4. SEDIMENTATION

4.1 INTRODUCTION

In this study the sediment yield has been estimated by three methods. The first one as the delivery ratio of the potential erosion. It gives the final soil which is transported as sediment to the exit of a basin, in this case only sheet erosion (calculated by USLE) is taken into account, no riverbed and gullies erosion. The second method is the estimation of transported sediment based on total solids in the water, as analyzed during last year. The third method consist of an empirical graphical procedure of predicting sediment yield as a function of the catchment area by using an envelope of data of a large number of rivers plotted against size of catchment.9

The results of these estimations are described in the following sections.

4.2 GROSS EROSION-SEDIMENT DELIVERY METHOD

In this method the results of USLE are used.

The sediment yield is calculated as follows[10]:

$$Ys = E(DR)/Ws$$

Where:

Ys= Sediment yield per unit area (ton/ha)

E = Gross erosion (ton)

DR= Sediment delivery ratio (%)

Ws= Area of watershed above the point for which the sediment yield is being computed (ha)

The value of DR can be obtained as follows:

$$DR = A^{\alpha}$$

Where:

A= Drainage area (km^2)

The α factor depends on the basin area and is given in *Table I.4.1* and *Figure I.4.1*.

[9] N. Hudson, 1973. Soil Conservation, BT Batsford Limited, London, page 291
[10] W.H. Wischmeier & D.D. Smith, 1978. page 45.

Table I.4.1 Factor α in Function of Drainage Area

Drainage Area, A (km^2)	Rate of Sedimentation (α)
0.05	0.58
0.1	0.52
0.5	0.39
1	0.35
5	0.25
10	0.22
50	0.153
100	0.127
500	0.079
1,000	0.059

Source: SCS of the USA (1971). As quoted by M.J.Kirkby & R.P.C. Morgan, 1984.

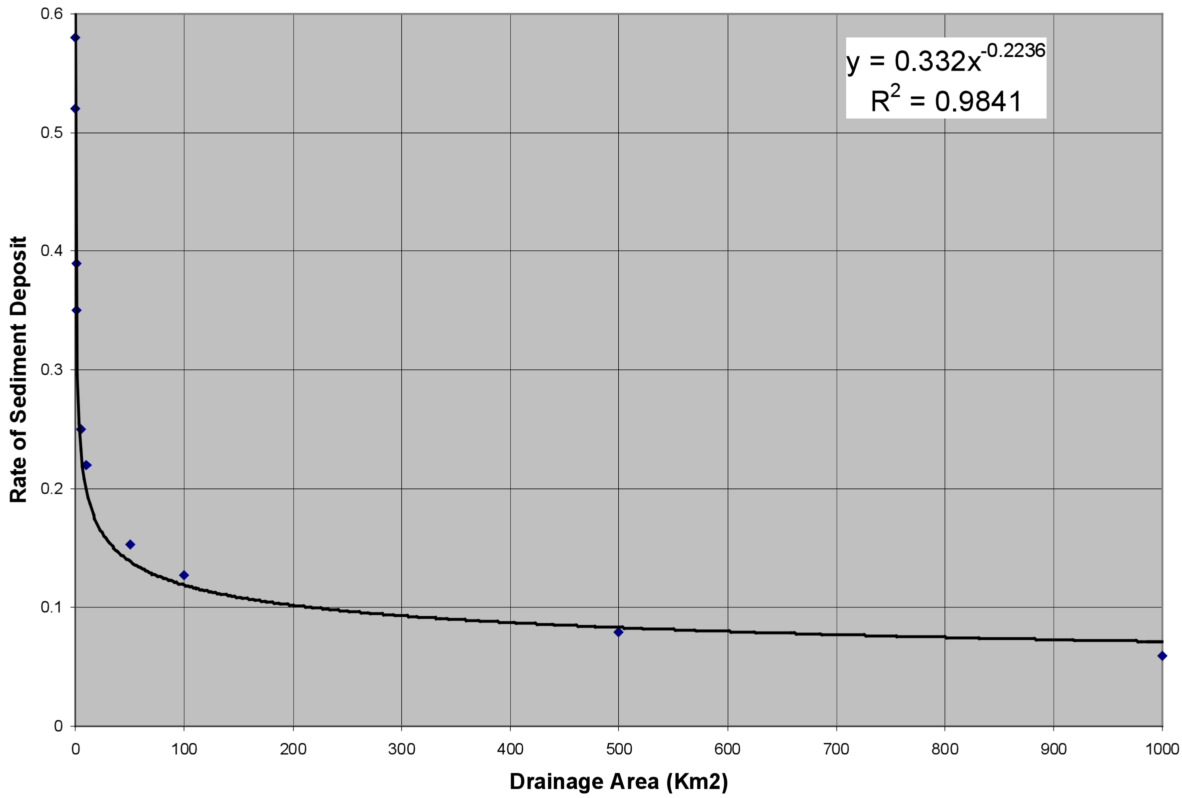

Figure I.4.1 Rate of Sediment Deposit in Function of Drainage Area

Results of this estimation are shown in *Table I.4.2*. It can be observed that the delivery ratio is about 2%, which means the final eroded soil that is carried as sediment to a specific point of the basin, in this case to the exit of each micro-basin.

Table I.4.2 Estimation of Sediment Production from Erosion (Delivery Ratio Method)

No.	Code	Microbasin	Total Area (Ha)	Total Erosion (Ton/year)	Average Potential Erosion E (Ton/ha/year)	Alpha	DR(%)	Sediment Ys=E(DR)/Ws (Ton/ha/year)	Sediment Ys=E(DR)/Ws (m^3/km^2/year)
1	Acho	Choluteca	2,489	392,621	157.74	0.22	2.05	3.23	258.19
2	Achi	Chiquito	4,143	354,814	85.64	0.20	2.10	1.80	143.60
3	Dsj	Sabacuante	4,749	374,615	78.88	0.19	2.10	1.66	132.81
4	Cg	Qda. Grande	2,514	193,764	77.07	0.22	2.05	1.58	126.23
5	Dgr	Laguna El Pescado	1,551	116,920	75.38	0.25	1.97	1.49	118.88
6	Dchi	Mololoa	730	43,870	60.10	0.29	1.79	1.08	86.07
7	Cgr	Ojojona	5,029	240,066	47.74	0.19	2.11	1.01	80.49
8	Csj	Ingles	1,471	67,115	45.63	0.25	1.96	0.89	71.58
9	Agr	Grande	5,287	238,091	45.03	0.19	2.11	0.95	76.01
10	Esj	Tatumbla	7,303	320,631	43.90	0.18	2.12	0.93	74.44
11	Asa	Sapo	294	12,476	42.44	0.36	1.47	0.63	50.00
12	Dg	Quiebramontes	1,896	72,838	38.42	0.24	2.01	0.77	61.67
13	Echi	Trojas	1,998	69,672	34.87	0.23	2.01	0.70	56.21
14	Bchi	Lomas	1,128	38,176	33.84	0.27	1.90	0.42	51.56
15	Asj	San Jose	2,260	68,941	30.50	0.23	2.03	0.62	49.61
16	Bg	Guacerique Arriba	4,904	123,869	25.26	0.19	2.11	0.53	42.56
17	Hg	Horcones	1,097	27,450	25.02	0.27	1.90	0.47	37.99
18	Cchi	Burras	376	9,276	24.67	0.34	1.57	0.39	30.95
19	Bsj	Aguila	1,066	25,935	24.33	0.27	1.89	0.46	36.80
20	Bgr	San Jose	13,944	330,501	23.70	0.15	2.11	0.50	40.06
21	Ag	Guacerique Abajo	729	12,694	17.41	0.29	1.79	0.31	24.93
22	Aqs	Qda.Salada	2,682	43,678	16.29	0.22	2.06	0.44	26.78
23	Ig	Dulce	1,677	27,325	16.29	0.24	1.99	0.32	25.88
24	Eg	Guaralalao	4,350	54,429	12.51	0.20	2.10	0.26	21.01
25	Aqg	Qda.Grande	1,042	12,729	12.22	0.27	1.89	0.23	18.43
26	Fg	Quiscamote	3,041	36,711	12.07	0.21	2.07	0.25	19.98
27	Gg	Mateo	4,215	40,921	9.71	0.20	2.10	0.20	16.29
		Total or Aver.	81,965	3,350,128	41.36		1.98	0.82	65.89

4.3 SEDIMENT TRANSPORT

By using the data of total solids of 1999 (average of dry and rain seasons) the estimation of sediment transport was done as shown in *Table I.4.3* and *Figure I.4.2*.

Table I.4.3 Sediment Transport (1999)

Tributary	Area (Km2)	Total Solids (mg/l)	Station	Mean Q (m^3/sec)	Station	Sed-Transport (m^3/km^2/year)
Guacerique	244.23	113.42	Batallón-Guaralalao	1.393	Guacerique II	16
Concepción (San José R.)	258.11	285.00	Entrance Reservoir	0.895	Concepción	25
Sabacuante	47.49	79.33	Q.Sabacuante	0.427	El Aguacate	18
Tatumbla	73.03	67.00	Q. Tatumbla	0.359	El Incienso	8

Although the data are restricted to few stations and the Chiquito River is not sampled, the results show a clear higher concentration of sediments dissolved in the stream of the San José River at the entrance of Concepción Dam. This situation can be explained by the large agriculture area in this micro-basin which correspond to 4.2% of it, representing the highest ratio in the whole Study Area (*see Table I.3.9*). It must be noticed that the ratio of forest cover also is the highest in this microbasin with 11.5%, however, the effect of agriculture and neighboring villages just upstream of the reservoir is significant. On the other hand, Tatumbla tributary has the lowest rate of sediment transported, proper of a micro-basin with large rate of forest cover (6.1%), the second of the whole Study Area.

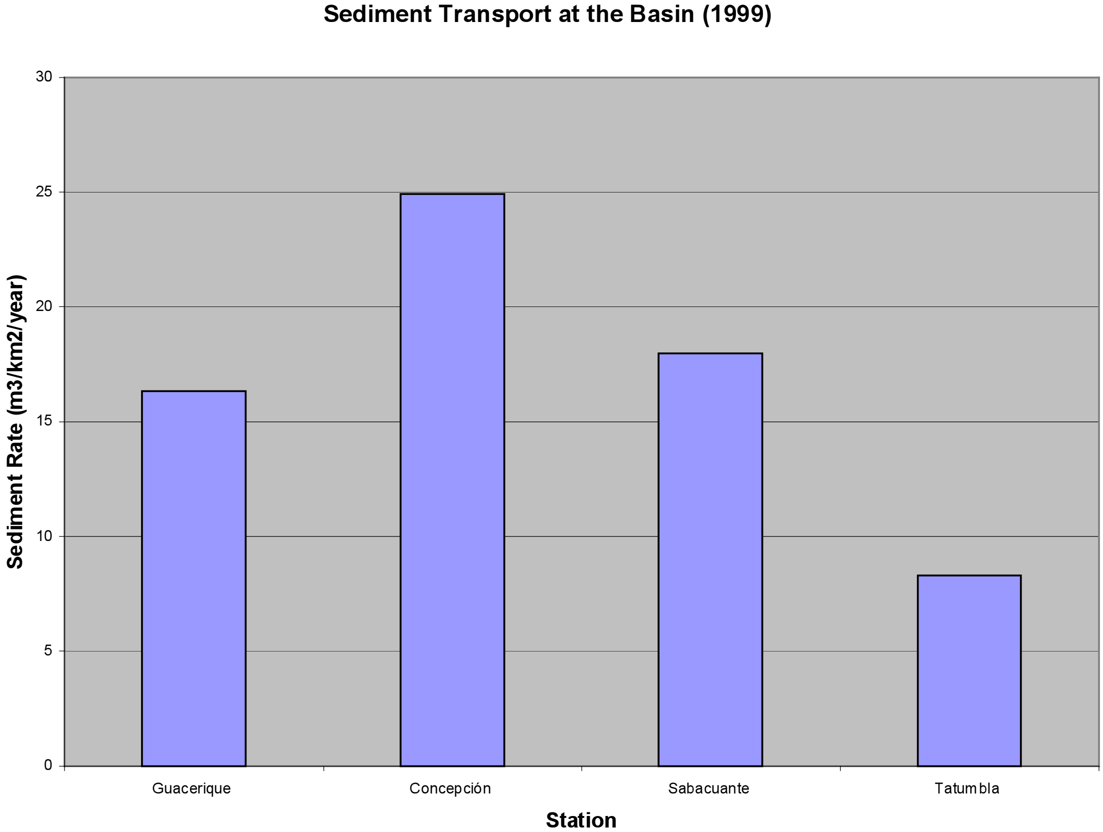

Figure I.4.2 Sediment Transport at the Tributaries of the Choluteca River in Tegucigalpa (1999)

4.4 SEDIMENT YIELD IN FUNCTION OF CATCHMENT SIZE

The total sediment yield in the Study Area was estimated by using a graphical method. In *Figure I.4.3* we can observe sediment yield has been plotted against a series of catchment areas, drawing an envelope which enclose a chosen percentage of the plotted points.

By using this graphical method the sediment yield for the Study Area was estimated as shown in *Table I.4.4* and *Figure I.4.4*.

Table I.4.4 Estimation of Sediment Yield in Function of Catchment Area

Tributary	Area (km^2)	Sediment Yield (ton/ha/year)	Sediment Yield ($ton/km^2/year$)	Sediment Yield ($m^3/km^2/year$)
Choluteca (Main)	24.89	15.40	1,540	1,232
Q.Sapo	2.94	30.00	3,000	2,400
Guacerique	244.23	7.00	700	560
Q. Grande	10.42	30.00	3,000	2,400
R. Grande	258.11	6.80	680	544
San José	168.50	6.00	600	480
Q. Salada	26.82	14.50	1,450	1,160
Chiquito	83.74	5.80	580	464
TOTAL:	**819.65**	**5.00**	**500**	**400**

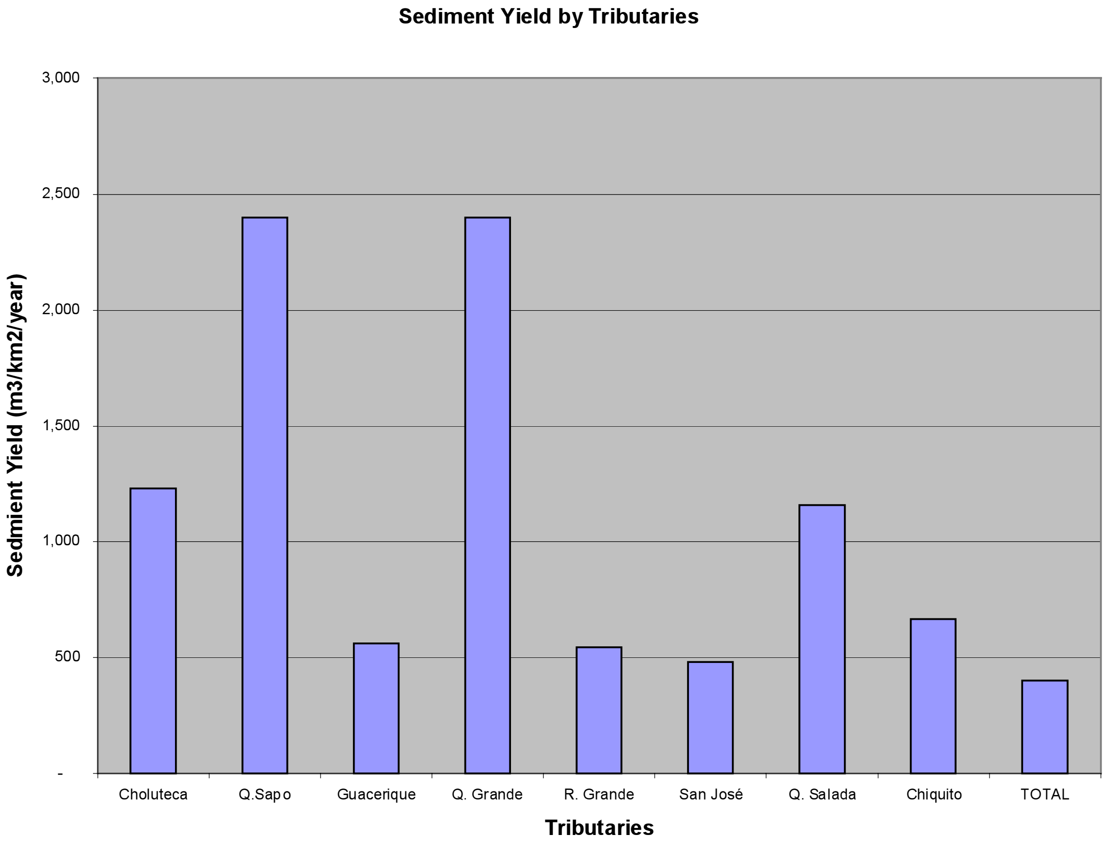

Figure I.4.4 Sediment Yield by Tributaries in the Choluteca River Basin at the Study Area

5. MEASURES FOR EROSION/SEDIMENT CONTROL

5.1 INTRODUCTION

Basically the measures for the reduction of erosion and sedimentation are of two types: a) biologic-forestry and b) engineering.

The first ones have the purpose to protect the bare areas and recover the degraded mountainous zones. These measures pursue the reduction, retention and delaying of the liquid and solid discharges from the basins, because when the runoff of the highlands are reduced, the erosive activities up and down will be reduced and the hillsides will be stabilized. They can be used as complementary measures for the river bed treatments or as measures for agriculture soil conservation. As long as these measures fulfill the objective of erosion/sediment control, the engineering works, more expensive, would be of less magnitude. Main characteristics of the species for vegetative treatments are: rapid growing, roots should be long, strong and deep, growing in degraded areas, good reproduction in stakes, branchs or seeds. Among the species which can be used in the area are: Vetiver Grass, Lemon Grass, Leucaena, Izote (local name), etc.

The engineering works have the purpose to establish an equilibrium within the riverbed, either increasing the solidity of it or reducing the velocity of the flow. For the stabilization of small riverbeds and hillsides the most common works are small dams or walls for sediment retention (pequeñas presas o muros para retención de sedimentos), which at the same time reduce the erosive process and retain the vegetal soil near the source of it. These small dams make an effect of leveling up of the gradient according to the compensation gradient of the riverbed at the rear of the dam, finally producing the stabilization of it.

For the Study Area vegetative measures should be introduced for erosion control in the hillsides specially in those used for agriculture.

For this purpose a Pilot Project Area has been located at the Chiquito River micro-basin where erosion is high and during Mitch several landslides were generated, producing several debris flows downstream which cut off the road between Tegucigalpa and Valle de Angeles in the areas of Santa Elena and Jardinera Streams at the outskirts of the Chimbo Village (*Figure I.5.1*)

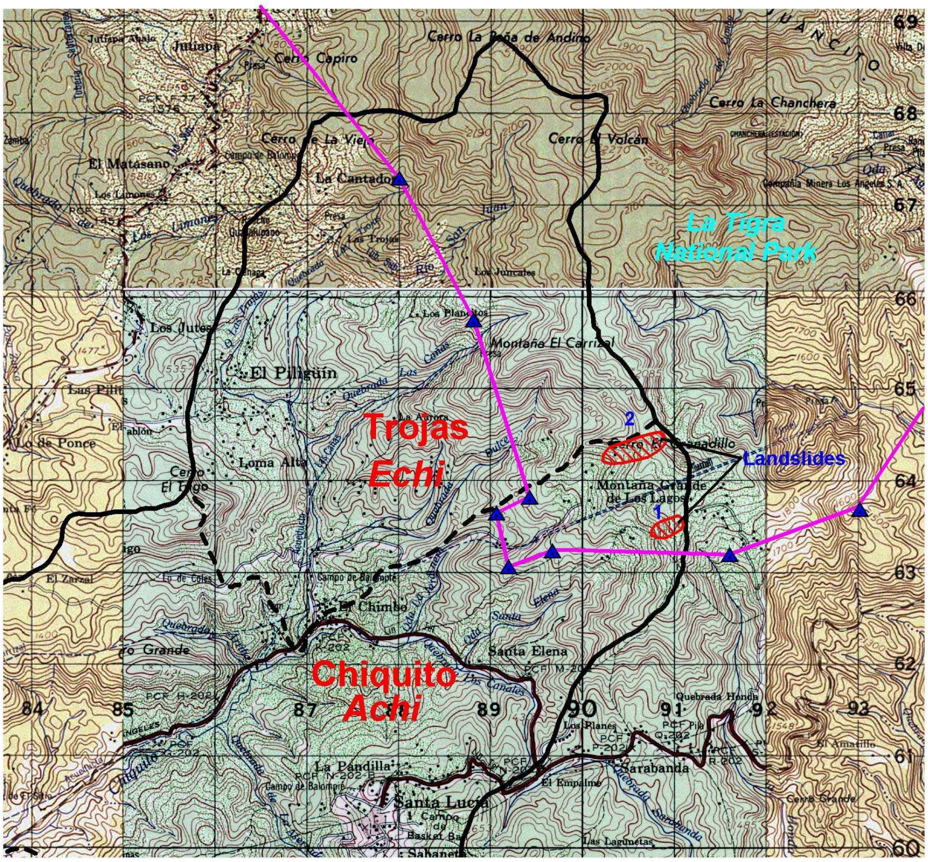

Figure I.5.1 Location of the Pilot Project Area at the Micro-basin of the Chiquito River. The Two Landslides are Located at La Tigra National Park.

As a consequence of the Hurricane Mitch one big landslide (100x50m) located at Quebrada Santa Elena (*Photo I.5.1*) converted into debris flow and washed out several houses downstream. Another larger landslide (700mx350m) was initiated at the upstream of Quebrada La Jardinera/Jabonera (*Photo I.5.2*). One house inside it was destroyed and one other is cracked remaining on it. Portions of this landslide flowed down as debris flow, but the main body of the land remains. Considering that it is a potential hazard in the case of future long duration rainfall, a special and complete study of these two areas is necessary for their permanent stabilization.

Photo I.5.1 Landslide at Santa Elena Stream Produced during Hurricane Mitch. (150mx50m). It Became a Large Debris Flow that Destroyed Several Infrastructures.

Photo I.5.2 Landslide at Jabonera Stream (700mx350m). It was Partially Triggered during Hurricane Mitch, However the Large Mass Remains in Unstable Condition. There is a Potential Risk of Becoming a Huge Debris Flow during a Next Event. Detailed Study for its Complete Stabilization is Deemed Necessary.

It is known that an USA-AID sponsored project (LUPE) was working at some degree on this area several years ago, however as the project ended it was not followed up. More recently, after Hurricane Mitch, FAO was introducing Vetiver Grass and some other local plants for erosion control, however, magnitude of the project seems to have been so small because only small remains of such works can be seen.

As trials for afforestation of this area was already done by FAO but could not be successfully implemented due to opposition of the neighbors regarding the type of species to grow, it is recommended a series of incentives be given to them in order they shift their activities from agriculture to forestry or at least perform soil conservation works such as contour cropping and terraces.

In this study the implementation of vegetative treatments and sediment retention dams are recommended as pilot project in the tributary area of these two streams Quebrada Santa Elena and Quebrada Jardinera (or Jabonera as also it is known). These works are to be implemented for the retention of sediment at the highlands in streams of first and second order. Proposal and costs of these measures are explained in the following sections.

5.2 LIVE BARRIERS

The live barriers are belts of perennial plants of dense growing and resistant to the run-off pressure. They are planted perpendicular to the slope in order to control erosion a retain sediment. Installing and maintenance needs much less work than infrastructure works.

Among the several locally known kind of grass used in these type of works are: Vetiver (Valeriana), Napier (Elefante), King Grass, Guinea, Jaragua, Lemon grass, etc. However, excepting the first all of them need fertile soils, and some of them are invaders or not resistant to drought. Others are not enough rigid to form natural terraces.

Due to that, it is highly recommended in the pilot study area the Vetiver grass (Vetiveria Zizanioides) be cultivated for live barriers. It can grow up in gradients up to 60%, elevations between 0 to 2,500 masl, and rainfall more than 500 mm per year. It has high resistance to drought. The system of roots is deep and dense, creating a live net like a spiderweb inside the soil which becomes a natural terrace (*Figure I.5.2*).

Separation between bundles should be 10 to 15 cms i.e. 7 bundles per meter. Distance between barriers depend on the gradient of land, however, usually 2m vertical is normal.

For this study the live barriers are recommended as a complementary work of that of small dams for sediment retention. The live barriers should be installed in an average belt of 100m (50m per side) along the riverbeds of the streams, whenever this have no dense forest cover.

5.3 MICRO SABO DAMS FOR SEDIMENT RETENTION

Due to economical reasons, it is considered to use two types of dams a) basically narrow streams of highlands, small dams of dry masonry of 1 to 2m height and 5 to 10m length b) for wider and permanent streams in less inclined riverbeds, gabion dams of 3 to 4m of height and 15 to 20m length are proposed.

5.3.1 DRY MASONRY

Regarding the first type, during our field inspection to Concepción Dam sub-basin we could observe several dams of 1 to 2m of dry masonry constructed directly by SANAA from 1991, which were fill up by 1998 (during 7 years) (Photo I.5.3,I.5.4). More recently from Oct/1999 SANAA is conducting a project of dams for sediment retention in that same sub-basin through an NGO called IHPEJ (Integración Hondureña de Promoción Empresarial Juvenil). They have already worked about 10,000m of riverbeds with separation between dams of 10 to 12m and length of dams of 7 to 12m.