HYDROELECTRIC EXPLOITATION AND SUSTAINABLE DEVELOPMENT OF THE YALONG RIVER

Chen Yunhua: Professorial Senior Engineer,General Manager of Ertan Hydropower Development Company Ltd.

Abstract: The middle and lower reaches of the Yalong River are China's few river basins with favorable conditions for hydropower development. The abundant water resources of the Yalong have environment-friendly features in all perspectives. With the river running through Ganzi Tibetan Autonomous Prefecture and Liangshan Yi Autonomous Prefecture of Sichuan Province in China's Southwest, development of the Yalong will greatly promote economic development and social advancement of the minority areas. Only when a river basin is developed and managed by a vigorous and responsible company can a harmony between environment and development be achieved to the maximum extent, and a successful implementation of the strategies for sustainable development be assured.

Ertan Hydropower Development Company Ltd. (EHDC) has been authorized by the Central Government to exploit the hydropower resources of the Yalong River. This is a glorious mission and historical responsibility for the Ertaners. EHDC has been making a plan for ecological protection of the river basin with corresponding solutions, which will be demonstrated in the overall planning of the basin.

Through construction of Ertan Hydroelectric Project, outstanding achievements and successful experience have been obtained in resident resettlement and environment protection. The development-oriented policies brought practical opportunities to the affected people, and the environment management efforts have started to show their effects. Hydropower development has proved to have more benefits than disadvantages in terms of environmental impacts.

With the successful completion of Ertan Project as a new start, EHDC is looking into the future, and will follow the development guideline of "basin, cascading, rolling and comprehensiveness", and persistently pursue after environment- friendliness and sustainable development. We are confident that the Yalong river basin will become a successful example in China and even in the world for execution of sustainable development strategies in hydroelectric development.

The Yalong river, originated from the southern foot of the Bayankala Mountains in Yushu Prefecture of Qinghai Province, stretches from northwest to southeast, passing by Ganzi Tibetan Autonomous Prefecture and Liangshan Yi Autonomous Prefecture of Sichuan Province, and joins the Jinsha River near the city of Panzhihua. It belongs to the Yangtze river water system, and is the biggest tributary of the Jinsha. From its headstream to confluence, the main stream of the Yalong is 1,571km, which covers a catchment area of 136,000km2, creates a natural fall of 3,830m, and gives a multi-year average inflow of 1,890m3/s and an annual runoff of 59.6 billion cubic meters at its confluence. Stretching to the southeast of Qinghai-Tibetan Plateau and lying between the Jinsha and Dadu rivers, the Yalong river Basin is a long but narrow strip of land which is 950km from south to north and 135km from east to west. In the east, north and west, the basin is surrounded by mountains of over 4,000m above sea level.

1 THE UNIQUE WATER RESOURCES OF THE YALONG RIVER

1.1 Summary

The Yalong river has abundant hydropower resources, with a big natural fall and large constant inflows. It has a technically developable capacity of 34.62GW, which represents an annual power generation of 184.04TWh. Out of which, the main stream of the river has a hydropower reserve of 33.40GW, and a technically developable capacity of 28.56GW, representing an annual power generation of 151.64TWh, and accounting for roughly 24% and 5% of the total generation of Sichuan Province and the whole country respectively. So it is a unique treasury of clean energy.

Twenty-one cascade schemes have been planned along the main stream of the Yalong, utilizing 2,813m of its natural fall. With proper combination of the sizes of the cascade schemes and good regulation performance of the reservoirs, the reservoir capacity factor of the Yalong river is 0.32. Lianghekou, Jiping and Ertan are the controlling reservoirs, which add up to a total regulation capacity of 15.8 billion m^3.

The middle/lower section of the Yalong river (from Lianghekou to the confluence) flows through Ganzi Tibetan Autonomous Prefecture, Liangshan Yi Autonomous Prefecture, and Panzhihua Municipality. With concentrated distribution of power projects as planned, small quantity of land acquisition and resettlement, and minor inundation losses, projects in this section of the river have high economic performance, favorable development conditions, and prominent benefits in terms of power generation and other areas. It will also play an important role in promoting economic development and social progress of the minority areas. Therefore, it is one of the best among China's 12 hydropower sources. Recent development activities will focus on this section of the river, which accommodates Jinping (I & II), Guandi, Ertan (completed), and Tongzilin.

Ertan Hydropower Station was built between 1991 and 2000, with an installed capacity of 3,300MW. Before completion of Ertan, the hydropower resources of the Yalong river had not been well recognized by the public. Construction of Ertan opened the prelude for development of the Yalong river Basin, and unveiled the mysterious river, making people surprised at its rich resources, unique environment-friendliness and superior development conditions.

1.2 Natural Features of Environment-friendliness

To some extent, all environmental impacts caused by construction of hydropower projects can be summarized into two categories – hydrological impact and land inundation resulted from dams. Hydrological impact is reflected by the influence in silt discharge, water quality, water temperature, aquatic plants and fish resources in the reservoir area and the downstream course. Reservoir inundation is represented by the impact on biodiversity, loss of farm land and forest, resettlement of people, and loss of historical, cultural or natural relics.

The unique characteristics of the resources of the Yalong river are not only reflected in their superior technical and economic indicators, but are also and more particularly demonstrated by the nature of all-perspective environment-friendliness.

The Yalong river has a deeply-cut narrow river course, with steep slopes and high mountains along the river. The relative height of the mountains is normally 500-1,500m, and the slopes are usually 30-45° or above (60-70° in the big Jinping River Bend), which form a typical "V" valley. The special features and poor conditions have led to scarce population and little farm land. Therefore, dam construction will only need to move a small population and inundate a small quantity of farm land.

Distribution of vegetation types in the valley is closely related to the sea level and relative height, with the steep slopes dotted with scarce trees, bushes and grass clusters adapted to hot and dry valley-type climate. The planned reservoir areas have already been disturbed by human activities, particularly the excessive felling of the forest over the past decades. As a result, none of the forest resources along the river with easy access are left over, and the remaining trees only cover a small area in a scattered manner, which are generally common species of low protection values or economic values. With low precipitation, and dry and hot climate, the valley areas amid the high mountains are not suitable for human-beings or plants. Further upstream, due to excessive grazing and unbalanced existence of the natural species of wild lives, the plateau grassland has been badly destroyed, resulting in sharp deterioration of its functions for retaining of soil and water. Hydropower development will give the destroyed ecology a chance for alleviation and restoration.

The planned reservoir areas do not involve any natural reserves. Due to scarce population, there are few cultural relics in the Basin, and no relics of significance have been discovered in the reservoir areas. On the contrary, formation of the reservoirs will create a number of natural forest parks, which, like a series of emeralds, will constitute an ecological zone in the upstream of the Yangtze river.

Small resettlement and low inundation losses are outstanding features of the hydropower projects on the Yalong river. In this respect, it is the best among China's 12 planned hydropower sources. The unique environment-friendly feature has made it possible to minimize, through more effective mitigation measures, the adverse environmental impacts resulted from construction of dams, and has

created an opportunity to improve the heavily destroyed ecology, to raise the environmental benefits, and to promote economic development and social progress through protection and restoration of the basin environment in the process of hydropower development.

Primary Facts of Major Projects

	Lianghekou	Jinping-I	Jinping-II	Guandi	Ertan	Tongzilin
Capacity (MW)	3,000	3,600	4,400	1,800/2,400	3,300	450/600
Mean Annual Generation (TWh)	116.87	166.20	210.81	87.13	170.00	25.66
Farmland Inundated (ha.)	492.90	508.50	0	45.40	2,182	4.10
Unit Inundation of Farmland (ha./MW)	0.1643	0.1413	0	0.0189	0.6612	0.0068
Unit Inundation of Farmland (ha./GWh)	0.0422	0.0306	0	0.0052	0.1284	0.0016
Forest Inundated (ha.)					2,480	
People Resettled	4,925	3,641	0	298	45,812	2,420
People Resettled per MW	1.6417	1.0114	0	1.1242	13.8824	4.0333
People Resettled per GWh	0.4214	0.2191	0	0.0342	2.6948	0.9431

1.3 The River Calls – the Minority People Are Eager for Development

The dominant residents affected by Ertan hydroproject and to be affected by the upstream power projects are Tibetan and Yi minorities, and there are totally 19 minorities in the whole basin of the Yalong river. The north of Jinping River Bend is mainly inhabited by Tibetan people, while the south of the Bend (downstream of the river) is mainly inhabited by Yi people. Due to difficult access and insufficient and barren farmland, the majority of the people are still living in poverty. Hydro-energy resources are the primary resources in the basin, so development of the river will greatly improve the economic development and social advancement of the minority areas, which has been a long wish of the people living there.

During his second visit to Ertan on April 19, 1999, President Jiangzemin gave EHDC an inscription, which reads: “Further develop the hydro-energy resources of the Yalong river, and accelerate economic development and social advancement of the minority areas.” This fully affirmed the significance that development of the Yalong will bring to this area.

2 OUR VISION IN DEVELOPMENT OF THE YALONG

The unique and abundant resources of the Yalong are a generous gift from the nature. The resources should be utilized in a positive and environment-friendly manner, and greatest efforts should be made to minimize the negative impacts on the environment. The developer who carries out this task has to be an organization that is responsible to the society, to history, and to the environment.

2.1 EHDC Authorized by the State to Develop the Yalong River

On October 20, 2003, the State Development and Reform Commission confirmed in its reply to EHDC that, “In order to implement the cascade development of the Yalong river Basin, Ertan Hydropower Development Company Ltd is hereby consented to develop the hydro-energy resources of the Yalong river Basin, and to change the company name into Yalong river Basin Hydropower Development Company at an appropriate time, which shall be fully responsible for construction and management of the cascade power projects on the Yalong river, with the original shares of the investors remaining unchanged”. The document also says that, “The Yalong is one of the rivers in our country which have the most favorable conditions for hydro-energy development, and is also one of our most important hydropower sources. Please make an overall arrangement according to the cascade development plan approved by the State, accelerate the preparatory works, and speed up the development process.”

The State’s authorization is a full affirmation of EHDC’s success in construction of Ertan Power Station and its persistent efforts in promoting development of the Basin, and is a great trust in EHDC.

To develop the hydropower resources as authorized by the State and under the guideline of "basin, cascading, rolling, comprehensiveness" is a glorious historical mission and responsibility of the Ertaners.

2.2 EHDC's Vision for Harmonious and Sustainable Development of the Society, Economy and Environment

Endowed with the unique resources and shouldering the authorization of the Party and the State, EHDC is determined to promote the harmony between development of the resources and that of the society, economy and environment, and to create a Tennessee-like valley with picturesque scenery, economic prosperity and social civilization.

By developing the resources of the Yalong, EHDC will gradually grow up into a large first class IPP of international level providing over 25GW of clean energy.

2.3 Overall Solutions for Basin Development and Environment Protection

EHDC is making an agenda for technological development for next decade, and overall solutions for basin development and environment protection are one of the most important parts. Instead of the current practice of evaluating the environmental impacts of each individual project, the overall solutions will require investigations, researches, planning and designs to be done with a view to protection and improvement of the environment of the entire basin. The solutions are then reflected in the design of each individual project and get gradually implemented in the process of cascade development, so as to maximize the overall ecological and environmental benefits.

While it is certainly necessary to watch over the impact of a reservoir on local environment and climate, and to take effective measures to mitigate such impact, it is however far from enough just to focus on the reservoir and its peripheral areas. The vulnerable and fast-deteriorating ecological status in the upstream of the Yalong river has attracted our serious attention. Because of unrestrained grazing and unbalanced species of animals, the upstream grassland and marsh land once dotted with numerous lakes and covered with exuberant aquatic plants are now seriously destroyed, with their function for retaining of soil and water rapidly deteriorated. The headstreams of the Yangtze River, the Yellow River and the Yalong river are all facing the similar ecological calamity. We fully realize that, deterioration of the ecology in the upstream areas not only have direct impact on the hydrology of the rivers, but also have significant impact on the climate and ecology of the whole country.

As a developer with a strong sense of social responsibility, we will, through investigations and researches, make development plans that will cause the least possible disturbance to the environment, and work out solutions that will do the best in restoration of the ecology. Different characteristics in different sections of the river will be fully considered and treated separately, so that hydropower development and environment protection are best coordinated: in river sections with better environment-friendliness, i.e. the middle and lower reaches, sufficient mitigation measures will be taken in parallel with hydropower development; in the sections where the ecology is more vulnerable, i.e. the upstream course of the river, hydropower development will be dominated by restoration of the ecology, and the aim will be to save the aggravating environment by implementing restoration programs developed on the basis of thorough investigations and researches, and to improve the living standard of the local residents by implementing economic aid programs and by developing ecological industries, thus cutting down the spoliatory use of the ecological resources that are already extremely unendurable, particularly the highland grassland.

Using differential strategies for development of the basin will be more helpful to restoration of the environment and creation of a benign circulation between environment protection and hydropower development.

2.4 Environment-friendly Tenet Reflected in Planning, Research and Design

An environment-friendly tenet is of utmost importance for achievement of the harmony between environment and hydropower development. Tenet determines the behavior. Only when the environment-friendly conception is incorporated into the hydropower development plans and environment protection designs and such designs are strictly carried out in the hydropower

development activities with a view to the overall benefits of the entire basin, can the adverse environmental impacts be minimized to the maximum extent.

3 ERTAN HYDROELECTRIC PROJECT – A CASE HISTORY FOR SUCCESSFUL HANDLING OF SOCIAL AND ENVIRONMENTAL ISSUES

Ertan Hydroelectric Project was the first power project built on the main stream of the Yalong river. With an installed capacity of 3,300MW (550MW X 6) and a designed multi-year average annual production of 17TWh, it is a large power source in the power grids of Sichuan and Chongqing, with its capacity accounting for 30%, and generation accounting for 25%, of the total of the two grids, and was China's largest power station completed in the 20th century. The 240m-high double-curvature arch dam is the highest in China. It was a key project in China's "Ninth Five-year Plan", and was the first project in China which was constructed through a full range of international competitive bidding (ICB) using FIDIC contract forms. It was also the only project world-wide which received, as a single project, the biggest sum of loan (930 million USD equivalent) from the World Bank. As a result, when sorted by nationality, people from 47 countries participated in the construction.

As a strategic quest for sustainable development of the Yalong, Ertan made a lot of outstanding achievements and successful referential experience in resettlement and environment management. The development-oriented policies brought substantial opportunities to the resettled people, and the practice was highly commended and disseminated by the World Bank. Thorough observation and assessment proved that, in terms of environmental impacts resulted from project construction, there are more benefits than damages. Formation of the reservoir changed the local climate in a manner that is favorable for restoration of the vegetation. With its favorable impact on the ecology getting gradually developed, the environment protection efforts will begin to show the results.

3.1 Summary of Ertan Resettlement Work

The project caused resettlement of 45,812 persons, among whom 28,482 persons were from rural villages, 12,454 from the county town of Yanbian, 1,263 from the township towns, and the rest from utilities and enterprises, etc. A total of 2,181 ha of farm land and 2,480 ha of forest land were inundated. The total resettlement cost was RMB2,214.12 million.

Implementation of resettlement programs was carried out with strong support of the government authorities at different levels and under the leadership of the governmental resettlement organizations. The government played a key role in making the people understand, motivated and organized.

Scientific planning and thoughtful designs are the key factors for successful implementation of the resettlement work, and a well-planned resettlement program is already halfway to success. Before making the resettlement plan, EHDC did a lot of physical investigations together with the design institute and resettlement authorities. During the process, and under the "man-oriented" principle, the public was encouraged to participate, and numerous families were visited to collect their ideas, so that their wishes could be understood, respected, and better satisfied if possible at all. Such investigation efforts provided a sound basis for formulation of the resettlement plans. Deep investigation proved the verity as revealed by the Chinese saying – "To teach one how to fish is far better than to give him a fish", and gave us a chance to understand the eagerness for development of the people who had lived in the gorges generation by generation. Extensive interviews and public participation helped to establish the idea of "development-oriented resettlement". The aim was to create new opportunities for sustainable development, and to ensure that the living criteria of the resettled people would not be debased, so as to achieve the goal of "smooth move, stable settlement, and achievable prosperity".

Among the 28,482 rural resettlers, 9,089 persons moved up to a higher altitude near their original villages, 5,395 persons moved out of the reservoir area to Hongge - a newly developed resettlement area, 1,423 persons were taken by a number of villages, 1,347 persons chose to be self-employed or to seek for jobs on their own, and the rest settled down in other resettlement areas. To properly accommodate the affected people, 772 ha of paddy field and 234 ha of dry land were reclaimed, and 360 ha of farmland were spared out through adjustment, which made a total of 1,366 hectares of farmland available for the resettled people; a total of 652,100m^2 of housing was built; 2 reservoirs were built with a total storage of 1.28 million m^3 and an irrigation coverage of 570 ha; 2 tap-water

factories were built in the central resettlement area, with a total supply capacity of 1,500t day; a pumping system with five relay stations was built, which provided irrigation for 433 ha of land; 127km of irrigation trenches and 205km of dikes were built.

In order for the resettlers to have necessary ability for sustainable development, EHDC has made tremendous efforts at the advice of the Environment and Resettlement Panel of Experts (ERP) retained as required by the World Bank, which include:

1) Free supply of electricity. EHDC provides 33GWh of free electricity to the pumping system at Hongge, out of which 3GWh was for compensation of gird loss, so that there will be no economic burden for irrigation.

2) Strong capital support. From each MWh of electricity produced by Ertan Power Plant, 1 RMB yuan is drawn out as the reservoir maintenance fund, 80% of which is used, through the Provincial Resettlement Office, in post-resettlement rehabilitation. Through the governmental resettlement organizations, EHDC gives a payment of 2 million RMB yuan per year to Yanbian County as rehabilitation fund for maintenance of the pump stations and coverage of personnel wages, etc. In addition, 2.7 yuan is drawn out from each MWh of electricity produced in the whole province of Sichuan, which is used through the Provincial Resettlement Office for post-resettlement rehabilitation of all the reservoir projects in the province, including Ertan hydroproject.

With the strong backup of the resettlement funds, training of the resettlers, experiment of new species of crops, and introduction of quality fruit species and many other efforts achieved satisfactory results. The new fruit industry benefited the affected people and raised their living standards to a considerable extent. Fruit planting brought smile to the faces of the resettlers, and became a new shining spot of the local economy. The new species of loquat cultivated by the resettlers held independent intelligence property right and became a popular product in the Japanese market; litchi, mango and other fruit was also popular in the markets of Sichuan and the peripheral provinces. The relevant organizations of Yanbian County is now encouraging expansion of the plantation area from the current 5,000 mu to 50,000 mu (3,333 ha.).

(3) Good infrastructures provided possibilities for development of agriculture- related business. Convenient road systems and reservoir waterway made it possible to transport the quality fruit and other agricultural products out of the area for further delivery to the domestic and international market, and made it practical to run factories producing canned fruit, sweet potato vermicelli, etc. Transportation business and agricultural processing have also made some resettlers to become wealthy owners of private businesses.

EHDC's efforts were highly commended by the various resettlement organizations and the World Bank, and the company was praised as a "enlightened owner". In the Aide-Memoire of May 2000, the resettlement mission of the World Bank commented: "By end of April 2000, EHDC had disbursed 99.8% of the resettlement budget to the Provincial Resettlement Office. Among the disbursed funds, 95% (approx. RMB1,930 million) had been disbursed to the affected counties. Physical resettlement of Ertan project has been substantially completed, with 100% of the rural residents totaling 28,482 persons having moved out the reservoir area. By end of April 2000, a total of 652,100m^2 of housing had been completed, with 32.2 m^2 per capita on average. Although the per-capita square meters of house were somewhat reduced, the quality of the houses was greatly improved." In June 2001, EHDC sent a Memorandum to the World Bank, confirming the agreement reached with the Provincial Resettlement Office for final settlement of the outstanding work. EHDC committed that January 1, 2001 would be the starting date for collection of the reservoir maintenance fund from the company's sales revenue, and that 80% of the fund would be used for post-resettlement rehabilitation. The World Bank Mission praised EHDC's commitment, and commented that it was especially commendable given the fact that EHDC was actually accepting the responsibilities out of its legal obligations regardless of its unhealthy financial status. In its subsequent correspondences the World Bank commented that "the extra fund provided by EHDC has started to show its effect, such as completion of the irrigation facilities, full payment of the personal compensations, and increase of per-capita farmland. These measures have resulted in restoration of the resettlers' income, particularly that of the move-out resettlers."

3.2 Successful Resettlement Experience

Contribution of the Resettlers With the State benefits in mind, the resettlers contributed a lot to the successful completion of the project construction and resettlement work. Such contribution was one of the premises for the overall success of the project.

Assistance of the World Bank Ertan project resettlement work was carried out in accordance with Chinese laws and regulations as well as the World Bank policies. Consulting services of the ERP and supervision of the World Bank mission provided helpful guidance to implementation of the resettlement work. Starting from 1992, both ERP and the World Bank mission visited the project once or twice a year depending on the progress of the work. During their visits, performance of the resettlement work was reviewed, existing issues were pointed out or criticized, and helpful recommendations were given. Such criticism and recommendations timely and effectively urged improvement of the resettlement activities.

Attention and Understanding of, and Cooperation between, the Owner and Governmental Resettlement Authorities The resettlement organizations at different levels played a key role in the process, particularly in doing propaganda, making explanation efforts, and organizing move activities. EHDC, "the enlightened owner", continued to follow the "man-oriented" conception, and committed itself to a long-term support for future development of the resettlers despite its own business difficulties.

The "Development-oriented" Conception Shared by All the Parties During the construction process, EHDC, the resettlement organizations, and the World Bank all shared one common idea – to create for the resettlers new development opportunities by materializing the "development-oriented" resettlement conception. New opportunities were the best means to convince them to leave their beloved homeland.

Public Participation Extensive participation by the public during the resettlement investigations was a decisive factor for formulation of a scientific, practical and flexible resettlement plan.

3.3 Environment Protection

We hold the opinion that, when we comment on the environment issues of such a large project as Ertan project, we should look at both aspects of the impact, just like two sides of a coin:

(1) The Inherent Environment-friendliness of a Hydroelectric Project

When our ears are flooded by intense controversy about disturbance to the primordial rivers by hydropower projects, we should never neglect one primary fact – the property of hydropower being clean and renewable. Hydropower development reduces consumption of non-renewable energy, particularly coal, and therefore reduces discharge of soot, waste water, carbon dioxide, and sulfur dioxide, which in turn incontestably decreases the possibility of acid rain, mitigates the air pollution resulted from soot, and moderates emission of greenhouse gas. To this end, we think that, when we discuss the environment issues, we should first study the environmental benefits brought by replacement of non-renewable energy resources with hydropower. Hydropower development in Norway and La Grande Complex in Canada have presented excellent examples for their almost perfect harmony with the environment.

If calculated at the average coal consumption of Sichuan in 2002, Ertan Hydropower Plant, with a capacity of 3,300MW, can save 6.3 million standard tons of coal per year, which correspondingly reduces 230,000t of sulfur dioxide, 50,000t of soot, 1.9 million tons of cinder, and 45 million tons of waste water.

By August 31, 2004, Ertan project had accumulatively generated 64.64TWh of electricity. Calculated at China's average consumption of coal for power generation in 2003, which was 381g/kWh, the electricity produced by Ertan project equals to a saving of 24.63 million tons of coal. When calculated at the average emission of greenhouse gas in China's coal-fire power industry, which is 1,300g/kWh, this production represents a reduction of greenhouse gas emission by 84 million tons.

When the hydropower resources of the Yalong river are fully developed, the annual generation of electricity will reach 151.64TWh, equivalent to a saving of approx. 58 million tons of coal and a reduction of about 200 million tons of greenhouse gas.

(2) Disturbance to Environment by Dam Construction and Corresponding Mitigating Measures

This is the aspect that brings controversy to hydropower projects. As a responsible developer, we paid sufficient attention to possible disturbance to the environment as early as in the planning stage. During the design period, a full-perspective appraisal was made, so as to develop all possible mitigating measures, which would serve to minimize the adverse impact and maximize the favorable aspects, and help achieve the goal of bringing more benefits than damages to the environment.

Ertan Project was located in deep gorges with high and steep slopes, so reservoir inundation losses were relatively light. With a backwater length of 145km and an area of 101km^2, the reservoir submerged 2,182 ha of farm land and 2,480 ha of forest land. As result of the topography, vegetation is distinctly distributed in a vertical manner. The normal reservoir level is El.1,200m, but in the El.1,100-1,200 range the dominant vegetation consists of scarce trees, low bushes and clusters of grasses.

Before the nation-wide mandatory preservation of natural forests was launched in 1998, the river course of the Yalong river had the function of log transportation by floating. Before commencement of Ertan Project, heavy felling was done to the forest of the Yalong river Basin. Before 1985, an average of 1.1 million m^3 of logs were produced per year in the Yalong Basin, which was reduced down to 0.3-0.4 million m^3 by 1994. Most of the areas submerged by the reservoir had already been destroyed by human activities, with the wildwood scarcely scattered in strips varying from 10 to 200 ha. With in 10,100 ha of the reservoir area, only 1,000 ha of primordial vegetation was left over which had been exposed to relatively less damages, accounting for only 10% of the total area flooded by the reservoir.

In October 1995 and July 1996, two biodiversity surveys were carried out. The Biodiversity Survey Report for Ertan Reservoir Area indicated that the biodiversity status in the reservoir area was rather poor, and there were no endangered species of animals or plants requiring special protection. The report proved that most of the areas had been destroyed by human activities, and half of the area had been used for crop planting, grazing, residence and felling of timbers or firewood, or was simply wasteland.

Ertan Project sits within the Endemic Bird Area (EBA) belonging to the “South China Forest (low altitude zone below 2,000m above sea level)” and “Mid-Sichuan Forest (mountainous area above 2,000m above sea level)”, which are 2 of China’s 12 EBAs. Therefore, birds were surveyed as indicative lives for biodiversity. The reservoir buffer zone was a major mitigation measure for protection of biodiversity. Preservation of the broad-leaf forest in the buffer zone was of special significance for protection of the endangered species of birds.

As revealed by the meteorological survey section in the reservoir area, minor meteorological changes after formation of the reservoir included increase of natural precipitation, increase of relative humidity, slight decrease of sunshine hours, fall of the maximum temperature, rise of the minimum temperature, occasional rain in the dry season, and less floods in the wet season. The dry and hot valley-type of climate in the peripheral areas has changed in a manner that better facilitates growth of vegetation and living of wild lives. Amphibians and crawlers have a better living environment, so biodiversity will get improved.

Meteorological Data from Yumen Survey Section in Ertan Reservoir

Year of Measurement	1997	1998	1999	2000
Mean annual relative humidity	66%	68%	69%	71%
Mean annual precipitation	1,098.6	1,493.2	1,533.6	1,372.0
Total annual sunshine hours	2,465.8	2,275.2	2,395.2	2189.7
Maximum temperature (°C)	39.4	39.0	37.7	36.3
Minimum temperature (°C)	-0.8	-0.2	-1.9	-0.8
Start of rainy season	June 14	May 24	June 7	
Average rainy days per year	140	156	137	147

Note: Reservoir was impounded on May 1, 1998.

Sedimentation is another topic of interest. The multi-year average annual silt discharge upstream the reservoir tail is 233t/km, and the silt load content is 0.435kg/m^3. Model tests and calculations indicate that, after 30 years of operation, 250 million m^3 of the reservoir storage will be lost, with the sedimentation reaching 83km upstream the dam; after 100 years, 1,070 million m^3 of the storage will be lost, with the sedimentation reaching 55km; after 250 years, 95% of the dead storage and 55% of the live storage will be lost. However, such projection has not taken into account the ongoing Jinping Hydropower Project or other planned power projects upstream Ertan river, nor has it assumed possible reduction of sedimentation as a result of improved environment expected from preservation of the natural forest and the overall solutions for ecological protection in the Yalong river Basin.

3.4 EHDC's Care and Endeavors for Environment

The great task of being responsible for development of the Yalong requires that we should not be shortsighted when we come to environment protection. As a basin developer, we are an active promoter for hydropower development of the basin, but in the meantime we are also an aspiring exponent and faithful practitioner of environment protection.

Assessment of environmental impacts for Ertan was performed together with the feasibility study of the project as early as in 1980. Re-assessment was made twice respectively in May 1988 and December 1994 in accordance with the new criteria nominated by the World Bank, which passed the Bank's review.

In April-May 1992, together with a group of environmental volunteers, EHDC undertook an extensive investigation of the ecological environment of the Yalong Basin, and obtained a better understanding of the overall environment. We were sad to find that, due to excessive timber felling, most of the exuberant forest was gone, leaving behind bald mountains and countless stubs.

Between September 16 and October 28, 1997, EHDC sponsored another tour for investigation of hydro-energy resources and environment along the Yalong river Basin, which was participated by China Central Television Station (CCTV), the Department of Publicity of Panzhihua Municipal Party Committee, and Chengdu Hydroelectric Investigation and Design Institute. The group traced up the river and reached the headstream of the Yalong river in Qinghai Province. The group spent 33 days and traveled more than 6,000km, and obtained a great deal of first hand information. Through CCTV, a picture of the deteriorating ecology resulted from unrestrained felling of the forest and excessive grazing on the grassland was presented to the public, and it was strongly appealed to protect the ecology in the upstream of the Yangtze river. These efforts helped a great deal to arouse the care and attention of the society for the severe destruction of the ecology in the West.

In order to better protect the environment in the periphery of Ertan reservoir, EHDC actively supported Panzhihua Municipality as early as in 1993 in its application for establishment of "Ertan National Forest Park", which was approved in October of the same year. With the joint efforts of Panzhihua Municipality and EHDC, the hills that used to be bald all year round before construction of Ertan Project are now covered with verdant trees, and the reservoir has become a popular tourist attraction known for its beautiful lake views and magnificent mountain scenes.

In addition to the funds used in establishment of the reservoir buffer zone and reforestation of the production areas adjacent to the dam, EHDC also put in sufficient manpower to be directly responsible for maintenance of the buffer zone. At present, Ertan Power Plant has been making routine patrol tours in the buffer zone. The Power Plant is also responsible for permanent meteorological observation and monitoring of sedimentation, water quality, water temperature, etc.

The Central Government approved that, starting from January 1, 2001, a reservoir maintenance fund of 1.0 yuan/MWh was to be drawn out from the sales revenue, and 20% of the fund was to be used in environment protection of Ertan reservoir area and the rest of the Basin.

Through operation management of the Power Plant, EHDC has deeply recognized that legal assurance and public participation are of utmost importance to the environment. At the urge of EHDC, Sichuan Provincial Government has promulgated regulations for administration of medium and large reservoirs.

Control of waterborne diseases was yet another area closely watched over by EHDC. Historically there were cases of schistosomiasis in four of the townships in the reservoir area. EHDC disbursed large funds to help eliminate possible re-occurrence of the disease, including health check and wide-

spread elimination of snails before reservoir filling to cut out possible source and medium of infection. EHDC's efforts in schistosomiasis control were highly commended by the government and health departments, as well as the World Bank and the local residents.

3.5 Environmental Review and Assessment by the World Bank

During the construction period, the World Bank had its environment mission visiting the project every year, reviewing the environment work performed on the project. Between October and December 1995, March and May 1996, and March and May 2001, the environmental experts recommended by the World Bank made three biodiversity investigations on terrestrial lives in the reservoir, and, as indicative lives, birds were given special attention. The 2001 investigations indicated that part of the forest vegetation was improved, the vegetation in the buffer zone was in a process of restoration, the secondary vegetation in the vicinity of the dam was growing well, and the peri-reservoir biodiversity indicators did not drop.

The investigation activities included extensive interviews with the local residents. Based on a thorough study of the interrelation between their living needs and environment protection, the residents were encouraged to do ecotype tourism so that they may benefit from the good environment, and increase of their income would in turn inspire them to pay more attention to environment protection.

"As China's first large hydroelectric project built in full compliance with international practice and yet in consideration of China's practical situations, with the joint efforts of the parties involved, Ertan Hydroelectric Project fully satisfied the requirement of the Chinese Government and the World Bank in terms of environmental management, which reached the international level and achieved high praise of the World Bank." This is the conclusion of Ertan's environmental works as commented in the "Environmental Report" of the "Implementation Completion Report" reviewed and accepted by the World Bank.

In May 2001, the environmental works of Ertan Project passed completion acceptance review organized by the State Environment Protection Administration of China.

4 SUSTAINABLE DEVELOPMENT – A LOOK INTO THE FUTURE

Ertan project made world-recognized achievements in its construction. "Commissioning of the first two units of Ertan Hydroelectric Project, China's largest hydroelectric project completed in this century, symbolizes that China's hydropower engineering has reached the advanced international level." In 1998, a total of 587 academicians from China Academy of Science and China Academy of Engineering voted commissioning of Ertan Project as China's top ten technological events of the year, recording it into China's engineering history as a monument of the century.

The ten years of construction of Ertan project have now become a historical frame, and will become our new start for development of the Yalong river Basin. The experience we have obtained in respect of project construction and sustainable development will provide great reference to our future development.

4.1 The Guideline for Development of the Yalong River Basin

As a new business represented by Ertan Hydropower Development Company Ltd., river basin hydropower developers have only been in existence in China for around 10 years. A basin developer is one who is given by the State the authority to develop a particular water system, utilizes the hydro-energy resources as his exploitation objects, and takes construction and operation of hydropower projects as his strategic elements, with the goal of maximizing the social, economic and environmental benefits of the entire basin. Through 10 short years of grope, basin development has worked out a development guideline of "basin, cascading, rolling, and comprehensiveness", which is well accepted in the business.

The "basin" development principle is a scientific strategy to secure harmonious and sustainable development of the resources. The natural features of the water resources have determined that development of the resources of a relatively independent river must be considered as a whole. Splitting a river basin is disadvantageous to protection of the overall environment, to coordination and exertion

of the compensation benefits of the cascade projects, and to sustainable development of the society, economy and environment of the basin. Therefore, developing a river by a single developer is the best solution and assurance for reasonable use of the resources and better protection of the environment.

The “cascading” manner of development is determined by the nature of water resources and the interrelations among the power sources on the river. Such nature requires that hydropower development should be planned scientifically and implemented in right steps.

The “rolling” development mode is to take one power plant as the starting basis, and to realize the development continuity using its revenues. It also refers to rolling accumulation of experience and competence achieved from construction and operation of successive projects with a goal to raise the efficiency in management of cascade projects and use of resources. The rolling process is a process in which a basin developer learns and grows, and is also one in which he makes himself sustainable, and is therefore the best opportunity for him to grow into a learning organization.

“Comprehensiveness” is the final goal for basin development. Together with development of the hydropower resources, other related resources also get properly used, such as tourism, fishery, navigation, agriculture, etc., so as to achieve the overall social, economic and environmental benefits of the basin.

4.2 Our Tenet – Sustainable Development of Society, Economy and Environment

In order to realize sustainable development of society, economy and environment of the Basin, EHDC is working out overall solutions for hydropower development and ecological environment of the Yalong River Basin, which will be reflected in planning of the cascade projects. Achievement of the goal requires a strong technical backup. In view of this demand, EHDC established in 2003 a long-term relationship for cooperation in scientific researches with Tsinghua University and other famous universities. Through application, the Ministry of Personnel approved setup of a postdoctoral workstation in EHDC, which was inaugurated in March 2004, and environment protection and sustainable development will be one of the major topics for the workstation.

Developing water resources of the Yalong river is a glorious mission of EHDC entrusted by the Party and State. Harmonious and sustainable development of the society, economy and environment is a goal that we will persistently pursue after, and is also our historical obligation that we would never shirk.

During the development process, we will always follow the tenet of environment- friendliness, insist on sustainable development strategies, and implement the projects under the guideline of “basin, cascading, rolling and comprehensiveness”. Based on the successful experience achieved from project construction and environment management of Ertan, we will, with our hands, build the Yalong river into a valley with picturesque scenery, prosperous economy and advanced society, making it another example in China and even in the world for its successful implementation of sustainable development strategies.