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Northern Areas Strategy for Sustainable Development

Background Paper

Water

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TABLE OF CONTENTS

List of Acronyms vi

Foreword vii

Executive Summary ix

1. Introduction 1
    - 1.1. Context and Rationale of the Background Paper 1
    - 1.2. Background Paper on Water and Stakeholders' Participation 1
    - 1.3. Mountain Environments 2
        - 1.3.1. Geology 2
        - 1.3.2. Climate 3
        - 1.3.3. Vegetation 4
        - 1.3.4. Mountain Watersheds 5
    - 1.4. Mountain Hydrology 6
        - 1.4.1. Systems' Approach for Mountain Hydrology 6
        - 1.4.2. Snow and Glacier Hydrology 6
        - 1.4.3. Water and Energy Budget 8
        - 1.4.4. Erosion and Sediment Transport 9
    - 1.5. Water Resources And Utilization 10
        - 1.5.1. River Flows in the Indus Basin Irrigation System 10
        - 1.5.2. Upper Indus River Flows 12
        - 1.5.3. Water Resources of the Northern Area 12
    - 1.6. Main Uses of Water 15
        - 1.6.1. Water for Agriculture – Food Security 15
        - 1.6.2. Water for People – Health Security 18
        - 1.6.3. Water for Nature – Ecological Security 20
    - 1.7. Water Resources And Environmental Management 20
        - 1.7.1. Uncertainty in Environmental Management 22
    - 1.8. Gaps in Information and Reliability 22

2. Issues and Trends 25
    - 2.1. Key Issues 25
        - 2.1.1. Water Resources Development and Management 25
        - 2.1.2. Water for Agriculture – Food Security 26
        - 2.1.3. Water for People – Health Security 26
        - 2.1.4. Water for Nature – Ecological Security 27
    - 2.2. Trends 27
        - 2.2.1. Indus River Flows Variability (Supply) 27
        - 2.2.2. Increase in Water Requirement (Demand) 28

3. Consequences of Inaction 31

4. Current Initiatives 33
- 4.1. Water Resources Development 33
  - 4.1.1. Village Irrigation Systems 33
- 4.2. Change in Mountain Irrigation Systems 34
  - 4.2.1. Channel Construction 34
  - 4.2.2. Innovation in System Design Parameters 35
  - 4.2.3. Adjusting New Systems 35
- 4.3. Management of Water Resources 36
  - 4.3.1. Managing Water Distribution 36
  - 4.3.2. Managing Channel Maintenance 37
  - 4.3.3. Other Physical Infrastructures 37
  - 4.3.4. Irrigation Specialists 37
  - 4.3.5. Field-level Water Management Experimentation 38

5. Stakeholders and Institutions 39
- 5.1. Federal Government Institutions 39
  - 5.1.1. Water and Power Development Authority 39
- 5.2. Public Sector Institutions of the Northern Areas 40
  - 5.2.1. Planning and Development Department 40
  - 5.2.2. Agriculture Department 40
  - 5.2.3. Forest Department 40
  - 5.2.4. Northern Area Public Works Department 40
- 5.3. NGOs 40
  - 5.3.1. Aga Khan Rural Support Programme (AKRSP) 40
  - 5.3.2. Water and Sanitation Engineering Programme (WASEP) 41
  - 5.3.3. Other Programmes of Aga Khan Foundation 41
- 5.4. CBOs 41
- 5.5. IUCN 41
- 5.6. Other International Organizations 42

6. The Way Ahead 43
- 6.1. Options 43
- 6.2. Options for Water Resource Development and Management 43
  - 6.2.1. Master Plan for Water Resources Development and Management 43
  - 6.2.2. Managing Shortfall in Supply and Demand of Water and Institutionalisation 43
  - 6.2.3. Surface Water Resources Development 45
  - 6.2.4. Minimizing Water Losses 46
  - 6.2.5. Increasing Storage (domestic, stockwater, irrigation, ecosystem) 47
  - 6.2.6. Planting of Glaciers 47
  - 6.2.7. Hydro-Power Development 47
  - 6.2.8. Mobilizing New Financial Resources 48
  - 6.2.9. Launching a Movement 48
  - 6.2.10. Effect on Other Sectors 48
- 6.3. Options for Achieving "Food Security" 49
  - 6.3.1. Operational Management of the *Kuhl* System 49
  - 6.3.2. Managing the shortfall in Supply and Demand of Water 49

6.3.3. Improving Productivity of Water Use 50
6.4. Options for Achieving "Health Security" 50
6.4.1. Provision of Safe Drinking Water 50
6.4.2. Safe Disposal of Effluents 51
6.5. Options for Achieving "Ecological Security" 51
6.5.1. Managing the Productive Environments 51
6.5.2. Managing the Wetlands 52
6.6. Recommended Options 52
6.6.1. Options for Water Resource Development and Management 52
6.6.2. Options for Achieving "Water Security" 54

Annex I: List of Participants invited for the Pre- and Post-draft Workshops 57

Annex II: Recommendations of the Pre-draft Workshop 59
Issues 59
Recommendations 60

Annex III: Proceedings of the Post-Draft Review Workshop 61

References 64

LIST OF ACRONYMS

AKRSP	Aga Khan Rural Support Programme
AKDN	Aga Khan Development Network
AKCSP	Aga Khan Cultural Services, Pakistan
AKHS	Aga Khan Health Services
AKPBS	Aga Khan Planning and Building Services
BACIP	Building and Construction Improvement Programme
GoP	Government of Pakistan
IG	Interest Group
LB&RDD	Local Bodies and Rural Development Department
P&DD	Planning and Development Department
NAPWD	Northern Areas Public Works Department
NACS	Northern Areas Conservation Strategy
NASSD	Northern Areas Strategy for Sustainable Development
NA	Northern Areas
NAA	Northern Areas Administration
NGO	Non-Government Organisation
WASEP	Water and Sanitation Extension Programme
WSHHSP	Water Sanitation Hygiene and Health Studies Project

FOREWORD

The Northern Areas have a unique and critical role to play in the sustainable development of Pakistan. Although they span a relatively small geographical area, the Northern Areas serve as a vital catchment for the Indus River, upon which a majority of Pakistan's irrigated agriculture and hydroelectricity depends. The Northern Areas also contain the nation's most important natural forests, extensive mineral reserves, and a wealth of biodiversity. Dramatic scenery, some of the world's highest mountains, and a rich cultural and archaeological heritage make the Northern Areas one of the most visited tourist destinations in the country.

Over the last several decades, however, many of the Northern Areas' natural resources have come under increasing pressure, as a result of a growing human population and the opening of the Karakoram Highway. At the same time, it has become increasingly recognised that the isolated nature of many of the region's communities, coupled with the Northern Areas' high-altitude and fragile environment, poses special constraints and challenges to development. Perhaps more so than in any other part of Pakistan, there is a need in the Northern Areas to ensure that social and environmental considerations are fully integrated into the development process.

In response to these concerns, the Northern Areas Administration began the preparation of a Northern Areas Strategy for Sustainable Development in 1999, with the financial assistance of the Swiss Agency for Development and Cooperation, and the Norwegian Agency for Development Cooperation; technical support has been provided by IUCN–The World Conservation Union. The Strategy addresses a broad range of social, economic and environmental issues, and seeks to provide a comprehensive policy framework for the sustainable development of the region. It responds directly to the provisions and recommendations of the National Conservation Strategy, adopted by the Government of Pakistan in 1992.

In parallel, *The State of the Environment and Development in the Northern Areas* summarises in a single volume the key information gathered during the preparation of the NASSD. It is the first report of its kind to be produced for the Northern Areas, which provides a succinct, up-to-date and readily accessible analysis of the status of the most important environment and development sectors in the Northern Areas, including information on major trends and issues, the responses taken by both government and civil society to date, and strategic options for the future. It also provides a baseline against which future change can be measured and establishes the context and foundations for the Northern Areas Strategy for Sustainable Development.

During early consultations at the tehsil level, and with key governmental and non-governmental organizations 16 areas of intervention were identified as being critical for the NASSD. These include sectors like: water; agriculture; forestry; biodiversity; rangelands and livestock; the private sector; energy; urban environment; and cultural heritage and sustainable tourism. In addition, some crosscutting themes were identified as crucial to each sector, including population, poverty and environment; communication for sustainable development; environmental education; NGOs; gender, environment and development; environmental health; and governance.

To address the needs of each of these areas, basic information was gathered through consultations and literature reviews. This data was analysed through background papers commissioned on each of the sectors and themes identified. The draft of each paper was shared with the larger community of stakeholders of the NASSD as well as experts in the relevant field of knowledge.

The papers follow a similar format: analysis of the current situation; issues; past and present initiatives in the sectors and thematic areas along with the lessons learnt; stakeholders; and recommended policy and action measures. The authors have also addressed cross-sectoral linkages and environmental concerns for the sake of more integration in planning for sustainable development.

There were constraints to developing these Background Papers and in some cases these hurdles were only partially overcome. These included the fragmented and scattered nature of information, the prevalent culture of not sharing information, contradictory and unreliable data, lack of thinking on cross-sectoral linkages and integrated planning, and lack of expertise in developing linkages with the environment.

Parts of the information of the papers were then incorporated into the State of the Environment and Development (SoED) and the main strategy, i.e., NASSD. However, since the Papers contain a wealth of extremely useful information, a decision was taken to produce a series of NASSD Background Papers.

Considering the need and importance of timely sharing information with the stakeholders, these papers are being produced without extensive editing. The authors have sole responsibility for the views expressed and data presented.

EXECUTIVE SUMMARY

Background

Population of the Northern Areas increased by four-fold in the last 50 years, which resulted in an increase in water use by almost six-fold. The country is facing a continued drought since the last three years, which has led to a water crisis situation in the country. But the crisis is not about having too little water to satisfy population needs. It is a crisis of managing water so badly that millions of people in the country including the Northern Areas – and the environment – suffer badly. The domestic water use represents only a small part of the total water use. Industrial water use in the Northern Areas is almost negligible. Far more water is needed to produce food. We are not sure how much water must remain in our ecosystems to maintain them, but indications are that we are approaching the limits of how much water we can divert. Providing six times more water now than 50 years ago has significant impacts on people and the environment of the Northern Areas.

Taking in to account the importance of water for sustained economic development and environmental management of the Northern Areas, water was identified as one of the priority topics for the preparation of the background paper. It provides a vehicle for exploring key issues in depth along with essential information about the subject, summarizes trends, and offers some of the practical solutions. Secondary information and discussions with stakeholders form the basis for the paper, together with the author's personal knowledge of the subject.

Resource Picture

Incident rainfall in valleys varies from 100 to 200 mm, which is insignificant to support agriculture or any other form of vegetation. With increasing altitude, the amount of annual precipitation that falls as snow increases, and the amount, which does not melt during the year in which it falls, also increases. This phenomenon gives rise to a perennial ice cover on the surface - a glacier. Where they exist in significant amounts, glaciers are an important natural reservoir of water and play an important role in the annual cycle of high and low river flow. About 10-20% Northern Areas is covered by glaciers. An additional amount, which is as high as 30-40%, has a seasonal snow cover. This represents a significant form of natural storage, which lasts from a single season, in the case of the transient snow cover, to decades or centuries in the case of the larger glaciers. The importance of this natural reservoir is the greatest in Northern Areas and for the Indus basin. The glaciers of the Northern Areas are a primary factor in determining both water availability and sediment in the upper Indus basin.

Mean annual precipitation near the termini of glaciers is generally less than 100 mm. The annual water exchange at the altitude of over 5000 m can exceed 1,000 mm and the mean annual runoff for at least one glacierised basin - the Batura - exceeded 1,500 mm during a summer melt season. Glaciers are both elements of the high mountain hydrologic cycle and indicators of both spatial and temporal variations in it. The low altitude, climatological stations, which exist in the Northern Areas, could be providing a very incomplete picture of the hydro meteorological environment of the mountains or the changes that are occurring.

Historical information regarding water resources, requirement and use is not available and thus different agencies and people make judgements. Indus River flows data at different points in the Northern Areas is available. However, such data do not provide any information regarding the water use in the Northern areas, as the water is diverted to *Kuhls* prior to reaching to the Indus River or its tributaries. Thus all water use diversions in the Northern Areas are being done upstream of the Indus river tributaries prior to their entry to the Indus River. Therefore, water use in the region is over and above the average Indus River flows of 55.5 billion m3 at the Partab gauging station. The reliability of Indus river flows data in the upper reaches and at the upstream of Tarbela is reasonably high.

Key Issues

Augmenting the quantum of useable water resources is a pressing need for the Northern Areas and for Pakistan in the face of the rising population, which by conservative estimates would increase by 2% per annum in Pakistan for the next 25 years. For Northern Areas higher rate of population growth is expected and thus it might increase by 3% per annum for the next decade. What this implies is that, just to maintain the present level of usage per capita and the productivity per unit of water by the end of the next decade (2011), the present water diversion would increase by at least 3%. Thus for the next decade, there is a need to have additional water diversion facility of around 34% for agriculture and domestic water requirements within existing framework of operation and maintenance.

Water Resources Development and Management

- Managing the shortfall in supply and demand of water for various sectors i.e. agriculture, urban and rural domestic water supply, ecosystems, etc, including the management of seasonal shortfall in water supply because of reduced snow- and glacier-melt in the late winter season (March to May);
- Harnessing of additional water from: a) either stream flows to meet the demand and to the extent such diversions are feasible; or b) through minimising the losses in conveyance of water in open channels for multiple water use; such losses are primarily due to the rugged mountainous terrain, gradient of the channel and extremely high infiltration rates;
- Improving adequacy, reliability, equity and equality in water availability caused primarily due to inappropriate water allocation and distribution;
- Effective maintenance and cost-recovery of water systems;
- Development of cost-effective hydel-power systems for water lifting using effective technology in terms of water and energy efficiency;
- Minimising effects and impacts of water development and management on other sectors like biodiversity, fisheries, agriculture, tourism, and recreation.
- Participation of water users is essential in operation, maintenance and cost recovery for irrigation and domestic water supply systems.

Water Security

- Realising the highest feasible agricultural productivity of water through development of appropriate water use and crop production practices;
- Meeting the crop water requirements by conjunctive use of stream flows and rainfall, by effectively operating (well designed and well constructed) *Kuhl* systems;
- Preserving a productive irrigation environment by reducing the chances for extreme seepage and breaches due to the deferred maintenance.
- Provision of safe water supply to urban and rural population due to increased health security measures and population increase;
- Providing safe disposal of the sewerage, agricultural and industrial effluents;
- Managing water quality of surface water systems;
- Management of water streams, wetlands and watersheds.

Recommended Options

Recommended options for the water sector are presented under two core objectives: a) water resources development and management to augment existing water supplies; and b) water resources management for achieving water security in terms of food, health and ecological perspectives. The 1st core objective covers options, which are common to all the sub-sectors of water. The 2nd core objective covers options, which are specific to the three sub-sectors of water use. The options under the two core objectives are presented both for the short-term (2-3 years) and long-term periods (> 3 years).

Options for Water Resource Development and Management

Short-term Options

- Preparation of Master Plan for water resources development and management should be given the highest priority so that all the necessary details for feasibility and identification of potential locations for the irrigation schemes are included in an Atlas.
- Shortfall in supply and demand of water should be managed through stakeholder's participation in management that makes decisions and oversee operations including raising awareness, education and communications of stakeholders.
- Conservation of existing water losses can augment the existing water supplies. This could be achieved through identification of sensitive reaches, which contribute for excessive conveyance losses and breaches and introduce either use of fine-sediments for blocking the pores or lining using the geo-synthetic liners. Managing the velocity of water in the *Kuhls* would also help to minimize scouring and siltation. Improvements in the existing design of *Kuhls* can help to address both the hydraulic regimes of low and high flows. Preparation of an Action Plan for improving the conveyance efficiency of the existing *Kuhls* would be an effective tool for systematic implementation.
- New financial resources have to be mobilised for continued O&M of the water systems for various uses through recovery of the O&M cost especially for the domestic water supply systems. Ultimately such mechanisms have to be developed for agricultural water systems. In rural areas, same *Kuhl* is used for domestic, agricultural and ecosystems, therefore, Water Users' Organizations would be encouraged to enforce water fee to mobilize resources for

maintaining and managing the water systems. Area Water Boards can play vital role through federations of Water Users' Organizations for enforcing water fee and cost recovery.

- There is an urgent need to launch a movement for creating awareness through training and education of all the stakeholders about the importance of the finite resource and future requirements not only for the Northern Areas but also for Pakistan's Indus basin. The demand for water would certainly increase in future for the downstream areas, which would have serious impacts on the development of water in the Northern Areas. Furthermore, the quality concerns would increase in future and thus better management of return flows have to be made.

Long-term Options

- Management of shortfall in supply and demand of water would be possible through: a) improved urban and regional planning to locate towns and agro-based enterprises near sources of water, which would be sufficient to meet the expanding needs in the future; b) rationalizing sectoral and inter-sectoral water allocations; c) reviewing options for introducing water tariff for various purposes to reflect the value of water in use; and d) encouraging the private sector participation. Necessary legal and regulatory infrastructure has to be created to make the private sector investment viable.
- Institutionalisation of water sector institutions is essential to improve and enhance the existing infrastructure for water resources development and management. For this purpose, there is a need to establish Water Management Authority with Area Water Boards and Federations of the Water Users' Organizations to ensure active participation of stakeholders.
- Preparation of Action Plan for the development of new *Kuhls* or remodelling of the existing *Kuhls* is needed considering the cost-effectivity. Formulation of an integrated approach for water development, management and use is an essential element of the Action Plan. Furthermore, there is a need for instituting transparent and participatory procedures for water allocation in the new *Kuhl* commands.
- Increasing storage (domestic, stockwater, irrigation and ecosystem) through the introduction of small-scale storage ponds/tanks at the farm or command level and lining of these tanks using the geo-synthetic liners, where it is cost-effective. Introduction of sand filters would help to provide safe and clean water for drinking and stockwater use especially during the late winter months (March to May).
- Hydro-power development is crucial to augment water supplies through: a) indigenisation and commercialisation of small-scale hydropower generators; b) construction of small-scale hydropower units at locations where water can be lifted for multiple water use; and c) introduction of water lifting turbines on the perennial streams to lift water. These turbines work under water head and lift water based on quantity of water and available head.

Options for Achieving "Water Security"

Short-term Options

- Management of the shortfall in supply and demand of water for agriculture is possible through adjusting cropping pattern and cropping intensity in line with water availabilities. Drought resistance varieties of wheat should be evaluated to reduce the demand of water during the months of March to May;

- Improving productivity of water use should be given due consideration through improving Warabandi system to manage shortfall in supply and demand and to improve reliability, efficiency and equity in water distribution. Improving control of water can lead to minimise losses at diversions and distribution at the farm level. Furthermore, the improved layout and field levelling can help to improve irrigation application efficiency and to reduce number of irrigations i.e. as high as 20 irrigations are applied to wheat crop;
- Concept of fertigation can be introduced to increase the productive and economic efficiency. Furthermore, use of bio-fertigation using composts or animal wastes can help to improve soil structure. This would help to reduce the irrigation requirements in the long-run.
- Introduction of furrow irrigation using round basin or broadbed planting systems instead of flood irrigation for fruit plants and vegetables.

Long-term Options

- Managing the shortfall in supply and demand of water through the construction of water lifting schemes to meet shortfall during peak demand period of March-May.
- Improving productivity of water uses through the introduction of high efficiency irrigation systems viz sprinklers and drip irrigation using the available hydraulic head due to topography.
- Provision of safe and clean drinking water through the introduction of sand filters to filter sand and silt particles from the *Kuhl* water and appropriate water treatment to control the biological impurities. Introduction of water fee for cost recovery is needed to maintain the water supply systems on sustainable basis.
- Proper collection and treatment of sewage and other effluents prior to their discharge into freshwater bodies is essential. Sewage should not be dumped into *Kuhl* system at all. Furthermore, practical and economically viable sewage treatment options should be explored and applied. Aquatic ecosystems should be regularly monitored for impacts on the aquatic and other life forms.
- Wetland management plans and programmes should be developed and implemented to maintain alpine- and sub-alpine wetlands, which are unique in the country due to the occurrence of cold-water flora and fauna.

1. INTRODUCTION

1.1. Context and Rationale of the Background Paper

In the past 50 years, population of the Northern Areas increased by four-fold, whereas water use for human purposes increased by almost six-fold. Furthermore, the country is facing a continued drought since the last three years. This has led to a water crisis situation in the region and in the country. But the crisis is not about having too little water to satisfy population needs. It is a crisis of managing water so badly that millions of people in the country including the Northern Areas – and the environment – suffer badly. The most obvious uses of water for people are drinking, cooking, bathing and cleaning, which represent only a small part of the total water use. Industrial water use in the Northern Areas is almost negligible. Far more water is needed to produce food. We are not sure how much water must remain in our ecosystems to maintain them, but indications are that we are approaching – and in many places have surpassed – the limits of how much water we can divert. Providing six times more water now than 50 years ago has significant impacts on people and the environment of the Northern Areas.

Will continuing the way we manage water lead to crisis? Indeed, many parts of Northern Areas are already suffering water crisis that affect their people and the ecosystems. Majority of people in the Northern Areas lack access to safe drinking water and access to sanitation. Even sufficient water is not available to produce food. And with increasing populations and demand on water, other areas of the region will join them. We have already destroyed some of the important wetlands. Therefore to ensure sustainability of water, we must view it holistically, balancing competing demands on it – domestic, agricultural, industrial and environmental. Sustainable management of water resources requires systemic and integrated decision making that recognises the interdependence of three areas. Firstly, decisions on land use also affect water, and decisions on water also affect the environment and land use. Secondly, decisions on economic and social front are currently sectoral and fragmented, which affect hydrology and the ecosystems in which we live. Thirdly, decisions at the national and local levels are interrelated.

Taking in to account the importance of water for sustained economic development and environmental management of the Northern Areas, water was identified as one of the priority topic for the preparation of the Northern Areas Conservation Strategy. Therefore, water was included as one of the key-topics for the preparation of the background papers.

1.2. Background Paper on Water and Stakeholders' Participation

Background paper on "Water" provides a vehicle for exploring key issues in depth along with essential information about the subject, summarizes issues and trends, and offers some of the practical solutions for addressing them. It envelops a set of General Guidelines, together with Subject Specific Guidelines conceptualised from the pre-draft workshop, organized at the Serena Hotel Gilgit on 12th May 2001, which was helpful for the design and scope of "Table of Contents" for the background paper. Secondary information and discussions with stakeholders form the basis for the paper, together with the author's personal knowledge of the subject.

The draft of the background paper was circulated to all the stakeholders and post-draft workshop was organized at the Serena Hotel, Gilgit on November 24th 2001, which was helpful for incorporating the viewpoint of stakeholders and for fine-tuning of the background paper.

The proceedings of the pre- and post-draft workshops were summarized by the author and presented along with the list of participants in Appendices I to III.

1.3. Mountain Environments

Water resources can be defined with relative precision; the term "environment" is somewhat more ambiguous. In the context of factors affecting flow of water through a watershed in Northern Areas, the mountain environment may be defined covering aspects of: a) geology; b) climate; and c) vegetation.

1.3.1. Geology

Geology defines composition and structure of rocks forming floor of watershed. From the standpoint of water resources' development and management in the Northern Areas, three primary geological factors to be considered are: a) resistance of geologic materials to the dominant forms of erosion; b) tectonic stability of the region; and c) extent to which the geologic materials are fractured or having voids and thus permitting storage and movement of groundwater (Alford 1989).

Resistance of geologic materials to erosion cannot be quantified. Chemical processes of disintegration predominate in warm and wet environments and producing fine-grained sediments. Physical processes are dry and may produce relatively coarse-grained sediments. Soil-forming processes are partly determined by biological processes and are thus strongly dependent on temperature and moisture. The physical processes are more common in the Northern Areas compared to the chemical and biological processes due to the extreme aridity. However, in the wet alpine and sub-alpine zones, chemical and biological processes are also active.

Tectonic activity of the Northern Areas is of importance primarily to determine the extent to which the Indus River system is in geomorphic equilibrium – the uniformity with which kinetic energy is distributed throughout the system from the headwaters to the mouth of a watershed. As tectonic activity increases, slope angles between the headwaters and the local base level of the river system increase, thus increasing the kinetic energy within the system. Following some form of tectonic uplift, a landscape, such as a mountain watershed, readjusts to a new state of equilibrium at differing rates in different locations. This adjustment to a new equilibrium state can create local areas of high energy – and thus, erosion – which may be misinterpreted as resulting from some other cause, e.g., improper land use (Alford 1989). This aspect should be clearly understood by the environmentalists while preparing the conservation plans for the Northern Areas.

Fractures and other void spaces within the geologic materials are the primary factors in determining the existence and importance of groundwater resources in the Northern Areas. Where the rock is neither porous nor permeable at depth, such as in the case of un-fractured granite, there is no groundwater, no matter how "wet" the surface environment may be. The best groundwater environments are well-sorted alluvium, cavernous limestone, or sandstones. Mountain watersheds of the Northern Areas are poor groundwater environments. The rocks forming the core of a mountain range of the Northern Areas commonly have limited porosity and permeability, limiting groundwater occurrence to local fracture zones or pockets of alluvium (Hagen 1980).

1.3.2. Climate

Climatological stations, in areas of extreme relief, are often located on valley floors that commonly have a much different "topoclimate" from adjacent slopes or ridges (Geiger 1966). Two stations in close proximity, located in the valley, can produce much different values, if one is located at the base of a windward slope and the other is at the base of a leeward slope. The challenge for the climatologist in the Northern Areas and, by extension, the environmental planner or manager is to develop techniques that will represent accurately the spatial patterns of existing topoclimates (Alford 1992).

Climate of the upper Indus basin is transitional between that of Central Asia and the Monsoon climate of the South Asia (Rao 1981). It varies considerably with latitude, altitude, aspect, and local relief, e.g., rain shadows caused by high mountain masses such as Nanga Parbat. The availability of climatic data varies widely in the area. There are few climatic data for the upper Indus basin, but long-

Table 1: Mean rainfall of selected locations of the NA (average of 1960-90)

Months	Mean Rainfall (mm)					
	Astor	Bunji	Chilas	Gilgit	Gupis	Skardu
January	35.2	4.2	8.4	4.0	5.2	21.0
February	49.4	6.1	12.7	6.0	6.7	24.3
March	82.6	16.2	30.0	12.6	9.2	40.3
April	87.1	22.9	31.9	23.0	20.4	26.3
May	71.2	28.7	27.7	25.3	24.0	26.4
June	19.8	7.2	7.6	6.1	8.2	8.8
July	21.0	14.5	11.6	15.6	11.4	9.1
August	23.5	18.4	12.4	15.5	15.8	10.5
September	18.5	8.8	3.0	6.5	8.5	7.1
October	30.0	10.7	12.8	8.4	3.8	10.4
November	13.6	2.6	4.0	1.8	1.3	6.4
December	25.8	4.0	11.1	4.1	4.4	13.7
Annual	477.7	144.4	173.2	129.0	118.9	204.2

term temperature and precipitation records are available for Astore, Bunji, Chilas, Gilgit, Gupis and Skardu (Table 1). The most significant features of the regional climate of the upper Indus are the low overall precipitation, the great range of mean monthly temperature values, the low winter temperatures, and severe frosts during portions of the winter season.

Rainfall data of the Northern Areas indicate that while annual totals may be low at the altitudes of the valley floors, individual storm totals may be quite high. This tendency for precipitation to be low overall, but for there to be a small number of storms each year, sometimes with intense rainfall events, has considerable hydrological and geo-morphological significance, especially in terms of erosion, mass movements, and the production of debris flows (Ferguson 1984).

Most of the precipitation is not derived from the Monsoon, but from depressions moving in from the west during the spring and summer. Monsoon disturbances do occasionally succeed in extending sufficiently far north to enter the Northern Area, however, and, when they do, precipitation levels can be substantially increased. Variability is as important as the more obvious aridity (Rao 1981). Although the valley floors are quite arid, precipitation amounts almost surely increase substantially with increasing altitude (Dreyer et al. 1982). As examples, measurements of the thickness of the annual layers of ice in the firn basin of the Batura glacier and the monitoring of the annual discharge of melt water from the glacier have led Chinese investigators to suggest that precipitation above the regional snow line (4,700-5,300 m) may exceed 2,000 mm annually (Batura Glacier Investigation Group 1979). Canadians working further to the east near the Biafo glacier found, totals in excess of 1,400 mm annually at comparable altitudes.

1.3.3. Vegetation

Vegetation and the surface water and energy environment evolve together. This fact is reflected in concepts of plant succession within ecosystems. In the absence of disturbance, plant communities follow one another in a somewhat predictable sequence and the surface environment is altered by each in turn. In determining the possible impacts of vegetation manipulation, either removal or replacement, it is useful to understand that, at least from the perspective of hydrology, a "forest" is much more than a collection of trees. A forest is a complex assemblage of trees, bushes, and other under-story plants, ground litter, soil, and, often in the mountains, bedrock. This assemblage of environmental elements modifies the impact of precipitation on the surface, increases the potential water infiltration into the surface, and alters the nature of energy exchange processes on and near the surface. It is the assemblage of elements, and not the trees alone, that modulate the hydrologic cycle. Removal of the trees, if accompanied by a loss of under-story vegetation, litter, and soil as well, may well produce measurable changes in the flow of water and energy into, through, and from the site. Replacement of the trees -- "reforestation" - will not restore the pre-existing conditions until sufficient time has passed for the elements of the mature forest -- the under-story, litter, and soil - to have been replaced.

On the macro-scale, there is an altitudinal zonation of vegetation throughout the mountains of the HKG region of the Northern Areas (Hagen 1980 and Goudie et al. 1982). On the meso-scale, this altitudinal zonation in the Northern Areas is complicated by patterns associated with aspect, increasing in importance with altitude and from east to west through the region. Attempts to affect the water or sediment flows from any basin of the Northern Areas through vegetation manipulation must be based upon an understanding of these zonations, as well as considerations of the total surface area of the basin supporting a natural vegetation cover. If this percentage is low, as a result of altitudinal or aspect constraints on vegetation growth, then changes in water or sediment balances will be difficult to accomplish through the mechanism of vegetation manipulation.

In Northern Areas, due to aridity, vegetation can only survive in areas where either snow is available or water is made available through irrigation. The erosion is basically derived from geologic processes. The vegetation is concentrated around nullahs and streams. Thus channel erosion contributes significantly to the sediment transport. Therefore, different type of watershed management is needed compared to the wet mountains.

1.3.4. Mountain Watersheds

Definition of a "mountain" or a "mountain watershed" must be determined by the purposes for which the definition is required. The classical definition has emphasized botanical zonation (Messerli 1983), but this is not particularly useful for hydrological studies.

For hydrological purposes, the mountain watersheds of the Northern Areas are best considered in geophysical, rather than botanical terms, reflecting variations in water and energy exchange as a function of topography and meteorology rather than zonation of vegetation (Alford 1992). In mountainous terrain of the Northern Areas, the interaction between topography and meteorology produces a situation in which the following takes place.

- In the Northern Areas, precipitation varies complexly with the aspects of altitude and terrain i.e. it varies from 120 mm to 2000 mm. There is commonly an "orographic" gradient, in which precipitation amounts vary along altitudinal gradients. Generally, "windward" slopes will be wetter than "leeward" slopes. With increasing altitude, the percentage of precipitation falls as snow increases.
- In the Northern Areas, the evaporation losses decrease with altitude as available energy decreases (Lambert and Chitrakar 1987).
- Steep mountain slopes of the Northern Areas cause water produced by rain or snowmelt on the surface to run off quickly into stream channels (Petts and Foster 1985).
- In many cases, shallow mountain soils and impermeable geologic formations of the Northern Areas can provide little storage for soil moisture and groundwater, as the soils are normally of extremely coarse textured.
- Vegetation of the Northern Areas may be zoned based on both altitude and aspect, limiting the hydrological impact of either removal or replacement to within narrow geographical limits for any single mountain watershed of the region.

1.4. Mountain Hydrology

1.4.1. Systems' Approach for Mountain Hydrology

Mountain hydrology is the study of hydrologic processes and interactions within mountain watersheds (Alford 1985), not, the study of the aggregate flow of water from those watersheds as measured at adjacent, lowland, gauging stations. This necessitates a shift in emphasis in the application of analytical methodologies and approaches developed for studies of water resources in the lowland environments of Pakistan. While the discharge of rivers, as measured at discrete stream-gauging stations, remains important, it is much more important to understand something of the variation in production of runoff into stream channels between adjacent stream gauges (Alford 1992). Without this sort of understanding, development of water availability estimates for un-instrumented sites of the Northern Areas, or forecasts of water availability with time, will remain problematical.

Water resources are only a single factor in any environment, and such resources cannot be understood without some understanding of the larger system, of which they are a part and with which they interact. This larger system is defined primarily by interdependent interactions among topography, climate, geology, vegetation, and human modifications of these elements of the environment (Barry 1981 and Baker 1944). In Northern Areas, as a first approximation, the most critical factors are topography and meteorology. The topographic factors of local relief, slope angle, and aspect influence the timing, volume, and spatial variability of water and energy in a mountainous terrain (Alford 1985). In the mountains there is no regional climate as such, but rather a mosaic of local "topoclimates" (Thornthwaite 1953) determined by variations in slope angle, aspect, and relative altitude (Flohn 1974 and Geiger 1966).

1.4.2. Snow and Glacier Hydrology

In the Northern Areas, with increasing altitude, the amount of annual precipitation that falls as snow increases, and the amount, which does not melt during the year in which it falls, also increases. This phenomenon gives rise to a perennial ice cover on the surface - a glacier (Patterson 1981). Where they exist in significant amounts, glaciers are an important natural reservoir of water and play an important role in the annual cycle of high and low river flow. In countries, such as Norway and Switzerland, that are extensively "glacierised", the hydroelectric generation industries place a high priority on understanding annual fluctuations in the amount of water stored as ice in these glaciers (Meier and Roots 1982). Similar activity is essential to understand the fluctuations in the amount of glacier- and snow-melt to predict temporal and spatial variability in the water availability from the Northern Areas of Pakistan.

About 10-20% Northern Areas is covered by glaciers (Watanabe 1976). This is a percentage comparable to that of the Swiss Alps. An additional amount, which is as high as 30-40%, has a seasonal snow cover. This represents a significant form of natural storage, which lasts from a single season, in the case of the transient snow cover, to decades or centuries in the case of the larger glaciers. The importance of this natural reservoir is the greatest in Northern Areas and for the Indus basin (Evans 1977).

The major mountains of the Northern Areas contain some of the longest glaciers outside the Polar Regions, and it is probable that they are a primary factor in determining both water availability and sediment in the upper Indus basin. There are more than 100 glaciers that are 10 km or more in length, with several exceeding 50 km. These glaciers have maxima of both snowfall and ablation (snow and ice-melt) during the summer half year - and are among the steepest in the world. Their termini are the lowest in the region, often reaching subtropical desert conditions (Mason 1930).

Mean annual precipitation near the termini of Northern Areas glaciers is generally less than 100 mm, with a summer daily maximum of 15 mm. Equilibrium lines (the altitudinal zone on the glacier surface where accumulation as snowfall is just balanced by melt) lie in the range of from 4,800 to 5,400 m. Studies have shown that the annual water exchange at the equilibrium line can exceed 1,000 mm and the mean annual runoff for at least one glacierised basin - the Batura - exceeded 1,500 mm during a summer melt season (Batura Glacier Investigation Group 1979). This means that the glaciers of the Northern Areas have very high "activity indices", an indicator of the total amount of water passing through the glacier system annually. Consequently they have high flow rates in terms of glacier melt, ranging between 100 and 1,000 m/year, while there is historical evidence of flow rates of 30 m/day for a glacier in the late 1800s. Depth of glacier-melt was used as an indicator of flow due to lack of flow data. It is apparent that the glaciers of the Northern Areas have advanced periodically well beyond their present termini positions, often at very high rates. The early scientific literature for the region records instances of glacier advances that have dammed rivers, creating large transient lakes which have subsequently led to massive flooding in downstream areas as ice dams were breached (Mason 1930).

As a result of the high rates of flow, the Northern Areas glaciers both actively erode their beds and transport the erosion products to the headwaters of glacial rivers, which then move the sediment into the larger rivers of the region. The percentage of sediment contributed as a direct consequence of glacier erosion is unknown, but, taken together with the stream erosion of older glacial moraines and alluvial valley fills, it could account for the bulk of the sediment moving through the upper Indus system (Ferguson 1982).

Glaciers are both elements of the high mountain hydrologic cycle and indicators of both spatial and temporal variations in it. The low altitude, climatological stations, which exist in the Northern Areas, could be providing a very incomplete picture of the hydrometeorological environment of the mountains or the changes that are occurring (Alford 1992).

Based on the interaction with participants of the pre- and post-draft workshops and personal communications with glacier experts from Canada, who worked in the Northern Areas for over 40 years, the author confirmed the option of planting glaciers by the local people in the high mountains. The discussions revealed that scientifically it can be proved that planting of glaciers is possible in environments similar to those of the glacierised. The local story is based on a concept of planting the male and female glaciers. In fact, the male glacier is one, which has been glacierised long ago, whereas the female piece is still young and more like deposited snow. The interface of the male and female pieces provides an environment, which is transitional and helps snow to enter in to the process of glacierisation. Thus further deposition of incident snow helps the glacierisation process. However, there is a need to document such practices based on systematic assessment of the effects and impacts of local planting efforts.

1.4.3. Water and Energy Budget

Hydrologic cycle, a concept familiar to those concerned with water resources' management, is a useful qualitative model describing the flow of water through the ocean-atmosphere-land continuum. Much more useful for purposes of resource development planning and management, however, is the concept of the water budget and the associated energy budget. Water moves through ecosystems as a series of flows and storages (Figure 1). Flows are associated with relatively high energies while storages represent a state in which there is temporarily insufficient energy to produce further movement. Examples of flows are precipitation, evapotranspiration and surface runoff. Storages exist in the form of seasonal snow deposits or glaciers, lakes and groundwater. Water and energy budgets provide a method for determining the nature and magnitude of these flows and storages. Water resources' management is primarily concerned with altering or duplicating one or the other, e.g., the reservoir behind a dam duplicates storage naturally provided by snow and lakes. The dam, by raising the water level, increases the energy associated with flow.

Although the water budget involves a simple concept, in practice the evaluation of the relationship for the mountainous environments is difficult because of a number of reasons. Both precipitation and evaporation are measured at single points within a basin, while surface runoff and groundwater recharge are commonly measured as areal averages. A fundamental problem in evaluation of a water budget for a basin involves, in the first instance, the conversion of all variables to a common set of dimensions. This means that either precipitation and evapotranspiration have to be converted to areal averages (volume/area), or surface runoff and groundwater recharge to point values with dimensions of depth/area (Mather 1974). In mountainous terrain, however, these methods are of limited value, without some understanding of how the various elements of the budget vary with local variations in altitude, slope angle, and aspect (Barry 1981 and Alford 1985).

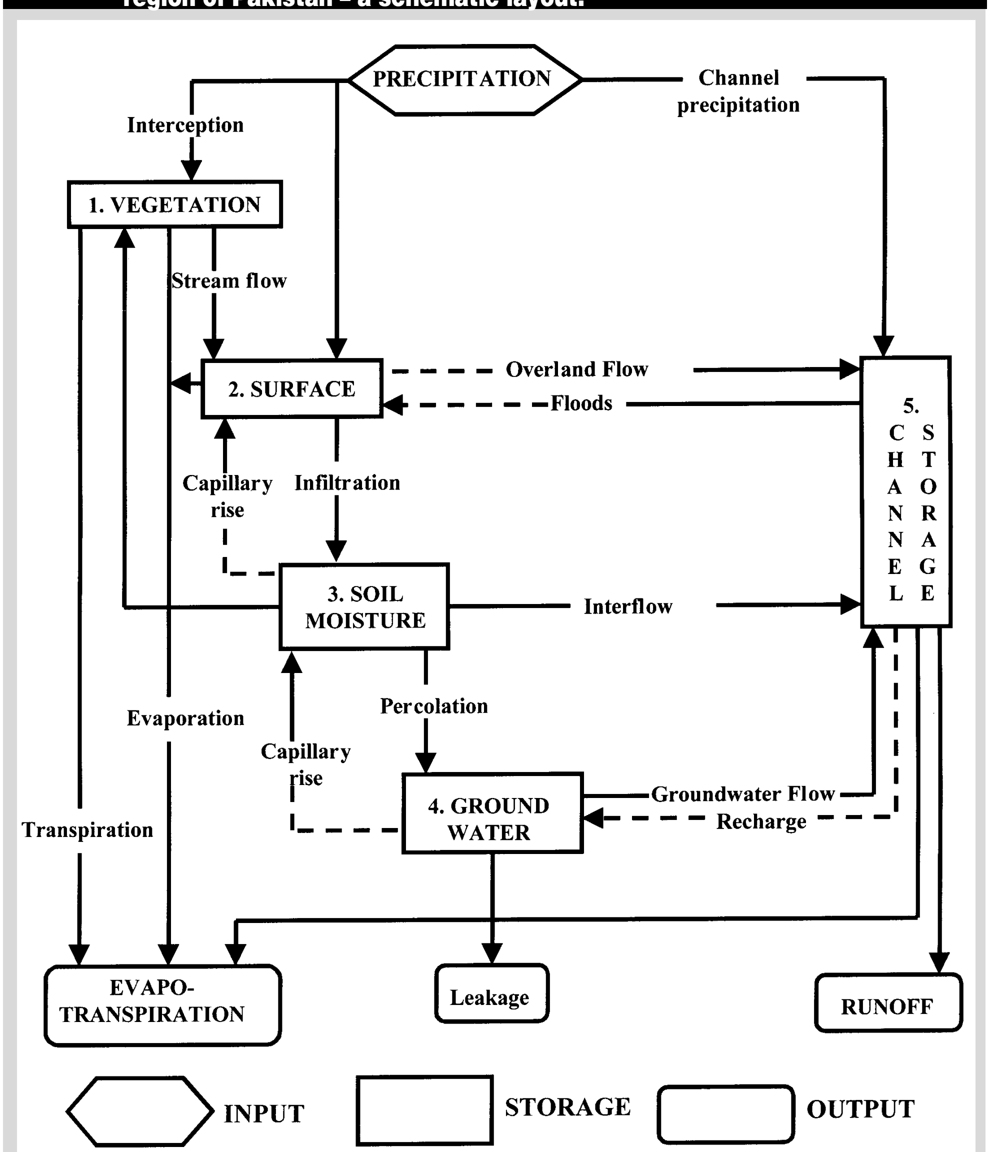
> *... because of the characteristic irregularities of topography, surface and subsurface texture, and contrasts of albedo, high mountains of the Northern Areas present extremely difficult problems of hydro meteorological or energy exchange observation and sampling, and are poorly suited to the modelling or mathematical treatment of data (IAHS 1982).*

Obviously, a major problem in mountain hydrology is the quantification of these "characteristic irregularities". A major premise on which this study can be based is that the value of any element of the water budget, as measured at a single point in a mountain region, is non-representative of the region as a whole. The basic datum for the study of mountain hydrology is the quantitative relationship among a number of such measurements, as they vary with altitude, or with slope, aspect, or angle - the slope of the gradient describing this variation. There is a clear need for an analysis of the spatial and temporal variations of water and energy budgets within the region, using both the available databases and the best-available concepts provided by studies in similar environments in other mountain ranges (IAHS 1982, Croft and Bailey 1964, Baker 1944, and Alford 1985). The current data limitations do not support such an analysis for water and energy budget for the Northern Areas. However, for future planning of water resources development and management such data have to be collected to suit the needs of the mountains.

1.4.4. Erosion and Sediment Transport

In an average year, the entire Karakoram and Trans-Karakoram region above the Partab gauging station yields 160 million tons of sediment. This is equivalent to approximately 640 tons/km2/year or 0.15 km3 of unconsolidated sediment (Ferguson 1982).

Figure 1: Water and energy budget for the mountainous ecosystems of the HKH region of Pakistan – a schematic layout.



There is a marked spatial variation in annual runoff and sediment yield. The Trans-Karakoram headwaters of the Indus River in Tibet and Ladakh, upstream of the Shyok confluence, appear to provide relatively little runoff and sediment, whereas the main Karakoram Range, extending across the Shyok, Braldu, and Hunza basins into the edge of the Gilgit basin, contributes disproportionately much more. The Hunza, in particular, yields 39 per cent of the total sediment load at Partab from only 9% of the area above that station. Erosion rates, as indicated by sediment transport data, vary by a factor of approximately six among the stations for which data are available. Some of this difference may be explained by differences in surface area, in that a larger basin provides more sites for intermediate storage of sediment in transport than does a smaller basin. The data generally, however, appear to correlate well with valley-to-summit relief differences among the basins and the glacier cover percentage. The relief provides the energy required for sediment transport while the glacial and peri-glacial moraines and alluvium are the source of much of the sediment (Ferguson 1982 and Goudie et al. 1982).

The average of 63 million tons of suspended sediment carried each year by the Hunza River is a very high load for a river draining only 13,200 km2. The mean yield on a per unit area basis is 4,800 T/km2/yr, about twenty-five times the global average. Comparison with other areas is complicated by the scale dependence of sediment load per unit area, as a result of increased depositional opportunities in larger basins. However, if load is compared against basin area to allow comparison of relative erosion rates in terms of vertical departures from the general trend, only two other mountain regions plot as high as the western Karakoram: the Nepal Himalayas and the southern Alps of New Zealand, both similar to the Karakoram in tectonic activity and glacier cover but each experiencing much greater annual precipitation as rain and snowfall. The only river system with an even higher erosion rate for its size is the middle Yellow River and its tributaries in the semi-arid plateau northeast of the Himalayas where thick loess (wind-blown dust) deposits are being dissected by gullying (Figure 2). The Yellow River is more comparable to the Indus River in terms of sediment load per unit basin area and the watershed environments.

Together, the Hunza and Gilgit rivers contribute almost as much sediment to the upper Indus basin as the entire eastern Karakoram that is four times more extensive. The denudation (erosion) rate for the entire Karakoram Region is over 1,000 tons/km2/yr (0.4 mm/yr) and the region contributes 40 per cent of the load of the Indus River from only 15 % of the total area. This denudation rate is very high by world standards, despite there being no recognised significant contribution from accelerated soil erosion resulting from human uses (Goudie et al. 1982).

1.5. Water Resources And Utilization

1.5.1. River Flows in the Indus Basin Irrigation System

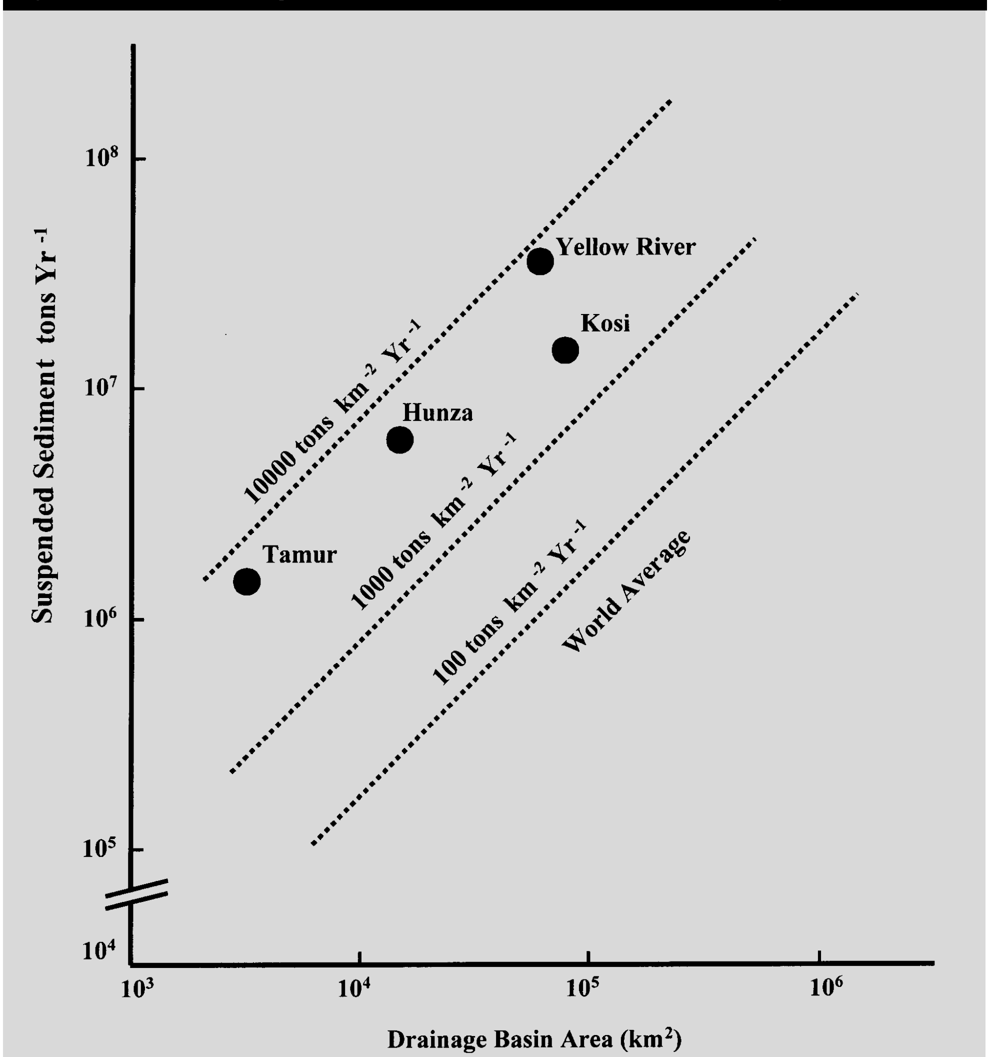
Variability in river flows of the Indus Basin Irrigation System (IBIS) is a major limitation in the development of run-of-river type irrigated agriculture in the Indus Basin, especially to meet crop irrigation requirements during low flow period of the Rabi season and early and late kharif season (WCD and Asianics 2000). Period of 1968-96 was considered to represent the post-storage inflows data for the probability analysis (Table 2). Indus rivers system provided 173 billion m3 of surface water in an average year during the post-storage period (Mangla and Tarbela). Bulk of the river flow was during the Kharif season, which was around five times the flow in the Rabi season (Ahmad et al. 2001).

Table 2: Variability of Rim-station inflows to the Indus Basin Irrigation System for the post-storage (Mangla and Tarbela) period (1968-96)

Probability (%)	Rim-station Inflows (billion m3) for Post-Storage Period 1968-96						
	Western Rivers			Eastern Rivers			Total
	Kharif	*Rabi*	Annual	*Kharif*	*Rabi*	Annual	
Minimum	94.0	19.9	114.9	2.3	0.0	3.6	118.5
10	111.6	20.4	135.5	3.7	0.9	5.3	140.8
25	124.2	24.0	153.2	5.1	1.1	7.1	160.3
50	136.0	27.1	162.1	8.2	1.6	10.7	172.8
75	148.5	29.5	180.9	12.7	2.4	15.4	196.3
90	159.7	32.8	189.6	18.5	3.4	20.1	209.7
Maximum	182.0	37.8	206.0	20.4	7.7	23.8	229.8

Source: Water Management Directorate, WAPDA.

Figure 2: Sediment rate per unit basin area of selected mountains regions of the world.



1.5.2. Upper Indus River Flows

The lowest annual river flows were almost half of the highest annual flows of the Indus River upstream of the Tarbela dam during the period of 1937-96. Similar trend was observed for seasonal flows of both the Kharif and Rabi seasons. The flows of the Kharif season were almost six times the flows of the Rabi season. The variability in seasonal and annual flows was mainly due to the variations in precipitation, topo-climates, temperatures, and snow- and glacier-melt. The mean annual flow in the Indus River upstream of Tarbela dam is around 75 billion m3, which constitutes around 43% of the total river flows available in the Indus basin (Table 3). The Northern Areas contributes around 72% to the flows of the Indus river at upstream of Tarbela. The contribution of Northern Areas in the country's water resources is of national significance and thus management of these resources should be given priority considering the increased value of water in the near future.

Table 3: Variability of inflows to the Indus River upstream of Tarbela Dam (1937-96)

Probability (%)	Inflows (billion m3) to the Indus River upstream Tarbela during 1937-96		
	Kharif	*Rabi*	Annual
Minimum	43.3	8.1	51.8
10	55.3	8.8	64.4
25	59.3	9.4	69.5
50	64.9	10.1	75.1
75	71.6	10.8	83.1
90	75.8	12.1	87.2
Maximum	88.7	15.3	100.8

Source: Water Management Directorate, WAPDA.

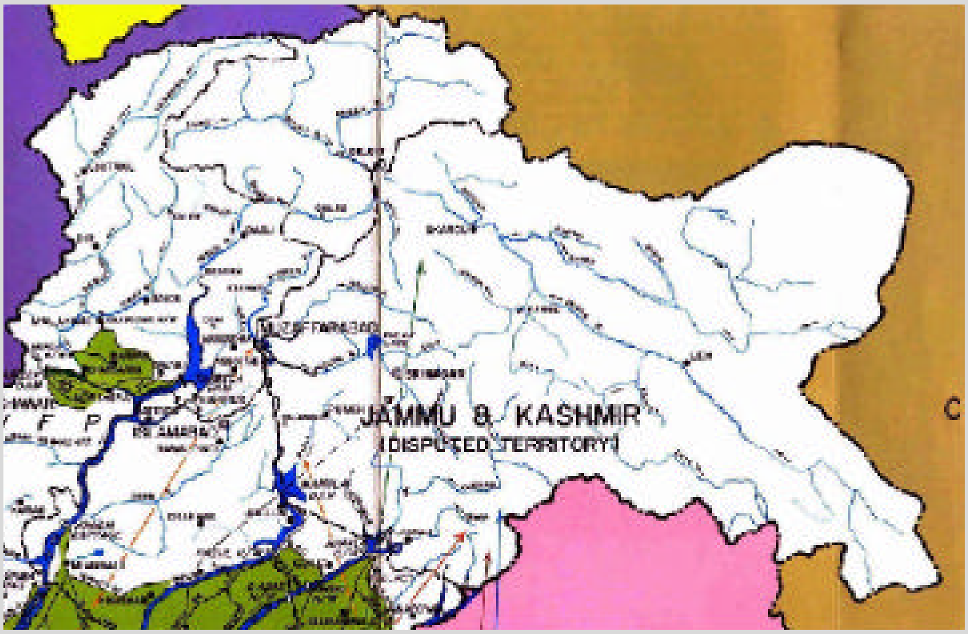
1.5.3. Water Resources of the Northern Areas

In the Northern Areas, water is drawn mainly from three sources namely precipitation, stream flow and spring water. However, the precipitation in the form of rainfall is so meagre that it hardly contributes for consumptive uses of water. Spring water is also limited and available under localised conditions. Therefore, stream flow provides the major part of the water use in the Northern Areas. Stream flows are diverted from streams and channels, which contribute to the tributaries of the upper Indus River. The layout of the tributaries of the upper Indus River is presented in Figure 3.

1.5.3.1. Precipitation

Precipitation in the form of rainfall is not sufficient to contribute significantly in meeting either crop water requirements or stream flows. The snow- and ice-melt are the major sources of precipitation contributing to the available water resources in the Northern Areas and in the upper Indus River. The low rainfall and aridity are the two major characteristics of the valley environments of the Northern Areas. The mean monthly and annual rainfall in the area ranges between as low as of 125 mm to 500 mm. The snowfall in the higher altitudes and in the glaciers environments sometime exceeds 2,000 mm.

Figure 3: Tributaries of the upper Indus River System of Pakistan



1.5.3.2. Stream Flow

Indus River system illustrates one of the major problems associated with estimating the hydrologic regime of many of the watersheds of the Northern Areas. At the headwaters of the upper Indus River in Tibet, mean annual precipitation is slightly more than 50 mm (Guan and Chen 1981), and the valleys through which the Indus River flows before reaching the Indus basin seldom receive more than 100 mm of precipitation annually. However, the Indus River immediately below the confluence of the Shyok and Braldu rivers has an annual runoff of 240 mm of water and, below the confluence with the Hunza and Gilgit rivers (Figure 3), an annual runoff of 370 mm. These tributaries, in turn, have annual runoff depths, which are often in excess of 1,000 mm. The Batura tributary to the Hunza River had a value of 1,570mm in 1970; a year of approximately average runoff, while the value for the entire Hunza river basin was 1,050 mm during that same year (Batura Glacier Investigation Group 1979). It is apparent that derivation of water budget for the Northern Areas, based solely upon the available precipitation data, would be extremely misleading and would have little value for guiding most types of environmental management strategies within any of the individual sub-basins of the Indus system. It is equally apparent that precipitation increases rapidly with altitude here, at least in the northern portion of the Indus basin within the Karakoram Range, but the extent of this increase has been the subject of only spotty and sporadic measurements (Dreyer et al. 1982 and Goudie et al. 1982).

Stream flow in the upper Indus River begins to rise marginally in March as snowmelt begins at the lower altitudes, but it is not until May, when melting begins at the altitudes of the glaciers, that significant increases occur. Between 40 and 70 % of the total runoff of the upper Indus basin and its tributaries occurs in July and August, when discharges are 15 to 40 times those in March (WAPDA 1979). The timing of this peak suggests an ice melt origin, which is supported by the fact that all significant tributaries are fed by glaciers. Spatial differences in average runoff appear to correlate with differences in the percentage of each basin covered by permanent snow and ice, while differences in the timing of the peak correlate with differences in the altitudinal distribution of this snow and ice cover.

Stream flow varies considerably from year to year. For example, runoff from the entire Karakoram Region (upper Indus plus Gilgit and Hunza rivers) was 370 mm in 1970 but 540 mm in 1973 (WAPDA 1979). Differences in the annual flow of the Indus, further downstream, have been related to winter snow cover as measured on satellite images, and by attempts made to forecast stream flow using this snow cover index, but there are complications with this approach. Runoff from the sub-alpine zone south of the Karakoram Range proper has a late spring snowmelt peak that ought to be bigger after an unusually snowy winter, but glacier-fed rivers normally have smaller discharges in the summer following the snowy winter because the lower and more slowly retreating snowline means a smaller ablation (melt) area. Annual variations in runoff from the Karakoram Range proper are primarily due to differences in July and August stream flow and these must represent changes in the storage term of the water budgets - fluctuations of glacier mass balance. These annual variations probably depend less on winter snowfall than on weather conditions and melting rates in the summer. A sunny summer thus can be expected to give higher runoff, at the expense of glacier storage (Paterson 1981). Stream flow will decrease abruptly when snowfall or prolonged cloud cover halts glacier melting. Year to year fluctuations of this kind may well apply over sufficiently extensive areas to affect regional runoff, but no attempts have yet been made to quantify this.

Seasonal variations in the discharge of the Indus River and its tributaries are not the only variations to be considered in any treatment of water resources' management or planning for the region. From time to time, the river's flow is affected by the creation of major natural dams as a consequence of glacier advances, mudflow, or landslide blocking. Flood waves, that have raised the level of the Indus River by as much as nine metres in only a few hours, have been related to the failure of such blocking (Mason 1930; Ives 1986). Hydrometric data for the upper Indus basin are summarised in Table 4.

Table 4: Surface water guaging stations and stream flow measurements in the upper Indus River of the Northern Areas

River	Station	Area	Mean Annual flows of upper Indus River		
		(Km^2)	(m^3/sec)	(mm)	(billion m^3)
Hunza	Danyor	13157	379	910	12.0
Gilgit	Gilgit	12095	287	750	9.0
Indus	Kachural	12664	990	270	30.2
Shyok	Yugo	33670	310	290	9.8
Indus	Partab	142700	1760	390	55.5

Source: WAPDA1979.

The Indus River at Partab gauging station contributes around 50.5 billion m3 to the mean annual flows, which increased to 75 billion m3 at the upstream of Tarbela. Thus contribution of the upper Indus River to the mean annual flows of the Indus River at upstream of Tarbela is around 72% - a significant contribution.

1.5.3.3. Springs

Spring water is available in the Northern Areas. Springs normally provide water for multiple water use but information on available resource in quantitative term is a major limitation. However, local communities have diverted spring waters for multiple water use. One of the beneficial aspects of spring water is that at the location of origin, the water is relatively clean and sediments are added only after the channel erosion during the transit stage.

1.6. Main Uses of Water

Water is life and thus it is an essential element for the human, flora, fauna, animals, ecosystems, etc. However, the water use can be described in three main categories namely water for agriculture, water for people and water for nature. The largest user of water is the agriculture sector in the country, where around 94% of water utilized annually is consumed by the agriculture sector. The water for people covers all aspects of domestic use in urban and rural areas. The water use for people constitutes around 4% of the total water use. Rest 1% is used for ecosystems (GWP 2000).

The water use for agriculture and people can be regarded as consumptive water use, whereas water for nature is regarded as non-consumptive water use except the flows below the Kotri Barrage, which cannot be retrieved even from groundwater due to quality concerns.

1.6.1. Water for Agriculture – Food Security

1.6.1.1. Mountain Irrigation

In the rugged mountains of Pakistan's HKH region, nearly all irrigation is done through *Kuhls*, small, often-lengthy channels usually constructed and maintained through the collective efforts of farmers and villagers. *Kuhls* carry water directed through a crude intake 'structure' from mountain streams fed by snowmelt, glacial melt, and/or springs for distribution through watercourses to clusters of small, often terraced fields, planted with food grains, vegetables, fodder, orchards, and trees. In basic physical appearance and characteristics, these *Kuhl* systems differ little from thousands of others encountered throughout the Indian and Nepalese Himalayas.

As one moves southwest, from the HKH along the mountain periphery of Western Pakistan into Chitral, the Tribal Areas, and the NWFP, elevations decline; larger valleys drained by such rivers as the Swat, Kabul, and Kurram interrupt the terrain; and annual precipitation diminishes significantly. Changes in the physical environment and accessibility are mirrored in variations in irrigation development. The familiar *Kuhl* systems are increasingly restricted to higher elevations and the upper ends of those favourably exposed tributary valleys where small perennial water sources are most likely to exist.

How extensive is the irrigated agricultural area in the mountains of Pakistan? What, collectively, is the command area of irrigation systems in this region? The answer to these questions would seem to be anyone's best estimate, considering the fact that formal surveys to assess cropped irrigated area or the command area of irrigation systems in this environment have never been done. Irrigation in Pakistan is dominated by the large canal systems dominating the Indus Basin, and readily available irrigation and irrigated agricultural statistics mirror this dominance. WAPDA's (Water and Power Development Authority) Directories for the provinces give detailed service area data for the Indus Basin systems, but completely omit any reference to irrigation outside that region. The most comprehensive review of irrigated agriculture in Pakistan in the past decade: the Revised Action Programme for Irrigated Agriculture, makes no mention whatsoever of irrigation systems or irrigated agriculture in Pakistan's mountain zones in either the main or supporting reports. Regrettably, the recently published Reports of the National Conservation Strategy (1992) and the National Commission on Agriculture (1988) are equally silent on the subject.

For example, in Gilgit District, in the Northern Area, nearly 19,000 ha were classified as cultivated area by the 1980 Agricultural Census, virtually all of which can be assumed to be irrigated. More than 9,000 ha of irrigable area apparently has been added to this figure by the irrigation system development activities covering 166 irrigation schemes supported by the Aga Khan Rural Support Programme (AKRSP) initiatives throughout 1987 (AKRSP 1987). Investigations recently carried out by WAPDA identified another 30 feasible irrigation schemes with potential to add a further 4,000 ha to the irrigable area in Gilgit (WAPDA 1988).

The literature on mountain irrigation systems in the Northern Areas of Pakistan - their characteristics, performance, management, and problems - is not extensive. In terms of system "types", available evidence suggests that small-scale surface irrigation systems - *Kuhls* - predominate, but in the larger intermontane valleys, large-scale systems are more important. In this background paper, the focus will be upon the *Kuhl* systems common to the Himalayan-Karakoram environment of the Northern Areas of Pakistan where a substantial programme of mountain irrigation development has been underway for around 20 years.

1.6.1.2. Mountain Irrigated Agriculture

The deep valleys cut by the Gilgit and Hunza rivers and their tributaries, as they drain the Karakoram Mountains, are the locus of permanent settlements in Gilgit District, in villages perched precariously on river terraces or the sides of alluvial fans often threatened by unstable talus just above. The climate is dry continental, characterised by a great range in average temperatures (45 ºC or more between January and July) and meagre annual precipitation averaging 145 mm/year in Karimabad and 129 mm/year in Gilgit. Moreover, annual variability anywhere in the world is high in regions that are largely in the rain-shadows of the greatest concentration of mountains in excess of 6,000 meters. Only at higher altitudes (above 3,000 m) where more precipitation falls and is accumulated as snow, do annual amounts substantially exceed 500 mm.

Throughout Gilgit District - and elsewhere in the Northern Areas and Chitral District - agriculture depends upon irrigation water supplied through small, farmer-constructed, gravity-fed systems. Water in these irrigation systems is derived primarily from snow or glacial melt. Less frequently, they are fed by perennial springs, the scarcest but most reliable water source, or by small rivers.

Generally, glacier-fed irrigation channels show the least year-to-year variability in discharge. However, water from glacial melt often carries large quantities of suspended silt much of which is subsequently deposited in the farmers' fields as a mixed blessing. During the period of seed germination and seedling growth, there is the risk that seeds will become buried too deeply to achieve a satisfactory germination rate or that seedlings will become coated with silt, inhibiting normal metabolism (Saunders 1983). On the other hand, silt is often important in the soil-building process, especially for improving soil structure.

Although channels supplied by springs dependent upon winter-spring recharge reflect some discharge variability, perennial spring water has several advantages over other irrigation sources. It is free of silt, it does not experience great variability, and, as noted by Whiteman (1985), it may be "up to 5 ºC warmer, and this has a significant advancing effect on spring growth" of crops. Springs, however, are a scarce source of irrigation water in the region.

The greatest flow variations are found in channels exclusively dependent upon snowmelt, the least reliable irrigation source. Farmers from snowmelt-dependent villages report a severe shortage of irrigation water once every 4-5 years and general problems of considerable year-to-year stream flow variability.

River-fed irrigation systems are also more vulnerable to annual variations in precipitation and are affected by seasonal fluctuations in river flow as well. A channel intake structure constructed to divert river water for irrigation during crop planting in March may be inundated or washed out when glacial melts subsequently increases river discharges in May-June. Later in the summer, the river diversion may have to be relocated further upstream to sustain irrigation supplies as river discharge diminishes.

Capturing water for irrigation is only part of the task of establishing and sustaining agriculture in the Northern Areas. Equally, perhaps even more arduous, is the concomitant and longer process of land development. In bringing land under the cultivation of principal crops for human and animal consumption - grains (wheat and barley), vegetables, potatoes, fruit trees (apricot and apple), fodder (alfalfa), and trees for fuel and fodder (poplar, willow, and Russian olive) - soils have been drastically modified.

In this region, irrigated crops are largely confined to three landform environments and their associated soils. In the valleys of the Hunza River and its tributaries, river terraces and alluvial fans have the greatest agricultural significance. The deeper and better-developed soils found on old river terraces are more important than those on terraces of more recent origin. The lower portions of alluvial fans, formed by small streams and hill torrents, are more intensively cultivated than the upper areas, because of the small proportion of coarse soil materials found there. In either instance, better soils are commonly the locus of grain and vegetable crops as well as orchards. Poorer, less developed soils tend to be used for fodder crops and trees for fodder and fuel.

Cone-shaped scree slopes produced by mass wasting of the surrounding barren cliffs and hills below 2100 meters are another locus of irrigated agriculture. However, because of the inherent instability of these slopes, their agricultural development presents special problems and tends to be both more recent and slower. The upper portions where finer materials are concentrated are cultivated first, usually with slope-stabilizing trees and fodder crops.

1.6.2. Water for People – Health Security

1.6.2.1. Domestic Water Supply

Glaciers and snow deposits are the principal sources of all water in the Northern Areas. The melted water enters streams, which subsequently feed man-made channels – *Kuhls* – that bring water into the settlements for agriculture, livestock and domestic requirements.

The water supply sector in Pakistan is characterised by extremely low level of coverage particularly in the rural areas. Presently, only 80% of the urban population has access to the piped water supply, whereas 11% of rural population is benefiting from this facility (GWP 2000). The situation is not better in the Northern Areas as the coverage of piped water supply claimed is only 40% but in reality it might be less than half. However, these systems are becoming more common in the Northern Areas as most settlements are established on slopes and thus the piped water supply systems can be operated by gravity. The observations indicated that many of the systems are either completely out of order or need some sort of rehabilitation (WSHHSP 1996).

The water supply systems in the urban centres of the Northern Areas are based primarily on the utilisation of surface waters. Groundwater use for domestic water supply is not common except in the low lying settlements in Gilgit town and a few riverside villages in Skardu and Chitral, where people draw water from shallow wells. Most of the urban centres depending on surface supplies face moderate to acute shortage of water during the winter months when the snow- and glacier-melt is reduced.

The rural areas of the region depend mainly on their irrigation channels – *Kuhls* – for the supply of water for domestic use. Water from the *Kuhls* is stored into small water pits, locally called Gulko, Sardawani and Chudong. These pits are filled from the *Kuhls* water and are usually 2-3 m deep and about 2 m in diameter. The benefits of the water pits are manifold including storage, temperature control and reduction in turbidity of water. Water from these pits is generally reserved for drinking and cooking purposes. The supply during the winter months is reduced due to reduced snow- and glacier-melt, which affects the quality of stored water. In summer months the pit water is replenished more frequently.

Table 5: Microbiological quallity of drinking water in water delivery systems of Northern Areas

Category	Percent of Samples Collected	
(E. coli per 100 ml)	Before Intervention	After Intervention
0	11	65
1-10	5	17
11-100	18	16
101-1000	48	2
>1000	18	0

WSHHSP (1996) concluded that all the improved and traditional water sources are contaminated with human and animal wastes. The results indicated that before the intervention only 11% samples were acceptable for domestic water use, whereas it was increased to 65% of the samples after the intervention (Table 5). Seasonal variations in contamination levels were also observed, where higher levels of contamination were observed in the water delivery systems during the summer season. It was also noted that the contamination levels in the delivery systems were comparatively lower during the winter season but higher faecal contamination levels were found in household water storage pits. The important factor affecting the water quality is the human and the animal activities in the surrounding of the water delivery systems.

Water quality at the source of the system was good but the faecal contamination level increases as these water channels enter into the inhabited area. High levels of contamination were observed in samples collected from the tail ends of the delivery system. Water pits also contribute to the contamination primarily due to in appropriate location and lack of proper disposal of animal and human waste especially in the rainy season (WSHHSP 1996). The results are in line with studies conducted in other parts of Pakistan. The water quality in the storage vessels is also in line with the water quality at source (Table 6).

Table 6: Microbiological quallity of drinking water in water storage vessels of Northern Areas

Category (E. coli per 100 ml)	Percent of Samples Collected	
	Before Intervention	After Intervention
0	17	35
1-10	9	39
11-100	21	21
101-1000	35	5
>1000	18	0

Spring water was found to be safe compared to other traditional water sources. However, some of the springs were highly contaminated with chemical and biological contaminations (WSHHSP 1996).

1.6.2.2. Sanitation

The coverage for sanitation in Pakistan is lower than the water supply coverage i.e. 60% and 14% in urban and rural areas, respectively. In most of the cities in Pakistan, the wastewater from the municipal areas as well as the effluent from the industries are disposed of untreated to the natural water bodies (GWP 2000). The situation in Northern Areas is not better than the rest of the country.

In some of the urban centres of the Northern Areas, sewerage system consists of sewage collection and disposal. Sewage is collected through RCC pipes and open drains. The collected sewage is disposed to nearby water bodies through gravity. In areas where sewage collection system is non-existing, sewage is discharged into groundwater through soakage wells, sometimes even without passing through septic tanks. In rural areas the proper collection and disposal system is almost non-existing.

Presently, the treatment of effluent waste in the Northern Areas is almost non-existence on the municipal front. Even in other areas of Pakistan, where such treatment plants have been constructed those are not in operation due to high O&M cost, especially due to the higher energy cost.

1.6.3. Water for Nature – Ecological Security

The use of water for agriculture and people will have serious implications on the ecology and environment of the Northern Areas. The water of the Indus River and its tributaries is of excellent quality. The total dissolved solids (TDS) range between 60 to 374 parts per million (ppm), which is safe for irrigated agriculture, domestic and industrial uses. The TDS in the upper reaches of the Indus River range between 60 ppm during high flow to about 200 ppm during low flow (GWP 2000). The use of chemical agriculture, fertilisers and pesticides, and the untreated sewage effluents are causing deterioration of water quality and such hazards would further increase in the future.

The human interference to the water streams in the Northern Areas has contributed towards accelerated channel erosion, which affects the quality of water - turbidity. However, in most of the watershed area plantations cannot be established without irrigation due to extreme arid climate. Erosion in the watersheds of the Northern Areas is normally due to the geologic erosion. Therefore, very little can be done to control the sediment flow into the water channels.

Indus valley is one of the six major internationally accepted migration routes for birds. There are at least 14 major lakes of national and international importance. These wetlands provide resting areas and feeding grounds along this migration route. Fears have been expressed that the reduced flooding and discharge of polluted drainage effluents into these water bodies may adversely affect wetlands ecology (GWP 2000). Although none of the wetlands of the Northern Areas are declared as Ramseur sites, however, these wetlands are important to maintain the existing ecosystems and environment. Rather these sites have to be further managed for tourism and recreation purposes. The wetlands of alpine and sub-alpine zones of the Northern Areas are important for maintaining the natural ecosystems of the mountain environments. These wetlands are unique in the country as they represent highlands, where snow- and glacier-melt contribute to the wetlands – coldwater wetlands, which are different than tropical wetlands of the Indus basin.

1.7. Water Resources And Environmental Management

In the context of factors affecting the flow of water through a watershed, the "environment" may be defined as: a) climate; b) geology; c) topography (or terrain); and d) vegetation. Environmental management, from a water resources' perspective, is a matter of determining the extent to which a change in any one, or some combination, of these factors will produce a corresponding change in the timing, volume, or quality of water flowing through the watershed. Alternatively, it is a matter of inducing a change in one or more of the factors so as to produce some desired change or correct a perceived imbalance. Environmental interactions are complex, and at least two of the factors -- climate and geology -- cannot be "managed" in any meaningful way due to the site-specificity of the Northern Areas. In the case of these two factors, it is essential to understand how each relates to the water and sediment balance of a watershed, but the only realistic management alternative is to make allowances for the prevailing conditions of climate and geology in the management planning. In every case, from a water resources' perspective, the primary goal of environmental management in the Northern Areas should be to understand the interactions within the environment well enough to predict, with reasonable accuracy, the probable outcome of any particular course of action.

Almost without exception, water resources' development or management projects in the Northern Areas are based upon an understanding of the water regime derived from a limited database. It is critical to be able to extrapolate these data spatially in order to understand the significance of any form of environmental manipulation for water resources. Extrapolation techniques have been proposed for the mountain environment, but they have not been widely tested in the Northern Areas. At the same time, individuals citing environmental monitoring instruments in mountain watersheds of the region rarely are aware of the diversity of the environment that surrounds them.

Water is an integral aspect of all facets of the mountain environment in the Northern Areas and enters into virtually every resource development or management project in some way. All disciplines involved in resource planning or management have developed numerous technologies for modifying the natural characteristics of volume, rate, timing, or quality of water at a site. Basically, all technologies are variations of a few basic themes: storage of water during a period of surplus for use in a period of deficit, transfer of water from an area of surplus to one of deficit, or improving water quality. While there are only a handful of ways in which the hydrological regime of an area may be changed beneficially, in practice, there is a virtually endless number of variations, combinations, and permutations of these basic themes (Dunne and Leopold 1978).

For most environments, such as forests, or grasslands, or deserts, entire literature is rich with discussions of appropriate technologies to modify the timing and volume of water flows. As the list of environmental elements considered grows linearly, the list of possible technologies to modify the water associated with that element grows exponentially. This means that any discussion of water resources' technologies, within the context of environmental management, is essentially open-ended. For this reason, the discussion in the background paper will deal with the basic concepts involved in individual environmental factors, rather than with specific technologies designed to deal with a specific problem in a particular location.

A major difference between mountain and lowland environments is related to the extent of spatial environmental uniformity -- the degree to which the characteristics of one place in the watershed may be predicted by studies in a second place. Environmental management procedures, which are successful in one part of the watershed may be transferred to another place with some degree of confidence. In a highland watershed, on the other hand, the distinguishing environmental characteristic is spatial heterogeneity. Two points within the watershed of the Northern Areas, separated only by a distance of a few kilometres, may differ from one another. The central dogma of a successful manager of mountain environments will be that measurements are not necessarily valid for any point other than the one at which they were made. A project that succeeds completely at one point within a mountain watershed may be much less successful at another. This demand that each environment in the Northern Areas must be treated in its own context and thus need for planning is much more vital than the lowlands.

1.7.1. Uncertainty in Environmental Management

For at least a portion of the Northern Areas, much has been made recently about the problems of uncertainty associated with the information upon which resource management or development decisions must be based. It has been argued that this information is fundamentally unsound, incorrect, in some cases even manufactured, and, perhaps, given the political realities and poor institutional linkages that characterise environmental management and development in the region, irrelevant.

In the case of the physical environment that determines the availability of water and the variations among elements of the hydrologic cycle over the region, reproducible information is provided by time-series' measurements made continuously by recording instruments, from periodic observations, or from geodetic surveys of watersheds. The instruments may be stream-gauges, precipitation gauges, or thermographs. The geodetic surveys result in the preparation of topographic maps. There are problems with the accuracy and representativeness of these types of data, but these problems are dealt with extensively in the literature on climatology, hydrology, and geodesy. Standard tests exist for determining, at least, the internal consistency of such data (Miller 1981 and Ward 1975).

There is no doubt that errors do exist in the hydro-meteorological database for the Northern Areas, just as they exist in databases for all of the major mountain ranges on earth. The challenge to the scientist studying this environment, or to the environmental manager or planner, is to use these data in as effective a manner as possible. This effectiveness will stem more from the conceptual models that are used in the planning or management process than from the absolute accuracy of the data (Baker 1944). The problem is not with the "uncertainty" of the database but with the ways in which the data are organised, interpreted, and used to develop management policies (Dunne and Leopold 1978 and Alford 1987).

The information on which this background paper is based has been taken from a variety of sources, including the hydro meteorological data collected by WAPDA and Pakistan Meteorological Department, and it presumably has varying degrees of accuracy. It has not been possible in most cases to analyse the original data sources and so the absolute accuracy could not be determined. Every attempt has been made to ensure that the data used possessed internal consistency. Patterns of precipitation and runoff, as reported in the literature, were compared to ensure, at least, qualitative agreement.

1.8. Gaps in Information and Reliability

The historical information regarding water resources, requirement and use is not available and thus different agencies and people make judgements. For example Indus River flows data at different points in the Northern Areas is available. However, such data do not provide any information regarding the water use in the Northern areas, as the water is diverted to *Kuhl*s prior to reaching to the Indus River or its tributaries. Thus all water use diversions in the Northern Areas are being done upstream of the Indus river tributaries prior to their entry to the Indus River. Therefore, water use in the region is over and above the average Indus River flows of 55.5 billion m3 at the Partab gauging station. The reliability of Indus river flows data in the upper reaches and at the upstream of Tarbela is reasonably high.

The climatic data reliability is also reasonable but such data do not provide any information regarding the availability of water in the region. The data regarding snow- and glacier is limited or non-existent. Only three meteorological stations for snow gauging have been established by Pakistan Meteorological Department and WAPDA in the Northern Areas at altitudes higher than 3,000 m with the assistance of CIDA. These stations provide point precipitation. Therefore, very little information can be generated out of these three stations.

Reliable estimates of command area or irrigated area are also not available. Similarly, information regarding water losses in the *Kuhls* is also not available. Thus management of water in the *Kuhl* system is difficult. Therefore, reliable estimates of the water availability and the command area of the *Kuhl* system are needed to improve water management in the region.

2. ISSUES AND TRENDS

2.1. Key Issues

Augmenting the quantum of useable water resources is a pressing need for the Northern Areas and for Pakistan in the face of the rising population, which by conservative estimates would increase by 2% per annum in Pakistan for the next 25 years (GWP2000). For Northern Areas higher rate of population growth is expected and thus it might increase by 3% per annum for the next decade. What this implies is that, just to maintain the present level of usage per capita and the productivity per unit of water by the end of the next decade (2011), the present water diversion would increase by at least 3%. Thus for the next decade, there is a need to have additional water diversion facility of around 34% for agriculture and domestic water requirements within existing framework of operation and maintenance.

2.1.1. Water Resources Development and Management

Even though large quantities of stream flows are being diverted for irrigation and domestic water needs, they are subject to the wide variations in the stream flows emerged from snow- and glacier-melt – which cause seasonal water shortages in the water conveyance systems for irrigation and other uses. This situation, representing the dependence of the water conveyance systems on stream flows, is not conducive for the most productive use of water for agriculture, as effective irrigation systems have to be designed and operated on demand basis.

There is also ample evidence that large quantities of water are lost in transit in the irrigation and other systems. The research studies revealed that water conveyance losses in the Indus basin system are in the order of around 50% (Ahmad 1999). These losses are even more in the Northern Areas and there are extreme cases, where these losses exceed 70% (Personal Communications with Director KARINA). Once the water supplies have been conveyed for their intended use, their utilization is subject to waste and whatever use is made is not the most productive. In agriculture, shortage of water at tail ends and inefficient irrigation applications in the *Kuhl* commands, and in municipal systems typify this waste by the wasteful use of water. The key issues are listed as under:

- Managing the shortfall in supply and demand of water for various sectors i.e. agriculture, urban and rural domestic water supply, ecosystems, etc, including the management of seasonal shortfall in water supply because of reduced snow- and glacier-melt in the late winter season (March to May);
- Harnessing of additional water from: a) either stream flows to meet the demand and to the extent such diversions are feasible; or b) through minimising the losses in conveyance of water in open channels for multiple water use; such losses are primarily due to the rugged mountainous terrain, gradient of the channel and extremely high infiltration rates;
- Improving adequacy, reliability, equity and equality in water availability caused primarily due to inappropriate water allocation and distribution;

- Effective maintenance and cost-recovery of water systems;
- Development of cost-effective hydel-power systems for water lifting using effective technology in terms of water and energy efficiency;
- Minimising effects and impacts of water development and management on other sectors like biodiversity, fisheries, agriculture, tourism, and recreation.
- Participation of water users is essential in operation, maintenance and cost recovery for irrigation and domestic water supply systems.

2.1.2. Water for Agriculture – Food Security

Water is an essential element for any form of agriculture in the Northern Areas. Almost all the agricultural production from the area is derived from the irrigated agriculture. Thus future growth of agriculture would depend on the development and management of water in the Northern Areas.

The relatively larger *Kuhls*, which were expected to provide a reliable source of irrigation supplies, have been falling in disrepair and their effective operation has become increasingly difficult due to number of reasons. The result is that there is a lack of reliability and equity in distribution of water, which has forced the tail-enders to reduce their command area. The important aspect is that due to heavy load of sediment in the stream flow and frequent landslides, there is a genuine need to maintain the *Kuhl* system much more frequently compared to the similar systems in other areas.

On the institutional front, the realisation for managing the system to meet the demand is just started. Providing technical backstop support to water users is no body domain. The line departments i.e. agriculture have yet to realise fully that the provision of technical backstop in water use and management of the *Kuhl* systems is equally important than that of the development of the new *Kuhls* or rehabilitation of the existing *Kuhls*. Deferred maintenance often results into rehabilitation of such systems. The success of the AKRSP programme is a good indication of the willingness of the water users' in organizing participatory irrigation management programme due to the rehabilitation requirement for the *Kuhl* systems. The enhanced technical support to the water users in the use of water and management of the *Kuhl* systems and realisation by them would provide desired results in terms of water productivity. For increasing the future agricultural production, to meet the demand of a growing population, the relevant key issues are described as under:

- Increasing the quantum of water supplies for agriculture;
- Realising the highest feasible agricultural productivity of water in through development of appropriate water use and crop production practices;
- Meeting the crop water requirements by conjunctive use of stream flows and rainfall, by effectively operating (well designed and well constructed) *Kuhl* systems;
- Preserving a productive irrigation environment by reducing the chances for extreme seepage and breaches due to the deferred maintenance.
- Participation of water users' is essential in irrigation management and cost recovery systems for irrigation water supplies.

2.1.3. Water for People – Health Security

According to the 1998 Census Report, the existing population of Pakistan is around 131.5 million with urban and rural population of 30% and 70% of the total population, respectively. With the shift of the population from the rural to urban areas, it is anticipated that by the end of 2011 (over the next 10 years), the urban population would increase by 40 percent in Pakistan, which would require around 40% increase in water requirement (GWP 2000). The increase in urban population growth in the Northern Areas during the next decade might be more than the average rate of population growth in the country. Thus in the urban centres of the Northern Areas, water supply and sanitation requirement would have to be greatly expanded. Therefore, it is safe to predict that domestic water requirement for the urban centres of the Northern Areas would be in the order of 50%.

The future domestic water supplies in the Northern Areas would have to depend largely on surface water. This would place a great challenge for the management of surface water, which is conveyed through open channels, and thus the water quality is threatened by pollution. The key issues related to the sub-sector on domestic water use are as under:

- Meeting the needs of the growing population representing competing demands for water, especially for the urban centres having 50% increase in population size in the next decade;
- Provision of safe water supply to urban and rural population due to increased health security measures and population increase;
- Providing safe disposal of the sewerage, agricultural and industrial effluents;
- Participation of water users' is essential in managing domestic water supply and cost recovery systems.

2.1.4. Water for Nature – Ecological Security

The competing demands from various sub-sectors of water would raise serious limitations to maintain the ecological balance. The right of water streams to flow and to provide water for wetlands will be affected adversely due to harvesting of water for other competing uses. In fact, the objectives of various sub-sectors of water are conflicting. The increase in population has also threatened the systems of water conveyance due to the disposal of sanitation and agricultural effluents into the water streams. The increase in the use of pesticides and chemical fertilisers have also resulted in to serious impacts on aquatic systems i.e. fish, etc. The key issues related to the sub-sector are as under:

- Managing water quality of surface water systems;
- Appropriate disposal of sewage and agricultural return flows;
- Management of water streams and watersheds;
- Management and upgradation of wetlands.

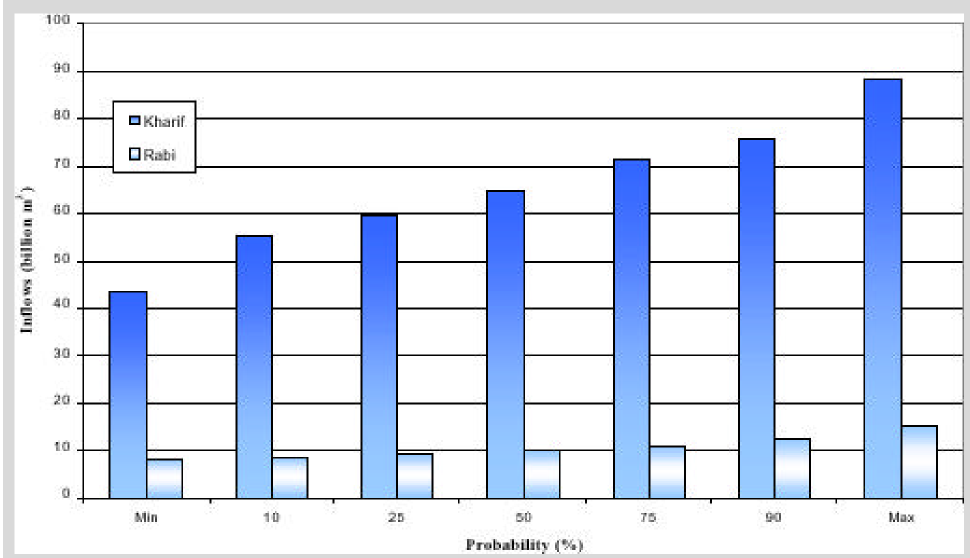
2.2. Trends

2.2.1. Indus River Flows Variability (Supply)

River flow is a stochastic process instead of a deterministic process. Therefore trends in terms of time series would not provide any meaningful information. Thus probability analysis was made for the Indus River flows at the upstream of Tarbela (Figure 4). The high variability in river flows poses serious threats for development and management of water in Pakistan and in the Northern Areas. The main issues are listed as under:

- River flows in the driest year were half of the wettest year; and
- Kharif season flows were around six-fold of the Rabi season flows.

Figure 4: Variability of inflows in the Indus River upstream of Tarbela dam during the period of 1937-96



Higher variability in flows and seasonality poses serious threats to the development and management of water. The question is that what is the sustainable level of water development, whether it should be based on average (50% probability) or 25% probability. Average flows mean that these flows will not be available for 50% years, whereas 25% probability means that these flows will not be available for 25% years. Thus the 25% probability is more sustainable level for the Northern Areas, because of lack of groundwater and aridity. Otherwise the farmers have to suffer during the dry years. It is better to have water development at sustainable level and than manage it more effectively.

2.2.2. Increase in Water Requirement (Demand)

Reliable time series data are not available regarding cropped area under the *Kuhl* systems and thus it is not possible to estimate actual crop water requirement. The other problem is the lack of sufficient climatic data to estimate crop evapotranspiration. However, some indicative information can be given based on the population growth rates. It is expected that population in the Northern Areas would increase at a rate of around 3% per annum during the next decade; therefore, increase in water demand would be around 34%. The increase in water demand to meet the requirement of the increasing population would have to be taken care from either increase in new irrigation facility or increasing the cropping intensity in the existing commands or through increasing productivity of existing crops.

It is estimated that increase in water demand for the domestic water sector would be around 50% during the next decade. Higher increase is expected due to increase in population of the urban centres because of the migration from the rural areas and realisation to have access to the safe drinking water and access to sanitation. This increase is in line with the expected 40% increase in Pakistan as a whole (GWP 2000).

The water demand for ecosystems would also increase due to higher awareness for conserving the biodiversity and other natural resources.

The competing demands from various sub-sectors like agriculture, domestic and ecosystems would require management of water to meet the conflicting objectives. Thus there is a need to have more effective distribution and allocation of water among different sub-sectors.

3. CONSEQUENCES OF INACTION

Relevant drivers like population growth, economic and social factors, technology, environment and governance, as presented in the previous section, guide the actions needed to address the key-issues. A 34% increase in population at the end of the next decade is expected with major shift to the urban areas. These issues also cover the pertinent elements for a sustainable water strategy – welfare of the people and equity, economic growth and development, efficient water use, sustainability, environment, policy and institutions.

Key-issues can be categorised under two broad areas of interventions namely water development and water management. Water development mainly refers to the harnessing of additional water supplies to meet the increasing demand of various sub-sectors. Water management largely refers to the management of existing and new systems in terms of reliability, equity, efficiency, productivity and sustainability of these systems to meet the demand of various sub-sectors. These two major areas of thrust have to be addressed to meet the domestic, agricultural and ecological needs of the Northern Areas to have security in terms of food, health and ecological aspects. Deferred maintenance of water systems always result into deterioration to an extent where major rehabilitation works are required. The core objective of water sector in the next decade should be to improve maintenance and management of the existing systems to reduce investments for building new water development systems. Construction of new irrigation schemes is normally capital intensive and time consuming.

Country is facing water drought since the last three years. In addition to this, there are serious financial constraints, which do not provide sufficient flexibility to initiate new irrigation schemes to meet all the future water needs. Thus higher priority has to be assigned for management of water in the short- and medium-term investments, whereas construction of new schemes can be considered for long-term investments. The inability or inaction to address the key issues in the water sector of the Northern Areas would result in serious threats to the water security in terms of food, health and ecological perspectives. Ultimately, this will result in the security concerns of the Indus basin irrigation system. The consequences of inaction are summarized as under:

- Mounting shortfalls in food production leading to more imports of food items from downstream areas of Pakistan. This would ultimately increase the burden on the exchequer of the federal government for higher subsidies for food items. Failing to provide higher subsidies on food items might lead to a famine like situation in the Northern Areas. This would also result in malnutrition, as poorest-of-the-poor will not be able to afford the balanced diet.
- In adequacies in municipal water supplies and sanitation leading to the pollution of water resources and deteriorating health standards. Mortality and Morbidity rates of the vulnerable sections of the population will increase. There are chances to have more dependence on hospital and medicine support to handle water-borne diseases, which is not a sustainable solution.

- Dependence on irrigated agriculture and depletion of the biodiversity and natural resources leading to increased silting and scouring and increased variability of flows.
- There are chances that some of the existing command areas might loose the chance of receiving water for agriculture and domestic purposes.
- The dependence on chemical agriculture leading to the deterioration of aquatic ecosystems i.e. trout fish, fauna, etc.

In the face of inaction scenario, there are serious implications for sustaining the resources of water (snow- and glacier melt), which is essential for the Indus basin irrigation system. Therefore, consequence of inactions to address the key issues should not be seen in the context of only the Northern Areas but also in the light of country's water resources and the irrigated agriculture.

4. CURRENT INITIATIVES

4.1. Water Resources Development

4.1.1. Village Irrigation Systems

Initial irrigation system development in the Northern Areas (Hunza, Gilgit) was a highly localized activity, concentrated in locations where water from glacial and snowmelt sources was easily developed by small groups of farmers using locally available technology and resources. Later, traditional chiefs, such as the Mirs of Hunza, began to exercise their growing feudal authority to mobilize a larger population for the construction of new Kuhls in more difficult locations, rehabilitation of older systems, and development of new land. Although a portion of the increased production resulting from enhanced and more reliable water supplies was extracted by a compulsory agricultural tax, the Mirs did initiate the irrigation development and modest settlement expansion where smaller, isolated group efforts could not. Following the arrival of the British-supported Dogra administration in Gilgit in the 1880s, a gradual decline in feudal authority began, accompanied by a reduction in irrigation system development. This trend continued after the independence of Pakistan until 1974 when the authority of the Mirs and Chiefs was formally abolished.

Beginning in 1982, the AKRSP has had an active programme of rural, institutional, and physical development, which has renewed irrigation development activities in the region with active participation of water users. In Gilgit District alone, hundreds of irrigation projects - improvement of older systems or development of new systems – were completed in villages through AKRSP - supported interventions.

A survey conducted by WAPDA in Gilgit and Hunza-Hispar River sub-basins identified 221 Kuhls supplying irrigation water to agricultural lands (WAPDA 1988). So far, most Kuhls have perennial flows, but seasonal discharge variations between low and high flows as great as 20 times were reported, reflecting that in more than 85% of the surveyed localities, the water source for the Kuhl systems was a combination of snow- or glacial-melt and springs (Velde and Hussain 1988). Kuhls, identified in the survey, varied greatly in channel length between source of water supply and command area, from a more typical 2-3 km to as much as 18 km in the case of Parri Kuhl. They also varied substantially in size. The discharge range between the smallest Kuhl and the largest was 7 lps (0.25 cussecs) to 425 lps (15 cussecs), although more than one-half of the Kuhls carried discharges between 7 lps and 28 lps (1 cussecs).

For systems in the 44 villages covered in the survey, it was possible to calculate the relationship of water supply per unit of cultivated area. In slightly less than one-half of these villages, the Kuhl systems delivered less than 0.75 lps per cultivated hectare (<6.5 ha/mm/day), ranging as low as 0.13 lps/ha (1.1 ha/mm/day). At such water supply levels, water is apparently scarce relative to land, and one would expect the system and field-level water management practices to reflect such conditions. For seven other villages, the systems supplied between 0.75 lps/ha and 1.25 lps/ha (10.8 ha/mm/day). In general, the Kuhl systems in the Hunza-Hispar villages varied more widely in the Gilgit River sub-basin. Also, for roughly one-third of all the villages, the Kuhl systems apparently supply water in relatively abundant amounts. This suggests that in those locations, land suitable for agriculture is scarcer than water.

4.2. Change in Mountain Irrigation Systems

After a generation or more of comparative quiescence, the 1980s have heralded in a period of renewed activity and change for farmer-managed irrigation systems in the Northern Areas of Pakistan, primarily in response to the AKRSP's rural development programme. Although there is evidence from systems surveyed in Hunza-Gojal of the continued vitality of proven ways to solve problems, and of carefully adjusting new systems to fit environmental conditions, it is also clear that there has been both institutional innovation and considerable farmer-initiated experimentation to modify the previous irrigation development practices or techniques. In the following discussion, a few examples that substantiate these observations are described.

4.2.1. Channel Construction

Successful irrigation channel construction in Hunza now involves a combination of local wisdom (knowledge derived from generations of past experience) and contemporary engineering technology. Alone, neither the source of knowledge nor skills is any longer sufficient to guarantee success. Instead, the failure to utilize both, frequently leads to the construction of poorly performing or failed systems, typically after an expenditure of substantial and scarce resources. The traditional method of determining the slope of a channel was the use of water as a level. Beginning from the source, water flowed along the channel as it was dug on a carefully estimated but un-surveyed line, with the objective of achieving the desired command. The approach "worked" as long as the scheme was physically possible. Thus, village elders were commonly consulted for advice on past glacial movements, avalanche and mud flow paths, and stream flows from glacial and snowmelt or springs. However, if an impassable outcrop was encountered during construction, or the velocity of water flow dropped so low that command was lost (conditions often discovered only after km of channel had been constructed), the project had to be redesigned or abandoned (Hudson 1983)

Alone, modern engineering science frequently has produced scarcely better results. In the mountainous environment of the Northern Areas, where physical conditions vary greatly within short distances, or from one season to another, the failure of engineering surveys and irrigation designs to draw upon detailed local knowledge greatly increases the probability of failure. The high proportion of unsuccessful irrigation channels in Gilgit District, designed and constructed by the Northern Areas' Public Work Department since 1974, without local consultation or participation, substantiates this conclusion.

In its intervention strategy of assistance to farmer-managed irrigation system development, AKRSP purposely links local knowledge with modern engineering skills in the planning, design, and construction of new Kuhls. Joint surveys of new systems' or improved systems' sites are done by engineers and knowledgeable farmers from the village and may involve several field visits. During channel construction, frequent consultation continues between farmers and AKRSP engineers to solve unanticipated problems. This collaborative approach has resulted in the successful implementation of several irrigation projects in Gilgit District, previously thought too difficult to implement. Two such projects have been constructed in the surveyed villages of Passu and Soust (Velde 1989).

4.2.2. Innovation in System Design Parameters

From the perspective of agency intervention in, and technical assistance to, small-scale mountain irrigation systems in the Northern Areas, the AKRSP's success in using a strongly participatory strategy that draws upon local knowledge and experience is possibly the innovation with the greatest long-run significance. The design criteria for irrigation channels assisted by AKRSPillustrate the value of such an approach. Following a survey and measurement of bed slope and conditions in older farmer-managed Kuhl systems in Gilgit District, empirically-based parameters were adopted and used as basic design criteria for new systems (AKRSP 1987). The stimulus for this change, at least in part, was the visible evidence of the failure of previous government-constructed irrigation systems in the Northern Areas where engineers had used "textbook" standards that were more appropriate to environments outside this region. The general farmers' satisfaction with and apparent absence of failure in AKRSP-assisted systems is firm evidence that studying existing Kuhl systems and skilfully drawing upon farmers' past irrigation experiences are valuable complements to modern engineering science in developing new mountain irrigation systems (Velde 1989).

The analysis made by Velde (1989) is partially correct. In fact, it is not the failure of the engineering techniques but rather failure of approach based on inappropriate techniques used by the public-sector professionals. Commonly the concepts of mountain engineering and mountain irrigation are hardly understood by the professionals and thus hardly any effort was made to document design principles and criteria for mountain irrigation systems. Verification of these principles has to be made based on the performance of the existing Kuhls in the Northern Areas. The major concern is the difference in level of understanding, capability and capacity of professionals and water users' actually involved in channel design and construction. Professionals have to accept that knowledge of ground realities is best known to the local communities.

4.2.3. Adjusting New Systems

Along with the substantial increase in command area created by renewed kuhl development, considerable attention has been focused upon the process of bringing new land into actual production. Some observers have thought the process inefficient and perhaps too slow (WB 1987). The new system in Passu illustrates the situation. A Kuhl completed in 1985 commands at least 273 ha, an area sufficient to increase five-fold the average landholding in Passu. However, more than 3 years after channel construction, less than 10% of the designed command was actually developed. Northern Area farmers know from experience that, regardless of how well designed and constructed, a new irrigation system will not immediately "fit" its environment. An initial period of adjustment is commonly required and farmers in the new Passu system are engaged in that process. Since the construction of the new Kuhl, they have relocated the intake to compensate for glacial retreat and to improve the bed slope condition in the upper reach of the channel; because of substantial leakage, which affected the Karakoram Highway, a 100-meter reach of new channel, had to be lined with cement and stone. Lastly, the new channel required stabilizing or "hardening", a process encountered elsewhere in new systems in Hunza-Gojal (Velde 1989).

Each year, as silt from glacial melt fills soil interstices along a longer reach of the bottom and sides of the main channel, discharge at the system head is gradually increased. Stabilizing or "hardening" the Kuhl in this way reduces the likely occurrence of major breaches that would be difficult and costly to repair. Clearly, new land cannot be brought under irrigated agriculture ahead of adequate water supplies, and Passu farmers estimate that it will be another 4 or 5 years before they can confidently operate their new system at full supply-levels (Velde 1989).

The ground realities based on AKRSP experiences and independent surveys conducted by international experts confirmed that involvement of water users is essential right from the beginning. This demands participation of water users in planning, design, layout and construction of the new schemes. The sustainability of new schemes constructed by contractors was questionable due to lack of effective participation of water users. Furthermore, the cost increases many-fold when contractors construct these schemes. Thus water users will be much more comfortable in adjusting new schemes if their participation is realized in the beginning and contractors are not involved in the construction rather water users construct the scheme by themselves.

4.3. Management of Water Resources

4.3.1. Managing Water Distribution

Warabandi - the practice of irrigation turns, taken according to an established roster, is used in Gojal systems, as it is elsewhere in Gilgit District, to equitably allocate water and ensure irrigation turns during periods of water scarcity in the irrigation system, notably between March and May. When the period of water scarcity is over, or where water scarcity is not a problem (e.g. the older irrigation systems in Passu), water distribution generally follows a relatively informal system of irrigation turns as and when needed. Field observations confirm that the Warabandi generally remains a durable, not easily changed irrigation management practice in Gilgit (Velde 1989).

Under the Warabandi system, each household in the Kuhl command takes its irrigation turn on a specific day, at a specified and equal period of time. Between farmers whose turns are closely proximate to one another, there may be frequent, informal trading or exchange of turns. Generally, food crops are given first priority in water use, followed in order by fodder crops such as alfalfa, and finally by trees. Thus, where night irrigation is practiced, it is usually for trees (food and fodder crops are commonly irrigated during the daylight hours). Amongst food crops, vegetables typically take priority over food grains, even to the point where an operating Warabandi can be interrupted out of turn should a farmer plead the necessity of water for a vegetable plot (Velde 1989).

4.3.2. Managing Channel Maintenance

Maintenance of irrigation systems reflects their common property origins and a continuing collective management basis. Traditionally, the general principle followed for maintenance of the common portion of the irrigation channel was an annual contribution from all farmers served, either in the form of labour or produce. The principle continues to be applied, albeit nowadays a farmer may also contribute cash in terms of labour or produce. Normally, spring is the time for general annual maintenance, before the first irrigation for the new crop year and when water flows are low or non-existent. On channels where silt loads are heavy, all the farmers may also participate in a one or two day mid-season desilting operation. Maintenance of lateral or field channels not common to the system is the responsibility of individual farmers.

Some villages employ a Chowkidar or Watchman during the irrigation season to patrol the common portion of the channel to adjust and clear debris from the channel intake, to plug leaks, repair small breaches, and otherwise monitor water supply conditions. In systems where Chowkidars are not employed, farmers will take regular turns patrolling and maintaining the common channel, usually at the time of their irrigation turn. Whenever a major breach or other maintenance emergency occurs, all the farmers on the channel will participate in its repair.

4.3.3. Other Physical Infrastructures

The physical infrastructures of other systems are generally straightforward and not elaborate. Sets of flat (ish) stones are often used as channel and field ditch-drop structures. Rudimentary, but functional, turnouts generally are constructed from selected rocks; occasionally carefully fitted wooden turnout "gates" or small pine outlets are encountered along channels. Sedimentation tanks or stilling basins have been built at the head of the main channels in Kuhl systems in Soust and Passu to reduce heavy silt loads carried by the glacial-origin water. The tanks on Soust Kuhl are meant to trap rock debris carried in the glacial melt as well, and they must be desilted from time to time during the irrigation season - a task done collectively by the irrigation community. Several farmers in Soust have dug shallow stills close to their fields. Here, removed silts are mixed with animal manure and spread on the fields to improve both soil structure and fertility.

In two older Kuhl systems in Soust and Nazimabad, overnight storage tanks have been built. These permit the augmentation of channel flows during daytime irrigation. However, such infrastructure is not as widespread among Hunza Kuhls as might be anticipated, perhaps because inexpensive construction of tanks that will not leak, and at the same time be of sufficient size for irrigation water, is difficult (Hudson 1983).

4.3.4. Irrigation Specialists

The Chowkidar is a traditional and familiar figure in Kuhl irrigation systems in the Northern Areas of Pakistan. Over time, a Chowkidar develops a highly detailed knowledge of the irrigation system in which he works. He is accountable to the farmers and they willingly pay him because he provides economies of specialisation for an essential service. However, should he fail in his duties, they also are likely to replace him quickly. In three Gojal villages - Soust, Morkhon, and Passu-land not immediately adjacent to the already developed command area is supplied water through lengthy new channels. Rather surprisingly, none of these villages yet has a Chowkidar for their channels, although farmers on the Soust Kuhl say they plan to hire a Chowkidar. Older systems in Morkhon or Passu do not have Chowkidars, thus their absence on the new Kuhls may be related to this fact.

On the new channel in Khaiber, however, a variation of the Chowkidar system has emerged in conjunction with another innovation: the VO's decision to collectively develop the command area for at least the first five years of operation. The new Khaiber Kuhl command land located two to three km from the village. Because new land remains in collective ownership, there are no specific individual responsibilities for irrigation, and this situation required Khaiber farmers to devise a new approach to manage irrigation of the new land. Of the two obvious possible solutions, viz irrigation done by small groups of farmers on a rotational basis or a modification in the traditional patrolling and maintenance responsibilities of hired Chowkidars, Khaiber farmers chose the latter. At a monthly salary somewhat equal to the local wage labour rate, three men were hired for the four-month agricultural season to do daily field irrigation activities in the new command area. These "Specialist Chowkidars" also continue to perform other tasks traditionally associated with them.

4.3.5. Field-level Water Management Experimentation

In general, and in contrast to land use-patterns in older irrigated areas, most of the developed land commanded by new Kuhl systems in Gojal has been planted with trees and fodder. This situation undoubtedly reflects the present physiologic environment of many newly commanded areas, e.g. steep slopes or newer river terraces, poor soil structure with high infiltration rates and low fertility: the conditions of which can only be changed rather slowly. Plantation of fuel trees, fodder crops, and orchards on the scale now underway is also an unusual phenomenon in Hunza-Gojal, and there is interesting evidence of farmer innovation and experimentation on field-level water management practices that fit the current conditions better.

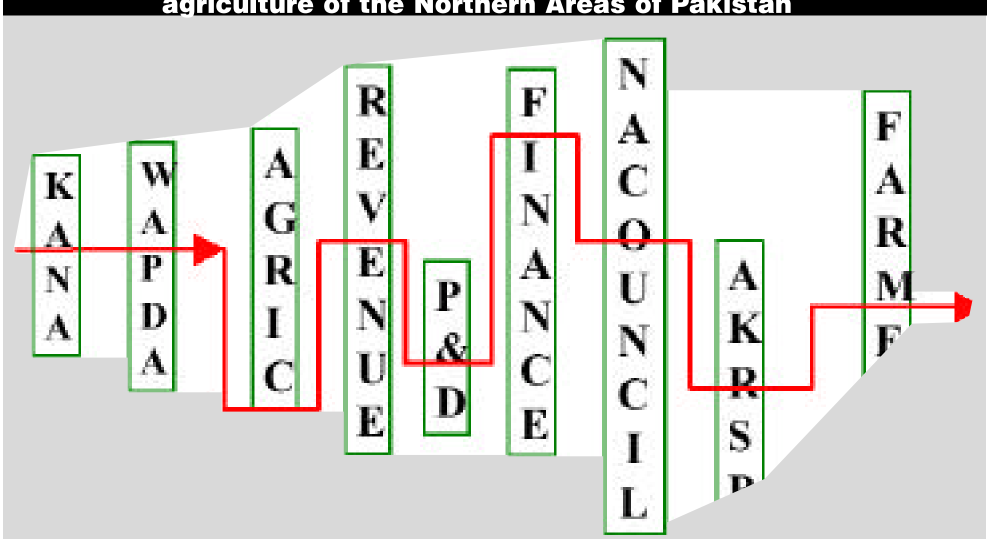
In Morkhon and Jamalabad, farmers have adopted a different technique for irrigated cultivation of crops planted on the scree slopes in the new Kuhl command. Instead of constructing the usual and costly stonewalled terraces and using basin irrigation practices, field ditches constructed along the contour deliver irrigation water to trees and alfalfa planted on shallow reverse slope terraces. This appears to be an adaptation of the furrow irrigation practices already used for potato cultivation on less steeply sloping fields. In several locations in the command area of the new Soust Kuhl, another modification of furrow irrigation is evident on steep slopes. There, in a few individual holdings, field irrigation ditches have been made as a series of linked "S"s down slope, and small drops have been fabricated from stone and polyethylene to reduce soil erosion as water is carried from one terrace level to the next one below (Velde 1989).

5. STAKEHOLDERS AND INSTITUTIONS

A wide number of stakeholders are involved in water management and use. The major stakeholders are rural communities, urban people, NGOs, CBOs, public sector institutions including line departments, and private sector agencies dealing with delivery services and marketing. The most important stakeholders are water users and their organizations.

The village level institutions existed in the Northern Areas were formulated by the AKRSP and now these Water Users Organizations are the most pivotal institutions managing the water resource for agriculture and domestic purposes. For the rural areas, the Kuhl system is used for both the agricultural and domestic water use. Therefore, the same stakeholders are involved for both the sub-sectors of water. The stakeholders involved in rural water supply and irrigated agriculture are presented in Figure 5. For the urban areas, the Kuhl system is used mainly for the domestic water supply. Therefore, the stakeholders are different than that of the rural areas, which include the line departments dealing with domestic water supply and the water users.

Figure 5: Major stakeholders in rural water supply and irrigated agriculture of the Northern Areas of Pakistan



5.1. Federal Government Institutions

5.1.1. Water and Power Development Authority

Water and Power Development Authority (WAPDA) is responsible for the development of water and power in the country. It is responsible for the collection of hydro-meteorological and flood data in catchments of the Indus River system. It is also responsible for planning and implementation of large-scale water and power projects in the Northern Areas.

5.2. Public Sector Institutions of the Northern Areas

The public-sector institutions in the Northern Areas include Planning and Development Department and the line Departments involved in area building activities.

5.2.1. Planning and Development Department

Planning and Development Department headed by a Secretary is responsible for the preparation of annual and five-year plans. It is responsible to evaluate the projects prior to the approval by the NA Council. It recommends allocation and distribution of financial resources to public sector institutions. It is also responsible to coordinate activities of the line departments especially under the integrated rural development projects.

5.2.2. Agriculture Department

Secretary heads Agriculture Department and Director technically administers it. Field staff is posted in all the five districts. Department is mandated to provide extension services to farmers in the area of agricultural engineering, soil conservation and on-farm water management. However, by and large the department is involved in provision of seed and fruit plants to farmers. Department also maintains nurseries for fruit plants and tissue-culture potato seed laboratory.

5.2.3. Forest Department

Secretary heads the Forest Department and Conservator Forest technically administers it. Field staff is posted in all the five districts. Department is mandated to manage the public sector forests through their Field Staff. Department is also responsible to provide services in farm forestry, soil conservation and watershed management and maintains nurseries for forest plants.

5.2.4. Northern Area Public Works Department

Secretary heads the Northern Area Public Works Department and Superintending Engineer technically administers it. Engineering staff is posted in all the five districts. Department is mandated to construct public works like buildings, roads, water supply schemes, water channels, etc. and provide engineering services related to construction, maintenance and repair of public works to all the line departments.

5.3. NGOs

5.3.1. Aga Khan Rural Support Programme (AKRSP)

The Aga Khan Rural Support Programme (AKRSP), a non profit, non-sectarian NGO, started its operation in Gilgit in 1982, with the objective of increasing the capacity of local people to identify and utilise opportunities to solve their own problems. The induced local capacity to plan and implement development programmes was intended to contribute to increased income and employment.

The First Phase (1983-86) activities of AKRSP focussed on the establishment of village level institutions for managing development and the funding of essential local infrastructure. It demonstrated the potential of community management visà-vis financial resources and physical assets (such as irrigation channels, link roads, storage reservoirs, etc.) and contributed to increases in income and employment.

For the Second Phase (1986 onwards), the AKRSP strategy lays emphasis on improving the integrated management of resources at farm, village, and valley watershed levels. This is to be achieved through work on farming systems, integrated livestock-cropping pasture systems, and contributions to valley planning and management. The strategy is expected to lead to improvements in the productivity and sustainability of natural resources and an enhanced capacity among villagers for managing common supra-village resources.

5.3.2. Water and Sanitation Engineering Programme (WASEP)

Water and Sanitation Engineering Programme (WASEP) is responsible for water and sanitation activities in urban areas and it has established more than 94 Water and Sanitation Committees to monitor the water supply and sanitation projects after withdrawal of the implementing agency from the village.

5.3.3. Other Programmes of Aga Khan Foundation

There are other programmes of the Aga Khan Foundation, which are involved in activities related to the development of the Northern Areas. The most prominent are listed as under:

- Aga Khan Central Education Board (AKCEB)
- Aga Khan Central Health Board (AKCHB)
- Aga Khan Economic Planning Board (AKEPB)
- Aga Khan Central Sanitation Programme (AKCSP)

The Aga Khan Foundation has arranged health services under the AK Central Health Board, where Aga Khan Health Services have been provided to the people of the Northern Areas. The relevant project to the water sector is the "Water, Sanitation, Hygiene and Health Studies Project (WSHHSP)". Under this project very useful studies have been undertaken regarding drinking water quality and sanitation issues in the Northern Areas.

5.4. CBOs

There are number of Community Based Organizations in the Northern Areas, which are being involved in activities related to advocacy, awareness, rural development, environmental management, education and health. The international agencies like IUCN and Aga Khan Foundation are involved in providing support to these CBOs. The joint forum of donors also coordinates small NGOs Grant Programme. These CBOs are engaged in activities at the grass root level. Rather the Northern Area provides an excellent opportunity for the development of CBOs due to the last two decades involvement of AKRSP in the community organizations.

5.5. IUCN

IUCN contributed significantly in the preparation of the National Conservation Strategy (NCS) for Pakistan. The NCS includes section on water. IUCN is now actively engaged in the preparation of the Conservation Strategy for the Northern Areas. Furthermore, it is also involved in environmental issues related to water and agriculture.

5.6. Other International Organizations

Other international organizations involved in various activities for the Northern Areas of Pakistan are listed as under:

- World Wide Fund for Wildlife (WWF)
- International Fund for Agriculture Development financed project on "Natural Resource Management"
- World Health Organization
- European Union financed Projects
- UNICEF

6. THE WAY AHEAD

6.1. Options

Options for water sector were analysed considering the sustainability of water resources development and management in terms of technical, environmental, social and ecological perspectives. Institutional sustainability is another essential element for evaluating any strategic option. The strategic options are presented under two core objectives and are given as under:

- Water resources development and management options to augment existing water supplies; and
- Water resources management options for achieving food, health and ecological security.

The 1st core objective cover options, which are common to all the sub-sectors of water. The 2nd core objective covers options, which are specific to the three sub-sectors of water use. The analysis of selected options was conducted considering the criteria of: b) feasibility of these options; b) acceptance by the stakeholders; c) requirement of the financial resources to implement the options; and d) institutional mechanisms available and required.

6.2. Options for Water Resource Development and Management

6.2.1. Master Plan for Water Resources Development and Management

The development and management of water resources in the Northern Areas is a complex, time consuming and expansive activity. Furthermore, there is a need to develop a comprehensive and participatory framework for action for development and management of water resources in the Northern Areas because same conveyance system is normally used for irrigation and domestic needs.

Therefore, the first most effort required is the preparation of the Master Plan for water resources development and management in the Northern Areas addressing the needs of agriculture, domestic and environmental sectors.

6.2.2. Managing Shortfall in Supply and Demand of Water and Institutionalisation

There is wide variability in the Northern Areas for supply and demand of water for different competing sectors i.e. agriculture, domestic, ecosystem, etc. The variability in supply and demand of water resulted in shortfall and thus various sub-sectors have to compete for availability of water.

There are two factors affecting the development of the water conveyance system and its utilization. Firstly, the discharge of Kuhl to the full supplies level and secondly the development of the utilization system (i.e. command area for agriculture and pipeline supply system for domestic water use) to use water efficiently.

For the agriculture sector, at certain places land is a limiting factor but in most of the cases water is a limiting factor. However, in general, water users are slow in developing the command area because the water users and the professionals undertake hardly any joint effort to address this issue. Thus there is a need to systematically study the problems related to the development of the command area so that benefits of designed command area are achieved in a period of 1-2 years. This is the area where engineering knowledge and local skills have to be grafted. Similar trends were observed in small dams built by the Government of Punjab.

For extending the use of available water resources through demand management, the strategic elements can be considered are as under:

- Improve urban and regional planning to locate towns and agro-based enterprises near sources of water, which are sufficient to meet the expanding future demands. This was a practice in the past but some of the newly constructed cities i.e. Islamabad are now facing extreme water shortages;
- Rationalize sectoral and inter-sectoral water allocations;
- Review options for introducing water tariff for various purposes to reflect the value of water in use;
- Stakeholder's participation in development and management of water resources that makes decisions and oversee operations including raising awareness, education, communications, etc. of stakeholders;
- Managing the water systems for performance monitoring, evaluation and feedback; and bench marking the performance of utilities; it can lead to reducing losses, wastage and leakage.
- Encourage private sector participation – necessary legal and regulatory infrastructure to be created to make the private sector investment viable.

The strategic elements of this option can be implemented only through active participation of all the stakeholders. At present, water is no body business in the Northern Areas. Therefore, appropriate institutional mechanisms are needed to address the issue of water in a holistic way. For this purpose, an autonomous "Water Management Authority" may be constituted to formulate policy guidelines for the public-sector institutions, NGOs, CBOs and the private sector and implement water resources development and management programmes under a participatory approach. The Authority will be responsible to identify the interdependencies among various stakeholders and create awareness at different levels including the stakeholders.

The devolution consistent with water and irrigation infrastructure and the institutional framework is presented in Figure 6. The Water Users' Organizations (WUOs) of the Northern Areas can be federated at the Tehsil level. At the District level these federations can be institutionalised in to Area Water Boards (AWBs). The Area Water Boards will work with the proposed Water Management Authority (WMA). The technical and support staff needed for the WMAand the AWBs would be provided through adjustments within the existing line departments (Figure 7).

The size of WMAand AWB will be kept as small as possible. No full-time technical and support staff is needed at the FWUOs and the WUOs level. They can have technical backstop support from the AWB and WMA. Thus very modest level of financial support is needed to establish the WMA. In fact the institutional reforms in the existing line departments can take care most of the expenses. However, seed money as one-time endowment may be provided to the AWBs and FWUOs. Continued financial support will be required for the WMA to maintain technical and the support staff.

Figure 6: Devolution consistent with water and irrigated agriculture infrastructure of the Northern Areas of Pakistan

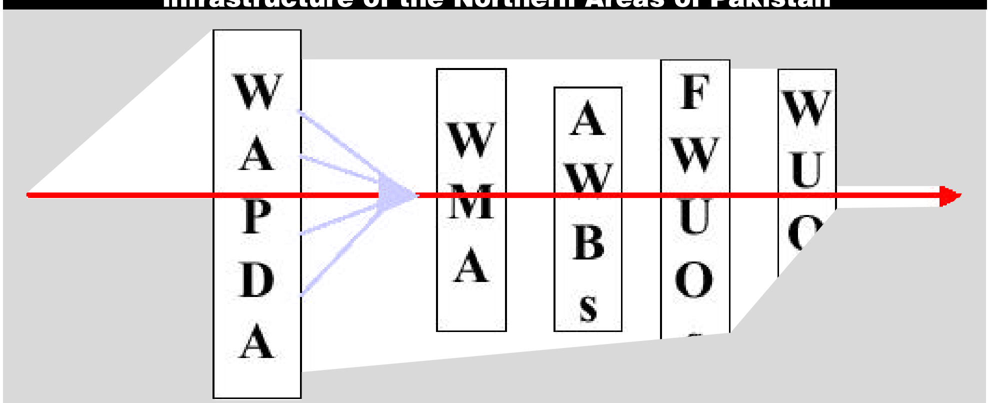
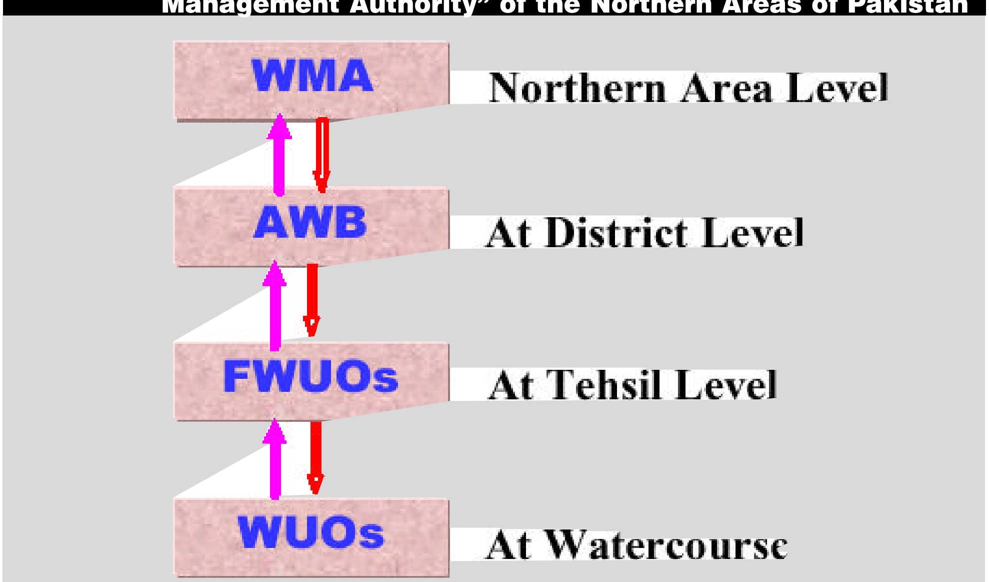


Figure 7: Institutional framework for the proposed "Water Management Authority" of the Northern Areas of Pakistan



6.2.3. Surface Water Resources Development

Augmenting the existing water supplies is going to be one of the workable options for the Northern Areas to meet the shortfall in the medium to long-term basis. The development of surface water resources is needed for all the three major sub-sectors of water use i.e. agriculture, domestic and ecosystem. The experience of the AKRSP in the last two decades has confirmed that there is a vast potential for the development of additional surface water resources and stakeholders are interested to participate in this process. For extending the use of available water resources, through development of surface water resources the strategic elements can be considered are as under:

- Preparation of an Action Plan for the development of new Kuhls or remodelling of the existing Kuhls considering the cost-effectivity of such developments;
- Formulation of integrated approach for water development, management and use;
- Improve and enhance the existing infrastructure for water resources development;
- Instituting transparent and participatory procedures for water allocation in new Kuhl commands.

The proposed "Water Management Authority" for the Northern Areas can ensure participation of various stakeholders, especially for the preparation of the Master Plan for the development of surface water resources. The Water Management Authority in collaboration with the existing line departments like Agriculture and Forestry and AKRSP may develop a system for the provision of technical backstop support to the water users' organizations for the development of new irrigation schemes. Networking is the most feasible mechanism based on the past experience. The line departments should restrict their activities to technical backstop support and monitoring, whereas the construction aspects should be left solely for the water users' organizations. The financial resources for surface water development can be made available through bilateral donors, international lending agencies like IFAD, World Bank, Asian Development Bank, etc. The Northern Areas provide unique environment for donors to initiate such developments. The government of Pakistan should also include Northern Areas as part of the Pakistan's Water Development Programme. Therefore resources from the public sector development programme should be extended to the Northern Areas.

6.2.4. Minimizing Water Losses

The development of new surface water resources is expansive and time consuming. Therefore, minimising the existing conveyance losses should be given higher priority because considerable savings can be made on short-term basis. The conveyance losses are huge due to the rugged terrain and excessive seepage in extremely coarse textured soils. In the Indus basin such losses are to the tune of 50%, whereas these can exceed to even more than 70% in certain Kuhls of the Northern Areas. For extending the use of available water resources, through minimizing the existing losses in conveyance and application, the strategic elements can be considered are as under:

- Identify sensitive reaches which contribute for excessive conveyance losses and breaches and introduce either use of fine-sediments for blocking the pores or lining using the geo-synthetics;
- Managing the velocity of water in the Kuhls to minimize scouring and siltation;
- Improving the existing design of Kuhls to address both the hydraulic regimes of low and high flows.
- Prepare an Action Plan for improving the conveyance efficiency of the existing Kuhls.

Water management of the existing Kuhls is essential to minimize the conveyance losses and thus provide additional water through savings. At present, there does not exist any institutional mechanism to provide support to the Water Users' Organizations. For this purpose, the proposed Water Management Authority in collaboration with the Department of Agriculture should work with Water Users' Organizations to improve the operational management of the Kuhl systems both for domestic and agricultural purposes. In fact, water from the Kuhls is used both for domestic and agricultural purposes.

6.2.5. Increasing Storage (domestic, stockwater, irrigation, ecosystem)

The storage of water is essential for addressing the requirement of domestic, stockwater, irrigation and ecosystem needs. The rural communities are facing difficulty in the winter season when water supplies are in short. Thus there is a need to introduce small-scale storage of water to meet the needs of various sub-sectors. For extending the use of available water resources, through increased storage of surface water resources, the strategic elements, which can be considered, are as under:

- Introduce small-scale storage pods/tanks at the farm or command level and lining of these tanks using the geo-synthetic liners, where it is cost-effective;
- Introduce sand filters to provide safe and clean water for drinking and stockwater use especially during the winter months;
- Introduction of earthen reservoirs and lining using plastic films at the tail end reaches of the Kuhl system to store the excess water especially at the nighttimes. The stored water can be used with high efficiency irrigation systems to grow orchards and creeper-type vegetables.

The proposed Water Management Authority can provide the technical backstop support to the Water Users' Organizations for the development of storage tanks and installation of sand filters. Due to increased awareness and demand for health security, communities would seek such interventions in the near future.

6.2.6. Planting of Glaciers

Planting of glaciers in ecologies similar to those of glacierised zones is common in local communities of the Northern Areas, as an option to develop resource of water in localities where snow changes to glacier through a process of glacierisation. The options recommended for the planting of glaciers are as under:

- Assessment of local experiences and their impact on development of glaciers and improvement in deposition of incident snow leading to the development of new water resources;
- Based on the assessment of the impact of local activities, develop a programme for large-scale testing of the concept of indigenous planting of glaciers;
- Documentation of appropriate methodology for planting of glaciers and identification of potential sites for large-scale introduction of planting of glaciers for development of water resources and irrigated agriculture.

6.2.7. Hydro-Power Development

The shortfall in supply and demand of water can be met more effectively if power supply is available to the water users to pump water. The water lifting from the Indus basin is limited due to higher delivery head and the lack of the availability of electric power. It will be difficult to use the diesel engines, as the initial capital cost is many-fold higher than the electric motors. Thus development of hydropower and availability to the water users on reasonable tariff is necessary to meet the shortfall in water availability during the peak demand periods. However, under the Khushal Pakistan Programme, diesel powered lift irrigation schemes are now being introduced at the pilot scale. The first scheme was designed using 75 hp-reconditioned engine with turbine pump, which seems economical for raising of orchards.

Private sector may be encouraged to provide services to the Water Users' Organizations or their federations to develop hydropower systems on turnkey basis. Cost effectivity and technical feasibility are the two essential elements for the hydropower development. For extending the use of available water resources, through increased hydropower developments for lifting of water, the strategic elements can be considered are as under:

- Indigenisation and commercialisation of small-scale hydro-power generators;
- Construction of small-scale hydropower units at locations where water can be lifted for multiple water use. Such locations are available especially the abandoned water mills for wheat flour, locally named as Grats, can be used for the installation of small scale hydro-power stations;
- Introducing the water lifting turbines on the perennial streams to lift water; these turbines work under water head and lift water based on quantity of water and available head. Low-head Chinese water lifting turbines have been used successfully in the Barani areas, whereas high head turbines would be required for the Northern Areas. These turbines can be manufactured locally by the pump industry with active involvement of PARC.

6.2.8. Mobilizing New Financial Resources

New financial resources have to be mobilised for continued O&M of the water systems for various uses through recovery of the O&M cost especially for the domestic water supply systems. Ultimately such mechanisms have to be developed for agricultural water systems. In rural areas, same Kuhl is used for domestic, agricultural and ecosystems, therefore, Water Users' Organizations may be encouraged to enforce water fee to mobilize resources for maintaining and managing the water systems. Area Water Boards can play vital role through federations of Water Users' Organizations for enforcing water fee and cost recovery.

6.2.9. Launching a Movement

There is an urgent need to launch a movement for creating awareness through training and education of all the stakeholders about the importance of the finite resource and future requirements not only for the Northern Areas but also for Pakistan's Indus basin. The demand for water would certainly increase in future for the downstream areas, which will have some impact on the development of water in the Northern Areas. Furthermore, the quality concerns would increase in future and thus better management of return flows have to be made. Furthermore, there is a need to create awareness and realization among downstream provinces of the Indus basin to share expenses for the development and management of water in the Northern Areas, if they are interested to protect water from pollution by sediments and agricultural chemicals.

6.2.10. Effect on Other Sectors

The negative impacts of water development and management on other sectors like biodiversity, fisheries, agriculture; tourism and recreation have to be minimized in terms of space and time. In fact pollution of water should be given priority by reducing the losses of irrigation water and reduced use of chemicals. Sanitary effluents have to be treated and their entry into fresh water streams should be completely blocked. This demands formulation of a comprehensive strategy for planning and development of water, which account for the negative externalities in the process of water development and management in the Northern Areas for the next decade. The Master Plan for Water Resources Development and Management should include aspects of environmental concerns like watersheds, natural ecosystems and surface water resources.

6.3. Options for Achieving "Food Security"

6.3.1. Operational Management of the Kuhl System

Operational management of the Kuhl system is needed to reduce the operational losses and to improve reliability, equity and efficiency of water availability for agriculture. Almost all the existing water resources for agriculture are drawn from the Kuhl systems, therefore operational management of these systems is necessary to meet the future needs of the next decade and to have uninterrupted water supplies. The operational management would also reduce the chances of breaches and landslides.

Capacities of the Water Users' Organizations have to be enhanced through knowledge and skill enhancement trainings and implementation of the operational management programme at the Kuhl level. The proposed Water Management Authority would arrange trainings for water users in operational management of the Kuhl system. For this purpose, trainers have to move to the actual Kuhl system rather than the trainees to the institute. AKRSP and the Agriculture Department should jointly work on this option by pooling their existing manpower resources to provide the trainers for training and then gradually evolve more permanent system of on-job trainings. The existing set up of the Karakoram Agricultural Research Institute for the Northern Areas (KARINA) has to be reoriented to develop a strong group on water development and management. The options or strategies required for improving the operational management of the Kuhl systems are as under:

- Measurement of water in the Kuhl system by introducing weirs at the head, middle and tail of the Kuhl system to have information about availability of water and extent of operational losses of water. The water users can construct such weirs and simple gauges can be installed for measurement of water. Calibrated discharge ratings can be provided to the water users to estimate the flows.
- Arrange on-job trainings of water users in operational management of the Kuhl system;
- Identification of sensitive reaches of the Kuhl system for immediate repair or maintenance to avoid serious damages and losses of water.

6.3.2. Managing the shortfall in Supply and Demand of Water

Presently, the cropping intensity is low compared to the potential thus in future there are fair chances of substantial increases in command area or increase in cropping intensity or both. Therefore, in future demand for water would increase to cope with increase in population and to provide better livelihood to rural communities.

In addition to the increase in demand, there are issues related to supply of water. There is a seasonality in water availability as water supply decreases during the winter months and acute shortage is observed during March-May due to increase in crop evapotranspiration. The peak demand for Rabi crops is during the months of April and May and farmers are facing shortage of water during this period. Although there is shortage of water during December-February but crop water requirement during this period is minimal. The options or strategies for managing shortfall in supply and demand due to seasonality are as under:

- Adjusting cropping pattern and cropping intensity in line with water availabilities;
- Drought resistance varieties of wheat may be evaluated to reduce demand of water during the months of March-May;
- Water lifting schemes may be introduced to meet shortfall during peak demand period of March-May.

6.3.3. Improving Productivity of Water Use

The productivity of water use has to be increased, as there are physical limits to the development of new surface water systems and to expand the command area and the cropping intensity. All these options of horizontal developments have limited scope. The other viable option is to improve the water productivity. There are ample opportunities for improving the productivity of water. The following strategies and options can be considered for improving productivity of water use:

- Improving Warabandi system to manage shortfall in supply and demand and to improve reliability, efficiency and equity in water distribution;
- Improving control of water to minimise losses at diversions and distribution at the farm level;
- Improving layout and field levelling to improve irrigation application efficiency and to reduce number of irrigations i.e. as high as 20 irrigations are applied to wheat crop due to excessive infiltration in coarse sandy soils;
- Introduction of high efficiency irrigation systems viz sprinklers and drip irrigation using the available hydraulic head due to topography;
- Furrow, round basin and broadbed systems can be introduced for fruit plants especially the deciduous plants, which helps to save water and increase productivity;
- Fertigation systems can be introduced instead of irrigation to enhance productive and economic efficiency. Furthermore, use of bio-fertigation using composts or animal/plant wastes can help to improve soil structure, which will ultimately reduce the irrigation water requirement. The use of composts will also help to reduce leaching of nitrates by reducing the fertilizer requirement.

6.4. Options for Achieving "Health Security"

6.4.1. Provision of Safe Drinking Water

Water for people is needed for drinking and other domestic uses including sanitation. Out of the total domestic water use the drinking water is most important, as quality concerns are serious.

The capacity of the Public Health Department and the Water Users' Organizations has to be enhanced for the provision of safe drinking water to urban and rural communities. WASEP has already introduced the tariff collection system in its partners villages. The introduction of water tariff system would also reduce the quality and demand issues. Rather demand water management will be much easier. The WSHHSP of the AKPBS can provide the technical backstop support in this regard. The following options are attractive for improving quality of drinking water and its availability:

- Improving the conveyance of water in the Kuhl system constructed for supply of water for drinking purposes by avoiding entry of sanitation and agricultural effluents and other wastes;
- Introduction of sand filters to filter sand and silt particles from the Kuhl water and appropriate water treatment to control the biological impurities. Filtering of water in pipeline systems is much effective and easier compared to surface channels;
- Effective design, construction and monitoring of pipeline water supply systems in the urban areas;
- Introducing water fee for cost recovery to maintain the water supply systems on sustainable basis.

6.4.2. Safe Disposal of Effluents

Disposal of sewerage and agricultural effluents is essential to maintain the productive environments for people, agriculture and nature. The disposal of sewerage is crucial to protect the fresh water resources for agriculture and people. The following options are attractive for improving quality of drinking water and its availability.

- Proper collection and treatment of sewage and other effluents prior to their discharge into freshwater bodies;
- Sewage should not be dumped into the Kuhl system;
- Practical and economically feasible sewage treatment options be explored and applied.

6.5. Options for Achieving "Ecological Security"

6.5.1. Managing the Productive Environments

Disposal of sewerage and agricultural effluents is essential to maintain the productive environments for nature. The disposal of agricultural effluents is crucial to protect the fresh water resources for maintaining the aquatic life in water streams and rivers. The following options are attractive for managing the productive environments of the ecosystems prevailing in the Northern Areas.

- Creating awareness to reduce the use of pesticides and chemical fertilisers and to reduce the irrigation losses to minimize leaching of chemicals and contamination of return flows;
- Sewage and agricultural return flows should not flow into water bodies and measures should be taken for their proper treatment;
- Aquatic ecosystems should be regularly monitored for impacts on the aquatic and other life forms.

6.5.2. Managing the Wetlands

Wetlands are the essential part of the mountain ecosystems. The Northern Areas are unique in the country, as wetlands of alpine and sub-alpine zones and coldwater wetlands are specific to these areas. These wetlands provide habitat for flora and fauna of alpine and sub-alpine zones of dry highlands, and those common to snow- and glacier-melt. The following options are recommended for managing the wetlands.

- Monitoring of quality and quantity of water in the wetlands of alpine and sub-alpine zones of the highlands;
- Monitoring of human interferences in wetlands and their impact on the sustainability of the wetlands ecosystems.

6.6. Recommended Options

Recommended options for the water sector are presented under two core objectives, which are listed as under:

- Water resources development and management to augment existing water supplies; and
- resources management for achieving water security in terms of food, health and ecological perspectives.

The 1st core objective covers options, which are common to all the sub-sectors of water. The 2nd core objective covers options, which are specific to the three sub-sectors of water use. The options under the two core objectives are presented both for the short-term (2-3 years) and long-term periods (> 3 years).

6.6.1. Options for Water Resource Development and Management

6.6.1.1. Short-term Options

- Preparation of Master Plan for water resources development and management should be given the highest priority so that all the necessary details for feasibility and identification of potential locations for the irrigation schemes are included in an Atlas. The Framework for Action given in the strategy would form the basis for the preparation of the Master Plan. The Atlas would include information on topography, geology, climate, water availability, agriculture, soils, etc.
- Shortfall in supply and demand of water should be managed through stakeholder's participation in management that makes decisions and oversee operations including raising awareness, education and communications of stakeholders. Thus management of the water systems for performance monitoring, evaluation and feedback; and bench marking the performance of utilities would lead to reducing losses, wastage and leakage of water in the Kuhl system.
- Conservation of existing water losses can augment the existing water supplies. This could be achieved through identification of sensitive reaches, which contribute for excessive conveyance losses and breaches and introduce either use of fine-sediments for blocking the pores or lining using the geo-synthetic liners. Managing the velocity of water in the Kuhls would also help to minimize scouring and siltation. Improvements in the existing design of Kuhls can help

to address both the hydraulic regimes of low and high flows. Preparation of an Action Plan for improving the conveyance efficiency of the existing Kuhls would be an effective tool for systematic implementation.

- New financial resources have to be mobilised for continued O&M of the water systems for various uses through recovery of the O&M cost especially for the domestic water supply systems. Ultimately such mechanisms have to be developed for agricultural water systems. In rural areas, same Kuhl is used for domestic, agricultural and ecosystems, therefore, Water Users' Organizations would be encouraged to enforce water fee to mobilize resources for maintaining and managing the water systems. Area Water Boards can play vital role through federations of Water Users' Organizations for enforcing water fee and cost recovery.
- There is an urgent need to launch a movement for creating awareness through training and education of all the stakeholders about the importance of the finite resource and future requirements not only for the Northern Areas but also for Pakistan's Indus basin. The demand for water would certainly increase in future for the downstream areas, which would have serious impacts on the development of water in the Northern Areas. Furthermore, the quality concerns would increase in future and thus better management of return flows have to be made.

6.6.1.2. Long-term Options

- Management of shortfall in supply and demand of water would be possible through: a) improved urban and regional planning to locate towns and agro-based enterprises near sources of water, which would be sufficient to meet the expanding needs in the future; b) rationalizing sectoral and inter-sectoral water allocations; c) reviewing options for introducing water tariff for various purposes to reflect the value of water in use; and d) encouraging the private sector participation. Necessary legal and regulatory infrastructure has to be created to make the private sector investment viable.
- Institutionalisation of water sector institutions is essential to improve and enhance the existing infrastructure for water resources development and management. For this purpose, there is a need to establish Water Management Authority with Area Water Boards and Federations of the Water Users' Organizations to ensure active participation of stakeholders.
- Preparation of Action Plan for the development of new Kuhls or remodelling of the existing Kuhls is needed considering the cost-effectivity. Formulation of an integrated approach for water development, management and use is an essential element of the Action Plan. Furthermore, there is a need for instituting transparent and participatory procedures for water allocation in the new Kuhl commands.
- Increasing storage (domestic, stockwater, irrigation and ecosystem) through the introduction of small-scale storage ponds/tanks at the farm or command level and lining of these tanks using the geo-synthetic liners, where it is cost-effective. Introduction of sand filters would help to provide safe and clean water for drinking and stockwater use especially during the late winter months (March to May).
- Hydro-power development is crucial to augment water supplies through: a) indigenisation and commercialisation of small-scale hydropower generators; b) construction of small-scale hydropower units at locations where water can be

lifted for multiple water use; and c) introduction of water lifting turbines on the perennial streams to lift water. These turbines work under water head and lift water based on quantity of water and available head.

- The indigenous hydel-power units for wheat flour (Grats) in the Northern Areas were replaced with electric-powered mills due to enhance the existing capacity. These abandoned hydel facilities can be used to install village level hydel-power plants.

6.6.2. Options for Achieving "Water Security"

6.6.2.1. Short-term Options

- Operational management of the Kuhl system can provide food and health security. Measurement of water in the Kuhl system should be initiated by introducing weirs at the head, middle and tail of the Kuhl to have information about availability of water and extent of operational losses. The water users can construct such weirs and simple gauges can be installed for measurement of water. Calibrated discharge ratings can be provided to the water users to estimate the flows. There is a need to arrange on-job trainings of water users in operational management of the Kuhl system. The identification of sensitive reaches of the Kuhl system is needed for immediate repair or maintenance to avoid serious damages and losses of water.
- Management of the shortfall in supply and demand of water for agriculture is possible through adjusting cropping pattern and cropping intensity in line with water availabilities. Drought resistance varieties of wheat should be evaluated to reduce the demand of water during the months of March to May;
- Improving productivity of water use should be given due consideration through improving Warabandi system to manage shortfall in supply and demand and to improve reliability, efficiency and equity in water distribution. Improving control of water can lead to minimise losses at diversions and distribution at the farm level. Furthermore, the improved layout and field levelling can help to improve irrigation application efficiency and to reduce number of irrigations i.e. as high as 20 irrigations are applied to wheat crop;
- Concept of fertigation can be introduced to increase the productive and economic efficiency. Furthermore, use of bio-fertigation using composts or animal wastes can help to improve soil structure. This would help to reduce the irrigation requirements in the long run.

6.6.2.2. Long-term Options

- Managing the shortfall in supply and demand of water through the construction of water lifting schemes to meet shortfall during peak demand period of March-May.
- Introduction of furrow irrigation using roundbasin or broadbed planting systems instead of flood irrigation for fruit plants and vegetables.
- Improving productivity of water use through the introduction of high efficiency irrigation systems viz sprinklers and drip irrigation using the available hydraulic head due to topography.
- Provision of safe and clean drinking water through the introduction of sand filters to filter sand and silt particles from the Kuhl water and appropriate water treatment to control the biological impurities. Introduction of water fee

for cost recovery is needed to maintain the water supply systems on sustainable basis.

- Proper collection and treatment of sewage and other effluents prior to their discharge into freshwater bodies is essential. Sewage should not be dumped into Kuhl system at all. Furthermore, practical and economically viable sewage treatment options should be explored and applied. Aquatic ecosystems should be regularly monitored for impacts on the aquatic and other life forms.
- Wetland management plans and programmes should be developed and implemented to maintain alpine- and sub-alpine wetlands, which are unique in the country due to the occurrence of cold-water flora and fauna.

ANNEX 1:

LIST OF PARTICIPANTS INVITED FOR THE PRE- AND POST-DRAFT WORKSHOPS

1. Dr. Farman Ali	RPM, AKRSP, Gilgit
2. Fida Hussain	Program Engineer, AKRSP, WASEP (AKPBS), Gilgit
3. Dr. Karim Ali Bhoi	Program Director, WASEP, Gilgit
4. Dr. Tameez Ahmed	Program Coordinator, H&H, WASEP, Gilgit
5. Mr. Manzoor Hussain	Program Manager, Engineering- WASEP, Gilgit
6. Mr. Haider Raza	Program Coordinator, Water Quality & Training, WASEP, Gilgit
7. Mr. Akber Shahzad	AD, Curricular, Education Directorate, NAS, Gilgit.
8. Mr. Zulfiqar Ali	Consultant, N.E.P., Directorate Of Education, Gilgit.
9. Mr. Jan Madad	Manager AKES, Konodas, Gilgit.
10. Mr. Shehbaz Khan	President NACCI, Gilgit.
11. Syed Yahya	C/O Aliyar, IUCN, Gilgit
12. Mr. Nasir Ali Shigri	Se, (NAPWD) Baltistan Region, Gilgit.
13. Ms. Tabbasum	IFAD, WID/NRM, Chilas.
14. Dr. Parveen Ashraf	Member Steering Committee, NASSD, C/O Project Director, NASSD, IUCN, Gilgit.
15. Mr. Sanaullah	Secretary, Agriculture, NAS, Gilgit.
16. Mr. Mehar Dad	Secretary, (Education), NAS, Gilgit.
17. Mr. Abdus Subhan Memon	Home Secretary, NAS, Gilgit.
18. Mr. Irshad Khan Abbasi	Director, WWF, Gilgit
19. Mr. Sulaiman Wali	Xen, NAPWD, Gilgit.
20. Dr. Hidyat Ali	Director, Agriculture, NAS, Gilgit.
21. Mr. Sher Jahan	Agriculture Eng., Agriculture Department Gilgit.
22. Mr. Munir Ahmad	Agriculture Engineer, KARS, Diamer Chilas.
23. Mr. Ghulam Tahir	Conservator, Forest, Northern Areas, Gilgit
24. Mr. M. Sharif	D.F.O, Forest NAS, Gilgit.
25. Mr. Rana Bashir Ahmed	Director, KARINA, Juglote (Sai), Gilgit
26. Mr. Juma Khan	DD, Agriculture, Gilgit.
27. Mr. Muhammad Ali Shah	DD, Fisheries, Nas, Gilgit.
28. Dr. Ahsan Ali	DD, Livestock, Nas, Gilgit.
29. Mr. Abdul Wahid	DD, Agriculture, Diamer, Chilas.
30. Mr. Gul Baz Khan	Planning Officer, P&DD, Gilgit.
31. Mr. Mohammad Nazir Khan	Assistant Chief, P&DD, Gilgit.
32. Mr. Ameer Ullah Baig	Met Officer, Met Department, Airport Road, Gilgit
33. Mr. Eiman Shah	President Press Club, Gilgit And Editor Waadi, Gilgit
34. Mr. Tariq Muneer	Bureau Chief, Badeshimal Gilgit
35. Mr. Nasir Khan	DD, PID, Northern Areas, Gilgit.

ANNEX 2:
RECOMMENDATIONS OF THE PRE-DRAFT WORKSHOP

Pre-draft workshop was held at Serena Hotel, Gilgit on May 12th 2001, in which author participated and gave presentation on the tentative outline for the writing of the Background Paper on "Water". After the presentation, there was general discussion. Based on the accepted outline by the participants, the participants were divided in to three groups covering aspects for agriculture, people and nature. The three groups outlined the issues and recommendations, which were presented in the afternoon session. The summary of issues and recommendations is given under:

Issues

Water For Agriculture

- Water conveyance losses in the Kuhl systems
- Lack of effective operation and maintenance of the Kuhl systems.
- Lack of water distribution schedules - Warabandi
- Non-enforcement of water charges
- Lack of awareness about importance and value of water
- Lack of storage facilities (small dams, tanks)
- Low organic matter in soils
- Un-levelled fields

Water For People

- Availability/accessibility of water
- Pollution's/contamination of water resources
- Quality/quantity of available water resources
- Management/efficiency of existing irrigation systems.
- Users rights/equity of water.
- Vulnerability of groups.

Water for Nature

- Shortage of water
- Less area under forests
- Floods, pollution and water quality
- Reduced production and productivity of land use systems
- Overgrazing of rangelands
- Drought
- Disease epidemics
- Wildlife migration
- Effects on gender use of forests

Recommendations

Water for Agriculture

- Check conveyance losses
- Ensure effective operation and maintenance for the Kuhl systems.
- Introduction of the Warabandi system to ensure equity of water
- Introduction of water tariffs
- Mass awareness program about efficient use of water
- Small dams/tanks for storage of water at the farm level
- Use of organic matter
- Land levelling
- Improved farming practices
- Equitable distribution of water
- Improved technologies or methods of water use.
- Awareness for the use of synthetic liners
- Hydra-ram pumps
- Lift irrigation systems
- Enhanced role of women in agriculture
- Awareness raising program for women related to efficient use of water.

Water for People

- Affordable, manageable, and sustainable supply of safe drinking water and introduction of storage system.
- Participation, access and use of available water for every one
- Empowerment of village organization/woman organization for management of natural resources.
- Equity and equality should be maintained for each segment of the society.
- Sewerage system should be strengthened.
- User's charges according to use/size.
- Municipal laws and enforcement.
- Awareness.

Water for Nature

- Protect wetlands.
- Avoid use of dynamites for fishing.
- Use of water for aesthetics/sports.
- Create less pollution
- Use of solar energy to minimize emissions
- Environmental education
- Balance between conservation and development
- Artificial regeneration and rotational grazing
- Alternate use of fuel and enforcement of regulations

ANNEX 3:

PROCEEDINGS OF THE POST-DRAFT REVIEW WORKSHOP

Dr. Shahid Ahmad, author of the Background Paper on Water, presented the paper to the key stakeholders in the post-draft workshop held at Serena Hotel, Gilgit on November 24th 2001. He emphasized the issues and recommendations as described in the background paper.

The major criticism on the background paper was that it does not provide feasibilities for water projects and potential locations were not identified, where water projects could be introduced in future. Furthermore, emphasis should be made on the practical nature of the paper instead of the strategy paper.

The author explained to the participants that the purpose of the background paper is to provide background information for the drafting team of the National Conservation Strategy. Therefore, it is basically a strategy paper. However, there is a need to conduct appraisals and feasibilities for implementation of the water development projects, which is a routine process of the public sector development programme. Thus the subject of feasibilities is outside the scope of the background paper. The background paper is based on the secondary information and fieldwork was not conducted, as TOR does not provide any support in this regard. The paper has already outlined the need for the formulation of the Master Plan for Water Development and Management, which will include list of all the feasible projects. The author also made it clear that there are papers on energy, agriculture and forestry, thus comments made relevant to the other sectors will not be considered under the background paper on "Water".

Participants contributed lively in the discussions, and relevant suggestions and comments made verbally or in written form were considered and are summarized as under:

- Northern Areas have some unique wetlands in high alpine and sub-alpine zones, so they need to be protected.
- Water rights of the Northern Areas may be clearly articulated as they provide almost 43% of the total water resources of Pakistan. Furthermore, there is a need to put value on water.
- Background paper on water is very useful document for water strategy but there is a need to develop Master Plan for Water Development and Management in the Northern Areas. This recommendation must be made more explicit in the document. Therefore, this paper can be best regarded as "Framework for Action".
- Village based flour grinding mills have been replaced by electric-powered mills primarily due to the expanding demand. Presently, water is not being used and going waste. This water can be utilized for small indigenous micro-hydel power projects, which must be supported with active participation of NGOs.
- Planting of glaciers be given due consideration as this is in practice in certain areas.
- Land holding is very small in Northern Areas; therefore, water productivity must be given higher priority.

- Water management must ensure availability of water at tail-end reaches of the Kuhl system. Earthen storage tanks must be introduced at tail-end reaches to store excess water, especially during night times.
- Background paper mentioned that Forest Department hardly provides any effective support to farmers for farm forestry or land use. In my opinion, the Forest Department of Northern Areas has demonstrated the community to plant trees in their farms and wastelands and that's why the farmers introduced farm forestry. The Department has also encouraged the farmers in social forestry through jointly operated Project of Forest Department and AKRSP during 1992-98. The communities planted more than 5 million plants in the Northern Areas.
- Water in Kuhls of Gilgit town is short for irrigation supply during the period of March to May. Larger Kuhls must be managed through partnership of public and private sectors. Irrigation department should be established in the Northern Areas for effective management of larger Kuhl systems. Active participation of communities is essential for sustainability of these systems.
- More than 70% of water seeps due to improper construction of water channels. Appropriate gradient must be ensured to avoid depressions between head and tail.
- Furrow irrigation may be introduced instead of flood irrigation to improve field efficiency. Furthermore, introduction of drought resistant varieties would help to increase the cropping intensity.
- It would be nice to change the structure of the current report by dividing it into sectors, i.e. water delivery systems, water for irrigation, water for drinking, etc. Water management should be dealt for each sector separately. Water management for Kuhls used for irrigation and drinking purposes is being done quite nicely with communities. As far as the improved water delivery systems are concerned most of the systems are defunct due to mismanagement or partially functional at the moment.
- Contamination in upper Indus rivers system is basically turbidity with seasonal trends, and also to some extent faecal contamination. On chemical side there are some heavy metals in springs as well as in nullahs. It would be fine to provide some information on these sides as well.
- The idea of having a water management authority is quite nice but there is need to legalize its roles and responsibilities. In addition to this it is also necessary to have a third regulatory party who will be responsible for monitoring the water quality and quantity according to WHO recommendations.
- Under treatment options it would be nice to list simple, practical and affordable options. Based on my experience it is quite difficult to make slow sand filters and to maintain it due to the reasons that it requires large surface area, and primary treatment option i.e. sedimentation tanks and baffles, etc.
- The idea of imposing water tariffs is very nice and ultimately we have to move towards it. WASEP has already introduced the tariff collection systems in its partner villages. I think most of the problems like water losses; introducing water tariff systems in urban areas can taper off continuity and quality. Keeping in view the existing piped water delivery systems it seems feasible to introduced flat rate per household, as we don't have metering systems in the Northern Areas.
- Community involvement in the project is not mentioned in the paper. I believe their involvement is necessary from the sustainability point of view. We have good examples of community involvement in rural water supply systems.

- The names of various stakeholders active in water are missing i.e. AKCSP, AKPBS, UNICEF, LB&RDD, etc. According to my knowledge AKEB, AKHB are not the main agencies working in this area, therefore correction should be made in relevant sections as per requirement.
- River Indus is the only source of water and has important effects accordingly. According to my suggestion Indus River should be taken as a separate and first topics of the paper.
- Erosion control measures, torrent control, water harvesting and spreading should be made part of this paper. If detailed account of these measures is not possible then Northern Areas specific measures should be mentioned at least because these are un detachable from the water resources depending upon soil morphology, texture and structure.
- Regional experiences particularly of those countries having mountains should also be made part of this paper for getting the full benefits of their experience for the development of water resource in Northern areas.
- Irrigation has links with environment and conservation i.e. aspects like flood prevention, erosion control, organic wastes, etc. have been studied in detail and various modules based on their co-relations for water supply and sanitation can be made part of this paper.

The author has considered all the comments and suggestions given by the participants. However, TOR and outline provided by the IUCN were used as framework for considering the comments. All the possible and relevant comments were considered while finalizing the background paper. We have to keep in mind that there are other papers covering agriculture, forestry, energy, etc. Some of these aspects will be covered under those papers. Furthermore, background paper is not aimed to provide methodology or models, otherwise the objective is lost.

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