.47347222	1788	0.125	August	120	May
Tshatsi	Tsheshingzor (Muna) Temporary	27.15841667	91.47097222	1709	1.212	August	0.0059	May
Tshatsi	Yesangmo	27.05341667	91.44411111	2007	0.06	August	0.0056	May
Tshatsi	Rothpa Ri	27.15905556	91.46308333	1736	0.222	August	0.0058	May
Tshatsi	Dranang Ri	27.15966667	91.46088889	1812	0.011	August	0.0054	May
Tshatsi	Yechiloori (Lumri)	27.1685	91.47347222	1220	0.25	August	0.0082	May
Tshatsi	Leypha Ri	27.14941667	91.45894444	1385	1.74	August	0.0082	May
Tshatsi	TshangRi (A)	27.14336111	91.44761111	1410	0.115	August	0.0069	May
Tshatsi	TshangRi (B)	27.14330556	91.44763889	1410	0.66	August	0.0069	May
Tshatsi	Tshatsi Ri	27.14319444	91.44041667	1443	0.02	August	0.0068	May

Table 8-4 shows the final water sources in Yurung Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 62 water sources.The highest dry discharge was recorded for Buga Apa Ri water source under Bangdala Chiwog with 3660.707 l/s and the highest wet discharge of 36.09 l/s from Khiga Ri water source under Dungsingma Chiwog.

Table 8-4 : Water Sources for Yurung Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Bangdala	Wanglakhoi ri						3.69	Feb
	Wangmo Amari						0.143	Feb
	Porila ri		91.3195	1965	0.0022	May	0.349	Feb
	Naepori		91.31108333	2016	0.005	May	3.663	Feb
	Buga Apa ri	27.02336111	91.32766667	2057	0.02	May	3660.707	Apr
	Chhema Tshampa ri	27.02286111	91.32683333	2057	0.004	May	0.003	Feb
	Khrokchangri						0.5144	Feb
	Rashu ri						0.823	Feb
	Bumpa ri						0.252	Feb
	Phutsungburi ri	27.04958333	91.32050000	1977	0.012	May	2.717	Feb
	Taktakpa ri A	27.03394444	91.32488889	1784	0.05	May	13.2	Feb
	Taktakpa ri B	27.03394444	91.32488889	1784	0.05	May	2.38	Feb
	Mengri						13.2	Feb
	Ngagpa ri						11	Feb
	Gurtung chelo ri						1.17	Feb
	Thabtsangrong ri						1.267	Feb
Thungo	Guitsho							Feb
	Lebe ri 1	27.10411111	91.33544444	1791	0.05	May	2.6	Feb
	Lebe ri 2	27.10411111	91.33544444	1791	0.05	May	2.95	Feb
	Lebe ri 3	27.10411111	91.33544444	1791	0.05	May	2	Feb
	Lebe ri 4	27.10411111	91.33544444	1791	0.05	May	40	Feb
	Thungo ri						4.14	Feb
	Gelong ri 1						7.16	Feb
	Gelongri 2						4.98	Feb
Khominang	Nyokho ri	27.02469444	91.34277778	1510	0.05	May	1.33	Feb

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Khominang ri	27.01694444	91.34058333	1610	0.061	May	9.86	Feb
	Rimung ri 1	27.02469444	91.34755556	1628	0.07	May	2.59	Feb
		27.02469444	91.34755556	1628	0.07	May		Feb
	Rimung ri 2						0.956	Feb
	Gomkholakhoi ri						4.22	Feb
	Gongtshenang ri						4.15	Feb
	Shingbu tothka khoi ri						2.4	Feb
	Bamda ri						2.52	Feb
	Goga daza ri	27.02891667	91.34236111	1452	5.29	May	0.196	Feb
Dungsingma	Thungo joog ri 1	27.02891667	91.34236111	1452	5.29	May	3.2	Feb
	Thungo joog ri 2	27.02891667	91.34236111				0.556	Feb
	Dupkang ri	27.02891667	91.34236111	1425	5.29	May	1.01	Feb
	Gongmarep ri 1	27.02891667	91.34900000	1452	5.29	May	2.74	Feb
	Khiga ri	27.02702778	91.34908333	1436	36.09	May	1.25	Feb
	Denang khoi ri	27.02702778	91.34908333	888	0.231	May	65.8	Feb
Chhorga-ngzor to Magarna	Phawang ri	27.03477778	91.36866667				152	Feb
	Phokchiri	27.04286111	91.36050000	850	1.2	May	4.01	Feb
	Dungsingma joog ri	27.03980556	91.35633333	869	12	May	23.7	Feb
	Lungtong ri 1 (Darburi)	27.03975000	91.35555556	879	9.01	May	258	Feb
	Lungtong ri 2	27.04394444	91.35544444	881	0.89	May	146	Feb
	Menkang ri	27.02672222	91.34836111	831	6.1	May	12.7	Feb
Khangma	Leshing ri (Magarna ri)	27.02672222	91.34836111	1240	0.055	May	9.25	Feb
	Monangsa ri	27.05730556	91.36013889	1053	0.0625	May	25.6	Feb
	Yongba ri	27.06097222	91.34986111	1284	0.17	April	2.12	Feb
	Gum ri 1	27.05230556	91.34994444	1362	0.35	April	0.323	Feb
	Gum ri 2	27.05230556	91.34994444	1362	0.35	April	0.667	Feb
	Gum ri 3	27.06072222	91.34661111	1225	0.12	April	1.9	Feb

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Karwang ri	27.05955556	91.35130556	1299	0.38	April	8.43	Feb
	Seri gomche ri	27.06144444	91.35577778	1667	0.555	April	0.2	Feb
	Sakhangma ri 1	27.06144444	91.35577778	1667	0.555	April	0.225	Feb
	Sakhangma ri 2	27.06030556	91.34808333	1651	0.255	April	1.28	Feb
	Phashi ri					April	5.93	Feb
	Udzorongpa ri	27.05205556	91.33372222	1638	0.232	April	0.042	Feb
	Lekpa apa ri 1	27.05411111	91.35877778	1463	0.762	April	43.636	Feb
	Sumthang yoe ri	27.05044444	91.33241667	1620	0.134	April	4.31	Feb
	Lekpa apa ri 2	27.05044444	91.33241667	1271	0.042	April	2.54	Feb
	Yoedung ri 1	27.05752778	91.35800000	1271	0.042	April	2.7	Feb
Mikuree	Joktangri	26.97738889	91.19902778	359	120	Jan	35.1	June
	Prengmatap	26.97786111	91.19877778				32.9	July
	Kharamree	26.97513889	91.19938889				16.7	July
	Khochiri	26.96763889	91.19894444				22.6	July
	Poskari	26.99733333	91.28888889	26.96730556	91.93194444	June	0.056	July
	Yebari	26.96286111	91.20469444				0.854	July
	Dingshingri						0.18	July
	Yangshawari	26.97469444	91.20238889				2.14	July
	Doyomri	26.97744444	91.21288889				3.49	July
	Zubrangri	26.96450000	91.21844444				0.5373	July
	Bumpari	26.97336111	91.21388889	551	0.7	Jan	0.3607	July
	Sengdeyphuri	26.96361111	91.22213889	702	2	Jan	0.376	July
	Khawangri	26.96333333	91.22511111	754	0.5	Jan	7.78	July
	Shangshari	26.95758333	91.22994444	862	0.8	Jan	0.06	July

Chiwog	Name of the water source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Jawakangkari	26.95777778	91.23002778				46.3	July
	Shapalungri	26.95944444	91.23613889				0.12	July
	Kharshingri	26.96058333	91.23438889				1.48	July
	Tatsela	26.96069444	91.23375000	1030	0.05	June	10.9	July
	Shera afari	26.96530556	91.23647222					
	Subiri	26.96400000	91.23677778				0.276	July
	Grangmalari						2.13	July
	Nepori	26.98319444	91.26222222	1349	0.11	Jan		
	Phadiri	26.97961111	91.26586111	1310	0.3	Jan	45	July
	Dongdongmari	26.98025000	91.26602778	1379	0.4	Jan	0.138	July
	Kangkari				Source dried up	Jan	0.45	July
	Dogpori	26.96452778	91.23300000	1053	0.21	Jan	0.014	July
	Sengdeyri	26.95411111	91.23680556	786	0.3	Jan	0.18	July
	Sondari				Source dried up	Jan	0.06	July
	Pangjari	26.96816667	91.21047222	583	0.22	Jan	0.36	July

Table 8-5 shows the final water sources in Dungmaed Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 29 water sources. The highest dry discharge was recorded for Jawakangkari water source under Mikuree Chiwog with 46.3 l/s and highest wet discharge from Joktangri water source under Mikuree Chiwog with 120 l/s.

Table 8-5 : Water Sources for Dungmaed Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Mikuree	Joktangri	26.97738889	91.19902778	359	120	Jan	35.1	June
	Prengmatap	26.97786111	91.19877778				32.9	July
	Kharamree	26.97513889	91.19938889				16.7	July
	Khochiri	26.96763889	91.19894444				22.6	July
	Poskari	26.99733333	91.28888889	26.96730556	91.93194444	June	0.056	July
	Yebari	26.96286111	91.20469444				0.854	July
	Dingshingri						0.18	July
	Yangshawari	26.97469444	91.20238889				2.14	July
	Doyomri	26.97744444	91.21288889				3.49	July
	Zubrangri	26.96450000	91.21844444				0.5373	July
	Bumpari	26.97336111	91.21388889	551	0.7	Jan	0.3607	July
	Sengdeyphuri	26.96361111	91.22213889	702	2	Jan	0.376	July
	Khawangri	26.96333333	91.22511111	754	0.5	Jan	7.78	July
	Shangshari	26.95758333	91.22994444	862	0.8	Jan	0.06	July
	Jawakangkari	26.95777778	91.23002778				46.3	July
	Shapalungri	26.95944444	91.23613889				0.12	July
	Kharshingri	26.96058333	91.23438889				1.48	July
	Tatsela	26.96069444	91.23375000	1030	0.05	June	10.9	July
	Shera afari	26.96530556	91.23647222					
	Subiri	26.96400000	91.23677778				0.276	July
	Grangmalari						2.13	July

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Nepori	26.98319444	91.26222222	1349	0.11	Jan		
	Phadiri	26.97961111	91.26586111	1310	0.3	Jan	45	July
	Dongdongmari	26.98025000	91.26602778	1379	0.4	Jan	0.138	July
	Kangkari				Source dried up	Jan	0.45	July
	Dogpori	26.96452778	91.23300000	1053	0.21	Jan	0.014	July
	Sengdeyri	26.95411111	91.23680556	786	0.3	Jan	0.18	July
	Sondari				Source dried up	Jan	0.06	July
	Pangjari	26.96816667	91.21047222	583	0.22	Jan	0.36	July

Table 8-6 shows the final water sources in Chongshing Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 39 water sources. The highest dry discharge was recorded for Bodo Ri (2) water source under Thongsa Chiwog with 7.04 l/s and the highest wet discharge from Yabrang ri water source under Chongshing Chiwog with 97.9 l/s.

Table 8-6 : Water Sources for Chongshing Gewog-Pemagatshel Dzongkhag

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Lanangzor	Tsampa ri	27.0213056	91.60525000	1936	0.17	May	0.012	October
Lanangzor	Risingma ri	27.0246389	91.60383333	1930	0.24	May	0.43	October
Lanangzor	Payang ri					May	0.032	October
Lanangzor	Gelong ri	27.0236111	91.36419444	1893	0.045	May	0.064	October
Lanangzor	Menchu ri	26.8582778	94.88138889			May	0.048	October

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Lanangzor	Remkho ri					May	0.478	October
Lanangzor	Phobla ri					May	0.012	October
Lanangzor	Phawang ri	27.0354167	91.36916667	890	26.2	May	3.08	October
Lanangzor	Naipo ri	27.0365000	91.37830556	830	23	May	3.6	October
Mandi	Repka ri	27.0026667	91.37261111	1780	0.25	May	0.141	October
Mandi	Khochiborang					May	0.012	October
Mandi	Mandi ri					May	0.012	October
Mandi	Kapa ri					May	0.017	October
Thongsa	Lebiri	27.0049722	91.38822222	1237	0.28	May	2.23	October
Thongsa	Murshey ri					May	0.011	October
Thongsa	Sengden ri					May	0.08	November
Thongsa	Langshing ri					May	2	November
Thongsa	Baynang ri					May	0.041	November
Thongsa	Bodo ri (1)	27.0194167	91.40322222	789	0.57	May	0.207	November
Thongsa	Bodo ri (2)	27.0193611	91.40333333	789	0.19	May	7.04	November
Thongsa	Kheshing ri	27.1207222	91.40350000	786	0.335	May	3.5	November
Thongsa	Tsab ri	27.0234167	93.42583333	743	16.01	May	4.64	November
Chongshing	Rejok (A)	27.992750	91.36686111	1685	19.1	June	3.32	September
Chongshing	Rejok (B)	27.992750	91.36686111	1685	19.1	June	0.2	September
Chongshing	Karma lama ri					June	0.012	September
Chongshing	Moktsar ri	26.9879167	91.37311111	118	0.011	June	1.02	September
Chongshing	Sangdhi ri	27.0055278	91.34341667	1030	31.1	June	2.55	September
Chongshing	Yabrang ri	27.0072222	91.34916667	1048	97.7	June	5.25	September

Chiwog	Name of the water Source	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Chongshing	Selung ri					June	0.022	September
Chongshing	Pandi ri					June	0.04	September
Chongshing	Jap ri					June	0.035	September
Yomzor	Chening ri	27.9754722	91.46894444	1621	0.25	June	0.51	September
Yomzor	Banang ri	26.9784167	91.36869444	1617	0.37	June	0.16	September
Yomzor	Koknang ri (1)	26.9714167	91.36675000	1637	0.05	June	0.7	September
Yomzor	Koknang ri (2)	26.9714167	91.36675000	1637	0.022	June	1.43	September
Yomzor	Bartse ri					June	0.03	September
Yomzor	Phedum ri jug					June	1.32	September
Yomzor	Phedum ri					June	0.01	September
Yomzor	Serma ama ri	26.9781111	91.36708333	1604	0.054	June	0.008	September

Table 8-7 shows the final water sources in Zobel Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, elevation, dry and wet discharge. The sample has been taken from 80 water sources sample.The highest dry discharge was recorded for Tshala Ri water source under Resinang Chiwog with 32.9 l/s and the highest wet discharge from Sangshing Yoeri (2) water source under Pangthang Dazachiwog with 0.626 l/s.

Table 8-7 : Water Sources for Zobel Gewog-Pemagatshel Dzongkhag

Chiwog	Source Name	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)			Discharge 2 (l/s)	
					l/s		Month	l/s	Month
Pangthang Daza	Braka Ri							0.01282	Jan
Pangthang Daza	Earthung (1)							0.02083	Jan
Pangthang Daza	Payka Ri							0.0303	Jan

Chiwog	Source Name	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)			Discharge 2 (l/s)	
					l/s		Month	l/s	Month
Pangthang Daza	Naka Ri							0.01042	Jan
Pangthang Daza	Manang Khari							0.02083	Jan
Pangthang Daza	Meme tsampari (1)	27.0405	91.4406	1975	0.0016		June	0.02564	Jan
Pangthang Daza	Omsha ri (2)							0.0303	Jan
Pangthang Daza	Lango Remong							0.04762	Jan
Pangthang Daza	Sangshing Yoeri (1)							0.06667	Jan
Pangthang Daza	Sangshing Yoeri (2)	27.0364	91.4339	1894	0.626		June	0.11111	Jan
Pangthang Daza	Gushing Rii	27.0407	91.4337	1755	0.061		June	0.11111	Jan
Pangthang Daza	Tshongparii	27.052	91.44	1995	0.05		June	0.03333	Jan
Pangthang Daza	Khalapangrii	27.0534	91.4439	2005	0.04		June	0.02778	Jan
Pangthang Daza	Zangpoyoerii (2)	27.0538	91.4372	1984	0.04		June	0.5	Jan
Pangthang Daza	Samtenzor rii	27.0529	91.4404	2004	0.09		June	0.38462	Jan
Pangthang Daza	Sangshing rii							0.0303	Jan
Pangthang Daza	Denmungrii	27.0501	91.4476	2043	0.0012		June	0.01449	Jan
Pangthang Daza	Chumanirii (1)	27.0533	91.3528	2039	0.05		June	0.02564	Jan
Pangthang Daza	Chumanirii (2)							0.00709	Jan
Pangthang Daza	Sangmoyoerii (1)	27.0534	91.444	2007	0.06		June	0.03704	Jan
Pangthang Daza	Kheritshongporii	27.0531	91.3579	2185	0.05		June	0.02778	Jan
Pangthang Daza	Phakporii							0.00901	Jan
Pangthang Daza	Sangmoyoerii (2)							0.02564	Jan
Pangthang Daza	Depa rii (1)	27.0605	91.4271	1921	0.083		April	0.04167	Jan
Pangthang Daza	Depa rii (2)	27.0601	91.4266	1929	0.075		April	0.01961	Jan
Pangthang Daza	Mewangrii							0.01389	Jan

Chiwog	Source Name	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)			Discharge 2 (l/s)	
					l/s		Month	l/s	Month
Pangthang Daza	Khamneyoerii							0.00877	Jan
Pangthang Daza	Dotakyoe	27.0576	91.4282	1943	0.149		April	0.01235	Jan
Pangthang Daza	Laipo Rii	27.0898	91.4296	1017	0.44		April	2.54	Jan
Zobel	Ngorkhee Yeeri(A)						NOT DONE	0.0167	Jan
Zobel	Ngorkhee Yeeri(B)							0.6667	Jan
Zobel	Dokhai Brangsari							0.5	Jan
Zobel	Tsangtseri(A)							7.5	Jan
Zobel	Tsangtseri(B)							6.98	Jan
Zobel	Tsangtseri(C)							0.6667	Jan
Zobel	Tauchungborangri (A)							0.5	Jan
Zobel	Tauchungborangri (B)							0.3333	Jan
Zobel	Tauchungborangri (C)							0.5	Jan
Zobel	Shorpori(A)							0.1667	Jan
Zobel	Shorpori(B)							0.16	Jan
Zobel	Womsharangri							0.4762	Jan
Zobel	Gushingzoreri							0.1111	Jan
Zobel	Khonmari							27.9	Jan
Zobel	Chumaniri							0.1667	Jan
Zobel	Rimung							0.0556	Jan
Zobel	Zangruri							0.8333	Jan
Ngangmalang	Ngangmala rii							0.998	Jan
Ngangmalang	Leshey rii							0.0303	Jan
Ngangmalang	Tshektshek rii 1							0.625	Jan

Chiwog	Source Name	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)			Discharge 2 (l/s)	
					l/s		Month	l/s	Month
Ngangmalang	Tshektshek rii 2							0.3077	Jan
Ngangmalang	Sey rii							0.037	Jan
Ngangmalang	Rashari							0.0278	Jan
Ngangmalang	Aneygonpari(A)							0.1667	Jan
Ngangmalang	Aneygonpari(B)							0.1538	Jan
Ngangmalang	Aneygonpari(C)							0.0333	Jan
Ngangmalang	Aneygonpari(D)							0.0377	Jan
Ngangmalang	Brangtseri							0.0303	Jan
Ngangmalang	Brangsachilori							0.8333	Jan
Ngangmalang	Khokkhokpari							1.25	Jan
Resinang	Tshelingore wabrangsari							1	Jan
Resinang	Tsulungyeymungri							0.667	Jan
Resinang	Changchungmungri							0.098	Jan
Resinang	Lebari(A)							0.04	Jan
Resinang	Lebari(B)							1.25	Jan
Resinang	Dokhari							0.067	Jan
Resinang	Bungsingmari							0.056	Jan
Resinang	Changsingzorejugri							0.03	Jan
Resinang	Gayjug							0.028	Jan
Resinang	Pelkayea (A)							0.0255	Jan
Resinang	Pelkayea (B)							0.0256	Jan
Resinang	Pelkayea (c)							0.0092	Jan
Resinang	Doetse Rii Singma							0.0471	Jan

Chiwog	Source Name	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)			Discharge 2 (l/s)	
					l/s		Month	l/s	Month
Resinang	Maangayea							0.3774	Jan
Resinang	Bumtey Rii							0.081	Jan
Resinang	Labee Rii							0.0473	Jan
Resinang	Bozong Rii							0.0545	Jan
Resinang	Tshala Rii							32.9	Jan
Resinang	Rangthang Rii							5	Jan
Resinang	Jamayea							20.4	Jan
Resinang	Megam Rii							0.0806	Jan

Table 8-8 shows the final water sources in Chhimoong Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 31 water sources. The highest dry discharge was recorded for Krashang riwater source under Chhimoong Chiwog with 11.9 l/s and the highest wet discharge from Awashing ri (1) water source under Chhimoong Chiwog with 17.8 l/s.

Table 8-8 : Water Sources for Chimoong Gewog-Pemagatshel Dzongkhag

Chiwog	Name of Sources	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Chhimoong Chiwong	Yangri	27.05608333	91.29311111	900	0.1	May	1	Dec
	Drakpaafari						0.78	Dec
	Awashing ri 1	27.05536111	91.29222222	229	17.8	May	6	Dec
	Awashing ri 2	27.05536111	91.29222222	229	18	May	1.6	Dec
	Krashang ri	27.05536111	91.29222222	229	18	May	11.9	Dec
	Napori	27.01841667	91.32011111	1627	0.93	May	7.1	Dec
Lungkholom	Dawari							Dec

Chiwog	Name of Sources	Latitude(N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
	Demri	27.00683333	91.31673333	1545	0.4	May	0.679	Dec
	Songsongma ri 1	27.00636111	91.31975000	1597	1.01	May	7.09	Dec
	Songsongmari 3	27.00636111	91.31975000	1597	1.01	May	0.66	Dec
	Meringmari 1	27.02766667	91.32022222	1738	0.05	May	2.8	Dec
	Meringmari 2						1.22	Dec
	Dogori						2.54	Dec
	Manri 1	27.02013889	91.34100000	1764	0.05	May	0.85	Dec
	Manri 2						0.65	Jan
	Dueyongbari	27.02238889	91.33822222	1850	0.03	May	0.91	Jan
Nyasikhar	Zangrapatongri	27.04786111	91.25375000	969	0.032	June	0.73	Jan
	Genri 1						0.657	Jan
	Chungtseri	27.03919444	91.24905556	990	0.022	June	1.385	Jan
	Bemari	27.04341667	91.24447222	989	0.02	June	0.38	Jan
	Utsungri	27.03263889	91.24461111	1007	0.202	June	1.34	Jan
	Yeychiloo ri	27.02566667	91.25016667	1047	0.034	June	1.58	Jan
Chiphoong	Lebari	27.02594444	91.23613889	915	0.035	June	0.52	Jan
	Kerongri 1	27.01433333	91.23730556	990	5	June	0.333	Jan
	Kerongri 2						2.3	Jan
	Chiphongri 1	27.01613889	91.22225000	1099	0.35	June	0.89	Jan
	Chiphongri 2						1.05	Jan
	Chiphungri 3						1.91	Jan
	Tsatseshumri	27.01072222	91.23544444	1086	0.21	June	3.8	Jan
	Tshatseshumri 3						1.32	Jan
	Khomangri	27.00513889	91.23561111	1308	0.227	June	1.3	Jan

Table 8-9 shows the final water sources in Norbugang Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, and elevation, dry and wet discharge. The sample has been taken from 41 water sources. The highest dry discharge was recorded for Lungtshering drang water source Gashari Chiwog with 14.6 l/s and wet discharge from Sema ri (a) water source under Gashari Chiwog Cwith 76.7 l/s.

Table 8-9 : Water Sources for Norbugang Gewog-Pemagatshel Dzongkhag

Chiwog	Lat DD	Long_DD	Altitude (masl)	Discharge 1 (l/s)		Discharge 2 (l/s)	
				l/s	Month	l/s	Month
Norbugang_Rinchhenzor	26.84606	91.04406	725	0.28	May	7.3	January
Norbugang_Rinchhenzor	26.84544	91.03289	710	0.271	May	5.9	January
Norbugang_Rinchhenzor	26.84061	91.05053	758	0.91	May	0.65	January
Norbugang_Rinchhenzor	26.86106	91.09331	778	0.95	May	0.02	January
Norbugang_Rinchhenzor	26.86275	91.09783	784	0.089	May	0.02	January
Norbugang_Rinchhenzor	26.85222	91.1035	802	0.162	May	3	January
Norbugang_Rinchhenzor	26.86028	92.01183	892	0.752	May	0.03	January
Norbugang_Rinchhenzor	26.86092	91.11117	898	0.175	May	0.02	January
Norbugang_Rinchhenzor	26.85333	91.10658	791	1.02	May	0.08	February
Nyingshing borang	26.85797	91.10014	768	0.183	May	0.125	February
Nyingshing borang	26.83575	91.13183	774	0.82	May	0.41	February
Nyingshing borang	26.85308	91.13519	836	0.211	May	0.08	February
Nyingshing borang						1.69	February
Nyingshing borang	26.84753	91.12658	943	0.472	May	0.25	February
Nyingshing borang	26.85828	91.09408	731	0.11	May	3.84	March
Nyingshing borang	26.85369	91.102	796	0.173	May	0.044	March
Nyingshing borang	26.85283	91.10797	787	0.98	May	0.3	March
Tshaelshingzor	26.85614	91.15136	837	0.198	May	4.48	March
Tshaelshingzor	26.85108	91.15678	837	0.27	May	0.1	January
Tshaelshingzor	26.85825	91.15808	942	1.12	May	0.049	March

Chiwog	Lat DD	Long_DD	Altitude (masl)	Discharge 1 (l/s)		Discharge 2 (l/s)	
				l/s	Month	l/s	Month
Tshaelshingzor	26.85069	91.15025	902	4.09	May	0.064	March
Tshaelshingzor	26.85386	91.17058	914	0.125	May	0.04	March
Tshaelshingzor	26.8560	91.163	942	0.436	May	0.45	March
Gashari	26.8335	91.21861	448	0.52	June	1.83	May
Gashari	26.8385	91.21836	568	76.7	June	3.2	May
Gashari						2.3	May
Gashari						0.8	May
Gashari	26.83514	91.22006	511	0.362	June	1.8	May
Gashari						0.5	May
Gashari	26.83567	91.22933	519	0.56	June	0.1	May
Gashari	26.83339	91.22839	468	0.762	June	0.4	May
Gashari	26.83208	91.22531	468	73	June	0.93	May
Gashari	26.83189	91.23467	433	1.1	June	14.6	May
Menchhu	26.84844	91.19136	1001	4.32	August	0.1	April
Menchhu						0.44	April
Menchhu						0.92	April
Menchhu						0.35	April
Menchhu	26.85233	91.19711	949	0.32	August	0.69	April
Menchhu	26.86014	91.25836	1110	0.484	August	2.93	April
Menchhu	26.85839	91.26144	1090	0.22	August	1.34	April
Menchhu	26.83364	91.24028	468	0.17	August	0.86	April

Table 8-10 shows the final water sources in Choekhorling and Dechhenling Gewogs under Pemagatshel Dzongkhag with different water source names, latitude, longitude, elevation, dry and wet discharge. The sample has been taken from 135 water sources. Kerongre water source with 1290 l/s shows the highest dry discharge and the highest wet discharge was recorded for Kulaphanre (3) water source with 351 l/s.

Table 8-10 : Water Sources for Choekhorling & Dechhenling Gewogs-Pemagatshel Dzongkhag

Name of the water source	Latitude (N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2(l/s)	
				l/s	Month	l/s	Month
Abidoroore						1.3	Nov
Agurtsongre (1)						1.06	Nov
Agurtsongre (2)						10.7	Nov
Bakhalashingre				Source dried up	June	14.5	Jan
Bangre						76.7	Dec
Bangre-Zangre stream						213	Dec
Barkazor (3)	26.824778	91.32119444	702	0.31	June	18.7	Jan
Barkazor (6)	26.827694	91.32436111	648	1	June	5.93	Jan
Barkazore (1)	26.824833	91.31822222	727	0.63	June	40.4	Jan
Barzore	26.908056	91.23519444	760	0.03	Jan	0.259	Dec
Bekahrpare	26.90225	91.20002778	1218	1.2	July	18.4	Jan
Betsasalare (1)	28.029167	91.29105556	800	0.124	May	25.5	Jan
Bidungre (1) right side	27.111111	91.23950000	517	0.11	May	0.908	Dec
Bidungre (2) left side	26.866028	91.23783333	509	0.35	May	69.9	Dec
Bidungrejugre (2)	26.866278	91.23930556	513	259	May	0.51	Nov
Bidurungjugre (right)	26.866139	91.2395000	517	0.13	May	0.908	Nov
Bongbonglare						155	Dec
Borongshingre	26.84325	91.33733333	796	0.7	June	232	Jan
Brangshawoongre (2)	26.826222	91.32777778	557	0.82	June	57	Jan
Brongshingre	26.843528	91.33394444	795	0.8	June	9.7	Jan
Chagdoatare	26.905889	91.23538889	823	0.02	Jan	0.48	Dec
Changchangmasharangre				Source dried up	June	87.8	Jan
Chenanre						67	Jan
Choekhorling (2)				Source dried up	June	7.19	Jan
Choekhorlingzampare	26.899139	91.22005556	1114	0.23	July	12.4	Jan
Chongmashingre	26.84875	91.32188889	941	0.14	June	157	Jan
Chongmashingre (1)						0.474	Dec
Chongmashingre (2)						23.3	Dec
Chortenjabre (1)				Source dried up	July	85.8	Jan
Chortenjabre (2)	26.898167	91.32166667	1119	0.8	July	3.23	Jan
Damcherangborangre	26.912944	91.25800000	642	0.31	Jan	4.14	Dec
Dangsingwoongre	26.893278	91.30019444	1056	0.77	Jan	4.66	Dec
Dezama-Lungkhangma stream				Source dried up	June	18	Jan

Name of the water source	Latitude (N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2(l/s)	
				l/s	Month	l/s	Month
Dongshingborangre	26.823667	91.33058333	519	0.77	June	819	Jan
Drungpachanglore	26.847278	91.33058333	912	0.6	June	293	Jan
Drungpachanglore left side ree				Source dried up	June	70.8	Jan
Drungpachangloree right side ree				Source dried up	June	102	Jan
Emelare						29.2	Nov
Gewogree (Choekhorling)	26.833361	91.34316667	475	2.2	June	24	Jan
Gonpare (2)	26.831444	91.28061111	856	0.121	May	1.28	Nov
Goyongjabree	26.902444	91.32063889	1156	0.001	July	7.35	Jan
Goyongre	26.903917	91.32219444	1188	15	July	6.87	Jan
Gurgang ©	26.9015	91.31916667	1144	0.5	July	37.4	Jan
Gurgangre	26.894722	91.28800000	834	0.82	Jan	50.6	Dec
Gurgangre (2)	26.90175	91.31913889	1116	0.9	July	47.1	Jan
Gurgangrejugre	26.849333	91.28436111	774	0.55	May	69.9	Nov
Hazore	26.823028	91.33963889	453	6.01	June	485	Jan
Jagartalare	26.859972	91.30813889	955	0.918	May	205	Jan
Jamare				Source dried up	July	9.26	Jan
Jamarr (leftsidere)	26.904222	91.32594444	1220	0.8	July	3.34	Jan
Jazamokhoire						167	Jan
Jazamoyoungre (1)						12	Jan
Jazamoyoungre (2)						15.2	Jan
Jogre	26.904528	91.24411111	488	0.41	Jan	0.517	Dec
Kalakpazampare (left)						9.69	Jan
Kanandurungre (left)						167	Jan
Kanglungre				Source dried up	June	440	Jan
Kerongre	26.903083	91.31997222	1150	25	July	1290	Jan
Kerongsangmore				Source dried up	July	168	Jan
Khachiborangre (1)	26.837778	91.35072222	666	2.32	June	7.13	Jan
Khachuiborangre (4)	26.837333	91.35213889	637	2.6	June	8.86	Jan
Khachuiborangre (5)	26.837278	91.35213889	675	2.6	June	26.7	Jan
Khangruborangre	26.885917	91.3147500	1088	2.1	July	167	Jan
Koknangre	26.841972	91.35252778	758	0.01	June	22.8	Jan
Koknangre	26.908556	91.33013889	1337	0.01	July	18.7	Jan
Kulaphanre (3)	26.883917	91.24586111	634	351	May	0.415	Nov
Kulaphanre (5)	26.883917	91.2412500	635	0.45	May	1.23	Nov
Kurminthongsare	26.827778	91.3222500	629	0.67	June	100	Jan
Laguborangre (1)	26.903028	91.31877778	1164	0.21	July	25.9	Jan

Name of the water source	Latitude (N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2(l/s)	
				l/s	Month	l/s	Month
Laguborangre (2)	26.902917	91.31897222	1151	0.1	July	30	Jan
Laijungbrangsare (2)						1.66	Jan
Lebure	26.905472	91.23425000	881	0.43	Jan	0.121	December
Leburi	26.842806	91.35069444	703	0.001	June	35.4	Jan
Lungthrizorjabre	26.83625	91.83694444	884	0.51	May	2.48	Nov
Manire	26.890778	91.32055556	1114	1.21	July	43.1	Jan
Manire	26.885722	91.29858333	1261	0.52	Jan	4.16	Dec
Manire (1)	26.911944	91.22977778	876	2	Jan	1.37	Dec
Manirejugre	26.894556	91.28611111	796	0.3	Jan	25.6	Dec
Marungre	26.899833	91.23608333	429	187	Jan	243	Dec
Meriphure (1)	26.865833	91.25722222	999	0.249	May	57.1	Jan
Meruri (1)	26.829972	91.28333333	720	6	June	26.6	Jan
Meruri (3)	26.843556	91.31666667	718	0.45	June	479	Jan
Mingserbubrakre						3.19	Jan
Mingserbure						16.7	Jan
Murshingre (1)	26.842444	91.28883333	787	1.23	May	15	Nov
Murshingre (2)	26.842444	91.28883333	787	1.23	May	2.3	Nov
Mursupetre (1)						21.9	Jan
Mursupetre (3)						9.15	Jan
Neytsangchebre (7)	26.835472	91.33850000	1118	0.36	July	20.1	Jan
Neytsangchere (4)	26.895639	91.31905556	1131	0.21	July	26	Jan
Neytsanglamphrangre (2)	26.975222	91.19827778	1097	Source dried up	July	1.23	Jan
Ngajimre	26.848472	91.32255556	1007	0.01	June	219	Jan
Ngeptangre	26.851389	91.28063889	872	48	May	46.7	Nov
Ngetshanglamre (1)	26.876972	91.31475000	1024	0.075	May	2.5	Jan
Nyetsanglamphrangre (3)						4.32	Jan
Pangkhoire	26.904444	91.24416667	642	0.33	Jan	5.97	Dec
Phekhangchiree	26.903889	91.32144444	1171	0.001	July	16.7	Jan
Pheshingkhoiree				Source dried up	June	24.1	Jan
Rabalingkhoire (2)	26.836056	91.26811111	637	0.31	May	0.5155	Nov
Rabalingkhoire (2)	26.836056	91.26811111	637	0.314	May	0.652	Nov
Rashikhoiere						43.1	Jan
Raymanre	26.915833	91.25702778	671	168	Jan	8.4	Dec
Raynangpore	26.904111	91.33333333	1269	0.5	July	2.83	Jan
Rebalingmore					June	105	Jan
Rebalingmore						48.9	Jan

Name of the water source	Latitude (N)	Longitude (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2(l/s)	
				l/s	Month	l/s	Month
Rebalingmore	26.834639	91.26272222	611	0.45	May	0.652	Nov
Redumare	26.89975	91.32144444	1145	0.01	July	27.5	Jan
Relakpore	26.89875	91.25430556	473	173	Jan	0.212	Dec
Resingmare	26.912972	91.23077778	830	0.01	Jan	0.113	Dec
Retsalore	26.909389	91.23538889	752	2.1	Jan	0.272	Dec
Ridzommore	26.910778	91.23961111	594	2.82	Jan	27.01	Dec
Sanglebaleere (2)				Source dried up	July	1.91	Jan
Sayjemre (1)	26.826583	91.31533333	735	0.45	June	40.7	Jan
Sermongre	26.920167	91.24277778	743	Source dried up	Jan	4.52	Dec
Serphure	26.911667	91.25705556	522	56	Jan	14.7	Dec
Shongnanzore				Source dried up	July	65.4	Jan
Soinagrangnangre	26.901667	91.29466667	836	1.12	Jan	25.3	Dec
Soinangjugre						0.44	Dec
Soinangrangnangre	26.842944	91.29016667	800	32	May	6.28	Nov
Soinangre	26.900444	91.25308333	497	0.82	Jan	0.605	Dec
Sundhipagamre	26.910583	91.23950000	606	0.02	Jan	16.1	Dec
Tharpare	26.842722	91.34369444	760	0.2	June	7.45	Jan
Tralire						161	Dec
Tshongdoyaere	26.869778	91.23444444	426	0.66	May	5.07	Nov
Tshongdoyayre (1)	26.869722	91.23958333	428	0.04	May	5.07	Nov
Tsoplaspring				Source dried up	July	7.42	Jan
Tsulungrangnangre	26.852389	91.28591667	842	0.56	May	2.26	Nov
Waikhare (1)	26.8955	91.31713889	1117	4	July	22.7	Jan
Waikhare (5)	26.895806	91.31677778	1105	3	July	65.5	Jan
Yarjewoomgre (2)	26.8265	91.31530556	808	0.55	June	40.7	Jan
Yarjewoongre (1)	26.827444	91.31600000	767	1.1	June	66	Jan
Yebabaytsangre				Source dried up	July	3.17	Jan
Yetpashere grangnangre				Source dried up	June	8.47	Jan
Zangkholomri	26.826639	91.34319444	440	8.31	June	156	Jan
Zangre						84.3	Dec

Table 8-11 shows the final water sources in Shumar Gewog under Pemagatshel Dzongkhag with different water source names, latitude, longitude, elevation, dry and wet discharge and measurement method. The sample has been taken from 68 water source. The highest dry discharge was recorded for Ngori water source with 32.5 l/s under Denchi-Yalang chiwog and the highest wet discharge from Cherungri 4 under Denchi-Yalang chiwog with 162 l/s.

Table 8-11 : Water Sources for Shumar Gewog-Pemagatshel Dzongkhag

Chiwog	Source name	Latitude_DD (N)	Longitude_DD (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Denchi-	Khamdorong 1	27.03969	91.42425	2173	0.103	Sept	20	Jan
Denchi-	Khamdorong 2				Source dried up	Sept	3.4	Jan
Denchi-	Putungri	27.02503	91.41694	2259	0.8	Sept	5.3	Jan
Denchi-	Danibrakri	27.02817	91.41675	2158	1.2	Sept	27.3	Jan
Denchi-	Chrungri 1	27.03939	91.41922	2163	5	Sept	20	Jan
Denchi-	Chrungri 2	27.0335	91.41836	2209	1.02	Sept	13	Jan
Denchi-	Cherungri 3	27.03431	91.41975	2161	0.2	Sept	20	Jan
Denchi-	Danibrkri(Khothakpa)	27.03369	91.41978	2239	0.01	Sept	3.2	Jan
Denchi-	Thamdorong 1	27.02367	91.41547	2317	0.03	Sept	20	Jan
Denchi-	Thamdorong 2	27.02317	91.41531	2135	0.34	Sept	20	Jan
Denchi-	Thamdorong 3	27.02256	91.41708	2120	0.13	Sept	12.6	Jan
Denchi-	Cherungri 4	27.0355	91.41978	2186	162	Sept	18.5	Jan
Denchi-	Thamdorong 4	27.02006	91.41222	2156	1.2	Sept	5.7	Jan
Denchi-	Ngori	27.01972	91.41356	2177	0.81	Sept	32.5	Jan
Batseri	Rephai	27.83867	91.28083	1337	1.01	Sept	20	Jan
Batseri	Tsangtseri	27.03339	91.43172	1547	0.76	Sept	9.87	Jan
Batseri	Lebari	27.03522	91.44425	1558	2.01	Sept	20	Jan
Batseri	Pangthangdazajug	27.03558	91.43336	669	0.56	Sept	20	Jan
Batseri	Sangshingyoe	27.03567	91.43364	1839	0.88	Sept	19.4	Jan
Batseri	Boleypamri	27.03564	91.43361	1867	0.12	Sept	20	Jan
Batseri	Rokshari 1	27.03842	91.42922	1810	0.22	Sept	20	Jan

Chiwog	Source name	Latitude_DD (N)	Longitude_DD (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Batseri	Rokshari 2	27.03869	91.42911	1862	0.33	Sept	20	Jan
Batseri	Rokshari 3	27.03892	91.42903	1825	0.111	Sept	6.45	Jan
Batseri	Canadangri	27.05336	91.42403	1976	0.8	Sept	2.93	Jan
Nangkor	Mowari 1	27.05339	91.42411	1248	0.127	Oct	20	Jan
Nangkor	Mowari 2	27.04872	91.40389	1133	0.122	Oct	20	Jan
Nangkor	Mowari 3	27.04836	91.40417	1123	0.33	Oct	2.86	Jan
Nangkor	Zachhu					Oct	20	Jan
Nangkor	Amari					Oct	20	Jan
Nangkor	Rampori 1	27.04089	91.39875	1135	0.21	Oct	20	Jan
Nangkor	Rampori 2	27.04539	91.40875	1130	0.01	Oct	20	Jan
Nangkor	Rampori 3	27.04411	91.39569	1125	0.09	Oct	20	Jan
Nangkor	Rampor 4	27.04878	91.39869	1105	0.129	Oct	20	Jan
Nangkor	Phishingri 1	27.04825	91.39811	1119	0.57	Oct	4.22	Jan
Nangkor	Phishingri 2	27.04064	91.39897	1116	0.47	Oct	20	Jan
Nangkor	Cherungri 1	27.04447	91.44308	1283	1.2	Oct	20	Jan
Nangkor	Cherungri 2	27.04458	91.421	1252	1.2	Oct	20	Jan
Nangkor	Tshokchu	27.04294	91.42103	1333	1.01	Oct	21.8	Jan
Nangkor	Kongnangri 1	27.04439	91.42069	1573	0.89	Oct	20	Jan
Nangkor	Kongnangri 2	27.05064	91.42644	1671	0.73	Oct	4.78	Jan
Nangkor	Drupchuri	27.05047	91.41903	1616	0.6	Oct	2.65	Jan
Nangkor	Toetpalung	27.06153	91.40392	1606	10	Nov	20 l	Jan
Nangkor	Chezupamri 1	27.05369	91.42117	1556	0.62	Nov	1.67	Jan
Nangkor	Chezupamri 2	27.05311	91.41867	1664	1.3	Nov	20	Jan
Nangkor	Cherungri(Borangchiloo)	27.03792	91.42253	1731	5	Nov	3.19	Jan
Nangkor	Chezupamri 3	27.05478	91.42500	1736	1	Nov	20	Jan
Nangkor	Cherungtet	27.05308	91.42461	1672	0.66	Nov	1.57	Jan
Nangkor	Tsheshingrijug	27.05739	91.40194	1428	0.73	Nov	4.9	Jan
Nangkor	Gomchu	27.06003	91.40306	1530	1.12	Nov	4.6	Jan

Chiwog	Source name	Latitude_DD (N)	Longitude_DD (E)	Altitude (masl)	Discharge 1(l/s)		Discharge 2 (l/s)	
					l/s	Month	l/s	Month
Nangkor	Dodojug	27.06000	91.40347	1490	1.02	Nov	20	Jan
Nangkor	Shingthangri 1	27.05853	91.40308	1270	0.5	Nov	20	Jan
Nangkor	Shingthangri 2	27.05808	91.56947	1283	3	Nov	3.75	Jan
Shali-	Kawderi 1	27.05006	91.42183	1953	0.1	Oct	20	Jan
Shali-	Kawderi 2	27.06842	91.41664	2033	0.21	Oct	20	Jan
Shali-	Kheri	27.06919	91.40864	1788	0.177	Oct	20	Jan
Shali-	Tsheshingri	27.06642	91.40919	1587	0.62	Oct	20	Jan
Shali-	Brungshey 1	27.06556	91.38736	1306	0.131	Oct	20	Jan
Shali-	Brungshey 2	27.06544	91.38733	1302	0.34	Oct	20	Jan
Shali-	Kharshingri	27.06067	91.39611	1248	0.177	Oct	2.13	Jan
Shali-	Dongshingyey	27.05550	91.39853	1238	0.34	Oct	4.5	Jan
Shali-	Dawshey	27.06386	91.38825	1267	0.48	Nov	25	Jan
Shali-	Mrogchiri	27.16044	91.46922	1179	0.4	Nov	2.48	Jan
Shali-	Meringmari	27.06644	91.40033	1236	2.11	Nov	3.07	Jan
Shali-	Totpalung (Sharangzor)	27.06336	91.40231	1587	2.2	Nov	4.6	Jan
Dagor	Chenphuri (muna)	27.16867	91.47344	1667	13	Nov	16.7	Jan
Dagor	Pamri	27.17539	91.42278	1744	1.4	Nov	1.8	Jan
Dagor	Gashikahari 1	27.16139	91.47169	1738	0.56	Nov	1.07	Jan
Dagor	Gashikahari 2	27.16028	91.47142	1752	0.68	Nov	1.03	Jan

Table 8-12 shows the final water sources in Nganglam Thromde under Pemagatshel Dzongkhag with different water source names, latitude, longitude, elevation, dry and wet discharge and measurement method. The sample has been taken from 16 water sources. The highest wet discharge was recorded for stream b water source with 741 l/s between khalaktang ri& Dezama chiwog and the highest dry discharge from DCCl a and Tsenkari a under Tsenkari and DCCL & nearby with 179 l/s and 179 l/s.

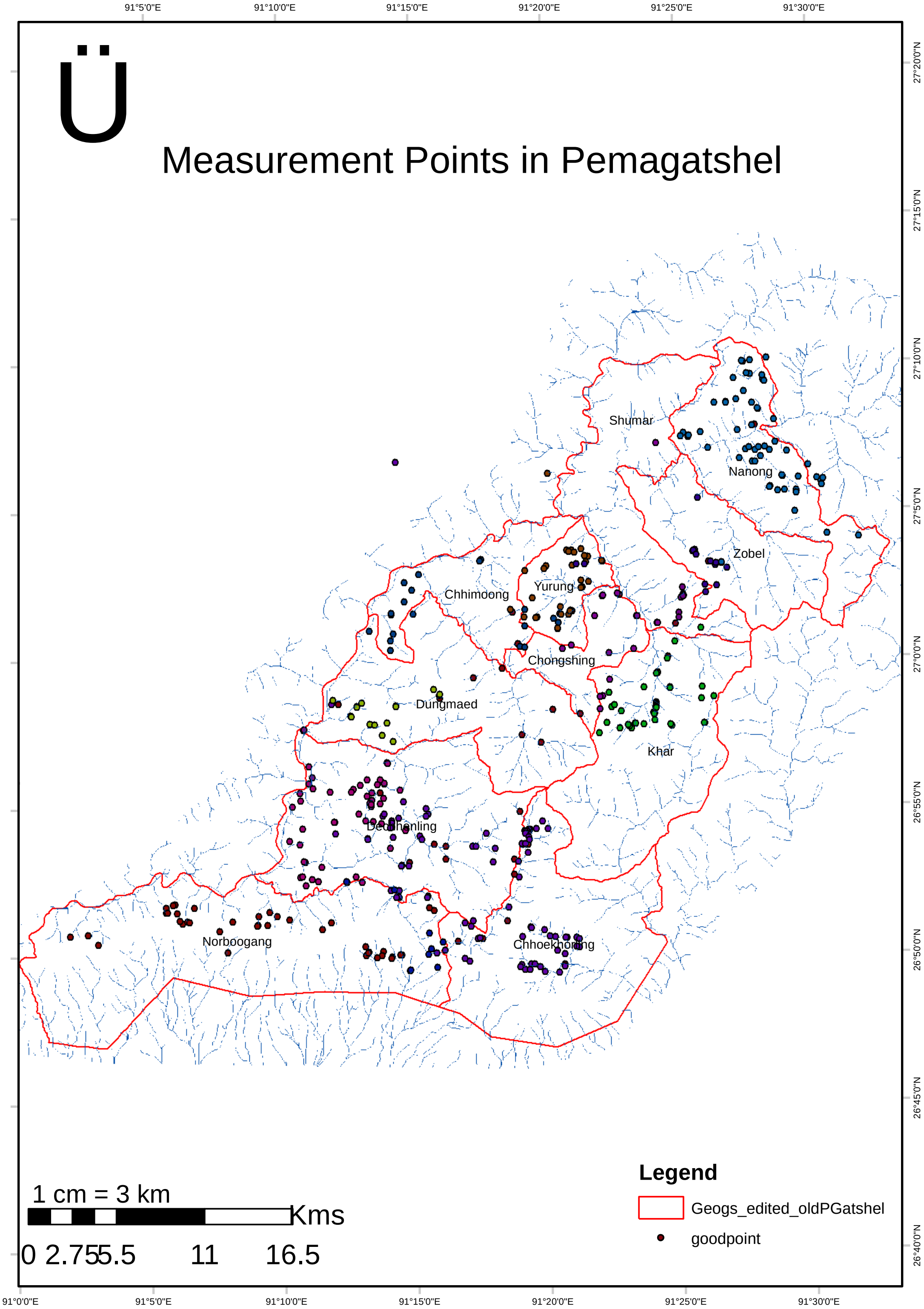
Table 8-12 : Water Sources for Nganglam Thromde-Pemagatshel Dzongkhag

Chiwog	Name of the stream	Latitude(N)	Longitude (E)	Altitude	Discharge 1(l/s)

					l/s	**Month**
DCCL & nearby	DCCl a	26.87044	91.23661	435	179	August
Tsenkari	Tsenkari a	26.87044	91.23658	435	179	August
Tsenkari	Dop Zachhu ri	27.87544	91.23797	436	2.5	August
Gashari-Bali area	Yesangmo Daza ri					
Gashari-Bali area	Gashari Grangnang ri					
Gashari-Bali area	Tsokporong ri	26.42478	91.22656	354	0.067	August
Gashari-Bali area	Sambari bali ri	26.87467	91.20706	368	0.96	August
Gashari-Bali area	(near sambaribali)	26.87503	91.20642	382	0.11	August
Army water source	Khalaktang ri	26.83697	91.25967	625	2	August
Infront army family colony	Barkatsang ri	26.83558	91.85378	578	0.11	August
main town source	Tsatsa ri	27.87544	91.26669	577	136	August
In between khalaktang ri & Dezama	Stream a	26.84067	91.26669	728	0.12	August
	stream b	26.84567	91.25836	741	0.132	August
Zalashing area	police checkpost source	26.83372	91.25781	507	0.121	August
Checkpost area	Satsalu ri	26.82503	91.24658	346	0.45	August
Pagaladrang	Metogang (1)	26.82642	91.26336	617	0.891	August

Appendix II

Annex 1. Measurement Points in Pemagatshel



Annex 2.Survey Questionnaire

Following questionnaire was used for the household survey in the Dzongkhag.

Questionnaire for Household Survey		
Q No	Question	
Survey No	Dzongkhag, Gewog, Chiwog	
1	Water Source Type	
2	Water Source Name	
3	No of Households Benefitted by source	
4	Main Use of Water	H/I/D/L/O
5	Is the Present Water Source Adequate	All Year
		Only during Summer
		Never
6	Source Abandoned?	Yes /No
7	Reason	P/D/O
8	Potential for New Source	Yes
		No
9	GPS coordinate	Latitude
		Longitude
10	RWSS	Yes
		No
11	RWSS Coverage	%
12	RWSS Functional	1/2/3/4
13	Land Use	Chhuzhing
14		Kamzhing
15		Fallow
16		Orchard
17		Others - specify
18	Annual Cropping	Annual Y/N
19	Irrigation Water Availability	Abundant

		Adequate
		Inadequate
		Severe Shortage
20	Satisfaction with Water Quality?	Very Satisfied
		Somewhat Satisfied
		Neither
		Somewhat dissatisfied
		Very dissatisfied
21	Reason	A/B/C/D/E/F
22	Common diseases	No
		Diarrhea
		Dysentery
		Typhoid
		Cholera
		Malaria
		Skin Diseases
		Eye Infection
		Others - specify
	Survey Date	Month
		Year

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