

**Economic Losses
To
Kulekhani Hydroelectric Project
due to
Siltation in the Reservoir**



FINAL REPORT

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Abbreviation

BIWMP	Bagmati Integrated Watershed Management Project
BM	Bench Mark
CNPS	Central Nepal Power Stations
DDC	District Development Committee
DSCWM	Department of Soil Conservation and Watershed Management
ENE	East-North-East
ETS	Electronic Total Stations
E-W	East-West
GIS	Geographic Information System
GWH	Giga Watt Hour
HMG	His Majesty's Government
IWMP	Integrated Watershed Management Project
KHP	Kulekhani Hydroelectric Project
KHPP	Kulekhani Hydroelectric Power Project
KHS	Kulekhani Watershed
LRMP	Land Resource Mapping Project
MW	Mega Watt
MWH	Mega Watt Hour
NEA	Nepal Electricity Authority
ROR	Run-off-river
RUPES	Rewarding Upland People for Environmental Services
SCWM	Soil Conservation and Watershed Management
USA	United States of America
VDC	Village Development Committee
VPR	Value of Priority Ranking
WSW	West-South-West

I INTRODUCTION

1.1 Background:

In 1973, Central Nepal Power System (CNPS) had a total of 39.2 MW electric power generating capacity of which 31.5 MW was from run-of-river (ROR) type hydropower and 7.6 from thermal source. Generating capacity of the ROR power stations was reduced to 26.5 MW in the dry season. Considering the annual increasing rate of demand (about 20% in every five years), the peak load of 65 MW and an annual output of 282 GWH would be required in 1980. To cope with such increased demand and also to meet a further 5 years' demand increase after the completion of the project, a generating capacity of 40 to 60 MW had to be completed. On the other hand, all hydroelectric power stations in CNPS before the Kulekhani Hydropower Project (KHP) were ROR type and consequently the power available in the dry season was less than the monsoon season, whereas the demand was larger at that time. The 92 MW capacity reservoir type KHP came in existence in the limelight as the best one to satisfy these conditions.

Kulekhani watershed area lies in a fragile physographical region that experiences intense monsoon rainfall events. The watershed area has been intensively used in response to meeting people's basic needs for food, fodder, fuel wood, fibre, and shelter. As a result, the erosion processes in the watershed transport an enormous amount of sediment to the reservoir. On the one hand the sediment deposited in the reservoir reduces the life of the reservoir and the equivalent sediment brings about economic loss. Environment management plays an important role in developing strategy for watershed management and soil conservation and hydropower generation.

Upland communities are often among the poorest of the poor. They live on marginal land and possess very few other assets. These communities often provide valuable environmental services to the communities living downstream. Downstream users of such environmental services take benefit from these services without having to pay for these. Transferring part of the benefit from the environment services to upland communities would provide those communities incentives for supplying such services in a sustainable way.

RUPES (Rewarding Upland Poor for Environment Services) aims to enhance the livelihoods and reduce poverty of the upland poor while supporting environmental conservation at local and global level. Winrock International, Nepal is implementing RUPES programme in Kulekhani watershed of Nepal in order to promote sustainable livelihoods among upland communities in the Kulekhani Watershed of Nepal.

Total area of the Kulekhani Watershed (KWS) is 12,495.6 Ha. It is further divided into 8 sub-watersheds. Each sub-watershed has separate drainage. All the water drained from the watershed accumulates in 7 km long reservoir created by constructing 114m high rock filled dam.

1.2 Objective of Study

The objective of study are:

- To estimate economic losses to hydropower project due to sedimentation.
- To estimate economic benefits to hydropower projects due to conservation measures.
- To recommend measures for implementing RUPES Kulekhani.

1.3 Scope of the study

The scope of this study is to provide: information on sedimentation process and its effect in the reservoir; its value in terms of economic loss; economic benefits to hydropower projects due to conservation measures; and mitigation measures to be taken for the implementation of environmental management activities for RUPES Kulekhani so that the life span of the reservoir would be prolonged rewarding the upland population through the study of past reports, research papers, analysis of available data consultation meetings, and field visit.

1.4 Limitations:

Kulekhani Hydroelectric Plant is the first reservoir type power plant in Nepal. Information and experience on such project is limited and inadequate. Erosion and sedimentation are common phenomenon in the fragile mountain of Nepal. However, researches in this field are limited and information is not easily available. The present study was mainly based on the secondary data, therefore the study had the following limitations.

- Very limited research on the erosion processes from different landuse with different slopes, sedimentation of the reservoirs, sediment transportation rate in the rivers and streams with different morphology, rainfall intensity and its effects on erosion are carried out. Also, whatever the research are carried out, because of poor documentation its accessibility is very difficult. Besides, different assumptions have been made by different organisations for the same thing.
- Budgetary and time constrains to conduct an in-depth study.

II GENERAL DESCRIPTION OF KULEKHANI WATERSHED

2.1 Location

The Kulekhani Watershed area lies within latitude of 27° 23' 25" to 27° 41' 31" north and longitude of 85° 02' 46" to 85° 16' 16" east. The watershed area lies at northeastern part of Makawanpur district in the Central Development Region of Nepal.

2.2 Topography

The Kulekhani catchment basin is made up of uneven terrain, hills, and valleys. The watershed area is further divided into eight sub-watersheds represented by eight different rivulets which drains into the reservoir.

The slope of the KWS varies from 0% to 60 % and the altitude varies from 1530 m (the highest level of the reservoir) to 2606 m, the highest point of the catchment area. Table 2.1 gives sub-watershed wise land distribution in different slopes.

Table 2.1: Area of sub-watersheds in different slope.

Name of sub-watershed	00 - 03 %	03 - 15 %	15 - 30 %	30 - 60 %
	Area in Ha	Area in Ha	Area in Ha	Area in Ha
Bisingkhel	46.3	374.1	360.6	201.6
Kitini	53.2	472.3	724.7	215.4
Kunchhal	89.5	528	748.2	232.6
Naliban	36.7	543.5	720.3	210.5
Palung	170.3	749	1343.9	607.2
Simlang	81	193.4	414.1	236.6
Tasar	21.4	272.2	445.9	115.7
Tubikhel	57.3	575.1	1066.6	588.9
Total	555.7	3707.6	5824.3	2408.5
Total Area in Ha		12496.1		

Source: BIWMP, DSCWM

2.3 Geology

The Kulekhani region lies within two physiographic provinces: the Mahabharat Lekh to the south and the Midland to the north. The geology of the Kulekhani area consists of Precambrian to Cambrian metamorphic rocks of the Markhu formation, Kulekhani formation, Chisapani formation, Kalitar formation and granites (Stocklin and Bhattarai, 1977) Metamorphic rocks.

Metamorphic rocks of schists, granite, quartzites, crystalline limestones and various sorts of their intermediate rocks are well bedded in general. The Main Boundary Thrust, which is one of the most striking structure in the Himalayan geology, runs in a E-W to ENE-WSW and bounds the Mahabharat range composed of ancient metamorphic rocks (midland Groups) with structurally geosynclinals and controls the alignments of principal mountain ridges and valleys. The major structures in the Kulekhani area are tending concordantly to the Main Boundary Thrust, i.e. in E-W to ENE-WSW directions.

2.4 Soil

The mountain soils are derived from the parent rock consisting mostly of phyllite, granite and quartzite. In most places phyllite being susceptible to weathering gives rise to ferruginous

soil. In quartzite zone, there is very little development of soil. In places where granite rocks are exposed the feldspar is highly weathered and gives kaolin-bearing soil. The climate also works differently in the soil formation in the mountainous part.

2.5 Climate

Kulekhani watershed is under the influence of two major climatic zones namely warm temperate humid zone and cool temperate humid zone, which are in between the altitude 1500 to 2000m and above 2000m respectively. The average temperature in the warm temperate humid zone is 15 to 20 degree Celsius and 10 to 15 degree Celsius in the cool temperate humid zone.

In Kulekhani, all sources of water come from the annual precipitation by summer monsoon during June-September and also by westerly. About 96% rainfall is from monsoon and only 4% is from westerly. Monsoon cloud enters in the month of June in eastern Nepal and slowly it moves towards the west. While moving, it gives heavy precipitation to south of Mahabharat range.

Table 2.2: Annual average Precipitation in Kulekhani (mm)

Stations	Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Daman		12.11	29.78	32.98	63.38	132.90	314.00	535.90	423.90	153.70	63.70	7.30	7.09	1776.74
Markhu		26.63	26.71	42.76	46.63	122.70	264.50	400.30	303.80	158.50	46.04	17.18	17.13	1472.88
Chisapani		19.43	20.27	42.42	67.23	184.20	336.50	562.90	508.40	228.20	63.22	5.91	23.53	2062.21
Average		19.39	25.59	39.39	59.08	146.60	305.00	499.70	412.03	180.13	57.65	10.13	15.92	1770.61

Source: Department of Metrology 2002.

2.6 River System

The Kulekhani river system is the tributary of the Bagmati river and falls in the second category as it originates in the Middle Mountains. It is further divided into eight divisions based on the drainage system. Each system is known by the name of the major river that catches all the incoming water drained towards it. They are: Palung Khola, Sankhmool, Tistung Khola, Bisingkhel Khola, Chitlang Khola, Reservoir, Simbhanjyang Khola and Tasar Khola. Each river system represents separate watershed and they are Palung, Kitini, Kunchhal, Bisingkhel, Tubikhel, Simlang, Nalibang, and Tasar respectively. Table 2.3 gives the salient features of the river network in Kulekhani watershed.

Table 2.3: River network

Kulekhani Watershed	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar	T o t a l
Name of the river	Palung Khola	Sankhmool Khola	Tistung Khola	Bisingkhel Khola	Chitlang Khola	Reservoir	Simbhanjyang Khola	Tasar Khola	
Length of the rivers (km)	156.59	77.53	60.87	41.09	93.54	45.66	105.41	44.33	625.02
Area covered by rivers (Km ²)	28.7	14.66	15.98	9.83	22.88	9.25	15.11	8.55	124.96
Density of rivers (km/km ²)	5.46	5.29	3.81	4.18	4.09	4.94	6.98	5.18	5.00

Source: BIWMP - 2003

Total length of the rivers in the Kulekhani Watershed is 625 km and the area is 124.97. The average density is 4.96 km/km².

2.7 Landuse

Land use is the reflection of geographical, socio-economical, and cultural characteristics and practices of an area. It is known as classification of land as it is being used at the present. In other words, it is the categorization of land on the basis of its present use. The great diversity of landscapes and climates in Kulekhani watershed is reflected in exceedingly complex landuse options. Agriculture, which includes arable cultivation, horticulture, grazing and fodder collection, influences the vast majority of the land. Types of cropping pattern may range from three crops per year to one crop in a year.

Table 2.4: Sub-watershed wise Landuse of Kulekhani Watershed (ha).

Sub-Watershed	Barren	Builtup	Cultivation	Forest	Grass	Nursery	Plantation	River /Lake	Shrub	Total
Bisingkhel		0.6	540.7	282.3					159	982.6
Kitini			893.1	415.6			3.1	9.9	144	1465.7
Kunchhal	0.3	0.5	999.7	303.5					294.2	1598.1
Naliban	1.4		627.2	853.9			8.6		19.7	1510.8
Palung	21.9		1246.8	1512.5	11.3		31.3		46.7	2870.5
Simlang	0.1	0	455.5	303.2	0	0	7.3	117.7	41	924.9
Tasar	0	0	583.1	162.7	0	0	5.3	7.4	96.5	855
Tubikhel	0	0	772.1	1383.7	0	24	0	3.5	104.8	2288
Total	23.7	1.1	6118.2	5217.4	11.3	24	55.6	138.5	905.9	12495.6
%	0.19	0.01	48.96	41.85	0.09	0.19	0.45	1.1	7.25	100%

Source: BIWMP 2003.

Terracing is a dominant feature of land use, as it has permitted the farmer to grow crops on slopes that would have long since washed away without such measures. The type of terrace is a function of water availability, the physical constraints of the slope and the cropping possibilities. The level of terrace maintenance is determined by the productivity of the site.

Land use pattern in the Kulekhani Watershed according to BIWMP shows that about 48.96% of the total land of the watershed constitutes agricultural land, forest occupies about 41.85%, shrub land covers about 7.25% and river/lake about 1.1%. The grass, nursery, plantation, barren and built-up area covers about 0.93%. The table 2.4 shows land use pattern of the sub-watersheds.

Table 2.5: Sub-watershed wise distribution of agricultural land (cultivated land) in terms of Pakho, Khet and Tar (Area in ha).

Watershed	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar	Total	%
Sloping Terrace (Pakho)	928.89	729.16	715.67	422.18	619.31	446.43	632.61	531.54	5025.79	82.14
Levelled Terrace (Khet)	103.07	42.16	7.13	28.22	39.09	9.17	3.69	43.63	276.16	4.51
Valley Terrace (Tar)	214.84	121.68	268	90.3	113.6	0	0	8.04	816.46	13.34
Total	1246.8	893	990.8	540.7	772	455.6	636.3	583.21	6118.41	100

Source: DSCWM, 1992

Division of agricultural land are given in Table 2.5. Of the 48.96% cultivated land, 82.14% is sloping terrace (Pakho), 4.51% is levelled terrace (Khet) and 13.34% is valley terrace.

2.8 Land System

Land Systems are defined according to recurrent patterns of landforms, geology, slopes, and arable agricultural limits within the physiographic regions and each is into a number of land systems. According to the LRMP classification the KWS lies in the Middle Mountain Region. The watershed is divided in four land systems and five land units. Dominant soils, dominant slopes, and dominant soil texture also are described, which are given in the table 2.6.

Table 2.6: Land system, land form and land unit.

Land System	Land Form	Land unit	Dominant soils	Dominant Slope	Dominant Texture	Seasonal Range of Depth to Water Table
9	Alluvial plains and fans	9a. River channel	Psammments Ustorthants	< 1 degr	Fragmental Sandy	0 - 2 m
		9b. Alluvial plains	Ustifluvents Flevaquents Ustochrepts	< 1 degr	Loamy/ Bouldery	0 - 2 m
		9c. Alluvial fas	Ustochrepts Haplustaifs	1 - 5 degr	Loamy/ Bouldery	1 - 15 m
10	Ancient river terraces	10a. Non-dissected	Typic & Rhodic Haplustalfs Ustochrepts	0 - 5 degr	Loamy	> 2 m
		10b. Dissected	Ustochrepts	0 - 5 degr	Loamy	> 2 m
11	Moderately to steeply sloping Mountainous terrain		Typic, Rhodic, Udic, Anthropic, Subgroups of Ustochrepts Dystrochrepts Haplumbrepts	< 30 degree	Loamy Skeletal	> 50 cm to bedrock
12	Steeply to very steeply sloping Mountainous terrain.		Lithic Subgroup of 11 and Ustorthants	> 30 degree	Loamy Skeletal	< 50 cm to bedock

Source: LRMP, 1980-1984

2.9 Demographic Situation

Demographic composition of Kulekhani watershed is heterogeneous. Tamang, Magar, Gurung, Chettri and Brahmin are the major ethnic groups. There are 17779 families and their population is 102,058. Agriculture is the major source of livelihood and their daily life is blended with the nature surrounded them. Land use status is one of the responses to the basic need of population.

Table 2.7: Population and households of each sub-watershed.

Name of Sub Watershed	House Holds	Population		
		Male	Female	Total
Palung	2289	5919	6130	12049
Kitini	3389	9620	9286	18906
Kunchhal	2036	6451	8669	15120
Bisingkhel	1717	4586	4993	9579
Tubikhel	1725	4886	5281	10167
Simlang	1715	4486	4968	9454
Nalibab	1907	4968	4995	9963
Tasar	3001	8669	8151	16820
Total	17779	49585	52473	102058

Source: BIWMP, 2002.

III METHODOLOGY

The effect of environment degradation can be visualized in terms of sediment accumulated in the reservoir. Though the effect is in the reservoir, its causes are the activities and natural phenomenon taking place in its catchment area. Therefore, it is important to know the different sediment sources known as soil erosion, its cause and means of transportation up to the reservoir. Methods used to determine sediment volume and economic loss due to sedimentation, which we can directly translate in terms of monetary value are discussed below.

In order to accomplish this study, information were collected through the following approach:

- The reservoir site was visited in November 2002, joined sedimentation survey team of NEA, and conducted the survey together with the team using eco-sounding machine.
- Discussion with local people of Kulekhani Watershed.
- Discussion with experts, especially working in Department of Soil Conservation and Watershed Management, Bagmati Integrated Watershed Management, and Soil Conservation and Watershed Management Component of the NARMSAP and Nepal Electricity Authority.
- The study is based on the secondary data available from the past studies and records. Especially, information from Department of Soil Conservation and Watershed Management, Bagmati Integrated Watershed Management, Nepal Electricity Authority, Department of Hydrology and Meteorology, and Department of Survey has been used.
- Sedimentation rate, economic loss due to sedimentation and benefit of conservation were determined on the basis of secondary data.
- The benefit due to conservation was calculated converting preserved soil to energy resulted from the land use change from 1992 to 2001.
- Different parameters have been taken to rank different micro-watersheds in order to recommend the priority areas for conservation. Mainly, the information and data on soil loss, land use, land system, rainfall, river system, and sedimentation have been used. Topographic map produced by the Survey Department on a scale 1:25,000 has been used to measure the river length and gradient.

3.1 Sediment Production:

Sediment production is due to erosion, which includes all processes that result in the physical wearing down of the earth's surface. The processes are complex, consisting of natural (geological) erosion and accelerated (man made) erosion. Natural erosion rates are very high in Nepal because of the constant tectonic uplifting of the major mountain ranges and consequent down cutting of the river systems. The net results of these underlying forces are unstable slopes that cannot maintain their river-canyon form. Natural erosion is characterised by different forms of mass wasting, particularly mass movement (such as landslides, rock failures, slumps), riverbank cutting, and gullying.

On the other hand, accelerated erosion induced by an increasing population pressure on a limited land resource has caused an increasing proportion of the soil loss. Besides, forest clearing, overgrazing, poorly maintained marginal arable lands and fire have greatly altered the natural vegetation of Nepal, leaving the soil open to degradation. Accelerated erosion is characterised by the loss of topsoil by sheet and rill erosion (Carson, 1985).

There is no data of soil loss due to mass wasting and bank erosion. The data given in the table 3.1 has been used to calculate soil erosion due to different land use only. However, soil loss

due to riverbank cutting and mass wasting have been calculated by deducting the loss due to landuse from the total volume of sediment measured in the reservoir.

Table 3.1: Estimated soil loss due to Landuse (area in Ha and sediment in m3)

Watershed	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar	Total Ha	LU %	Rate ton/Ha	Total Production M3
Sloping Terrace	928.89	729.16	715.67	422.18	619.31	446.43	632.61	531.54	5025.8	40.22	40	125644.75
Levelled Terrace	103.07	42.16	7.13	28.22	39.09	9.17	3.69	43.63	276.16	2.21	10	1726.00
Valley Terrace	214.84	121.68	268	90.3	113.6			8.04	816.46	6.53	5	2551.44
Forest	1505.3	415.6	303.5	282.3	1383.7	303.4	853.9	162.6	5210.3	41.70	15	48846.56
Grass	11								11	0.09	32	220.00
Landslide	7.4								7.4	0.06	200	925.00
Plantation	31.3	3.1				7.2	8.6	5.3	55.5	0.44	15	520.31
Shrubs	46.7	144	294.2	159	104.7	41.1	19.7	96.5	905.9	7.25	32	18118.00
Nursery					24				24	0.19	15	225.00
Lake/Rivers		9.9			3.5	117.6		7.6	138.6	1.11	0	0.00
Barren	21.9		0.3			0.2	1.4		23.8	0.19	32	476.00
Built up			0.5	0.6					1.1	0.01	10	6.88
Total	2870.4	1465.6	1589.3	982.6	2287.9	925.1	1519.9	855.21	12496	100.00		199259.94

Source: Watershed Management Plan of Kulekhani Watershed, 1992 IWMP Technical Paper No. 1/1992

3.2 Sediment Transport

Thapa, et al (1995) estimates a sedimentation rate of 6,000 tonnes/km²/yr for the Himalayan rivers and 4,700 tonnes/km²/yr (2937.5 m³/km²/yr) for other rivers. These estimates are based on the assumption that sedimentation would be steady and that storage capacity and sediment inflow are related by specific relationship such as that proposed by Brune's curve developed on the basis of the data obtained from the rivers in the United States and assuming factors such as sediment delivery ratio to be 50%.

A study done in the Middle Hills (Dailekh district) also has considered sediment delivery ratio to be 50% (Carson, 1987). He has not considered the delivery from the mass wasting in this ratio. The ratio given is only for a small portion of sediment that comes from surface erosion. However, he stresses that the majority of the sediment entering the river is a result of mass wasting process from the catchment area.

A significant portion of eroded sediment drops out prior to reaching the conveying river of the watershed and average "Sediment delivery ratios" have been considered 50% of the total production.

3.3 Sediment Measurement

A sonic Echo-sounding machine of model type PS-20 R portable precision with transmission frequency of 200kHz and accuracy 3 cm + (depth * 1/1000) was used for underwater survey. All benchmarks were fixed with geodetic co-ordinates and an Electronic Total Station (ETS) checked all survey line lengths. The base map of the reservoir was prepared from the blown up topographical map of scale 1:25,000 produced by Department of Survey. Initially 18 lines of measurements were used and they were increased to 38. Altogether there are 60 benchmarks (BM) set so far to fix the lines of measurements. A rope marked at a distance of every 20 m distance was stretched between the two sets of benchmarks along which the depth of water was measured from a rowboat with an echo-sounding machine (Figure 3.3).

The shore-to-shore distance was measured by rope and the ETS. The distance between BM-to-BM, BM to shore, shore to echo on and BM to echo off points were measured by ETS. While measuring the depth by sonic sounding equipment at every 20m fixed on the rope, the sounding graph was marked and depth value was printed out on the marks. The reference water level considered was 1530.2m, which is the full supply level (FSL) of the reservoir.

The average depth was calculated by dividing the total sectional area below reference water level by shore-to-shore lengths. Any decrease in water depth indicates deposition (sedimentation in the reservoir) and the increment indicates erosion. The sediment deposition or erosion is computed by multiplying the mean of the average water depths of two cross-sections by the area of the reservoir surface between the two cross sections. Table 3.2 gives the detail of actual measurement of sediment in the reservoir.

Table 3.2: Sediment deposited up to November, 2002.

Year	Dead Volume M m3	Reduced in dead volume M m3	Live volume M m3	Reduction in live volume M m3	Total capacity M m3	Total reduction in reservoir capacity M m3	Sediment deposited in different years M m3	Sedimentation Rate cu.m/ha/yr	Dead storage reference m
Designed 1982	12.00	0.00	73.30	0.00	85.30	0.00	0.000	0.00	1471.00
1983	11.88	0.12	73.20	0.10	85.08	0.22	0.220	17.46	1471.00
1984	11.76	0.24	73.10	0.20	84.86	0.44	0.220	17.46	1471.00
1985	11.64	0.36	73.00	0.30	84.64	0.66	0.220	17.46	1471.00
1986	11.52	0.48	72.90	0.40	84.42	0.88	0.220	17.46	1471.00
1987	11.40	0.60	72.80	0.50	84.20	1.10	0.220	17.46	1471.00
1988	11.28	0.72	72.70	0.60	83.98	1.32	0.220	17.46	1471.00
1989	11.16	0.84	72.60	0.70	83.76	1.54	0.220	17.46	1471.00
1990	11.04	0.96	72.50	0.80	83.54	1.76	0.220	17.46	1471.00
1991	10.92	1.08	72.40	0.90	83.32	1.98	0.220	17.46	1471.00
1992 (March '93)	10.80	1.20	72.30	1.00	83.10	2.20	0.220	17.46	1471.00
Dec' 93	7.60	4.40	70.70	2.60	78.30	7.00	4.800	380.95	1471.00
Sept' 94	6.50	5.50	61.30	12.00	67.80	17.50	10.500	833.33	1471.00
Nov '95	3.00	9.00	60.80	12.50	63.80	21.50	4.000	317.46	1471.00
Dec '96	2.80	9.20	60.60	12.70	63.40	21.90	0.400	31.75	1471.00
Nov '97	7.60	9.45	55.55	12.70	63.15	22.15	0.250	19.84	1480.00
Nov '98	7.42	9.63	55.87	12.38	63.29	22.01	-0.140	-11.11	1480.00
Nov '99	6.98	10.07	55.66	12.59	62.64	22.66	0.650	51.59	1480.00
Nov '00	6.80	10.25	55.58	12.67	62.38	22.92	0.260	20.63	1480.00
Nov '01	6.79	10.26	55.57	12.68	62.36	22.94	0.020	1.59	1480.00
Nov '02	6.74	10.31	55.56	12.69	62.30	23.00	0.060	4.76	1480.00

Source: Nepal Electricity Authority - Report on Kulekhani Reservoir Sedimentation Study, 2003.

Note:

- 1 The intake was raised from the level of 1471m to the level of 1480m and sloped to adjust the sediment deposition in 1997. This caused an increment in dead volume and decrease in live volume by 5.05M m3.
- 2 Planimeter was used to calculate surface area until 1997, whereas autocad was used to calculate surface area from 1998 onwards. Table 4.2. indicates sediment in all measurement except in 1998.
- 3 In 1998, sedimentation in the reservoir indicates negative value, which is not possible. This must be due to change in method measuring the area of the reservoir. Therefore, the error is due to difference in calculation methods.

3.4 Sedimentation Rate

In march 1993, the Department of Soil Conservation and Watershed Management carried out a monitoring survey and concluded that a total of 2.2 million cubic meters of sediment have been deposited in the reservoir in 10/11 years, i.e. from the opening of the reservoir to the end of the monsoon of the year 1992. Of the 2.2 M m3, 1.2 M m3 was deposited in the dead

storage and 1.0 M m³ was in the live storage. The average rate of sedimentation was 1587 m³/km²/year. Since 1993, monitoring survey of sedimentation has been doing every year. Based on the actual measurement the average rate of sedimentation from the beginning to the end of 2002 is 8692 m³/km²/year. From 1996 onwards, the deposition rate gradually decreased. An average rate of deposition for this period (1996 to 2002) was 2472 m³/km²/year. However, the sedimentation rate was in decreasing trend and dropped to 476 m³/km²/year in the year 2002. Total volume of sediment deposited in the reservoir was 0.06 M m³ in that year.

Table 3.3: Average rate of sedimentation

Year	Sediment Yield m ³	Sediment production m ³	Production Rate m ³ /ha/yr	Production Rate discarding 1993-1995 years	Yield rate (m ³ /km ² /Year)
1982	0	0	0	0.00	0.00
1983	220000	440000	3492.06	3492.06	1746.03
1984	220000	440000	3492.06	3492.06	1746.03
1985	220000	440000	3492.06	3492.06	1746.03
1986	220000	440000	3492.06	3492.06	1746.03
1987	220000	440000	3492.06	3492.06	1746.03
1988	220000	440000	3492.06	3492.06	1746.03
1989	220000	440000	3492.06	3492.06	1746.03
1990	220000	440000	3492.06	3492.06	1746.03
1991	220000	440000	3492.06	3492.06	1746.03
1992	220000	440000	3492.06	3492.06	1746.03
1993	4800000	9600000	76190.48	0.00	0.00
1994	10500000	21000000	166666.67	0.00	0.00
1995	4000000	8000000	63492.06	0.00	0.00
1996	400000	800000	6349.21	6349.21	3174.60
1997	200000	400000	3174.60	3174.60	1587.30
1998	560000	1120000	8888.89	8888.89	4444.44
1999	660000	1320000	10476.19	10476.19	5238.10
2000	260000	520000	4126.98	4126.98	2063.49
2001	23000	46000	365.08	365.08	182.54
2002	60000	120000	952.38	952.38	476.19
Total	1126810	2253619	17886	69254	34627
Average				3847.44	1924

The average rate of sedimentation is quite high and we can't take it as normal rate of sedimentation. A rational rate of sedimentation has been calculated by careful judgement of sedimentation trend. The whole period (1982 - 2002) has been divided in three phases, namely: pre-disaster phase (1982 - 1992), disaster phase (1993 - 1995), and post-disaster phase (1996 - 2002). Sedimentation of disastrous period is considered as an exceptional case. Therefore, an average of sediment deposited during pre and post disaster phase is considered to calculate the rate of sedimentation. The table 3.3 gives an average sedimentation rate resulted both from landuse and geological turmoil (mass wasting and riverbank cutting), which is 1924 m³/km²/year.

3.5 Sedimentation in terms of Economic Loss

Installed capacity of the KHP is 92 MW (both phases) at the maximum discharge rate of 13.1 m³/sec. Since the use of this plant is made during peak hour of power consumption and dry season, each and every drop of water generates income. Whatever sediment deposits in the reservoir, replace water and minimizes power generation thus decrease revenue.

To get the economic loss due to sedimentation, the volume of sediment has been converted into the volume of water and the water volume has been converted into energy (KWH).

Environment degradation in terms of monetary value has been calculated multiplying the unit rate by total energy that the water displaced by the sediment could produce.

To calculate the economic loss in subsequent years, average rate of sedimentation - 1924 m³/km²/year, as given in table 3.3 has been used.

3.6 Benefit due to Conservation Programme

People have been cultivation in levelled terrace and valley terrace since long time as they are stable land, easy to cultivate and yields high. As the population pressure increased, cultivation in sloping terrace started. Mostly, those lands are marginal forest fringes.

Table 3.1 shows that different landuse has different soil loss. Sloping terrace has soil loss as high as 40 ton/Ha/year and the forest has 15 ton/Ha/year. The GIS map of Kulekhani shows that the agricultural area from 1978 to 1992 increased and the forest area during the same period decreased. On the contrary, from 1992 to 2001, the forest area increased and the agricultural area decreased. As 82.14% of the agricultural land in 1992 was sloping terrace (Table 2.5), this land has changed into forest. It is assumed that due to conservation programme people understand the importance of conservation and damage caused by cultivation in the marginal land. Therefore, conversion of sloping terrace to forestland preserves 25 ton/Ha/year.

Conservation programme has not only increased the forest area, but also has preserved the existing forest. Based on GIS map between 1978 and 1992 the rate of deforestation is 11.45%.. The whole forest would have been disappeared by the year 2001 if the conservation programme were not implemented in that area, at this rate. Therefore, the benefit of conservation has been considered equivalent to the difference of soil loss between the barren land and the forest, which is 17 ton/Ha/year.

The ratio of soil loss due to landuse to landslide and riverbank cutting is 40:60. The rate of soil loss due to geological turmoil increases at the same ratio as loss due to land use, as both of them are related to natural conservation. The benefit of conservation has been translated in terms of economic benefit through the conversion of conserved soil into energy.

3.7 Prioritisation

It is not possible to launch a programme throughout the whole area due to limited resources and time. Therefore, programme should be started first in the area where it is urgent. In order to know the degree of urgency, micro-watersheds are subject to evaluation on the scale of priority ranking values. Priority ranking values of parameters developed by DSCWM have been used to calculate weighted value.

A sub-watershed is considered as a unit for priority ranking. Eleven parameters that affect soil erosion and sedimentation are determined. Watersheds are ranked objectively giving factorised weighted value for each parameter. Using weighted value of parameters priority interventions are determined and prioritised. Activities required for environmental management for different sub-watersheds have been selected taking into account the parameters used to mark the sub-watersheds and its position in the list due to the ranking value. Based on the ranking value of the parameter, different sub-watersheds have been recommended with different emphasis on different SCWM activities.

IV RESULTS AND DISCUSSION

4.1 Economic Losses to Hydropower Project due to Sedimentation

The materials generated due to erosion and mass wasting are carried by water and wind and deposited in the reservoir. It is difficult to figure out the exact quantities of soil loss due to surface erosion and mass wasting and its rate of transportation up to the reservoir due to the lack of reliable data and information. However, quantities of delivery in Indra Sharober have been measured. Among the processes production, transportation, and deposition; sedimentation (deposition) in the lake is the most reliable data we have as it was obtained by direct measurement.

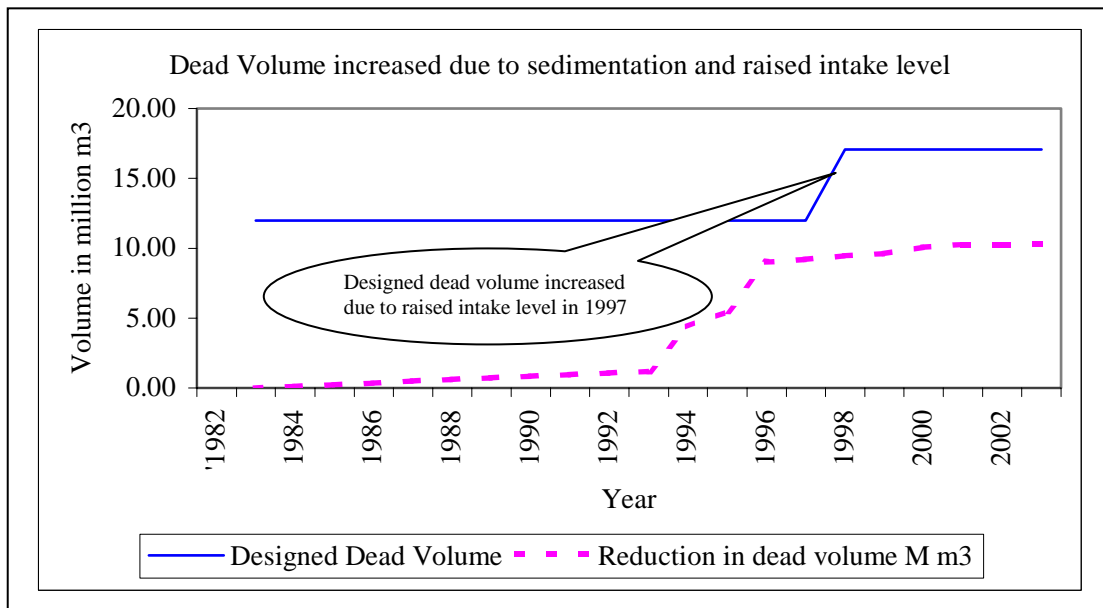


Figure 4.1: Expansion of dead storage due to raising of intake.

In march 1993, the Department of Soil Conservation and Watershed Management carried out a monitoring survey and concluded that a total of 2.2 million cubic meters of sediment have been deposited in the reservoir in 10 to 11 years, i.e. from the opening of the reservoir to the end of the monsoon of the year 1992. Of the 2.2 M m³, 1.2 M m³ was deposited in the dead storage and 1.0 M m³ was in the live storage. Since 1993, monitoring of sedimentation is has been doing regularly. At the end of 2002, the total volume of sediment reached to 23 million m³. Of the total deposition, 12.69 million m³ was deposited in the live storage and 10.31 million m³ in dead storage, which are about 55% and 45% respectively.

On the 19th July 1993 a catastrophic flood due to erratic cloudburst caused excessive erosion in the watershed therefore deposition of unpredicted amount of sediment piled up in the reservoir. The measurement taken in the December of 1993 shows a deposition of 4.8 M m³, which gives a rate of 381 m³/ha/yr. The subsequent year remain even worse. On the following year, unbelievably it jumped by 10.5 million m³ and dropped down to 4 M m³ on the year 1995. Figure 4.3 reflects the effect of sedimentation in terms of energy and economy loss.

There are two major sources of sediment namely: landuse and geological turmoil (landslide, riverbank cutting etc). It is difficult to estimate the sediment from geological turmoil. Sedimentation from landuse has been calculated in the table 4.1 and the sediment from

geological turmoil has been calculated by deducting the quantity obtained from landuse from the quantity got from the actual measurement in the reservoir.

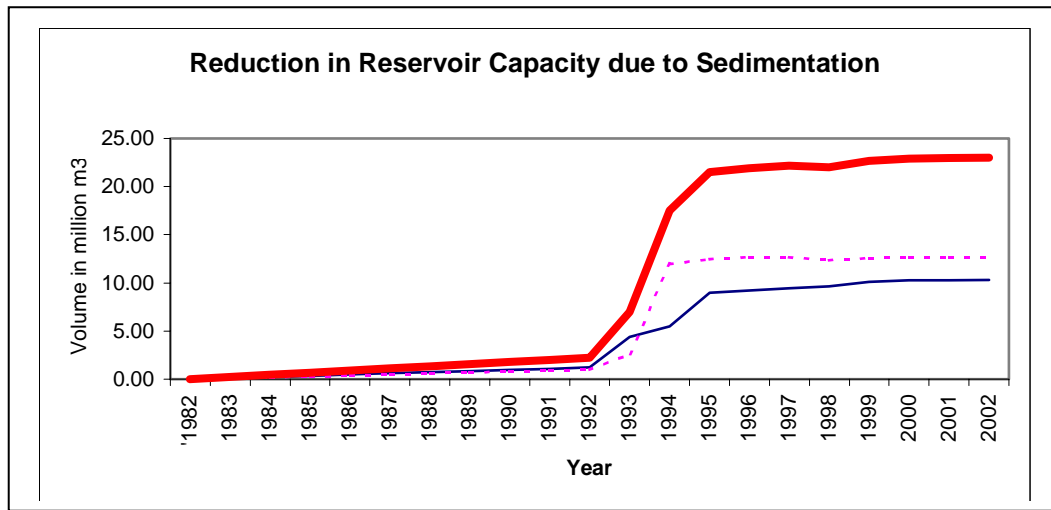


Figure 4.2: Decreasing storage capacity of reservoir.

A relation can be established from the sedimentation rate obtained by measurement and the estimated sediment obtained from the landuse (Refer table 3.1 and 3.3). Considering the average yielding rate of normal years (i.e. 1924 m³/km²/year), total sediment deposition per year is 242424 m³/year. Considering 50% yielding rate and 199259.94 as total production due to landuse, the landuse contributes 99630 m³ per year to the sedimentation in the reservoir. This quantity is approximately 40% of the total deposition. Then the remaining 60% comes from the geological turmoil.

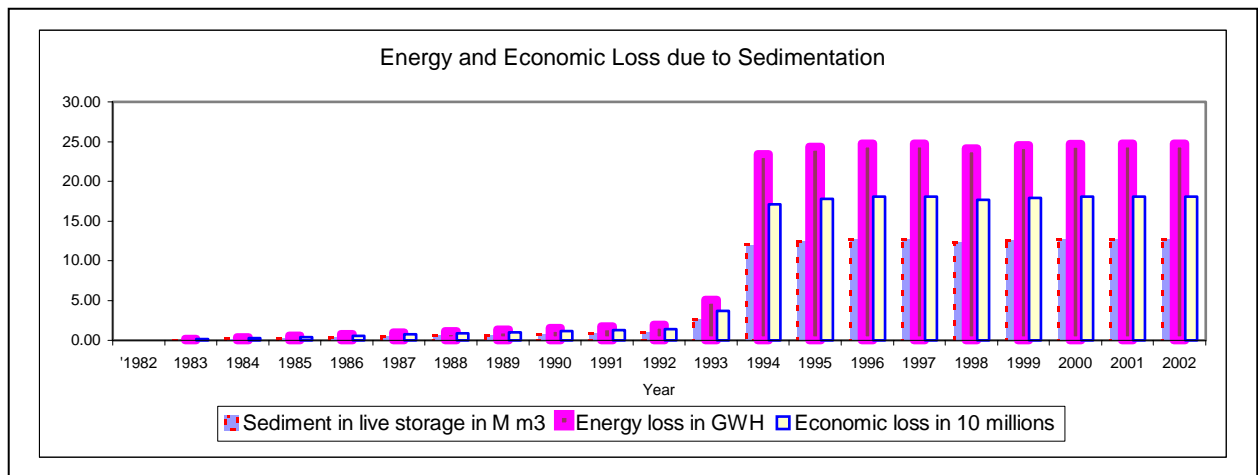


Figure 4.3: Effect of sedimentation in energy and economic loss.

The factual figure obtained from the measurement shows that a loss of 180.72 million rupees has occurred on the year 2002 at the rate of Rs. 7.30 per unit. Considering normal rate of sedimentation and 55% retention in the live storage, each year energy generation capacity decreases by 260.1 MWH. This gives an additional loss of 1.9 million per year. The table 4.1 shows a projected loss for 10 years from the year 2002.

After the devastating flood of 1993, two major structures namely: sloping intake and check dam were built in the reservoir to overcome with the unforeseen problem of sedimentation in the dead storage and protect main part of the reservoir from direct inflow of sediment respectively.

Table 4.1 : Projection of sediment deposition and economic loss at an average sedimentation rate of normal years.

Year	Sedimentation rate in live storage (million m ³ /yr)	Total sediment in million m ³	Sediment in terms of electricity GWH	Cost per unit at present market rate Rs.	Loss per year in million Rs
2002	12.6900	12.6900	24.7557	7.30	180.72
2003	0.1333	12.8233	25.0158	7.30	182.62
2004	0.1333	12.9566	25.2758	7.30	184.51
2005	0.1333	13.0899	25.5359	7.30	186.41
2006	0.1333	13.2232	25.7959	7.30	188.31
2007	0.1333	13.3565	26.0559	7.30	190.21
2008	0.1333	13.4898	26.3160	7.30	192.11
2009	0.1333	13.6231	26.5760	7.30	194.00
2010	0.1333	13.7564	26.8361	7.30	195.90
2011	0.1333	13.8897	27.0961	7.30	197.80
2012	0.1333	14.0230	27.3561	7.30	199.70

Since the completion of check dam at the mouth of Palung Khola in 1999, accumulation of sediment in up stream of the check dam is given in the table 4.2. Though the check dam has been effective in stopping major portion of sediment in the upstream of the dam, this has also occupied live volume of the storage. The check dam has no relation with natural conservation; therefore erosion rate does not decrease. Eventually, the sediment flows towards the main storage once the space at the upstream of the check dam is filled, unless the sediment is removed mechanically. Besides, it involves very high cost.

Table 4.2: Water volume and sediment at different sections in different years.

S.No.	Survey lines	Surface Area between lines in m ²	Volume of water in m ³ Nov '98	Volume of water in m ³ Nov '99	Volume of water in m ³ Nov '00	Volume of water in m ³ Nov '01	Volume of water in m ³ Nov '02	Volume of Sediment in m ³ in 1999	Volume of Sediment in m ³ in 2000	Volume of Sediment in m ³ 2001	Volume of Sediment in m ³ 2002
1	Bm 101 to Bm 102	54460.44	1128148	1128148	1112626.8	1116166.7	1097377.9	0	15521.22	-3539.93	18788.85
2	101-102-Spl-Int	41475.16	1815989.9	1823455.4	1851243.8	1848962.6	1833202.1	-7465.53	-27788.36	2281.14	15760.56
3	Spl-Int-1-Int	91945.02	4375663.5	4443702.8	4399109.5	4326932.6	4514500.5	-68039.32	44593.34	72176.84	-187567.8
4	1-Int-1-2	74318.65	3929970.2	3921795.2	3831126.4	3775759	3901729.1	8175.05	90668.75	55367.4	-125970.1
5	1-2-3-4	150961.11	7541262.3	7655237.9	7589569.8	7612214	7495219.1	-113975.6	65668.08	-22644.16	116994.86
6	3-4-5-6	144234.92	6759569.5	6963661.9	6891544.5	6954286.7	6894429.2	-204092.4	72117.46	-62742.19	59857.49
7	5-6-7-6	36774.2	1839997.1	1845329.4	1858016.5	1877874.5	1864451.9	-5332.26	-12687.1	-19858.06	13422.58
8	6-7-8-9-8-8A	110083.43	4990632.3	4942746	4993934.8	5116677.8	4981275.2	47886.29	-51188.79	-122743	135402.62
9	BM 8 to BM 8A	6073.27	43545.35	48646.89	47675.17	46217.58	48788.6	-5101.54	971.72	1457.59	-2571.02
10	8-9-9-10	61713.03	2594415.8	2527457.1	2557388	2623729.5	2570347.7	66958.64	-29930.82	-66341.51	53381.77
11	9-10-10-11	34693.1	1603862	1610974.1	1596229.5	1617739.3	1602821.2	-7112.09	14744.57	-21509.72	14918.03
12	BM 11-Bm 13	42110.01	714326.14	678111.53	689340.86	681901.43	672356.49	36214.61	-11229.33	7439.43	9544.94
13	10-11-13-12-12A-12B	120645.4	5220929.7	5351226.7	5290904	5285475	5236010.4	-130297	60322.7	5429.05	49464.61
14	12-13-12-15	26578.8	951786.83	949527.63	952318.4	920158.06	919626.48	2259.2	-2790.77	32160.34	531.58
15	12-15-15-14-14-14A	66113.01	2462709.8	2322219.6	2320897.4	2259081.7	2257759.4	140490.15	1322.26	61815.67	1322.26
16	14-15-15-16	57007.59	2219590.5	2067950.3	2052843.3	2043152	2029470.2	151640.19	15107.01	9691.29	13681.83
17	BM 14 to Bm 14A	37169.47	281248.99	276912.55	266133.41	266752.9	278771.03	4336.44	10779.14	-619.49	-12018.13
18	15-16-16-17	32412.61	1220334.8	1163774.8	1146109.9	1128931.2	1108997.5	56560.01	17664.87	17178.68	19933.76
19	A1-A2-16-17	54365.76	5640861.4	1804671.4	1774498.4	1721763.6	1717958	3836190	30172.99	52734.79	3805.6
20	A1-A2-B1-B2	26338.59		663732.47	659649.99	637262.19	642793.29	-663732.5	4082.48	22387.8	-5531.1
21	B1-B2-C1-C2	39970.63		968288.63	963891.86	936511.98	955298.17	-968288.6	4396.77	27379.88	-18786.19
22	C1-C2-18-19	60966.02		1614684	1612246.4	1577190.9	1618343	-1614684	2437.64	35055.46	-41152.06
23	18-19-20-21-21A-21B	97817.16	2270825.4	2249305.6	2263489.1	2262511	2337830.2	21519.78	-14183.49	978.17	-75319.21
24	21A-21B-21C-21D	46769.05	627640.65	673942.01	679320.45	655935.93	710889.56	-46301.36	-5378.44	23384.52	-54953.63
25	BM 21C to Bm 21D	8855.73	33976.48	36810.32	37784.45	36308.49	39260.4	-2833.84	-974.13	1475.96	-2951.91
26	20-21-21-G	35668.75	758317.63	744050.13	743693.44	763846.28	788279.38	14267.5	356.69	-20152.84	-24433.1
27	G-21-22-23	58409.13	1116490.5	1087870.1	1096339.4	1110357.6	1130216.7	28620.47	-8469.32	-14018.19	-19859.11
28	22-23-24-25	26714.89	515063.08	509452.95	514528.78	522276.1	520940.36	5610.13	-5075.83	-7747.32	1335.74
29	24-25-25-26	5946.6	126811.25	123481.15	124492.07	129130.42	125770.59	3330.1	-1010.92	-4638.35	3359.83
30	25-26-27-28	26578.8	550579.84	521343.16	533569.41	553503.51	542207.52	29236.68	-12226.25	-19934.1	11295.99
31	27-28-29A-29B	35078	619126.7	586504.16	608603.3	625089.96	627896.2	32622.54	-22099.14	-16486.66	-2806.24
32	BM 29A to Bm 29	24698.38	99863.78	108014.25	112212.97	114600.48	113612.55	-8150.47	-4198.72	-2387.51	987.93
33	29A-29B-29A-29-29-30	6540.03	97152.15	99473.86	102449.57	104542.38	99408.46	-2321.71	-2975.71	-2092.81	5133.92
34	29-30-31-32	23893.3	328174.48	345855.52	353381.91	364492.29	341674.19	-17681.04	-7526.39	-11110.38	22818.1
35	31-32-33-34	22735.51	301472.86	296925.76	308975.58	324549.41	319433.92	4547.1	-12049.82	-15573.83	5115.49
36	33-34-35-36	21523.19	261829.61	243534.89	235678.93	233419	219536.54	18294.72	7855.96	2259.93	13882.46
37	35-36-37-38	33525.08	244230.21	231323.05	199306.6	174498.04	135776.57	12907.16	32016.45	24808.56	38721.47
38	BM37 to Bm38	10552.38	12909.08	14140.19	12944.25	11572.44	6683.17	-1231.11	1195.94	1371.81	4889.27
	Total	1855716.2	63299308	62644282	62384069	62361375	62300943	655026.28	260212.71	22694.23	60431.88
	Sediment deposited in upstream of the check dam (S. No. 38,37 and 25% of 36)							16249.73	35176.38	26745.353	47081.355
	Sediment deposited in downstream of the check dam.							638776.55	225036.33	-4051.122	13350.525
	Percentage of the total sediment deposited in the upstream of the check dam							2.48	13.52	117.85	77.91

Source: NEA, 2002

4.2 Benefit to Hydropower Project due to Conservation Measures

The sedimentation measurement in the reservoir shows that there is abrupt change from the fourth year of the calamity (i.e.1993). The deposition on the third year after the flooding was

measured 4 M m³, which dropped to 0.4 M m³ (table 3.2 and 4.2). In average, this situation more or less was maintained till the latest sedimentation measurement report of NEA 2003. This is an indication of geological stability and improvement in soil erosion. Conservation activities implemented in this area have been effective in bringing this result. This fact is supported by the positive landuse change given in the table 4.3.

Table 4.3: Landuse situation of Kulekhani Watershed from 1978 to 2001.

S.No.	Landuse	1978		1992		2001	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
1	Agriculture	5359.68	42.89	6112.22	48.91	5568.00	44.56
2	Forest	5884.30	47.09	5210.67	41.70	6730.00	53.86
3	Others	1252.44	10.02	1173.53	9.39	198.42	1.58
	Total area	12496.42	100.0	12496.42	100.0	12496.42	100.0

Source : Winrock 2004

The landuse pattern of Kulekhani watershed has been changed. This is a generally accepted fact that decreases in forest and increases in agricultural area accelerate erosion process or vice-versa. The above table shows that agricultural land increased by 6.02% and forest area decreased by 5.39% during the period between 1978 and 1992. On the other hand, the agricultural land decreased by 4.35% and the forest area increased by 12.16% in between 1992 and 2001. We do not have exact data on when it started to decrease the agricultural land and increase the forest area during the 1992 - 2001 period. However, there is a logical relation between the sedimentation deposited and landuse during that period.

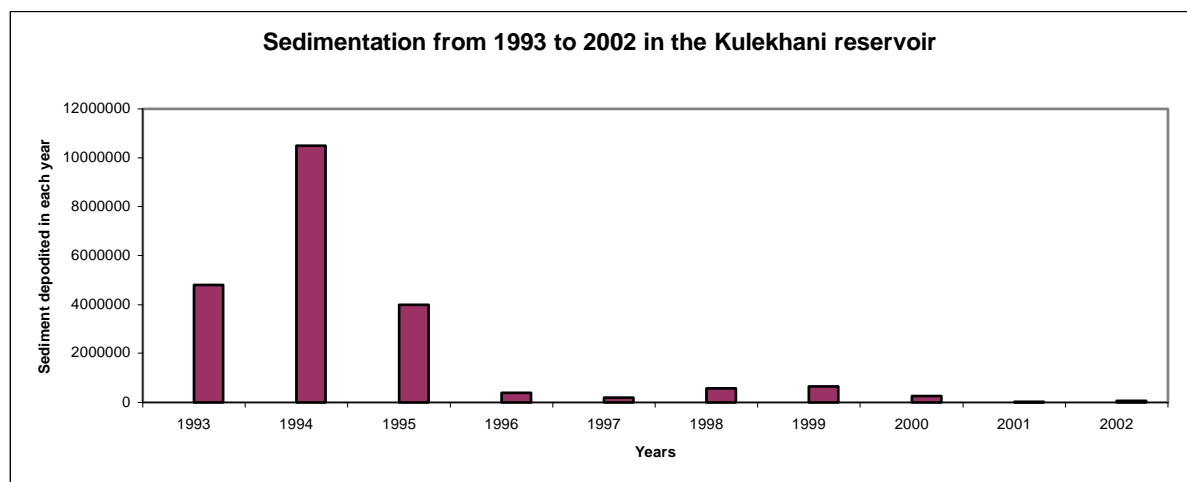


Figure 4.5: (Data source: NEA- Report on Kulekhani Reservoir Sedimentation Study, 2003)

Sedimentation measurement done in the reservoir shows that excessive sediment was deposited in the years 1993 to 1995, which is also reflected in the above graph (Figure 4.5). Though there are several other factors like heavy rainfall, to bring this situation however, landuse is one of the major factors to accelerate the process. Effective conservation programme plays a major role in stabilizing the land and minimizing the soil erosion. Especially, the conservation behaviour like, the growth and maintenance of the forest and adoption of conservation friendly agricultural practice, of the people living in the upland areas of the reservoir. The table 4.3 and the sedimentation in the reservoir (Figure 4.5), particularly during the 1992 to 2001 period can be read in the light of conservation and observe the following:

- The year 1992 was the peak time of increase of agricultural land and decrease of forest area.

- The rate of deforestation is 11.45% per year.
- In the early years of that period (1993 to 1995) exceptionally high volume of sedimentation deposited in the reservoir.
- In the later years (1996 to 2002), rate of sedimentation decreased in the reservoir.
- The agricultural areas decreased and forest area increased in the Kulekhani watershed.

The landuse data of 2001 given in the table 4.3 indicates that a 544 ha of agricultural land have been changed into forest. Logically, there are no chances to change valley and levelled terrace to forest. Marginal land or sloping terrace, which have high erosion potential, is the only land that could have been changed. There is a difference of 25 ton/ha/year soil loss between agricultural land (sloping terrace) and forest. At the rate of 0.625 m³/ton, the landuse change has conserved a volume of 8500 m³ soil from loss, which is 4.3% of the total soil loss due to the landuse. While translating it in terms of economic value, it comes out to be Rs 60,524.00.

Valuation of increased forest area alone doesn't capture the positive impact of conservation programme. The programme has contributed to preserve the existing forest also. Otherwise, the whole forest would have been disappeared by the year 2001 at the rate of deforestation between 1978 and 1992, which is 11.45%. An area of 5210.67 ha has been maintained and saved from being converted into a barren land. Taking into account the soil loss difference between forest and barren land (table 3.1) the conservation programme has to be credited 17 ton/ha/year, which is equivalent to 55400 m³ /year. Converting it into economic value, it comes out to be Rs 394,472.00.

So far, we have discussed the economic benefit caused by only landuse change due to positive effect of conservation, which is 40% only. It has already been discussed in 4.1 that 60% of the sediment comes from mass wastage and riverbank cutting, which are also directly related to natural conservation. This fact has been supported by the sedimentation in the reservoir between 1993 and 1995, which were the initial years of forest maintenance. Therefore, positive effect of conservation in saving soil loss from landslide and riverbank cutting is 95850 m³, which is equivalent to Rs 682, 495.00 in terms of monetary benefit.

The above are the direct benefit we can convert into economic terms. This gives a total of Rs. 1,137,491.00. This is an evidence of positive effect of conservation programme in the landuse change and its positive impact in the environment.

Positive impact of landuse change has been reflected on the sedimentation in the reservoir. It is difficult to say the sedimentation rate of different years of pre-disaster years as there is only one monitoring survey done before the catastrophic cloud burst. However, the stabilization of land in three years and gradual decrease of sedimentation rate is the result of conservation work being implemented in the upstream of the reservoir.

4.3 Priority Ranking

Several parameters vital for soil conservation and watershed management of the area under consideration are taken. Various weighted values ranging from 1 to 10 are given to each parameter. The rational is to give the lowest weighted value to the parameter that has the least influence on soil erosion and the highest weighted value to the parameter having the greatest influence on soil erosion. The weighted value is multiplied by the proportion of the area and summed with the value of each parameter to give a weighted total value of each parameter, which is used to fix priority ranking. The highest weighted total value will indicate the priority for soil conservation and watershed management programmes.

Population Density: Population density denotes the number of people living in unit area. We have to understand it, mainly subsistence farmers dependent on natural resources, but not the urban population. Human population is one of the major factors that cause erosion. The economic activities are associated with increasing population and contributing more and more to the topsoil erosion. Higher the population more is the exploitation of natural resources and causes land degradation and deforestation. Acceleration of developmental activities also causes erosion, which then contributes in sedimentation. Land use status is one of the responses to the basic need of population.

Table 4.4: Population density and weighted value of each sub-watershed.

Name of Sub Watershed	House Holds	Population			Area of Watershed (km ²)	Population Density (no./km ²)	Weighted Value
		Male	Female	Total			
Palung	2289	5919	6130	12049	28.71	419.68	9
Kitini	3389	9620	9286	18906	14.66	1289.63	10
Kunchhal	2036	6451	8669	15120	15.98	946.18	10
Bisingkhel	1717	4586	4993	9579	9.83	974.47	10
Tubikhel	1725	4886	5281	10167	22.88	444.36	9
Simlang	1715	4486	4968	9454	9.25	1022.05	10
Nalibab	1907	4968	4995	9963	15.11	659.36	10
Tasar	3001	8669	8151	16820	8.55	1967.25	10

Source: BIWMP, 2002.

The lowest weighted value is 1 (one) for the density less than 50 persons in a square kilometre. The weighted value increases upon increment of the population. Higher the value, denser is the population, and more serious to the environment. In this case, the weighted value is closer to the upper limit, i.e. 9 and 10. This means that the sub watershed is densely populated and is in alarming condition. Population and density is given in the table 4.4.

Shape Index: Shape index is the ratio of area of watershed to the square of the length of its basin measured from its outlet to its divide near the head of the longest stream along a straight line (Horton 1932). The shape and size of a watershed affect the stream flow hydrograph and peak flow rates, and sedimentation. Runoff from a watershed with a low form factor does not concentrate as quickly as it does from a watershed with a high form factor of the same size. The former is less likely to have an intense rainfall simultaneously over its entire extent than area of equal size with a larger form factor but may not be same for small watershed close by area. A compact basin will yield a value close to 1, while a long and narrow basin will yield a low value and generally a lower peak runoff. Erosion and sedimentation problems due to landslide and bank cutting are greater as the shape index approaches closer to 1 and lower as shape index move towards 0.

Table 4.5: Shape index and weighted value

Name of Watershed	Area of watershed	Length of river	Rf	Weighted Value
Palung	28.71	7.625	0.49	4.9
Kitini	14.66	9	0.18	1.8
Kunchhal	15.98	7.5	0.28	2.8
Bisingkhel	9.83	7.25	0.19	1.9
Tubikhel	22.88	9.75	0.24	2.4
Simlang	9.25	5.75	0.28	2.8
Naliban	15.11	9.875	0.15	1.5
Tasar	8.55	8.375	0.12	1.2

Source: * BIWMP, 2002 ** HMG, Survey Department

$$Rf = A/L^2$$

Where: A = Watershed Area
Rf = Shape index and
L = Length of the basin.

From the prospective of shape index, Palung is the most vulnerable area and Tasar is the best among the eight watersheds.

Land use verses slope class:

Table 4.6: Landuse verses Land slope class.

SW_NAME	Landuse*	00 - 03 %	VPR* *	03 - 15 %	VPR* *	15 - 30 %	VPR* *	30 - 60 %	VPR* *	Total	Weighted Value
Palung	Barren	0.7	1	2.1	2	11.4	4	7.7	7	104.4	
	Cultivation	153.9	1	543.9	2	466.6	2	82.4	4	2504.5	
	Forest	3.1	1	180.4	2	836.1	3	485.7	4	4815	
	Grass	0	1	2.9	2	6.3	4	1.8	6	41.8	
	Land Slide	0	10	0.7	10	4.5	10	2.2	10	74	
	Plantation	12.5		17.5		0		1.3		0	
	Shrub	0.1	1	1.5	2	19	4	26.1	6	235.7	
			170.3		749		1343.9		607.2		7775.4
Kitini	Cultivation	46.3	1	383.6	2	404.9	2	58.2	4	1856.1	
	Forest	2.9	1	42.1	2	236.1	3	134.5	4	1333.4	
	Plantation	1.3	1	1.7	2	0.1	3	0	4	5	
	River/Lake	1.3	5	6	5	2.1	5	0.5	5	49.5	
	Shrub	1.4	1	38.9	2	81.5	4	22.2	6	538.4	
			53.2		472.3		724.7		215.4		3782.4
Kunchhal	Barren	0.1	1	0.2	2	0	4	0	7	0.5	
	Builtup	0.1	5	0.4	4	0	3	0	10	2.1	
	Cultivation	86.2	1	452.6	2	431.9	2	29.1	4	1971.6	
	Forest	1	1	40.2	2	172.3	3	90	4	958.3	
	Shrub	2.1	1	34.6	2	144	4	113.5	6	1328.3	
			89.5		528		748.2		232.6		4260.8
Bisingkhel	Builtup	0.1	5	0.4	4	0.1	3	0	0	2.4	
	Cultivation	41.2	1	304.2	2	184.6	2	10.7	4	1061.6	
	Forest	2.9	1	29.9	2	100.9	3	148.6	4	959.8	
	Shrub	2.1	1	39.6	2	75	4	42.3	6	635.1	
			46.3		374.1		360.6		201.6		2658.9
Tubikhel	Shrub	0.3	1	9.2	2	55.6	4	39.6	6	478.7	
	Cultivation	50.5	1	406.7	2	290.6	2	24.2	4	1541.9	
	Forest	5.5	1	145.4	2	707.9	3	524.9	4	4519.6	
	Nursery	0.7	1	12	2	11.3	2	0	4	47.3	
	River/Lake	0.3	5	1.8	5	1.2	5	0.2	5	17.5	
			57.3		575.1		1066.6		588.9		6605
Simlang	Cultivation	6.9	1	97.1	2	252.3	2	99.3	4	1102.9	
	Shrub	0.5	1	5.3	2	16.5	4	18.8	6	189.9	
	River/Lake	69.2	5	39.7	5	7.3	5	1.4	5	588	
	Forest	3.6	1	47.8	2	134.9	3	117.1	4	972.3	
	Barren	0.1	1	0.1	2		4		7	0.3	
	Plantation	0.7	1	3.4	2	3.1	3	0	4	16.8	
			81		193.4		414.1		236.6		2870.2
Naliban	Forest	18.9	1	254.5	2	416.9	3	163.6	4	2433	
	Plantation	0.3	1	4.8	2	2.4	3	1.1	4	21.5	
	Shrub	0	1	8.4	2	10.7	4	0.6	6	63.2	
	Cultivation	17.5	1	275.4	2	289.6	2	44.8	4	1326.7	
	Barren	0	1	0.3	2	0.7	4	0.4	7	6.2	
			36.7		543.4		720.3		210.5		3850.6
Tasar	Cultivation	14.4	1	209.4	2	304.7	2	54.7	4	1261.4	
	Forest	1.4	1	48	2	89.9	3	23.3	4	460.3	
	Plantation	2.2	1	2.2	2	0.7	3	0.2	4	9.5	
	River/Lake	2.7	5	3.3	5	1.3	5	0.3	5	38	
	Shrub	0.7	1	9.3	2	49.3	4	37.2	6	439.7	
			21.4		272.2		445.9		115.7		2208.9
Grand Total		555.7		3707.5		5824.3		2408.5		34012.2	

Source: *BIWMP, ** DSCWM

Landuse refers to the existing or present use. It is a major natural resource available to men. Land denotes a complex of the earth's surface, sub-surface, and supra-surface attributes with regard to configuration. The main land attributes are landform, soil, water, climate, landuse, and fauna. Landuse status, a response to the basic needs of the population, is one of the major factors that affects in the soil erosion, therefore has been considered for the priority ranking.

The Kulekhani is located in the middle mountain region with different slopes. The slope is another factor that has important role on infiltration, surface runoff, and ground water contribution of stream flow. It affects adversely in production as the rainwater washes the nutrient topsoil away. It is a major factor affecting the time of overland flow and concentration of rainfall in stream channels and flood magnitude. It is also an important factor affecting erosion and sediment production. The greater the slope the more will be the erosion and the failure of the slope results in landslide.

The table 4.6 indicates that 19.9% of the total area falls on 30 to 60 % slope, which is high erosion potential area. 16.8% of this area is under cultivation, which is 6.6% of the total cultivation area and 3.2% of the total watershed area. An agricultural practice in such marginal areas accelerates in erosion process.

Time of concentration: The time required for water to travel from the most distant point on the watershed to the watershed outlet is known as the time of concentration. If other factors remain constant, erosion rate is inversely proportional to the time of concentration. In other words, the longer the time of concentration, the lower is the probability of soil loss. Anticipated negative effect due to time concentration is landslide, flooding, and riverbank cutting. It can be determined by the following formula.

$$T_0 = L \times (1.15/15)^x \times H^{0.38}$$

Where T_0 = Time of concentration

L = Length of watershed along the main stream from the outlet to the most distant ridge in kilometres.

H = The difference in elevation between the watershed outlet and the most distant ridge in kilometres.

Table 4.7: VPR on the basis of Time of concentration.

Name of Watershed	Length of river in km.	Highest point (m)	Lowest point (m)	Elevation diff. (km.)	1.5/15	(H) ^{power} .38	Time of con.(Tc)	*VPR
Palung	7.625	2551.0	1780.0	0.771	0.077	0.906	0.530	10
Kitini	9.000	2338.0	1580.0	0.758	0.077	0.900	0.621	10
Kunchhal	7.500	2360.0	1580.0	0.780	0.077	0.910	0.523	10
Bisingkhel	7.250	2240.0	1520.0	0.720	0.077	0.883	0.491	10
Tubikhel	9.750	2520.0	1520.0	1.000	0.077	1.000	0.748	10
Simlang	5.750	1520.0	1406.0	0.114	0.077	0.438	0.193	10
Nalibab	9.875	2550.0	1520.0	1.030	0.077	1.011	0.766	10
Tasar	8.375	2240.0	1520.0	0.720	0.077	0.883	0.567	10

Source: HMG, Survey Department

* HMG, Department of Soil Conservation and Watershed Management.

Annual Precipitation: All water, which falls from the atmosphere to the earth's surface in various forms in a year, is annual precipitation. However, it has been considered only rainfall for the purpose of this study. It is the foremost factor in the process of sedimentation as it causes erosion/landslide, and transports the isolated part of the earth to its destination i.e. reservoirs through river channels.

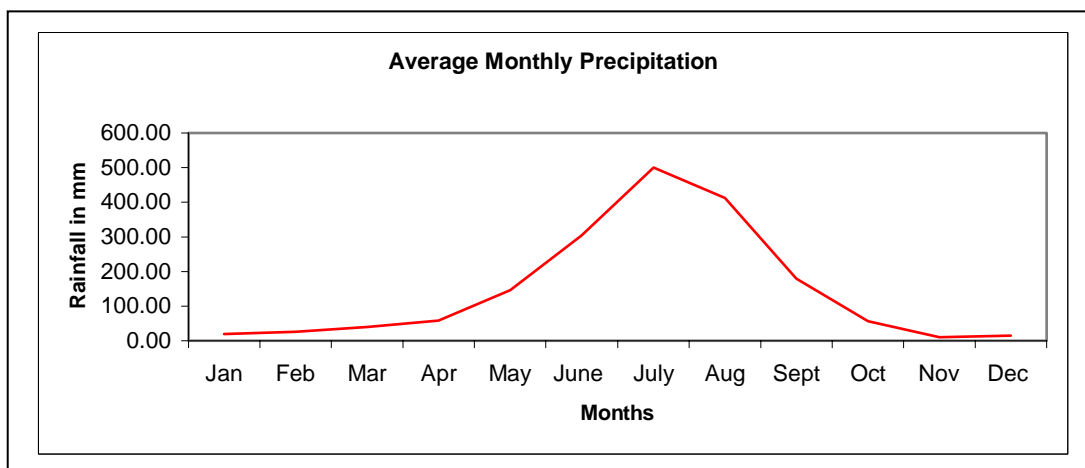


Figure 4.5: Rainfall distribution in a year

Rainfall data of Kulekhani was taken from the average of three stations namely, Daman, Markhu and Chisapani located around and inside the watershed. The graph (figure 4.5) gives monthly average rain fall pattern in a year.

The figure 4.5 also shows that May, June, July, August and September are the months the precipitation exceeds 100mm. The remaining months precipitate less rain. The average annual rainfall in the watershed area is 1770.61 mm (Table 2.5).Kulekhani is small area and there is no isohyetal map or separate rainfall data for individual sub-watershed. Precipitation for all sub-watersheds of Kulekhani is considered as 1770.61 mm, which is more than the national average 1600mm. However, even though it plays a key role in an individual watershed it does not affect in prioritisation as all sub-watersheds have the same value.

Drainage Density: Drainage density is the average length of streams per unit area in a watershed. Kulikhani is divided into 8 sub-watersheds having rivers of different lengths and numbers. Total length of rivers in Palung watershed is the highest and the Bisingshel has the shortest length. The density of drainage is given in table 4.8.

Table 4.8: Drinage Density of Kulekhani Watershed.

Watershed	Palung	Kitini	Kunchhal	Bisingshel	Tubikhel	Simlang	Naliban	Tasar
Name of the rivers	Palung Khola	Sankhmool Khola	Tistung Khola	Bisingshel Khola	Chitlang Khola	Reservoir	Simbhangyang Khola	Tasar Khola
Length of the rivers (km)	156.59	77.53	60.87	41.09	93.54	45.66	105.41	44.33
Area covered by rivers (km ²)	28.7	14.66	15.98	9.83	22.88	9.25	15.11	8.55
Density of rivers km/km ²	5.11	4.93	3.51	5.33	5.24	5.26	6.75	4.33

Source: BIWMP

While giving the weightage value to each watershed, all of them fall under the category <10, which has the priority ranking value 1. Therefore, it does not play significant role in prioritisation. However, drainage density has key role in erosion and sedimentation through the action of bank cutting, bed scoring, and transportation of eroded materials. In similar situation, higher drainage density indicates more erosion.

Slope of watershed: Slope is the degree of deviation of a surface from the horizontal. It contributes appreciably to the time of concentration of water in a water basin. The slope of a watershed has important influences on infiltration, surface runoff, and ground water contribution of stream flow. It is one of the major factors affecting the time of overland flow

and concentration of rainfall in stream channels and flood mitigation. Besides, it plays a key role in erosion, mass wasting, and transportation of materials. Higher the slope, more it accelerates the process of soil loss. Table 4.9 gives the area of different sub-watershed in different slopes. As Tubikhel has the highest, i.e. 4.19 weighted value it requires the first priority from the prospective of slope in management.

Table 4.9: Area of sub-watersheds in different slope.

Name of sub-watershed	00 - 03 %		03 - 15 %		15 - 30 %		30 - 60 %		Total Value	Weighted Value of WS
	Area in Ha	VPR	Area in Ha	VPR	Area in Ha	VPR	Area in Ha	VPR		
Bisingkhel	46.3	1	374.1	2	360.6	4	201.6	7	3648.1	3.71
Kitini	53.2	1	472.3	2	724.7	4	215.4	7	5404.4	3.69
Kunchhal	89.5	1	528	2	748.2	4	232.6	7	5766.5	3.61
Naliban	36.7	1	543.5	2	720.3	4	210.5	7	5478.4	3.63
Palung	170.3	1	749	2	1343.9	4	607.2	7	11294.3	3.93
Simlang	81	1	193.4	2	414.1	4	236.6	7	3780.4	4.09
Tasar	21.4	1	272.2	2	445.9	4	115.7	7	3159.3	3.69
Tubikhel	57.3	1	575.1	2	1066.6	4	588.9	7	9596.2	4.19
	555.7		3707.6		5824.3		2408.5		48127.6	
							Total Area		12496.1	3.85

Source: BIWMP, DSCWM

Land use coverage: Area covered by different land use in each sub-watershed was obtained from GIS section of the BIWMP. Priority value of each land use of each sub watershed as given below was assigned. Then, weighted value of each watershed was calculated relating priority-ranking value with its land use coverage and area of the sub-watershed. Weighted value of each sub-watershed in light of landuse coverage is given in table 4.10.

Table 4.10: Land use coverage in ha.

Landuse*	Barren	Builtup	Cultivatio	Forest	Grass	Nursery	Plantation	River/ Lake	Shrub	Total Value	Value of WS
VPR**	6	3	6	3	4	6	3	10	6		
SW_NAME											
Bisingkhel		0.6	540.7	282.3					159	5046.9	5.14
Kitini			893.1	415.6			3.1	9.9	144	7577.7	5.17
Kunchhal	0.3	0.5	999.7	303.5					294.2	8677.2	5.43
Naliban	1.4		627.2	853.9			8.6		19.7	6477.3	4.29
Palung	21.9		1246.8	1512.5	11.3		31.3		46.7	12569	4.38
Simlang	0.1	0	455.5	303.2	0	0	7.3	117.7	41	5088.1	5.50
Tasar	0	0	583.1	162.7	0	0	5.3	7.4	96.5	4655.6	5.45
Tubikhel	0	0	772.1	1383.7	0	24	0	3.5	104.8	9591.5	4.19
Grand Total										59683.3	4.78
Area	23.7	1.1	6118.2	5217.4	11.3	24	55.6	138.5	905.9	Total	12495.70

Source: *BIWMP, **SCWM

Coverage wise, cultivation has the highest coverage, which is 48.96%. Cultivation includes, sloping terrace (Pakho), levelled terrace (Khet), and valley terrace (Tar). The forest follows the cultivation with 41.85%. Built up covers the lowest area that counts 1.1 Ha, this is only.01% of the total area. Among the sub-watersheds, Simlang is the worst from the prospective of landuse and requires the first priority for management.

Landuse land system erosion potential: In view of varying degrees of soil erosion in different watersheds lying in different topographical and ecological zones, it is expedient to classify the watersheds in a district in to three classes such as high, medium and low, in order of severity of erosion condition (Malla, 1991).

Based on soil loss from different land use patterns and intensity of cultivation, all cultivated land types are categorized into high, medium, and low erosion potential areas. Similarly, forestlands are grouped into high, medium, and low erosion potential areas depending upon the crown density, which correspond to heavy soil loss and land degradation.

Table 4.11: Landuse and land system erosion potential.

Erosion Potential **	VPR*	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar	Area
Low	2	54.6	24.1	7.1	49.7	72.8	110.3	0.1	32.5	351.2
Medium	4	2156	716	979.9	709	1763.8	359	882	261.8	7828
High	6	659.9	725.6	611.1	223.9	451.4	455.7	628.6	560.6	4317
Total Area		2870.5	1466	1598.1	982.6	2288	925	1510.7	854.9	12496
Weighted Value of WS		4.42	4.96	4.76	4.35	4.33	4.75	4.83	5.24	

Source: *DSCWM, **BIWMP

Based on the slope gradient classes, soil characteristics, and others, all land units, also known as land system are grouped into high, medium, and low erosion potential areas.

From the prospective of land use and land system, erosion potentiality of the land of the Kulekhani watershed also classified in low, medium, and high classes. Cumulative area of different classes due to land use and land system of each sub watershed is given in the table 4.11

The weighted value for the erosion potential based on land use and land system varies from 4.33 to 5.24. This indicates that the erosion potentialities of the sub-watersheds lie between medium and high classes. However, Tasar comes on the top of the priority list.

Land Capability: In general, capability groupings of land are based on their potentials, limitations for sustained production, risk of soil damage, and erosion hazard. In Nepal, classification is based on the effects of combination of soils, landform, characteristics, and climate (LRMP, 1980-1984). Soil physiography, climate, geology, and geomorphology have been integrated into the framework of land system mapping, which is the basis for the land capability classification.

Table 4.12: Land capability.

Class*	VPR**	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar	Total
Class 1	1	170.4	0	0	0	0	0	0	0	170.4
Class 2	1	502.4	176.1	341.6	248.6	340.1	0	0	0	1608.8
Class 3	2	1401.3	956.4	878.6	483.9	691.7	414.8	616.8	613.5	6057
Class 4	3	796.4	333.3	377.8	245.2	1249.1	285.8	888.1	227.3	4403
Class 6	4	0	0	0	0	0	0	0	0	0
Class 8	5	0	0	0	4.9	7.2	225	5.9	14.2	257.2
	Total	2870.5	1465.8	1598	982.6	2288.1	925.6	1510.8	855	12496.4
Weighted Value of		2.04	2.11	2.02	2.01	2.41	3.04	2.60	2.32	

CLASS DESC

Class 1 Soils are deep and suitable for agriculture and forestry

Class 2 Soils are deep and well drain, Terracing for agriculture

Class 3 Soils are 50 to 100 cm deep and well drain, Terracing is mandatory when used for Agriculture

Class 4 Soils are 20cm deep, Not suitable for agriculture

Class 6 Soils are < 20cm deep, Fragile and poor generation potential

Class 8 Sand bed

Source: *BIWMP, **DSCWM

Among eight different types of land classified on the basis of their capabilities in Nepal, only six classes are available in Kulekhani watersheds. Sub-watershed-wise distributions of area of different classes and calculation of weighted value of each of them are given in the table 4.12. From the aspect of land capability, Simlang is the most vulnerable among the sub-watersheds as the weighted value comes out 3.04

Lithology: Different types of rocks, because of their process, time, and composition during formation have different response to erosion. Lithology is taken into account to study mass movement. The geological map of the Kulekhani watershed indicates that the southern portion of the watershed is composed of Palung granite while the northern part is predominantly schist (Galay, et al., 1995). Basically, there are only two types of rocks in the Kulekhani watershed.

Areas of different sub-watersheds having different rocks were calculated. Then weighted value of each sub watershed was calculated by relating the area and value for priority ranking. The priority ranking value for granite and schist are 1 and 8 respectively. The weighted value for each sub watershed is given in the table 4.13

Table 4.13: Lithology

Sub watershed	Granite Km2	Schist Km2	Total VPR (A*VPR)	Weighted Value
	VPR =1	VPR=8		
Palung	15.8	12.91	119.08	4.15
Kitini	7.33	7.33	65.97	4.50
Kunchhal	0	15.98	127.84	8.00
Bisingkhel	0	9.83	78.64	8.00
Tubikhel	0	22.88	183.04	8.00
Simlang	0	9.25	74	8.00
Nalibab	9.1	6.01	57.18	3.78
Tasar	8.55	0	8.55	1.00

Source: Galay, et al., (1995)

4.4 Prioritisation for Implementing RUPES

Conservation practices are associated with daily life of people. It is less expensive; people can give continuity; and conserves the nature in a sustainable way. Sharing the benefit and involving the local communities in this programme increases the feeling of ownership of their resources as well as sense of responsibility to protect it.

“Environment is the sum total of all conditions and influences that affected the development and life of organisms”. The interplay of material cycles and energy flows in natural ecosystems generates a self-correcting homeostasis with no outside control or set points. The ecosystem is capable of self-maintenance. However, the equilibrium is very sensitive to external stimuli, such as human activities promoted by socio-economic goals (Sharma, 2000).

The only solution to overcome this problem is to adopt conservation approach in using natural resources, which can be achieved through environmental management. Environmental management is interdisciplinary approach to resource conservation and recycling and it acts as a regulatory force on human greed in resource exploitation and resource wasting (Sharma, 2000). The central theme of environmental management is “the reduction or minimisation of impact of human activities on the environment, thus an endeavour to avoid the misuse and abuse of environmental resources”.

All the eight sub-watersheds have been evaluated on the basis of the priority ranking value of 11 key parameters sensitive to soil erosion. Now, the sub-watersheds are prioritised I to VIII on the basis of the weighted value obtained from the process of priority ranking. Higher value indicates higher priority for soil conservation and watershed management activities. The table 4.14 gives priority position of each sub-watershed.

Priority ranking is the method of selecting sub-watershed on the basis of urgent need for its conservation. However, based on the ranking value of the parameter different sub-watershed should be treated with different emphasis on different SCWM activities. Yet, there are activities, which have to be determined and prioritise. Those activities have to select taking into account the parameters used to mark the sub-watersheds and its position in the list due to the ranking value.

Table 4.14 : Priority ranking

S N o	Subwatershed →	Palung	Kitini	Kunchhal	Bisingkhel	Tubikhel	Simlang	Naliban	Tasar
	Major stream →	Palung Khola	Sankhmool Khola	Tistung Khola	Bisingkhel Khola	Chitlang Khola	Reservoir	Simbhang yang Khola	Tasar Khola
	Area of subwatershed in Ha	2871	1466	1598	983	2288	925	1511	855
1	Population Density	9	10	10	10	9	10	10	10
2	Landuse verses slope	2.71	2.58	2.67	2.71	2.89	3.1	2.55	2.58
3	Shape Index	4.9	1.8	2.8	1.9	2.4	2.8	1.5	1.2
4	Time of concentration	10	10	10	10	10	10	10	10
5	Annual Precipitation	2	2	2	2	2	2	2	2
6	Drainage Density	1	1	1	1	1	1	1	1
7	Slope of watershed	3.93	3.69	3.61	3.71	4.19	4.09	3.63	3.7
8	Land use and coverage	4.38	5.17	5.43	5.14	4.19	5.5	4.29	5.45
9	Erosion potential (LU & LS)	4.42	4.96	4.76	4.35	4.33	4.75	4.83	5.24
10	Land Capability	2.04	2.11	2.02	2.01	2.41	3.04	2.6	2.32
11	Lithology	4.15	4.5	8	8	8	8	3.78	1
	Total weighted value →	48.53	47.81	52.29	50.82	50.41	54.28	46.18	44.49
	Priority position →	V	VI	II	III	IV	I	VII	VIII

On the other hand, highest value always may not represent the priority sector. We can take the examples of population in the urban areas and high-sloped rocky mountain. The pressure of population in urban area may not be on the natural resources of the same district or political boundary. Similarly, Rocky sloped mountain with no cover may not be erosion potential. In such situation we have to use the judgement of experts and determine the priority.

The Table 4.15 gives different SCWM emphasis based on the adverse effect caused by the different parameters. Using weighted value of parameters from the table 4.14 and SCWM emphasis from table 4.15 priority intervention required for environmental management for different sub-watersheds are given below. All SCWM activities have to be carried out in all the sub-watersheds on the basis of availability of resource and time.

Simlang: Weighted value of Simlang is 54.28, which is the highest therefore falls on the top of the priority list. Major pitfalls in the area are cultivation in slope, poor land coverage, poor soil quality, over population, and fragile land. To overcome the problem, activities focusing on conservation farming, productivity farming, on farm conservation, conservation plantation, gully treatment, family planning and bioengineering should be instigated.

Kunchhal: Kunchhal falls on the second priority as it's weighted value is 52.29. The sub-watershed is prone to landslide, bank cutting, surface erosion, and land degradation as it falls on the geologically fragile zone with poor land cover, high population pressure, and low concentration time. For the management of these problems, activities like conservation awareness, conservation plantation, on-farm conservation, bioengineering application, family planning, and engineering structures are proposed to implement with priority.

Bisingkhel: The third priority to be given to Bisingkhel as the weighted value of priority ranking of the sub watershed is 50.82. Drawbacks of this sub-watershed are fragile geology, short flood period, and low green coverage. There is high population pressure on the natural resources. Major environmental problems in this area are, mass wasting, river bank cutting, gully erosion, and land degradation. The remedies of these problems are to avoid deep soil disturbing activities in geologically weak area, provide engineering structures, make use of bioengineering technology, emphasise on on-farm conservation, and introduce family planning.

Tubikhel: The sub-watershed is positioned comparatively at higher altitude and steeper part, which placed area on the fourth position in the priority ranking scoring a weighted value of 50.41. Like in other sub-watersheds, fragility, low concentration time, and high population pressure are dominant here. There are potential chances of mass movement, gully erosion and land degradation. It can be minimized the adverse effect through the activities like; on-farm cultivation, conservation plantation, development of buffer strip and shelterbelt, and conservation structures.

Table 4.15: Matrix on parameters. Adverse effect and priority emphasised activities.

S.No.	Parameters	Possible adverse effect due to parameter	Priority solutions (Activities)
1	Population Density	Land degradation (Soil erosion, loss of productivity) deforestation	Conservation awareness, conservation plantation, productivity conservation.
2	Landuse verses slope	Surface erosion, Loss of productivity, landslide	On-farm conservation, Productivity conservation
3	Shape index	Erosion, landslide, river bank cutting	Conservation plantation, gully treatment, Conservation structures
4	Time of concentration	Landslide, flood, riverbank cutting	Plantation, Stream bank protection, gully treatment, Conservation structures
5	Annual precipitation	Surface erosion, landslide	Conservation plantation, conservation structures, Ground coverage
6	Drainage Density	Soil loss, sediment transport	Conservation plantation, gully control, conservation structures
7	Slope of watershed	Landslide, land degradation	Conservation plantation, on-farm conservation
8	Landuse coverage	Surface erosion, gully erosion	Conservation plantation, on-farm cultivation, gully treatment, productivity conservation, buffer strip and shelter belt
9	Landuse land system erosion potential	Surface erosion, mass movement, land degradation	On-farm conservation, productivity conservation, conservation plantation, conservation structure.
10	Land capability	Soil erosion, land degradation	Conservation farming, Conservation plantation, compost using,
11	Lithology	Mass movement	Avoid deep soil disturbing activities in geologically fragile area.

Palung: Palung is the largest sub-watershed of Kulekhani watershed but it has got a weighted value of 48.53 and secured the fifth position in the priority ranking. As the value for both shape index and time of concentration in the sub-watershed are high, major environmental hazards could be riverbank cutting, landslide, flood, and erosion. Therefore, priority programmes in this area would be conservation plantation, gully treatment, and conservation structures.

Kitini: As in most of the sub-watersheds, population is one of the major problem of environment degradation. Besides, major parts of Kitini falls on the high erosion prone area and shorter runoff time has worsened the situation. These are the major factors enabling Kitini to place on the sixth position in the priority list with a score of 47.81. These are the major causes of land degradation, deforestation, erosion, mass movement, and riverbank cutting. Environmentally friendly programmes like, conservation awareness, on-farm conservation, productivity conservation, conservation plantation, conservation structure, stream bank protection, and gully control could minimize the adverse effect in the sub-watershed.

Naliban: The seventh sub-watershed in the priority list scores 46.18. Population pressure and time of concentration are major problems in the sub-watershed. Problems likely to be encountered due to these are deforestation, land degradation, surface erosion, and riverbank cutting. Therefore, priority programmes in this area would be conservation awareness, conservation plantation, and conservation structures.

Tasar: The last sub-watershed in the priority list scores 44.49. Major part of Tasar falls on the high erosion prone area and shorter runoff time has worsened the situation. At the same time, it is over burdened with population pressure. These are the major causes of land degradation, deforestation, erosion, mass movement, and riverbank cutting. Programmes like, conservation awareness, on-farm conservation, productivity conservation, conservation plantation, conservation structure, stream bank protection, and gully control could minimize the adverse effect in the sub-watershed.

V CONCLUSION

1. Sedimentation, as seen after measurement of sediment in the reservoir, indicates a serious threat on the life span of Indra Sarobar (Kulekhani Reservoir) and demands urgent environmental solution. The problem is in the reservoir but its causes and sources are around in its catchment area. Sediment accumulated in live storage alone has caused a loss of Rs 181 million in a year and it keeps on increasing by Rs 2 million each year. People are heavily dependent on the land and forest resources for the fulfilment of their basic needs like food, fodder, and fuel wood. For sustainable use of these natural resources, urgent need for environmental conservation and management of sub-watersheds through the participation of surrounding communities is necessary. Resources are limited so it is not possible to launch a programme throughout the whole catchment area at a time. This can be simplified by ranking the sub-watersheds on the basis of evaluation of different parameters; prioritise them; and implement the activities according to the priority.
2. Check dams can stop flow of sediment to some extent in the reservoir. Once the available space is filled the sediment eventually transfers to the reservoir. It means, it does not prevent the production but slow down the flow of sedimentation in the reservoir for sometime. Soil erosion continues and the sediment produced is stored temporarily until the storing capacity of the check dam permits. Besides, it involves high cost and technology. On the contrary, conservation programme run in the upstream of the reservoir minimises soil loss, reduce the rate of sediment production and thus increases the lifespan of the reservoir. At the same time, the programme uplifts the economy of the communities living over there as vegetative topsoil yields more. Diversified activities under the programme intend to enhance the income generative programme that promote production and reduce stress on land.
3. The socio-economic system of man in contrast to natural ecosystem is founded on a material base. Increasing demands and aspirations of human society create a rising demand for goods and services. Thus human being imposes changes on natural ecosystems and increasing control of his environment often creates conflicts between his goals and natural processes. This causes over extraction of natural resources and landuse without considering its capability activates land degradation thereby leading to soil erosion. Landuse status shows that conservation programme implemented so far has been giving direct benefit of Rs 1, 137,491.00 each year. Local resource based conservation friendly income generation programme run in mutual trust builds symbiotic relation between the surrounding communities and Hydropower promotes natural preservation and prolongs the life of reservoir.
4. Conservation is related to natural resources available in the given area and human population. Degree of conservation depends upon how carefully the resources have been used maintaining inter and intra generation equity and upholding natural balance. Conservation is “the management for the benefit of all life including humankind of the biosphere so that it may yield sustainable benefit to the present generation while maintaining its potential to meet the needs and aspirations of the future generation”. Human population is central to the conservation as it is superior to all living beings, equipped with technology and necessitated with growing needs. If the contribution of the hosting communities is not valued and benefit of their territory is not shared with them, it may cause another disaster.

5. Local people are not only caretaker but also the principal owner of natural resources of their territory. Therefore, upstream communities have right to charge for the services they are providing to balance the local ecosystem and claim their equitable share from the benefit gained through the use of their resources.

VI RECOMMENDATION

1. Kulekhani Hydroelectric Power Plant (KHPP) generates electricity more than one billion rupees at the present capacity each year. The KHPP should allocate certain amount from its income for research, conservation, river training, and development of surrounding areas that support in prolonging the life of the reservoir.
2. The most vulnerable areas are marginal agricultural lands, overgrazed pastures, and the forest area near the agriculture fringe. These areas should be the primary targets for soil conservation programme. It would be desirable to take the measures entangled with economic benefit such as slope corrections and development of shelterbelts and buffer strips that would benefit the upland people financially and protect the environment at the same time.
3. Rainfall induced topsoil erosion is greatly accelerated by human activities. Better land management like, terrace improvements, adoption of conservation friendly irrigation practices (drip, sprinkle and flooding depending on degree of slope), handing over the forest management to locals, users or in other words increasing local governance in managing watershed resources.
4. The best way of involving people in conservation is to create awareness in maximizing productivity through proper land use on sustained basis. Through extension and technical support, agricultural, forest, and grazing lands can be managed in line with its capacity thereby decreasing the erosion, which may lead to an increase in production.
5. Major portion of sediment yield in the reservoir is due to the landslide and stream bank cutting. Landslide treatment and riverbank protection should be carried out through bioengineering application. Local people are not keen to participate in programmes to control landslide and stream bank erosion as these activities involve high cost and technology and are less oriented towards productivity conservation. Therefore, the KHPP should allocate certain budget annually from its income and carryout these activities, which should be a part of government policy framework.
6. People are still accustomed to conventional methods of farming and are heavily dependent on land resources. Alternative methods that minimize tilling the land should be introduced in the surrounding community. Skill training that enhances indigenous skill and local resources together with the linkage to the market would be an appropriate programme in the area. Promotion of high value cash crops and production of less perishable commodities along with storage facilities would be suitable in this area. These activities could diversify and promote the economic activities, ultimately reducing the pressure on land.

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