

4 Identification of environmental impact

4.1 Preliminary analysis of environmental impact of hydropower development

The main environment factors during the hydropower development on the upper reaches of the Ayeyawady River include engineering construction, reservoir inundation, land occupation and resettlement of migrants during the hydropower development, as well as engineering operation after the hydropower development.

4.1.1 During the hydropower development

The hydropower development will interrupt the original surface land, destroy vegetation, affect landscape and cause soil erosion; if not treated, waste water, exhaust gas, noise and waste slag will bring about temporary pollution and destruction to water environment, atmospheric environment, acoustical environment and landscape in local region; if not given more attention, the malaria may be easy to outbreak in the construction area, and therefore has some negative impact on construction workers.

Resettlement of migrants, infrastructural construction and land reclamation will have some influence upon land resource, soil erosion, terrestrial organisms, etc.. Resettlement of migrants will also exercise certain influence on living quality of migrants, population health and social economy.

The construction of the hydropower development engineering may provide a large number of employment opportunities for local residents, promote development of both secondary industry and tertiary industry, and stimulate development of local economy and society.

4.1.2 After the hydropower development

After implementation of the hydropower development plan, the dam will split aquatic environment, and may unfavorably affect fish resources. Engineering dispatch and operation will alter hydrological regime of natural river course, and affect water environment,

aquatic environment at the upper reaches of Ayeyawady River and lower reach of Myitsone Dam. The implementation of this plan will submerge a certain quantity of forest vegetation and affect terrestrial plants in the upper reaches of Ayeyawady River ,as well as habitats of terrestrial animals; and such execution will migrate a certain quantity of residents, and submerge a certain number of houses, roads, bridges and other infrastructures.

The implementation of the hydropower development plan may directly bring plenty of clean energy to Myanmar, provide better conditions for local economy in energy and transportation, greatly enhance flood control capacity for Myitkyina city, and improve navigation and irrigation conditions at the downstream. In the meanwhile, some quantity of electricity from hydropower development can also be sent to neighboring countries, converting its resources advantage into economic advantages. The implementation of plan is of great significance to sustainable development of economy, society and environment of Kachin State or even Myanmar.

4.2 Identification of environmental impact

4.2.1 Basic procedure of identification of environmental impact

Based on in-depth survey of existing terrestrial ecosystem and aquatic ecosystem over the upper reaches of Ayeyawady River, as well as environmental quality monitoring, pollutant source survey and public questionnaire survey, and according to the characteristics of hydropower development at the upper reaches of Ayeyawady River and baseline conditions of regional environment, and the nature of environmental impact is identified (favorably or unfavorably); environmental impact identified is further analyzed, and impact significance (no, small, medium and large impact), impact type (reversible or irreversible), impact range (local river reach or whole river reach) and impact time span (short term or long term) are identified. On the basis of the above-mentioned comprehensive analysis, identification results is obtained by the matrix method.

4.2.2 Identification results of environmental impact

Environmental impact is identified in terms of natural environment, ecological environment

and social environment, and identification results are shown in Table 4.2-1.

(1) Environmental impact assessment elements

Based on identification of environmental impact, main environmental elements can be divided into assessment elements of ,natural environment, ecological environment and social environment.

Assessment element of natural environment includes hydrological regime, water environment, local climate, environmental geology, acoustical environmental, atmospheric environment and solid waste.

Assessment element of ecological environment includes terrestrial plant, terrestrial animal, aquatic organism and soil erosion.

Assessment element of social environment includes resettlement of migrants, social economy, religion & national culture, land resources, utilization of water resources, infrastructures, landscape & tourism, population health and flood control.

(2) Scope of environmental impact

Based on identification of environmental impact, the environmental elements affecting the whole river reach of hydropower development include hydrological regime, water environment, local climate, terrestrial organism, aquatic organism, social economy, religion & national culture, utilization of water resources, landscape and tourism; and the environmental elements affecting local river reach of hydropower development include environmental geology, acoustical environment, atmospheric environment, solid waste, soil erosion, infrastructure, resettlement of migrants, land resources, population health and flood control.

(3) Time span of environment impact

Table 4.2-1

**Schedule of identification of environmental impact elements of hydropower development
on the upper reaches of Ayeyawady River**

Environmental elements		Natural environment						Ecological environment					Social environment									
		Hydrological environment	water environment	Local climate	Environmental geology	Acoustic environment	Atmospheric environment	Solid waste	Ecological integrity	Terrestrial plant	Terrestrial animal	Aquatic organism	Soil erosion	Resettlement of migrants	Social economy	Religion & national culture	Land resources	Utilization of water resources	Landscape & tourism	Infrastructure	Population health	Flood control
During hydropower development	Engineering construction		-1R		-1R	-1R	-1R	-2R	-1R	-1R	-1R	-1R	-2R		+2R	-1N	-1R		-1R		-2R	-1R
	Land occupation								-1N	-1N	-1N		-2N	-1N			-1N		-1N			
	Reservoir submersion	±2N	-1N		-2N				-2N	-2N	-1N	±2N	-1N	±2N	-1N	-1N	-2N		-1N	-1N	-1R	
	Resettlement of migrants		-1R			-1R	-1R	-1R	±1R	±1N	±1N	±1N	-1R	+2N	+1N	±1N			+1N	+1N	+2N	
After hydropower development	Dam obstruction	±1N										-3N										
	Plant operation	±2N	±1N	+1N	-1N				-1N	+1N	-1N	-2N		+2N	+3N			+2N	±2N	+3N		+2N
Impact range		●	●	●	◎	◎	◎	◎	●	●	●	●	◎	◎	●	●	◎	●	●	◎	◎	◎
Time span of impact		L	L	L	L	S	S	S	L	L	L	L	S	L	L	L	L	L	L	L	S	L
Comprehensive identification results		±2NL●	±2NL●	+1NL●	-2NL◎	-1RS◎	-1RS◎	-2RS◎	-2NL●	-3NL●	±2NL●	-2NL●	-2NS◎	+3NL◎	+3NL●	±1NL●	-2NL◎	+2NL●	±2NL●	+3NL◎	±2N◎	+2NL◎

Note: "+" and "-" means favorable impact and unfavorable impact respectively in terms of impact nature; "1", "2" and "3" means small impact, medium impact and great impact respectively in terms of impact extent; R and N means reversible impact and irreversible impact respectively in terms of impact type; "◎" and "●" means local area and whole assessment area in terms of impact range; "S" and "L" means short-term impact and long-term impact respectively in terms of time span of impact.

Time span of environmental impact of the implementation of hydropower development is identified, which is divided into short term (environmental impact lasts for a short time and it is not accumulative) and long term (environmental impact lasts for a long time and it is accumulative).

Based on identification of environmental impact, the environmental elements causing great and long-term environmental impact mainly include hydrological regime, water environment, aquatic organism, terrestrial organism, resettlement of migrants, social economy, utilization of water resources and infrastructure; the environmental elements causing great environmental impact but only a short term include population health, soil erosion and solid waste.

4.2.3 Selection of environmental impact assessment elements

According to significant impact upon the environment elements and environmental problems from the implementation of hydropower development ,main environmental assessment elements of the hydropower development include hydrological regime, water environment, aquatic ecology, terrestrial ecology, resettlement of migrants social economy, religion & national culture , land resources and utilization of water resources.

General environmental assessment elements include local climate, environmental geology, landscape & tourism, infrastructure, population health, flood control, ect.; and the elements affecting the environment quality during construction of the hydropower development engineering include atmospheric environment, acoustic environment, solid waste, soil erosion, ect.. Considering that the impact is local, temporary and restorable, as well as many uncertain factors, a brief analysis is only given to the environmental impact assessment on the stage, and a detailed analysis will be carried out in the project feasibility study report.

4.3 Restrictive factors analysis of implementation of hydropower development

(1) Resettlement of migrants

As the hydropower development of Ayeyawady River is an overseas hydropower development BOT project, whose investment is made by a Chinese enterprise, according to international convention, the investor shall provide financial support for the hydropower development, and the local government of the project shall solve the problem of resettlement of migrants based on the country's actual situation. The impact of the hydropower development upon social environment will certainly attract great attention from international community, especially impact upon non-voluntary migrants. Improper resettlement of migrants or negative social impact arising from the hydropower development may become restrictive factor of the hydropower development. The government shall attach great importance to resettlement of non-voluntary migrants and other social problems caused by the hydropower development.

The migrants affected by the hydropower development on the upper reaches of Ayeyawady River are mainly concentrated in Myitsone reservoir area. involving 11,807 persons in Mistone hydropower station. The migrants are mostly residents of Kachin State. It is recommended that positive publicity of the hydropower development be strengthened before resettlement of migrants, to reduce misunderstanding arising from some non-objective reports, and to obtain understanding and support from non-voluntary migrants and local residents. During resettlement of migrants, production and living level of the migrants should be guaranteed, and close attention should be given to the will and custom of the migrants. The local residents should be energetically encouraged to participate in the hydropower development and services, so as to gain the opportunity of continuous development.

(2) Hotspot of biological diversity

The assessment area is located within the Indo-Myanmar Bio-diversity Hotpot, one of 34 global bio-diversity hotpots. In the assessment area, 12 kinds of rare endangered plants in IUCN Red List and CITES Appendix II are found, as well as 2 kinds of endemic plants. Furthermore, 73 kinds of rare endangered animals in IUCN Red List and CITES Appendix are found, including 32 kinds of mammals, 25 kinds of birds, 12 kinds of reptiles, 2 kinds of

amphibians and 2 kinds of butterflies.

After the implementation of the hydropower development on the upper reaches of Ayeyawady River, the cascade reservoirs may submerge some individuals of rare or endangered plants, such as *Dipterocarpus retusus* Blume, *Tetrameles nudiflora* R. Brown, *Bhesa robusta* and *Aquilaria malaccensis* Lam., which will exert certain influence on their populations, but won't cause extinction of these species; the implementation of the hydropower development has both positive and negative impact to rare or endangered animals in the area. While some animal habitats are submerged, new habitats will be created. Except that a minority of animals with weak migration will be subject to decrease, a great majority of animals will not be obviously affected in both population and quantity.

As a result, the rare or endangered animals and plants in the area will not become the restrictive factor of the implementation of the hydropower development on the upper reaches of Ayeyawady River; however, great attention should be paid to protection of rare or endangered animals and plants during the hydropower development.

5 Forecast and assessment of environmental impact

5.1 Impact on hydrological regime

After the implementation of the hydropower development in the upper reaches of Ayeyawady River, several additional reservoirs with different adjustment performance and operation mode will be provided there. Along with control of plant dispatch and operation, hydrological regime in the upper reaches of Ayeyawady River will certainly undergo great changes. Such hydrological parameters as flow, water area, water depth, flow pattern and water temperature are different from those of natural rivers, which mainly find expression in the follows aspects:

Continuous water body of the river will be divided into some units of different size by artificial buildings, and natural river reaches will become several reservoirs with different scales and adjustment performance.

Water surface in the reservoirs will be broadened, together with obviously increased water area and volume; water body of the reservoirs will be transformed from rapid flow pattern into slow flow pattern; as the reservoirs have different adjustment performance, water level within the reservoir will not be greatly altered. Water level of the reservoirs of daily regulation hydraulic power plant varies in daily regulation, its range of variation is between normal water level and dead water level, and one regulation cycle is completed within one day and night; for annual regulation hydraulic power plant, one regulation cycle is divided into several periods, i.e. impoundment period, water abandonment period, water supply period and non-storage and non-supply period. When the reservoirs are in dispatch and operation, water level varies between dead water level and normal water level.

As the flow below the plant dam is controlled by the plant dispatch and operation, flow pattern, flow quantity and flow velocity are different from those of natural rivers. The flow is reduced against natural rivers in flood season, while the flow is increase against natural rivers in dry season. The runoff tends to become even throughout one year.

The river reach of the hydropower development is located above Myitkyina, with total length of about 773km, including 353km Nmaiha River, 375km Malikha River and 45km trunk stream. The hydropower development scheme covers 5 annual regulation reservoirs, i.e. Yen-an, Kaunglanhpu, Chibwe, Laza and Myitsone, 2 daily regulation reservoirs, i.e. Piza and Wutsok, and 7 cascade regulation reservoirs, with total capacity of 13.544 billion m³. All these plants are under dam development, and tail water of the upper reservoir is connected with back water of the lower reservoir.

5.1.1 Impact upon river pattern

The river reach of the hydropower development in the upstream of Ayeyawady River is divided into 7 reservoirs with different sizes, with obvious increased water area of the river and raised multiple of water surface of 6.36. Please refer to Table 5.1-1 for changes before and after impoundment of cascade reservoirs.

Table 5.1-1 Changes before and after impoundment of cascade reservoirs										
	Item	Unit	Yenan	Kaunglanhpu	Piza	Wutsok	Chibwe	Laza	Myitsone	Total
Natural state	River length	km	22.3	83.7	37.8	34.7	52.8	127.4	226.1	584.8
	Water area of river	km ²	5.24	10.22	5.65	8.38	9.28	34.30	38.18	111.25
	Average water width of river	m	235	122	149	241	176	269	169	
Cascade reservoirs	Water area of reservoir	km ²	22.90	35.59	10.53	20.09	39.81	285.48	404.83	819.23
	Reservoir capacity	10 ⁸ m ³	12.37	31.72	5.35	3.21	19.39	123.28	132.82	328.14
	Average water width of reservoir	m	1027	425	279	579	754	2241	1790	

After the impoundment of the cascade reservoirs, water area of the reservoirs will be greatly raised, however, most of the upstream of Ayeyawady River consists of gorges, so water area still maintains the characteristics of the gorges. Water area will be increased from 111.25km² of natural rivers to 819.23km². Although water area is considerably raised, such increase is relatively small in comparison with water area at the upstream of Ayeyawady River. As a result, after impoundment of cascade reservoirs, the increase in water area exerts no remarkable effect on water area patter of the gorges. From the viewpoint of single plants, as most areas of Laza reservoir and Myitsone reservoir are

composed of wide valleys, water area is greatly raised after impoundment, which exercises relatively great impact upon water area pattern of the river valleys.

After the cascade hydropower stations are built, the changes in water area and average width of the river before and after impoundment of the plants are shown in Figures 5.1-1~5.1-2.

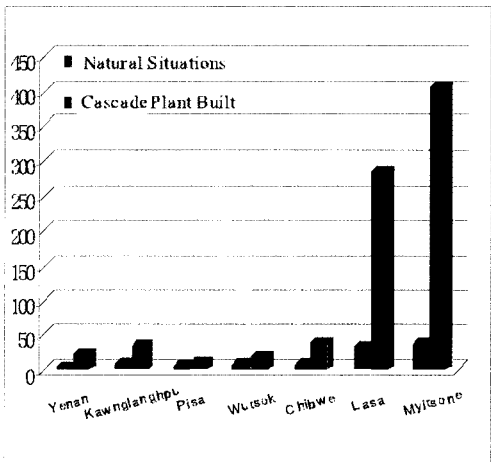


Figure 5.1-1 Changes in water area of the river before and after impoundment

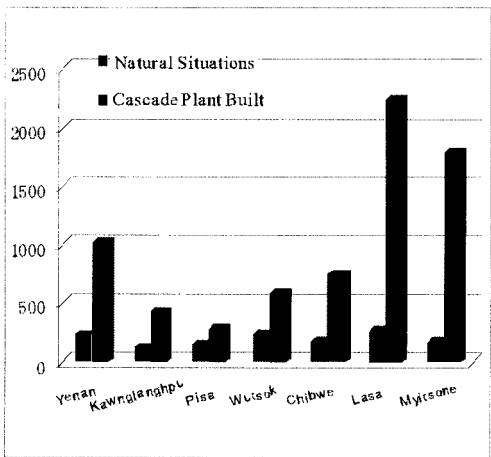


Figure 5.1-2 Changes in average width of water surface before and after impoundment

5.1.2 Impact upon runoff

(1) Natural runoff and flow of cascade reservoirs

In accordance with water level data of Myitkyina Hydrologic Station since 1971 and in combination with observed data of Myitsone Hydrologic Station and Chibwe Hydrologic Station by Hydrographic Office of Yangtse River Commission, the verification and calculation shows that the runoff is not evenly distributed through one year in the cascade plant dams. It mainly concentrates from May to October, accounting for about 80% of total average runoff in the past years. It is relatively great in July, accounting for about 21% of total runoff all the year around. The runoff from November to April next year only occupies about 20% of total average runoff in the past years.

(2) Changes in runoff after operation of cascade reservoirs

Completion of the cascade reservoirs will exert certain influence upon the runoff in the river reach of the hydropower development. The runoff adjustment and calculation shows that when the cascade reservoirs are in joint operation, monthly flow out of the reservoirs is different from the flow of natural dams. Under general circumstances, the flow out of the reservoirs is somewhat reduced against natural situation in flood season (from May to October), with the former accounting for about 90% of the latter generally. The flow out of the reservoirs is somewhat increased against natural situation in dry season (from November to April next year). Except Kaunglanhpu and Laza, the flow out of other cascade reservoirs is slightly raised against natural situation, and the flow out of Myitsone cascade reservoir is 111% of the flow into the reservoir.

Before and after completion of the cascade reservoirs, the daily regulation reservoir Wutsok and the annual regulation reservoir Myitsone are selected as representative, and the changes in their flow are shown in Figures 5.1-3 and 5.1-4.

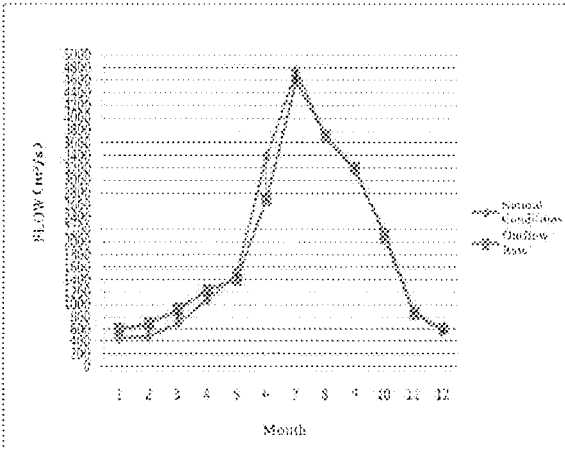


**Figure 5.1-3 Monthly changes
in flow of Wutsok dam**

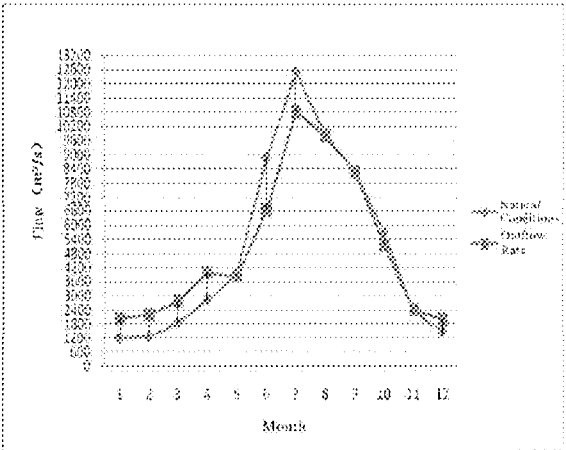


**Figure 5.1-4 Monthly changes
in flow of Myitsone dam**

As a whole, from the viewpoint of changes in both time and space of annual runoff, as joint operation of cascade reservoirs slightly changes annual distribution of the runoff, the runoff mainly concentrates in high water period (from May to October). In high flow period, the runoff accounts for about 73%~80% of total average runoff in the past years; in low water period (from November to April next year), the runoff only accounts for about 20%~27% of

annual average runoff.

5.1.3 Impact upon water level and flow velocity

(1) Impact on water level

After the cascade reservoirs are completed, with the impoundment of the reservoirs, water level of the cascade reservoirs will be raised, and water level at the dam sites before and after such completion undergoes obvious changes. According to the relationship between water level and flow at the dam sites, as well as the runoff adjustment results with joint operation of the cascade reservoirs, the changes in water level before and after completion of the cascade reservoirs were calculated.

Changes in water level in the plant dams before and after the cascade reservoirs are in detail shown in Table 5.1-2.

Table 5.1-2 shows that under natural situation, as the dams are located in narrow river valleys, water level therein varies greatly within one year, the largest change 8m for Myitsone dam and the smallest change 3m for Yen-an dam. When the cascade reservoirs are in joint operation, water level therein varies more greatly through one year, the largest variation 43m for Kaunglanhpu dam and the smallest variation 13m for Myitsone dam.

Before and after completion of the cascade reservoirs in the upper reaches of Ayeyawady River, the daily regulation reservoir Wutsok and the annual regulation reservoir Myitsone are selected as representative, and the changes in water level in their dams are shown in Figures 5.1-5 and 5.1-6.

(2) Impact upon flow velocity

After the cascade reservoirs are completed, water level of the reservoirs will be raised, and flow velocity from the end of the reservoirs to the place in front of the dams will be reduced. In contrast with pre-construction of the reservoirs, water level in the water courses near the

**Table 5.1-2 Monthly changes in water level in the dams before and after
completion of cascade reservoirs**

Plant	Item	Monthly water level of the dams (m)											
		Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Yenan	Natural water level	872	872	872	872	873	874	875	874	874	873	872	872
	Completed water level	1009	1002	992	984	984	1001	1010	1010	1007	1004	1009	1011
	Water head	137	130	120	112	111	127	135	135	133	131	137	139
Guanglanhpu	Natural water level	666	666	666	667	667	669	671	670	669	668	667	666
	Completed water level	866	856	845	833	832	853	875	875	875	875	875	873
	Water head	199	190	178	166	165	184	204	206	206	207	208	206
Piza	Natural water level	528	528	528	528	529	531	533	531	531	530	528	528
	Completed water level	663	662	656	650	651	657	665	664	661	664	665	665
	Water head	135	134	128	122	122	126	132	132	130	134	137	137
Wutsok	Natural water level	392	392	392	393	393	396	397	396	395	394	393	392
	Completed water level	520	514	511	510	511	517	525	524	522	524	525	524
	Water head	128	122	119	118	117	121	128	128	126	130	133	132
Chibwe	Natural water level	248	248	248	249	249	252	254	252	252	250	248	248
	Completed water level	396	393	389	385	386	393	400	400	398	400	400	399
	Water head	149	145	141	137	136	141	146	147	147	150	152	151
Laza	Natural water level	224	224	224	225	225	228	229	228	227	226	225	224
	Completed water level	363	358	351	345	343	349	366	368	369	370	370	368
	Water head	139	134	127	120	118	122	136	140	141	144	145	144
Myitsone	Natural water level	138	138	139	139	140	143	146	144	143	141	139	139
	Completed water level	242	240	238	234	232	235	241	242	243	245	245	244
	Water head	103	101	99	94	92	91	96	98	100	104	106	105

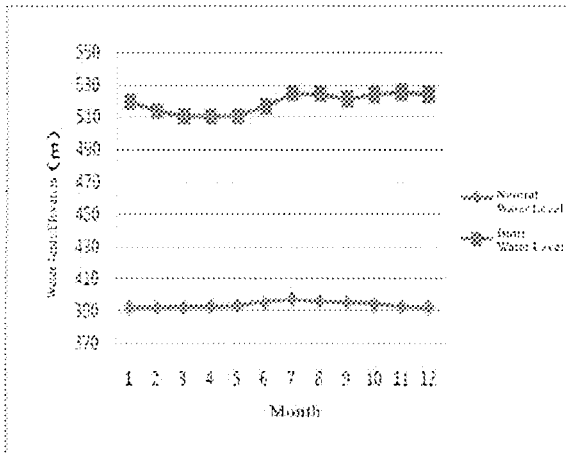


Figure 5.1-5 Monthly changes in water level in Wutsok dam

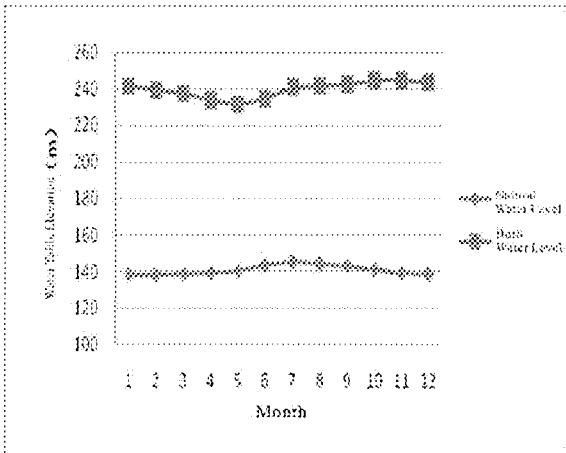


Figure 5.1-6 Monthly changes in water level in Myitsone dam

dams and the sections within the reservoirs in the cascade reservoirs will be greatly increased, while water level in the sections at the end of the reservoirs will be slightly changed. Flow velocity in the sections near the dams and the sections within the reservoirs in the corresponding cascade reservoirs will be greatly reduced, while flow velocity in the sections at the end of the reservoirs will be slightly changed.

5.1.4 Impact upon sediment

After the cascade reservoirs are completed and operated, under the impact of sediment trapping of the reservoirs, sediment concentration in the middle and downstream reaches of Nmaiha River and in the downstream reaches of Malikha River will experience great changes. The influence of river sediment mainly finds expression in the leading reservoirs. After two upstream reservoirs, i.e. Yenau (in the upper reaches of Nmaiha River) and Laza (in the upper reaches of Malikha River), are completed, the vast majority of sediment will be trapped by these two reservoirs, and deposited in the dead reservoirs. As the sediment within the confluence is further trapped by the cascade reservoirs in the middle and downstream reaches, the sediment entering into Myitsone reservoir located at the trunk stream of Ayeyawady River will be greatly decreased, so the sediment concentration of water body of the river at the downstream of Myitsone will also be reduced.

Under the impact of sediment trapping of the reservoirs, sediment concentration of discharged water will be reduced. As the tail water of the upper reservoir of the cascade development is connected with the backward water of the lower reservoir, except Myitsone reservoir, the discharge of clean water will exert slight flushing influence upon the river beds in the downstream reaches of other cascade reservoir dams. The discharge of clean water of Myitsone reservoir will produce certain flushing influence upon the river beds in the downstream reaches of these dams, and with the same flow, water level in the downstream reaches will be somewhat reduced. As the downstream river reaches tend to balance sediment concentration, the relationship between water level and flow in the river reaches below the dams will get stabilized basically.

5.1.5 Impact upon downstream hydrological regime

(1) Impact upon downstream flow

Joint operation of the cascade reservoirs will exercise some impact upon the downstream flow, and such impact will come into existence after completion of the reservoirs. Changes in downstream flow of Myitsone dam before and after completion of the cascade reservoirs are in detail shown in Table 5.1-3.

Table 5.1-3 shows that after the cascade reservoirs are put into joint operation, the downstream water flow of Mistone hydropower station dam in low flow period (from November to April next year) will be somewhat increased compared to natural situation, and the rate of such increase will be gradually smaller from upstream to downstream reaches. Water flow of Myitkyina will be averagely raised by 46.2% against natural situation, that of Katha by 31.8% and that of Thabeikyin by 27.0%. The downstream water flow in high flow period (from May to October) will be somewhat decreased against natural situation, and the amount of such decrease will be gradually smaller from upstream to downstream reaches. Water flow of Myitkyina will be averagely reduced by 8.3% against natural situation, that of Katha by 5.8% and that of Thabeikyin by 4.9%. Through joint operation and regulation of the cascade reservoirs in the upper reaches of Ayeyawady River, the downstream water flow of Myitsone can be regulated in both flood

season and dry season; however, distribution law of the runoff through one year will not be changed as a whole. As Ayeyawady River mouth is about 2,700km from Mistone hydropower station, to which interval Chindwin River, Myitnge River, Mu River, Yaw River and Mon River and other greater branches converge. Of them, the largest branch is Chindwin River, with watershed area of 114,000km². It may be estimated that after implementation of hydropower development at the upper reaches of Ayeyawady River, the flow at the river mouth will be somewhat increased in low flow period; slight difference exists between the flow at the river mouth in high flow period and that in natural conditions.

Table 5.1-3 Comparison of changes in downstream flow of Myitsone before and after the cascade reservoirs

Section	Item	Monthly flow (m3/s)											
		1	2	3	4	5	6	7	8	9	10	11	12
Myitsone	Natural situation	1169	1256	1862	2840	3968	8887	12505	9752	8296	5665	2354	1454
	Cascade reservoirs completed	2041	2208	2781	3985	3843	6643	10812	9811	8261	5159	2410	2007
	Flow ratio	174.59%	175.80%	149.36%	140.32%	96.85%	74.75%	86.46%	100.61%	99.58%	91.07%	102.38%	138.03%
Myitkyina	Natural situation	1183	1271	1884	2874	4015	8993	12655	9869	8395	5733	2382	1472
	Cascade reservoirs completed	2055	2223	2804	4019	3891	6750	10962	9928	8360	5227	2439	2025
	Flow ratio	173.71%	174.90%	148.83%	139.84%	96.91%	75.06%	86.62%	100.60%	99.58%	91.17%	102.39%	137.57%
Katha	Natural situation	1716	1854	2743	4176	5826	13049	18376	14370	12239	8352	3465	2134
	Cascade reservoirs completed	2588	2805	3663	5321	5702	10806	16683	14429	12204	7846	3521	2687
	Flow ratio	150.82%	151.29%	133.54%	127.42%	97.87%	82.81%	90.79%	100.41%	99.71%	93.94%	101.62%	125.91%
Thabeikyin	Natural situation	2024	2187	3236	4925	6872	15391	21675	16949	14436	9851	4087	2517
	Cascade reservoirs completed	2896	3138	4155	6071	6748	13148	19981	17009	14401	9345	4143	3070
	Flow ratio	143.08%	143.48%	128.40%	123.27%	98.20%	85.43%	92.18%	100.35%	99.76%	94.86%	101.37%	121.97%

Changes in water flow of the downstream of Myitsone before and after the cascade reservoirs are in detail shown in Figures 5.1-7~5.1-9.

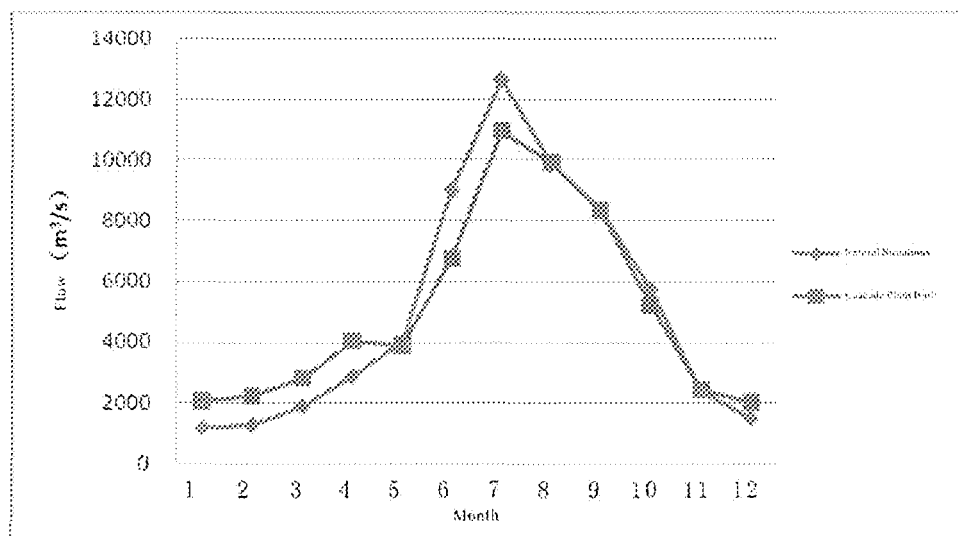


Figure 5.1-7 Changes in flow of Myitkyina

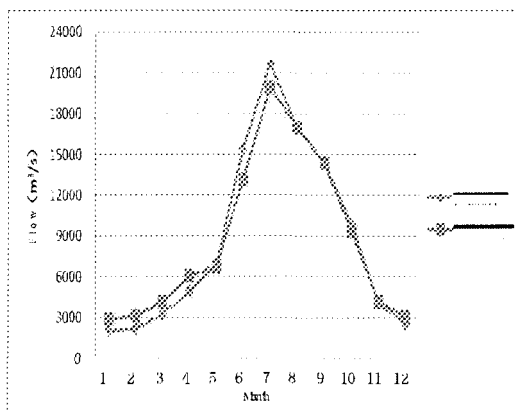


Figure 5.1-8 Changes in flow of Katha

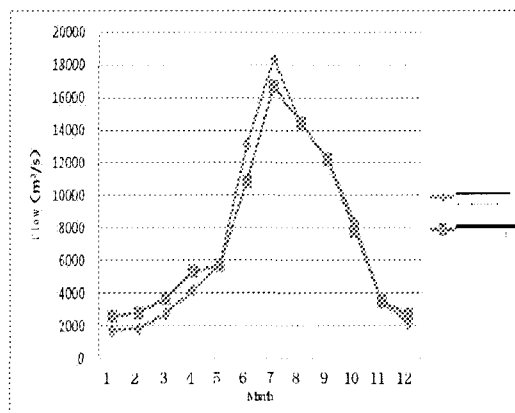


Figure 5.1-9 Changes in flow of Thabeikyin

(2) Impact upon downstream water level

Construction of the cascade reservoirs will exert certain influence upon downstream water flow. Along with changes in water flow of the river, water level of the river will also undergo some changes. Due to data limitation, the impact upon water level of Myitkyina River in the downstream reaches of the dam is just analyzed. The changes in water level of Myitkyina before and after completion of the cascade reservoirs are in detail shown in Table 5.1-4.

Table 5.1-4 Comparison of changes in water level of Myitkyina before and after the cascade reservoirs **Unit:m**

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Natural situation	131.9	132	132.5	133.3	134	136.3	137.4	136.6	136.1	134.9	132.9	132.2
Cascade reservoir completed	132.6	132.8	133.2	134	133.9	135.4	136.9	136.6	136.1	134.7	132.9	132.6
Water head	0.7	0.8	0.7	0.8	-0.1	-0.9	-0.5	0	0	-0.3	0	0.4

Table 5.1-4 shows that after the cascade reservoirs are put into joint operation, water level of Myitkyina from November to April next year will be somewhat increased against natural situation, and such increase is largest in February and April, about 0.8m. Water level from May to October is somewhat decrease against natural situation, and such decrease is largest in June, about 0.9m. For main courses below Myitkyina of Ayeyawady River, with afflux from greater downstream tributaries, the influence of joint operation of the upstream cascade reservoirs upon the downstream water level will be gradually declined.

The changes in water level of Myitkyina before and after the cascade reservoirs are in detail shown in Figure 5.1-10.

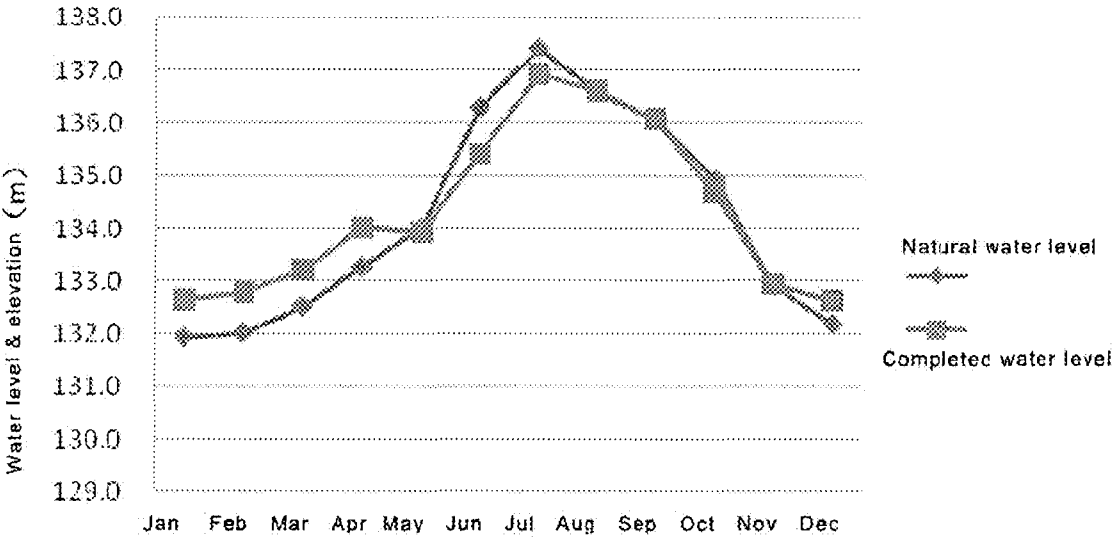


Figure 5.1-10 Changes in water level of Myitkyina before and after the cascade reservoirs

5.1.6 Summary

Under impact of construction of cascade plant dams, the former continuous water bodies in the upper reaches of Ayeyawady River are divided into 7 reservoirs with different sizes.

Generally, the end of the upper reservoir is connected with the back water of the lower one. From the analysis of vertical section, water level of the river will increase to 100m and more due to obstruction by the dam and man-made structures, and reservoir area of different sizes will be formed, and vertically distributed in the form of cascade. From the horizontal plane of point, the water surface will be widened, and area of water surface will be increased by 3~16 times. After annual regulation reservoirs (such as Mistone and Laza) are built, the reservoirs will be obviously increased in both size and volume, flow rate will be decreased, the water body of the reservoir area will be changed from turbulent flow to tranquil flow; water flow of the lower reach will be controlled by the hydropower stations, so flow regime, discharge, flow rate will be different from the natural river course. Discharge will be increased during dry season and reduced in flood season. Runoff is steady in a year. After the day-based regulating reservoirs (Pisa and Wutsok) are built, water surface area of the reservoir area will be enlarged, and flow rate will be reduced. The discharge in the lower reaches of the dam site will be determined by the releasing discharge. During day-based regulating, the discharge and water level of the lower reach will have greater change.

5.2 Impact on water environment

Development of cascade hydropower stations will have some influence on the water quality of the river because the dam obstruction and reservoir impoundment change the hydrologic situations, and storage of water environment will be changed. The impact will last long time and will be irreversible.

(1) Oxygen demand

The water quality of the main water course and tributary of the upper reaches of the Ayeyawady River is good. Regardless of flood season and dry season, BOD and COD are much lower than standard limit. Flow rate of the river is greater and water body features stronger reoxygenation before the reservoirs are built. After the reservoirs are built, depth of the water body will be increased, water speed will slow down, and reoxygenation by water body will become weaker. As volume of water body increases, environment capacity of

BOD and COD in the reservoir area will be increased. The current BOD and COD of water body in the upper reaches of Ayeyawady River is mainly from chemical reaction of organic compounds of forest, and is relatively constant. After all cascades are built, if current pollution sources have no greater change, increase in pollutants of BOD and COD will be very limited. It is estimated that BOD and COD in the reservoir area will not exceed standard value after dilution and degradation through water body.

(2) Organic chemicals

Before the reservoirs are built, the stronger turbulent diffusion is propitious to dilution, mixture and degradation of organic compounds in the water body, and reoxygenation by water body is stronger. After reservoirs are built, the water depth will be increased, water flow will be slower, deposition will be strengthened, and reoxygenation by water body will be lower. As volume of water body increases, the environment capacity will be increased, and concentration of organic compounds will be reduced. The river reach of hydropower development in the upper reaches of the Ayeyawady River features good water quality and lower organic compound indicator. After the cascades are built, the total concentration of the organic compounds will be reduced when the current pollutant source has no great change. However, the concentration of the organic compounds in the nearshore waters of the towns and reservoir bay will be increased as compared to the concentration before reservoirs are built.

The bigger towns in the reservoir area include Chibwe and Putao, where drainage of sewage may affect the waters or reservoir bay in Laza and Myitsone reservoir area. Although population of Chibwe and Putao will be increased, drainage of domestic sewage and agricultural non-point pollution to the river will be increased after reservoirs are built, the increase is not great, and total amount of waste drained to the river is still smaller. Meanwhile, Laza and Myitsone reservoirs are year regulating reservoirs, and water exchange is frequent during operation of the hydropower stations. In general, all the reservoirs have better self-purification capacity. Thus reservoirs have small impact on water quality of nearshore waters of the towns or reservoir bay.

(3) Inorganic pollutant

Suspended material is the main carrier of heavy metal and inorganic pollutants. Before formation of the reservoirs, the flow velocity is greater and features stronger absorption, relocation diffusion and lower sedimentation. Water body can easily self-purification and dilute, the inorganic pollutants in the river can be absorbed by the suspended material. After formation of the reservoirs, the flow velocity will be slower, and sedimentation will be stronger, this is good for sedimentation of inorganic pollutant in the water body. On the other hand, reduction of flow rate and increase of water depth will weaken diffusion of pollutants and erosion of substrate, cause deposition of sediments. The absorbed inorganic pollutant will be accumulated on the substrate, and content of the inorganic pollutants in the sediment in the substrate will be increased year by year. Normally, the content is far lower than the adsorption quantity of accumulated sediment.

According to forecast results of water quality of main water course and tributary of the upper reaches of the Ayeyawady River during flood and dry seasons in 2009, current concentration of lead, chrome, nickel, mercury, arsenic, zinc, etc is lower. Furthermore, in the river reach of the hydropower development, there are no local large factory and mine producing inorganic toxicological indicators to pollute the water body. Thus, the content of the inorganic pollutants in water body of the reservoir area and releasing water due to power generation will lower after the cascade reservoirs are built. The inorganic pollutants in the water body of the upper reaches of the Ayeyawady River will be purified.

(4) Water clarity

After the cascade reservoirs in the upper reaches of the Ayeyawady River are built, the water level will rise, water depth will be increased, water flow will slower down, residence time of the reservoir water will be extended, deposition will be stronger, suspended material in the water will deposit quickly. Sediment in the water flow to the reservoirs will deposit in the reservoirs to reduce the sediment concentration and discharge of the water body. Due to accumulative action of all cascades, the sediment concentration of the inflowing water of the cascade reservoirs will be lower than the natural condition, and water clarity will be

increased further.

Water quality of the hydropower development reach in the upperstream of the Ayeyawady River is sound, only individual indexes in the flood season exceed the limit values. Because there is no industrial pollution on both banks of the river, fertile and pesticide are rarely used, the people lives dispersedly, and the living water drainage quantity is less and spreading, the less pollutants flow into the river. Therefore, individual indexes exceed the limit values in the flood season may be caused by arising decomposition of higher plant in water or fallen leaves of some trees and seeds of forest in the water collection area. After completion of the cascade reservoir, under the circumstances that current pollution sources are not changed significantly, pollutant increment in the reservoir is really limited, and water quality in the reservoir will not change significantly after dilution and decomposition of water body. It is preliminarily forecast that, organic concentrations of the near-bank water area of towns or bays may be increased than those before construction of the reservoir, with less influences on the water quality.

5.3 Impact on aquatic ecology

5.3.1 Impact on aquatic organisms

5.3.1.1 Phytoplankton

After completion of construction of the cascade hydropower stations, the original rivers are changed into river way reservoirs, the water body environment is converted from river ecological model into reservoir ecological model, with increased water area, reduced water flowing rate, delayed staying time of nutritional organics in water body, settled sand, increased transparency of water body, effusion of nutritional substances in the immersed soil area, increased organic substances and nutritional salts in water, and these changes are beneficial for growing and reproduction of phytoplankton and offer rich stuff to fish and aquatic animals in the reach. It is forecast, after implementation of hydropower stations, types and stocks of phytoplankton in the reservoir may change. Due to different hydrological situations and ecological environment in the reservoir area, there may be

some differences on types of phytoplankton.

For Pisa, Wutsok and other daily regulated reservoirs, a certain water flowing conditions are kept in the reservoirs, with reduced flowing rate from the end of the reservoir to before the dam. It is forecast that, after completion of construction of the hydropower stations, stock of phytoplankton in the reservoir area may be increased, and diatom is the dominant phyla. Due to high exchange degree of water body of the reservoirs, density and living creatures of phytoplankton in the lower reaches of the dam are close to those before the dam.

For Kaunglanhpu, Laza, Myitsone and other annually regulated reservoirs, at the beginning period of completion of construction of the reservoirs, owing to a large number of immersed soil, less water body exchange frequency, static water or slow flowing area in the reservoir is increased, transparency of the water body is increased, photosynthesis of phytoplankton is powerful, the phytoplankton is growing rapidly, and diatom, green alga and blue-green alga will become dominant populations. Especially the green alga and blue-green alga, for the static water area is increased, their types are also increased and density and living creature quantity of the phytoplankton will be increased evidently. If continuous input of nutritional substance of the reservoir is evident, percentage of the blue-green alga may exceed that of the diatom favoring flowing water or micro-flowing water.

5.3.1.2 Zooplankton

Similar to phytoplankton, after completion of construction of the reservoirs, owing to changes of hydrological situations and ecological environment, it does not only affect growing and reproduction of zooplankton, but also affect quantity and community structures of zooplankton. At the beginning period of construction of the reservoir area, protozoon in the immersed regional soil will enter water. Bacteria in a large number of organic scraps offer rich foodstuff to small zooplanktons (protozoon and rotifer), type and density of protozoon and rotifer will increase, large zooplanktons (cladocera and copepoda) will increase rapidly, which will become the period with the richest zooplanktons in the reservoirs and offer rich foodstuff to fish and aquatic animals in the reservoirs. With longer

water storage time of the reservoirs and the reservoir control mode is stabilized, types of zooplanktons are reduced, the community is stabilized, quantity and living creature quantity of zoobenthos adapting flowing water (protozoon and rotifer) are decreased in the cascade reservoir, and protozoon favoring static water like ciliate, brachionus, synchaeta, polyarthra, cladocera leuchtenbergianum and other zooplanktons will be increased significantly. Quantities of collotheceae, short& small stab cyclop, mesocyclops notius, mesocyclops thermocyclopoides and other open water types, and square cornuta sars, bosmina and other types adapting relatively low flowing rate will be increased in the reservoir bay and water area along the river.

Changes of hydrological situations under the dam and physical and chemical properties of water body affect zooplanktons under the dam. Composition of the zooplanktons under the same is similar to that before the dam, and the stock is lower than that before the dam. For most cascade hydropower stations are connected from beginning to end, effective habitat space of zooplanktons a in the lower reaches of the dam is contracted and total quantity of zooplanktons is reduced; however, such disadvantageous degree and scope are limited, only evident in the reach near the dam.

Affected by water level jacking of the cascade reservoirs, nutritional substances in the tributary returned area are increased, which are beneficial for growing and reproduction of zooplanktons. Types and stocks of zooplanktons are increased; the upper reaches of the water return area are flowing reaches, and zooplanktons keep ecological conditions constant.

For Kaunglanhpu, Myitstone, Laza and other cascade hydropower stations with relatively powerful reservoir regulating performance, after completion of construction of the reservoirs, volume of the reservoir is increased, water area is large, sources of the nutritional substances are increased, types of zooplanktons are increased, densities and living creature quantity are increased and increasing amplitude of the static water community is large.

5.3.1.3 Zoobenthos

Development of the river cascade changes space distribution of the river sources and confluences and shortens the distance. Affected by jacking of backwater in the reservoir area, after implementation of the hydropower stations, the capability of carrying sand by water flow at the end of the reservoir is reduced, partial traction load arising from shaping of water flow in the upper reaches of the end of the reservoir will settle at the foot of the reservoir, partial suspended load will be separated out from water flow and settle at the foot of the reservoir. On the other side, water content in the discharge water flow is reduced, and erosion on local river bed in the lower reaches is enhanced. Composition of sand and stone at the foot of the river will change, and reproduction of stone-sticking eggs is affected.

Implementation of hydropower development makes evident changes of water body of the Nmaiha River and the Malikha River in the upper reaches of the Ayeyawady River. Natural river ways are changed into reservoirs of different scales. Due to slow flowing, deepening water, longer staying of nutritional substances in the reservoir and substrate transferred from gravel and sand models to silt and sludge models, type structures of zoobenthos in the reach of the reservoir will change a lot.

Aquatic insects in the river reaches are dominant, most of which are flowing species requiring high ecological environment, poor ecological adaptation and sensitive to pollutions. Of them, trichoptera, ephemeroptera and plecoptera favoring cold and pollution-free water flow area with low ecological adaptation are dominant in most section surveys, and pollution-resistance species like oligochaeta is very low in the section surveys. For there is rare population in the river reach without pollution sources, after completion of construction of the cascade reservoirs, water quality in the reservoir area will not be changed. Therefore, for Yen-an, Pisa, Wutsok and other hydropower reservoir zones still at river status in the reach, composition of zoobenthos will not change significantly. For static water area in the reservoir area, such as Kaunglanhpu, Myitsone and Laza hydropower station reservoir areas, ephemeroptera which was ordinary before construction of the reservoir almost disappear in the reservoir area, the ordinary trichoptera becomes

occasionally appearance, oligochaeta and chironomus are main phyla and chironomus subfamily is dominant, for the phyla adapts to static water and can withstand low-oxygen environment. With longer water storing time, densities and living creature quantities of zoobenthos will increase stably, ratio of oligochaeta will increase stably, and percentage of chironomidae will rise accordingly.

5.3.1.4 Periphytic algae

After implementation of hydropower stations, ecological environment of algae will change greatly, and living quantities and communities of adherent algae will vary correspondingly. These changes are represented as follows: less impact on the end water area of the reservoir and impoundment of the reservoir, and less impact on adherent algae; the reservoir is affected by the filling, the original belt along the bank is immersed, new belt along the bank will shape, the adherent algae will change correspondingly, and such change is subject to hydrological situations of different filling. After shaping of the reservoirs, waterfront of the reservoir shall be extended. Regulating function of the hydropower station make water level stable in the lower reaches of the hydropower station, transparency in the low flow period and average flow period, which are beneficial for growing adherent algae. It is forecast type quantity, stock quantity and resource quantity of the adherent algae will be increased.

5.3.2 Impact on fish

5.3.2.1 Impact on fish by blocking of the dam

Direct impact on the water ecological environment by hydropower development is damaging continuity of flow and causing fragmenting of ecological environment, which are common issues of dam projects of all hydropower stations. As for migratory fishes, blocking affects of the dam may cause failure of life history of some individuals. For fish without obvious migration features and resident fishes, long-term consequences of breaking of the ecological environment may lead to reduction of diversity of fish community heredity and affect population survival.

As for the flowing area cascade development, the lowermost cascade is the cascade affecting swimming of fishes most. In the hydropower development proposal in the upper reaches of the Ayeyawady River, Myitsone is the lowest cascade and the lower reaches of confluence of the two rivers. As for catadromous fish *Anguilla nebulosa* and *Anguilla bengalensis*, separated by Myitsone Hydropower Station, habitat scope of the eels will be reduced. According to the survey, only a small number of the eels swim to the upper reaches of the dam. The eels are catadromous fish and grow in fresh water. In the lower reaches of Myitsone Dam, trunk of the Ayeyawady River is about 2700Km long, the eels still have relatively large habitat space, and construction of Myitsone Dam will not affect the completion of its life history. Besides, the two eels are widely distributed in the lower reaches of the Ayeyawady River and the estuary in Southeast Asia. In a general view, hydropower development in the upper reaches of the Ayeyawady River can not cause disappearance of the two eels, and will just affect distribution scope of the eels.

Construction of cascade in the upper reaches of Myitstone divides the river into several ecological systems of reservoir which are similar and simple, and impact of habitat fragmentation for fish are evident. According to comprehensive analysis on fish distribution in the upper reaches of the Ayeyawady River, migrating habits and spawning habits, most kinds of fishes in the area are resident with short migration distance. Proper ecological environment can be found in the lower and upper reaches of the dam and the life history can be completed. Hydropower development may not affect continuity of the population. However, fragmentation and breaking of the ecological environment for fish may form different scale of heterogeneous populations. Gene exchange between populations is affected.

5.3.2.2 Impact on fishes by hydrological situations

Implementation of hydropower development at the upper reaches of Ayeyawady River will affect hydrological situations in the upper reaches and the lower reaches of Myitsone Dam. The degree of impact depends on operation of the reservoir, tributary confluence and etc.

After implementation of the hydropower development, water body features in the upper

reaches of the Ayeyawady River may suffer from significant changes. For Kaunglanhpu, Laza, Myitsone and other annually regulated reservoirs, flow in the lower reaches of the dam varies significantly. Compared with natural conditions, flow in the low water period in the lower reaches of these cascade hydropower stations is increased, decreased in the high water period and runoff in the lower reaches is re-distributed throughout the year. For the lowermost cascade Myitsone, discharge flow of Myitsone Reservoir will be no lower than $775\text{m}^3/\text{s}$, occupying about 15% of average flow of Myitsone Dam for many years, which can satisfy the ecological environment water demands in the lower reaches. For Pisa, Wutsok and other daily regulated reservoirs, flow in the lower reaches varies little. For partial tributary confluence areas connected with the reservoirs, affected by jacking of backwater in the reservoir area, the natural hydrological situations may change; the tributary reaches not affected by the backwater of the reservoirs still keep the original hydrological rule.

For fishes in the reservoir area, due to changes of the hydrological situations, fishes carry out short-distance migrations for seeking proper living conditions. The migration routes vary with different ecological types. After completion of construction of the dam, water flow in the reservoir area is slower. the original fishes adaptable to rapid flow and demersal living migrate to the end of the reservoirs and tributaries, and number of populations will be reduced. These fishes include: *Schizothorax*, *Sisoridae* and partial species of *Cobitidae*. Opposite to rapid flow adapted and benthic species, pelagic fishes adapting low flow, such as *Channa*, *Xenentodon cancila*, *Osteobrama belangeri*, *Barilius barila*, *Raiamas guttatus*, *Barilius barnoides*, *Gobiidae*, and *Puntius chola* etc., for surface temperature of top water is raised in the reservoir area, the food is rich, living space is more and the population quantity is large. The above changes are evident in Myitsone and Laza Hydropower Stations.

After implementation of hydropower development, quantity of aquatic organisms is increased, quantities of small fishes, shrimps and other zoobenthos will be increased, and corresponding quantities of predatory fishes are increased with rich foods. These fishes include *Siluridae*, *Clariidae* and *Channidae* and etc.

It is pointed out that, relatively stable and meek environmental conditions in the reservoir area are ideal habitat and reproduction site for widely distributed fishes. Under the circumstances, small foreign fishes out of the reservoir area will be increased. The small foreign fishes are brought in with species introduction in most cases, such as *pseudorasbora parva*, Gobiidae and etc., which are highly adaptive to the environment. While depriving food and space with commercial fishes, they eat fertilized eggs of the commercial fishes, and easy to reproduction in the reservoir area, develop rapidly and become harmful to reservoir fishery. Therefore, in operation management of the reservoirs, introducing foreign varieties need consideration.

5.3.2.3 Impact on fishes by changes of physical and chemical properties of water body

(1) Impact of changes of water temperature

Water temperature is a key physical factor in water environment and aquatic ecological system. Of natural rivers, water body is relatively small, turbulence and mixing functions are improved, free surface of unit water body is increased and the river temperature varies with air temperature. After reservoirs are constructed on rivers, especially large reservoirs, water level is deeper, flow rate is lower, flow status is changed, the reservoir forms a water body with high thermal capacity with structure of water temperature is changed. Affected by geographical location, shape and scale, water volume, adjusting performance, and operation mode of the reservoirs, the water temperature features of temporal and spatial variation at the end of the reservoir, in the reservoir area and at the lower reaches of the dam are different from those of natural river courses, which will influence ecological environment and human's production activities a lot. For fishes, impact of water temperature variation are represented in time variation of reproduction and growth, and secondary impact arising from changes of physical and chemical environment of water temperature changes.

Similar to Danjiangkou Reservoir in China, the Baihe River Hydrological Station is located 216Km in the upper reaches of Danjiangkou Dam, is not affected by backwater of Danjiangkou Reservoir, and the water temperature is of natural river type. Before and after

water storage in Danjiangkou, temperature of Baihe River varies a little. Meanwhile, the measurement station (Zihe) in the upper reaches is more than 700Km away from the measurement station (Xiantao) in the lower reaches, before construction of the reservoirs, water temperature in months is almost the same. In the same month, water temperature difference of the stations does not exceed 1°C, and the correlation is very close, which represents powerful mixing and even water temperature of natural river ways. Of the cascade power stations in hydropower development, Yenan and the upper reaches of Laza Reservoir tail keep the natural water temperature features and are not affected by the project. Schizothoracinae and Sisoridae widely distributed in the area are not affected by the hydropower development.

Of the cascade hydropower station areas, depending on structural features of the cascade reservoirs, there are some differences in water temperature variation. In a general view, water temperatures in the reservoirs drop from April to October, and water temperatures in the reservoirs rise slightly from November to March. Although water temperature increasing in the coldest seasons is beneficial for fishes living throughout the winter, water temperature decreasing in the growing season affects the growth of fishes. For schizothoracinae, labeoninae, sisoridae and other cold water fishes, sexual maturity will be delayed, the reproduction season will be shortened and growing time for offspring will be cut down.

(2) Impact by water quality

The water quality is subject to changes of flow status. Construction of the dam affects conveyance of materials. Changes of water level influence growing, photosynthesis for algae and other energies and materials cycling, and ecological environment of the water area is affected. After completion of construction of the cascade reservoirs for hydropower development, for the water level is raising, water is deeper, water flower is lower, water staying time is longer, sedimentation is improved, suspension in water settles faster, silt is settled in the reservoirs, sand content and sand conveyance in water body are reduced, superposition of the cascade makes silt content from reservoirs in the lower reaches lower

than that in natural conditions and transparency of water body is improved. The cascade power stations for hydropower development are located in mountainous areas, which are sparsely populated and have inconvenient traffic, almost free of external pollutions and water quality in the reaches is high. There is no town in the upper reaches of Chibwe Hydropower station, with sparse villages and rare inhabitants. Therefore, after the hydropower development, water quality in the reservoir keeps sound conditions. Meanwhile, the reservoirs submerge precious metal panning sites along the river, which can relieve impact of water quality in local areas and is beneficial for fishes. In a general view, changes of water quality arising from hydropower development have less influence on fishes in the hydropower development reaches.

5.3.2.4 Impact on fished by changes of substrate of riverbed

Development of the river cascade changes space distribution of the river sources and confluences, and shortens distance between them. Affected by jacking of backwater in the reservoir area, after the hydropower development, sand carrying capabilities at the end of the reservoir are affected. Part of the suspended load formed by erosion in the upper reaches of the end of the reservoir will be settled at the bottom of the reservoir, and part of the suspension load is separated out from water flow and deposit on the bottom. On the other side, sediment content of the discharge water flow is reduced, which improves erosion of riverbed in the lower reaches. When composition ratio of sand and stone of substrate at the river bed is changed, reproduction of partial species giving birth to stone-sticking eggs is affected.

In the hydropower development scheme, it is estimated that silt accumulation at the end of Laza and Yen'an Reservoirs will be enhanced, and water scouring to partial river reaches of Myitsone will be strengthened. However, vegetation coverage rate along the two rivers is high, sand content in water body is few; therefore, it is forecast that filling up at the end of Laza, Yen'an Reservoirs and erosion in the lower reaches of Myitsone Dam are not evident, so the substrate for fishes to give birth to eggs won't be affected obviously. Changes of substrate of the riverbed need further observation.

5.3.2.5 Impact on fishes by changes of food organism

After the hydropower development, water surface in the reservoir is wider, water flow is slower, nutritional materials are delayed and transparency is improved, which are beneficial for reproduction of planktons. Species and quantities of phytoplanktons and zooplanktons will be increased. Although bank line in the reservoir is long, with frequent raising and falling of water levels, water-fluctuation zone almost free of living creatures is formed, zoobenthos in the reservoir area will change correspondingly, ratio of the former dominant aquatic insects will be reduced and densities of oligochaeta and mollusk will be increased. Therefore, the food organisms for fish in the reservoir area is changed from zoobenthos, periphytic algae in turbulent ecological environment to phytoplanktons and zooplanktons mainly, and community structures of food in the reservoir is beneficial for growing and reproduction of fishes feeding on planktons and favorable to low flow and static water.

For the middle and lower reaches of the Malikha River, with slow steep and large submersion areas, area of littoral zones are enlarged significantly and quantities of adherent algae, zoobenthos and aquatic plants increased. Similar changes will occur in the Nmaiha River. For the middle and upper reaches of the Nmaiha River, with steep slope, littoral habitat for adherent algae, zoobenthos and other food organisms is very limited; therefore, the quantity is not obviously high, while it is obvious at the tributary confluence area.

After completion of the reservoirs, due to changes of aquatic environment, productivity of aquatic organisms is increased, total fishing yield in the reservoir area is increased and composition of fishing captures is changed. Of them, captures in Myitsone and Laza Hydropower Station are changed a lot. Fishes like barbinae, labeoninae, siluridae, heteropneustes, schilbidae and etc. favoring low flowing or static water may become dominant groups, and the yield will be increased; fishes favoring turbulent will be decreased in the reservoir area even disappear. In particular, schizothoracinae and sisoridae will move to tributary of the reservoir area or narrow flowing water area at tail of reservoir, not appeared in the reservoir area anymore.

5.3.2.6 Impact on important habitats of fishes

Impact of hydropower development on fishes are changing hydrodynamic conditions of the spawning site and feeding ground; namely, the flowing water body features in the reach of the reservoir are changed to the static water body features. For most fishes, slowing water in reservoir enables them save energy consumption for overcoming current and offers more foods, which are beneficial for their growing; at the same time, most fishes in the hydropower development reaches are spawning adherent and sinking eggs, and the influence on the spawning site is limited. Main impact of the hydropower development are varieties which highly depend on flow water environment, such as schizothoracinae and sisoridae, and the way of impact are changing of environmental conditions of spawning site and feeding ground.

According to *Fauna Sinica - Cypriniformes (Volume II)*, schizothoracinae is middle or small-sized fish in plateau area in Asia, which is adaptive to environment of water body in plateaus and living in the upper reaches of rivers. It seldom move to the middle or lower reaches with lower altitudes. Some of them are distributed in the middle reaches, and limited to the upper reaches of tributaries. Schizothoracinae in the hydropower development area is scaled species, and generally lives in turbulent of valley river. They can live throughout the low temperature period for 3 to 5 months each year, and feed on benthic invertebrate and periphytic algae, with characters of growing slowly, delayed sexual maturity, low reproduction, and early reproduction seasons at time of April or May each year. The spawning site is located in the river beach with flowing water and gravity substrate. After spawning, the eggs sink into the bottom of water, with a little sticking at the beginning, and then are pushed into gravity seam for development. In the process of survey, schizothoracinae collected from the Ayeyawady River are species with low specialization degrees, and generally distributed at the edges of Qinghai-Tibet Plateau. Seen from survey results, schizothoracinae in the trunk of the middle or upper reaches of the Ayeyawady River is relatively centralized, individuals collected along the trunk are large, some of them have matured sex glands and the spawning sites are centralized in trunks. Low-age

individuals are collected at confluences of tributaries, which mean that the confluences of tributaries are key feeding grounds for schizothoracinae. After the hydropower development, at Chibwe reach and Kaunglanhpu reach of the Nmai hka River, the flow rate is low, spawning site of schizothoracinae is greatly affected by submersion of the reservoir, and spawning site of schizothoracinae in the reservoir area will be transferred to the tributary area. Spawning site of Yen an reservoir area will be transferred to the end of the reservoir. Affected by jacking of backwater of the reservoir, conditions of the feeding ground for schizothoracinae at the tributary confluences will be improved, which is beneficial for increase of population.

Sisoridae fishes normally inhabit at the upper reaches of rivers or hill streams with gravel, attach on stones with developed special structure of chest and abdomen and creeps, so it is highly adaptive to turbulent living environment. The reproduction seasons vary with different species of Sisoridae, generally commencing from May to June after water temperature is raised, and June to July is the peak period for reproduction. Eggs have little sticking, and need to be incubated in gravels. Spawning site is located at the transition area between turbulent and low flow in valleys. Impact of the hydropower development on sisoridae is similar to those of schizothoracinae; however, sisoridae is small-sized, and more selective for streams in hills. Impact on them by the hydropower development is less.

5.3.2.7 Impact on endemic fishes

According to records in FishBase, there are 4 endemic species in the Ayeyawady River, *Garra poecilura*, *Hemibagrus peguensis*, *Schistura acuticephalus* and *Schistura paucifasciata*, which are not acquired in this survey. Seen from features of life history of fishes, these species are highly adaptive to flowing water and widely distributed in the hydropower development reach. However, restricted by time and scope of the survey, no individual is obtained. Based on the analysis of ecological behaviors of related species, these species are small fishes adaptive to flowing water environment and lay sticking eggs.

Garra poecilura is demersal fish prefers to inhabit in turbulent environment with rocks at the bottom of water, sticks to stones with suckers. It lives on periphytic algae, plant scraps and

larve of aquatic insects.

Hemibagrus peguensis is widely distributed, and most of them are demersal fishes and inhabit on trunk and tributaries with substrates of gravel. They feed at night, live on zoobenthos, such as spiral shell, freshwater mussel, aquatic insects and their larva, shrimp, small fish, and occasionally eating advanced plant scraps and algae. They lay eggs on flowing water beach from June to July, and eggs are attached to rocks for incubating.

After the hydropower development, due to reduced flowing water in the reservoir water, proper conditions for *Garra poecilura* and *Hemibagrus peguensis* may be affected. However, there are a large scope of proper habitats in the reservoir area, such as tributary reach which is not submerged and the lower reaches of Myitsone Dam. Therefore, the hydropower development will not affect species continuing of *Garra poecilura* and *Hemibagrus peguensis* significantly.

According to *The loaches of the subfamily nemacheilinae in China* (Cypriniformes: Cobitidae) record, *Schistura* generally inhabits on gap of gravel of Qinghai-Tibet Plateau and adjacent areas, hollow bank at the turning of rivers, deadwood, weed and stack pushed by water and other hidden places. Its scale is degenerated and even disappeared, and it is adaptive to behave in flowing water and gap of gravel, and plant feeding type in severe cold areas, living on adherent algae (diatom) on gravel or mud surface. It is inferred that *Schistura acuticephalus* and *Schistura paucifasciata* inhabit in hill streams. The hydropower development affects hill streams less; therefore, it is judged that the hydropower development affects *Schistura acuticephalus* and *Schistura paucifasciata* less.

5.3.2.8 Impact on main commercial fishes

According to survey and analysis, main commercial fishes in the upper reaches of the Ayeyawady River include *Bangana pierrei*, *Tor putitora*, *Bangana delvdevi*, *Barbodes hexagonolepis*, *Schizothorax meridionalis*, *Garra qiaojiensis* and *Neolissochilus stracheyi*. Seen from environmental features of species distribution, *Bangana pierrei* and *Neolissochilus stracheyi* are distributed in one and two level tributaries of Machanbow

reach of the Malikha River, *tor putitora* is distributed in Chibwe reach of the Nmaihka River, Laza Reach of the Malikha River and Myitsone Reach of the Ayeyawady River; *Garra qiaojiensis* is only collected in Chibwe reach of the Nmaihka River. These species are highly selective for hills and rivers with relatively low flow. *Barbodes hexagonolepis* and *Schizothorax meridionalis* which are mainly distributed in the middle and upper reaches of the Nmaihka River are highly adaptive to ecological environment in gorge reaches. *Bangana delvdevi* is widely distributed in the Nmaihka River, the Malikha River and the Ayeyawady River which is highly adaptive to different ecological environments.

The 7 commercial fishes lay sticking and sinking eggs, and require small scope to complete their life history. The hydropower development in the upper reaches of the Ayeyawady River block free migrations of individuals in different reaches, but it does not influence these species on completing life history and populations in different reaches can continue. Due to long-term results of the habitat fragmentation, genetic diversity of these commercial fishes may decline. For *Bangana pierrei* and *Neolissochilus stracheyi* only distributed in tributaries, the hydropower development does not produce any impact.

After completion of Myitsone, Laza and other large reservoirs, main food for fishes such as zoobenthos, periphytic algae in the reservoir area are increased, which are beneficial for these fishes. It is forecast that, after the hydropower development is carried out, quantities of *tor putitora* and *Bangana delvdevi* will be increased largely. For *Garra qiaojiensis*, the adaptive environment and food foundation have been improved. Due to selection particularity of ecological environment, the increasing of population is not obvious. For *Schizothorax meridionalis* and *Barbodes hexagonolepis* distributed in the upper and lower reaches of the Nmaihka River, cascade construction in the middle and upper reaches of the Nmaihka River has limited promotion on the food foundation, so the population quantities keep at the current level, and populations distributed in trunk are migrated to the end of the reservoir and tributary of the Nmaihka River.

5.3.3 Impact on *Orcaella brevirostris*

Orcaella brevirostris is one of the only four freshwater finless porpoises in the world. It likes

living in large groups and lives on small fishes, cephalopods and other shellfish. *Orcaella brevirostris* is distributed disjunctively. It lives in coastal shallows, or muddy freshwater at some estuaries in Southeast Asia and Australia. Around the Asian Land, their distribution range is from the Gulf of Bengal to Malacca and the Gulf of Thailand. The freshwater populations are mainly distributed in the Ayeyawady River and Mekong River. The river close to Mandalay of Myanmar is the habitat of *Orcaella brevirostris*. Affected by cut-down of the habitat (the area has been reduced by almost 60% in the past 10 years), the population size of the species has dropped dramatically in recent years. The number is less than one hundred based on optimistic estimation. So it is regarded as one of the most endangered dolphins in the world. In 2004, *Orcaella brevirostris* was listed in IUCN red list and listed as species in severe danger. To protect the species, the Myanmar government has established a conservation area with an approximate length of 72km onward from 330km of the lower reach of Myitkyina.

After the hydropower development is carried out, according to the reservoir regulating achievements, during the high flow period, the outflow is low, and the average monthly outflow is 87.6% ~ 100% of the inflow at Myitsone Hydropower Station; power generation in the low flow period makes high outflow, and monthly outflow is 100% ~ 127.8% of inflow in dam site. Compared with natural conditions, runoff of the lower reaches of Myitsone Dam in the high flow period is increased in the flood period, and is decreased in the low flow period. The annual and monthly runoff will vary in a narrower range and tend to be stable. The catchment area of Myitsone Hydropower Station is 47,300 km², and the catchment area of Katha Hydrological Station about 350km in the lower reaches of Myitsone is 85,800 km². Without considering variations of regional rainfall, runoff of Katha Hydrological Station in the high flow period is 93% ~ 100% of natural conditions, and runoff in the low flow period is 100% ~ 115% of natural conditions. The hydropower development has less influence on hydrological conditions in the protection area of *Orcaella brevirostris*, so it will not affect *Orcaella brevirostris*.

5.3.4 Summary

Most fishes in the upper reaches of the Ayeyawady River are resident fishes with short migration distances. The hydropower development in the upper reaches of the Ayeyawady River does not affect population continuing. However, separation by the dams may cause genetic differentiation of different fish individuals.

Main impact on the catadromous fishes *Anguilla nebulosa* and *Anguilla bengalensis* is blocking of dam which may affect their distribution, but completion of the life history will not be affected. The lower reaches of the Ayeyawady River below Miysone is about 2700Km, so the two eels still have large habitat space.

In combination with ecological behaviors of related species, endemic fishes are small fishes adapting flowing water environment and lay sticking eggs. The hydropower development affect ecological environment for *Garra poecilura* and *Hemibagrus peguensis*, but population will remain; main habitat for *Schistura acuticephalus* and *Schistura paucifasciata* is mountain stream, and the hydropower development has less impact.

Main commercial fishes in the upper reaches of the Ayeyawady River lay sticking and sinking eggs and require small scope of habitat to finish its life history. The hydropower development will not influence these species, and populations in the cascade areas can continue. Owing to long-term consequences of habitat fragmentation, genetic diversity of some commercial fishes may be retrograded. Subject to changes of food organisms, population number of *Tor putitora* and *Bangana delvdevi* will be increased largely in the reservoir area.

Protection area of *Orcaella brevirostris* in the middle reaches of the Ayeyawady River is about 370Km away from Myitsone Hydropower Station. For confluences in the area, hydropower development in the upper reaches of the Ayeyawady River has little influence on protection area of *Orcaella brevirostris*, so the existence of *Orcaella brevirostris* won't be affected.

5.4 Impact on terrestrial ecology

5.4.1 Impact on terrestrial plants

5.4.1.1 Impact after the hydropower development

Main impact of the hydropower development are reservoirs submerging forest land, and combined regulating of the cascade reservoirs changes hydrological situations of rivers and minor climate around the reservoirs, and the terrestrial plants are affected.

(1) Impact by submerging forest land

After impoundment of the reservoirs, the cascade reservoirs submerge a forest land area 660km². A large area of forests are distributed in the upper reaches of Myitkyina City of the Ayeyawady River, especially Kaunglanhpu, Pisa and Wutsok areas, the forest coverage rate is over 90%, and these forest plants play key functions in reserving water sources, keeping soil, regulating climate and etc. Therefore, reduction of the forest land has impact on ecological functions of the forest land. Seen from the submersion losses, the submerged forest land area by reservoirs is only 1.85% of total area of the evaluated area. Compared with the entire evaluated area, such impact is limited.

(2) Impact on zonal vegetation and biomass

After the hydropower development, the existing plants under the submerged line of the cascade reservoirs in the evaluated area will be affected, which causes losses of biomass and growing quantity in the area. See Table 5.4-1 on losses of biomass and growing quantity in the evaluated area.

Seen from Table 5.4-1, after the hydropower development, losses of main plants in the evaluated area are *Bombax ceiba*, *Tetrameles nudiflora*, *Dendrocalamus spp.* and other dominant tree colony, with biomass losses 75.8% of the total loss. This is because this type is the mostly distributed one in the evaluated type; and *Shorea robusta*, *Datiscaceae* and *Musa spp.* are dominant forest colonies, and the total loss is 13.3% of the total loss. This is because biomass of unit area of the type is large, and the loss area is also large; the

dominant beach like orange, farmland, *Adina rubella*, rose, giant reed, *Neyraudia* sp. and etc., the loss is less, for the colony biomass is less.

**Table 5.4-1 List of changes of plant biomass and growing quantity in the
evaluated area after the hydropower development**

Type	Plant type	Damaged coverage area (hm ²)	Loss of biomass (10 thousand t)			Loss quantity of growing (10 thousand t)	
			Biomass loss of trees	Biomass loss of shrub	Total loss of biomass	Growing quantity loss of arbor	Total growing quantity loss
I-1	Keruing, shorea robusta	4331.24	180.35	0.80	181.15	2.13	2.93
II-2	Datiscaceae	83.80	1.71	0.01	1.72	0.02	0.03
II-3	Duabanga grandiflora, Chukrasia tabularis, Polyalthia suberosa	133.90	7.69	0.02	7.71	0.04	0.06
II-4	Banyan, Spondias pinnata, Caryota ochlandra	167.12	5.65	0.02	5.67	0.06	0.08
III-5	Castanopsis India	214.96	4.64	0.02	4.66	0.03	0.05
III-6	Castanopsis	176.47	4.19	0.02	4.22	0.05	0.08
III-7	Yunnan Castanopsis, Castanopsis acuminatissima A. Dc	164.29	2.66	0.02	2.68	0.03	0.05
III-8	Castanopsis calathiformis	143.90	1.95	0.01	1.96	0.04	0.05
III-9	Castanopsis Spach	161.98	2.67	0.02	2.69	0.06	0.08
III-10	Red lotus forest	117.04	5.27	0.02	5.29	0.08	0.09
III-11	Engelhardtia roxburghiana, tag alder forest	118.02	2.20	0.01	2.22	0.03	0.05
III-12	Symplocos forest	73.36	1.94	0.01	1.94	0.04	0.05
IV-13	Silk cotton, Datiscaceae, Dendrocalamus forest	41408.26	1821.67	4.35	1826.02	32.26	36.60
V-14	Shorea robusta, Datiscaceae and Musa balbisiana forest	14484.00	319.86	1.23	321.10	5.72	6.95
VI-15	Alangium platanifolium, mountain ebony—Mikania micrantha Kunth, Fragrant Eupatorium Herb Colony	1971.52	1.16	0.33	1.48	0.09	0.42
VII-16	Adina rubella— rose— giant reed colony	2906.68	1.16	0.39	1.55	0.12	0.51
VIII-17	Rubber plantation	2000.00	37.56	0.07	37.63	0.37	0.44
VIII-18	Orange park	231.83	0.03	0.01	0.04	0.00	0.01
IX-19	Farmland	10.00	0.00	0.00	0.00	0.00	0.00
IX-20	Slope soil (slash and burn cultivation)	1113.80	0.00	0.04	0.04	0.00	0.04
	Total	70012.17	2402.36	7.40	2409.76	41.18	48.57

Seen from impact of growing quantity of main plants, the hydropower development has different impact on the loss of the growing quantity. Growing quantity of tree layer is 0.43 ~ 7.79t/ (ha·a) , and growing quantity of shrub. The growing quantity losses of sparse forest are evident, which is caused by high growing quantity of bamboo forest.

(3) Impact on ecological environment of the lower reaches

After the hydropower development, 7 reservoirs of different scales are formed to make water area in the upper reaches increased. However, in the lower reaches of the dam, owing to changes of hydrological situations of rivers, minor climate and environment of the bank may change, which influence the regional ecological environment.

(4) Impact on minor climate

After the hydropower development, the water level is raised. Water area in the evaluated area is much larger than that of natural conditions. Under natural conditions, water area in the hydropower development reach is 11125.91hm², after construction of the cascade reservoirs, the water area is 81923.09hm², which is increased by about 70797.18hm² than that in natural conditions. Increasing of water area in the reservoir area increases humidity of surrounding plants, reduces temperature difference and is beneficial for the growing of plants in the reservoir area.

(5) Impact on bank plants by changes of water level in the reservoir area

Regulating operation of the reservoir will cause corresponding changes of water levels in the reservoir, and the reservoir bank forms water level fluctuating zone. Due to frequent water level raising and falling, ecological conditions in the water level fluctuation zone is not stable.

Falling depth of the cascade reservoir is 15 ~ 50m. In particular, falling depth of Kaunglanhpu Reservoir is 50m, falling depth of Chibwe Reservoir is 35m and falling depth of Laza Reservoir is 30m. See Table 5.4-2 on falling depths of cascade reservoirs.

Table 5.4-2 List of falling depth of cascade reservoirs for hydropower development

Falling depth in the hydropower development proposal (m)	Yenam	Kaunglanhpu	Pisa	Wutsok	Chibwe	Myitsone	Laza
	20	50	30	25	35	15	30

After surveying plants in the reservoir area with relatively high falling depth, plants in Kaunglanhpu reservoir include *Castanopsis sp.*, *Castanopsis acuminatissima* A. DC, plants in Chibwe reservoir area include *Dipterocarpus spp.* and *Shorea robusta* and plants in Laza reservoir area include *Bombax ceiba*, *Tetrameles nudiflora* and *Dendrocalamus spp.* forest. Besides, shrubs are distributed in banks of the reservoir areas, including *Adina rubella*-*Rosa sp.*-*Arundo donax* community, as well as *Syzygium spp.*, *Litsea salicifolia*, *Eurya sp.*, *Adina rubella* and etc. These plants adaptive to fluctuation raising and falling of river will be submerged after the reservoirs are filled with water. It is possible to conserve such plants by collecting seed and transplanting the seedlings.

(6) Impact on rare and endangered plants

There are 12 rare and endangered species, 2 endemic species as well as the *Cyathea spp.* and Orchidaceous species listed in annex II of CITES found in the evaluated area. Besides, some new species are found, one new species of *Maesa* (Myrsinaceae) and *Ampelocalamus kachinensis* N.H.Xia (Gramineae: Bambusoideae) are distributed in Myitsone area.

Dipterocarpus tonkinensis and *Tetrameles nudiflora* in this survey are distributed in Myitsone reservoir area and distributed under the submerged line of Myitsone Reservoir. They are the constructive species of local plants. Impoundment of the reservoir affects the colony. After viewing and analyzing the ecological environment and local plant data, such colony is still distributed in the area with altitude 700m. Therefore, after Impoundment of Myitsone Reservoir, some of the individuals are submerged, but it will not cause disappearance of the species.

Craibiodendron stellatum and *Mangifera sylvatica* in this survey are distributed in Chibwe reservoir area. Of them, altitude of *Craibiodendron stellatum* is 1670m, altitude of *Mangifera sylvatica* is 1097m, which are distributed above the submersion line (normal pool

level of Chibwe Power Station is 400m), so the reservoir will not affect. However, some of *Bhesa sinensis* and *Aquilaria malaccensis* in Chibwe reservoir area will be submerged.

Cephalotaxus griffithianus, *Dipterocarpus turbinatus*, *Taiwania cryptomerioides* Hayata, *Holarrhena pubescens* Wall. ex G.Don in this survey are distributed in Chibwe and Myitsone reservoir areas, but the distribution altitudes are not determined. Impoundment of the reservoir may submerge some of them.

Bretschneidera sinensis in this survey is distributed in Ratbow Village of Grape County, which is not in the submersion area of the cascade reservoirs, and impoundment of reservoir will not affect it.

Camellia irrawadiensis Barua and *Ampelocalamus kachinensis* are distributed in Myitsone reservoir areas. Altitude of *Camellia irrawadiensis* Barua is about 50~300m, with few individuals and *Ampelocalamus kachinensis* is about 200m. Some of the individuals are submerged by Impoundment of Myitsone Reservoir, but it will not cause disappearance of the two species.

Altitude of the newly discovered plant species *Maesa* sp. nov. is 50 ~ 800m, with few individuals. Impoundment of the reservoir will submerge individuals below the submersion line of the reservoir.

The species *Cyathea* spp., *Orchidaceae* spp. listed in CITES Appendix II have vast habitats in the northern Myanmar, and there are a large elevation range for them, only a part of the individuals of these species will be inundated after the water rising to the normal impounded level, so the construction of the hydro-power will have not much impact on these species.

5.4.1.2 Impact during the hydropower development period

Impact on plant resources during the hydropower development period are represented in the construction period, initial filling stage and migrant settlement period.

(1) Construction period of the sub-project

Construction of the sub-project will disturb the ground and directly damages some aboveground plants. These plants grow and reproduce above the submersion line and other areas, so construction of the sub-project will not cause disappearance of these plant species and severe reduction of individuals. Impact of construction of the sub-project is limited, and will not cause failure of reproduction and keeping of plant species. Therefore, construction of the sub-project will not cause destructive impact on plant diversity, and have limited impact on plant systems in tropical rainforest areas.

According to on-site survey, plants surrounding the hydropower dam are different. Plants around Myitsone, Chibwe, Laza, Yenam and etc. are sparse tree and bamboo forests with *Dendrocalamus spp.* dominant, with powerful regeneration power and fast recovery after completion of the sub-project; secondary forest with evergreen *Castanopsis spp.* dominant and primary forest with *Dipterocarpus spp.* dominant are distributed around Wutsok, Pisa, Kuanglangpu and other dam sites, which are steep. The construction may affect some arbors. Comparatively speaking, impact on plants in the area are larger than other areas.

(2) Initial filling period

At the initial filling period, impoundment of the reservoir may be disadvantageous to plants submerged. According to statistics, initial impoundment of the reservoir will submerge a forest land 65981.69hm², 63778.34hm² of which are forest land, 1971.52 hm² of which are sparse forest land and 231.83hm² of which are other forest lands. Of the submerged forest lands, spare tree and bamboo and sparse tree and *Musa spp.* forest are dominant, about 84.7%; the secondary is primary forest with *Dipterocarpus spp.* and *Shorea robusta* dominant and secondary forest with *Castanopsis spp.*, *Schima wallichii*, *Symplocos sp.* and etc. dominant; the tertiary is beach shrubs with *Adina rubella* dominant, which is mostly affected by the hydropower development and can not be easily recovered after submersion. Seen from the whole flowing area, such plants are still reserved in other local reaches and areas in the lower reaches of the hydropower stations; after normal operation of the reservoirs, such plants will be migrated to banks of the reservoir area from these areas to

make the plants recovered.

(3) Migrant settlement period

In the process of migrant settlement, construction of settlement houses and relocation may affect plants in the areas. The secondary forest, sparse tree and bamboo forest or sparse tree and *Musa spp.* land and sloping field shrub are mostly affected by the settlement period, and ecological environment of such plants is intermediate. Therefore, the settlement relocation has less influence on local plant resources.

5.4.2 Impact on terrestrial animals

5.4.2.1 Impact on mammals

(1) Impact after the hydropower development

After operation of the reservoirs, the river ecological system is gradually transferred into lake ecological system. With time passing by, minor climate in the reservoir areas changes, which affect mammals perched in the reservoir areas and make some species move far away from surroundings of the reservoir. Some highly adaptive species can find proper ecological environment around the reservoirs. Generally speaking, impact on mammals by the hydropower development are represented as follows.

1) Impact on habitat

According to the survey, in addition to several rare mammals in severe danger distributed in subalpine cold belt, other mammals in severe danger are distributed in evergreen broad-leaved forest on banks. After impoundment of the reservoir, part of the habitat will be submerged. To some extent, the community distribution is affected. However, most mammals have powerful migration capabilities, and integral migration of the community can promote communication and merging of low altitude community and high altitude community, which improve the community quality. Meanwhile, disappearance of the former habitat and expansion of the new habitat may remove some individuals.

2) Impact on food chain

Some mammals in the evaluated area live on amphibian and reptile. Within a short period after impoundment of the reservoir, amphibian and reptile in some areas are reduced, which may affect food chain of some mammals and food sources in the upper reaches for precious animals are less. Meanwhile, with enlarged water area and improved ecological environment, quantities of amphibian and reptile will be increased, which increase quantity of species in the upper reaches of the food chain.

3) Impact on ecological gallery

The evaluated area is located in high, middle and low valley mountain areas. Turbulent rivers are the ecological insulation for some wild animals. After filling the reservoirs, water flow is slow, water area is wide, water is deeper, which increases the possibility for some animals across the rivers and is beneficial for animal migration, and offer conditions for communication between animals on both banks.

Besides, the expanded water area will offer new perching space to otter. If water quality is high in the reservoir area, aquatic vertebra which otter lives on can maintain in the reservoir area, the otter community can be maintained.

(2) Impact during the hydropower development

In the process of hydropower development, land occupancy for construction, auxiliary facilities construction, material transportation, mountain explosion, tunnel excavation and other construction activities may influence the mammals.

1) Habitat loss

Construction of the sub-project will occupy and damage some areas, which leads to retrograding and losing of some mammals habitats. Once the habitats are retrograded, lost or damaged, quantities of animal communities will be reduced. At the same time, some wild animals have to leave the construction area and migrated to undamaged habitats. The community density in the migration area will be increased to accelerate competition among communities and the food chain may be unstable within a short time.

2) Breaking of ecological environment

The newly constructed traffic road, auxiliary facilities and etc. may form many separation galleries and non-natural scenic spots, which may break the ecological environment for animals, and some wild animals can not cross these ecological barriers. With division of the ecological environment, the wild animal communities are also separated, and dispersion and communication among communities are affected.

(3) Impact on rare and endangered mammals

1) Rare and endangered mammals in the reservoir submersion zone and non-submersion zone

Most mammals have relatively powerful migration capabilities, and most precious mammals are distributed in the submersion zone and non-submersion zone and are not limited in a small space. Under general conditions, if the mammals are larger, the range of activity is larger and the distribution is wider. Therefore, types and quantities of the mammals affected by the hydropower development are related to areas of the submersion zone.

① Species not distributed in the submersion zone

Rare mammals distributing narrowly also live here, such as *Ailurus fulgens*, *Moschus berezovskii*, *Budorcas taxicolor*, *Naemorhedus baileyi* etc. and they are not affected by the hydropower development.

② Rare species distributed in the submersion zone

Cuon alpinus, *Felis chaus*, *Catopuma temminckii*, *Capricornis milneedwardsii* etc. are rarely distributed in the submersion zone, which are no more than 5% of the quantity in the evaluated area. They are mainly distributed in mountain land forest far away from river banks. The hydropower development does not affect these animals, and the community can exist stably in the non-submersion zone through migration and self-maintenance.

③ Species distributed in the submersion zone in large

Trachypithecus shortridgei, *Lutra lutra*, *Arctictis binturong*, *Rusa unicolor* and Gaur *Bos gaurus*. perch in bank rainforest or monsoon areas. The distribution amount in low-altitude valley rainforest is over 50% of the whole evaluated area. In the reservoir submersion areas, these species are distributed in large, which is 10% ~ 15% of the evaluated area, and submersion by the reservoir may affect. However, the reservoir submersion area is not the only ecological environment for such species. They can migrate to adjacent habitat along the altitude. The impact from loss of the old habitat can be made up and compensated by new habitats.

④ Species distributed in the submersion zones and non-submersion zones

In addition to the above species, other rare species are evenly distributed in the submersion zones and non-submersion zones. Impact of the hydropower development depends on migration capabilities and adaptation.

2) Migration and adaptation capabilities of rare species

Species have different migration capabilities and adaptations. Most mammals have relatively powerful migration and adaptation capabilities and can prevent disadvantageous impact arising from hydropower development. Therefore, the hydropower development will not affect most rare species significantly.

Migration ability and adaptation ability always correlated. Weak in migration always means weak in adaptation. There are only 5 mammal species recorded which are weak in migration ability at the assessment region. They are Slow Loris *Nycticebus bengalensis*, Eastern Hoolock *Gibbon Hoolock leuconedys*, Chinese Pangolin *Manis pentadactyla*, Sunda Pangolin *M. Javanica* and Red Panda *Ailurus fulgens*.

Lesser panda is not distributed in the submersion zone and is not affected by the hydropower development.

Slow loris's special behavior makes them easily be influenced, because of their slow activity and nocturnal habit. Their response to environmental stress is passive. But there

are only two sites recorded this species, including Myitsone and Kaung Lungphu. The population is few and even distributed. Therefore, the influence for this species is unobvious.

Hoolock gibbon is a typical arboreal mammal which is endangered around the world. They rely on big trees and never go down to the ground in all their lives. This makes they also respond the stress passively. But our records about this species is mostly in the evergreen forest at higher elevation above the designed water level, but less below it. Therefore, the construction will bring slight influence to the population if forest resources above submerged line are protected well.

Pangolins highly rely on good habitat quality because of their single feeding habit. They have the most passive response to the stress. Influence will be brought to them. Fortunately, most of their population is distributing in the montane evergreen forest. So the influence is not notable.

The habitat selection of Shortridge's langur is similar as the gibbon. Their distribution ranges are somewhere superposition, but the langurs have wider niche than the gibbons, and more closer to the river basin. That means this species may be much more easily influenced by the construction. However, langurs can migrate efficiently to escape from the stress. So their populations will safely sustain.

5.4.2.2 Impact on birds

(1) Impact after the hydropower development

Long-term interference: after the reservoir is shaped, the local ecological environment is changed to interfere on birds around the reservoirs.

Transition of ecological environment: after the reservoir is put into operation, water level in the reservoir is raised, water area is increased and flood bed appears, some birds are migrated to higher altitude areas due to changes of water levels, such as *ichthyaetus* and *polyplectron bicalcaratum*; and some species favoring flood land will be increased, such as

scolopacidae.

Change of food: forming of reservoir will affect distribution and composition of living creatures in the reservoir area. For widely distributed birds, due to high adaptation to environment, change of food distribution influence the birds less, such as Pycnonotidae; for birds with strict requirements on food intake, change of the food distribution influence the birds more, which may lead to changes of distribution of the birds, such as *Tadorna ferruginea*.

Besides, shaping of the reservoir area offers sufficient water resources to birds in dry seasons to make them spend through drought periods. Meanwhile, shaping of reservoir and wet land in a large area offers rich food and hidden environment to birds which favor such ecological environment, and diversity of regional birds is richer.

(2) Impact during the hydropower development period

Impact of the hydropower development on birds include land occupancy for the sub-project, earthwork excavation, large machinery operation, explosion operation and etc., which may lead to fluctuation of communities and etc. The scope of influence is only limited to a smaller construction area.

(3) Impact of the hydropower development on bird community

Pelicans-ducks & geese-egrets-gulls community: this community mainly includes swimming birds and wading birds. After shaping of the reservoirs, the proper ecological environment area is increased, which is beneficial for growing communities.

Waders-kingfishers community: rising of water level in the reservoir area may submerge part of the habitats.

Accipiters-owls-hornbills community: distribution of the community has relatively high altitude, and the habitation environment will not be affected by the hydropower development.

Lapwings-wagtails community: the communities are distributed at river bank, wet land

farmland ecological environment, and the habitat is affected by falling of water level in the reservoir.

Coucals-pheasants-blackbirds community: the communities prefer to the bottom layer of the shrub environment which is close to water on selection of ecological environment. The reservoir area will offer more similar ecological environment to coucal - pheasant –thrush communities. Submersion of the reservoir will not affect their survival space.

Owlets-cuckoos-minivets-bulbuls-woodpeckers community: the communities are distributed in the transition zone of forests and shrubs. Impoundment of the reservoir will not lead to submersion or breaking of the ecological environment in large, and the communities will not be threatened.

Pigeons-parrots-bee-eaters-drongos-starlings community: the communities are widely distributed, from shrubs and farmlands on both banks of the rivers to mountain areas. For the community quantities are large and widely distributed, the hydropower development has less influence.

Flycatchers-warblers-flowerpeckers-sunbirds community: the communities are widely distributed, from banks along the river to high-altitude forest ecological environment. Submersion of the reservoir has less influence.

(4) Impact on rare and endangered birds in severe danger

Ardea imperialis usually lives in low-altitude streams and swampy areas. Ecological environment for perching ardea insignis is 3 lakes of different sizes in Laza area. After impoundment of the reservoir, there are lakes and swamps of different sizes formed in the appraise zone, which offers more habitation environment to ardea insignis and is beneficial for habitation of ardea insignis.

Brachypteryx hyperythra perches in density shrubs under trees, with high-quality hiding places, and has fine migration capabilities. Submersion of the reservoir will not affect the ecological environment. After the reservoir is put into operation, reproduction can be

continued in the evaluated area.

Spelaeornis chocolatinus inhabits in forest, forest edge and secondary plants, and is distributed at high-altitude areas which are far away from banks, and the hydropower development has less influence.

Ichthyophaga ichthyaetus perches in streams, lakes and low-flow Rivers and etc. Direct impact of the hydropower development are reduction of ecological environment, and community retrograding, ecological environment spot and etc. will not appear. Besides, a large number of increased water areas in the reservoir are beneficial for developing communities.

Alcedo Hercules mostly perches on streams, low land and small hills, and branches or stones with water nearby. Impoundment of the reservoir will submerge part of the ecological environment, and the submerged ecological environment is only a small portion in the evaluated area, and the hydropower development has less influence.

Arborophila atrogularis perches in shrubs to large forests with altitude 1300m in small groups. It is widely distributed in the evaluated area, from shrubs to forest areas. Only a small amount of areas are submerged by the reservoir. It has powerful adaptation capabilities to environment, and reduction of the ecological environment has no significant influence on the species.

Gallinago nemoricola is widely distributed with a large difference of altitude. A small amount of areas are submerged by the reservoir, with less proper ecological environment, so impoundment of the reservoir has less influence. Meanwhile, due to improvement of wet land conditions and adding of mudflat and beach, the community growing is promoted.

Tragopan blythii perches in mountain land ever-green broad-leaved forests especially the developed wet ever-green broad-leaved forest. It spends throughout the winter in low mountain areas, and has relatively high adaptation capabilities. There is rare ecological environment in the submersion area of the reservoir, and the hydropower development has less influence.

Beautiful Nuthatch perches in coniferous forest, behaves in single, couple and a small group and lives on insects. Seen from the survey record, Beautiful Nuthatch is widely distributed, from Yenan to Chibwe. Wide distribution range means that Beautiful Nuthatch has relatively high environmental adaptation, and the hydropower development can not be a threat.

Ichthyophaga ichthyaetus in lakes, rivers, pool and other opening areas, lives on fish and water bird, and catches water bird and other birds on the water. The hydropower development shall offer more proper ecological environment to Anapchi and offer more food sources to Pallas's Fish-eagle, which is beneficial for survival and reproduction..

Ciconia nigra perches at banks of rivers, near streams of swampy mountain areas and builds nestles on concave or shallow holes on steep mountains as well as high and large trees on wet lands. *Ciconia nigra* with nestle on steep mountains are easily affected by water levels in the reservoir area. However, there is much proper ecological environment in the evaluated areas. After the hydropower development, increasing of the water flowing area can increase the area of ecological environment. Generally speaking, the hydropower development has less influence.

Leiothrix lutea normally perches in ever-green broad-leaves forest, ever-green and deciduous forest shrubs or bamboo forest, and seldom behave at forest edge. It does not only behave in the lower layers of the bosage but also take food in the middle layer or the crown, and occasionally seeks food on ground and it is omnivory bird. A small amount is distributed at the edge of submersion areas of the reservoir. Submersion of the reservoir only covers a small area, and the hydropower development has less influence.

Stachyris oglei perches in wet and dense shrubs, and behaves under bamboos and forests of ever-green broad-leaves forest. The altitude is high in the evaluated area. Seen from the horizontal distribution, habitat of *stachyris oglei* is relatively separated from the submersion area of the reservoir. Therefore, the hydropower development has less influence.

Spelaeornis chocolatinus, *Macronous gularis* and *Garrulax nuchalis* usually behave in

dense shrubs, bamboo jungle, weed land and farmland. Proper habitat of the three kinds of birds in the evaluated area is wide, and migration in a small amount can satisfy migration demands. The hydropower development has less influence.

Ichthyophaga humilis is a kind of prey bird perches in forest and normally behaves in rivers in mountain land forest and both banks of streams. It lives on fish, and occasionally take some reptiles; it builds nestle on high and large arbor trees on both banks of rivers in forest, and sometime builds nestle on farmland and grassland. Impact of the hydropower development are losses of forests and high and large arbors along the rivers, submersion of rocks, depositing of silt and etc. to make the habitat affected. However, ichthyaetus favors clear environment, and shaping of Myitsone and other reservoirs can satisfy food demands, which is beneficial for growing communities.

Polyplectron bicalcaratum mostly behave on grassland under broad-leaved forest singly. For the secondary deciduous rainforest and ever-green rainforest ecological environment will be partially submerged, so the distribution scope will be reduced. Such ecological environment submerged by the reservoir is small, with stable community development; therefore, the hydropower development will not cause community retrograding, ecological environment spotting and etc.

Falco peregrinus is widely distributed, like mountainous regions, hills, fields, rivers, swamps, belts along the bank, opening farmland, field and villages. For it is highly adaptive to different ecological environments, it has fine survival capabilities, and the hydropower development can not be a threat to it.

Hill Myna perches on forestry flat grounds or mountainous region; normally clear ground at forest edge or in the forest, and these ecological environments are distributed near mountainous region and farmland. A small amount of such areas are submerged by the reservoir, a large number of the species are distributed in the evaluated areas; therefore, the hydropower development will not affect the grackle community significantly.

Anthracoceros coronatus mainly perches in ever-green broad-leaves forest on low hills and

the bottom of hills, and occasionally takes food on the ground. Impoundment of the reservoir will submerge some broad-leaves forest at the foot of the mountain, and the perching will be affected. A small number of such ecological environment are submerged, and the species has excellent migration capabilities; therefore, the hydropower development has less influence.

Leiothrix argentea perches in plain and hill, and behave in ever-green broad-leaves forests, shrubs and bamboo jungles in groups. A small number of proper ecological environments are submerged by the reservoir, with rare distribution, so the hydropower development has less influence.

Buceros bicornis mainly perches in ever-green broad-leaves forest on low hills, the bottom of hills and plains. It behaves singly in the reproduction period, and likes to behave on high and large trees in the non-reproduction period. A small amount of proper ecological environment is submerged by the reservoir, the species is distributed at edges, with a small amount, and the hydropower development can not cause significant impact.

Aceros nipalensis perches in the mountainous region forest, builds nestle in tree holes and lives on banyan fruit and other fleshy wild fruits. In this survey, *aceros nipalensis* is distributed in mountain forest with high altitude, sparsely distributed, and the hydropower development has less influence.

Acridotheres albocinctus perches in sparse tree grass land, forest edge and clear field in low hills and plains at the foot of mountains, and farmlands, pastures and trees near villages, and valleys and swamps occasionally. The species is widely distributed in the evaluated area. Impoundment of the reservoir only submerges a small amount of proper ecological environments; therefore, the hydropower development has less influence.

5.4.2.3 Impact on reptiles

(1) Impact after the hydropower development

1) Impact of impoundment of the reservoir

During filling period of the power station, rising of the water level can make some reptiles in the reservoir area out of their habitats, such as *Draco maculatus*, *Calotes versicolor*, *Calotes mystaceus* and etc. of Lacertiformes, and *Rhabdophis subminiata*, *Ptyas korros*, *Sinonatrix aequifasciata* and etc. of Serpentiniformes; however, *Draco maculatus*, *Rhabdophis subminiata*, *Ptyas korros*, *Sinonatrix aequifasciata* have powerful swimming and migration capabilities, most of them can migrate to other proper ecological environment out of the submersion zone, and impoundment of the reservoir can not drown individuals; however, *Typhlops diardi*, *Calotes versicolor*, *Calotes mystaceus* and etc. have poor swimming capabilities, and impoundment of the reservoir may cause some individuals drowned. This survey does not discover reptiles only distributed in the submersion zone, so impoundment of the reservoir can not cause disappearance of species in the submersion zone.

2) Impact of changes of the ecological environment

After completion of construction of the dam, the original river ecological environment has been changed into reservoir environment, which is beneficial for reptile adapting static water environment, such as *Heosemys grandis*, whose community quantity may be increased; *Rhabdophis subminiata*, *Ptyas korros*, *Sinonatrix aequifasciata*, *Xenochrophis piscator* and etc. adapting flowing water are affected, and are forced to migrate to streams, tributaries, spring places and etc.

3) Impact on terrapin by construction of the dam

Construction of the dam will change ecological environment of terrapin living in rivers, such as *Heosemys grandis* and *Kachuga trivittata*. There may be some barriers for upstream and downstream migration for terrapin. *Heosemys grandis* can survive in static lake water, and construction of the dam has less influence; no data shows *Kachuga trivittata* is applicable to wide water front environment or not, and the river environment in the lower reaches of the dam can ensure the demands of survival and reproduction.

(2) Impact during the hydropower development period

Construction of “three wastes” from construction: waste water, waste slag and noise from

the construction may affect reptile individuals and their food compositions in the construction area, and some of the individuals migrate to the outside.

Change of the perching environment: during the construction period, shrub jungle coverage near the construction area is low, brightness on the ground is sufficient, dryness is higher, community quantities of lizard may be increased, and Asian House Gecko and house lizard which depend on buildings may appear. The construction transportation may affect *Ptyas korros*, *Rhabdophis subminiata*, *Lygosoma indicum*, *Draco maculates* and etc., and may cause death of some individuals. Reptiles distributed in the belt have fine adaptive capabilities, and the compositions and quantities can not change in a general view.

(3) Impact on rare and endangered reptiles in severe danger

Advantageous impact in the evaluated areas by the hydropower development including the increasing of perching area, food diversity etc. for some species; disadvantageous impact including change of ecological environment, migration caused by the dam and etc. Table 5.4-3 shows the impact on reptiles in the evaluated areas by the hydropower development.

According to comprehensive analysis, the hydropower development may affect some species like *Xenochrophis piscator*, *Naja kaouthia*, *Ophiophagus hannah* and *Kachuga trivittata*. and etc. and may be obvious for *Xenochrophis piscator*. Based on this survey, the hydropower development can not make the species in the evaluated area; for *Melanochelys trijuga*, *Varanus salvator*, *Indotestudo elongata*, advantageous and disadvantageous impact may occur. In a comprehensive view, there is no influence. Due to increased proper ecological environment, community quantities and distribution scope of *Heosemys grandis* adapting static water environment may be increased.

5.4.2.4 Impact on amphibians

(1) Impact after the hydropower development

1) Impact by impoundment of the reservoir

During filling period of the reservoir, amphibians like *Fejervarge limnocharis*, *Bufo*

melanostictus, *Odorrana rotodora*, *Microhyla ornate*, *Polypedates mutus* and etc. in the submersion zone will be out of their habitat. However, these amphibians have relatively powerful swimming and migration capabilities, and most of them can migrate to other ecological environment out of the submersion zone, and impoundment of the reservoir can decrease a small number of individuals. Besides, during the filling period, many amphibians migrate to the edge of the submersion zone, which may increase interspecies crossing and species competition within a short time. However, for amphibians in the non-submersions, the impact are small.

Table 5.4-3 List on Precious Reptiles in Severe Danger in the evaluated area by the Hydropower Development

No.	Species	Advantageous influence		Disadvantageous influence		Comprehensiv e influence index
		Type of influence	Influence index	Influence model	Influence index	
1	<i>Python molurus</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-1	0
2	<i>Naja kaouthia</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-1	-1
3	<i>Ophiophagus Hannah</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-2	-1
4	<i>Xenochrophis piscator</i>	Increased ecological models and food diversity	+1	Reduced habitat, human-made disturbance	-2	-2
5	<i>Varanus dumerilii</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-1	0
6	<i>Varanus salvator</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-1	0
7	<i>Kachuga trivittata</i>	Enlarged habitat, increased food	+2	Change of the ecological environment, and migration by the dam	-2	-1
8	<i>Pyxidea mouhotii</i>	Increased ecological models and food diversity	+1	Slightly reduced habitat	-1	0
9	<i>Indotestudo elongate</i>	Disturbance of ecological environment reduced	+1	Slightly reduced habitat	-1	0
10	<i>Melanochelys trijuga</i>	Disturbance of ecological environment reduced	+1	Slightly reduced habitat	-1	0
11	<i>Heosemys grandis</i>	Enlarged habitat, increased food	+3	Migration caused by the dam	-2	1
12	<i>Cyclemys dentata</i>	Increased ecological models and food diversity	+1	Reduced habitat, disturbance and catching	-1	0

Notes: influence index: “-3” = relatively obvious disadvantageous influence “-2” = certain disadvantageous impact observed, “-1” = slight disadvantageous impact, “0” = almost no impact, “+1” = slight advantageous impact, “+2” = certain advantageous impact observed, “+3” = relatively obvious impact

2) Impact by change of ecological environment

After the reservoir is shaped, the water level is raised, water front area is increased, the former flowing water ecological environment is changed into static water environment, which are beneficial for amphibians adapting static water environment like *Fejervarge limnocharis*, *Bufo melanostictus*, *Microhyla ornata*, *Ichthyophis glutinosus* and etc. to make the community quantities increased; species adapting flow water environment like *Tylototriton verrucosus*, *Philautus odontotarsus*, *Odorrana livida* and etc. which are forced to migrate to streams, tributaries, spring sites and etc. For regulating of the reservoir in the lower reaches of the dam, disadvantageous impact of flood and dryness are relieved, and survival and development of amphibians are benefited generally.

(2) Impact during the hydropower development period

Impact by “three wastes” from construction: waste water, waste slag and noise produced in the construction may affect amphibians and their food compositions. In a general view, occupancy area for the project is small. The “three wastes” from the construction rarely affect composition of amphibians, as well as quantities and distribution ranges.

The construction may slightly affect habitats of the amphibians in construction site. For species only adapting streams, rivers and spring sites like *Tylototriton verrucosus*, *Philautus odontotarsus*, *Odorrana livida* and etc., the distribution quantities may be reduced for the construction activities; for species adapting slope and forest area like *Polypedates gongshanensis*, *Microhyla ornata*, *Microhyla heymonsi* and etc., there is basically no influence; for species adapting rivers, river belts, farmland and trunk road like *Fejervarge limnocharis*, *Bufo melanostictus*, *Microhyla ornata* and etc., the construction may be beneficial.

(3) Impact on precious amphibians in severe danger

Precious amphibians in severe danger in the evaluated area cover *Rana hexadactyla* and *Polypedates gongshanensis*, which are mainly distributed in streams, rivers and spring sites. There is a small number of *Rana hexadactyla* in the submerged zone. Impoundment of the reservoir forces it to migrate to streams, rivers and spring sites out of the submersion

zones; the survey indicates that there are many proper ecological environments within the submersion zone. Therefore, the hydropower development can not be a threat to a species. Altitude for distribution of *Polypedates gongshanensis* is very high, so impoundment of the reservoir can not cause disadvantageous impact.

5.4.2.5 Impact on butterflies

(1) Impact after the hydropower development

After the hydropower development, improvement of conditions in the reservoir area increases the probability of human's behaviors, and may affect the survival of butterflies. Besides, minor changes in the reservoir area can attract more butterflies.

Host plant of *Troides aeacus* and *T. helena* is aristolochia and its favored lily and Pittosporaceae, which are rare, so impoundment of the reservoir has less influence. Therefore, submersion of the reservoir has less influence on *troides aeacus* and *troides helena*.

2) Impact during the hydropower development

During the construction period of the cascade power stations, the original topography may be changed, which affect perching of butterfly, which is forced to migrate to the outside within a short time, such as *chilasa agestor*, *graphium sarpedon*, *papilio memnon* and other species perching on shrubs and stream environment.

5.4.3 Summary

The hydropower development in the upper reaches of the Ayeyawady River will submerge partial forest land, which is a small portion of the evaluated area, within 2.0%. Most of the evaluated area is forest land, and most of the submerged plants are still distributed above the submersion line, so submersion of the reservoir has no significant influence on the ecological environment.

For protected rare and endangered plant species, there are not any rare species which are completely submerged, and they are distributed in other sites. Meanwhile, transplantation in other sites may be used to protect the species. For other protected plants, impoundment

of the reservoir can submerge some of the individuals. The hydropower development can not cause disappearance of the species and impact on the species is limited.

Impoundment of the reservoir affects ecological environment of terrestrial animals to some extent. For terrestrial animals in the submersion zones, except some species reduced for poor migration capabilities, communities and quantities of most animals will not be affected significantly. After impoundment of the reservoir, boundary effect of the reservoir may offer high-quality habitat for some animals in the reservoir area and is beneficial for some animals.

5.5 Analysis of influences of water loss and soil erosion

(1) Influences during the hydropower development period

Construction of the cascade power station in the upper reaches of the Ayeyawady River will change topography of the project area, damage plant and soil structures and accelerate water loss and soil erosion.

During the construction preparation stage, the construction surfaces are separate, and removal for land requisition, road development, construction site construction, construction power introduction and other jobs will be finished in the period. Road excavation and reimpoundment, bridge setting-up, taking materials and preparing materials, pipeline laying and etc. cause high volume of earthwork and separated, which cause water loss and soil erosion.

During the construction period, the construction surface area is large and centralized. Trans-year construction may lead to evident water loss and soil erosion. It is represented as follows: reimpoundment and diversion for cofferdam of the pivot project, cross construction of the foundation excavation, high volume of the earthwork, scheduling and provisional stacking; high volumes in sand yard and stone yard, stacking for a long time; during the provisional earthwork stacking period, based on complicated compositions and sparse structures, severe water loss and soil erosion may occur under external forces; complicated construction technology for the water conveyance holes and overflow channels, plus steep

topography and severe construction conditions, so it is hard to control water loss and soil erosion during the construction period; water loss and soil erosion of the excavated soil slope and refilled slope unavoidably occur.

The hydropower development also involves migrant settlement, road to the outside and power transmission project. The migrant settlement mainly includes the civil engineering of houses. Although the disturbance is low, the disturbance area is large, and the water loss and soil erosion are not ignored. For the involved road to the outside and power transmission and telecommunication project, the construction sites are located in mountainous regions and the mountain is steep, the water loss and soil erosion arising from the earthwork project are severe, which affects the downstream reaches most. Belt erosion surface is formed on the excavation line above the construction cutting, with potential danger of upward cutting erosion.

(2) Influences after the hydropower development

During operation of the cascade power stations, due to changes of cushion conditions under the project, influences of the water loss and soil erosion are represented in the water erosion influences arising from the reservoir bank and the dam shoulder out of stability, and influences on the reservoir arising from water loss and soil erosion in the water collection area in the upper reaches.

Cascade reservoirs in the upper reaches of the Ayeyawady River are river course reservoirs. Mountainous body on both banks of the reservoir are wide and thick, rock stability of the dam shoulder is sound and the plants on the reservoir bank are well developed. After impoundment of the reservoir, most of the reservoir bank will not suffer from bank corruption and erosion. Affected by local bank structure, after impoundment of the reservoir, local collapse and other erosions may occur.

5.6 Analysis of local climate influences

After completion of construction of the cascade power stations in the upper reaches of the

Ayeyawady River and impoundment of the reservoir, water front area in the reservoir is increased than that of the natural rivers, the land area is corresponding reduced, the lower cushion is changed from land with low thermal capacity to water with high thermal capacity and the evaporation quantity is increased with the water front. Because water and land have different physical properties, there are differences in absorption, reflection, storing and releasing of the sun radiation energy. Such differences will be back to the atmosphere through processes, and bottom structure of the atmosphere is affected to make the original climate element field changed and minor climate around the reservoir affected.

(1) Precipitation and air temperature

Generally speaking, during high-temperature seasons, the water surface temperature is lower than that of the land, atmosphere structure above the water surface of the reservoir area is stable, and the precipitation is less; during low-temperature seasons, the water surface temperature is higher than that of the land, the atmosphere structure is unstable, and the corresponding precipitation is increased. Influences of the reservoir in precipitation are making the geographical distribution for precipitation changed, and the precipitation is re-distributed. For a single reservoir, the phenomenon is obvious, which influences least in the average precipitation in the entire flow area. Therefore, the hydropower development in the upper reaches of the Ayeyawady River will not cause significant changes of precipitation in the basin.

After completion of the cascade reservoir, due to change of properties of the cushion, energy exchange means and strength between the lower cushion and air are changed. Affected by the horizontal exchange arising from the water and land temperatures, air temperature near the reservoir is changed. Analyzing from seasons, in hot seasons (March to May), the air temperature is rising, temperature rising of water body needs absorbing a large number of heat, so the temperature rising is slow, this is the heat absorption period of the reservoir, and the water surface temperature is a little lower than the land surface temperature; in cold seasons (November to February in the next year), the air temperature is reduced, the reservoir stores a large number of heat, the water temperature reduction is

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slower than the air temperature, in the process of temperature reduction of the water body, a large number of heat will be conveyed to the atmosphere in latent heat and sensible heat to warm up the air, so the water surface temperature is higher than that of the land. Analyzing from annual data, for the temperature rising period is more than the temperature reduction period in a year, annual average temperature after impoundment of the reservoir is higher than that before impoundment the reservoir. Besides, due to regulating function for temperature by water body, annual and daily temperature differences in the reservoir area and nearby areas are small.

Besides, in rainy seasons (June to October), the reservoir water temperature is lower than that of the land. Air flow through the reservoir is increased, the upward moving is poor to make the probability of convection climate near the reservoir area is reduced, such as reduced days of thunderstorm and hail.

(2) Humidity and evaporation

After the cascade reservoir is filled with water, due to increase water front area, the evaporation quantity is increased and the environmental humidity in the reservoir area is increased. The relative humidity is affected by temperature and humidity degree of the lower cushion. After construction of the reservoir, the annual average temperature is raised a little, and water source of the lower cushion is sufficient to enhance evaporation and increase air humidity.

Evaporation quantity in the reservoir area is related to the climate thermal factors, which depend on temperature and humidity. Although the sun radiation is high in hot seasons and rainy seasons, the evaporation force is large; however, for air temperature near the water body is reduced and sufficient steam can not be supplied, the evaporation steam is reduced. In cold seasons, although the effective sun radiation is lower than that in hot seasons and rainy seasons, the temperature in the reservoir area is higher than that before construction of the reservoir to offer more steam and increase the evaporation quantity. Besides, after construction of the reservoir, the air speed is high, which can offset the influences on evaporation quantity arising from reduced temperature and increased humidity, and the

total evaporation quantity almost remains the same.

Fog is a large number of water drops and crystal particle suspended in the middle layer of the atmosphere close to the ground. Conditions for forming fog are relative humidity of air is 100%, and the air temperature is below the condensation point. Based on different forming conditions, the water area is radiating fog, horizontal fog, steam fog and etc. For steam is sufficient in the reservoir area, when relative humidity of the atmosphere is high, with a little radiation temperature reduction, the air will be saturated, with condensation, and radiation fog occurs. In hot seasons, temperature near the reservoir is low. When warm and wet air flows through the lower cooler cushion and is cooled, the horizontal fog occurs. The steam fog occurs when the steam evaporated from the warm water surface under the conditions that the water temperature is higher than the air temperature. In particular, in nights of cold seasons, when cold air flows through warm air above the reservoir, steam fog occurs.

(3) Wind

After impoundment of the reservoir, flat and smooth water surface replaces fluctuated water surfaces, with smaller coarseness and accelerated wind speed; on the other side, after impoundment of the reservoir, water level is raised, the valley bottom is widened, relative height of both banks is reduced, length of the air zone is longer and funneling effect of the river valley is weakened. These factors play different roles to make the wind speed vary in the upper and downstream reaches before and after construction of the reservoir.

For there are thermal differences between the reservoir temperature and surrounding land temperature, the 1-day-cycle water-land wind may occur. During daytime, the water surface temperature is lower than that of the land, the air pressure gradient towards the land occurs, and the air is blown to the banks from the reservoir; oppositely during night, the air is blown to the water from the land to form the change of air directions. For most cascade reservoirs in the upper reaches of the Ayeyawady River are river course reservoirs; therefore, such phenomenon is not so evident, and the range is limited.

In a word, analyzed from current observation and measurement data within the territory of

China, influences of impoundment of the reservoir are advantageous. Humid reservoir climate is beneficial for growing crops and plants; the annual and daily temperature differences in the reservoir area and the surrounding area are small, which bring advantageous conditions to agriculture and forest planting, and improve productive force and stability of ecological systems around the reservoir.

5.7 Comparative analysis of environmental impact in different development schemes

Analysis of environmental impact in recommended hydropower development scheme I is made above. Major differences between scheme I and scheme II lie in Guanglanhpu~Chibwe of Nmaihka River. In the river reach, 3 cascades are arranged in the scheme I, i.e. Piza (665m)-Wutuo (525m)-Chibwe (400); 2 cascades are arranged in the scheme II, i.e. Lating (665m)-Chibwe (450). Comparative analysis of environmental impact in these two schemes is made as follows:

(1) Hydrological regime

Major differences in impact of two schemes upon hydrological regime find expression in river pattern, runoff and water level.

In terms of river pattern, in the scheme I, 7 water reservoirs of different sizes are formed, with water area of about 819km²; in the scheme II, 6 water reservoirs are created, with water area of about 821km². As a whole, two schemes are subject to no great differences in their impact on river pattern. Major differences lie in Guanglanhpu~Chibwe of Nmaihka River.

In terms of runoff, the scheme I consists of 5 annual regulation reservoirs and 2 daily regulation reservoirs, with total adjustment reservoir capacity of 13.544 billion m³; the scheme II consists of 6 annual regulation reservoirs, with total adjustment reservoir capacity of 14.112 billion m³. The scheme II exerts more impact upon annual distribution of natural runoff of Nmaihka River than the scheme I does.

In terms of water level, impact of two schemes upon water level mainly exists in the water reservoir of Chibwe hydropower station. In the scheme I, normal water level of Chibwe hydropower station is 400m, dead water level 365m, changing by around 35m; in the scheme II, its normal water level is 450m, dead water level 410, changing by around 40m. The comparison shows that the scheme II exerts a little greater impact upon water level of Chibwe reservoir in Nmaiha River than the scheme I does.

As a whole, the scheme I has slightly less impact upon hydrological regime than the scheme II does.

(2) Aquatic ecology

From the viewpoint of impact on dam obstruction, the cascade in the lowest reaches is Myitsone in both schemes, which create the same obstruction to migratory fishes, but have slight difference in their impact on non-migratory fishes in Guanglanhpu~Chibwe of Nmaiha River only. In the scheme I, 3 dams are arranged along the river reach; in the scheme II, 2 dams are arranged. The comparison shows that the scheme I has a little more impact on obstruction to fishes and genetic diversity of population in the river reach than the scheme II does.

From the viewpoint of fragmentation degree of fish habitat, the scheme I divides Nmaiha River into 6 discontinuous river reaches, while the scheme II divides Nmaiha River into 5 discontinuous river reaches. The scheme I has a little more impact on fragmentation of fish habitat than the scheme II does in this river reach. However, these two schemes exert basically same impact on fragmentation of fish habitat in Malikha River and Ayeyawady River.

In the scheme II, normal water level of Chibwe cascade is 450m. Reservoir backwater has greater effect on hydrological regime of major tributary Nuoqianka of this river reach than in the scheme I, thus reducing river reach length of Nuoqianka. Therefore, the scheme II exerts a little more effect on the fishes than the scheme I does in the river reach.

As a whole, both schemes are subject to slight difference in their impact on aquatic ecology,

and the scheme I has a little more effect on aquatic ecology than the scheme II does.

(3) Terrestrial ecology

From the viewpoint of submerged vegetation area, submerged forestry covers about 660km² in the scheme I and about 661km² in the scheme II. Both schemes are subject to slight difference in their impact of regional vegetation, and major differences lie in 400m~450m belt above seal level at both sides of the river reach of Chibwe reservoir. It is thus concluded that both schemes are subject to slight difference in their impact on rare and endangered animals and plants, and have basically same effect on such animals and plants.

From the viewpoint of declined belt formed in the reservoir, declined belt in Chibwe reservoir reaches 40m in the scheme II, whose altitude ranges from 410m to 450m; declined belt in Chibwe reservoir comes to 35m in the scheme I, whose altitude ranges from 365m to 400m. The comparison shows that the scheme I has a little less effect on declined belt than the scheme II does.

As a whole, the scheme I has slightly less effect on terrestrial ecology than the scheme II does.

To sum up, in terms of hydrological regime, aquatic life and terrestrial life, the scheme I has a little less environmental impact than the scheme II does. Therefore, the recommended scheme I shall be adopted as feasible environmental scheme.