ANNEX - 2

DISASTER PREVENTION PLAN

The Study
on
The Disaster Prevention Plan
for
Severely Affected Areas by the 1993 Disaster
in
The Central Development Region of Nepal

FINAL REPORT

Supporting Report

Annex-2 : Disaster Prevention Plan

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1. BASIC CONCEPT OF DISASTER PREVENTION PLAN

1.1 Overall Basic Concept

1.1.1 Basic Concept

In mountainous areas, the natural slopes sometimes became unstable due to topographical and geological activities, and the natural hazard phenomena such as failure, landslide, debris flow occurs. In such mountainous debris activation is generally called "mass movement". This phenomenon itself is no more than one of natural phenomena which unstable slopes are to be stable. However, once after this phenomenon happen in the human society, and threaten human life or their fortune, it would be called "disaster".

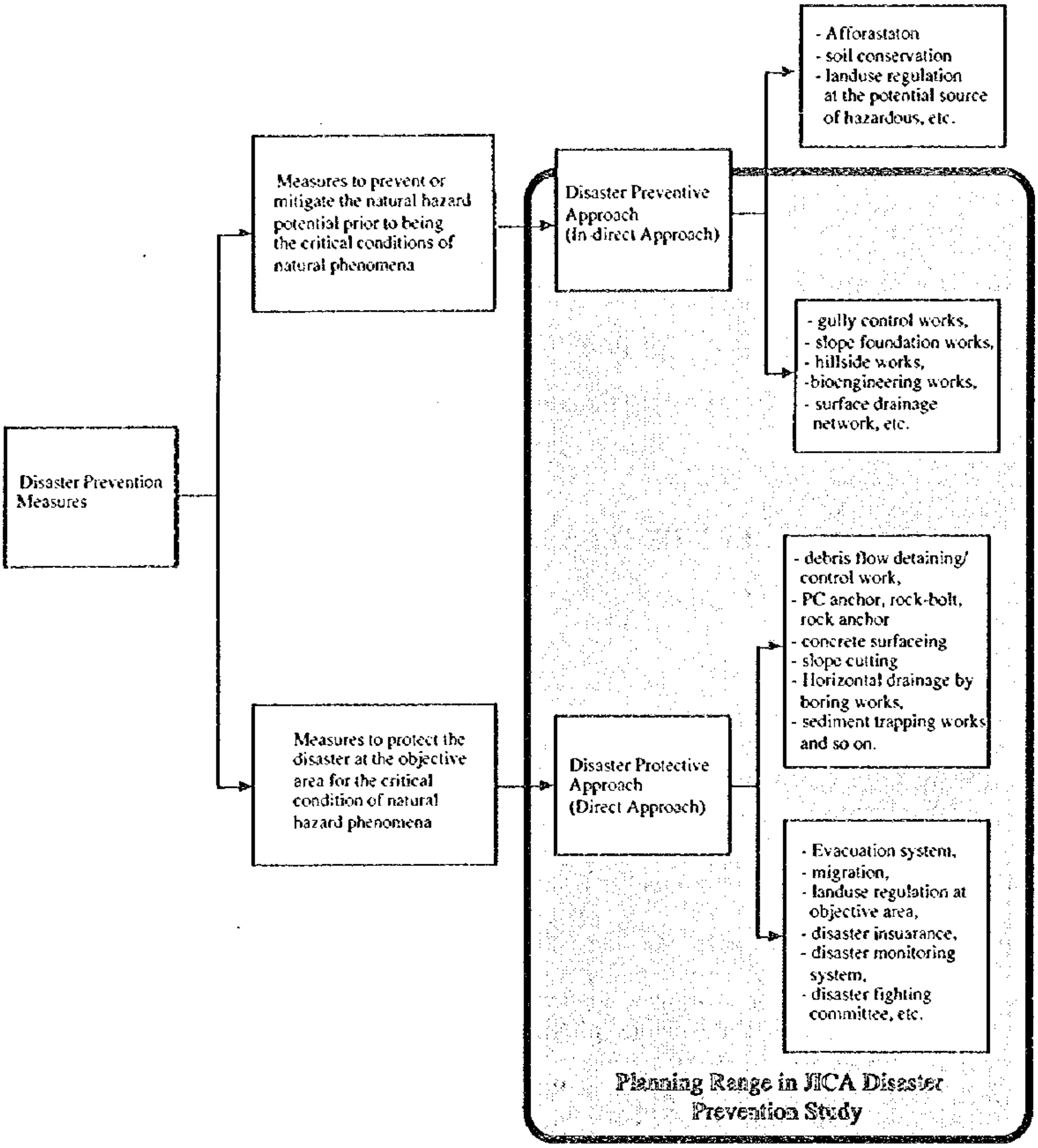
To prevent such disasters, there area basically two kind of approaches as follows:

(1) To prevent or mitigate the natural hazard potential prior to being the critical condition of the natural phenomena,

(2) To protect the disaster at the objective human society against the critical condition of natural hazard phenomena.

The former approach is called "Preventive measures" or "In-direct measures" which will be take before being critical condition of the natural phenomena. The later is called as "Protective measures" or "Direct measure" which will be taken for the critical condition of the natural hazard phenomena to the human society. The Sabo planning is generally to consider the best combination of the both approaches and to evade the disasters for the long term viewpoints. In this Study also, the both measures are taken for the CDPP as well as IDPP formation.

The classification of disaster prevention measures and indicate the range of countermeasures which are applied in the plan formulation of the CDPP and IDPP.



Classification of Disaster Prevention Measures

Generally, the disaster prevention project are formed only the critical area against the high potential of disasters, and most of the project sites urgently requires some countermeasures to protect the disasters. Under such circumstances, the disaster prevention works were generally put priority in the structural measures of "Protective Approach" even it is costly since the viewpoints of the basic human needs.

On the other hand, taking into consideration of the huge potential of hazardous and the limitation of the financial aspects, it is not practical to depend on only the structural measures of protective approach, which must be required many massive structures to meet the force of disaster energy and it will take huge amount of cost.

Accordingly, the plan formulation of the Study will mainly put force in the non-structural measures of protective approach with minimum input of structural measures of protective approach.

In addition, there are many places which is so far not seriously damaged but it will be seriously being hazardous areas in the Study Area. In such areas, the structural measures of preventive approach will be aggressively applied to prevent the further disasters. If it is left without anything, it must be much more difficult to treat it. The study team believes that the earlier actions must be much economical.

Based on the detailed field investigation, the Study Team felt that the non-structural preventive measures such as afforestation and soil conservation measures can be applied only limited places in which the stability of the slope is still guaranteed. Once the slopes or gullies became unstable, the foundation works as the structural preventive measures would be required prior to the non-structural preventive measures. On the other hand, the areas which are applicable the non-structural preventive measures are usually attractive as the productive areas for the sloped agriculture activities, or sources of firewood or pasture. Then, the candidate areas for non-structural preventive measures are almost overlapped with the potential areas for community development. Concerning to the land availability and development potential of the community, the area for non-structural preventive measures will be treated in the community development aspects with dense discussion with the people's group and not concerned in the disaster prevention planning.

Accordingly, the disaster prevention plan in the Study will be basically formed as the following concepts:

(1) To propose minimum structural protective measures by the government works,

(2) To apply non-structural protective measures to cover beyond the effects of structural protective measures by the people's participation works

(3) To propose structural preventive measures utilising appropriate technologies by the people's participation works.

1.1.2 Planning Range and Scale

As mentioned in the above sub-section, the disaster prevention plan in this Study will concern the structural and non-structural protective measures, and structural preventive measures by appropriate technologies. For the non-structural preventive measures such as afforestation and soil conservation measures will be considered in the community development aspects in Annexes 6 through 8.

The disaster in the community is not caused by the phenomenon occurred in the same community area. The causes are the landslide in the upper area and its sediment flown down belong the reaches. So that the master plan should be executed for the consistent whole area, however, in this Study, only the point of basic arrangement for the structures, will be described for the master plan.

The Study Team examine the disaster prevention plan for the disaster by similar causes of the 1993's disaster, removing its special and limited area's causes, and add to make the plan for temporary or short time period against 1993's disaster.

1.2 Preventive Measures

1.2.1 Structural Preventive Measures

The structural preventive measures for this Study is to control the debris production in the mountain areas or streams, and to prevent the slope failure or landslides in which the natural phenomena became unstable but not being critical yet. To put it concretely, the hill side works and the gully control works for the river side or riverbed are proposed for this considering appropriate technologies in Nepal.

The prevention, comparing to the human health, is to make strong body and constitution against illness. But once a healthy body becomes sick, it must be solved by other means. That is the protection measures describing later.

Since a structural measure as prevention is only for before disaster, a protection measures is surely needed to save the objective areas from the rocks or debris produced in the upper areas. For the disaster prevention, it is very important to combine rationally these prevention and protection, so the Study Team advises such arrangement for the mechanism of the 1993's disaster, not taking only one of two measures.

1.2.2 Non-structural Preventive Measures

The non-structural preventive measures are included afforestation, soil conservation works, landuse regulation on the slope or existing forest and so on. Since such activities can be applied only for the non-critical areas against the disasters and they are highly related to the community development activities, the non-structural measures will be treated in the community development aspects. Afforestation will be considered in the community forestry sector, and soil conservation will be considered in agriculture sectors. Landuse regulation on the slope or existing forest will be also concerned in these sectors.

1.3 Protective Measures

1.3.1 Structural Protective Measures

A structural protective measure is to protect the landslides and debris flow before attacking the objective area, by power or volume (structures).

For this purpose, the counter force suited for the attacking power is necessary, and the structures must be strong. If a phenomenon over the planned objective scale occur, there will be a possibility to destroy the structures or to damage by lack of capacity. In this study, the hardware measures mean the check dams to hold debris flow before the objective village or in the river.

Considering the above, the point of a hardware measure for protection are as follows.

- The objective scale for the structure is not for all amount of the 1993's disaster. (At the 1993's disaster, 380,000 m^3 of debris was estimated.)
- The protection measure is temporary and emergency measure for the case of over effective of prevention measure.

The objective scale is small or medium rainfall after the 1993's disaster, it means about 20 year return period rainfall scale. In the case of the structure is for both protection and prevention, the objective scale is settled as much as possible, not considering 20 year return period.

1.3.2 Non-structural Protective Measures

The structural measures opposing the nature has the limits. In consider of these limits, the philosophy is necessary ; "a man saves himself for himself from the disaster" for the excess disaster energy to the structures. In this study, based on this philosophy, the Study Team recommends strongly the evacuation system as a non-structural protective measure. The base of the evacuation system is to evade disaster by the people's own mind or action. The most important thing to carry out this, is to fully recognise for the people that they have to act by themselves not by the directions of others.

According to this basis, the Study Team will give the basic information, and show the problems for the execution in this report.

The basic policy for the plan is as follows.

- To formulate a realistic and available plan
- To introduce the ultramodern technology and their execution plan for the future
- To positively take the local information and tools in the plan
- To execute the field survey and to take its result of analysis for making realistic plan

The objectives of a non-structural preventive measure is to review the following points to make a plan. The Study Team also make a plan on this objectives.

- Where, how, and how level is the danger?
  (Disaster Mapping, Hazard Assessment and Hazard Mapping)

- How to evade?
  (Evacuation System)

1.4 Design of Structural Measures

The design point of the structural measure is as follows:

- The main structures for protection measures will be made of concrete, because it opposes by power.

- The design scale is as big as possible for its geological aspects.

- Structural preventive measures are made by local materials with people's participation as much as possible. Under this policy, the structures except the main structures is designed simple.

- The structural preventive measures are generally designed as simple technologies such as gabion and riprap, and it will be not permanent structures with their effects for more or less 10 years. For the simple structures, the engineering with vegetation or bio-engineering is positively taken to the plan, to make up for the limits of durability.

2. DISASTER PREVENTION PLAN FOR PHEDIGAON/PHATBAZAR

2.1 Overall Disaster Prevention Plan

2.1.1 Objectives and Summary of Overall Plan

A lot of unstable slopes still exist here and there in the Phedigaon/Phatbazar. Therefore, it can be said that a potential of recurrence of disaster having the same magnitude as that occurred in 1993 is high in near future. To prevent or mitigate such a potential damage, an overall disaster prevention plan is established as shown in Figure 2.1.1.

Figure 2.1.2 shows areal divisions of the Study area. Anticipated pattern of disaster in the respective area and magnitude of damage occurred in 1993 are shown below.

Pattern of Anticipated Disaster and Damage

Area	Disaster Pattern	Damage in 1993
Upper area	• Loss of forests and cultivated lands caused by landslide • Washing out of cultivated lands and houses caused by gully erosion	• Several losses of lives • There are a lot of unstable slopes in this area at present
Alluvial fan area (middle area)	• Washing out of cultivated lands and houses caused by debris flow	• A great losses of lives • Houses were completely destroyed
Lower area along river course	• Damage of cultivated lands caused by flooding	• Covered with sand and debris about 50 cm deep • Cultivated lands were reclaimed at present

Major damaged areas in the community are concentrated in the alluvial fan formed just downstream part of Ghatte Khola and Dhungakate Khola basins. Photo 2.1.1 Contrasts the general view of phedigaon before and after the 1993 disaster. Before the said disaster was taken place, the area on the alluvial fan had been utilised for residential areas and farm land. However, ground surfaces of the alluvial fan have been covered by debris flow deposits at present. Cause of the disaster was debris flow which were flushed out from the upper reaches of the alluvial fan as shown in Photo 2.1.2. Therefore, first priority of the overall disaster prevention plans should be put on the countermeasures against the debris flow.

On the other hand, villagers living in this area desire strongly to reclaim the farm lands at first and they have been worked out for rehabilitation of the river course by themselves. If the area on the alluvial fan could be remained as a wasteland without utilisation of land for any purpose, it would be used for a huge sand retarding basin against the mud and debris flows as shown in Figure 2.1.3. Taking into account the villager's wishes, however, such countermeasures as provision of huge sand retarding basin are impossible. As for the countermeasures, therefore, it is planned to prevent flushing out of mud and debris flows in the upper area, to construct coffering/training dikes and channel works against mud flow in the alluvial fan area, and to provide the channel works in the lower area as shown in Figure 2.1.4.

All weather motorable roads are not provided yet in Phedigaon, as the river has been flooded so frequently. Therefore, improvement of river course in the alluvial fan and plane areas to Palung village is indispensable for construction of all weather access road to secure the safety against medium scale floods. The river improvement works in the lower reaches are proposed also taking into account such a purpose in this overall disaster prevention plan.

2.1.2 Structural Plan Formulation

(1) Countermeasures in upper area

To mitigate damages caused by mud and debris flows in the downstream alluvial fan area, the following measures are planned in the upper area.

(a) Countermeasures against source and debris flow

Causes of soil erosion at the mountain slopes in the upper area are mainly classified into the following 2 patters and the countermeasures are summarised as below:

Pattern of soil Production and Countermeasures

Pattern of Soil Erosion	Countermeasures
Gully erosion	A series of small scale groundsills by using gabions will be arranged continuously so as to prevent extension of the gully erosion
Landslide	Foot of mountain will be consolidated by sediment deposition on river bed by constructing check dams and then, hillside slope will be stabilised. On the other hand, sodding or tree planting will be made for stabilisation of topsoil on the hillside slope.

(b) Countermeasures against flushing out of debris flow

For mainly trapping and controlling the debris flow, the massive check dam of concrete gravity type is planned.

(2) Countermeasures in alluvial fan area

Location of the original river course is not clear at present, because the surface of the alluvial fan area is covered with the gravels and boulders. Beside, it has a tendency of recurrence of the debris flow again in the near future even if small or medium size flood is taken place, as the longitudinal gradient of the river bed has frequently been changed remarkably as shown in Figures 2.1.5 for Dhungakate Khola and Figure 2.1.6 for Ghatte Khola respectively. Therefore, river channel improvement is necessary to secure the stable river course against the medium size flood. By this channel works secondary movement of soil in the alluvial fan will be minimised and lands on this area can be utilised more effectively.

In case that the same magnitude of heavy rainfall in 1993 is taken place, the effect of the countermeasures against the upper area mentioned in paragraph (1) will be insufficient. Therefore, coffering/training dikes will be arranged in addition to the channel works to minimise the flooding and depositing of the mud and debris flows on the alluvial fan area as shown in Figure 2.1.4.

(3) Countermeasures in lower area along river course

In the 1993's disaster, mud flow was flooded on the area in the vicinity of Phatbazar and farm lands were damaged. therefore, to secure the flow capacity against the medium size flood, river channel improvement is also required in the lower reaches in connection with the channel works planned in the alluvial fan area.

2.1.3 Arrangement of Structures

Structures planned in Section 2.1.2 are listed in each stream in Tables 2.1.1 (1) through (5) and their arrangements are shown in Figure 2.1.2. Brief explanations of the arrangement of structures are as follows;

(1) Dhungakate Khola basin

Figure 2.1.7 shows the detailed arrangement of the structures in Dhungakate Khola basin. 2 check dams are planned in this basin to control flushing out of the mud and debris flows to be taken place in future. These dams, concrete gravity type, are planned strong enough to withstand shock of the mud and debris flow. The longitudinal profile of along the check dams site is shown in Figure 2.1.8. Besides, taking into consideration of the heavy damage due to landslide in the 1993's disaster on the upper most reach, a series of groundsills by means of gabions with bioengineering are adopted. The longitudinal arrangement of structures of Dh-2 through Dh-7 are shown in Figures 2.1.9 through 2.1.11.

(2) Ghatte Khola basin

Figure 2.1.12 shows the detailed arrangement of structures in Ghatte Khola basin. In general, scouring of gullies are heavy in three tributaries, which join with the tributary from the right bank in this basin. Therefore, they will become a major source of the mud and debris flows in future. Especially, there exist several houses here and there alongside the downmost mountain stream. Under the present circumstances, it is planned to provide a series of groundsills by means of small scale gabions in the mountain stream, and sodding or tree planting with bioengineering on the hillside slope, to prevent the scouring and landslide. Figure 2.1.13 shows the longitudinal profile of series of check dams for Gh-1 through Gh-3. At first, it was planned to construct a concrete check dam at the location just upstream of the alluvial fan area, as for the major countermeasures in this basin. However, this plan was abandoned, since geological condition of the proposed damsite, especially on the right bank, is insufficient for foundation of the concrete dam. Besides, it was judged not effective from the reasons that the construction of the check dam with a large sand trapping capacity would be difficult and further the dam construction would affect greatly to stability of slopes excavated on both abutments in the future.

(3) Bhottekoria Khola basin

Figure 2.1.14 shows the detailed arrangement of structures in Bhotekoria Khola basin. Width of the mountain stream in the downstream stretch of this basin is rather wide and at present, restoration works of the river course have been made by villagers living there. Under the present circumstances, it is considered not practical to plan the concrete check dam in this stretch as for the countermeasures against mud and debris flows.

Therefore, a concrete check dam (Bh-1) is planned to be constructed at a narrow gorge in the middle reaches of the basin. Mainly for the scouring prevention purpose, several numbers of groundsills made of gabions are planned to be provided on the stream bed deposits in the upstream portion of this check dam. Figure 2.1.15 shows the longitudinal profile along the check dam Bh-1 site. On the other hand, a huge amount of sediments caused by landslide has been flushed out again and deposited on the mountain stream which joins with the tributary from the right bank at the downstream of this check dam. To arrest and settle these sediments, a series of groundsills (Bh-5) is planned to be provided continuously on this mountain stream. Figure 2.1.16 shows the longitudinal profile of series of small check dams for Bh-4 and Bh-5.

(4) Alluvial fan area

To establish a disaster prevention plan in the alluvial fan area, it is considered very important to control the flow directions of flood and debris flow. For this purpose, a concrete coffering/training dike is planned at first to withstand shock of the debris flow at the respective boundary portions of Ghatte Khola basin and Dhungakate Khola basin at the outfall of the alluvial fan area. Besides, it has a tendency to divert the flow direction of flood and debris flow in Dhungakate Khola towards Ghatte Khola, since the river bed elevation of the former is about 4 m higher than that of the latter in the alluvial fan area as shown in Figure 2.1.17. To withstand this tendency, therefore, several training dikes made of gabions are planned to be provided on the left bank of Dhungakate Khola.

It is anxious about recurrence of a large scale land sliding at the right side mountain slope caused by scouring of the flood flow, since the existing condition of the said slope of the Dhungakate Khola is unstable. Photo 2.1.3 shows the large unstable slope formed the dip slope on the right bank of Dhungakate Khola. Therefore, the revetment works made of gabion are planned at the right bank of the Dhungakate Khola in the upper portion of the alluvial fan area.

It is considered better to restore the river course as same condition as that before the 1993's disaster from the viewpoints of wishes of land owners and villagers as well as the economical reason. The river banks are planned to be protected by vegetated riprap and flow capacity of the river is settled assuming the design flood of once in 20 years.

(5) Lower area along river course

In the lower area from Phedigaon through Phatbazar up to Palung bazaar, channel excavation with partial bank protection works by gabions were carried out by the Makwanpur DDC under the financial support from the IFAD. The existing channel capacity is, however, not sufficient to flow the flood with a 20 year-return period without overflow. Channel enlargement is therefore planned in the lower area along the Phedigaon Khola.

Due to the topographic constraints, the design slope of channel in lower area would much gentle than the upstream alluvium cone area, and it is feared that the channel at lower area would be easily filled with sedimentation so that the design gradient of channel would be changed dramatically. To mitigate such imbalance of sediment performance, the dual-sectional channel is proposed for the lower area aiming at increasing sediment tractive force by flood flowing with under the super-critical flow. The channel works in lower area are planned up to upper part of Palung bazaar just about 200 m upstream from the confluence of the Garti Khola. The treatment of the confluence would be rather complicate and it is required to consider the design of the other tributaries such as Garti Khola, Bangkoria Khola and Kaiseri Khola which are the out of the Project Area in the

Study. The proposed longitudinal profile of Phedigaon Khola is shown in Figure 2.1.18, and the proposed cross section is shown in Figure 2.1.19.

2.2 Selection of Priority Schemes

Out of the overall disaster prevention plan, a feasibility study is made for the most important and urgently necessary schemes with top priority. To select the top priority schemes, comparative studies are made.

2.2.1 Criteria for Selection of Priority Schemes

The priority of countermeasures against disaster to be taken in each area is selected comprehensively after evaluating the magnitude of damages, the urgency and the economical effects of the respective scheme.

(1) Magnitude of damages

Degree of the land devastation is remarkable in the both the Dhungakate Khola and Ghatte Khola basins in the upper area as shown in disaster map in Annex - 1. In the alluvial fan area, the river courses are suffered from heavy damages due to the mud and debris flows. To the contrary, lower area in the alluvial plane area, there is no missing of houses and farm lands, and roads damaged have already been restored. Therefore, it can be evaluated that the degree of damages in the lower area is relatively small as compared with those in the upper area and alluvial fan area.

(2) Urgency of Countermeasures

Taking into consideration of a risk against disaster taken place in future, urgency of the countermeasures is indicated on a hazard map as shown in Annex - 1, that is, the priority of urgency is given to the area having the highest hazard rank. The highest hazard rank areas are widely distributed in the both of Dhungakate Khola and Ghatte Khola basins as shown in hazard map in Annex - 1. Furthermore, the mountainous areas in these basins will become a source of the mud and debris flows which are flushed down to the downstream alluvial fan area in the future. Therefore, it can be evaluated that the top priority of the urgency is given to these upper basins.

(3) Economical Effects

Economical effect is evaluated whether the land is available for an intended purpose adequately or not, by the implementation of the restoration works. In the alluvial fan area which was suffered from a heavy damage, it is not expected to establish a plan of land use without restoration works against the debris flow in the upper area, since there is a risk of recurrence of the debris flow again. From this viewpoint, it can be said that the economical effect of the said restoration works is quite high in Dhungakate Khola and Ghatte Khola basins which can create new benefit for agriculture products at alluvium fan area. On the other hand, economical effect of the river improvement works in the lower area is rather low, though the farm lands alongside the river course will be secured though it is in tentative base, and the existing access road to Phedigaon village will also be rearranged suitably. Because these restoration works have already been carried out by the villages themselves, and all the farm land has been already restored.

(4) Overall Evaluation

Overall ranking (a to c) and priority (A to B) on the magnitude of damages, urgency of countermeasures and economical effects in the respective districts are evaluated as shown below:

Overall Evaluation in Respective Districts

District		Magnitude of damages	Urgency of countermeasures	Economical effects	Priority
Upper area	Dhungakate Khola	a	a	a	A
	Ghatte Khola	a	a	a	A
	Bhottekoria Khola	b	c	b	B
Alluvial fan area		a	a	a	A
Lower area		c	a	c	B

Notes; a: Relatively high A: First priority district
b: Medium B: Second priority district
c: Relative low

From this above Table, the first priority have to be given to Dhungakate Khola and Ghatte Khola basins in the upper area, and the alluvial fan area.

2.2.2 Priority Structures and Order of Performance

The disaster prevention structures to be planned in the respective priority area are shown in Figure 2.1.1 and as listed below:

Priority Structures and Order of Performance

District	Structures	Total Numbers of Structure	Numbers with First Priority	Order of Performance
Dhungakate Khola	Concrete check dams	2	2	1
	A series of groundsills	5	5	2
	Hillside works	3	-	-
Ghatte Khola	A series of groundsills	3	3	2
	Hillside works	2	-	-
Alluvial Fan Area	Coffering dikes	2	2	3
	Training dikes	6	6	5
	Channel works	2	2	4
	Revetment	1	-	-

Priority Structures have to be selected in accordance with the order of performance taking into account the results of economical evaluation. Therefore, it is considered desirable to construct all structures planned, if there is no economical problems. Feasibility studies will be made on the first priority scheme with biggest effect against the disaster.

3. DISASTER PREVENTION PLAN FOR NAMTAR/TILAR

3.1 Overall Disaster Prevention Plan

3.1.1 Objectives of Overall Disaster Plan

The most serious damage in Namtar suffered by the 1993's disaster was the washing out of the bazaar on the terrace by the flood. Photo 3.1.1 contrasts Namtar bazaar before and after the 1993 disaster, in which all the bazaar are washed out along the Manhari Khola. Also it occurred the debris flow in the tributaries, new landslide in Manahari, new landslide in Khola, and the enlargement of gully erosion.

With such damages of the 1993's disaster, the condition of Manhari Khola, especially near Namtar Area, was greatly changed.

The phenomena of the changed river are as follows.

1) In the main stream of Manhari Khola, the river bed was dramatically risen up with the debris flow from the upstream.

2) In the tributaries, Syarse Khola, Khade Khola and Gorduwa Khola, the debris flow occurred.

3) From the confluence of Syarse Khola, the main stream of 40~50 m wide expanded to 200 m for about 6 km long.

4) The slope failure and landslide occurred on the outer river bank due to the meandering the river and erosion by flooding.

5) In the upstream from Namtar, the river width was enlarged by gully erosion.

There were two kinds factors for the 1993's disaster. One is river bed aggradation due to the over abundant debris flow from the upstream.

As mentioned in Annex-1, Namtar is located just downstream of the knick point of Manhari Khola, at which the river gradient suddenly changes from steep to gentle. In such area, the sediment material are easily deposited so that the sediment transportation capability of the river is decreased. Reflecting the topographic characteristics at Namtar stretch, the river width becomes much wider, and remarkable meandering river course are formed nearby the Namtar stretch. Such conditions gave the remarkable riverbed aggradation and widening the river course at the stretch, and which made much more serious damages than the other portions along the Manhari Khola.

Another factors of disaster at Namtar is the bank erosion phenomena due to the debris flow from the tributaries. The flood on the mainstream was pushed away and was changed the flow direction to the opposite site from the tributaries by forming alluvial cone of debris at outfall of the tributaries.

Considering the above disaster characteristics, the anticipated pattern of disaster in the Namtar and magnitude of damage occurred in 1993 are shown below:

Pattern of Anticipated Disaster and Damage

Area	Disaster Pattern	Damage in 1993
Upstream area of Manhari mainstream and tributaries	• Tremendous amount of sediment yield by landslide, failures, gully erosion and bank erosion.	• Almost no human damage since there is less residential areas. • Severe land devastation of forest and gullies.
Stretch along Namtar community	• Washing away of cultivated lands and houses caused by riverbed aggradation, bank erosion, flood meandering and debris flow of the tributaries.	• A major part of the community are completely washed out (71 houses were washed away) • Rich cultivation area along the mainstream are severely eroded or buried by the sediment.

Prior to formulate the comprehensive disaster prevention plan for the basin, it is necessary to consider the reality of the project implementation. In the case of Namtar, the upstream basin are seriously devastated and that the cause of the damages to the community, and it should consider the watershed management approach on the upstream basins in the long-term viewpoints.

On the other hand, the upstream area is so far less residents and the countermeasures must be quite expensive and heavy financial load will be given for long-time. In addition, it takes quite long time to be effective in visual at Namtar community.

Taking into account the urgency of the countermeasures, cost effectiveness of the upstream countermeasures, as well as the difficulty of the participatory disaster prevention measures in the upstream, the Disaster Prevention Plan is focused on the Namtar stretch, at which the direct causes of the damages are treated and proposed.

Accordingly, the main objectives of the disaster prevention plan for Namtar are defined as follows:

1) To mitigate sediment transportation and riverbed aggradation at Namtar stretch,

2) To prevent the debris flow occurred in the tributaries being attacked to the mainstream,

3) To restore the cultivated land along the mainstream (To restore the natural river courses)

4) To control the major sources of disaster damages such as landslide, big failures and so on.

3.1.2 Structural Plan Formulation

The structural plan for the whole area is shown in Figure 3.1.1 and summarised as follows:

1) The detaining/controlling measures for the sediment transportation and riverbed

aggradation from the upper Manhari Khola.

In the upstream stretch of Manhari Khola from Namtar just downstream of the knick point, the riverbed is covered with the thick unstable soils such as debris bar. This is to control these debris flow as well as from slope failure areas along the streams.

2) The debris flow control measures on Syarse, Gorduwa and Khade Khola

To detain the sediment transported by the debris flow around the outfall of tributaries and to prevent the terrace along the tributaries from the erosion.

3) The flood control measures along the stretch of Namtar community

To maintain the stable river courses in the centre of the river and to restore the cultivation area by stabilisation.

3.1.3 Arrangement of Structures

Based on the above structural plan, the arrangement for sediment-control structures will be planned as follows:

1) To arrange check dams to detain the excess sediment from the main stream of Manhari Khola

2) To arrange the check dams to control the outflow of debris flows in the tributaries

3) To arrange a channel work to stabilise the river channel in the main stream.

4) To arrange groundsills at the confluence with mainstream to prevent the degradation of the riverbed just downstream of the check dam.

6) The revetment works to prevent lateral erosion.

The overall structure plan is divided by the mechanism of disasters into:

1) area for the sediment from the main stream, and

2) area for the debris by the tributaries.

The detailed explanation of arrangement of structures are as follows:

(1) Area for the sediment from the mainstream

To detain and control the sediment transported from the upstream devastated basin of the Manhari Khola, two check dams at around the knick points of the Manhari Khola are planned namely "Check dam Na-1" and "Check dam Na-2" as shown in Figure 3.1.1. The longitudinal profile at the stretch along the damsite is shown in Figure 3.1.2.

a) Check dam Na-1:

Check dam Na-1 is planned at about 1 km downstream from the confluence of Chayau Khola, Bardeu Khola, Mahabir Khola on the mainstreams. The large scale failure on the right bank continues for 500 m long along the right bank of the mainstream, of which the dam site is just downstream. According to the DPTC report, the collapsed area is estimated at 25,625 m^3 and the volume of the failure is at 102,500 m^3, which is classified into large scale. The Check dam Na-1 will be effective for stabilisation the upstream right bank in addition to detain and control the sediment transportation to the downstream.

The proposed damsite exposes the fresh bedrock on the both banks and it seems the suitable site in the geological viewpoints though the riverbed is not confirmed. The dam height shall be as high as possible in the view of the maximum effect to mitigate the sediment transportation capacity to the downstream without the upstream gully control and hillside measures.

In addition to the sediment detaining and control purpose, the multipurpose usage of Check dam Na-1 is considered. Taking into consideration of the rural electrification needs of the community, in which so far no electrification is done, micro-hydropower development shall be considered to divert the water by the Check dam Na-1. The river flow diversion for irrigation purpose is also possible.

b) Check dam Na-2:

Check dam Na-2 is planned at about 500 m downstream from the proposed Check dam Na-1 site. At the stretch near the Na-2 damsite, a large amount of sedimentation deposited which was transported by the 1993 disaster, however, some eroding activities are found and the river is getting lowered by the normal flood after 1993. The main objective of Check dam Na-2 is defined to detain such unstable sediment material at the stretch to mitigate the sediment transportation to the downstream.

In addition to the river control purpose, it is planned to utilise as the river cross structures for smooth transportation. The existing rural road from Tribhuvan highway to Namtar community is so far not permanent route due to no river cross structures such as bridge and causeway on Manhari Khola, on which the vehicle can not pass during the rainy season from June to October. Considering such needs of community development aspects, Check dam Na-2 is planned as Multipurpose Check dam of utilisation for the river cross transportation structures.

(2) Area for the debris by the tributaries

To mitigate the damages to the community by the debris flow activities from the tributaries, countermeasures to debris flow from tributaries as well as the stretch of the mainstreams at which the river is seriously affected by the tributaries are planned as shown in Figure 3.1.1. The proposed structures are check dams at the outfall of the tributaries, groundsill, channel work and bank protection works along the main stream. The detailed design concepts are as follows:

a) Check dams at the outfall of the tributaries

There are three tributaries from which the debris flow affects directly to the community. They are Syarse, Khade and Gorduwa Khola. Each one check dam at outfall of the tributary is planned to prevent the debris flow affects to the main stream river course. The proposed structures are named as "Check dam Na-3" at Syarse Khola, "Check dam Na-5" at Khade Khola, and "Check dams Na-6 and Na-7" at Gorduwa Khola.

According to the sabo engineering theory, it should be planned to construct the series of check dams from the upstream to the downstream with the balance of the estimated amount of sediment yield by the debris flow, however, it is very far from the practical measures in Nepal considering the tremendous amount of sediment yield from the tributary basins. Accordingly, it is proposed that the check dam shall be constructed from the downstream as the urgent remedial measures to mitigate the damages to the most important area of the community. It would be possible to consider the continuous activities to the upstream as the permanent solution according to the process of the further disaster activities.

For the designing check dam at outfall of the tributaries, it is noted that the scouring of the downstream must be fully assessed by the construction of the check dams so that the thick unstable material are deposited near the confluence.

b) Groundsills on the main stream

Groundsills on the mainstream at the downstream of the confluence are planned at the two confluence. One is at the downstream of Syarse and Khade Khola confluence, and another is the downstream of Gorduwa confluence. The main objective of the groundsill is to control the flood flow to the downstream and to prevent the river bed scouring on the upstream. The flood flow of the main stream are severely affected by the violence of the tributaries, and it is the main cause of the damages to the community. Considering that the groundsill to control the flood flow would be highly required.

In addition, the river bed consolidation at the upstream confluence would be essential to plan the check dam at outfall of the tributary. The stability of the tributary check dams is quite doubtful without the downstream consolidation works. It can be said that the construction works of the check dam at outfall of the tributary and the groundsill at the downstream of the confluence should be one package without separation. Figure 3.1.3 shows the designed river slope by construction of check dam Na-3, and groundsill Na-4 at the stretch of Namtar community.

Based on the above necessity of the main stream consolidation works at the confluence, the two groundsills namely "Na-4" at the downstream of the Syarse and Khade Khola, and "Na-8" at the downstream of Gorduwa Khola along the main stream are proposed in the overall disaster prevention plan.

c) Channel works along the main stream

The devastated river channel at the stretch downstream from the confluence of the Syarse Khola, is dramatically widen by the 1993 disasters. Such channel without fixing the river course will allow the flood to braid in full width of the existing devastated river, and it is feared that the bank erosion to the remained community along the main stream would be activated by the further flood. It is quite important to control the flood flow at the centre of the river with adequate river width.

Channel works are proposed therefore at the downstream of the proposed groundsill Na-4 for 420 m long up to the confluence of the Gorduwa Khola as shown in Figure 3.1.4. The proposed channel width is set at 50 m taking into account the enough capacity against the 20 year probable peak flood. The channel is designed by the vegetated riprap to cover the surface as the countermeasures to bank erosion.

By the channel works, the land reclamation works along the river is also expected at which cultivation activities can be allowed for the landless people. The expected reclamation area would be about 10 ha by channel work directly.

d) Bank protection works on-spot

It is observed that the severe bank erosion at the outer course of the main stream at the meandered portions. At such portions, the bank protection measures are planned by gabion or boulder riprap.

3.2 Selection of Priority Schemes

Out of the overall disaster prevention plan as shown in Figure 3.1.1, a feasibility study is made for the most important and urgently necessary schemes with top priority. To select the top priority schemes, comparative studies are made on the sociological urgency, engineering priority aspects as well as the economical effect of the structures to be provided.

3.2.1 Criteria for Selection of Priority Schemes

In the case of Namtar disaster prevention plan, the following three criteria are considered for priority assessment:

1) Importance of the objective area of the countermeasures,
2) Effect of the countermeasures
3) Urgency of countermeasures,

(1) Importance of the objective area of the countermeasures

There are mainly three different objectives to prevent the disasters by the countermeasures, which are human lives, social infrastructures, cultivation land, and unused land. It is no doubt that saving human lives are essentially important for disaster prevention works. Accordingly, the number of affected houses must be major factor to determine the importance of the objective areas. The density of houses and bazaar in the objective area should be assessed to the priority assessment. The next importance is set at the social infrastructures and cultivation land, which is highly effected to the people's activities. The number of rural infrastructures and area of cultivation land in the objective area shall be considered to determine the importance of the objective area. After them, the area of unused land such as forest, pasture area shall be considered as followed to the houses / bazaar, rural infrastructures and cultivation land as the important objective to protect, which is indirectly or long term affected to the human livings such as water regulation, sources for firewood, and to breed the livestock and so on.

Considering the above, the priority assessment is carried out based on the quality and quantities of the following aspects of the objective area:

Priority a : Area of high density population and buildings
Priority b: Area of cultivation land and high density of rural infrastructure,
Priority c: Area of forest and pasture, and others.

(2) Magnitude of disaster potential of the objective disaster phenomena

The every countermeasures have direct disaster objectives such as to detain the sedimentation, to protect the debris flow, to protect the bank erosion and so on. The second criteria to select priority schemes is defined to estimate the magnitude of the disaster potential at the objective disaster phenomena at the site of countermeasures. For this aspect, the following criteria are defined:

Priority a : The structure will be effective to the disasters phenomena which have higher disaster potential.
Priority b: The structure will be effective to the disaster phenomena which have not so high disaster potential.

(3) Urgency of the Countermeasures

The urgency of the countermeasures are selected as the third criteria for priority assessment. The assessment is made based on the output of hazard assessment described in Annex-1. The hazard level of the objective area of respective structure will be assessed and the following criteria are defined:

Priority a : Objective area is within high or medium hazard area,
Priority b: Objective area is within low hazard area or out of hazard zone.

3.2.2 Results of Priority Assessment

Based on the criteria defined in the above sub-section 3.3.1, priority assessment is carried out by the Study Team. The results are summarised as follows:

Results of Priority Assessment

Structure	Location	Importance of Objective Area	Magnitude of disaster potential	Urgency of the Countermeasures	Overall evaluation
Check dam Na-1	Manhari	a	a	a	A
Check dam Na-2	Manhari	a	a	a	A
Check dam Na-3	Syarse	a	a	a	A
Groundsill Na-4	Manhari	a	a	a	A
Check dam Na-5	Khade	a	b	b	B
Check dam Na-6	Gorduwa	b	b	a	B
Check dam Na-7	Gorduwa	b	b	b	B
Groundsill Na-8	Manhari	b	b	a	B
Channel work Na-9	Manhari	a	a	a	A
Other protection works		b	a	b	B

Notes; a: Relatively high A: First priority district
b: Medium B: Second priority district

The overall evaluation is made that countermeasures which is judged all the high priority in the three aspects are defined as A, and the others are B.

In the viewpoints of objective area, all the structures which is expected to effect to mitigate the disaster damages at Namtar stretch on the right bank are defined as high priority so that the population density of the area is high and many important rural infrastructures such as school, health post, VDC office, irrigation facilities, rural road, suspension bridge are located in the area. The downstream from the confluence of the Gorduwa Khola along the main stream as well as the along the tributaries are defined as priority "b". The left bank of the main stream is in the upper area also defined as priority "b" since the cultivation land is mainly found along the left bank.

In the view of the magnitude of disaster potential, the huge disaster potential are found in the upstream of the Manhari Khola as well as Syarse Khola in the sediment yield and debris flow aspects. Accordingly, the countermeasures at the upstream of Manhari Khola and Syarse Khola are defined as priority "a". The countermeasures at the other tributaries such as Khade and Gorduwa Khola are defined as priority "b".

In the view of the urgency of the countermeasures, the risk against the disaster at the objective areas are assessed based on the Hazard map. Since the area along the main stream are defined as high hazardous area, most of the measures are defined as the high priority.

3.2.3 Priority Structures

Based on the above priority assessment, the priority schemes of the Namtar Disaster Prevention Plan are formulated. The location of priority structures are shown in Figure 3.1.1, and listed as follows:

ID No.	Type of Structure	Material	Quantity	Function
Na-1	Check dam	Concrete	1	To detain and control the sediment transportation to the downstream, To support the unstable slope on the right bank of the upstream.
Na-2	Check dam	Concrete	1	To detain the unstable sediment material on the upstream riverbed, To stabilise the river bed on the upstream.
Na-3	Check dam at Syarse Khola	Concrete	1	To mitigate the debris flow attacking to the main stream, To protect the left bank of Syarse Khola.
Na-4	Groundsill	Concrete	1	To stabilise the river channel on the Manhari main stream, To protect scouring the toe portion of Check dam Na-3.
Na-9	Channel work	gabion with vegetation	1	To control river course, To protect the river bank, To reclaim the farm land on the both sides of the river.

4. DISASTER PREVENTION PLAN FOR CHISAPANI

4.1 Overall Disaster Prevention Plan

4.1.1 Objectives and Summary of Overall Plan

The terrace field in Chisapani are gradually disappearing by gully erosions and collapses. These erosions and collapses affect not only on the farmland but also on the living places, which makes people's lives so vulnerable.

According to the hearing survey and direct communication to the villagers, the majority of the villagers are so pessimistic to stay there due to high disaster potential at the area, and they hope to migrate somewhere in Terai if they can receive some financial support.

The Study Team carried out the detailed field investigation, and found that more than half of the community have already been lost by severe gully erosions, land slides, and collapses. There area three major gullies in Chisapani area, Majuwa, Chisapani and Garchi Khola. Among the three tributaries, the whole Majuwa Khola basin were almost disappeared. No residents and farmland exists except at the most upper basin of devastated forest area. At the Garchi Khola basin, the gully gradient is more than 45° and the gully was deeply eroded and expanded remarkably. No fertile soil is remained in the basin and the there is almost no possibility to recover the lost land in the basin.

On the other hand, the Study Team found out that the disaster activation in Chisapani Khola and the tributary basin is actually serious but it is possible to sustain the community by the structural measures for a few decade at least. Major part of farm land is still remained with fertile soil, and the community exists along the western ridge of the basin. It is difficult to recover the lost land also in Chisapani Khola basin but there is a possibility to sustain the existing residential area and farmland against the further disaster for a few decades.

The mechanism of residential area and farmland erosion are considered as follows:

a) Along with the progress of undercutting and deepening, the layer of weathered rocks and the top soil are eroded. The toes of slopes are eroded through gully erosions, and then the plane slides occurred. As a result, these natural phenomena will bring about another massive landslide.

b) As the gully erosions and collapses expand, the plane slides around the layer of weathered rocks and the top soil above the erosions and collapses are generated gradually toward the upstream.

c) Since the 1993 disaster, the headwaters have been totally devastated. Thus it is expected that a debris flow, made of eroded and collapsed soils, will break out by a heavy rain.

The main causes of the disaster in the community are plain slides, collapses, landslides and failures due to gully erosion. There are some countermeasures to mitigate such disaster phenomena such as series of consolidation works on the gully and hillside works on the lower part of the slopes. To carry out such measures would also expect that the people in the village will have a hope to stay and continue the productive activities to improve their living standard, which would be possible to migrate themselves in future if they like.

Considering such a technical acceptability to the disaster prevention works as well as the people's needs for provision the sustainable farming activities, overall disaster prevention plan for Chisapani area are formulated.

Prior to the designing the structural plan, it is noted that the disaster evacuation measures are essentially required for Chisapani so that the structural measures could not prevent the disaster potential completely but to mitigate the disaster potential and to sustain the activities for a few decades.

The objective of structural measures are therefore:

1) To sustain the existing community and farm land in the Chisapani Khola and the tributary basins, particularly to protect soil erosion and collapses due to development of the gully erosions.

2) To prevent the gully bank erosion and washing out of the upper cultivation area on the right bank of Chisapani Khola.

3) To prevent the debris flow which will be occurred at the headwater of chisapani Khola attacking to the downstream community.

4.1.2 Structural Plan Formulation

Based on the above anticipated disaster pattern overall disaster prevention plan for Chisapani is formed as shown in Figure 4.1.1. There are three major causes of the further disasters at the existing community and farm land as follows:

1) Continuous erosion at four gullies in the existing community will trigger the instability of the gully bank slope by toe scouring phenomena. The gullies will be subsequently expanded and erode the existing farmland from the edge gradually. The continuous gully erosion at Chisapani Khola will make the deep gully and which will make unstable the residential area on the western ridge.

2) Continuous plane slide on the sloped farmland land will devastate existing farmland, forest and pasture land on the sloped land.

3) Large scale of failure is accelerated at the existing devastated area at the headwater of Chisapani Khola, which will damage to the downstream residential area as well as farm land by the occurrence of debris flow.

Taken into account the above major causes of disaster at Chisapani area, the following countermeasures are proposed as the components of the structure plan.

Countermeasures	Objective areas	Anticipated effect
Gully control works (Series of small check dams)	- Chisapani Khola - Dharapani Khola - Two small gullies	- gullies are protected against gully bank and bed erosion, - toe portion of gully bank slope are protected and the plane slide at residential area and farm land along the gully is mitigated, - top soil on the sloped agriculture land is sustained, - existing residential area is sustained.
Checkdams at the lower edge of the sloped land	- Downstream part of Chisapani Khola	- Gully erosion at Chisapani Khola will be mitigated, - series of groundsills can be constructed by provision of foundation by construction of check dams, - Gully bank slope are stabilised and the residential area and farm land along the gully are stabilised. - lower part of the sloped land and western ridge of the community is sustained.
Hillside works	- Right bank of the Chisapani Khola at the lower edge of the sloped land, - At critical portions on the sloped land	- existing forest and pasture land are sustained, - afforestation activities will be possible by provision of the foundation by hillside works, - Soil loss from existing farm land will be mitigated by slope stabilisation.
Checkdam at downstream of large scale failure	- large scale failure at headwater of Chisapani Khola	- instability of the large scale failure is mitigated and the disaster potential to the downstream residential area is mitigated. - Gully erosion at Chisapani Khola is mitigated and the surround residential and farm land will be sustained.

A checkdam is constructed right below the collapsed portion to trap a future debris flow. The dam is made of concrete because gabions are not strong enough for this purpose.

Large check dams along the Chisapani Khola are constructed to fix and stabilise the toes of hill slopes.

4.1.3 Arrangement of Structures

Based on the above structural plan formulation, arrangement of structures are made as shown in Figure 4.1.2. The detailed explanation are as follows:

(1) Gully control works

Series of small gabion check dams are proposed along four gullies, Chisapani, Dharapani and the other two gullies so that they consolidate the bases of gully erosions longitudinally as shown in the sketch of Figure 4.1.3. The places where these gabions have no more influence to the upper slope on the bank, are protected by gabion walls which prop the upper slopes. Above these gabion walls, the hillside works are installed.

From the long term viewpoints, the vegetative measures for hill slope stabilisation and soil conservation are required to be installed as well. The measures will be effective to protect the toes of gully bank slope from collapse, and to prevent the further massive landslide along the gullies.

The gabion check dams at Chisapani Khola are proposed near the residential area which will have 5 m to 6.5 m in height and 20 to 25 m in the crest length. There are seven gabion check dams are proposed considering the longitudinal characteristics of the gully as shown in Figures 4.1.4 and 4.1.5.

At Dharapani Khola, 13 check dams are proposed. Among them, two check dams of 7.5 m proposed at the outfall are designed as the concrete structure as the foundation of the upstream series of gabion check dams. The gabion check dams are designed as 4.5 to 6 m in height taking into consideration of the longitudinal characteristic of the gully as shown in Figure 4.1.6.

It is noted that the height of series of gabion check dams shall be reviewed at the design stage, which is so far designed at 4.5 to 6.5 m in height. If it is too high in the viewpoint of stability, it shall be lowered as required, instead the number of gabion check dam shall be increased to cover the upstream toe portion of the check dam by design sediment slope. The design sediment slope is generally estimated two-third of the original river gradient.

At the two other gullies located on the east of Dharapani Khola, series of gabion check dams with 4 m height are proposed.

(2) Checkdams at the downstream part of Chisapani Khola

The sloped land spread in the community is gradually eroded from the lower part on the right bank of Chisapani Khola. To sustain the sloped land in the long term viewpoint, it is required to provide the foundation work at lower part of Chisapani Khola as toe protection measures. For this propose three check dams are proposed. The dam height is designed as 20 m as shown in Figures 4.1.4 and 4.1.5, which is assumed the possible maximum height in the view of the structural stability. These check dams, however, cannot stabilise the upper portions of hill slopes at all, thus the hillside works are required to be installed to protect erosions and collapses of upper hillside. Also, the prop wall is proposed for the foundation works of the hillside works after the pockets of check dams filled with sedimentation.

(3) Check dam at the downstream of large failure area

There is a large scale failure at the headwater of Chisapani Khola. The failed slope is forming instability and there is high possibility to collapse in large volume and trigger debris flow to the downstream by the further rainstorm. Stabilisation works will be necessary to protect the further failure of the area so that the major residential area is located on the left bank at the downstream. The debris flow at Chisapani Khola would also seriously affect to the stability of the whole sloped land in the community.

However, the direct measure for the stabilisation works would be quite difficult since the unstable slope is almost vertical and quite high. Considering the difficulty of the direct countermeasures, it is proposed to construct Check dam at just downstream of the large collapse area at the bottle-neck of the gully. The proposed dam, which is called "Check dam Ch-1", of which height is about 10 m with crest length of about 27 m. The fresh rock foundation is observed on the both banks at the damsite. Check dam Ch-1 is designed as concrete structure so that it is required to trap debris flow. Check dam Ch-1 is expected to mitigate the debris flow to the downstream residential area as well as the detain the toe portion of the unstable large scale failure.

(4) Hillside work in the sloped land

On whole sloped land in Chisapani area, there are many cracks which are occurred by the plane slide activities. Particularly, there is one critical portion in the eastern edge of existing farm land and the upper forest area. The unstable top soil is not so thick however, if the top soil are being slide, the existing residential houses at the lower part of the slope will be damaged. For the purpose to protect the residents from the damage, prop wall for two rows with 100 m long is proposed.

4.2 Selection of Priority Schemes

4.2.1 Criteria for Selection of Priority Schemes

Based on the basic concept of the disaster prevention plan at Chisapani area, which is to protect the existing residential area and farm land, overall disaster prevention plan are provided within Chisapani Khola basin. In this chapter, the priority schemes among the components of overall plan are assessed by the following criteria:

(1) Urgency of countermeasures

The urgency of the countermeasures are highly related to the hazard potential in future. Accordingly, the urgency of the countermeasures are assessed based on the hazard map which is provided in Annex-1. Identified zones as high hazard are along Chisapani, Dharapani and the other gullies, to which the countermeasures would be defined as the urgently required measures.

(2) Cost effectiveness of the countermeasures

In case of the same priority in the aspect in urgency, the higher cost effective measures shall be in priories. Because, the budget for disaster prevention measures would be usually not sufficient to satisfy the prevention needs completely. In that case, the maximum effect to disaster prevention should be taken within the limited budget.

For example, the gully erosion at Chisapani Khola is quite serious and the bed rock is already exposed with a depth of 10 to 20 m. The objective area along Chisapani Khola is on the bank with fertile soil on the slope. Thus it is required the check dams as foundation works will be required as high as about 20 m height, which must be massive concrete structure and it will be quite costly. In that case, the cost effectiveness will not so high.

(3) Importance of the Objective Area

Although at some areas which are defined as the high hazardous, if there is no residents, farm land or some important rural infrastructures, the needs of disaster prevention is would be not confirmed, so that no damages to the human lives and property are expected. In this viewpoints, the importance of the objective area in the view of population, infrastructure density and the area productivity will be one of the criteria for selection of priority schemes.

4.2.2 Priority Structures

According to the three criteria proposed in the former sub-section 4.2.1, the priority assessment is carried out for all the structures nominated in overall plan. The results are as follows:

Structure	Urgency of countermeasures	Cost effectiveness	Importance of objective area	Overall evaluation
Check dams at Chisapani Khola Ch-2, Ch-3, Ch-4	b	c	c	B
Prop wall at Chisapani Khola Ch-9	a	b	b	B
Check dam at Chisapani Khola Ch-1	a	a	a	A
Series of small check dams at Dharapani Khola Ch-6	a	a	a	A
Series of small check dams at Dharapani tributary1 : Ch-7	a	a	a	A
Series of small check dams at Dharapani tributary2: Ch-8	a	a	a	A
Hillside work at Chisapani Khola Ch-10	a	a	b	A
Series of small check dam at Chisapani Khola : Ch-5	b	b	a	B
Prop wall on the sloped land Ch-11	a	a	b	A

Note : a: high priority, b : medium priority, c : low priority
A : Priority schemes, B : Semi-priority scheme

4.2.3 Selected Priority Structures and Order of Performance

Based on the priority assessment mentioned in the former sub section 4.2.2, the priority schemes for disaster prevention structures are selected as shown in the following table. The order of performance which is considered the mechanism of disaster are also proposed in the table:

ID No.	Structure	Function	Order of performance
Ch-1	Check dam at Chisapani Khola	To trap debris flow	1
Ch-6	Series of small check dams on Dharapani Khola	To protect gully erosion	2
Ch-7	Series of small check dams on Dharapani tributary 1	To protect gully erosion	2
Ch-8	Series of small check dams on Dharapani tributary2	To protect gully erosion	2
Ch-10	Hillside works at Chisapai Khola	To protect bank erosion of gully	1

5. DISASTER PREVENTION PLAN FOR MAHADEVBESI BRIDGE

5.1 Overall Plan for Disaster Prevention of Mahadev Besi Bridge

5.1.1 Objectives

Taking the cause of formidable destruction of Mahadev Besi Bridge into consideration, it is intended to protect a new bridge built up at the same site from similar disastrous events. As synoptically discussed in Annex 1, Chapter 5.1 (General of Disaster Analysis at Mahadev Besi Bridges), the major cause of bridge destruction obviously stemed from the anomalous flood water which accompanied a great deal of boulders and sediment. Although a major component of bridge destruction is not necessarily clear yet, nobody can discuss the event without considering the problems of sediment outflows from upstream. Hence, one of the most significant objectives evolved in this project is to control the sediment as much as possible.

Sediment control contains erosion control which prevents the yielding of sediment at its source areas on mountain slopes and also contains to properly adjust the transportation of sediment along the river channel as well as to bring about longitudinally and laterally equilibrated situations of the river. For the purpose of protecting Mahadev Besi Bridge, major objective of this protect cannot but be put on the latter because the accomplished of such works as being classified into the former will be unexpectable in near future.

5.1.2 Technical Framework

In order to set up the framework of engineering techniques necessary for the protection of Mahadev Besi Bridge, it will be convenient to review the causes of the destruction of the bridge in 1993 disaster. They can be brightly itemised as follows:

a) enormous amount of sediment outflows from upstream

b) conspicuous accumulation of sediment on the riverbed during the period of flood time

c) shortage of cross-section under the bridge due to sediment accumulation

d) lateral migration of floodwater toward the left bank near the bridge

e) striking of boulders and driftwood on the bridge structures

Among these factors of the cause of bridge breakdown, b) and c) seem to be the chief ones leading to the direct destruction of the bridge.

So-called debris-flows that are usually generated in steep torrents with several degree of gradient seem to have not struck the bridge. Instead, floodwater or super concentrated sediment water which is heavily loaded with boulders and sediment is supposed to have been generated in the upstream channel adjacent to Mahadev Besi Bridge. That must have been like a hydraulic force generated by repeated blockades of the channel with debris/sediment and washing them out by floodwater.

The technical framework, accordingly, shall be disposed to eliminate such injurious components of sediment-load floodwater. The following are the key points to be reckoned with for the formulation of countermeasures.

i) From the long-term point of view, it is essential to reduce the yielding of sediment in its source areas. But in a wide extent of areas, intensive landuse of hill slopes, geologically and geomorphologically worst situations as well as the poorest circumstances in the basin interfere in this essential principle. There is little hope to succeed in the protection of reduction of sediment yielding through the improvement of vegetation, for the time being. As for the protection of Mahadev Besi Bridge, this way of consideration is far from the affective measures.

ii) Many residuals of sediment flowed out in the 1993 disaster still remain in the main channel and the tributaries of Agra Khola. They are ready to move downstream on occasion of the next coming flood. Not only on the riverbed but also at the foot of collapsed hill slopes there exists a lot of unsettle sediment. Transportation of such sediment should be controlled to attain the safety of the bridge because longitudinal as well as lateral profiles of Agra Khola are far from equilibrated situations. Although the riverbed elevation around the bridge site seems to be descending at the moment of this time to a considerable degree, it should be feared that the riverbed could be suddenly raised, resulting in an unexpected consequence of high-water level and hereby giving damage to the bridge structures. Under such circumstances, sediment control works in the river channels through well designed check-dams and others are indispensable.

iii) In the lower segment of the main channel of Agra Khola from the confluence of Mel Khola to the bridge site, there are found big boulders and sediment on the riverbed, and the neighbouring river terraces consisting of colluvial deposits still have enough potential to supply such big granite boulders that will strike the bridge. It is urgently needed to detain them around the existing position so that they would not disturb temporarily settled situations of the riverbed. Countermeasures in this segment of the river channel are much more important than those in the upper segments in terms of a short-term viewpoint

iv) The sharp bent of the river course located at about 500 m upstream the bridge site exerts much unfavourable influence on the settlement of river equilibrium, horizontally as well as longitudinally up to the bridge site. As for this lowest segment it is substantially needed to check the riverbed longitudinal with low dams and to regulate the flow direction with groundsills and spur dikes so that the floodwater may pass the bridge site without lateral migration or deviation of streams. Stabilisation of the riverbed or an equilibrated profile in the lowed segment of Agra Khola must be prerequisite for the safe maintenance of Mahadev Besi Bridge.

v) It is not worth programming and implementing those works as mentioned above unless definite steps are taken to conserve the river environment and to maintain the structures newly built up. Selfish and greedy quarrying of stones and gravel from the riverbed around Mahadev Besi Bridge has become prosperous lately. It is clear that such kind of deed will give the worst effect on a natural equilibrium of the river itself, for instance. Apart from mechanical countermeasure, all the administrative ways of river management should be examined as part of technical framework. Otherwise the engineering efforts will be in vain.

5.1.3 Overall Plan Formulation

Based upon the outlines of technical framework mentioned in preceding Section 5.1.2, the overall plan of IDPP Mahadev Besi Bridge can be set up as shown in Figure 5.1.1. This plan does not necessarily include such a grand scope of plan as being bearable against the most severe event like the 1993 disaster, but it will be formulated on a proper scale which may bear up the issue of the usual event of flood disasters. The scale in terms of flood probably may not exceed a 25-year return period.

Overall plan can be broadly classified into two categories. One is to control the sediment outflow from upstream and the other is to stabilise the river channel, particularly in the lower reaches. The accounts for each are as follows:

1) Countermeasures to control the sediment

Outflow amount of sediment can be herewith presumed to be nearly the same kind as the amount estimated by the DPTC in 1994 after the 1993 disaster. According to the report published by the DPTC, the total amount of sediment was estimated 1.34 million m^3, while the suspended load was estimated 1.12 million m^3. Then, the bed-load to be dealt with as an objective amount of sediment in this plan can be assumed to be 0.22 million m^3. This amount can be said rather small in estimation, in a sense, as compared with the gigantic 1993 disaster. But this clearly depends upon the estimated amount of the wash load which is not so easy to estimate exactly. Hence, the objective amount of sediment of 0.22 million m^3 in this plan is presumable to be applied correspondingly.

Countermeasures to reduce sediment yielding on its source such as hillside works and tree-planting on hill slopes in the upper basin will not be included in this overall plan for the reason as mentioned in Section 5.1.2 (refer to the paragraph (i)).

Check-dams to detain and control further transportation of sediment downstream are to be arranged in the lower channel of Agra Khola in this overall plan for the reason as mentioned in Section 5.1.2 (refer to the paragraph (ii) and (iii)).

The number of check-dams and their dimensions shall be designed so that the total control capacity of check-dams would be not less than an estimated bed-load amount of sediment. Considering the aim of this project to protect Mahadev Besi Bridge from sediment outflows, the proposed sites of check-dams shall be disposed in the lower river channel downstream the confluence with Mel Khola.

Figure 5.1.1 shows the location of check-dams and the outlines of proposed check-dams are shown below:

Outlines of Proposed Check-dams

Notation	Effective Height of Check-dam H (m)	Mean Width of Sediment Deposition B (m)	Original Riverbed Gradient (1/n)	Expected Capacity of Sediment Control E (m^3)
No.1 Check-dam	4.0	6.0	1/40	38,400
No.2 Check-dam	5.0	8.0	1/40	80,000
No.3 Check-dam	4.0	8.0	1/40	51,200
No.4 Check-dam	5.0	6.0	1/35	52,500
Total				222,100

In the table above, expected capacity of sediment control E is roughly estimated by the equation, $E = nBH^2$. And it is presumed that the amount of E would reconcile the amount to be controlled.

2) Countermeasures to stabilise the channel

The river channel situated in the most downstream of Agra Khola between the sharp bent of the river course about 500 m upstream Mahadev Besi Bridge and the confluence with Mahesh Khola is still unstable longitudinally as well as laterally. It is feared that the existing situations of the river regime would give injurious effects on the safe maintenance of Mahadev Besi Bridge, as mentioned in Section 5.1.2 (refer to paragraph (iv)).

To cope with those unstable situations it is needed to take countermeasures so as to stabilise the channel to a considerable extent as shown in Figure 5.1.2. The following structures are proposed.

- Groundsill No.1 with a view to controlling excessive amount of sediment from upstream as well as conserving the existing riverbed around a sharp bent of the river course.

- Groundsill No.2 with a view to consolidating the riverbed upstream and lowering the riverbed downstream so that it may reconcile the riverbed gradient downstream as well as direct a proper course of the river channel.

- Several spur dikes on the right bank downstream with a view to checking and adjusting the direction of the floodwater so that a smooth passage of the floodwater at the bridge site can be secured.

They can be briefly tabulated as below.

Outlines of Proposed Groundsills and Spur Dikes

Notation	Nos.	Effective Height (m)	Length of Structure (m)	Existing Riverbed Gradient (%)	Planned Riverbed Gradient (%)
Groundsill/No.1	1	5.0	98.0	1.8	1.3
Groundsill/No.2	1	3.0	76.0	1.5~1.7	1.3
Spur Dike	5	2.0~3.0	9.0	-	-

Groundsill No.1 with the effective height of 5m may substantively act as a low check-dam although it is named a groundsill herein for convenience sake. It is expectable for this groundsill to detain sediment to some extent as well as to play sorting the size of sediment. This point may deserve much attention. Setting of groundsill No.2 combined with a series of spur-dikes has nothing to do with quantitative control of sediment but is of significance to realise the establishment of a stable channel. The longitudinal design profile is shown in Figure 5.1.3.

In the sense of desirable application of bio-engineering, spur-dikes made of gabions should be composed of "vegetated gabions" through the use of sprout-capable fanciness and simultaneously should be well managed and maintained even after implementation.

3) Recommended additional countermeasures

In addition to the above-mentioned countermeasures it is recommended to take some of additional countermeasures into consideration. Desirably additional works to ensure the safety of Mahadev Besi Bridge can be enumerated as follows:

i) What is of most important among those works is to dismantle the old piers and the approach embankment on the right bank to keep flood discharge capacity.

ii) As against the dismantled portion of the right bank it is needed to arrange a proper revetment as well as its foot-protection works.

iii) In order to protect the abutments and piers of the bridge from unexpected localised scouring it is recommended to arrange the riverbed covering works with stone-pitching and others.

iv) Some parcels of the land adjacent to the right-bank abutment are recommended to form a small riverside park by way of combining with vegetated spur dikes in the river channel.

v) In terms of management and maintenance of the groundsills, the spur dikes and vegetation, it is necessary to build a management road which may be set out on the high-water channel along the river course from the bridge up to the groundsill upstream. Quarry of stones and gravel in this segment should be prohibited.

5.2 Selection of Priority Schemes

5.2.1 Criteria for Selection of Priority Schemes

The criteria for the selection of priority schemes may consist of the following components.

a) Objective scale of natural disaster

b) Scale of countermeasures envisaged

c) Effectiveness of countermeasure structures

d) Accessibility for implementation

e) Managerial matters

a) As for the objective scale of such natural disasters as coming from flood water, debris/sediment flows and landslides, it is actually convenient to express it in the return period in hydrology. The scale of heavy rainfall or flood discharge obviously exceeds the probability of the return period of 200-year or 300-year. Whereas, it may be reasonable to set it less than 30-year, because it is urgent for us to determine some priority schemes.

b) As for the countermeasures necessary for the protection of the bridge it cannot be possible to formulate a large-scale flood/sediment control project since some of priority projects should be selected to materialise in the near future. Financial circumstances will also be serious constraint.

c) Effectiveness of countermeasures, particularly of mechanical countermeasures for the present, should be deliberately examined. According to the experienced facts in the field of sediment control engineering, the effectiveness of sediment control structures located upstream far from the objectives of protection will not rapidly spread toward the downstream. Usually it takes a long time, scores of years sometimes. Hence, the countermeasure structures should be located in the river channel near the bridge.

d) Accessibility to the sites of the structures is also of significance so long as the implementation matters are concerned. Poor accessibility without roads will naturally hinder rapid and economic implementation.

e) The management and maintenance are, needless to say, important components upon selecting priority schemes. Schemes to be implemented prior to others should be located in the areas easy to manage.

5.2.2 Selected Priority Schemes

Judging from the above-mentioned criteria for the selection, priority schemes are to be confined to those works which stabilise the river channel in the lowest segment of Agra Khola, that is, those structures shown in (2) countermeasures to stabilise the channel, in section 5.1.3.

Thus, the selected schemes include neither check-dam nor hillside works, but the groundsill No.1 which will be arranged at the immediate downstream of a sharp bent of the river channel is expected to play the role to detain and control the sediment from upstream for the time being. Hillside works in the upper basins are too far from the fact we face, since the devastated basins extend wide and the effect of those works cannot be expected in a short period of time.

Groundsill No.2 and spur dikes can lead to the establishment of a stabilised channel, both vertically and laterally settled, towards the site of Mahadev Besi Bridge.

6. OVERALL DISASTER PREVENTION PLAN FOR KULEKHANI RESERVOIR

6.1 Approaches to Overall Plan Formulation

6.1.1 Current Major Issues

As described in Chapter 5 in Annex-1, there are three major issues in the Kulekhani watershed as shown below:

1) Sustainable operation of Kulekhani hydropower plants is not guaranteed due to marginal storage volume below the intake structures of the power facilities in the Kulekhani reservoir.

2) Regulating capacity of the Kulekhani reservoir is rapidly decreased and the generation capacity to meet the peak load in dry season cannot be expected after 2010, taking into account the observed sediment deposition in the reservoir.

3) The basinwide watershed management activities are not supported by the people in the watershed due to less impact to the rural development by the activities.

The first issue is the rather serious matter, and it will be required the urgent countermeasures to continue the power generation activities of the both of Kulekhani No.1 and No.2 power stations. The remaining storage at below the intake is only about 3 million m^3, which is much smaller than the sediment deposition volume by July 1993 disaster. It means that the dead storage will be filled with sediment by the next disaster at once, and no more power generation activities will be enable after then.

The second issue is not the urgent matter which will come around 15 years later. The minimum required storage to guarantee 4 hour peaking operation through the year is estimated at 48 million m^3 whereas the current effective storage is about 63 million m^3. However, the economic loss of losing effective storage by accumulation of sedimentation will be quite big. The countermeasures with having sufficient feasibility would be found and shall be taken the immediate actions if such feasible countermeasures can be found out.

The third issue is the rather complicate. The people in the watershed as well as electricity users in the nation will not easily understand the importance of the watershed management activities so that the effect of the activities is generally invisual and unquantified. Under the conditions of unquantified benefit, it would be difficult to allocate the sufficient budget to execute the watershed management activities. To encourage the watershed management activities, therefore it would be required to establish the dense monitoring system to quantify the effect of watershed management activities.

6.1.2 Problem Analysis

The problem analysis is carried out according to the theory of Project Cycle Management Approach, hereinafter referred as "PCM" approach in the Study.

PCM approach is broadly applied for project planning, implementation and evaluation. In the latter half of 1960's, The United State Agency for International Development, USAID, at first introduced the theory of PCM, which is the logical frame works of project planning, among the objectives, output, activities and input. By applying the PCM approach it can be logically explained the plan formulation of the project.

After 1970's, many international agencies, such as UNDP, UNICEF, GTZ, NORAD, JICA and so on, followed the PCM approach for project planning.

Figure 6.1.1 shows the problem tree of the Kulekhani watershed. The two core problems are defined by the Study team, and the direct cause and immediate effect by the core problems are assessed. The direct causes are put the lower part of the core problems and the immediate effect was put on the upper part in the Figure.

Based on the above major issues, the core problems are identified in the Kulekhani watershed as follows:

1) Decrease life of Kulekhani Hydropower Plants,

2) The watershed people's priority in basin development rather than basin conservation.

By repeating the above assessment, the relation between the causes and the effects of the problems are developed as shown in Figure 6.1.1.

According to the developed problem trees, there are three major flow of problems, and the three root causes of the problem flows are found as shown below:

1) Marginal capacity of dead storage of Kulekhani reservoir,

2) No direct benefit by providing sediment control measures, and

3) No clear policy in watershed management activities.

As shown in Figure 6.1.1, there are various problems developed from the roots causes of problems, and finally come to the core problems. The immediate effects of the core problems would be " Less reliability to the government from electricity users and people in the watershed".

6.1.3 Objectives Analysis

Objectives of the overall disaster prevention plan for Kulekhani reservoir must be solving the two core problems mentioned above. And it would be required to solve the roots causes to create the core problems as shown in Figure 6.1.1.

The objective tree is developed according to the PCM procedures, which is prepared based on the problem tree, as shown in Figure 6.1.2. According to the theory, objective tree is provided to assess the effects when the problems consisted of the problem tree are solved. Then, the problems will be replaced with the affirmative sentences in each colum in problem tree. After those process, the objective tree which indicate the relation ship between "immediate cause - immediate effect" will be changed to "mean - objective" relations.

The means are located on the lower part of the tree in Figure 6.1.2, and the objectives is locate on the upper part at the end of allows. The two main objectives of the project are defined as referred to the two core problems which are summarised below:

1) To sustain the life of Kulekhani hydropower plants,

2) To carry out watershed management by people's participation.

When the project is successfully implemented and to satisfy the two core objectives above, it will be expected to satisfy both of electricity users and people in the watershed by the implementation of the project.

6.1.4 Approaches to Overall Disaster Prevention Plan

Based on the objectives analysis mentioned in the former sub section 6.1.3, the three major approaches are found as shown in Figure 6.1.3, which are as follows:

1) Sloping intake approach,
2) Sand resources development approach,
3) Integrated watershed management approach.

As indicated in Figure 6.1.3, the above three approaches are inevitably required to satisfy the two core objectives.

To sustain the life of Kulekhani hydropower plants, it is required to maintain the power intake, and effective storage, and to mitigate sediment yield in the watershed. On the other hand, mitigation of sediment yield would not be success unless the people's needs in the watershed are taken into account. For mitigation of sediment yield, it is required to provide gully control works, to carry out appropriate forest management as well as to apply proper contour farming technics, all of which are the major sources of sedimentation to the reservoir. However, it is required that people become interested in participation in watershed management activities to promote such sediment mitigation activities. To satisfy the people's participation, rural development aspects should be taken into account in the integrated watershed management approach.

Accordingly, to achieve the core objectives above, three different approaches would be inevitably required. The details of respective approach will be explained in the following sub sections 6.2 through 6.4 respectively.

6.2 Sloping Intake Construction Approach

The sloping intake construction approach is currently in the construction stage by the NEA with a financial support from the OECF, Japan. As mentioned in Annex-1, Clogging intake by the further sedimentation is the most critical issues for sustaining power generation of both of No.1 and No.2 power stations.

The NEA has taken immediate actions to the critical issues and the construction works of sloping intake structures commenced on November 1996. According to the construction schedule, the rehabilitation works will be completed before the rainy season of 1997 so that it is possible to solve the matters without any risk in rainy season.

Table 6.2.1 shows the project design matrix of sloping intake approach, and the justification of the countermeasures were carried out in " the Comparative Study on Alternative Countermeasures for Kulekhani Disaster Prevention Project," November 1994 by the NEA. The study evaluated some alternative plans to meet the objective for sustaining the functions of the intake structures against sedimentation progress as shown below:

Alternative 1: Dredging around the intake, Alternative 2: Dredging around the intake combined with the construction of check dams,

Alternative 3: Dredging around the intake combined with the sand flushing tunnel, and

Alternative 4: Improvement of the power intake by raising the intake water level according to the progress of sediment level.

The optimum solution to sustain the intake structures was to improve the power intake by raising the intake water level according to the progress of sediment level in Alternative-4. The results of the comparative study were summarised as follows:

Alternatives	B-C (million US$)	EIRR (%)	Remarks
(1) Dredging	31.69	16.19	
(2) Dredging with check dams	29.64	14.83	
(3) Dredging with sand flushing tunnel	-	-	not feasible in technical viewpoint
(4) Sloping intake	37.19	18.80	

Based on the results above, the NEA decided to implement the restoration of the intake structures in the Kulekhani reservoir. Figure 6.2.1 shows the general layout of the sloping intake structures.

By implementing the sloping intake structures, the critical conditions of power intake due to clogging by sedimentation will be solved and power intake will be maintained for long time, which is one of the important component to sustain the life of Kulekhani hydropower plants.

6.3 Sand Resources Development Approach

6.3.1 Basic Concept of the Sand Resources Development

After providing a countermeasure for the intake structures, how to guarantee the four-hour peak operation of the Kulekhani power stations shall be considered.
As mentioned in Annex-1, a 48 million m^3 of storage capacity is at least required to guarantee the four-hour peak operation in the fry season, with a 90% dependability.

Figure 6.3.1 shows the trend of effective storage of the reservoir. Based on the trend of decreasing the storage capacity for the last fifteen years, it is assumed that the function of the four-hour peak operation will not be guaranteed after 2013, which is about fifteen years from now. In case of the severe trend from the previous three years, however, it can be assumed that the guarantee period for the four-hour peak operation is up to 2004, which is just seven years from now.

Considering the important role of the Kulekhani reservoir to the national power supply network, the countermeasure should be taken into account based on the assumption of the severe trend. And the recommended countermeasures are the ones against at least a next severe event like the 1993 disaster to guarantee the four-hour peak operation before 2004.

As analysed in objective analysis described in Figure 6.1.3, the procedures for attaining the objectives will be as follows:

1) To find out direct benefit by sediment control works,

2) To improve the economic viability of the sediment control measures,
3) To implement countermeasures, then
4) To maintain effective storage of the reservoir.

To satisfy the objectives above, the sand resources development approaches are proposed. The idea of the approach is that the sediment deposition shall be excavated and to transport as the construction material to Kathmandu city. The sand excavated from the reservoir will be treated as the resources and it will be expected to yield the benefit by selling to the market in Kathmandu city. Moreover, it is expected to excavate sediment material from the effective storage of the reservoir, and the decrease of effective storage would be mitigated continuously which would be also contributing to delay of investment for alternative power plants to Kulekhani hydropower plants and will be resulting the saving national investment.

6.3.2 Current Situation of Sand Quarry in Kathmandu Valley

Construction works especially the residential and commercial buildings as well as economic and social infrastructures are continuously growing in the Kathmandu valley. As the result, the demand of construction materials such as cement, sand and so on are rapidly increasing. The rivers in the valley which were to be the major sources of sand supply in Kathmandu valley, however, excess sand excavation from the rivers in the valley is going to affect to the river bed degradation, and important bridges in the city are currently in the critical conditions due to severe scouring of the foundation.

Figure 6.3.2 describes the newspaper article, which pointed out the current situation of the major bridges in Kathmandu city. The foundation of bridge piers are severely eroded by river bed scouring. Figure 6.3.3 shows the location of major sand quarry sites in Kathmandu valley. Most of sand quarry sites are located along the Manhari Khola, major tributary of Bagmati river flowing from north-west of the Valley to the centre of the city. There are many bridges located on the downstream of such sand quarry sites.

Considering the serious effects of the sand excavation from the rivers in the Kathmandu valley, the District Development Council (DDC) of Kathmandu city have prohibited sand excavation from the rivers in July 1996 to solve the problems of river bed degradation.

6.3.3 Sand Demand Estimation

Since there is no available data for sand consumption in Kathmandu as well as Nepal, demand of sand resources in the Kathmandu valley as the construction materials is estimated based on the cement consumption in Nepal.

(1) Cement consumption in Nepal

The followings are the cement consumption record:

Source of Cement Supply	Unit	1992 / 93	1994 / 95
Domestic Supply	1,000 kg	247,891	326,839
Import	1,000 kg	175,161	124,868
Total	1,000 kg	423,052	451,697

Source : Economic survey, Ministry of Finance

As shown in the table above, the cement consumption in Nepal is estimated at about 450,000 ton in 1994/95, and it is in increasing trend with 2.2% per annum..

(2) Cement consumption in Kathmandu valley

There is no available data of cement consumption in Kathmandu valley. Therefore, hearing survey to the major cement producers, Himal, Udaypur and Hetauda Cement Factories are carried out by the Study Team. According to them, between 30 to 50% of their production were usually transported to Kathmandu valley. Accordingly, it is assumed that about 40% of cement in Nepal is consumed in Kathmandu valley. Therefore, the estimated annual cement consumption in Kathmandu valley is as follows:

451,697 x 0.4 = 180,690 ton.

(3) Sand demand in Kathmandu valley

Generally in Nepal, the ratio of cement and sand mixture for concrete, or mortal for building construction as 1:5 in weight. Therefore, the sand demand in weight in Kathmandu valley is:

180,690 ton x 5 = 903,450 ton/year.

In converting weight to volume, the specific weight of sand with 2.2 ton/m^3 is applied. The estimated demand in volume is:

903,450 ton / 2.2 ton/m^3 = 410,660 m^3 / year.

The demand of sand as the construction material in Kathmandu valley is therefore estimated at 410,660 m^3 / year as of 1994, and it is in increasing with 2.2% per year.

6.3.4 Sand Supply Sources to the Valley

The major sand quarry sites in and around the Kathmandu valley are investigated by the Study Team through the hearing survey of sand transporter as well as sand merchant in Kathmandu. The following table shows the major sand quarry as well as annual supply amount of sand:

Name of site	Location	Number of tracks per day	Annual sand supply volume (m^3)	Remarks
Nibarahi	Inside of valley	80	148,628	land excavation (class B)
Bhaktapur Joukhel	Inside of valley	10	18,578	land excavation (class B)
River site	Inside of valley	20	37,157	river excavation (illegal) (class A)
Belkhu	60 km form valley	100	185,785	river excavation (class A)
Ghatbesi	65 km from valley	8	14,863	river excavation (class A)
Palung	60 km from valley	6	11,147	river excavation (class A)
TOTAL		224	416,158	

source : investigated by the Study Team

Among the major sand quarry sites above, river side in the valley is irregularly quarried by the sand supplier, and it will be prohibited in near future. The observed annual sand excavation for Kathmandu valley is 416,158 m^3, which is almost same volume estimated based on the cement consumption.

The three major sand quarry sites are outside from the Kathmandu valley, which are about 60km away from the Kathmandu valley. According to the investigation, 211,795 m^3 /year of sand resources are transported from outside of the valley, and it shares about 50% of the total demand in the valley.

Based on the investigation results above, the Kulekhani reservoir could be alternative sources of sand quarry to Kathmandu valley so that the distances between the valley to Kulekhani reservoir is much closer than the three major sand quarry sites outside of Kathmandu valley.

6.3.5 Market Price of Sand Material in Kathmandu Valley

Market price of sand material at Kathmandu valley are investigated by the hearing survey through the sand merchant. According to them, the price of sand resources depends on the locations. The standard prices of the three major sand quarry are as follows:

Sand Price per Track (about 5 m^3)

Items	Nibarahi (inside of valley)	Palung (outside of valley)	Belkhu (outside of valley)
Distance from Kathmandu valley	0km	60km	43 km
Payment to landowner	Rs.250	Rs.0	Rs.0
DDC Tax	Rs.150	Rs.150	Rs.150
VDC Tax	Rs.50	Rs.110	Rs.0
Club Tax	Rs.0	Rs.0	Rs.25
Sand Excavation and Loading	Rs.550	Rs.300	Rs.425
Transportation and unloading	Rs.1,200	Rs.2,000	Rs. 1,700
Total Marketing Price	Rs.2,200	Rs.2,560	Rs.2,300

Source : Investigated by the Study Team

The investigation results indicate that the transportation cost shares major part of market price which about 54% for Kathmandu valley and 70 to 80% for outside of Kathmandu valley. The distance from the Kathmandu valley will be the key issue to determine the market price of sand resources in Kathmandu.

The investigation prices above are for the dry season, and the marketing price in rainy reason would be about Rs.1,000 / truck higher than the dry season. Because, the major quarry sites along the river will be closed and the deficit in sand resources is observed in the Kathmandu market.

6.3.6 Price for Sand Resources in the Kulekhani Reservoir

The sand price of Kulekhani reservoir is estimated based on the observed marketing price of sand in Kathmandu valley. Considering that transportation cost is the major part of the marketing price of sand, some alternate routes, which are under construction by the villagers committee or INGO, are also assessed to estimate the marketing prices. The estimated price of sand of Kulekhani reservoir are as follows:

Items	Existing Route (Tribhuvan highway)	Chitlang route	Daksinkali route
Distance from valley	60km	32km	42km
Payment to land owner	Rs.0	Rs.0	Rs.0
DDC Tax	Rs.150	Rs.150	Rs.150
VDC Tax	Rs.110	Rs.110	Rs.110
Club Tax	Rs.0	Rs.0	Rs.0
Sand excavation and loading	Rs.300	Rs.300	Rs.300
Transportation and unloading	Rs.2,000	Rs.1630	Rs.1,780
marketing price	Rs.2,560	Rs.2,190	Rs.2,340

Sources: estimated by the Study Team

In case that sand resources are excavated from the Kulekhani reservoir, DDC tax as well as VDC tax will not required to pay as the reservoir is owned by the Nepal Electricity Authority. However, considering the impact to the regional economy, it is remained with the same amount for DDC and VDC taxes as Palung sand quarry.

The location of three alternate routes for sand transportation from the Kulekhani reservoir to Kathmandu valley is shown in Figure 6.3.4. The existing route from Kulekhani dam to Kathmandu valley through Tribhuvan highway, the distance is about 60 km, and it takes about 4 hours. The transportation cost is estimated same as the Palung due to the same distance from the valley and almost the same route is taken. The cost is about Rs.2,560 per truck, which is much expensive than the Belkhu with Rs.2,300 per /truck. Considering that the sand transportation condition from Palung is not active with 6 tracks per day, it is assumed that the viability of the Kulekhani reservoir for sand resources development is not expected. Even that DDC and VDC taxes are not considered, the sand price becomes Rs.2,300 / per truck, which is the same price with the Belkhu, and it would not be feasible.

In case that Chitlang route is taken, the price of sand of Kulekhani reservoir becomes cheaper than any other places in and around the Kathmandu valley. However, it is physically not possible to take the Chitlang route.

Figure 6.3.5 shows the longitudinal profile of the three alternate route between Kulekhani reservoir and Kathmandu valley. The Chitlang road is quite steep with the average slope is more than 5 %, and it is not possible to transport the full loaded trucks. The route passes in the Kulekhani watershed and it would affect seriously to forest degradation as well as soil erosion along the route, which would affect directly to the sedimentation to the Kulekhani reservoir. Considering such situations, it is not recommended to take the Chitlang route for sand transportation.

The Daksinkali route which is under construction by Plan International, INGO, is much better condition in the topographic aspects. As shown in Figure 6.3.5, the average slope is less than 5 %, which is rather gentle than the existing Tribhuban highway. The distance from Kulekhani reservoir to Kathmandu city is about 43 km, which is almost same as the Belkhu. In case that Daksinkali route is taken the sand price of Kulekhani reservoir becomes about Rs.2,340 per truck, which is almost same price as the Belkhu. In case that some adjustment of DDC tax, VDC tax, as well as the sand excavation and loading cost, it will be much cheaper than the Belkhu.

6.3.7 Prospects for Sand Resources Development at Kulekhani Reservoir

Based on the investigation above, it seems that the sand resources development approach to mitigate the sediment accumulation in the effective storage of Kulekhani reservoir would be feasible in the view of technical and economical aspects. The following conditions will be required to provide for successful sand resources development activities:

1) The cost of Kulekhani sand resources at Kathmandu valley shall be less than Rs.2,200 per truck by adjusting DDC, VDC taxes as well as the cost for sand excavation and loading. By such adjustment, the cost will be cheaper than any other sand resources in and around the Kathmandu valley.

2) The existing route as well as Chitlang route for sand transportation would be not viable to activate the sand resources development of Kulekhani reservoir. On the other hand, Daksinkali route would be useful to transport the sand in technical and economical viewpoints. In that case, however, some road improvement works, such as bridge construction, road widening, drainage network as well as asphalt pavement would be required for sustaining the sand transportation activities.

3) In case that the sand price at Kulekhani reservoir make less than Rs.2,200 per truck, all the sand excavated from Belkhu, Ghatbesi and Palung with about 200,000 m^3 / year will be alternated by the sand of Kulekhani reservoir, and about 20% of sediment deposition of Kulekhani reservoir would be excavated and the reservoir will be recovered with the excavated amount.

4) The recovered storage volume of the effective storage will yield another benefit to recover the regulating capacity, which can create about 2 kWh / m^3 of electricity in dry season by both of the Kulekhani No.1 and No.2 power stations. In case that 200,000 m^3/year of sand excavation is carried out only for 1 year, the amount of energy recovered is estimated about 0.4 Gwh for every year, which is equivalent to 24,000 US$ for every year of power tariff.

6.3.8 Proposed Components of Sand Resources Development Approach

Table 6.3.1 shows the Project Design Matrix for Sand Development Approach for Kulekhani Disaster Prevention Plan. The proposed components of the approach are:

1) Procurement of excavation equipment such as backhoes, bulldozers, and wheel loaders as the required numbers with the target sand excavation volume.

2) Provision of sand excavation site at the upper part of reservoir and the access road from the existing inspection road to the reservoir,

3) Invitation to the construction material suppliers for selling sand resources from the NEA,

4) Upgrade of transportation route of Daksinkali road for being attractive of Kulekhani sand resources in the sand market in Kathmandu valley,

5) Provision of sand stock yard between Kulekhani dam and Kathmandu along Daksinkali route for storing the sand resources and selling in rainy season,

6) Provision of sand stock yard on the upstream edge of Kulekhani reservoir for smooth loading activities.

6.4 Integrated Watershed Management Approach

6.4.1 Basic Concept

As shown in section 6.1 above, watershed management approach should aim at not only decreasing sediment yield in the watershed but also encouraging community development with due attention to environmental issues. In the previous decade, the Kulekhani Watershed Management Project was carried out and some areas in the watershed was improved by the activities. However, the contribution to the sediment yield in the watershed as well as the improvement of people's living area not sure by the project activities, and clear strategy will be needed to continue the watershed management activities in the economic viewpoints.

For the soil conservation activities, the current sediment yield of 1.18 million m^3, will be too high to control by the physical approach such as check dams, dredging and so on, and the reduction of sediment yield by the watershed management approach will be inevitably required for sustaining the reservoir as well as hydropower plants. The clear strategy or objective will be required for attaining the effect on reduction of sediment yield through the watershed management approach.

The approach to reduce the sediment yield in the watershed will not easy and the people's participation will be important to success the approach. If some target are defined by the discussion among the people's group, the DOSC and the NEA, the NEA or electricity users shall have the benefit to sustain the reservoir and hydropower generation. It is recommended to allocate the some benefits to the watershed for development aspects. Based on such, regulation, the watershed management approach would have clear vision for cost-benefit aspect, and will be encouraged by the regulation for co-operative activities by the people in the watershed and furthermore expected to expand the watershed management approach to the other areas by having the clear target and objectives.

The above system that watershed management approach is carried out not only by the people in the watershed but by all the people who have an access to electricity. The benefit by watershed management therefore should not be given to the electrified people but also to be allocated to the residents in the watershed. Some electricity tariff therefore shall be allocated to the residents in the watershed which is depended on their efforts and progress to reduce sediment yield.

For the activities, the DOSC shall be a leading role and shall have responsibility to reduce the sediment yield, and the clear objectives, target, institution and regulation shall be established together with the related agencies.

The People's understanding and participation are essentially required for such activities like proposed in the CDPP approach and also like implemented by the DOSC in the Kulekhani Watershed Management Project. The countermeasures, therefore, shall be the CDPP approach which aims at the improvement of rural conditions through soil conservation and slope protection approaches. The following components shall be included in the basin-wide watershed management approach for sediment control of the Kulekhani reservoir:

1) Forestry programme such as agro-forestry and community forestry,

2) Improvement of terrace farming,

3) Landslide treatment and gully control for conservation of existing agricultural land,

4) Slope stabilisation works along trail and irrigation canal,

5) Stream bank protection works for conservation of existing farm land along stream.

All the components above may not visually contribute to decreasing sediment discharge, but it must be effective for the reduction of sediment yield in the normal rainy season as well as for the decrease in the number of landslides and slope failures due to an extreme rainstorm line the 1993 disaster.

6.4.2 Proposed Approach

For realising the integrated watershed management approach the following process shall be taken:

1) The project area shall divided into several sub-watershed or the VDC wide, and the CDPP approach, which is considered both aspects of the disaster prevention and community development , shall be taken one by one.

   Phedigaon / Phatbazar area shall be defined as one of the sub-watershed area, and the implementation works shall be proceeded from the Phedigaon / Phatbazar area as the CDPP project.

2) The clear target of the sediment yield mitigation shall be defined by the DOSC and the NEA to be visualise the benefit of the approach for sustaining the function of the Kulekhani reservoir. It is also effective to trigger the financial support from the electricity users for the watershed management activities by the people.

3) Among the component of the watershed management approach, the NEA or the electricity users shall contribute in some financial aspect for the measures which would be directly effective to mitigate sediment deposition into the reservoir such as:

   - Gully control works,
   - River bank protection works,

- Afforestation program.

4) Monitoring of the watershed management activities would be quite important to evaluate the effects to the mitigation of sediment yield as well as the improvement of the people's living standard.

6.4.3 Proposed Components of Integrated Watershed Management Approach

Table 6.4.1 shows the Project Design Matrix for Integrated watershed management approach. The proposed components of the approach are:

1) Agricultural research and cash crop production,

2) Rural infrastructure such as road, irrigation, school, health post, water supply and communication,

3) Hazard assessment and mapping and multipurpose gully control works,

4) Disseminating community forestry program,

5) Demonstration farm for horticulture, herbs and valuable trees with improved contour farming,

6) Needs assessment of the community in the watershed.

Table 2.1.1 (1) Main Features of Proposed Structures on Dhungakate Khola

ID No.	Type	Material	Quantity	Purpose
Dh-1	check dam	concrete	1	*Control of sediment yield *Propping toes of landslides at right bank upstream
Dh-2	check dam	concrete	1	*Propping toes of landslides at right bank upstream
Dh-3	a series of small check dams	gabion	9	*Prevention of river bank erosion
Dh-4	a series of small check dams	gabion	14	*Prevention of river bank erosion and gully erosion
Dh-5	a series of small check dams	gabion	7	*Prevention of gully erosion
Dh-6	a series of small check dams	gabion	14	*Prevention of gully erosion
Dh-7	a series of small check dams	gabion	13	*Prevention of gully erosion
Dh-8	hillside works	vegetative dry masonry	5 steps	*Prevention of river bank collapse
Dh-9	hillside works	vegetative dry masonry	4 steps	*Prevention of river bank collapse
Dh-10	hillside works	vegetative dry masonry	3 steps	*Prevention of river bank collapse

Note: Refer to Figure 2.1.1 to find a plan of locations of structures.

Table 2.1.1 (2) Main Features of Proposed Structures on Ghatte Khola

ID No.	Type	Material	Quantity	Purpose
Gh-1	a series of small check dams	concrete	21	*Prevention of gully erosion
Gh-2	a series of small check dams	gabion	12	*Prevention of gully erosion
Gh-3	a series of small check dams	gabion	13	*Prevention of gully erosion
Gh-4	hillside works	vegetative dry masonry	2 steps	*Prevention of river bank erosion
Gh-5	hillside works	vegetative dry masonry	3 steps	*Prevention of river bank erosion

Note: Refer to Figure 2.1.1 to find a plan of locations of structures.

Table 2.1.1 (3) Main Features of Proposed Structures on Bhottekhoria Khola

ID No.	Type	Material	Quantity	Purpose
Bh-1	check dam	concrete	1	*Prevention of sediment yield
Bh-2	check dam	gabion	1	*Prevention of collapse in right river bank upstream and secondary erosion transport of sediment
Bh-3	check dam	gabion	1	*Prevention of sediment yield
Bh-4	a series of small check dams	gabion	10	*Checking of stream-bed under-cutting
Bh-5	a series of small check dams	gabion	9 3	*Prevention of bank collapse
Bh-6	a series of small check dams	gabion	4	*Preventing the outflow of collapsed sediments

Note: Refer to Figure 2.1.1 to find a plan of locations of structures.

Table 2.1.1 (4) Main Features of Proposed Structures on Alluvial Fan

ID No.	Type	Material	Quantity	Purpose
Ph-1	coffering dike	masonry	1	*To give due direction of sediment outflows
Ph-2	coffering dike	masonry	1	*To give due direction of sediment outflows
Ph-3	training dike	vegetated gabion	6	*To train sediment-water flows
Ph-4	channel works	vegetated riprap with drop-check gabion	1	*To give a stable channel laterally and longitudinally
Ph-5	channel works	vegetated riprap with drop-check gabion	1	*To give a stable channel laterally and longitudinally
Ph-6	revetment	vegetated gabion	1	*To protect the channel from landslides

Note: Refer to Figure 2.1.1 to find a plan of locations of structures.

Table 2.1.1 (5) Main Features of Proposed Structures between Phedigaon and Palungbazar

ID No.	Type	Material	Quantity	Purpose
Pa-1	channel works	vegetated riprap	1	Flood control between Phedigaon and Phatbazar

Note: Refer to Figure 2.1.1 to find a plan of locations of structures.

Table 6.2.1 Project Design Matrix for Sloping Intake Constructuion Approach

Narrative Summary	Verifiable Indicators	Means of Verfication	Important Assumptions
Overall Goal			
To sustain the life of Kulekhani Hydropower Plant	Operation of Kulekhani power plants are continued after the next severe events.	Operation record of NEA. (for power generation)	All the other facilities of Kulekhani hydropower plants are well maintained.
Project Purpose			
To maintain power intake of Kulekhani reservoir for long time	Remaining storage volume below the intake is more than 6 million m3	Annual reservoir sediment survey by NEA	Sediment yield in the watershed is mitigated by the integrated watershed management activities.
Output			
1 Intake structures become safe against the sediment inflow.	Intake strucutures are renovated before the rainy season of 1997.	Construction progress report of NEA	No other problems occur around the intake structures.
2 Intake water level is raised according to the progress of sediment deposition.	Remainig storage volume below the intake.	Annual reservoir sediment survey by NEA	Timing to raise low water level is not delayed
Activities			
1-1 Construction of sloping intake structures			The structures are timely constructed before the nexit severe disaster attachs to the watershed.
2-1 Provision of mobil cranes to put the stoplogs in front of intake according to the progress of sedimentation.			The crane is well maintained by the NEA.
			Pre Condition
			Financial support from foreign donors is realised.

Table 6.3.1 Project Design Matrix for Kulekhani Sand Resources Development Project

Narrative Summary	Verifiable Indicators	Means of Verfication	Important Assumptions
Overall Goal			
To sustain the life of Kulekhani Hydropower Plant	4 hour peaking operation is continued after 2010 as long as possible.	Operation record of NEA	All the other facilities of Kulekhani hydropower plants are well maintained
Project Purpose			
To maintain the effective storage of Kulekhani Reservoir	Effective storage with 48 million m3 is kept after 2010 as long as possible.	Annual reservoir sediment survey in the reservoir by NEA	Sediment yield in the watershed is mitigated by the integrated watershed management activities
Output			
1 Effective storage of Kulekhani reservoir is recovered by artificial excavation activities	Annual excavation volume with 50 to 200 thousand m3 is carried out.	Record of excavation by NEA	Sediment inflow into reservoir is reasonalbe compared with the sand excavation capacity
2 Excavated sand is sold in Kathmandu as construction material	Trucks with more than 10,000 / year transports sand to KTM	Number of tracks at sand quarry site is counted by NEA	Expenditures for sand excavation is within reasonable range
Activities	***Input***		
1-1 Procurement of excavation equipment like backhoe, bulldozer and wheel loaders.			Excavaton equipment is well functioning during the dry season
1-2 Selection of sand quarry sites and and preparation of access road to sand quarry site			Sand excavation from Kathmandu valley is strictly regulated by the government
1-3 Invitation to construction material suppliers for selling sand resources from NEA			Stock yard for sand is provided in KTM
1-4 Upgrade of transportation route from Kulekhani to Kathmandu for being atractive of Kulekhani sand within reasonal price. (Kulekhani - Daksinkali Road)			***Pre Condition*** All the relative government agencies such as NEA, DOR, DOSC, KTM and DDC support the idea of the Project.

Table 6.4.1 Project Design Matrix for Kulekhani Integrated Watershed Management Project

Narrative Summary	Verifiable Indicators	Means of Verfication	Important Assumptions
Overall Goal			
The watershed is well managed by the people's participation	Comparison of people's needs and the activities in Integrated Water Management.	Periodical household survey by monitoring team. (DOSC)	Contituous watershed management activitis by the user's committee
Project Purpose			
Living standard of peopl in the watershed is improved	Annual income and saving in every household	Periodical household survey by monitoring team. (DOSC)	Proper monitoring system is provided by the government.
Sediment yield in Kulekhani watershed is decreased	Periodical landuse pattern updating by GIS system	Updated GIS data. and annual reservoir sedimen survey results. (TU / DOSC)	The benefit of Kulekhani hydropower shall be distributed to the people
Output			
1 Income level of villagers is improved	Annual income in every household.	Periodical household survey by monitoring team. (DOSC)	Advantages to market ascees is maintained
2 Rural infrastructures are improved	Infrastructure ratio to the number of population.	Periodical VDC survey by monitoring team. (DOSC)	Maintenance works is properly done by the user's committee
3 Gully control works are realised	Measureing the area of bank erosion and ratio of countermeasures.	Periodical VDC survey by monitoring team. (DOSC)	Technical support for maintenance are provided by the government or NGO to the user's committee
4 Forest area is not decreased	Measureing area of fores and number of trees distributed from the nursary.	Periodical VDC survey by monitoring team. (DOSC)	
5 Edge protection and drainage at contour farm is improved	Ratio of drainage faciliti and edge protection of slope agriculture land.	Periodical VDC survey by monitoring team. (DOSC)	
Activities	***Input***		
1-1 Agriculture research and cash crop production			User's committee is formed to participate the project implementation and maintenance.
2-1 Rural infra development such as road, irrigation, school, health post, water supply and communitcation.			NEA or electricity users shall understand the importance of Integrated Watershed Management activities and some financial support will be done.
3-1 Hazard assessment and multipurpose gully control works.			
4-1 Dessiminating community forestry programme			***Pre Condition***
4-2, 5-1 Demonstration farm for horticulture, herbs and valuable trees with improved contour farm.			All the relative government agencies such as DOSC, NEA, DDC, VDC, and MOLD support the idea of the Project.
1-2, 2-2 3-2, 4-3 5-2 Needs assessment of the community in the watershed			