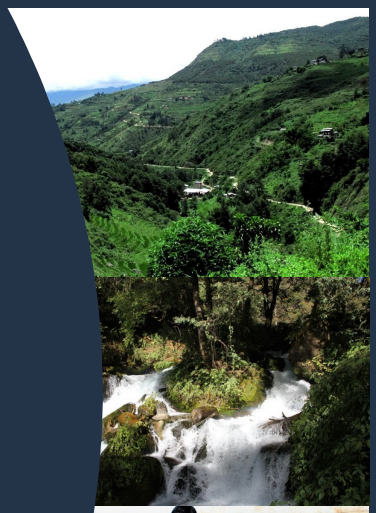
Integrated Watershed Management Plan

Baychhu watershed, Wangdue Dzongkhag Punatsangchhu Basin



Watershed Management Division
Department of Forests & Park Services
Ministry of Agriculture & Forests

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Integrated Watershed Management Plan
Baychhu Watershed, Punatsangchhu Basin

Watershed Management Division
Department of Forests and Park Services
April 2015

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ACRONYMS

DGM	- Department of Geology and Mines
DHMS	- Department of Hydromet Services
DPH	- Department of Public Health
DHPS	- Department of Hydropower Services
DoA	- Department of Agriculture
DoFPS	- Department of Forests and Park Services
DoL	- Department of Livestock
DO:	- Dissolved Oxygen
DDM	- Department of Disaster Management
DoR	- Department of Road
DRE	- Department of Renewable Energy
EC	- Electrical Conductivity
FCU	- Faecal Coliforms Unit
GAO	- Geog Administration Officer
GEAO	- Geog Extension agriculture Officer
GEFO	- Geog Extension Forest Officer
GNHC	- Gross National Happiness Commission
HOCL	- Hypochlorous acid
LUPP	- Land Use Planning Project
MoAF	- Ministry of Agriculture and Forests
Masl	- Meters Above Sea Level
NEC	- National Environment Commission
NGO	- Non-Governmental Organizations
NTU	- Nephelometric Turbidity Units
pH	- Acidity or alkalinity of water as measured by pH
PPD	- Policy and Planning Division
RDC	- Research Development Centre
RGoB	- Royal Government of Bhutan
RNR	- Renewable Natural Resources
SPAL	- Soil and Plant Analytical Laboratory
SWAT	- Soil and Water Assessment Tool
TDS	- Total Dissolved Solids
WHO	- World Health Organization
WMP	- Watershed Management Plan
WMD	- Watershed Management Division

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ROYAL GOVERNMENT OF BHUTAN
Ministry of Agriculture & Forests
Tashichhodzong, Thimphu : Bhutan

MINISTER

MESSAGE

Bhutan consists of mosaic of watersheds drained by five major and two minor river basins. Within these river basins, there are numerous streams, streamlets and rivulets that form the smaller watersheds within the river basins. Watersheds can vary in scale from big rivers basins like Punatsangchhu to a small catchment of a drinking water source.

For Bhutan, watersheds are the mainstay of our economy. They are important for the provision of water for drinking, irrigation and generation of hydropower; serve as essential habitats for the rich biodiversity of flora and fauna and enhance scenic beauty of the landscapes for attracting visitors through ecotourism. Besides, well managed watersheds also provide other important provisioning, protection and regulatory services like, food and shelter for wild animals, erosion control, regulation of water flow and climate, water purification and stream bank stabilization. Therefore, it is important for Bhutan to manage these watersheds sensibly to ensure the sustainability of services from the watersheds for the wellbeing of our citizens. Understanding these aspects is imperative to appreciate the needs for maintaining healthy watersheds to sustain important functions and how human activities can be harmonized with natural systems.

On the hindsight, watershed conditions and their functional integrity in different parts of our country continue to worsen despite our efforts to protect and manage them. Such changes leading to degradation of watershed resources are a cause of serious concern for all of us as health of the watersheds and quality of ecosystems is the foundation of our national economy and the welfare of farming communities in particular.

That said, an integrated watershed approach in managing watersheds in Bhutan is not an option but a necessity so that important principles and concepts of holistic landscape management can

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Tashichhodzong, Thimphu : Bhutan

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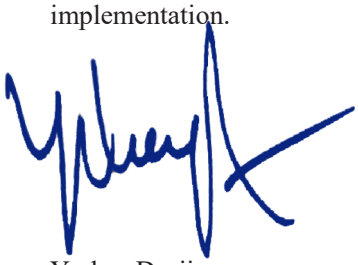
MINISTER

be translated into doable actions based on sound useful ul science and acceptable socioeconomic practices supported by a matching multi sectoral interventions to address the emerging problems.

I am happy that Watershed Management Division under the Department of Forests and Park Services has piloted and completed the preparation of the first Integrated Watershed Management Plan for Baychhu Watershed, Punatshangchhu River basin, Wangdue and urge all the relevant agencies within Ministry of Agriculture and Forests and beyond to support the implementation of the various activities to accomplish the expected objectives of the plan. I am confident that the implementation of the plan will generate much needed insights and experiences in managing the resources in the watershed. The integrated and collaborative approach can be gradually up scaled to cover the watersheds in the entire country in the foreseeable future building a sound foundation for conservation and management of watersheds based on environmentally sustainable, economically efficient and socio-culturally equitable and acceptable code of practices.

Finally I like to convey my full support for the adoption and implementation of this plan. I would like to congratulate the Watershed Management Division and the planning team and other concerned agencies involved in preparation of the plan and look forward to its successful implementation.



Yeshey Dorji
Minister

FOREWORD

Watersheds sustain life. In Bhutan, all of us live in one or another watershed and depend on it for our livelihood. Besides agriculture, Bhutan's economy is mainly driven by hydropower, which in turn depends on healthy watershed conditions to maintain a continuous supply of water for electricity generation. This underscores the importance of protecting and managing watersheds to sustain primarily their provisioning and regulating services. Considering the importance of protecting watersheds, the watershed approach to natural resource management was adopted and watershed management became one of the priority focal areas of the Department of Forest & Park Services (DoFPS). The watershed approach can provide a unique and effective way to assess the environment, identify problems, establish priorities for preservation or restoration, and to implement solutions based on a holistic and cross-sectoral assessment. The Watershed Management Division was created in 2009 with the vision "*to ensure effective and integrated watershed management to maintain and improve water & watershed conditions and contribute to sustainable livelihoods through provision of watershed services*".

Since its inception, the Watershed Management Division has played its part in adopting appropriate polices and strategies to guide the process forward. This included the development of a Roadmap for Watershed Management, and a Guideline for the Classification of Watersheds, amongst others. Rapid assessment and classification of watersheds for the Wangchhu and Punatsangchhu basins was carried out in 2011 and critical or degraded watersheds were identified. Baychu watershed was identified as a critical watershed, prompting the development of the present watershed management plan. The plan outlines the implementation of activities based on locally appropriate strategies to ensure sustainable management of the watershed. The plan is an outcome of extensive consultations at Dzongkhag and Geog levels, as well as technical field assessments by subject matter specialists elaborated into concrete interventions in the course of write-shops at the national level.

I would like to congratulate the Watershed Management Division and its team for bringing out the first ever watershed management plan in the country. I sincerely hope that respective stakeholder agencies identified in the plan successfully implement the identified activities and thus contribute to the effort of managing the watershed on a sustainable basis.

(Chencho Norbu)
DIRECTOR GENERAL

EXECUTIVE SUMMARY

The Punatsangchhu basin is one of the most important basins in Bhutan, as it encompasses a large area of almost 10,000 km^2. The basin drains the west-central part of Bhutan, namely Gasa, Punakha, Wangdue, Tsirang, Dagana and Thimphu Dzongkhags entirely or in parts towards the Brahmaputra via the Sunkosh River. It covers a wide variety of agro-ecological zones from sub-tropical in the south (c.100m.a.s.l) to snowcapped mountains in the north (7000m.a.s.l).

The Punatsangchhu basin has been delineated into 52 separate watersheds, using the Arc SWAT tool with a maximum threshold of 5,000 ha. Based on a rapid assessment and classification study carried out for this basin in 2011 using the approved Guideline for Classification of Watershed (2010), seven of the 52 watersheds were classified as "critical", triggering the requirement for a Watershed Management Plan. These watersheds are:

- Baychhu, Wangdue Dzongkhag,
- Powkhoachhu, Tsokhanachhu and Nevchanthaychhu, Tsirang Dzongkhag, and
- Buedulumchhu (incorporating Baleychhu and Zharingaychhu), Dagana Dzongkhag.

This Watershed Management Plan deals with Baychhu critical watershed, which has been classified primarily due to its role as drinking water source.

Since water from the Baychhu is used for drinking, irrigation and hydropower generation, the health of its watershed has implications on communities living in the area, both within and outside watershed. Specifically, the watershed is the source of drinking water for the largest urban settlement in the Punatshangchhu basin, which therefore requires appropriate management interventions. Accordingly, this watershed management plan has been developed to address various land use and water related problems within the watershed. The goal of the plan is to achieve sustainable management of natural resources within the watershed, This plan is expected to improve the flow of ecosystem services and thereby enhance the livelihood of local communities within its boundaries and urban settlers beyond its boundaries. Importantly, the sustainable management of Baychhu watershed also joins Punatshangchu which ulitimately contributes to the generating hydropower of PHPA I and PHPA II.

Participation of local communities was an integral part of the planning process. Therefore, the approach adopted by the plan is based on integrated watershed management and participatory

planning and consultations were conducted with the Dzongkhag Forestry Sector of Wangdue, RNR sectors and local government leaders of Kazhi, Phangyuel and Nyisho Geogs.

The plan consists of four chapters. The first three chapters deal with the current situation within the watershed, while the second part deals with appropriate management interventions to be implemented to manage the identified problems.

Specifically, chapter 1 to 3 of the plan discusses the current general conditions of the watershed, including physical features – land use and land cover types, climate and hydrology, geology and soils, biodiversity and socio-economic conditions. The chapter discusses the existing emerging environmental and social issues including the beneficiaries that depend on the resources of the watershed.

Chapter four of the plan deals with the interventions that are necessary to be planned in detail and implemented by relevant stakeholders within the watershed in an integrated, participatory and collaborative manner. The major activities proposed in the Plan fall within the following broad thematic areas - conservation of natural resources; livelihood improvements for the local communities; enhancing ecological goods and services; and empowerment of local communities in decision-making on the management of natural resources. Further, the Plan proposes an enabling institutional arrangement, a funding source and mechanism to implement the planned activities.

The activities identified in the current management plan will be integrated into the area-based development conservation plans of the sectoral programs the decentralized Dzongkhag and Geog plans through a coordinated participatory planning mechanism. Based on the activity log frame provided, management activities will be implemented according to Geog boundaries. The roles and responsibilities of local communities, external stakeholders and various committees are all detailed in the plan.

The plan strongly emphasizes the importance of monitoring & evaluation processes. A workable mechanism is recommended for regular monitoring and periodic evaluation of the implemented activities during the plan implementation. A final evaluation of the plan is proposed as a mandatory process to verify that the expected outcomes and outputs from the implementation program were achieved as planned. The management plan is for 5 years and will be revised if found necessary.

ACKNOWLEDGEMENTS

This management plan is an outcome of the collaborative work with various stakeholders both at field and Ministry level. The Dzongkhag Forestry Sector, Wangduephodrang facilitated in conducting consultation workshops and data collections. The Municipal office provided data on water quality tests and information on preliminary water treatment process at the Tencholing water treatment plant and water offtake point at Rikizampa. The Dzongkhag Health Sector, Wangduephodrang supported by providing information on bacteriological analysis. The Geog administrations and communities of Kazhi, Phangyul and Nyisho provided support during conduct of field assessments at the geog and Chiwog level.

The Soil and Plant Analytical Laboratory, NSSC conducted tests and provided data for various water quality parameters. The participants of the write-shops provided input in framing the outline and content of the management plan.

The project on capacity building under the NUFFIC program helped in building capacity of staffs and stakeholders. Under the program, experts from University of Saxion and Witteveen+Bos provided one set of training on integrated watershed management planning and hands-on-training for conducting water quality tests and discharge measurements.

The BC-CAP project funded by Government of Austria provided the financial resources for holding consultation workshops for the plan at the Geog and Dzongkhag level.

Therefore, Watershed Management Division would like to thank the Ministry and Department for the management support and policy direction. In addition, many thanks are due to all the institutions and individuals involved in the whole process of watershed management planning from rapid assessment and classification of watersheds carried out

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CHAPTER 1: BACKGROUND

1.1. Watershed Management in Bhutan

Bhutan is a mountainous country located in the Eastern Himalayas. Its combined topographical and climatic features form a mosaic of watersheds that provide the basis for the wellbeing of the country's people's.

Geographically, Bhutan is divided into five major and two minor river basins (Tab.1). Without exception, human activities take place in all these basins. Watershed management therefore holds the key to identifying problems and potential improvements associated with the conservation, rehabilitation and sustainable use of natural resources.

Tab. 1: River Basins and their tributaries in Bhutan

Major River Basins		Tributaries
1	Wangchhu	Haachhu, Pachhu, Thimpchhu
2	Punatsangchhu	Mochhu, Phochhu, Dangchhu, Dagachhu
3	Manas	Mangdechhu, Chamkharchhu, Kurichhu, Drangmechhu
4	Amochhu	-
5	Ningriamachhu	-
Minor River Basins		**Tributaries**
6	Maochhu	Kharchhu, Gongchhu, Gulechhu, Ruthalgongchhu
7	Jomochhu	Near Daifam in SamdrupJongkharDzongkhag

Source: LUPP 1997, Ministry of Agriculture

Several policy documents in Bhutan stress the need for watershed management to achieve poverty reduction, environmental sustainability and sustainable development. Watershed management is also covered in several pieces of Bhutanese legislation, including Article 5 of the Constitution of Bhutan 2008, Bhutan 2020, National Forest Policy 2011, Forest and Nature Conservation Act 1995, Land Act of Bhutan 2007, Bhutan Water Vision 2025, Bhutan Water Policy 2008 and Bhutan Water Act 2011. Much of the policy background demands effective and integrated watershed management to maintain and improve water and watershed conditions and so contribute to sustainable livelihoods through provision of watershed services.

Recognising the importance of watershed management, the Royal Government of Bhutan in 2009 established the Watershed Management Division (WMD) under the Department of Forests and Park Services. The division was designated as the national focal agency for operationalizing the watershed management program as part of a larger initiative in developing integrated frameworks for the major river basins in the country.

In close consultation with managers, stakeholders and communities, the division has developed common program objectives and practical measures to contribute towards the overall development

goals of GNH by sustaining the flow of natural resources and better stewardship of watersheds.
As part of its mandate, the division has developed a roadmap to plan and implement strategic activities in watershed management. The document "Guideline for Classification of Watershed" was subsequently developed in 2010 to identify and classify watersheds within each river basin according to its level of degradation. For practical purposes, watersheds across the country were delineated using a maximum threshold area of 5,000 ha (50 km^2). A total of 186 watersheds were identified and were assigned a unique identity number (Fig. 1). This process forms the investigation part of the Watershed Management (WM) cycle. The basic steps in WM cycle including investigation, planning, implementation and monitoring is detailed in Annexure II.

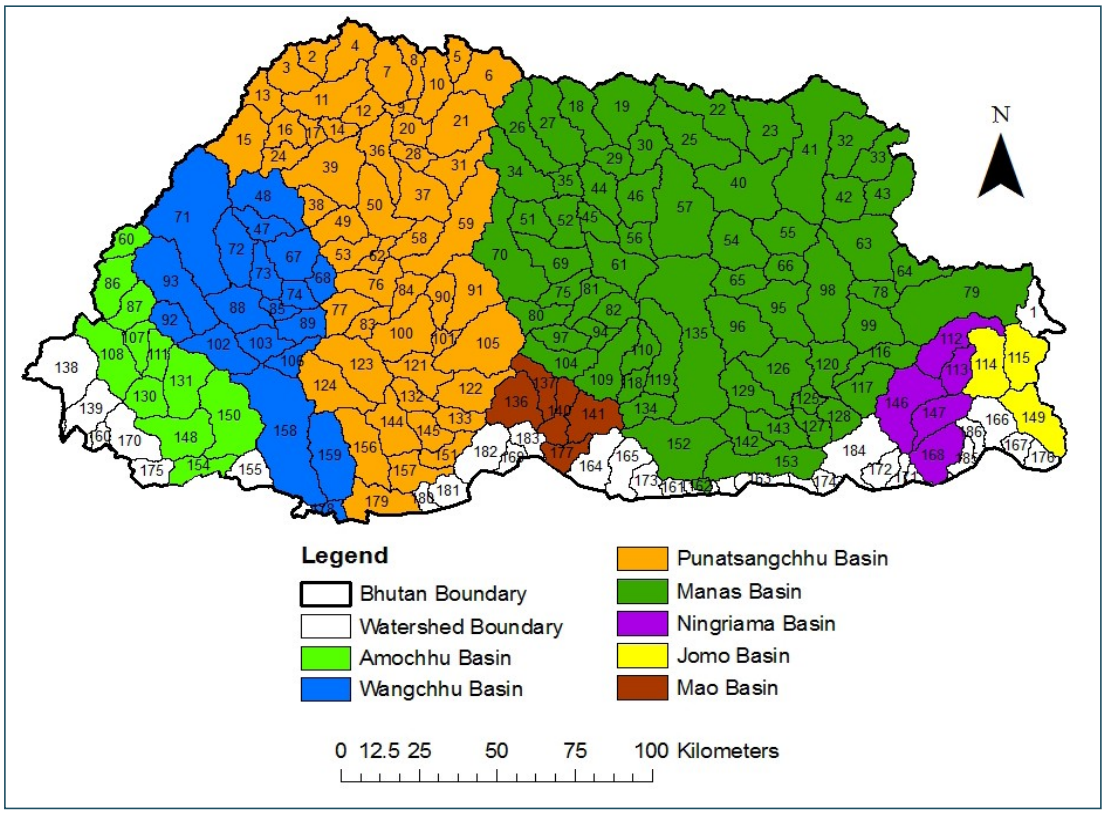

Fig. 1: Map showing 186 watersheds in Bhutan classified using the 2010 Guidelines

The two important documents, 10th Five Year Plan (2008-2013) and (Bhutan 2020) aspire being developed for all river basins in Bhutan. However, the resourcing requirements for this would be significant. Since most of the watersheds in Bhutan are in pristine condition, there is no urgent need to develop master plans for all the basins. A practical and cost-effective strategy is to focus on the most 'degraded' watersheds where the most urgent management attention is required while periodically monitoring those watersheds classified as having a 'normal' state.

If all the critical/degraded watersheds within a river basin are identified, and Watershed Management Plans (WMPs) are developed and implemented for all these watersheds, then this would be seen as significant progress towards achieving the master plan for the entire basin. In effect, the cumulative WMPs of all the degraded watersheds in a basin will form the Watershed Management Plan for that entire basin.

1.2 Punatsangchhu Basin

Punatsangchhu basin was selected considering the presence of several degradable along the Punatshangchu basin for the first study in view of the number of highly degraded watersheds within it and also the potential future impacts associated with a number of mega hydropower projects currently being commissioned within the basin. A location map for the Punatsangchhu basin. (Fig. 2)

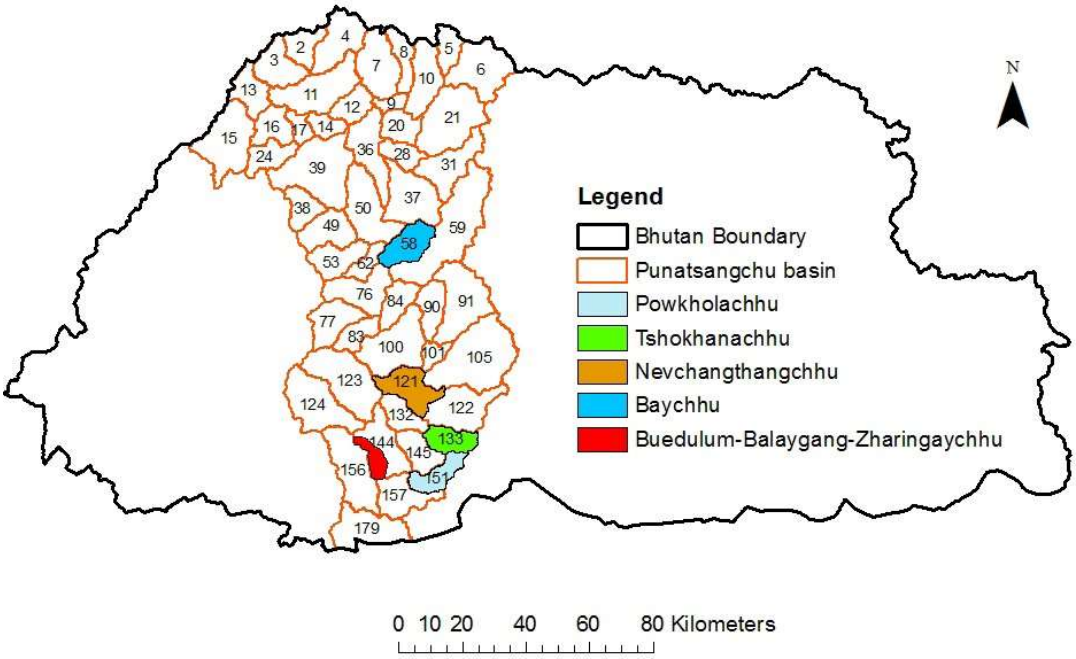

Fig. 2: The PunatsangChhu Basin

The Punatsangchhu basin covers a total area of 9,725 km^2 comprising mainly of 5 Dzongkhags: Gasa, Punakha, Wangdue, Tsirang and Dagana (see Table 2). The other five Dzongkhags which partially fall in the basin include small parts of Thimphu, Sarpang, Trongsa, Chukha and Paro.

Tab. 2: Details of Dzongkhags within the Punatsangchhu Basin

Dzongkhag	No. of Geogs	Area (km2)	Population	Population Density (per km2)
Gasa	4	2,900	3,100	1
Punakha	11	1,100	23,000	20
Wangdue	15	3,100	31,000	10
Dagana	14	1,600	23,000	15
Tsirang	12	600	13,000	20
Thimphu	6	300	-	-
Sarpang	4	10	-	-
Total	73	9,700	94,000	10

The altitude ranges from e100 m a.s.l in the south to 7100 m a.s.l in the north covering different agro-ecological zones of sub-tropical along downstream parts of the basin (Tsirang, Dagana), warm temperate in the central areas (Wangdue and Punakha) and alpine in the north of the basin (Gasa and higher areas of Wangdue and Punakha Dzongkhags).

There are 52 watersheds within the Punatsangchhu basin. Based on the rapid assessment and classification, five watersheds consisting of seven streams were classified as "critical" (Fig. 2 & Tab. 3). Buedulumchhu-Balaychhu-Zaringaychhu in Dagana and Baychhu in Wangdue were prioritized to be taken up for watershed management planning.

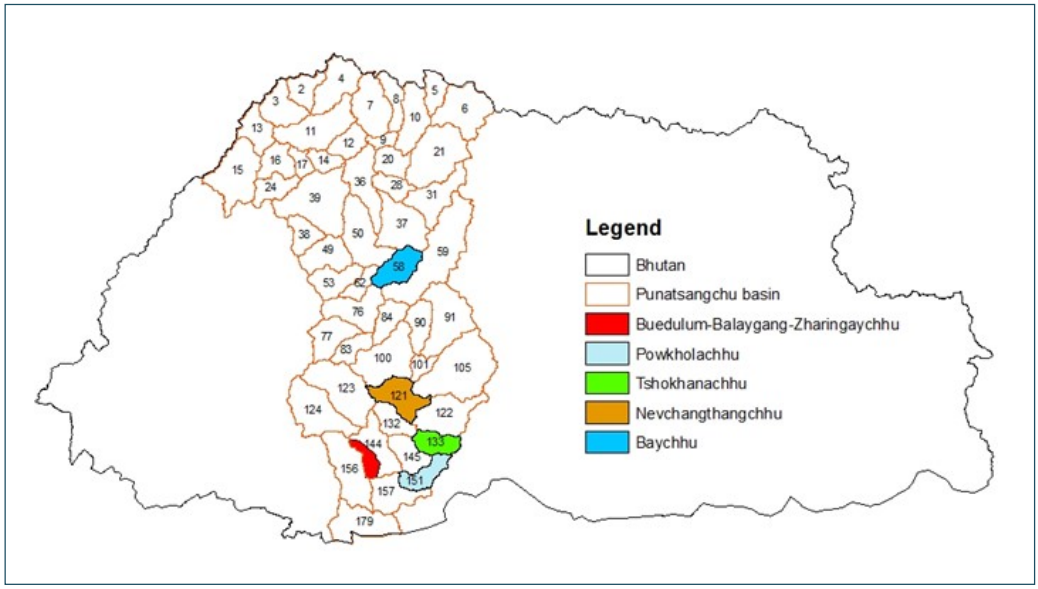

Fig. 2: Critical watersheds within Punatsangchhu Basin

Results of the watershed assessments including the plans and programs were presented to the Sector Heads of the two Dzongkhags and local government leaders separately. Issues related to each of the designated watersheds were appraised during consultative meetings and management plans were subsequently developed.

Tab. 3: Details of critical watersheds in the Punatsangchhu basin

Dzongkhag	Critical Watershed	Streams	Reason for Critical Classification
Wangdue	Baychhu	Baychhu	Drinking water catchment
Tsirang	Powkhoachhu	Powkhoachhu	Highly degraded
	Tsokhanachhu	Tsokhanachhu	
	Nevchanthangchhu	Nevchanthangchhu	
Dagana	Dagana	Buedulumchhu	
		Baleychhu	
		Zharingaychhu	

The following sections of this Watershed Management Plan document relate to the Baychhu watershed.

CHAPTER 2: DESCRIPTION OF THE BAYCHUU WATERSHED

2.1 Bio - Physical features

2.1.1 Location and area

Baychhu watershed lies in Wangdue Dzongkhag and is bounded by Kazhi Geog, Phangyul Geog and Nisho Geog. (Fig. 3)

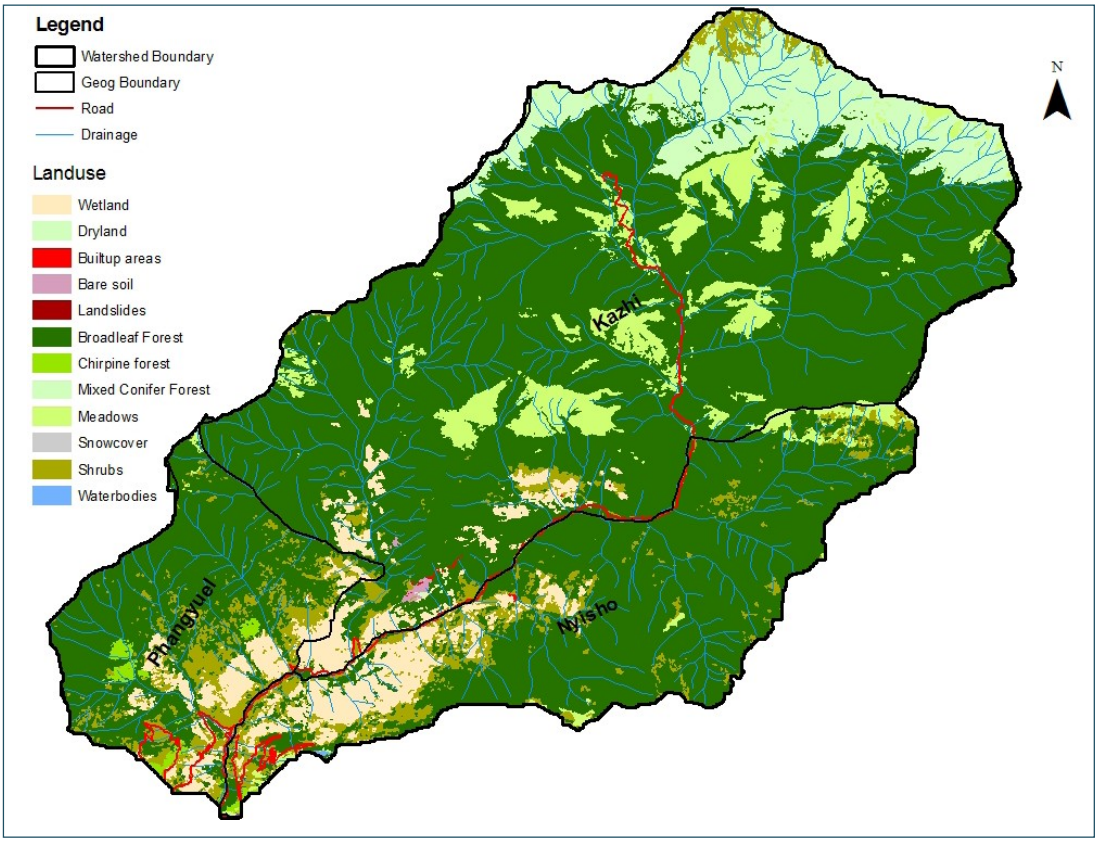

Fig. 3: Map of Baychhu watershed within Punatshangchhu basin

The total catchment area of Baychhu watershed is approximately 14,600ha of which 9,200ha is located in the Kazhi Geog, 3,400 ha is in Nyisho Geog and the remaining 2,000 ha falls in Phangyuel Geog (Tab. 4).

Tab. 4: Area of Geogs in the watershed (NSSC, 2011)

Geog	Total Area (ha)	Area within watershed (ha)
Kazhi	62,900	9,200
Nyisho	11,700	3,400
Phangyuel	3,200	2,000
Total	77,800	14,600

The altitude of the watershed ranges from 1400 to 4000 m a.s.l and is bound by high ridges to the west and east. The Baychhu stream that drains the watershed joins main river Dangchhu which finally drains into Punatsangchhu (Figure 3).

As per the guideline for assessment and classification of watersheds, a watershed can be categorized as critical by function if water from the main stream is mainly used for drinking purposes by a growing population both from within and outside watershed area. Accordingly, based on the assessment carried out in 2012 by the Watershed Management Division of the Department of Forest and Park Services, Baychhu watershed is classified as a "critical watershed" by function.

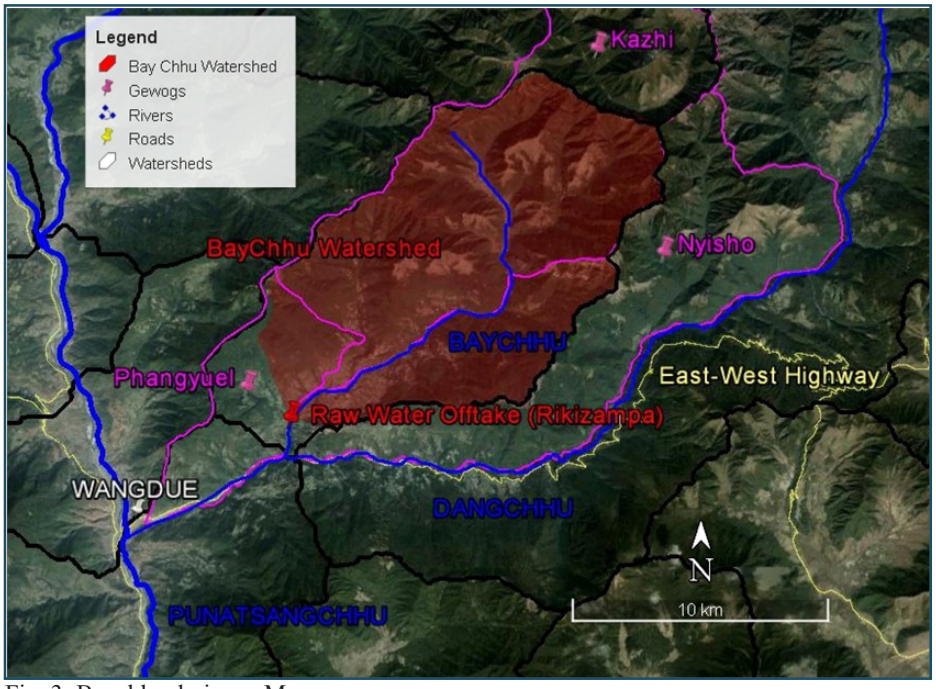

Fig. 3: Baychhu drainage Map

2.1.2 Land use and land cover types

Forest forms dominant land use covering 80% of the total watershed (Table 5 and Figure 4) and comprises mainly of broadleaved (71%), followed by mixed conifers (8%), and others (<1%). The other substantial land areas are grassland (7%), shrub (7%) and agricultural land (7%) including wetlands and dry lands. The main crops grown are rice, potatoes, chilies, oranges and other vegetables. Besides agriculture, livestock is one of the main sources of livelihood.

Tab. 5: Land use in Baychhu watershed, (NSSC, 2011)

Land use type	Area (acre)	Percent (%)
Wetland (Chuzhing)	2,200	6.0
Dryland (Kamzhing)	280	0.8
Broadleaved Forest	26,000	71
Conifer Forest	160	0.4
Mixed Conifer Forest	2,800	7.7
Grassland	2,600	7.0
Snow cover	10	0.03
Water bodies	10	0.03
Barren area	30	0.1
Landslides/Degraded land	< 1	0
Built-up area	10	0.03
Shrub land	2,500	7.0
Total	**36,500**	**100**

The slopes of lower reaches of the Baychhu watershed are dominated by terraced paddy fields with isolated patches of broadleaved forest. These forest patches are used for collection of leaf litter for cattle bedding and also as a source of organic manure for agriculture.

The northern parts of the watershed are primarily covered by forest. This forest serves as grazing ground for livestock and wild animals including “Tshethar Yaks”. Small parts of the watershed in the extreme north of the watershed are covered by snow which is one of the main sources of water for the Baychhu.

2.1.3 Biodiversity

Vegetation

The major plant species along the upper reaches of the watershed comprises of *Abies densa, Tsuga dumosa, Picea spinulosa, Pinus wallichiana, Juniperus recurva, Quercus semecarpifolia and Rhododendron.* Bamboos (*Yushania macrophylla* & *Borinda grossa)* are found in the cool broad-leaded forests, mixed with *Quercus glauca, Q. oxyodon, Acer, Betula alnoides, Q. griffithii, Myrica esculenta, Benthamedia capitata, arboreum, Juglans regia, Alnus nepalensis,* etc. In the lower reaches, *Pinus roxburghii, Q. lanata,Q, glauca, Q. griffithii, Acer oblongum, Dalbergia sericea, Schima wallichii, Rhododendron arboreum, Sapium insigne* etc. can be found. The invasive weeds observed are *Ageratina adenophora, Chromolaena odoratum and Parthenium hysterophorus. Potamogeton distinctus* is a major weed in the paddy fields.

Wild Life

In the upper reaches of the watershed, the major wildlife species are Musk Deer, Sambar, Goral, Serrow, Himalayan Black Bear and Wild Pig. Common bird species include Pheasants, Fowls, Nut Crackers, Common Crows and Yellow-Billed Magpies.

In the lower reaches, common animals include Assamese Macaques, Grey Langurs, Barking Deers, Wild Pigs and Porcupines. Among the birds, Kalij Pheasants, Emerald Doves, Red-Vented Bulbuls, White-Throated Laughing Thrushs and Blue Whistling Thrushs are observed.

Aquatic Biodiversity

The fish species along the Baychu are Snow Trout *(Schizothorax richardsonii)* and Cat Fish *(Parachilo glanishodgarti and Pseudechene issulcata)*. The major macro invertebrates found in the Baychhu are the nymphs of Dragonflies, May Flies and Stone Flies which are generally indicators of good water quality. Dobson flies are found in lower reaches of the river which can tolerate higher levels of water pollution.

2.1.4 Geology and soil type

The Baychhu watershed falls under the Greater Himalayan Sequence (Grujic, 2002) which comprises of sedimentary and limestone based parent materials. The slopes on both sides of the valley are scattered with outcrops of granite rocks.

The soil texture varies from sandy loam to silty clay (LUPP report of Kazhi Geog, PPD, MoAF). Due to heavy monsoon rains and rapid surface runoff, gully formation is a common feature of the area.

The Baychhu carries heavy sediment loads emanating from development activities (farm road construction, stone quarrying, landslides and surface erosions) as well as from the rest of the catchment. Sediment load is higher during the paddy transplantation season as flood waters from preparation of the paddy field are discharged into the Baychhu.

2.2. Demographic features

2.2.1 Socio economic features

Infrastructure

Development facilities available for use by communities of the Baychhu watershed include three RNR centers, one Basic Health Unit, six outreach clinics, two community schools, three primary schools and one middle secondary school. The main road to Baylangdra is located along the river valley and several farm roads have been constructed inside Baychhu watershed.

Beneficiaries

The communities that falls within the watershed are directly dependent on Baychhu and its tributaries both for drinking and irrigation. The total population in the Baychhu watershed area is 6250 (Table 6) comprising of 630 households. Among the three Geogs in the watershed, Nyisho has the largest population of 2680 (Figure 6).

Tab. 6: Household and population within the watershed boundary

Geog	Chiwogs	Households	Total Population	Population living on Farms
Kazhi	6	210	1900	920
Nyisho	5	260	2680	820
Phangyuel	5	160	1670	990

Source: Bhutan, RNR Statistics, 2012.

Other beneficiaries include the communities of the Bajo Township, the Tencholing Army camps, Wangdue Dratshang and other settlements along the highway between Bajo and Chuzomsa with a population of c. 7500.

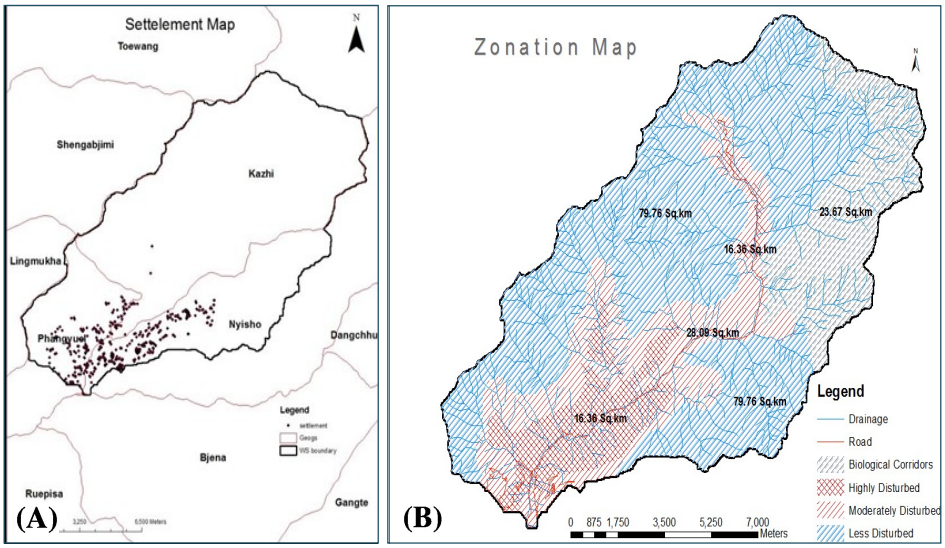

Fig. 4: A) Settlement map & B) Disturbance map

2.2.2 Agriculture and Livestock

The communities located in the three Geogs of the Baychhu watershed are mainly dependent on agriculture and livestock. Rice cultivation, potato and chilly are the dominant cash crops in the area besides Maize, wheat, barley, vegetables and some fruit crops are also grown (Table 7). The non-wood forest produces (NWFPs) collected from nearby forests also contributes to their cash income

.

Tab. 7: Agricultural production yields in the Baychhu watershed

Crops	Crop Parameters	Geogs					
		Kazhi		Nyisho		Phangyuel	
		Dryland	Wetland	Dryland	Wetland	Dryland	Wetland
Cereal	Cultivated Area (acres)	238	22.6	167	151	-	596
	Production (MT)	284	289	6	182	596	827
	Yield (kg/acre)	1123	1300	1519	1069	827	1388
Vegetables	Cultivated area(acres)	241	-	91	240	1388	-
	Production(MT)	769	-	3	297	-	-
Species	Cultivated area(acres)	0.27	-	1645	8	-	-
	Production(MT)	0.22	-	23	4	-	-
Oil seed	Production (MT)	3.03	-	15	7	-	-
Fruit trees	Number	1111.0		297		9791	

Source: RNR Statistics 2012

Phangyuel Geog has the largest area under agricultural production - contributing to about 1000 metric tons of assorted agricultural produces while Nyisho has the smallest agricultural production area. The existence of large areas under agriculture and the associated requirements for external inputs such as chemical fertilizers and pesticides may lead to pollution of water.

Cattle are the most dominant livestock in all three Geogs (Table 8). Nyisho Geog has the largest cattle population, mainly local species managed under a free-range grazing system. Yaks are also found in the upper reaches of the watershed.

Tab. 8: Livestock Numbers in the Baychhu Watershed (Livestock statistics, 2012)

Livestock	Kazhi	Nyisho	Phangyuel	Total
Jersey Cross	109	153	173	440
Yak	907	-	-	910
Cattle	794	1221	824	2800
Horses	131	64	< 5	200
Pig	26	48	< 5	80
Poultry	366	187	51	600
Sheep	< 5	-	-	< 5
Goat	< 5	< 5	< 5	10
Total	2330	1660	1060	5050

Cattle grazing and cattlesheds by the river banks are potential sources of water contamination. Uncontrolled grazing in forests, barren land, fringes of paddy terraces and on steep slopes can also result in rill and surface erosion which are further sources of water pollution.

2.3 HYDROLOGY

2.3.1 Climate

The Baychhu watershed is climatically located in the upper reaches of the temperate zone of the Bhutan Himalayas. Based on the records from 1987-2007, annual mean precipitation is 990 mm with a maximum monthly mean precipitation of 240 mm in July coinciding with the peak monsoon month. The watershed is recharged by the monsoon mainly during the months from May to September and snowfall during the winter months at the higher altitudes above 3000 m.

Dry period starts from (Nov, Dec & Jan) where the temperature curve exceeds the precipitation curve (Fig. 7). Mean monthly temperatures range from 21.8 ºC in August to 8.8 ºC in January. Thus, rain recharge during the other nine months serves as the main water source during the dry winter months. This also highlights the important role of vegetation cover in sustenance of the watershed.

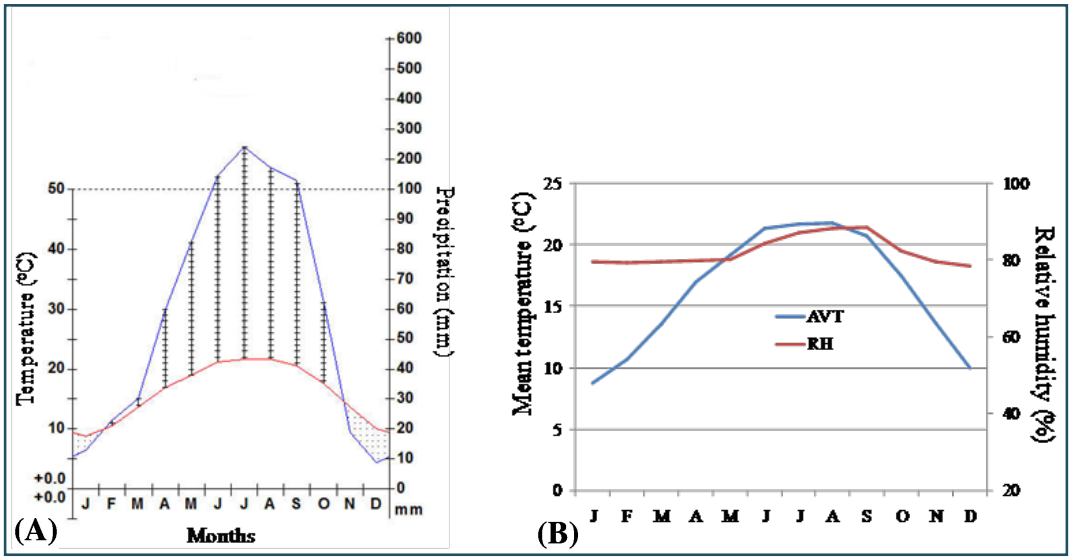

Fig. 7: Climatic conditions; (A) Walter Climate diagram. (B) Temperature and relative humidity correlation. Samtengang (1960 m.a.s.l), Baychhu watershed, Wangdue, Punatsangchhu Basin

The evapo-transpiration ratio (PER) for the Samtengang station is 0.9 indicating relatively dry conditions. Similarly, the warmth index (WI) is 136 which is similar to that of Mendeygang (132) located outside the watershed, confirming the coverage of relatively dry mixed conifer types of forest.

2.3.2 Flows

The Baychuu drains a total catchment area of about 14,600ha before joining the Dangchhu which finally drains into the Punatsangchhu. (Fig 5)

Information on precipitation, base flow and discharge is required to estimate water budget for the watershed area. Base flow is calculated using rainfall data of 2005 and the curve number method. This data shows that the highest rainfall and base flow is in July.

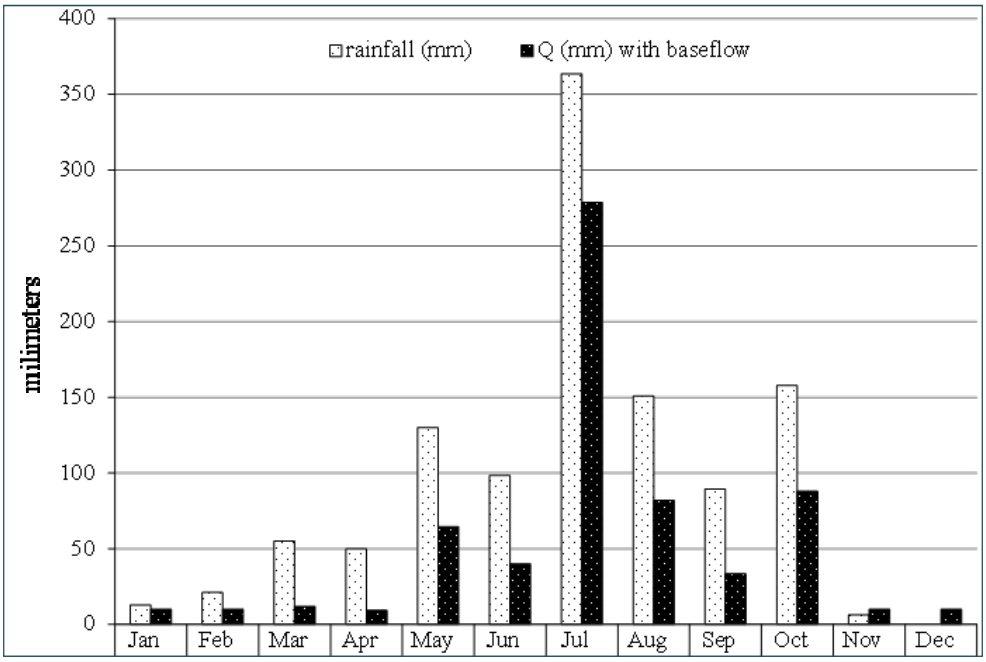

Fig. 8: Rainfall and base flow in 2005 for the Samtengang station

To generate consistent and credible hydrological information in the future, it is necessary to install and maintain a meteorological station in the Baychhu watershed. Information generated from this facility has wide areas of application, for example, in predicting droughts, floods, and outbreaks of pests in the watershed area.

Water discharges were recorded at six locations along the Baychhu during November 2013 and March 2014 (Fig. 9). Two of these locations were the main inlets for the drinking water (D4) and irrigation (D5) sources for Bajo. Flows were calculated using the velocity-area method. Based on these calculations, outflows from the watershed are approximately 4.5 - 5 m^3/s in the month of November while it is 1.91 m^3/s in March 2014. This compares to an estimateof 11 m^3/s during September.

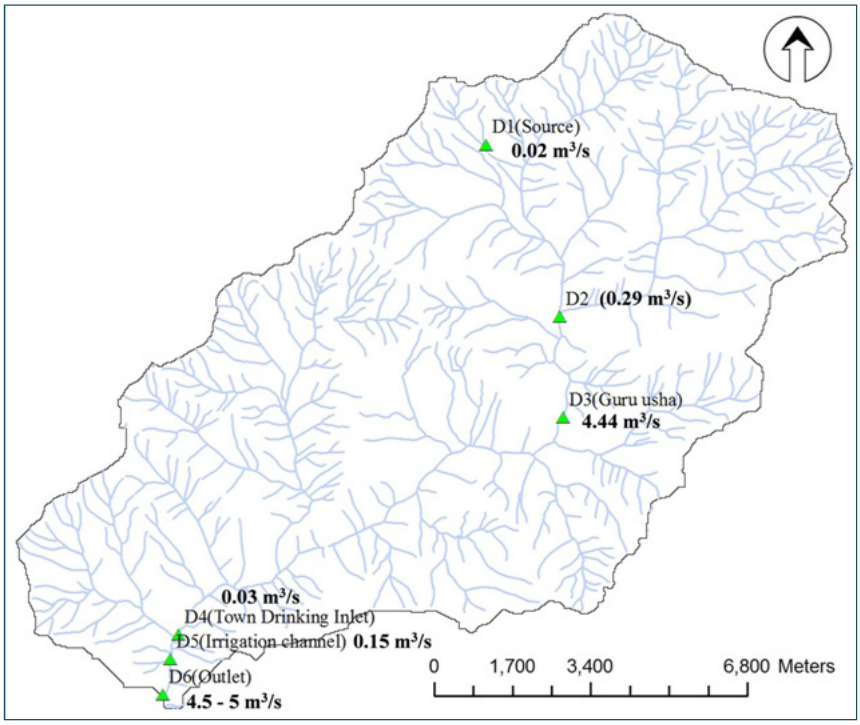

Fig. 9: Flow estimations in November 2013

Using the 2005 rainfall data (Fig. 7) for the Samtengang station, estimates have been developed for water availability in the Baychhu watershed (Fig.10). Water demand was calculated as per the UN standard of 20-50 litres/person/day.

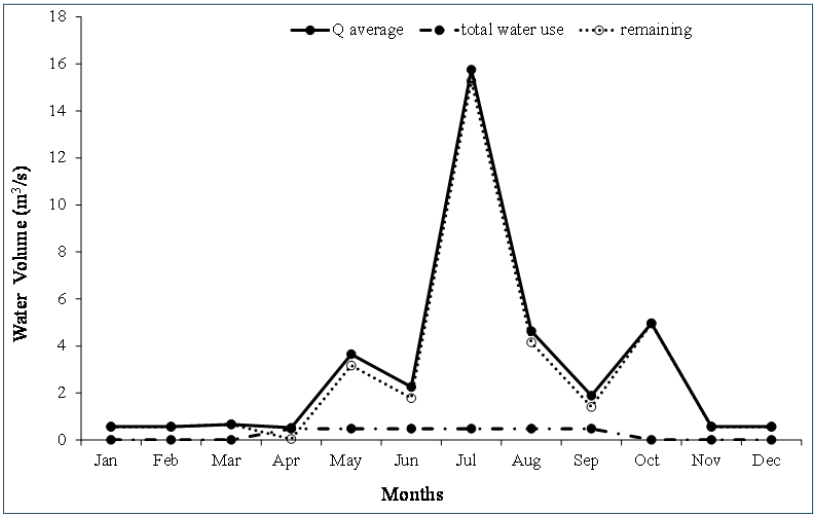

Fig. 10: Water Demand and Availability in Baychhu Watershed

Based on this assessment, it can be seen that water availability far exceeds demand in all months of the year. Water extraction has little impact on environmental flows in the river.

2.4 Water quality

Water from the Baychhu is collected, treated and distributed for domestic use by about 7500 people in the township of Bajo, army camp, school and surrounding areas. Water is diverted from the river near Rikizampa and passes through preliminary treatment near the offtake location prior to further treatment at the Tencholing water treatment plant in Wangdue Phodrang (Fig. 11).

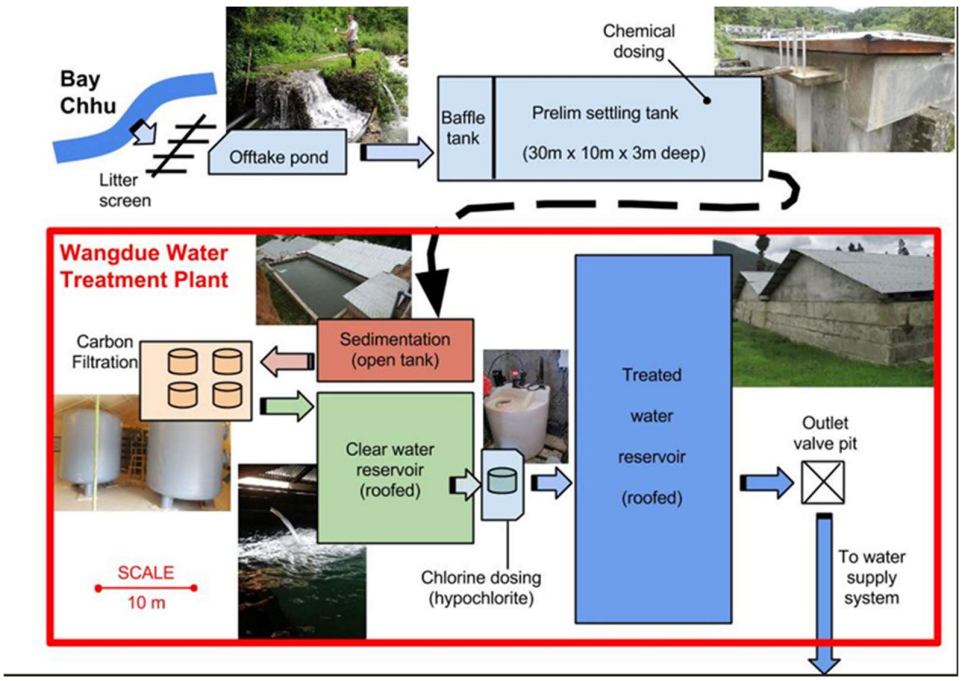

Fig. 11: Water treatment system

A range of water quality data sets were reviewed which are presented below.

2.4.1 Raw water physio-chemical parameters

Water quality sampling was undertaken at 5 sites (Fig. 12) as below:

1. Site 1: Upper Baychhu (upstream of monastery complex)
2. Site 2: Middle Baychhu
3. Site 3: Tributary of the Baychhu in the lower reaches of the watershed
4. Site 4: Lower Baychhu at Rikizampa (raw water offtake structure)
5. Site 5: Treated water from the Tencholing water treatment plant.

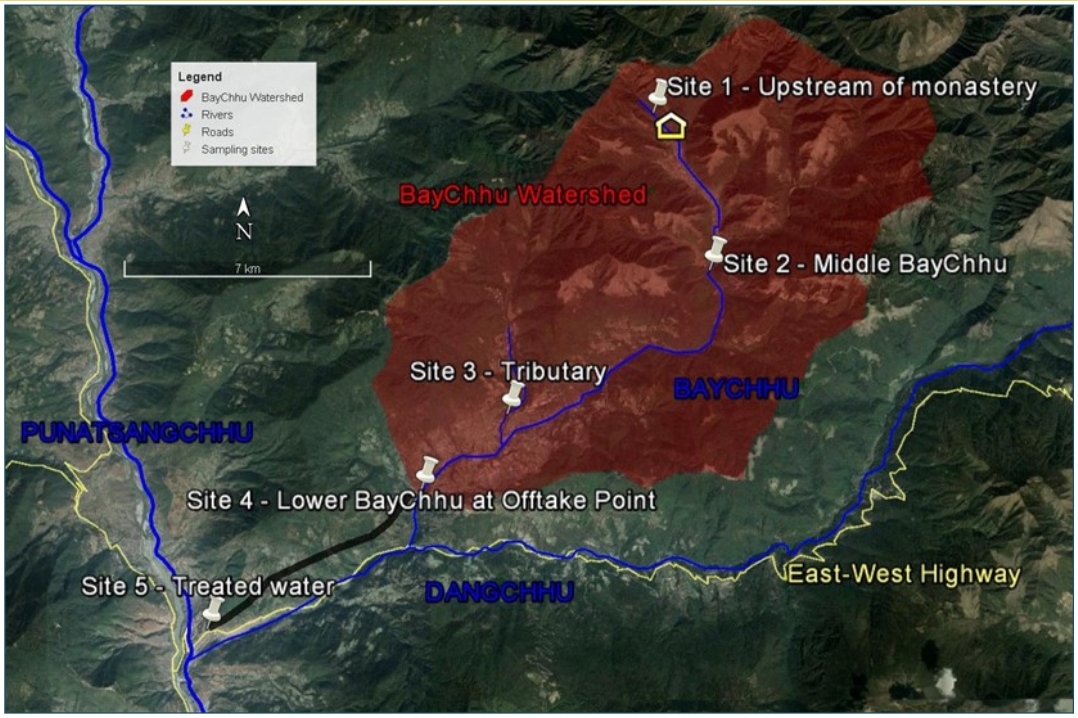

Fig. 12: Water Quality Sampling Sites

The first round of water quality sampling was undertaken in November 2013 for testing at the SPAL laboratory. (Tab. 9)

Water quality sampling was also again undertaken in July 2014. On this occasion, duplicate samples were collected at each location for quality assurance purposes. The results are summarized in Table 10. All the duplicate sample results were very similar and therefore only one value for each location is presented here.

Tab. 9: Water quality results from November 2013

Site	Description	Cond. EC uS/cm	pH -	Dissolved Oxygen DO mg/L	Phoshate as PO_4 mg/L	Nitrate as NO_3 (mg/L)	Nitrate as NO_4 (mg/L)	Temp. ^0C
1	Upper Baychhu	175	**8.4**	**3.5**	0	**0**	0	7
2	Middle Baychhu	225	8.3	3.4	1.5	0	0	12
3	Tributary	Not tested						
4	Lower Baychhu	210	8.6	-	3	0	0.5	13
5*	Treated water	Not tested						
G**	Guideline values	< 780 (US Regs)	6.5 - 8.5	-	TP < 0.5 (Bhutan Regs)	-	< 10 (WHO)	

Tab. 10: Water quality results from July 2014

Site	Description	Turbidity (NTU)	Cond. "EC" uS/cm	pH -	Phosphate as PO_4 mg/L	Nitrate as N (mg/L)	TDS (mg/L)
1	Upper Baychhu	0.4	**165**	**7.7**	**0.05**	**0.6**	**80**
2	Middle Baychhu						
3	Tributary	2.5	155	7.5	0.18	0.5	75
4	Lower Baychhu	3.5	205	7.9	0.06	0.5	100
5*	Treated water	2.5	210	8.1	0.05	0.4	100
G**	Guideline values	< 5 ideal <1 (WHO)	< 780 (US Regs)	6.5 - 8.5	TP < 0.5 (Bhutan Regs)	< 10 (WHO)	< 500 (US Regs)

5* Treated water from the Water Treatment Plant. Used to cross-check the regular WTP monitoring
G ** Guideline values for drinking water shown for reference.

2.4.2 Tenchholing Water Treatment Plant – Physio Chemical Parameters

The Tencholing Water Treatment Plant tests water quality most days at the inlet of the carbon filtration facility and the final treated water distribution pipe. Data is presented below from April-December 2014. (Fig.13, Fig.14 & Fig.15)

Analysis of this data can provide insight into the treatment efficiency of the plant. However, the data is only replicated in this report for information purposes as its accuracy or validity cannot be verified. Further monitoring and validation need to be undertaken in the future to allow a proper water quality assessment to be undertaken.

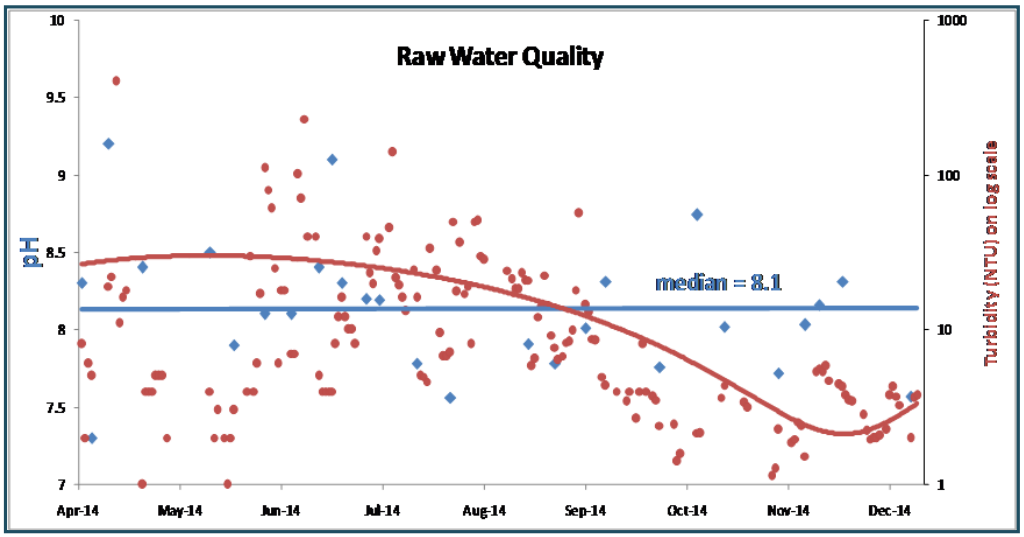

Fig. 13: Raw water quality (pH and Turbidity)

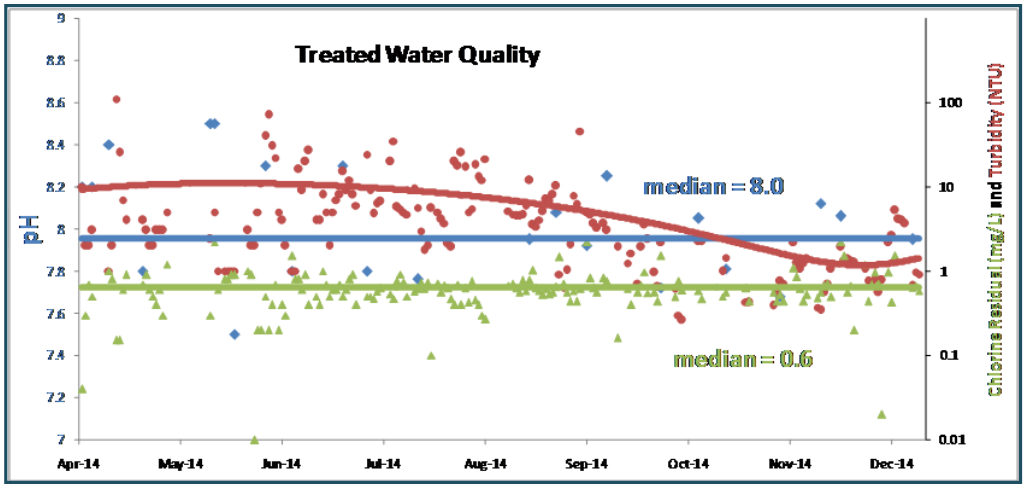

Fig. 14: Treated water quality (pH, Turbidity and Chlorine Residual)

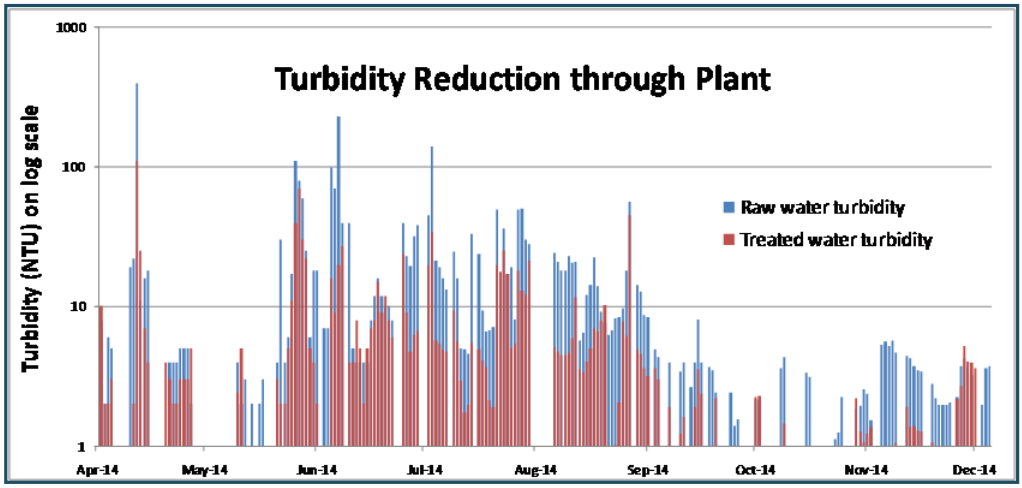

Fig. 15: Turbidity reduction through plant

2.4.3 Bacteriological water quality

In addition to the data presented above, the Department of Health collected sample water from various sites for bacterial analysis. (Tab. 11)

Tab. 11: Bacteriological Water Quality (Faecal Coliform Units / 100ml)

#	Location	Jan '13	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan '14	Feb	Mar	Median	Range
Raw water at Phangyul																		
1	Raw water offtake	36	41	35	41	> 50	> 50	-	-	12	10	2	3	6	3	2	12	2 - >50
2	Preliminary Settling Tank	28	36	41	36	> 50	> 50	-	-	16	14	4	15	5	5	4	16	4 - >50
Tencholing WTP																		
3	After filtration	31	32	28	35	> 50	> 50	Carbon Filtration System Upgrade		0	0	0		0	0	0	0	0
4	After Chlorination	-	-	-	-	-	-			6	3	6	20	2	0	0	3	0 - 20
5	Final treated water	-	-	-	-	-	-			-	3	-	20	6	-	1	5	1 - 20
Distribution network																		
6	Tencholing army camp	33	19	21	32	> 50	> 50			70	-	8	33	16	16	-	33	8 - 70
7	Tencholing primary school	-	-	-	-	-	-			52	25	15	30	18	13	-	22	13 - 52
8	Monastery	-	-	-	-	-	-			14	10	7	10	2	7	-	9	2 - 14
9	Bajo HSS	27	29	22	21	> 50	> 50			-	12	7	-	4	4	-	10	4 - 29
10	Bajo Hospital	-	-	-	-	-	-			8	5	3	35	8	2	-	7	2 - 35
11	Wangdue LSS	17	12	21	41	> 50	> 50			-	20	-	29	10	2	-	25	2 - 41

CHAPTER 3: ISSUES IN THE WATERSHED

Generally, the condition of the watershed was found to be good with relatively high vegetation coverage and low deforestation compared to other areas in the country. However, development activities are increasing in the watershed, eg: construction of farm roads. The issues affecting watershed condition along with their indicators, impacts and causes are summarized (Tab. 12)

3.1 Poor water management along farm roads and irrigation channels

3.1.1 Farm roads

Most of the farm roads in the watershed lack proper drainage systems, leading to increased erosion and landslides. Many of the cross-drains that are installed are non-functional or apparently due to the pipes being undersized (Hume) and the absence of catch pits. During the rainy season, the Hume pipes are blocked with sediment and debris causing overflow leading to landslides and gully formation.

Photo 1: (A) Absence of drainage on farm roads & water channel formation. (B) Lack of catch pits on depressions & streams along farm roads. (C) Blockage of hum pipes being too small in size & also due to lack of catch pits and debris entering & blocking the hume pipe diverting water onto farm roads. (D) Gully formation on farm roads

3.1.2 Irrigation channels

Irrigation channels are one of the most important types of structure in the watershed and have helped to maximize the amount of land that can be irrigated. Generally, irrigation channels are lengthy and built on natural slopes and so they are prone to leaking. On the one hand, this reduces the amount of water supplies at the end point and on the other hand it exacerbates the risk of land slips due to seepage. Examples of this nature can be seen in Chebakha in the Nyisho Geog where paddy fields have been found to be sinking at several locations. In other areas, overflows from irrigation channels are discharged on farm roads which affect their condition.

(A) Overflow & leakage of irrigation channel. (B) Damaged irrigation channel

3.1.3 Drinking water channels/ponds

Most of the drinking water is fetched from far away areas through HDPE pipes or natural channels. Some of these pipes are known to leak, which can contribute to erosion and landslides. For example, leaks from the drinking water pipes in the Samtengang Middle Secondary School in Nyisho Geog have contributed to several land slips along the Yariphu irrigation channel. Cementing of channels and repairing the pipes could help to address this issue.

Tab. 12: Summary of issues, their indicators, impacts and causes

ISSUES	INDICATORS	IMPACTS	CAUSES
Poor Water Management	Landslides and gully formation on farm roads		Poor road design, incomplete construction practices and lack of drainage systems
			Cross drains are non-functional of undersized hume pipes and lack of catch pits. Pipes get blocked leading to overflows destroying road over time through erosion.
	Overflow from irrigation channel onto farm roads and areas	Reduced water use efficiency as well as starting point for erosions	Leakage of irrigation channels & drinking water pipes
	Drinking water shortage at Chundu Goepna, Phangyuel	Sanitation problems for 11 house-holds and monastic students	Lack of storage tanks, leakage of pipes
Land Degradation	Loss of soil nutrients	Decrease in agriculture productivity	Use of chemical fertilizers pesticides and weedicides
	Sinking of paddy fields		Seepage from irrigation channels leading to subsidence & cracking & cracking further exacerbated by rain
	Erosion and landslides alongisde agricultural lands		Disturbance from road construction & rock extraction
			Intensive network of farm roads improperly constructed on steep slopes

ISSUES	INDICATORS	IMPACTS	CAUSES
Drinking Water Quality	High pathogen (bacteria) levels (FCU (0-78 FCU/100ml, mean 20 FCU/100ml)	Problem for drinking water	Open sewerage system with toilets & animal sheds along Baychhu including dumping of wastes and animal carcases
	High phosphate (1.5 - 3.0 mg/L)	Promote bacterial growth and environmental issues (algae presence)	Irrigation runnoff
	High turbidity (1-100 NTU)	High turbidity can provide pathogen shielding during the disinfection process. Besides, it will cause blockage of carbon filters	Erosion from farm roads, irrigation channels
	Water pH is alkaline (pH value of raw water between 7.3 - 8.5 and treated water b/w 6.2 - 8.5)	High pH reduces effectiveness of coagulation & disinfection	
	Low chlorine residual (< 0.5 mg/L) on some days	Low disinfection	Ineffective disinfection due to water pH being not optimal for treatment

ISSUES	INDICATORS	IMPACTS	CAUSES
Water Quality issues for other water uses	High sediment load with turbidity of 1-400 NTU, median 7 NTU	High turbidity will cause deposits/blockage of hydropower turbines & increase maintenance cost	Erosion in catchment and rainfall with high erosive forces during the monsoon period
	Mass debris (tree trunks)		Deforestation and poor land stabilization
Forest Degradation	Forest fires	Destroy vegetation, wild life and increase erosion	
	Deforestation	Loss of vegetative cover	Increase in timber demand and restriction on import of timber from sha Khotokha and Phobjikha
Human Wildlife Conflict	Damage to crops and irrigation channels	Decreased income to farmers	Habitat fragmentation

A second issue relates to traditional water management practices in the watershed. There are water management committees within the villages which have no external influence/input on the distribution of water throughout the watershed, particularly in the case of irrigation. When not in use, water in traditional schemes is often not properly diverted, causing fields to overflow and discharge onto farm roads or other forested areas. These provide the starting points for erosion and other land related problems.

The watershed management plan process can help in strengthening the capacity of water users and delivering appropriate training on water management practices and drawing up relevant by-laws. RNR Geog extensions staff can participate as observers while meetings are being conducted and minuted. Geog officials can intervene to settle any disputes which may arise. An appropriate penalty system should also be introduced.

3.2 Land degradation

3.2.1 Erosion/landslides

The impact of farm roads is prominent in the entire watershed and they are in fact the major cause of landslides. As explained earlier, due to poor road design and incomplete or improper construction practices, landslides and erosion are common along farm roads.

If timely maintenance is not undertaken, the entire stretches of watershed may lead to degradetion and subject to landslips in the near future owing to the steep topography of the watershed, a large proportion of sediment runoff is ultimately discharged to the main Baychhu. Therefore, maintenance of farm roads is of high priority not only to protect land from further degradation but also to reduce sediment pollution of the main river.

The planned developmental activities in the watershed may further degrade soil and water systems. The potential overflows from a 35km long proposed irrigation channel from the upper reaches of the watershed to Phangyul Geog could contribute to soil erosion and landslides along its route. In addition, diversion of water from the headwaters of the Baychhu into this planned irrigation channel will reduce downstream flows, especially during the dry season.

There were three landslides observed along the main 20 km farm road *(Photo 3)*. This road has no proper drainage system. These landslides are sources of sediment loads into the Baychhu. Several small scale granite quarries and the felling of trees within the drinking water supply catchment are also seen as potiential threat to impacting on water quality.

Photo 3: Landslides within watershed

3.2.2 Loss of soil nutrients

One of the concerns raised by farmers during consultation meetings was the loss of soil nutrients from agricultural lands due to poor farming practices. Nutrient loss is mainly due to the overuse of chemical fertilizers which not only have a negative impact on the environment but also negatively impact land productivity in the long run.

One strategy to avoid the loss of soil nutrients is to encourage organic farming which is already practiced in many small areas. A good example in Gendep and other areas in the Komathrang Chiwog is the farming of mustard, peas and wheat which are grown as winter crops in paddy fields. These crops have multiple uses for fodder, vegetables and manure which ultimately help to improve soil fertility.

It is important to upscale the above practice. Training and awareness programs can be conducted for preparation and use of organic pesticides, composting, FYM and growing of leguminous and other crops along with supply of seeds. Farmers can also be trained on the preparation and use of organic pesticides.

3.2.3 Sinking of paddy fields

Certain stretches of paddy fields in Chebakha Chiwog (Nyisho) of Pemathang, Aido, Jahangkha, Chebashong, Lungchina, Bahcena (batshaNyib), Kamgongkha, Lumacheywa and Tagongkha- have been found to be sinking. In some areas, cultivation had to be abandoned due to whole areas sliding down while in other areas certain parts of the field had sunk. In these areas, seepage from irrigation channels might have led to initial subsidence and cracking. When these cracks were not treated, seepage of rainfall water would have further aggravated the problem. In another location in just below Samtengang paddy fields started sliding down following construction of a road downstream and associated rock extraction activities. As a result, this whole area is left fallow at the moment however the owner has no other land to fall back on.

3.3 Pollution of the Baychhu

Water from the Baychhu is used for drinking by people in the town of Bajo, the RBA training center, the Dzongkhag monk body, civil servants working under Wangdi Dzongkhag and many other people. However, the Baychhu is heavily polluted from the dumping of wastes and drainage of irrigation water.

As indicated in Figure 16, most settlements in the Baychhu watershed are located along river courses and most of the agriculture fields are located in the lower part of the watershed. There is no proper waste and sewerage disposal system for these areas. Animal sheds, pit toilets and small factories are located along the river banks and effluent from these activities is discharged into the stream (see Photo 4).

Record with the health sector indicated that there were incidences of outbreak of water borne diseases in the past in Bajo with many people being admitted to Bajo hospital. This prompted the dzongkhag administration, wangdue to install the water treatment plant with carbon filtration unit in mid 2014.

With vast stretches of paddy fields in all three Geogs, there is intensive usage of chemical fertilizers, weedicides and pesticides, all of which would increase phosphate and nitrate loads to the Baychhu. Water monitoring at the drinking water offtake at Bajo show phosphorus concentrations of 1.5 to 3 ppm, which is higher than the Bhutan guideline value of 0.5 ppm (see Table 9).

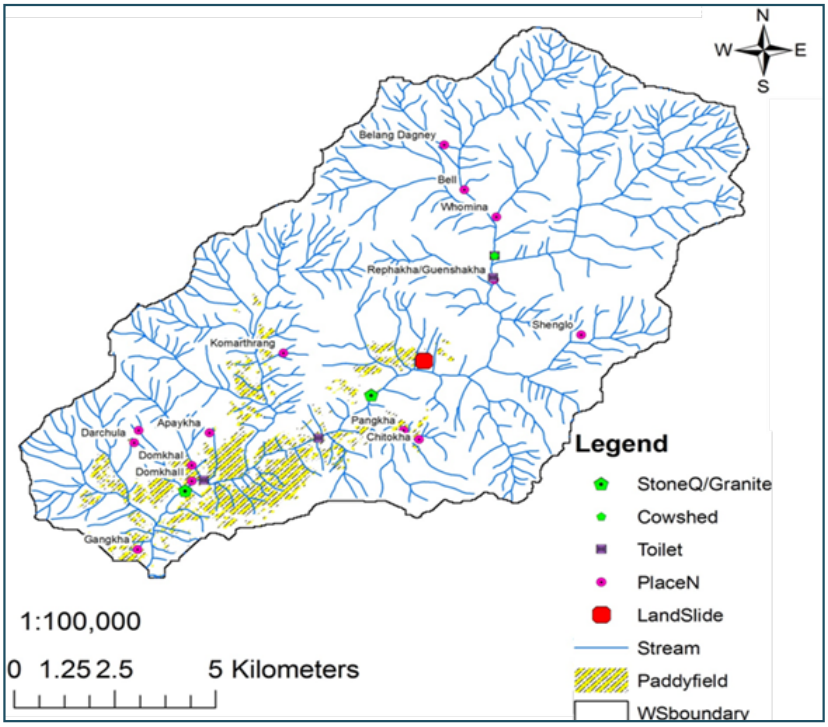

Fig. 16: Map showing potential sources of pollution in the Baychhu watershed

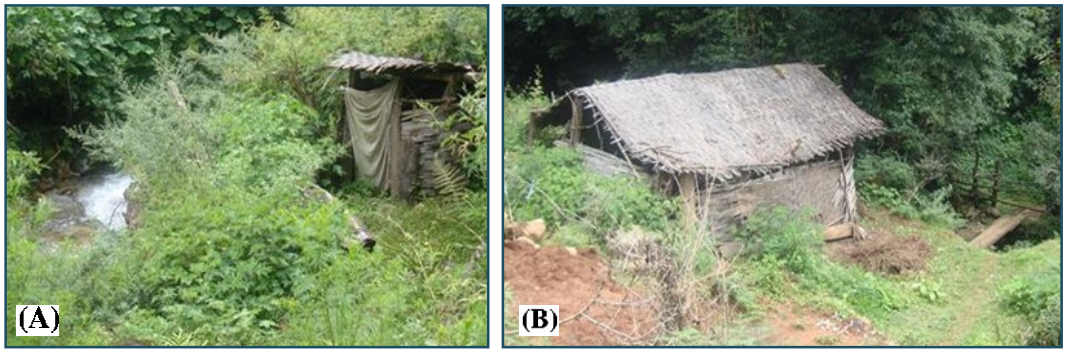

Photo 4: (A) Pit toilet & (B) Cowshed located on bank of Baychhu

High sediment loads from agriculture fields, farm roads and degraded land areas are also discharged into the Baychhu thus making the water undrinkable especially during the monsoon period. Disposal of animal carcasses in the stream is also a common reported practice which pollutes the water and poses health risks to downstream consumers. Based on the field inspection and the analysis of water quality test results in Table 9 & 10 and Figures 13, 14 & 15, the following comments are provided regarding water quality in the Baychhu watershed: The very upper reaches of the watershed (upstream of the monastery) have almost no development and can be considered pristine. The water has a neutral pH, reasonable levels of dissolved oxygen and low levels of turbidity and conductivity. Nutrient concentrations are typical of forested catchments.

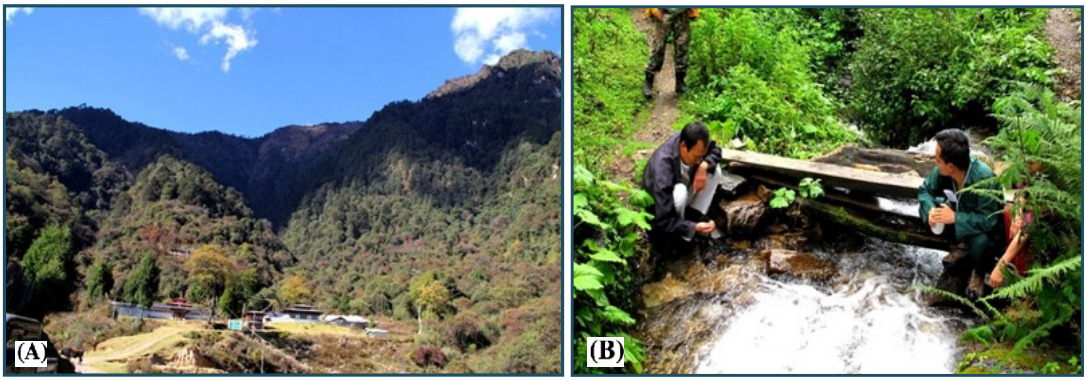

Photo 5: (A) Undisturbed catchment above & adjacent to Baelangdra Ney where Baychhu originate.
(B) Baychhu source during monsoon

The middle and lower reaches of the watershed include scattered human settlements and farms. Water from tributaries in these areas can therefore be expected to have a higher turbidity due to the higher level of disturbance. Some of the samples collected in this area showed very high phosphate concentrations, possibly due to fertilizer use, however nitrate levels are low and well below guideline levels.

Photo 6: (A) Settlements at upper to mid watershed. (B) Landuse practices in lower watershed

Based on the available physio-chemical analytes, water quality at the offtake point appears generally acceptable as a raw water supply. The water has a neutral pH, low conductivity and nutrient concentrations are not excessive. The recommended guideline values for different water quality parameters are shown in annex III. However, of concern are the very high bacterial concentrations in this water, and also the high phosphorus and turbidity levels which provide food and shelter, respectively, for the bacteria to thrive. Bacterial levels in the raw water were above 35 FCU/100ml for the whole first half of 2013, although these levels appear to have dropped since then.

It is important to recognize that these results are only based on a very small number of analytes. Water quality risk assessments also need to be based on a qualitative assessment of pollution risks in the watershed. Based on the field inspection, there are human activities in the watershed upstream of the offtake point which could result in pollution of the raw water supply and pose a risk to human health. The highest risk is the discharge of raw sewage from the human settlements which would introduce pathogens and risk of disease into the raw water supply, as evidenced by the high FCU counts, particularly in early 2013. As there is no sewage collection or treatment systems in the watershed, this is considered to be a high risk. Human sewage pollution is the single highest health risk to humans in water supply systems around the world, causing millions of deaths every year. Another lesser risk is the use of fertilizers and weedicides in the watershed. Such chemicals can be toxic to human health and also provide food and shelter for pathogens.

Water quality data for the treatment plant and distribution system was also reviewed. It should be noted however that the regular treatment plant monitoring data has not be been verified and may not necessarily be accurate. The results suggest that:

- The raw water received at the treatment plant has a highly variable turbidity (median 6 NTU, range 1 - 400 NTU) with a definite trend of high turbidity during the monsoon season when storms cause erosion within the watershed. High turbidity events would likely cause deposits/ blockage of the carbon filters, reduce treatment efficiency and increase shutdown maintenance requirements.

- The turbidity of the treated water (median 4 NTU, range 0 - 110) is also highly variable. The high values are very concerning. Such high turbidity can provide food and shelter for pathogens and protect them from chlorine disinfection (known as "pathogen shielding"). Note that during the dryer winter months, turbidity levels are generally low, resulting in ideal conditions for treatment to a drinking water standard. When the turbidity units are high, the water is washed back again 2-3 times till the water is cleaner for drinking purpose. Therefore, if it is treated at source, the cost for treatment would be much lower.

- The raw water received at the plant has a neutral to slightly alkaline pH (median 8.1, range 7.3 - 9.2) which is simply a result of the natural geology of the watershed. However, this is problematic in relation to the use of Alum as a coagulant. Effective coagulation only occurs between pH 5.8-6.5 when negatively charged forms of alum predominate. The high pH of the Baychhu raw water may be why effective coagulation is not occurring at the moment and the reason for the treated water having a high turbidity, even after passing through 2 sedimentation tanks and the carbon filtration system.

- Treated water pH (median 8.0, range 6.2 - 8.5) is generally neutral to slightly alkaline, which is also not ideal for chlorine disinfection. In water, chlorine is actually a mixture of HOCl and OCl- ions and their relative composition depends on the pH. HOCl is 100 times more effective as a disinfectant than OCl but is only predominant in an acidic range (say pH 5.8 - 6.5 similar to the optimum range for coagulation with alum).

- The chlorine residual in the treated water (median 0.6 mg/L, range 0 - 2) is acceptable on most days. However on some days the chlorine is very low or even zero which is concerning as there would be no disinfection on these days. In any case, disinfection may still be ineffective even when there is reasonable chlorine residual as discussed previously due to (a) pathogen shielding because of high turbidity and (b) the pH not being in the optimum range for HOCL.

- The bacterial water quality data confirms that disinfection is currently not effective. Data since the carbon filtration upgrade in mid 2013 shows relatively low FCU counts (most < 10 per 100mL). However, despite this, sampling from various locations in the distribution network shows that bacterial populations are present in relatively high concentrations, indicating bacterial growth in the system downstream of the treatment plant. As a result, domestic water users are currently being exposed to FCU levels averaging about 20, and as high 70. At these levels, drinking the water without boiling is dangerous. According to the Dzongkhag health sector, the high FCU content at consumer points could be mainly attributed to unhygienic condition of water storage tanks at institutions and individual houses.

3.4 Forest Degradation

One of the major causes of forest degradation is forest fire in Phangyuel Geog. Records maintained with Phangyuel Geog RNR shows that there were 5 incidences of forest fire in year 2014 alone damaging a total forest area of 3300 acres. Deforestation is not a major issue in the Baychhu watershed as the demand for timber until now has met through imports from Khotokha and Phobjikha. However, tree felling has been observed along the riparian zone in the upper reaches of the Chuchuna tributary although it is not clear why this is occurring. Further, a recent trend confirmed by Kazhi Geog officials is that local extraction of timber is increasing as import restrictions from the above areas are tightened. Therefore, it is important to address this issue to prevent further deterioration of the watershed. Livestock grazing and extraction of timber for fuel (especially along riparian zones) are some of the other contributors to forest degradation within the watershed area.

Additionally, there is a proposal for slate mining in Damchothang which is in the upper reaches of the watershed. The people of upper Kazhi have already given clearance for this operation to proceed. However, clearance by the lower communities is still under negotiation. In so doing, it is important to study the benefits of this proposal to the local communities, including appropriate environmental safeguards.

3.5 Human wildlife conflict

Human wildlife conflict is another major issue in the watershed. Wild pigs cause intensive damage not only by destroying crops, but also by digging up water source areas and irrigation channels. Other animals like the Sambar can also damage crops.

The Wildlife Conservation Division (WCD) has already started a community-based crop insurance scheme in Bhutan through the establishment of Geog Environment Conservation Committees (GECC). Due to resource constraints however, this has only been instituted in a few pilot Geogs across the country. Therefore, it is recommended that GECCs be established in all three Geogs within the Baychhu watershed and that the necessary seed money be provided following approval of this Watershed Management Plan.

CHAPTER 4: THE PLAN

4.1 Goals and objectives

The 10th five year plan mandates the Watershed Management Division (WMD) to come up with River Basin Management Plans (RBMP) for two river basins. As part of this requirement, management plans are to be prepared for all watersheds identified as critical within these two river basins. Together, these so-called "critical watershed management plans" would effectively form the RBMPs.

Identification of critical watersheds was based on the results of the rapid watershed assessment and classification process. Baychhu watershed was classified as critical watershed by function, meaning its protection and management is critical for sustained supply of good quality of water for drinking, irrigation and hydropower purposes. In this context, the overall goals and objectives of the Baychhu watershed management plan (see Table 12) is to protect and enhance watershed conditions by identifying issues and problems and recommend interventions so that all stakeholders understand the value of the watershed and act responsibly.

For the purposes of active development interventions, the Baychhu degraded watershed area was categorized into four types (see Figure 5). "Highly disturbed areas", consisting of areas of intensive agricultural land, were mostly concentrated near the settlements. These areas need immediate management interventions. The "forest areas" close to agricultural land and settlements are moderately disturbed. These areas also require management interventions but are a lower priority than the highly disturbed areas. The two other categories are "protected areas" and "high forests".

Tab. 13: Goals and Objectives

GOALS	OBJECTIVES
Institutional Strengthening	Stakeholder responsibilities: Integrate and coordinate various stakeholder responsibilities for management of the Baychhu watershed
	Integration: Integrate watershed management interventions into the local Geog annual plans
Watershed components	Land planning: Plan and manage landuse to protect and enhance the functionality of the Baychhu watershed
	Restoration: Restore degraded areas to approach natural conditions
Water quality	Gross litter: Manage the sources and transport of solid waste from the Baychhu watershed, particularly along the riparian zone, to protect ecological and human health
	Sediment loads: Undertake land management activities and riparian management to limit sedimentation pollution into the Baychhu, particularly doing the monsoon season, to protect the water treatment system as well as hydropower facilities downstream from excessive sediment loads
	Pathogens: Manage sewerage discharges to limit delivery of pathogens to the Baychhu.
	Fertilizer use: Investigate the type and amount of fertilizer use in the watershed. Continue to monitor nutrient levels in the Baychhu
	Water treatment: Ensure the Tenchholing water treatment facility is maintained and operated to meet required drinking water quality standards
Public participation	Raise awareness: Educate people in the Baychhu watershed to change behaviour on pollution and become more environmentally sensitive
	Stakeholder engagement: Establish strong upstream and downstream relationships to encourage long term stewardship for the Baychhu watershed.
Future	Research: Build ontraditional paddy farming practices to limit runoff pollution and maintain biodiversity, better understand impacts to water quality, and complete a gap analysis on knowledge and required resources for effective watershed management.

The specific objectives of the plan are as follows:

Objective 1: Identify and formalize institutional responsibilities

Presently, there are number of stakeholder agencies with different responsibilities for watershed management. However, this is not properly coordinated. Watershed Management Plans are to be developed and integrated into the local plans to ensure effective implementation. Following approval of the watershed management plans the management interventions are to be incorporated into the geog annual plans.

Therefore, one of the main objectives of this management plan is to identify and formalize clear responsibilities for watershed management by various agencies (see Annex I).

Objective 2: Protect and improve watershed components

Plan and manage land, vegetation and other watershed components to protect and enhance the existing natural areas and carry out restoration of potential areas to improve its condition.

Objective 3: Protect and maintain water quality in the watershed

As Baychhu water is used for drinking water for Bajo community, one of the main objectives of developing management plan is to indentify water quality problems and their causes and develop or recommend interventions to achieve or maintain acceptable water quality for drinking water and other domestic use.

Objective 4: Facilitate public participation and education

Watershed management is an integrated resource management and therefore participation of people or communities living within watershed is critical to the success of any watershed management program. Often times, people engage in behavior that can be harmful to the environment because they are not aware of the consequences of their actions on natural resources, or may not be aware of the inter-relationships of natural resources in a watershed. Efforts to increase public awareness can help to change an individual or group's behavior and result in actions that are more environmentally sensitive.

Further, it is also important to take on board the beneficiaries living outside the watershed as they are still impacted by any activities taking place within the watershed itself. It is also important establish a strong up-stream and down-stream relationship to encourage a long term community stewardship for the Baychhu watershed. Therefore awareness raising and sensitization of all stakeholders (government and local government institutions, local people and other relevant interest groups) on the importance of protecting and appropriate management of watershed is one of the main objectives of the management plan.

Objective 5: Identify research areas for future programs

Among other objectives, the plan also focuses on the needs and gaps in terms of knowledge as well as resources for managing the watershed. There is lack of information especially on climate and hydrology which could be taken up as part of research programs in future.

4.2 Planning Process

4.2.1 Consultation at Dzongkhag level

The planning process started by holding consultative meeting with the Dzoangkhag Administration authorities. During the meeting, results of the watershed assessment in Punatsangchhu Basin along with Baychhu critical watershed were presented including plans and programs for watershed management and issues were discussed.

4.2.2 Consultative meeting at Geog level

After the meeting with stakeholders at the District level, a meeting was held with local government leaders, extension officers and other relevant stakeholders of the geogs falling within the Baychhu watershed. The participants consisted of Gups, Geog Administration Officers, RNR-Extension Agents, staff from the Territorial Division, Mangmi and Tshogpas from each Geog.

During the meeting, results of the Dzongkhag level meeting were presented. Geog officials also delivered presentations on the plans and activities related to watershed management for their respective Geogs. During the meeting, issues and priority activities were identified.

4.2.3 Field visits and consultations at geog and chiwog level

Following the consultation meeting with Dzongkhag and geog level stakeholders, meetings were held at each of the three geogs comprising of Gups, Mangmis, Tshogpa, Geig RNR Staffs and representatives from communities (farmers) to discuss, identify and narrow down the real field issues. This was followed by field visit and detail assessment of the watershed to identify and validate the issues in the watershed. Several field visits were also undertaken to sample water at various locations for analysis. Additional data were also collected from Tencholing Water treatment Plant and Dzongkhag Administration of Wangdue. The information from consultations and field visits were compiled, analyzed and used for management plan.

Photo 7: Consultation meetings & group discussions at Kazhi, Phangyuel & Nyisho Geogs

Following the geog level consultations, writeshops were organized to discuss on the format and content of the plan as well as synthesizing information collected from the field. Participants for the writeshops consisted of management planning team and contributors. After technical endorsement of the management plan, the final draft plan was presented to the stakeholders at Wangdue for review and suggestions for finalization.

4.3 Management Strategies and Actions

Watershed management requires a multi-disciplinary approach involving all relevant stakeholders to ensure integrated and holistic planning and implementation. Based on the issues identified and discussed with stakeholders at the Dzongkhag and Geog levels, management strategies and actions are summarized in the Table 14 followed by detail description of each of the actions. The detail activities to be implemented specific to each geog are shown Annexure IV to VI.

4.3.1 Water management

Water from the Baychhu watershed is used as drinking water source for the Bajo Town, army camp, Dratshang, hospital colony, local schools and other Bajo communities. It is also used for irrigation purpose. Baychhu is also one of the major tributaries of the Punatsangchhu which contributes to hydro-power generation. Leaching of agricultural chemical residues (eg: fertilizers/pesticides) and sediments into waterways are therefore of concern. However, there is a need to accurately measure the concentration of pollutants in the water supply to assess the associated risks and plan accordingly to address any issues. The drinking water offtake is shown in the photo below.

Photo 8: (A) Pretreatment tank with alum dosing & (B) Preliminary settling tank collecting debris at drinking water offtake at Rikizampa

Tab. 14: Summary of management interventions for the Baychhu watershed

STRATEGIES	ACTIONS	RESPONSIBLE AGENCY
Storm Water Management	Ensure appropriate farm road management to reduce sedimentation loads discharged to the Baychhu	Geog Administrations
	Encourage the implementation of appropriate effluent management systems in agricultural fields	Geog Agriculture Extension
	Monitor and report on chemicals used in fertilizers and weedicides within the watershed	Geog Agriculture Extension
	Undertake water sampling and testing of the Baychhu near the offtake every 3 months	WMD, DoFPS
Water Treatment & Management	Relocate the alum dosing to the front of the settling tank to improve the contact time in the tank and maximize coagulation and sedimentation.	Municipal Authority, Wangdue
	Acidify the raw water in the baffle section at the front of the settling tank to reduce the pH down to the optimum range prior to addition of the alum	Municipal Authority, Wangdue
	Confirm the appropriate quantity for alum dosing by reviewing appropriate design documentation	Municipal Authority, Wangdue
	Acidify the treated water from the plant to increase the concentration of hypochlorite and improve disinfection	Municipal Authority, Wangdue
	Confirm that flow rates being supplied to and from the treatment plant are appropriate for the demand of Bajo and surrounding users. If required, reduce flow rates to improve treatment effectiveness	Municipal Authority, Wangdue
	If possible, avoid raw water input for 1-2 days from river following large storm events when turbidity is very high (> 100 NTU). Ensure sufficient storage at Tenchholing Water Treatment Plant for supply during such periods.	Municipal Authority, Wangdue
	Continue daily water quality monitoring testing program at the plant	Municipal Authority, Wangdue
	Roof rain water harvesting technology to conserve & utilize rain water for household use	Geog Administrations
	Increase water use efficiency by maintaining existing irrigation channels and laying of HDP pipes for drinking water channels to solve leakage issues	Geog administrations

STRATEGIES	ACTIONS	RESPONSIBLE AGENCY
Waste Management	Undertake an education program to raise the awareness of the inhabitants within the Baychhu watershed on the importance of proper waste management and impacts of dumping solid waste	Geog Administrations
	Implement formal waste collection scheme to reduce litter pollution in Baychhu	Geog Administrations
	Undertake an audit of sanitary facilities within the watershed and upgrade toilets to septic systems where required.	Geog Administration
Land management	Nutrient management to improve soil fertility through crop diversification by use of legume crops	Geog Agriculture Extension
	Identify landslide prone areas, gullies and degraded sites, and adopt appropriate stabilization measures	Geog Forestry extension
	Implement a watershed-wide program to maintain irrigation channels to reduce the incidence of rill and gully erosion	Geog Administrations
	Land stabilization in vulnerable & degraded areas including using sustainable land development and management techniques and SALT	Geog Administrations
	Protection of water sources through planting, fencing	Geog Forestry extension
	Improve vegetative cover through plantation of tree seedlings, orchard management, winter cropping	Geog Forestry and Agriculture extension
Livelihood Improvement	Construction of water storage tank and laying of pipes to avoid leakage in Chundu Goenpa, Phanguyel Geog where there is acute shortage of water, the water source being far away with a distance of 3 km	Geog Administration
	Support crop diversification with supply of high yielding climate resilient crop seeds	Geog Agriculture Extension
	Support livestock improvement programme including providing of seeds and seedlings of improved fodder and feeds and providing training on feed management	Geog Livestock Extension
	Explore the feasibility of a Payment for Environmental Services (PES) scheme for drinking water between watershed inhabitants and downstream users (Bajo community)	Dzongkahg Administration, Wangdue and WMD, DoFPS
Human Wildlife Conflict Management	Implement community-based crop insurance scheme in the 3 Geogs within the Baychhu watershed to deal with Human Wildlife Conflict issues	Dzongkahg Administration, Wangdue and WCD, DoFPS
	Encourage crop diversification amongst existing farmers to generate additional income	Geog Agriculture Extension

STRATEGIES	ACTIONS	RESPONSIBLE AGENCY
Forest Fire Management	Awareness programs on forest fires	Geog Forestry extension
	Training on basic fire fighting techniques	Geog Forestry extension
Monitoring & Evaluation	Water discharge measurement	WMD, DoFPS & Dzongkhag Administration, Wangdue (DzFS)
	Water quality testing	Wandgue Municipal
	Monitoring for implementation of plan activities	Dzongkhag Administration, Wangdue (DzFS) & WMD
Future Research Program	Generate weather data to calculate base flow, predicting of droughts, floods and outbreak of pests and diseases	DHMS, MoEA
	Generate information on seasonal flow (discharge) of Baychhu and its tributaries and conduct quality tests	Watershed Management Division
	Study the roles of vegetation (hedges) found in the interface with agricultural lands in preserving soil and water conditions, filtering of pollutants and control of erosion	RNR-RDC, CNR, WMD

It is important to protect the Baychhu from sources of pollution (waste, sediments and chemical fertilizers) by adopting various measures as follows:

- Monitoring use of chemicals in the watershed
- Proper management of effluent from agriculture fields (proper drainage systems)
- Livestock management and sanitation measures
- Solid waste management
- Farm road management to reduce sedimentation
- Water quality testing

The following specific recommendations are provided:

- Ongoing sampling and testing every 3 months (quarterly) to test the water quality of raw water from the watershed and treated water at the Tencholing treatment plant. So far, the

WMD team has only sampled on one day. It provides a baseline for future assessment so that seasonal and yearly trends can be identified. Also, if the regular water quality monitoring data from the treatment plant is to be used for future assessment, it needs to be validated as being accurate and valid.

- Based on the data analyzed in this report, the preliminary settling tank at Rikizampa does not appear to operating effectively and could be ameliorated with the following changes:

    - moving the alum dosing to the front of the settling tank to improve the contact time in the tank and maximize coagulation and sedimentation. Currently, the dosing is applied at the rear of the settling tank and so the opportunity for sedimentation is effectively wasted.
    - the pH of the raw water is not within the optimum range for coagulation with alum. As explained previously, alum is only effective when the water pH is slightly acidic however the Baychhu water is slightly alkaline. Sulphuric acid could be applied to the raw water in the baffle section at the front of the settling tank to reduce the pH down to the optimum range prior to addition of the alum.
    - there is no information available as to the optimum amount of alum dosing for the flow through the settling tank. Currently, two 20kg blocks of alum are hung into the water however it is unclear whether this is sufficient.

- The pH of the treated water from the Tencholing water treatment plant is also too alkaline for effective disinfection. As explained earlier, hypochlorite (HOCL) is only predominant when pH is acidic and so it is recommended that the water be acidified into the range of 5.8-6.5 to ensure effective disinfection. Acidification of the raw water earlier in the process as discussed above may be suitable for this purpose.

- An analysis of water supply vs demand should be undertaken to ensure that flow rates are optimized which will maximize treatment efficiency. For example, settlement rates and disinfection effectiveness reduce at higher flow rates. If the water treatment plant is processing more flow than what is required to service the demands of customers, then it would be preferable to reduce the amount of raw water sent to the plant.

- If possible, it may be preferable to avoid raw water input for 1-2 days from river following large storm events when turbidity is very high (> 100 NTU). Ensure sufficient storage at Tenchholing plant for supply during such periods.

- One strategy to reduce fertilizer application and improve soil fertility is to encourage organic farming, including the use of organic manure and organic pesticides. Farmers have already started crop diversification and intensification by growing peas, mustard, wheat and other crops as winter crops in paddy fields. Of particular interest is mustard which can be used as fodder, as a table vegetable and for green manuring. In some areas, it has only been planted this year (2014) for the first time, on a trial basis for the purposes of promotion and for

testing oil extraction. This watershed management plan could provide support to encourage and upscale this practice.

Poorly managed irrigation channels can lead to rill and gully erosion and reduce the availability of water for users. Therefore, proper maintenance of existing irrigation channels is necessary for efficient water management and controlling land degradation.

Any new irrigation scheme should be properly planned and implemented with environmentally friendly measures to minimize impact associated with water quality and quantity.

Roof rain water harvesting

Phangyuel geog experiences acute shortage of water both for drinking and irrigation. There is proposal to construct a 34 km irrigation channel from Kazhi to solve irrigation water shortage problem. For drinking water, Chundu Goenpa area has water shortage and therefore roof rain water harvesting technology be constructed at the Goenpa to provide sufficient water to the monastic students and the 11 households surrounding the goenpa. The engineering Division under the Department of Agriculture has developed a user friendly technology to harvest rain water to be used for drinking and other household uses (see Figure).

4.3.2 Waste management

Solid waste is littered ubiquitously throughout the watershed (see Photo 9). This is most likely due to a lack of awareness, lack of regulation and the absence of facilities such as waste pits. Dumping of waste into streams deteriorates water quality and is especially significant for drinking water. This issue calls for a need to create awareness on the importance of waste management, stronger regulation and establishing waste management facilities.

The lack of toilets has led to open defecation and pollution of water sources in the watershed. Further, waste water from household uses also drains to the Baychhu. Waste management could be improved if awareness meetings are conducted in parallel with the establishment of necessary facilities such as concrete waste pits and dust bins in strategic locations. Establishing links with the Wangdue Municipality for waste collection at these locations is also necessary. It would also be helpful if cleaning campaigns are conducted regularly along the Baychhu itself as well as other areas where current waste management is poor.

Photo 9: Open waste disposal in the watershed

4.3.3 Land management

Land management includes identification of landslide prone areas (including vulnerable farm road slopes), gullies and degraded sites, and adopting appropriate control measures. Land management measures will also include development of orchards, stabilization of slopes, development of pastures and appropriate research. The specific land management measures are detailed below.

Adopt land stabilization measures

Landslides are found in the watershed as shown in the photo below and most of them are either along the farm roads and alosngside agricultural lands. If left untreated, gully formation will take place and there is a huge risk of loosing agricultural lands in the long run. Therefore, it is important to adopt land stabilization measures on the existing landslide areas as well as those sites vulnerable to erosion in future. Measures include construction of check dams and retaining walls combined with growing of shrubs and grasses for stabilizing slopes and ensuring proper drainage system along farm roads. On vulnerable and degraded sites, sustainable land development and management techniques including contour hedgerows, terracing (particularly in Phanuyuel where there is water scarcity) and SALT (Soil And Agriculture Training) can be adopted to conserve soil and moisture and prevent starting of erosion which will also help improve land productivity.

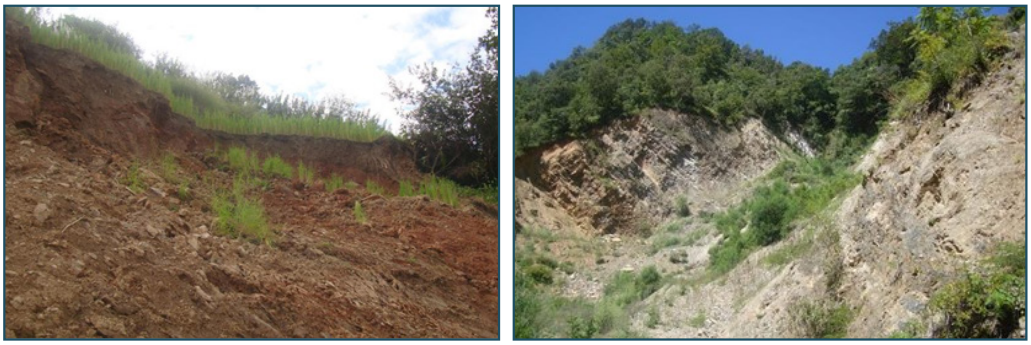

Photo 10: Landslides in watershed

In Nyisho geog, paddy fields at various locations were found to be sinking and sliding and in another area just below Samtengang, paddy field is sliding down. In such cases, land management activities like edge trimming, brush layering and construction of a retaining wall at the bottom of the field might help to stabilize this slope. Changing cropping patterns for few years and growing other crops such as legumes instead of paddy farming could also help to stabilize the area. Following appropriate restoration, paddy farming could start once again.

Soil nutrient management

The consultation meetings with farmers and Geog RNR have revealed that large amount of chemical fertilizers, pesticides, weedicide and fungicides namely Urea & Suphala, Cypermethrin & Chlorpyrifast, Butachlor, Glyphosate and, Mancozeb are used for different types of crops. Double cropping is practiced in most of the lands which results in intensive usage of fertilizers thereby increasing productivity issues in the long run and increases fertilizer discharge into Baychhu.

The Geog RNR has already been trying to promote crop diversification which needs to be further upscaled by providing seeds of leguminous crops to help improve soil fertility. Further, training on soil nutrient management including Farm yard Manure (FYM), preparation of organic pesticidesand composting can be imparted to farmers to reduce usage of chemical fertilizers.

Currently, there is also practice of collecting leaf litter from "Sokshing" forest for animal bedding which is a source of nutrition for the food crops. This traditional farming practice needs to be continued to by ensuring and regulating the use of sokshing on sustainable basis.

Improve vegetation cover

To conserve soil and moisture to improve land productivity, vegetative cover of bare and degraded areas can be improved through plantation of trees and shrubs. Orchard management will also help improve soil cover.

4.3.4 Livelihood improvement programme

Management of water for drinking and irrigation

There is acute shortage of water for drinking as well as irrigation in Phangyuel geog and particularly at Chundu Goenpa. Therefore, during the consultations, it was discussed that there is a need for a water storage tank at Goenpa, laying of water (3 km length) HDP pipes of 2.5 inch to ensure that there is no leakage of water along the way to the storage tank. Use of rain water harvesting technology is also recommended for preservation of rain water for use by monastic school and surrounding households. Further, most of lands are left fallow due to inadequate rain water for irrigation and paddyplantation and therefore the need to consider construction of the proposed irrigation channel was discussed and recommended. There is also need to solve leakage of drinking water pipes in Samtengang school and

other areas to increase water use efficiency and to make the water available thereby improving the hygiene of communities.

Besides, traditional water management systems are common throughout the watershed. These are generally managed by village-level water management committees which are formed and managed by the communities themselves. This watershed management plan could help to strengthen this traditional water use and management system by providing experts to participate in workshops, help in framing bylaws and impart appropriate training. When not in use, water systems should be diverted in a way that prevents seepage and overflows to farm roads and other areas.

Human wildlife conflict management

With a major portion of the watershed being covered by forest, this creates significant habitat for wild animals. As a result, Human Wildlife Conflict (HWC) such as damage to agricultural crops and livestock predation is reported widely in the watershed.

The Wildlife Conservation Division (WCD) has already started a community-based crop insurance scheme in Bhutan through the establishment of Geog Environment Conservation Committees (GECC). Due to resource constraints however, this has only been instituted in a few pilot Geogs across the country. Therefore, it is recommended that GECCs be established in all three Geogs within the Baychhu watershed and that the necessary seed money be provided following approval of this Watershed Management Plan.

Livestock development programme

Some chiwogs like Beldrok and Damchothang under Kazhi geog rear livestock for their livelihood. Besides, other villages in all the three Geogs livestock for livestock production as well as for production of farm manure for farming. It is therefore crucial to support the communities in improving their pasture as well as to improve feed and fodder development practices. Support should be given in form of providing mix of temperate pasture grass seeds to upland communities of Beldrok and Damchothang. Winter fodder cultivation can be promoted by providing seeds of oat and wheat to supplement fodder during dry season. Besides, training on silage making and winter fodder conservation should be provided.

Income generation

To improve the livelihood of communities within the watershed, various activities like crop diversification should be encouraged to generate additional income. The other avenue for generating income is to explore the feasibility of establishing a Payment for Environmental Services (PES) scheme for drinking water between the downstream water users in the town of Bajothang and upstream service providers in the watershed.

The number of people visiting Baylangdra Ney is increasing which is leading to increased generation

of solid waste. Therefore a mechanism should be established whereby visitors can pay a nominal fee to the local community to manage waste and improve the local environment.

4.3.5 Forest fire management

Forest type in Phangyuel geog within the watershed is dominated by Chir Pine forest which is susceptible to forest fires. There are incidences of forest fires almost every year damaging forests and vegetation cover. Phangyuel geog is also suffering from acute shortage of water both for irrigation as well as drinking water. The geog is fully dependant on rain water for irrigation and many paddy fields are left fallow due to lack of enough water for paddy plantation. In view of this, it is important to preserve vegetation cover to conserve soil moisture for which prevention of forest fires is of paramount importance.

4.3.6 Future research programs

The Baychhu watershed is a mosaic of landscapes with broadleaf, mixed conifer and chir pine forest ecosystems, low land agricultural paddy fields, upland pasture and dry lands. Agricultural farming in the watershed is characterized by secondary forest on the top of the ridges, houses and farmlands interspaced with sparse vegetative cover in the middle and lower portions (Photo 11).

The traditional practice of Sokshing (Life tree) is a woodlot in the vicinity of settlements which is an important component of farming systems in all three Geogs. Sokshing practice was found generally well managed and is in good condition as shown in photo below. The sokshing is a source of organic manure for the farmlands. The surrounding secondary forests are also a source of fuel wood, timber and other forest produce used for domestic consumption.

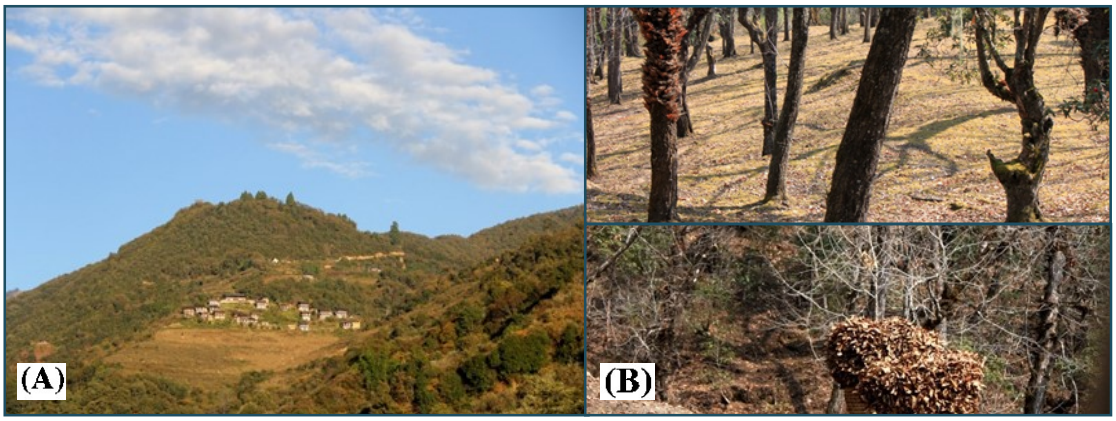

Photo 11: (A) A typical farmland with secondary forests on top and surrounding areas. (B) Sokshing forests

In the mid valleys, most of the agricultural lands and paddy fields are interfaced with vegetation cover mostly in the form of hedges (Photo 12). However, with development, network of farm roads were constructed that have lead to fragmentation of agriculture and forest ecosystems. Such activitiesmay lead to severe disturbances in the near future.

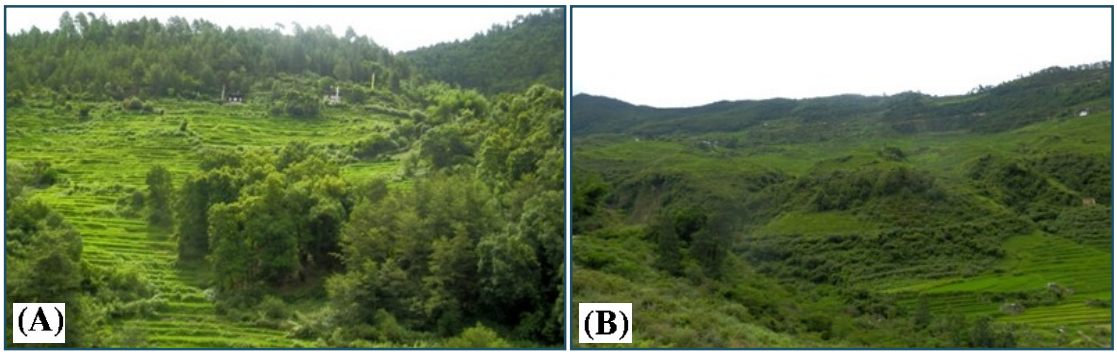

Photo 12: (A) Farmland with buffer vegetation & (B) Farmland with hedges in the interspaces

Against this backdrop, the research program with proposed activities is found important to understand the importance of traditional farming management system in managing the hilly, rugged and terrace. The research will also provide an insight into relationship between existing upstream farming practices and downstream water quality issues. Information generated will therefore help in having a baseline information on all the aspects described above and detailed below which will help to create awareness among people on importance of preserving vegetation as well as policy makers and donors for undertaking soil conservation measures. The research findings will also help all stakeholders including farmers and policy makers on the importance of traditional farming practices which is not only be sustainable, but also environmentally and climatically sensitive. As an immediate follow up, following research activities are being proposed to be carried out in the Baychhu watershed.

Generate climate data

There is lack of weather data for Baychhu watershed. There was one weather station at Samtengang, but is now non-functional. The climate information for Baychhu was generated using climate data between 1997 and 2005. In the light of climate change and its impacts, it is felt important to have consistent and reliable information on weather and climate to calculate base flows and for predicting droughts, floods and other issues to help cope up with and adapt to climate change impacts.

Generate information on Baychhu flows and discharge

Flow measurements for Baychhu were done for year 2013 and 2014 which has helped in setting up the baseline information. It is important to continue measuring the flow to generate reliable and consistent information on discharge and flows during different seasons of the year. The information combined with other weather parameters like rainfall and temperature will help in estimating the water budget as well as in predicting the droughts and floods.

Role of vegetation (hedges) in soil and water conservation

As per land use statistics for Baychhu watershed area, wetland makes up around 7% of the total land use while dryland makes up 1% of the watershed. In many areas, vegetation cover in the form of hedges can be found in the interfaces of agricultural lands. Research has shown that hedge rows can act as buffer to erosive forces during rain fall and run off situations.

From the information generated so far, it is clear that there is huge sediment load in the Baychhu as well as large amount of chemical fertilizer usage in agricultural lands. In this context, it would be critical to know the roles of hedges and other vegetative cover in regulating the run off as well as filtering of chemicals. Therefore, a simple research is being proposed to be carried out to investigate the role of hedges in conserving soil moisture, nutrient content and biodiversity in the agricultural fields. Vegetation along agriculture lands can also help in preserving biodiversity, both flora and fauna. Baychhu watershed has also been affected by the recent army worm outbreak and large chemicals were used to control the worm. It would be beneficial to know if biological controls such as birds inhabit in those areas.

4.6 Implementation strategies and mechanisms

4.6.1 Implementation strategy

The overriding strategy of the plan is to adopt an integrated watershed management approach in natural resources management and to mainstream its principles and processes into the policies, plans and programs of the relevant agencies within the watershed. The Watershed Management Division (WMD) is the focal agency for watershed management in the country and has adopted a process-approach to developing management plans. This process involves delineating and prioritizing watersheds based on the approved Watershed Classification Guideline (2010) that takes account of both biophysical and socioeconomic attributes.

As indicated in the roadmap for watershed management, the activities proposed in this watershed management plan will have to be incorporated in the annual plans of each respective sector. Management strategies and actions will be appropriately integrated into the area-based development and conservation plans of relevant sectoral programs, Dzongkhag and Geog plans through coordinated participatory planning mechanisms. Coordination between different line agencies at the Dzongkhag and Geog levels will be critical to ensure successful implementation of this plan. While the in-situ actions themselves will be executed by the field-based agencies in accordance with existing prescribed practices, the monitoring and evaluation of the outputs and impacts will be the done by the WMD. The roles of committees, stakeholders and implementing agencies are reflected in Annexures

I. Feedback in terms of reflection and readjustment shall inform successive planning cycles and guide future decisions in planning.

In accordance with the adopted area-based planning approach, the Geog plan becomes the major vehicle for bringing together different stakeholder interests (including those from the livestock, agriculture and forestry sectors amongst others) irrespective of land ownership. The Dzongkhag watershed management committee will ensure coordination and integration of relevant sectors to ensure the proposed activities enhance watershed conditions across all three Geogs.

4.6.2 Funding

As per the activity matrices in annexures, it is estimated that a sum of Nu. 106.351 million will be required to implement the watershed management interventions. All the activities will have to be funded by RGoB through the Geog Plans as part of their annual plans. However, in case of inadequate or unavailability of funds for implementing watershed management activities, the management plan can be used as a basis to solicit funds from hydro-power projects or any other donors. WMD will also facilitate in sourcing budget through donors as well as RGoB to ensure the implementation of plan activities.

4.6.3 Monitoring and evaluation

The responsibility for regular monitoring of activities during implementation shall lie with the relevant implementing agency and stakeholders (See Annexure I, III, IV & VI)). Monitoring progress of the development intervention and documentation of such activities are important not only for policy and decision makers, but also to learn and to upscale such activities in other areas The WMD jointly with Dzongkhag Administration Wangdue and the three Geogs will conduct monitoring of the plan's implementation on an annual basis.

Reports on the status of the implementation will be produced annually in order to provide progress updates to stakeholders and watershed communities. In addition, mid-term reviews and a final evaluation will be conducted to assess the overall impact and outcome of the planned activities.

4.6.4 Revision and amendment of Plan

This plan is developed for a period of five years (July 2015 to June 2019). The plan will be reviewed and amended by the WMD based on feedback from monitoring and evaluation reports. The final evaluation of the plan at the end of the plan period will be the basis for revising the plan in the next planning cycle as shown in Annexure II.

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- PPD, MoAF. 2010. Land Cover Mapping Project document
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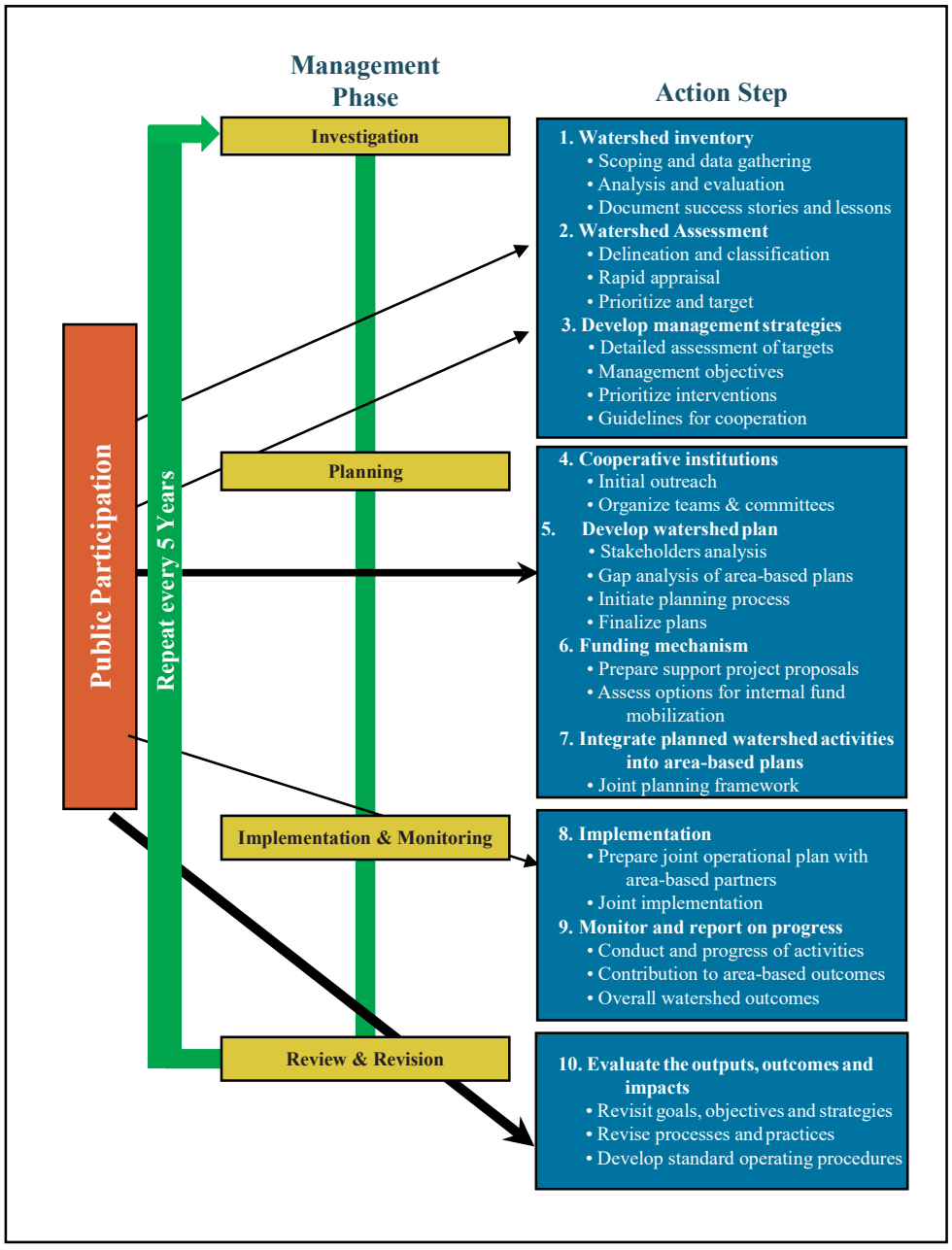
ANNEXURES

ANNEXURE I: STAKEHOLDERS AND THEIR ROLES

Main Stakeholder	Roles & responsibilities
Ggeog Tshogdue of the three Geogs (Kazhi, Nyisho and Phanyuel)	Discuss issues related to implementation of the plan Review and discuss progress of plan implementation Facilitate in conflict management
Geog BHUs	Collaborate with Municipal Wangdue and Geog administrations to carry out activities related to hygiene & sanitation
Geog Administrations	Integration of plan activities in their annual sectoral programs for budgeting & implementation Seek budget support and implement the watershed management plan activities
Divisional Forest Office, Wangdue	Regulate access to natural resources in critical watersheds Assist in establishing private & community forests Assist in protection of the riparian streams
Wangdue Dzongkhag Administration	Integrate and synchronize the watershed management plan activities into annual geog plans Monitor the progress of plan implementation and report to WMD Explore funding for implementation of plan activities
WMD	Provide technical support and other guidance for exploring, mobilizing funds and for implementation of plan activities Compile the progress of plan activities, carry out mid-term review and final evaluation and report to the Ministry
RDC Bajo and Yusipang	Provide technical support & research services
Communities of three geogs	Collaborate and provide necessary support during the implementing plan activities

ANNEXURE II: BASIC STEPS IN THE WATERSHED MANAGEMENT CYCLE



ANNEXURE III: WATER QUALITY PARAMETERS AND GUIDELINE VALUES

Parameter	Guidelines
Electrical Conductivity (EC)	US Regulations: <780 µS (based on TDS < 500 mg/L)
pH	US Regulations: 6.5 – 8.5
Dissolved Oxygen (DO)	WHO > 6 mg/L
Temperature	Canadian Guidelines:< 15 0C
Total Phosphate (TP)	Bhutan standard: < 0.5mg/L,
WHO < 0.05 mg/L for environment, 10 mg/L for health	
Faecal Coliforms	Bhutan Standard: < 10 C FU/100 ml
TSS (Turbidity)	WHO < 5 NTU
NO3 (Nitrate)	US EPA/WHO < 10 mg/L of nitrogen or 50 mg/L of nitrate

ANNEXURE IV: PLAN OF ACTIVITIES FOR KAZHI GEOG

Activity	Sub-Activity	Location	Unit	Implementer	Collaborator	Budget (Nu Million)
Storm Water Management	Construction of drainage system	All farm roads	55 km	GEAO & GEFO	Geog RNR/Geog adm	2.5
	Soiling					5
	Brast wall					1
	Retaining wall					2
	Soil conservation measures including brush layering and check dams					4
Waste management	Construction of concrete pits with roofing	All 10 chiwogs	30 nos	Wangue Municipal	Dzongkhag Health Sector, Geog RNR/adm	0.6
	Supply of dust bins		150 nos	-do-	-do-	0.5
	Awareness on waste management	Damchothang to Chumitsangkha (Kazhi)	10 times	-do-	-do-	1
	Cleaning campaign inlcduing cleaning of Baychhu Stream	Langijala to Chhuzomsa (Phangyul)	2 times/yr	-do-	-do-	0.2
	Cleaning of Granite factory area	Pogewo (granite factory area)	1 pit, 3 bins, cleaning campaign	Granite factory owner	-do-	0.1

Activity	Sub-Activity	Location	Unit	Imple-menter	Collaborator	Budget (Nu Million)
Land Management	Training on soil nutrient management (FYM and composting)	All chiwogs except Beldrok	12 times	GEAO	Geog RNR/adm	0.6
	Training on preparation of organic pesticide					1.8
	Supply of following leguminous seeds to the farmers for improving soil productivity					
	Pea		40000 pkts			1
	Beans		80000 pkts			2
	Soya bean		40000 pkts			1
	Dencha		4000 kgs			0.9
	Mustard		20000 kgs			0.5
	SALT on dry land					1
Livelihood Improvement Programme	Supplying seeds for fodder development	All chiwogs		GELO	Geog RNR/adm	
	Winter oat		10000 kgs			0.35
	Temperate pasture seeds		100 kgs			0.014
	Wheat		34560 kgs			0.05
	Training on straw urea treatment					0.02
	Preparation of pits and supply of urea for straw urea treatment		10 pits			0.008
	Breed improvement (AI)		10 sacks			0.5
	Supply of seedlings for following	All chiwogs except Beldrok				
	Citrus	Kazhi	2000	GEAO	Geog RNR/adm	0.08
	Persimmon	Gendey, Komathang, Kazhi	2000			0.28
	Peach	Bael, Kazhi	4000			0.24
	Pear	Bael, Kazhi, Komathang, gendey	6000			
	Walnut	Bael, Komathang	3000			0.36
	Apple	Bael, Kazhi	4000			0.24

Activity	Sub-Activity	Location	Unit	Imple-menter	Collaborator	Budget (Nu Million)
Livelihood Improvement Programme	Training on orchard management		3 times	GEAO	Geog RNR/adm	0.6
	Supply of hybrid seeds for cole crops	All chiwogs				
	Broccoli	Kazhi,Gendey,Bayel,	40000pkts			5.6
	Cabbage	Komathrang and Beldrok	40000pkts			5.6
	Culiflower		40000pkts			5.6
	Supply of OP seeds	All chiwogs				
	Carrot		30000pkts			0.75
	Raddish		30000pkts			0.75
	Coriander		30000pkts			0.75
	Spinach		30000pkts			0.75
Human Wildlife Conflict Management	Fencing of water source	All Geogs		GEFO	Geog RNR/adm	0.5
	Formation of Geog Wildlife committee					0.3
	Establish geog crop insurance scheme & provide seed money					0.7
	TOTAL					**49.74**

ANNEXURE V: PLAN OF ACTIVITIES FOR PHANGYUL GEOG

Activity	Sub-Activity	Location	Unit	Implementer	Collaborator	Budget (Nu Million)
Storm water management	Maintenance of existing irrigation channels	Yubaam	8 km	GEAO	Geog RNR/adm	1
	Establihsment of new irrigation channel	Damchothang to Phangyul	34 km			10
		Yubaam to Chungseykha&Gongchhu to Rebakha	8 km			1
	Drainage management through following activities to reduce sediment loads	All chiwogs(Location, length, where to where)		GEAO & GEFO	Eng. Div of DoA, MoWHS, Geog RNR/adm	2.5
	Soling		4 nos			3
	Soil conservation measures					
	Brush layering					0.3
	Check dams					0.8
	Laying of Hume pipes	Damluma				0.2
	Retaining wall					0.5
Drinking Water Management	Construction of water tank & solving leakage issues by laying of pipes	Chundu Geonpa	3 km	GEAO	Geog RNR/adm	0.05
	Fencing and plantation of Goenpa		3 acre			0.4
	Construct roof rain water harvesting technology					0.12

Activity	Sub-Activity	Location	Unit	Implementer	Collaborator	Budget (Nu Million)
Waste management	Construction of concrete waste pits with roofing	All chiwogs	7 nos	GEFO	Wangdi Municipal, Health Sector, Geog RNR/adm	0.7
	Supply of dust bins		158 nos			0.3
	Awareness &training on waste management		3 times			0.5
	Improvement of toilets and cattlesheds		30			1.2
Land Management	Training on soil nutrient management (use of FYM, composting)	All chiwogs		GEFO	Geog RNR/adm	0.5
	Supply of seeds of leguminous and other crops		5 times			1
	Training on SALT & other SLM technologies (counter hedgerows, terracing)					1
Livelihood Improvement Programme	Supplying fodder saplings & seeds	All chiwogs		GELO	Geog RNR/adm	0.024
	Ficusroxburghii		1000 no/yr			0.15
	Winter oat		1000 kg/yr			0.15
	Wheat		1000 kg/yr			0.15

Activity	Sub-Activity	Location	Unit	Implementer	Collaborator	Budget (Nu Million)
Livelihood Improvement Programme	Pasture development	All chiwogs		GELO	Geog RNR/adm	
	Napier grass stems		1000 no/yr			0.21
	Ruzi grass seeds		1000kg/yr			0.105
	Training on stall feeding & winter fodder conservation		5 times			0.25
	Construction of silo pits/hay storage stores					0.5
Human wildlife Conflict Management	Fencing of water source to protect from being dug up by wild boar	Chuzam &Yoezhip	acres	GFEO	Geog RNR/adm	0.5
	Formation of Geog Wildlife Committee					0.3
	Provide seed money					0.5
Forest Fire Management	Awarness on fire prevention and training on basic fire fighting techniques	All chiwogs	3 nos	GFEO	Geog RNR/adm	0.5
	TOTAL					**28.41**

ANNEXURE VI: PLAN OF ACTIVITIES FOR NYISHO GEOG

Activity	Sub-Activity	Location	Unit	Implementer	Collaborator	Budget (Nu Million)
Storm Water Management	Management of irrigation channels			GEAO	Geog RNR/adm	
	Cementing of channels	Chungkha	10 km			5
		Khanijo	0.5 km			3
	Laying of pipes (HDP/Hume)	Tashikabishong to Pangkha	6 km			4
		Bjana	0.5 km			0.6
	Retaining walls	Dophukha	0.1 km			0.5
		Sagama	0.1 km			0.6
		Bjana	0.5 km			0.6
	Soling and drainage for farm roads	Pangkha, Samtengang	2 km			6
	Laying of pipes for drinking water	Samtengang School	13 km			
Waste Management	Awarenss & training on waste management including concept of compost making from bio-degradable wastes	All 7 chiwogs		GEFO and GEAO	Wangdue Municipal, Health Sector, Geog RNR/adm	0.3
	Cleaning campaign	Geli-Kuenzaling & Chebakha				0.3
	Distribution of dust bins and installation of waste collection concrete pits	Geli-Kuenzaling & Chebakha		Municipal Authority	Geog Administration	1
	Collection & transportation of waste from Nyisho, Kazhi, Damchothang and other areas to Wand Watse Treatment Plant (may be 4 times peryear)	Geli-Kuenzaling & Chebakha	20 times in 5 years	Municipal Authority	Geog Administration	0.1

Activity	Sub-Activity	Location	Unit	Imple-menter	Collaborator	Budget (Nu Mil-lion)
Land Management	Management of sinking paddy fields inclduing edge trimming, brush layering, grass slip planting, broadcasting, fencing and plantation to stabilize	Pemathang, Aido, Lunchina, Bachena, Chebashong		GEFO & GEAO	Geog Administration	0.7
	Training on soil nutrient management (FYM, composting)	All Chwiwogs except Beldrok	12 times	GEAO	Geog Administration	0.6
	Training on preparation of organic pesticide	All Chiwogs		GEAO	Geog Administration	1.8
Livelihood improvement programme	Development of feed and fodder seeds	Samtengang, Chitokha, and Chebakha		GELO	Geog RNR/adm	0.6
	Supply of winter oat		10 kg/hh			
	Wheat		10 kg/hh			
	Ficus roxburghii saplings		20/hh			
Human Wild life Conflict Management	Formation of GECC	All chiwogs		GEFO	Geog RNR/adm	0.3
	Establish geog crop insurance scheme and provide seed money					1.5
Future Research programs	Establish Meteriological station at lower Kazhi	Kazhi	1 no	DHMS	Geog Admn of Kazhi	
	Generate climate data to calculate base flow, predicting of droughts, floods & outbreak of pests & diseases	Weather station at lower Kazhi		DHMS	Geog Admn of Kazhi	0.02
	Generate information on seasonal flow (discharge) of Baychhu and its tributaries and conduct quality tests	July 2014 sampling sites		CNR, RUB	NSSC, WMD, RNR-RDC	0.25
	Study the roles of vegetation (hedges) found in the interface with agricultural lands in preserving soil and water conditions, filtering of pollutants and control of erosion	All geogs		CNR, RUB	NSSC, WMD, RNR-RDC	0.25
	Study erosion rate from different landuse management practices	All geogs		CNR, RUB	NSSC, WMD, RNR-RDC	0.25
	TOTAL					**28.27**