Lake Basin Management Initiative
Experience and Lessons Learned Brief

Lake Titicaca

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1. Description

Drought and floods are the natural hazards that have the greatest environmental, social and economic impact on the Bolivian-Peruvian high plateau (*altiplano*) which includes the hydrological basin of Lake Titicaca, the Desaguadero River, Lake Poopo and the Salt Lake of Coipasa, collectively designated by the acronym TDPS. Through good management, the system can be regulated in benefit of the people who live in the region.

Territorial Scope

The project area (Figure 1) includes the hydrological basins of Lake Titicaca, the Desaguadero River, and lakes Poopo and Salar de Coipasa (TDPS system). The TDPS system is located in parts of Peru, Bolivia and Chile, spread between latitude 14° 03' to 20° 00' South and between longitude 66° 21' to 71° 07' West. The total area of the system is 143,900 km^2 and includes the sub-region Puno in Peru and the departments of La Paz and Oruro in Bolivia. The basins included in the TDPS system have the following characteristics:

This paper was presented at the Lake Basin Management Initiative Regional Workshop for Europe, Central Asia and the Americas held at Saint Michael's College in Vermont, USA, 18-21 June 2003. The workshop was organized by LakeNet in cooperation with SMC and the International Lake Environment Committee with funding from the Global Environment Facility, U.S. Agency for International Development, Shiga Prefecture Government and World Bank. The views expressed are those of the authors and not necessarily those of the project sponsors.

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Lake Titicaca

catchment area: 56,270 km^2
- average lake area: 8,400 km^2

medium altitude: 3,810 m above sea level
- average volume: 930 x 109 m^3

Desaguadero River

catchment area (intermediate): 29,843 km^2
length: 398 km
average slope: 0.45%

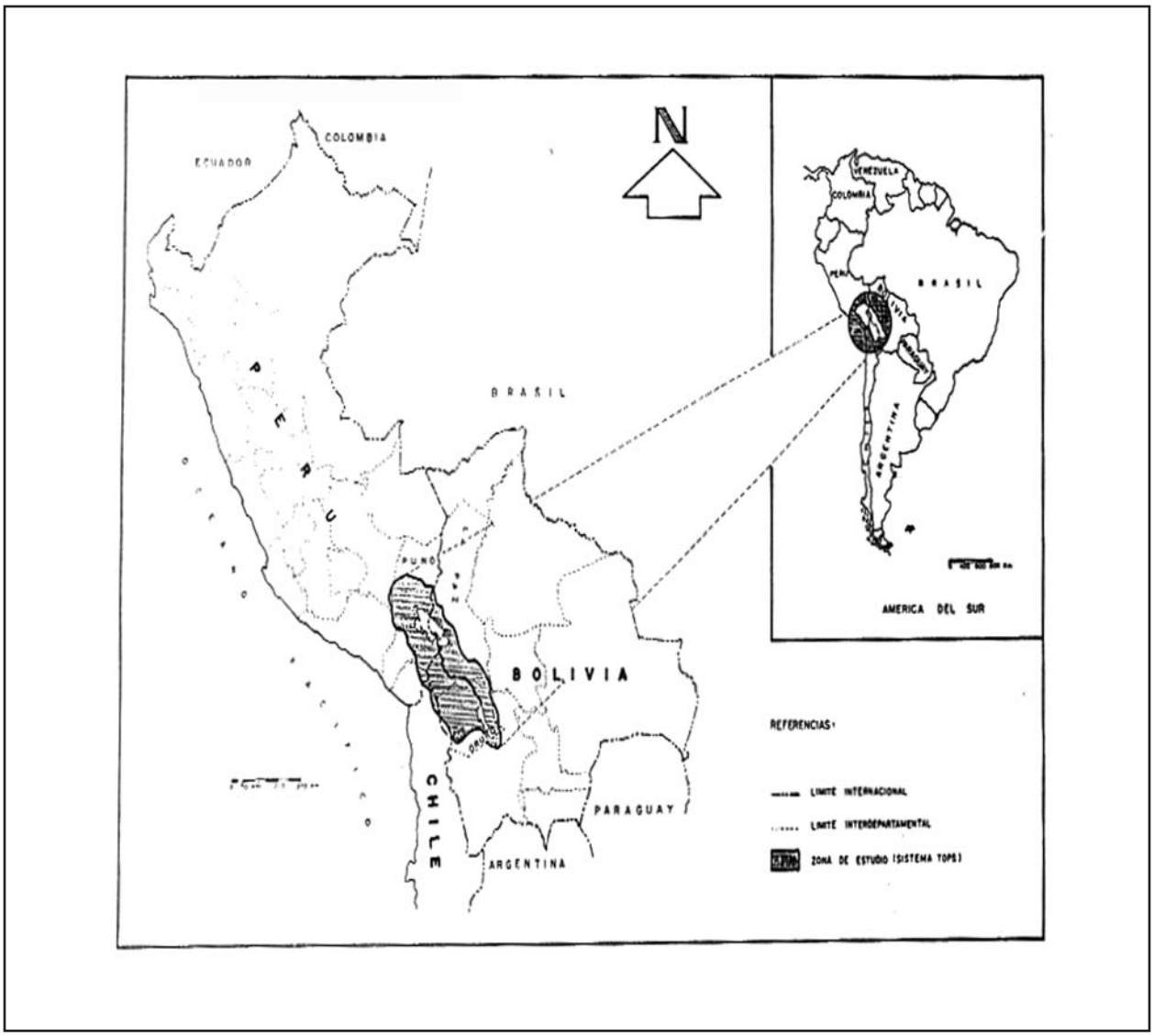

Figure 1. Location of Lake Titicaca on the border of Bolivia and Peru

The Desaguadero river comprises the following main sections: from km O to km 63 are wide plains, from the international Bridge to Nazacara; from km 63 to km 226 is a mountanous area, from Nazacara to Chilahuala; and from km 226 to km 398 there are flood plains, from Chilahuala to Lake Poopo.

Lake Poopo

catchment area (intermediate): 24,829 km^2 + 5,000 km^2 of Desaguadero

- average lake surface in 1991: 3,191 km^2
- median altitude: 3,686 m above sea level

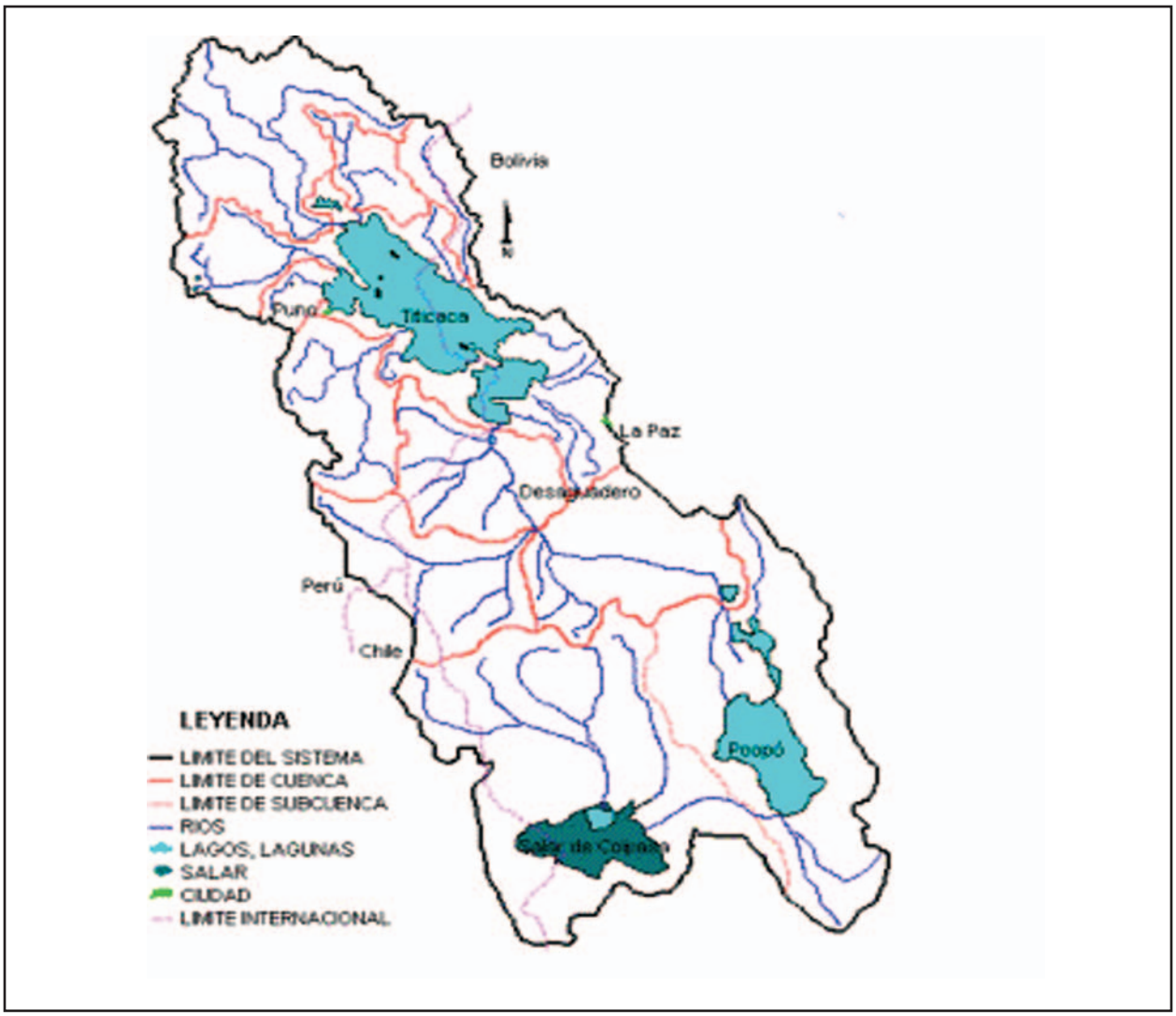

Figure 2. Lake Titicaca Drainage Basin

Lake Salar of Coipasa

catchment area (intermediate): 32,958 km^2

- average lake surface: 2,225 km^2
- average altitude: 3,657 m above sea level

Laca Jahuira river *(connects lake Poopo with lake Salar of Coipasa)*

- length: 130 km
- average slope: 0.2%

Lake Salar of Uyuni *(connected to lake Salar of Coipasa through the Negrojahuira "quebrada" of about 20 km long)*

catchment area (intermediate): 60,000 Km^2

- average lake surface: 12,000 Km^2
- average altitude: 3,653 m above sea level

The TDPS system is located in the Altiplano region. Its geographical limits are well defined by mountain systems. The Andes Range divides into two main ranges near Abra de la Raya, in southern Peru: the Occidental Range and the Oriental or Royal Range. The two ranges delimit the western and eastern portions of the Altiplano. The Oriental range separates the TDPS system from the neighbouring basins of Amazonia and Pilcomayo. The northern limit is the Carabaya range, that separates the TDPS system from the basin of the Madre de Dios River. In the south, the lnter-Salar mountains separate the TDPS system from the basin of lake Salar of Uyuni.

The Altiplano comprises a series of plains, mountain areas and a plateau called Puna. It has the characteristics of a closed basin. The highest point is Mount Sajama, which is 6,542 m above sea level, and the lowest point is Lake Salar of Coipasa, 3,653 m above sea level.

Because of the high altitude of the plateau, the climate is cold at night (8-10ºC year-round average) and is moderate during the daytime. Annual precipitation varies from 200 mm in the south to 1,400 mm in the northern part of the system, with the highest precipitation over Lake Titicaca. The thermal regulating effect of the lake make possible the development of many species of plants and animals and the establishing of indigenous communities.

Landscape and Drainage Area

The Lake Titicaca we know now is a remnant of what was the mega-lake Mantaro, which once covered most of the area of the *altiplano* at an altitude of almost 4000 meters above sea level. The age of this lake is not clearly established, but it is thought to have originated in the Quaternary Period. Due to the intense evaporation effects which are common in the *altiplano* this lake slowly reduced its size. The remnant of the Mantaro Lake was reactivated by the Caluyo glaciations which gave place to Cabana Lake to an altitude of 3900 meters. A consequence of the retreat of the glaciers was a drought which dried the immense mass of water of the lake. The remnants of Lake Cabana created lakes Ballivian and Escara. This phase reached its end because the rivers La Paz in the north and Pilcomayo in the south crossed the oriental range of the Andes and captured part of the altiplano basin. This meant that the waters of the Ballivian Lake drained toward the basins of the La Plata River and the Amazon River. Gradually two masses of water formed, one to the north and another to the south, connected by what later was the Desaguadero River. In a similar way, the desiccation process resulted in the formation of the salt lakes of Coipasa and Uyuni. During the two most recent periods of glacier growth and abundant precipitation, two more lakes were formed, Minchin and Tauca, 30,000 and 10,0000 years ago. At the end of the Tauca phase was developed what is now Lake Titicaca.

Geomorphology

The TDPS system constitutes a unity, where there are distinct plains, valleys and depressions, hills and plateaus of moderate slope, mountains and water surfaces. One-third of the area of the basin is occupied by mountains. Of this area, more than half are rounded mountains of volcanic origin. Colluvium deposits of foothills, moraine accumulations and river deposits occupy approximately 39 percent of the system. Another third of the area is occupied by typical units of the altiplano: plains of lake bed origin, depressions, and terraces. Particularly important are the wetlands, which are depressions where there is vegetation of great ecological importance.

The hills and plateaus are low mountain chains localized in the interior of the TDPS, which resulted from tectonic movements and are constituted in general, by sedimentary rocks. For practical purposes they form a single group and occupy almost a fifth of the region. Finally, it is necessary to mention the permanent water surfaces constituted by the lakes: Titicaca, Poopo, Uru Uru and other minor ones, which represent less than one-tenth of the region.

Ecosystems

The regional ecosystems of the TDPS basin can be classified in three large groups: Puna, Mountain and Aquatic.

The Puna ecosystem, which is developed from the shore of the lakes at an altitude of 3800-4000 meters. The area is located in the region called Puna, in which there are several ecological groups and landscapes: Humid Puna, Dry Puna, High Andean Semi-Desert Puna, High Andean Desert Grassland, Halophytic Prairie, High Andean Woodland and Big lakes of the Puna (micro-foliated forest) (Ribera, et al. 1994).

The Humid Puna ecosystem is defined by average annual rainfall of between 600 and 1000 mm, concentrated in the months of November to March. This rainfall is distributed in a topographical pattern that is more or less uniform between altitudes of 3000 and 4200 meters. The vegetation is characterized by the presence of hard gramineous disposed in clusters (*Stipa Ichu, Festuca* spp.) and low resinous bushes as well as several species of *Baccharis*. The mountain ranges are characterized by the presence of low bushes as the Khoa *(Satureja boliviana*), *Calceolaria parvifolia*, *Mutisia orbignyana*, several species of *Senecio*, *Adesmia miraflorensis*, and *Tetraglochin cristatum*. The Lamas (*Lama Lama*) stands out among the fauna, *Felis Jacobite*, small lizards (*Liolaemus multiformis*), snakes (*Tachimenes peruvianus*) and among the birds; (*Geositta punensis, G. cunicularia, Muscisaxicola rufivertex, Chloeophaga melanoptera*, *Phalcobaenus megalopterus*).

The Dry Puna ecosystem belongs to the southern part of the Humid Puna in the central highland, from Sica Sica and Patacamaya toward the south, adjacent to the Desaguadero River and Poopo Lake, to the vicinity of Quillacas, in the Department of Oruro, is characterized by progressive conditions of aridity toward the south. The annual line of 300 mm precipitation marks the south limit of this unit.

Mountain ranges and volcanic material plateaus are physiographically highlighted with saline and sandy blooming. The mountainous area from the inter-mountain ranges is uneven by the presence

of a series of temporary and permanent water courses. At the base of the mountain range a great piedmont deposit of wide surface has been formed where agricultural activities are developed.

The climate is oligorthermic with an average yearly range of 8-11° C. The pluvial rainfall in the region diminishes toward the south, with registrations that go from 400 mm to the 300 mm at the southern limit.

Vegetation is characterized by the presence of shrub formations (Tholares) of very resinous microfoliated leaves. Species of *Baccharis incarum* are pointed out, as well as the *Baccharis boliviensis*, *Parastrehia lepidophylla*, *Fabiana densa*. In some cases, these shrub formations reach up to a height of 2.5 meters. On some less cold microclimate hillsides, some cactus of the *Oreocereus* genus or cushion type such as the *Lobivia* sp. prosper.

Typical animals are the Quirquincho (*Chaetophractus nationi*), mice (*Auliscomys bolivienis*, *Ctenomys opimus*) and birds such as the Suri (*Pterocnemia pennata*) and *Buteo pocilochroos, Geositta punensis,* and *Muscisaxicola juninensis*.

Halophytic Prairie is not a zonal unit but is represented in several regions of the Dry Puna and Humid Puna. It is found adjacent to the Desaguadero River with scarce slope, composed by quaternary silts of saline soils. The vegetation is adapted to high concentrations of salts. Examples are the Cauchi (*Suaeda fruticosa var crassifolia*), *Hymenoxys*, *Salicornia pulvinata*, *Distichlis humil*is, *Anthobrryum triandrum*, *Parastrephia lucida* , *Triglochin maritima* and the *Muhlenbergia fastigiata*. These species do not form a continuous stratum of vegetation, but they appear like stains of dispersed cushions in the plain.

High Andean Woodland is characteristically bounded by Sajama National Park, where the micro foliated open trees that reach the highest elevations in the world are located, with the presence of the Keñua (*Polylepis tarapacana*), accompanied by the Tholas (*Baccharis incarum* and *Parastrephia lepidophylla*), as well as gramineous as the *Festuca* and *Calamagrostis* genus. Among the important wild fauna, the presence of the Vicuña (*Vicugna vicugna*) and the Suri (*Pteronegmia pennata*) are highlighted.

Wetlands correspond to herbaceous formations that are present as a tapestry of some centimetres high, dominated by species of the genus *Oxicloe* and *Distichia* and other grasses (CD- BOLIVIA 1997). These are ecosystems that are associated with bodies of water (rivers, streams and springs) of the whole High Plateau, they are very important as water reservoirs, especially in areas like the High Plateau where the hydrological deficit conditions are one of the main environmental restrictions. These areas are valuable because they are considered intensive shepherding zones for camelids (Llamas and Alpacas)

Aquatic ecosystems are: the rivers and lakes of the TDPS. Among the lakes the most important are: Titicaca, Poopo, Uru Uru , Coipasa Marsh and the lagoons of Soledad and Arapa.

Among the largest rivers are: Ramis, Ilave, Coata, Huancane, Suches, Tihuanacu and Keka in the Titicaca basin, Desaguadero, Mauri, Marques, Irpi Irpi,Umala, Ketho, Challa jahuira, Lauca y el Laca jahuira in the basin of TDPS .

The aquatic vegetation of Lake Titicaca presents in its banks a marshy vegetation characterized by the presence of the Totora (*Schoenoplectus californicus* ssp. t*atora* and *Juncus arcticus* ssp *andicola*), *Elodea potamogeton* and the *Myriophyllum quitensis*. In the deepest parts, there are several species of Chara and Potamogeton.

In Lake Poopo, salinity conditions are high, with species that cover 70% since its average depth is only 2.5 meters. *Chara popoensis, Potamogetum strictus, Myriophyllum elatinoides* and *Schoenoplectus californicus spp. tatora* are highlighted.

The fauna in both lakes is characterized by the presence of ducks *(Anas puna), A. flavirostris, A. georgica, Rollandia micropterum, Plegadis ridgwayi), Chocas (Fulica gigantea, Fulica americana*) and flamingos *(Phoenicoparrus sp.).*

Human History and Culture

The History of the TDPS region can be divided in three epochs: Before the Spanish, Colonial and Republican.

Before the Spanish

The evolution of the pre-Hispanic cultures in the area can be divided in five periods: the archaic, the formative, classic postclassical and Inca.

The Archaic period, from 8000-2000 BC, provides the first evidence of human occupation of the territory, from small groups of hunters and nomads who initiated the progressive occupation of this region. These groups are identified through stone instruments which were utilized in its various chores, as well as remains of paintings found in the walls of the caves.

The Formative period, from 1200 BC- 133 AD, was initiated with the appearance of the first sedentary communities, among them Tiahunacu I and II, Qaluyo and Chiripa, which were dedicated to agriculture and in lesser degree to rising of native animals .

The Classic period, from 133 - 1200 AD, is divided in three cultural horizons: Tiahuanacu III (133-375 AD), Tiahunacu IV (375-715 AD) and Tiahunacu V or Expansive (715-1200 AD). In this period the intensive agriculture and irrigation of the parcels were developed. Commerce was intensified, the society was stratified and the state was organized. Artisan and pottery works were developed and constructed with mud bricks and great temples and military fortifications were constructed as the city of Tiahuanacu.

The Postclassic or Post-Tiwanacu period, from 1200 –1300 AD, corresponds to the period of local states, represented by the Colla and Aymara civilizations, which extended all the way to Cusco in Peru and Chuquisaca in Bolivia. The most important Aymara communities in the *altiplano* were de Pacajes along the Desaguadero River and Charkas in the department of Oruro.

The Inca period, from 1430–1532 AD, was dedicated to conquering the adjacent civilizations like the Aymara. The Incas expanded their dominion in the 15th century to Chuquisaca and Tarija, now Bolivian departments. Later on, Huayna Kapac conquered the Cochabamba valley in Bolivia. The

Incas exploited the mineral wealth of the region, took advantage of the established raising farms of llamas and alpacas and other resources of the area.

Colonial period

This situation changed with the arrival of the Spanish in 1532. The land was divided in *encomiendas* and *repartimientos* (where the second is part of the first). Precious metals were exploited as a priority with heavy use of manpower. The Spanish introduced sheep and cattle, using the llamas like pack animals to transport minerals to the ports in the Pacific Ocean. A political administrative organization around urban centers was imposed.

Republican period, 1821-Present

With the liberation of the territories from the Spanish rule, incremental expropriation of the indigenous communities' land resulted in the formation of large properties owned by new landlords. This system of large haciendas remained until the application of the laws of agrarian reform of 1953 in Bolivia and 1969 in Peru.

These centuries of history have developed hostility and distrust in the indigenous population of the TDPS. Open market policies have reduced the prices of agricultural products. Also, the efforts of recent governments to provide infrastructure and services for the benefit of the cities have depressed the situation in rural areas even more. Nevertheless, there exists a great desire for a better living among the people of these areas which, if properly directed, could produce good results in the future.

As a result of improved communications infrastructure, from the point of view of ethnic characterization, the TDPS region is divided into three large areas: a Quechua zone in the north, an Aymara zone in the center, and a Quechua zone in the south. There also exists a Uro population distributed near Lake Titicaca in the Puno area of Peru, and at the Desaguadero River and Poopo Lake in Bolivia. In general, the population of the *altiplano* (TDPS) is indigenous. The mixed and occidental population is found in the cities and large towns.

Socio-economic Aspects

Distribution and urbanization of the TDPS population

From data of the last census, the total population of the TDPS is 2,781,862 inhabitants, of whom 1,636,174 live in urban centres and 1,151,494 in rural areas. Of the total, 1,079,849 persons live in the Peruvian sector and 1,158,937 in the Bolivian.

The percentage participation of the rural population in the total of the TDPS has been diminishing. The Peruvian sector passed from 68.2 percent in 1981 to 60.8 percent in 1993. In the Bolivian sector the rural population of the TDPS represents 42.7 percent of the total, while in 1976 was 52.4 percent in the La Paz Department and 48.9 percent in Oruro.

The principal urban centers in the Peruvian sector are Puno (96,827 inhabitants) and Juliaca (172,576); in the Bolivian sector are El Alto (506,792 inhabitants) and Oruro (183,422).

With the exception of the city of El Alto, Bolivia, the rate of population growth is less than the national average. In the sub-region of Puno, Peru, the rate for 1981-93 was 1.6 percent compared to a nationwide average of 2.1 percent. The same thing happened in La Paz and Oruro in Bolivia, where rates for the period 1976-92 were 1.66 percent and 0.58 percent respectively compared to 2.03 percent for the country as a whole. Growth rates in rural areas are even lower: 0.7 percent on the Peruvian side, and 0.53 percent in La Paz and 1.6 percent in Oruro. On the Peruvian side, the rural population remained stationary in the 1980s, while in the Bolivian sector the population diminished and is declining due to migration. Migration is mainly responsible for the urban population growth. In general, there is a tendency for people to move to the cities and towns.

Living conditions and poverty

The TDPS zone has the poorest people in both Bolivia and Peru. In the Peruvian sector, 39.8 percent of the population lives in poverty and 33.7 percent lives in extreme poverty, totalling 73.5 percent of the population who have not met their basic necessities. This situation is even worse for the rural population, where 41.1 percent lives in poverty conditions and 42.4 percent in extreme poverty, making a total of 83.5 percent. In Bolivia from statistics of 1976, 69.8 percent of the people in the rural areas, are below the poverty line and 28.7 percent fall below the line of extreme poverty. In 1988 the statistics indicated that the population in the poverty line were 67.4 percent and of extreme poverty 31.8 percent, indicating no improvement from what was shown in 1976-1988. On the other side, a study made by the Bolivian Ministry of Rural Affairs (MACA) and the JUNAC, following what was done by CEPAL in Mexico, found that in Oruro 64 percent of the population live under the subsistence line, 14 percent in conditions of subsistence, 12 percent in stationary conditions and only 10 percent over this line.

Employment, revenues and housing

In recent years, the TDPS has recorded a growth of the economically active population. In 1990, the growth was 39.2 percent in the Peruvian sector. It is estimated that the economically active population in the sub-region of Puno grew 83 percent between 1972 and 1990. In Bolivia this increment was 40 percent between 1976 and 1988 in the Department of La Paz.

The economically active population is largely concentrated in agricultural activities. It is estimated that in 1989 in the sub-region of Puno, 59.8 percent of the population were dedicated to agriculture and cattle raising, followed by participation in the services field (14.5%), commerce (10.6%) industry (7.8%) mining (2.47%), and construction (2,42%). In the same way in Bolivia, La Paz and Oruro Departments in 1988, 72.8 percent of the economically active population was dedicated to agricultural activities, followed by 7.09% in commerce, 4.3% in mining and 3.4% in the industry. But due to the poverty situation, the economically active population has been diminishing, and in its place commerce and services have grown.

The principal source of employment are the small family economic units which absorb laborers and members of the families involved as part of the business.

In part of the TDPS, the standard of living is one of the lowest in the two countries, with prevalent malnutrition among children. Income in rural zones is low. For example, the medium monthly income in Puno was $57 in 1987, representing 30 percent of income in urban areas and 40 percent of the national average income. Between 1975 and 1990, due to inflation, the minimum income lost 42 percent of its buying capacity in Puno, Peru.

Housing is a good indicator of the standard of living. In the rural sectors of the two countries , most of the housing is rustic, made with adobe, mud or stone walls, straw or corrugated iron roofs, and dirt floors. There are no services such as sewers, lights and garbage disposals. The situation is a little better in the small towns, but not by much. Services are concentrated in the cities and large towns, where coverage ranges up to 60 percent. This situation was somewhat improved in recent years. Sewage service in Puno reached 55.6 percent of the urban area and 31.1 percent in the rural sector, for an average of 41 percent in the sub-region.

Health and Morbidity

The principal health characteristics in the TDPS zone are elevated morbidity and mortality in infants and mothers. Child mortality is 89.9 per thousand in the Puno sub region, 95 per thousand in La Paz and 183 per thousand in Oruro. These values place the region among the highest infant mortality in Latin America, compared for example with values such as 94 in Haiti, 61 in Ecuador and 59 in Nicaragua. There is a high incidence of infectious sickness, especially respiratory and gastrointestinal.

Education

The levels of education in the TDPS are remarkably low, especially in the rural zones. For example global analphabetic in the sub region of Puno is 22.2 percent whereas in the rural Peruvian sector is 29% and 26.1% in the Bolivian. These numbers are elevated in comparison with the national average in Peru of 11.1 percent. Nevertheless it should be recognized that the analphabetic declined from 50% and 40% in the past decades to the present levels.

Productive activities

The primary sector continues to be the principal sector of the economy in the two countries. In Bolivia this sector represented 24.7 percent of the population, while in Peru the primary sector is less important, with 10.9 percent of the population.

High levels of contracted debt and services have reduced saving levels and created social inversion. The most deprived areas in the two countries are the ones in the TDPS region, where there are fewer options to receive credit. These priorities are preventing the solution of the chronic problems of the under-developed regions and increasing the poverty and deterioration of the environment.

The Agriculture, animal raising and fishing sectors are very important in the economy of the region. In the Peruvian sector of the TDPS, animal raising is predominant, while in the Bolivian sector, agriculture predominates. It is estimated that the area dedicated to agriculture in the Peruvian sec-

tor was 242,000 ha, of which in the last 12 years crops were harvested from 117,000 ha. (107,000 without irrigation and 10,000 with it). In the Bolivian sector, the extension is estimated as 385,000 has. of which in the last 12 years crops were harvested on an average of 165,000 ha. (150,000 ha. without irrigation and 15,000 ha. with it).

The principal product in the TDPS is potatoes, which account for 58 percent of gross income. Potatoes are followed by barley, oats and alfalfa, which represent altogether 22.1 percent of the production. Other products of some importance are quinua (5.9%), barley in grain (5.7%) and a tubercle named oca (3.4%)

The technological levels of production are low, characterized by a heavy use of the land, especially in the area around the Lake; scarce utilization of machinery, fertilizers, pesticides and improved seeds; and deficient administration. This situation is related to the low educational level, the lack of services and technical assistance, and inadequate production and commercialisation. Consequently, there are low crop yields and low production for the farmers.

Animal raising, rather than agriculture, is better developed in the Peruvian sector. The principal exploited species are cattle, sheep, alpaca, llama, pork and chickens. In addition, there are exploited cuyes (native rabbits), rabbits, and other minor species. From existing investigations, the average rural family in the Bolivian sector possesses: 2 cows, 24 sheep, a burro, 23 pigs, 3-4 chickens 6-8 cuyes, and a total of about ten alpacas and/or llamas.

Fishing is important in lakes Titicaca and Poopo. In Lake Titicaca, fishing is practiced in the coastal area. There are around 5,400 fishermen in the Peruvian sector and approximately 5,300 fishermen in the Bolivian sector of the lake basin. The principal species for fishing are: *karachi* and *ispi* among the native species and *pejerrey* among the introduced species. Trout was very important in the past but now it accounts for only 0.1% of the total extraction. It is exploited more in floating cages and fish farms. The more commercial species is pejerrey. The annual production is variable; from some statistics in Peru it is 6,290 tons and in Bolivia about 200 tons.

Forest production and vegetal resources

The actual forest production is of very low economic importance although there is future potential in trees and bushes. Nevertheless, there exists an intensive use of bushes for the production of fuel wood for domestic use.

Of the aquatic vegetal resources, there are two species of economic value: llachu with 3 varieties, Elodea potamogetum (yana or chancco llachu), Myriophyllum elatinoides (hinojo or waca llachu) and Patamogetum strictu (huichi huichi or chilca llachu) and the totora reeds, schoenoplectus tatora (green totora). These species are the base of the animal feeding and in low demand for human food and construction material.

Mining – Industry

Mining

Mining activity in the Peruvian sector has a moderate technical and equipment level, with relatively important production volumes. It is carried through exploitation of different sizes. There are a number of important micro enterprises or individuals who employ rustic technology. The principal mining products are tin, silver copper lead, zinc and gold. Besides the metallic mining exploitation, there are others of non metallic type for the cement industry, carbon, salt and construction gypsum.

In the Bolivian sector of the TDPS, mining has a big importance in the national production, nevertheless it has also had important falls in its contribution to the gross domestic product (GDP). The principal mineral products are zinc, lead, tin, silver and gold. Mining is principally dedicated to the exploitation of rich poly-metallic beds of the region, specially gold and tin. In the area also exists exploitations of non-metallic products for the cement industry phosphates, salt and construction gypsum.

Industry

Industrial activity, particularly agro industry, is very small in the TDPS. In the Peruvian sector, the manufacturing contributes 8.7 percent of the sub-regional GDP and occupied 7.8 percent of the economically active population. The majority of the industrial factories are in Juliaca, the city at the center of industrial activity in the sub-region. The most important activity is textile. Other industries of importance are the refreshment beverages and nonmetallic industries, which together absorb 90 percent of the labor force. In addition, there are a number of small establishments of artesian production which occupies more than 30,000 persons dedicated to the textile process of the alpaca fiber, which is an important product of nontraditional exportation. In Bolivia, it is noteworthy that the major part of industrial production is done out of the territory of the TDPS.

Tourism

For tourism and recreation, the region has an attractive socio-cultural and folkloric frame. Nevertheless, tourism is little developed. In the Peruvian sector, important centers are located in the cities of Puno and Juliaca, which have better hotel infrastructure. These cities are the base for the tourism fluxes to other centers such as July, Lampa, Huancane and Azangaro.

The city of Puno constitutes the major center of regional attraction, second after Cusco in Peru. In the Bolivian sector, the important centre is La Paz, a city that counts a large and varied hotel infrastructure. From there the fluxes go to other minor centers like Copacabana, Tiahuanacu and Oruro.

Altogether, the Titicaca region forms part of a tourism circuit which takes in the southeast part of Peru (Cusco-Puno) and the west-central part of Bolivia. Consequently, tourism development must be considered on a bi-national scale. Ecotourism is potentially important, but it will be necessary

beforehand to define a system of protected areas duly planned with minimum facilities for national and international visitors.

Eco-ethno tourism should ensure the maintenance of cultural authenticity and biological diversity. The participation of the local populations will allow the ethnic cultural re-appraisal, apart from strengthening its identity as an ordinary people. Vargas, 2002.

Due to the increased water flow of the Desaguadero River. Important floods occurred along the river, especially around lakes Uru-Uru and Poopo, affecting the city of Oruro.

2. Threats to the Sustainable Use of the Lake

The important problems of the TDPS system can be grouped into four main categories: physical problems caused by extreme weather events; problems derived from the deficient regulation of water resources; environmental degradation; and problems derived from socio-economic conditions.

Physical Problems

Climatic conditions of the *altiplano* region are characterized by a large degree of variability and the occurrence of extreme events. Frosts are a common problem in the region, but in some southern areas there are more than 300 days per year with frost (up to 313 days in Pamphuata). Freezing rain is also common, especially in northern areas in high altitudes; Quillisani, at 4600m above sea level, experienced during 1971-79 an average of 63 days per year with severe freezing rain. These severe extreme events limit traditional agricultural production.

Floods are becoming increasingly significant in the region. Increased average rainfall during the period 1984-90 produced an increase of water supplied into Lake Titicaca and caused severe floods affecting over 95,000 hectares around the lake. In 1986-87 the problem was further increased. Floods and droughts have caused serious damage to the TDPS system and its economy. Floods during 1985-86 caused estimated damage of $125 million ($41.2 million in the agricultural sector and $83.8 million to infrastructure). The severe drought of 1982-83 caused damage of $128 million ($105 million in crop production and $23 million in animal production). The 1989-90 drought caused damages mainly to crop production with estimated damages of $88.5 million.

Problems derived from the deficient regulation of the water resources

Adequate regulation of water resources in the *altiplano* is essential for both economic activities and natural resources. The main water body is Lake Titicaca, with a surface of 8,400 km^2 and a volume over 930 billion m^3. Although the size of the lake appears to guarantee water supply to the area, together, large problems arising from the poor regulation of its waters and the general TDPS system (the average water balance levels), make it necessary to further increase the inflow up to 14 m^3/s .

The main conclusion of this assessment is that the available current hydrological resources do not meet the demands in the system. Therefore it is essential to optimise resources in order to minimize deterioration and other negative impacts.

Currently, water from aquifers are not generally used. This is partly because a large portion of the deep wells are not operating due to lack of equipment and fuel. It is likely that these wells will become operational in the future. A positive consequence would be the lowering of the currently high water table, therefore decreasing evaporation. But operating deep perforations would have to be subject to control and regulations in order to guarantee that aquifers are not depleted.

The high basins of the TDPS system have numerous humid depressions, both natural and anthropogenic, close to the rivers and lakes; they are called *bofedales*. These humid areas play an important role in the system; they maintain valuable animal and plant resources, they provide pastures for animal production, and they play an important role in the hydrological balance. Uncontrolled exploitation of the groundwater can have many negative impacts in these important humid areas .

Environmental degradation

One of the most import problems of the *altiplano* region is soil erosion. Over a forth of the total area, amounting to 38,283 km^2, is highly vulnerable to erosion. There are three main causes of erosion: water, anthropic and eolith actions.

Current erosion levels and possible further intensification of erosion problems threaten agriculture in the region. Due to unfavourable climatic conditions in large portions of the region, the land available for agriculture is limited to an area of about 1.5 million hectares in the northwest *altiplano,* at an altitude of less than 4000 m and average precipitation greater than 500 mm/year. A direct consequence of erosion is the inflow of solid material to rivers, altering their morphology and equilibrium. In extreme cases, large quantities of solid material can alter the rivers or be the cause of lake formations, as happened in lakes Uru Uru and Soledad. In other cases, solid materials can be the cause of lake destruction, as is currently happening at Lake Poopo.

Lake Titicaca and its subsidiaries have salinity levels of less than 1 g/l. The first portion of the Desaguadero River, up to La Joya, has salinity levels of 1 to 2 g/l. From La Joya, the salinity level is over 2 g/l due to the influence of the subsidiaries. Salinity levels are further increased along the river. The southern parts of Lake Poopo are extremely salty with levels upon to 100 g/l.

Chemical, urban and industrial pollution is significant in the TDPS system, in both the rivers and sediments. The basin of Lake Titicaca is relatively non-polluted by heavy metals, although Puno is moderately polluted.

The first portion of the Desaguadero river, up to La Joya is moderately polluted by cadmium, arriving from the area of confluence with the river Mauri. The portion of the Desaguadero river from La Joya, and lakes Poopo and Uru-Uru are highly polluted by magnesium and heavy metals (Cd.,As. Co. Ni. Mn. Sb, Cu Zn, and Fe.). Sediments in the river Coata and in Puno are polluted with Cu, Cd, Mg, Zn, Ni and Co. Sediments are not polluting other rivers nor Lake Titicaca.

Natural ecosystems are endangered, resulting from the increased chemical, urban and industrial pollution. Heavy metal residues (Cd, Ni, As and Hg) are found in fish in Puno. Toxic products have induced malformation in fish from Lake Poopo.

The main sources of pollution by urban residual waters are the large cities of Puno, El Alto and Oruro, and to a lesser extent the towns of Juliaca, Ilave, Juli, Huancane and Desaguadero, although the problem is present in all towns of the *altiplano*.

Socio-economic factors

The economic recession that has affected Bolivia and Peru for the last decade has consequences in growth rates that were low and even negative in some years. This recession has occurred with more force in the TDPS and puts heavy pressure on the natural resources, especially soils, animal life and forests. To this situation could be added the losses caused to agriculture and animal raising due to big droughts and floods. Droughts and floods add to the loss of agriculture and animal raising.

In the increment of the population it is noticeable that in the coming years the rural population will have a tendency to remain stable in the TDPS, while the urban population could double. In the Bolivian sector, the rural population will continue the decreasing trend and the strong increment that is presenting the urban population will be due especially to the influence of the city of El Alto. In the Peruvian sector, the rural population has a tendency to a slight growth, , without considering the possibility that will also decrease as it happens in Bolivia, while the urban population will grow at a rapid rate.

The behavior of the rural economy, based in analysis made over the use of the land and the water and especially on the demographic evolution of the TDPS, permits forecasts in aspects such as changes in the area of agriculture, animal production stabilization, organization forms, and fishing activities.

Stabilization of animal production

The quantity of introduced species, particularly sheep and cattle, are the agents that cause damage to the natural pastures. Compaction of soil by cattle and intensive grazing by sheep have a serious impact in the environment. Nevertheless, there is a growing population of llamas and alpacas because of their commercial value and the growing interest of the communities in the exploitation of their meat and fiber. This interest should be endorsed by government institutions as well as private ones.

It is calculated that in some High Plateau communities, there are animal overloads that reach 30 percent. This value is in direct relationship to the erosion of the soil (Jordan, 1983). Satellite images indicate that in the High Plateau region of Oruro and Potosí there are some 5000 km^2 of sand banks caused by the over shepherding and agricultural activities. Excessive numbers of livestock have also evidenced problems in humid grasslands and wetlands that have caused the degradation of this type of vegetable formation. In many cases the wetlands have dried out.

Introduction of exotic species into water bodies

The introduction of exotic species to the basin of Titicaca lake like the Trout (S*almo truta*) in the decade of the years 1940 and of the Pejerrey (*Basilichtys bonaerensis*) in 1969 to Lake Poopo has created competition with the autochthonous icthic fauna to the point that it caused the extinction of the *Orestias cuvieri*. (Willwock, 1994). According to Loubens (1989) the catastrophe with the introduction of exotic fishes over the native ones, was the death toll caused by infestations to the *Orestias agassii* due to the protozoan parasite *Ichtyophitirius multifiliis* that in 1988 affected 70 percent of the annual native fishing . These had direct effects on the socio-economy of the Aymara and Uru indigenous population that live off the fishing.

The ecological consequences of the introduction of exotic fishes in relation to birds have not been investigated yet, but it is presumed that there are impacts from the disappearance of native fishes that provide food for many rare species of birds, these can be affected in their populations.

Fragmented agricultural parcels

In some areas of the *altiplano*, the excessive fragmentation of the land where rural families possess small and dispersed fragmented parcels, constitutes a difficulty for economic management. This system of property and exploitation causes a great loss of effort and resources and it is associated to high levels of poverty, constituting in a social problem. Consequently, it is important to help the formation of larger productive units, through the creation of agrarian associations or other forms of organizations.

Economic Capacity of the TDPS

The region of the TDPS is rich in resources: for mining activities, of fish for fishing and soils for agriculture. Important resources are being commercialised in the zones of economic integration like MERCOSUR or the Andean Community. These resources should be adequately and efficiently handled with the objective of reaching a better competitive advantage of their potential, which will permit them to receive the benefit of the integration in benefit of the TDPS population.

3. The Lake Titicaca Authority (ALT)

In the joint Presidential Declaration of 1955, subscribed among Bolivia and Peru, both presidents stated that because both countries have an indivisible condominium on the Titicaca lake's waters, they would be able to utilize them only by means of expressed agreement by both parts. They ordered the preparation of a Preliminary Study for the Use of its waters to a Binational Commission.

Then, in 1957 an expressed Agreement for such an end was signed, defining such condominium as indivisible and exclusive, agreeing that they must distribute the benefits of its use in equal shares, and establishing a compensation criteria in case there are bigger benefits for one country compared to the other.

The Peruvian Congress ratified these agreements in 1957, while the Bolivian Congress ratified them at the end of 1986. It must also be mentioned that parallel to the ratification of agreements, in a separate but coordinated way, both governments accomplished investigations and preliminary studies on the hydrologic balance of the lake.

With such intention, in 1984, the Presidents of the Peru, Fernando Belaúnde, and of Bolivia, Hernán Siles, the United Nations Organization proposed to make a technical assistance request to execute a hydro-meteorological integral study of the Titicaca lake basin, which might be used as a base to perform the rational and multiple use of the waters in benefit of both nations, when these, by common consent, decide doing it.

The Agreement for studies on Lake Titicaca resources was implemented in 1986, when both countries filed for European Union cooperation to finance and execute those studies. They were triggered by flooding occurred in that year. This cooperation concretized around 1991 and 1993 through the elaboration of a Binational Master Plan for the Control and Prevention of Floods, and for the Use of Resources of the TDPS Hydraulic System (Titicaca, Desaguadero, Poopó and the Salt plains of Coipasa).

Both countries approved the Binational Master Plan in 1995. It contemplates issues related to the use of resources of the lake's basin and also with the use of resources from the basins of the Desaguadero River, Lake Poopó and of Coipasa's Salt Lake, because it is a narrowly cross-linked system, with high risk of hydrologic vulnerability. It also considers measures for flood control and prevention on the area around Titicaca Lake, for environment preservation, and for the conservation of the system's biodiversity, recommending the establishment of a watershed authority which executes the Master Plan actions.

In this context, the creation and constitution of the Autonomous Binational Authority for the TDPS Hydraulic System was approved through an exchange of Diplomatic Notes between 1992 and 1996, defining its statutes and its economic and financial management regulations. This was ratified by the Congresses of both Republics between 1997 and 1999

Furthermore, a second phase has started in the application of binational agreements, through permanent consultations with the interested communities, mostly aboriginal. It considers International Agreements related to the issue such as ILO, and the Biodiversity Conservation one, including participation of the aboriginal population in decision making and the execution of works, which are mostly intended to contribute to economic and social development of the Bolivian and Peruvian *altiplano*.

Principal activities executed by ALT

Since the installation of the Binational Autonomous Authority of the TDPS Hydraulic System, (ALT), in 1996, with the economic contribution of the governments of Peru and Bolivia, in compliance with The Master Plan, the following actions have been performed with their respective investments:

Binational Works

a) Regulation Floodgates of Lake Titicaca: Executed between 1998 and 2001: 100%. Total cost: US$7,200,000.

b) Dredging of Desaguadero River in its Initial section: Executed between 2000 and 2002: material removed 1,500,000 m^3 (40 % of the project goal). Investment cost: US$ 4,800,000, to be executed between 2003 and 2005: 60 %. Cost to invest: USD $6,700,000.

Environment Preservation

a) Environmental zonification: Agreements with OEA and UNEP (PNUMA)

Elaboration of 12 Thematic Maps at 1:250,000 scale. Integration of maps through mathematical models

b) Lake Titicaca's Contamination Study: Agreements with IAEA

Agreement with the Andean Foment Corporation (CAF)

Sampling cruisers at the lake.

Analysis at biological, chemical and heavy metal laboratories

c) Facilities for Sewage Treatment: Sanitary sewage system in Desaguadero. Treatment Plants in Copacabana and Desaguadero

Binational Biodiversity Conservation Project

In 1994 Bolivia and Peru through their chancelleries applied for a joint petition to the United Nations Global Environment Fund (GEF) for the development of a Biodiversity Conservation Project in the Watershed of Lake Titicaca– Desaguadero– Poopo – and Coipasa Salt Lake (TDPS System). Between 1995 and 1997, through a consultancy contracted by the United Nations, the project's proposal was developed. In 1998 the agreement for the project was signed by the Bolivian and Peruvian governments and the United Nations.

The agreement with the UNDP/GEF contains provisions for

- Pilot programs in reed beds (*totorales*), peat bog *(bofedales)* and thola plants habitats;
- Rearing in semi captivity of suri, pisaca, giant frogs and ichthyic native species;
- Promotion and training of native communities;
- Hydro-biological resources;
- Evaluation of the pelagic mass of the lake; and
- Repopulating of native species.

Strategy of the Project

The project had a cost-benefit policy geared to face the global loss of the TDPS biodiversity. This was complementary to the activities of base line which faced directly de treat to the biodiversity through actions directed to eliminate the barriers for the sustainable use of the biodiversity resources. The actions were central in the demonstration of sustainable techniques for the management of the habitats and the endemic endangered species through pilot projects, increasing capacity of the stakeholders and local governments and strengthening of the management of the protected areas. In addition, it was to be elaborated a plan for the management of the biodiversity which will be the frame for the management of the protected areas. This plan will define evaluation policies for future investment in the region including the Binational Master Plan of the ALT.

Proposed alternative to continue with the project

In a recent evaluation made by GEF, the consultants proposed an alternative to the actual actions carried by the project, which was approved by the project committee, to redirect the project to the original plan .

The principal program and activities which are part of the proposed alternative are:

a) Sustainable use of the biodiversity in the Lake Titicaca basin through pilot projects:
   - Pilot programs and projects
   - An strategy to promote alternative income sources

b) Reinforce the biodiversity conservation in the Lake Titicaca basin:
   - Lake Titicaca National Reserve
   - Two new protected neighbour areas
   - Recuperation and reintroduction of key native species
   - Reduction of the treat to the aquatic biodiversity by the water contamination

c) Reinforce the technical and administrative capacity of the government and non- government institutions to plan, carry and monitor the biodiversity management and the conservation programs in the TDPS.
   - Managing Plan for the Biodiversity
   - Information campaign for biodiversity
   - Reinforcing of capacity for the sustainable use of the biodiversity
   - Reinforcing of the technical capacities of the government and NGO´s toward the sustainable use of the biodiversity
   - Reinforcing of the technical and administrative capacity of the ALT.

4. Lessons Learned

The lessons learned from this large process of the studies and negotiations between two countries oriented to the preservation and sustainable use of a shared hydraulic resource, for the regional importance for two countries, were collected in different instances. Steps like the ones listed below, are an example of the procedures, which could be followed by local organizations, regions and nations that share hydraulic resources:

- Define the juridical situation of the basin
- Carry out basic studies of the basin in a joint basis
- Obtain international assistance, if necessary
- Elaborate a Master Plan to determine the handling of the water resources and its use
- Establish a technical mix organisms (if possible) for the handling of the Master Plan
- Make the studies in a joint way and realize a system of geographic information. To define the positive or negative aspects which may happen in the future.

The conformation of mechanisms of coordination and permanent consultation with the interested stakeholders, in its majority from the area, which should participate in the decision making and the execution of the works specially of those oriented to contribute to the social and economic development of the TDPS.

Investigation areas

Projects which require international cooperation

According to the recommendations made by the Master Plan, it is convenient to perform continuous updates to the basic studies, which require permanent support from international and national experts and also provide funding to perform activities in conformity to what was established for ALT.

On the other hand, there is a feasibility project's database, aimed to consolidate ALT's work in regards to control and prevention of climate events, and on the sustainable use of natural resources of the Altiplano, directed to promote economic and social development of the TDPS water system. Among these the following must be outlined:

RESEARCH AND STRENGTHENING OF ALT	(US$ 000)
Implementation of a network of automatic meteorological stations all over the TDPS system	950
Formulation of a mathematical model to monitor contamination in Lake Titicaca and its affluents	500
Environmental zoning 1:25,000 of the TDPS Water Syste	600

Studies and monitoring of the environmental contamination at the TDPS Hydraulic System	800
ECONOMIC AND SOCIAL DEVELOPMENT	USD
La Joya Bifurcation works	5,000
Integral usage of Lake Titicaca's shores (5,000) Ha	
Minor communities sewage treatment with the use of micro phytical plants (reed beds or totora)	8,000
Implementation of Pilot integrated management of resources programs at the Huarina de Peñas watershed in Bolivia and the Zapatilla river in Peru	2,000
Use of hydro morphical areas on the rearing of camelids (3,200 Ha in 20 communities)	3,000
Promotion of tourism	2,800
Aquaculture and fisheries development of Lake Titicaca (10,000 Ha of reed beds for repopulating areas and 13,000 tones of native species extraction)	5,000

Efforts made for the conformation of capacities

The efforts made during the process of negotiations and studies between the two countries, oriented to the preservation and sustainable use of shared water resources have given place to the conformation of capacities in many fields: one to define the juridical situation of the basin; to claim resources from the international cooperation; made technical studies between the two countries; to establish common technical organization; to make works in joint basis. These efforts served to develop technical and institutional capacities to different levels.

Government, management, technical teams in different areas, relations with institutions and agencies to a sub regional, regional and national level, with the stake holders for the sustainable use of the resources and care of the environment. (seminars, courses, capacitation and involvement).

Participation of citizens and stake holders

For this purpose different channels were established depending of the degree of participation. In the case of citizens, in general, to inform them through different mediums (articles, publications, conferences, studies, reports and others) with the object to keep the media permanently informed about the negotiations, problems and situation of the project in general. For the case of the stakeholders in the basin, besides the information conveyed to the society, there are events for agreements, socialization, capacitation which permits to count with their support and involvement, as well as the development of local capacities for an effective capacitation in the design and imple-

mentation of programs to a sustainable and rational use of the resources of the basin contributing in this way to the improvement of the conditions and quality of life.

Institutional sustainability

There are agreements between Bolivia and Peru which made possible the conformation, for indefinite time, of a binational authority for the execution of The Master Plan For Flood Prevention and Resource Management in the TDPS.

The Binational Authority has different levels of coordination with the states (congress), the governments (secretaries of state) and other regional instances (prefectures, municipalities), in an special way, the indigenous communities, who in the case are the stakeholders of the TDPS, other institutions public, academic and private, and the general the civil society. This is the frame in which the Authority develops its work.

Monitoring

The monitoring as a system made it possible to compile and elaborate data during the execution of the project, and based in aspects of the plan, to establish clear priorities. Among the priorities are: the environmental conditions of the lake; activities supporting the management goals of the TDPS basin; human activities; natural events and its effects; which made it possible to relate the information with the monitoring, for the decision making.

Indicators

The indicators have a fundamental role giving information on which and what measurement through the activities of the project or external influence have resulted in transformations, like: the situation of native species related to invasive species (increment of diminution among others). water pollution (mining and its components and urban); indicators over the water resource for the rational use of the water; environmental indicators ,which permits know changes or results in the systems.

Previous Studies and Information Available

The Binational Master Plan was based on a wide range of studies in the area, including: geomorphology; climatologic; hydrology; hydro-geology; hydro-chemistry and pollution; fluvio-morphology; soils; soil cover and erosion; natural resources; and topography.

The analysis and evaluation of data from previous studies has been a important part of the work and source of information for the specific project of the Binational Master Plan.

Previous studies were divided into two main groups:

Sector studies: climatologic, hydrology, hydro-geology, hydraulic
Socio economy, agriculture and fishing.

Land-cover studies: cartography, topography and thematic maps (soils, vegetation, geology, etc).

The selection of meteorological and hydrometric sites and the development of data base were based on previous information:

Meteorological database (precipitation, temperature, evaporation, wind speed, etc.) .

Hydrometric database (river flow, level of lake Titicaca, solid transport and water quality). The characteristics of each hydrometric station were described and evaluated.

An important source of information was found in the existing libraries in Lake Titicaca Special Project (PELT) Peru and PELT Bolivia. These libraries provided an informative database that included the existing studies in the area. Additional sources of information were the National Meteorological and Hydrological Offices of Peru and Bolivia (Servicio Nacional de Metereologia e Hidrologia, SENAMHII). Each Basic Study incorporated a critical evaluation of the specific data used.

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