Lake Titicaca

Experience and Lessons Learned Brief

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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 (Figure 1). Through good management, the system can be regulated for the benefit of the people who live in the region.

1.1 Territorial Scope

Areas covered in this report include 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' S and between longitude 66°21' to 71°07' W. The total area of the system is 143,900 km² which includes the sub-region Puno in Peru and the cities of La Paz and Oruro in Bolivia. Characterisitic of the individual components of the TDPS system are presented in Table 1. The Desaguadero River comprises the following main sections: from km 0 to km 63 are wide plains, from the international bridge to Nazacara; from km 63 to km 226 is a mountainous area, from Nazacara to Chilahuala; and from km 226 to km 398 there are flood plains, from Chilahuala to Lake Poopo. Laca Jahuira River connects Lake Poopo with Lake Salar of Coipasa.

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

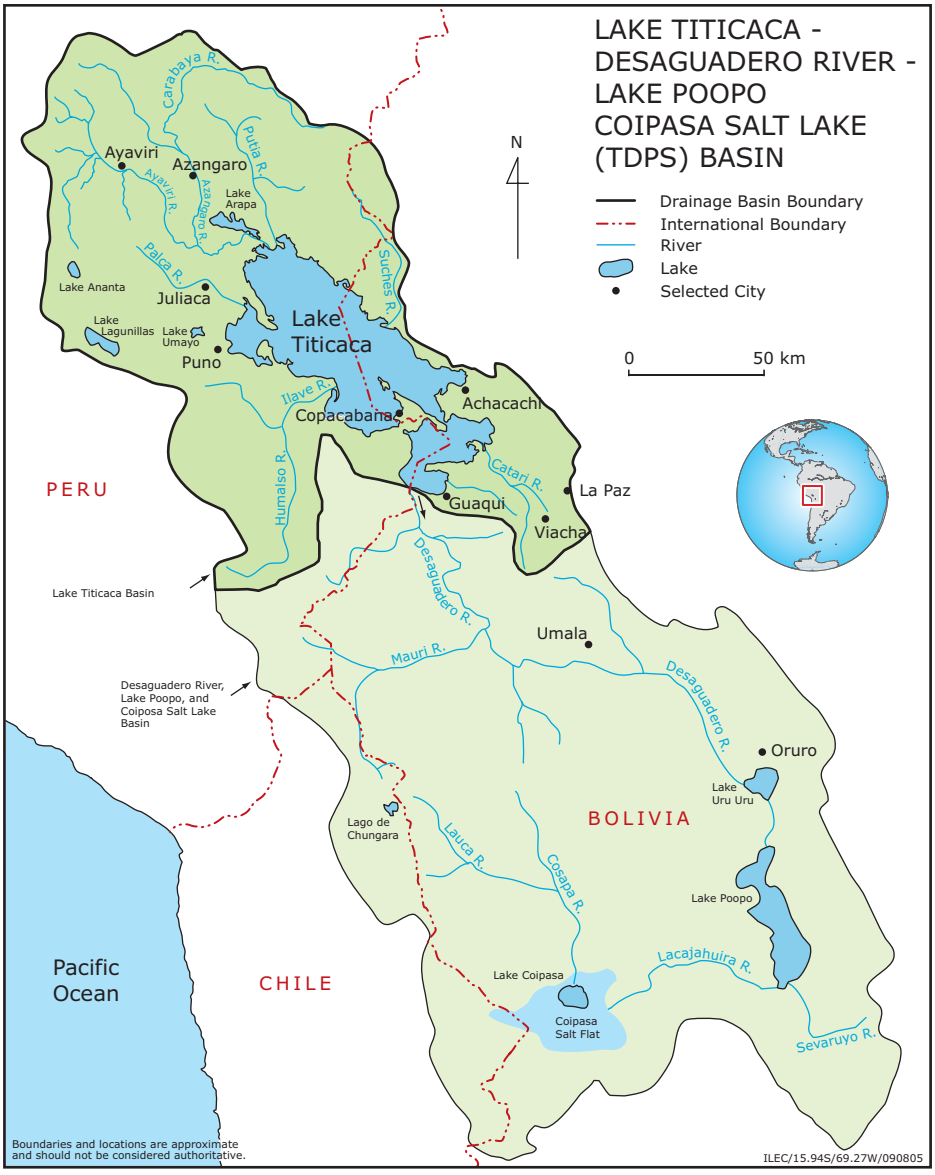

Figure 1. The Lake Titicaca/Desuguadero River/Lake Poopo/Lake Salar of Coipasa Basin.

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 neighboring 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 Inter-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 asl, and the lowest point is Lake Salar of Coipasa, 3,653 m asl.

Because of the high altitude of the plateau, the climate is cold at night (8-10°C 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 makes possible the development of many species of plants and animals and the establishing of indigenous communities.

1.2 Formation of the TDPS System

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 4,000 m asl. 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 in size. The remnant of the Mantaro Lake was reactivated by the Caluyo glaciations which gave place to Lake Cabana to an altitude of 3,900 m asl. 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 Lake Ballivian 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 is now 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 10,000 years ago. What is now Lake Titicaca developed at the end of the Tauca phase.

1.3 Geomorphology

The TDPS system constitutes a unified geomorphological system, where there are distinct plains, valleys and depressions, hills and plateaus of moderate slope, and 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 which form foothills, moraine accumulations and river deposits occupy approximately 39% of the system. Another third of the area is occupied by typical geomorphological 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.

1.4 Ecosystems

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

The Puna ecosystem is developed from the shore of the lakes at an altitude of 3,800-4,000 m asl. 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 600-1,000 mm, concentrated in the months of November to

Table 1. Characteristics of the TDPS System.

	Catchment Area (km^2)	Lake Area (km^2)	Average Altitude (m)	Length (km)	Average Volume (km^3)	Average Slope (%)
Lake Titicaca	56,270	8,400	3,810		930	
Desaguadero River	29,843			398		0.45
Lake Poopo	24,829	3,191	3,686			
Laca Jahuira River				130		0.2
Lake Salar of Coipasa	32,948	2,225	3,657			

March. This rainfall is distributed in a topographical pattern that is more or less uniform between altitudes of 3,000 and 4,200 m asl. 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 llamas (*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 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.

Temperature has an average yearly range of 8-11ºC. The pluvial rainfall in the region diminishes toward the south, with registrations that go from 400 mm to 300 mm at the southern limit.

Vegetation is characterized by the presence of shrub formations (*Tholares*) of very resinous micro-foliated leaves. Species of *Baccharis incarum* are pointed out, as well as *Baccharis boliviensis*, *Parastrehia lepidophylla* and *Fabiana densa*. In some cases, these shrub formations reach up to a height of 2.5 m. 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 humilis*, *Anthobrryum triandrum*, *Parastrephia lucida*, *Triglochin maritima* and *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 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 centimeters 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).

The main 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, and Desaguadero, Mauri, Marques, Irpi Irpi, Umala, Ketho, Challa Jahuira, Lauca, and Laca Jahuira in the non-Titicaca part of the TDPS basin.

The aquatic vegetation present on the banks of Lake Titicaca is a marshy vegetation characterized by the presence of the totora (*Schoenoplectus californicus ssp*. and *Juncus arcticus ssp*.), *Elodea potamogeton* and *Myriophyllum quitensis*. In the deepest parts, there are several species of *Chara* and *Potamogeton*.

In Lake Poopo, salinity conditions are high. Its shallow average depth of 2.5 m means that species that cover 70% of the area. *Chara popoensis*, *Potamogetum strictus*, *Myriophyllum elatinoides* and *Schoenoplectus californicus spp*. are common.

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.*).

1.5 Human History and Culture

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

1.5.1 Before the Spanish

The evolution of the pre-Hispanic cultures in the area can be divided in five periods: Archaic, 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 the region. These groups are identified through stone instruments which were utilized in 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 to a lesser degree, the 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 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 at 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 the Pacajes along the Desaguadero River and the Charkas of Oruro.

The Inca period, from 1430–1532 AD, was dedicated to conquering the adjacent civilizations such as the Aymara. The Incas expanded their dominion in the 15th century to Chuquisaca and Tarija, now Bolivian states. 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.

1.5.2 Colonial Period

The 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 as pack animals to transport minerals to the ports in the Pacific Ocean. A political administrative organization around urban centers was imposed.

1.5.3 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 population of Uro 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 is indigenous. The mixed and occidental population is found in the cities and large towns.

1.6 Socio-economic Aspects

1.6.1 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 centers and 1,151,494 in rural areas. Of the total, 1,079,849 persons live in the Peru and 1,158,937 in Bolivia.

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). The percentage of population in rural areas in the total TDPS has been decreasing. In the Peruvian sector, it has decreased from 68.2% in 1981 to 60.8% in 1993. In the Bolivian sector, the rural population of the TDPS represents 42.7% of the total, while in 1976 it was 52.4% in the state of La Paz and 48.9% in Oruro.

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% compared to a nationwide average of 2.1%. The same trend occurred in La Paz and Oruro in Bolivia, where rates for the period 1976-92 were 1.66% and 0.58% respectively compared to 2.03% for the country as a whole. Growth rates in rural areas are even lower: 0.7% on the Peruvian side, and 0.53% in La Paz and 1.6% 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.

1.6.2 Living Conditions and Poverty

The TDPS zone has the poorest people in both Bolivia and Peru. In the Peruvian sector, 39.8% of the population lives in poverty and 33.7% lives in extreme poverty, totalling 73.5% of the population who have not met their basic necessities. This situation is even worse for the rural population, where 41.1% lives in poverty conditions and 42.4% in extreme poverty, making a total of 83.5%. In Bolivia from statistics of 1976, 69.8% of the people in the rural areas are below the poverty line and 28.7% fall below the line of extreme poverty. In 1988 the statistics indicated that the population below the poverty line were 67.4% with 31.8% in extreme poverty, 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% of the population live under the subsistence line, 14% in conditions of subsistence, 12% in stationary conditions and only 10% over this line.

1.6.3 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% in the Peruvian sector. It is estimated that the economically active population in the sub-region of Puno grew 83% between 1972 and 1990. In Bolivia this increment was 40% between 1976 and 1988 in the state 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% 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 in the states of La Paz and Oruro in 1988, 72.8% 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 sources 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 US$57 in 1987, which is 30% of the income in urban areas and 40% of the national average income. Between 1975 and 1990, due to inflation, the minimum income lost 42% of its buying capacity in Puno.

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, with straw or corrugated iron roofs and dirt floors. There are no services such as sewers, lights and garbage disposal. 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%. This situation was somewhat improved in recent years. Sewage service in Puno reached 55.6% of the urban area and 31.1% in the rural sector, for an average of 41% in the sub-region.

1.6.4 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 subregion, 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 respiratory and gastrointestinal disease.

1.6.5 Education

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

1.6.6 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% of the population, while in Peru the primary sector is less important, with 10.9% 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.

In 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 sector was 242,000 ha, of which in the last 12 years crops were harvested from 117,000 ha (107,000 ha without irrigation and 10,000 ha with irrigation). In the Bolivian sector, the extension is estimated as 385,000 ha 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 irrigation).

The principal product in the TDPS is potatoes, which account for 58% of gross income. Potatoes are followed by barley, oats and alfalfa, which represent altogether 22.1% 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 commercialization. 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 metric tons and in Bolivia about 200 metric tons.

1.7 Forest Production and Floral Resources

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

Of the aquatic floral 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 are in low demand for human food and construction material.

1.8 Mining and Industry

1.8.1 Mining

Mining activity in the Peruvian sector is done at a moderate technical and equipment level, with relatively important production volumes. 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 metallic mining exploitation, there is mining of non-metallic materials such as carbon, salt and construction gypsum done for the cement industry,

In the Bolivian sector of the TDPS, mining has significant importance in the national production, but there has been a decline 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 there is also exploitation of non-metallic products such as phosphates, salt and construction gypsum.

1.8.2 Industry

Industrial activity, particularly agro-industry, is very small in the TDPS. In the Peruvian sector, manufacturing contributes 8.7% of the sub-regional GDP and occupied 7.8% 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 manufacturing. Other industries of importance are refreshment beverages and nonmetallic industries, which together absorb 90% of the labor force. In addition, there are a number of small establishments of artesian production which occupy 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.

1.9 Tourism

For tourism and recreation, the region has an attractive socio-cultural and folkloric appeal. Nevertheless, tourism is poorly 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 tourist visits 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 center is La Paz, a city that has a large and varied hotel infrastructure. From there, visitors go to other minor centers like Copacabana, Tiahuanacu and Oruro.

Altogether, the Titicaca region forms part of a tourism circuit which takes in the southeastern 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 and implement a system of protected areas that are well 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 local population will allow the ethnic cultural re-appraisal, as well as the strengthening of the identity of the people (Vargas 2002).

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.

2.1 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: 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 4,600 m asl, experienced an average of 63 days per year with severe freezing rain during 1971-79. 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 ha 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 US$125 million (US$41.2 million in the agricultural sector and US$83.8 million to infrastructure). Due to the increased water flow of the Desaguadero River, major floods have occurred along the river, especially around lakes Uru-Uru and Poopo, affecting the city of Oruro.

The severe drought of 1982-83 caused damage of US$128 million (US$105 million in crop production and US$23 million in animal production). The 1989-90 drought caused damages mainly to crop production with estimated damages of US$88.5 million.

2.2 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 km^3. Although the size of the lake appears to guarantee water supply to the area, 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 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, groundwater 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 wells 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.

2.3 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 unfavorable climatic conditions in large portions of the region, the land available for agriculture is limited to an area of about 1.5 million ha in the northwest altiplano, at an altitude of less than 4,000 m asl and average precipitation greater than 500 mm/yr. 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 saline 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 unpolluted 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 Mauri River. 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 Coata River and in Puno are polluted with Cu, Cd, Mg, Zn, Ni and Co. Sediments pollution is not thought to be a problem with other rivers or 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. These 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.

2.4 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 should be added the losses caused to agriculture and animal raising due to severe droughts and floods.

In coming years it is anticipated that 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 current decreasing trend and the strong growth present in the urban population will continue especially due to the influence of the city of El Alto. In the Peruvian sector, the rural population has a tendency toward a slight growth, without considering the possibility that it will also decrease as has happened in Bolivia, while the urban population will continue to grow at a rapid rate.

The behavior of the rural economy, based on analysis of land and water use and demographic evolution of the TDPS, indicates changes are likely in the area of agriculture, animal production stabilization, organization forms, and fishing activities.

2.4.1 Stabilization of Animal Production

The introduction of animal species, particularly sheep and cattle, has caused damage to natural pastures. Compaction of soil by cattle and intensive grazing by sheep have a serious impact on 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%. 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 5,000 km² of sand banks caused by overgrazing and agricultural activities. Excessive numbers of livestock have also resulted in problems in humid grasslands and wetlands that have caused the degradation of these types of vegetation formations. In many cases, the wetlands have dried out.

2.4.2 Introduction of Exotic Species into Water Bodies

The introduction of exotic species to the basin of Lake Titicaca such as trout (*Salmo truta*) during the 1940s and of the pejerrey (*Basilichtys bonaerensis*) in 1969 to Lake Poopo has created competition with the autochthonous fish fauna to the point that it has caused the extinction of *Orestias cuvieri* (Willwock 1994). According to Loubens (1989), the death toll caused by infestations to the *Orestias agassii* due to the protozoan parasite *Ichtyophitirius multifiliis* that in 1988 affected 70% of the annual native fishing was related to exotic species. This had direct effects on the socio-economy of the Aymara and Uru indigenous populations 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.

2.4.3 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 is associated with 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.

2.4.4 Economic Capacity of the TDPS

The region of the TDPS is rich in resources for mining activities, fish for fishing and soils for agriculture. Important resources are being commercialized 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 and wider benefit to the TDPS population.

3. The Lake Titicaca Authority (ALT)

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

In 1957 an agreement for such an end was signed, defining such condominium as indivisible and exclusive, agreeing that the parties must distribute the benefits of its use in equal shares. The agreement established 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 carried out 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, requested the United Nations to provide technical assistance to execute a hydro-meteorological study of the Lake Titicaca basin. This was to be used as a base for deciding the rational and multiple use of the waters for the benefit of both nations.

An 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. This was triggered by flooding that occurred in that year. This cooperation was made concrete 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.

Both countries approved the Binational Master Plan in 1995. The plan covers issues related to the use of resources in the whole TDPS basin rather than just Lake Titicaca, because the system as a whole is narrowly cross-linked with high risk of hydrologic vulnerability. The plan also considers measures for flood control and prevention on the area around Lake Titicaca, for environment preservation, and for the conservation of the system's biodiversity, and recommends 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, which defined its statutes and its economic and financial management regulations. This was ratified by the Congresses of both Bolivia and Peru 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). This phase considers international agreements related to the issues such as those covered by the International Labor Organization (ILO) and the Biodiversity Conservation including participation of the local indigenous communities 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.

3.1 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:

3.1.1 Binational Work

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

- 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%. Total cost: US$6,700,000.

3.1.2 Environment Management

- Environmental zonification: Agreements with OEA and UNEP (PNUMA); Elaboration of 12 Thematic Maps at 1:250,000 scale. Integration of maps through mathematical models.

- Lake Titicaca's Contamination Study: Agreements with IAEA; Agreement with the Corporación Andina de Fomento-(CAF); Sampling cruisers for use at the lake; Analysis at biological, chemical and heavy metal laboratories.

- Facilities for Sewage Treatment: Sanitary sewage system in Desaguadero; Treatment Plants in Copacabana and Desaguadero.

3.2 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 TDPS basin. 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 bogs (*bofedales*) and thola plant habitats;
- Rearing in semi-captivity of suri, pisaca, giant frogs and native fish species;
- Promotion and training of native communities;
- Hydro-biological resources;
- Evaluation of the pelagic mass of the lake; and,
- Repopulating of native species.

3.2.1 Strategy of the Project

The project had a cost-benefit policy geared to deal with the global loss of the TDPS biodiversity. This was complementary to baseline activities which dealt directly with biodiversity through actions to eliminate the barriers to the sustainable use of biodiversity resources. Central actions included:

demonstrating sustainable techniques for the management of habitats and 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, a plan for the management of the biodiversity which will frame the management of protected areas was to be elaborated. This plan will define evaluation policies for future investment in the region including the Binational Master Plan of the ALT.

3.2.2 Proposed Alternative to Continue with the Project

In a recent evaluation made by the GEF, 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:

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

- Reinforce the biodiversity conservation in the Lake Titicaca basin including: Lake Titicaca National Reserve; two new protected neighbor areas; recuperation and reintroduction of key native species; and reduction of the treat to the aquatic biodiversity by the water contamination; and,

- Reinforce the technical and administrative capacity of the government and non-government institutions to plan, carry out and monitor the biodiversity management and the conservation programs in the TDPS including: 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; and reinforcing of the technical and administrative capacity of the ALT.

4. Lessons Learned

The lessons learned from this process of the studies and negotiations between two countries oriented to the preservation and sustainable use of a shared water 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 water 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 of organizations (if possible) for the handling of the Master Plan; and,
- Make the studies in a joint way and develop a geographic information system to help define the positive or negative aspects which may happen in the future.

The development of mechanisms for coordination and permanent consultation with the interested stakeholders is important. These parties should participate in the decision making and the execution of the project, especially those activities oriented to contribute to the social and economic development of the TDPS.

4.1 Efforts Made for the Joint Development 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 joint development of capacities in many fields: to define the juridical situation of the basin; to seek resources from the international cooperation; to make technical studies between the two countries; to establish common technical organization; and to make works on a joint basis. These efforts served to develop technical and institutional capacities to different levels.

4.2 Participation of Citizens and Stakeholders

A series of different channels were established for the participation of citizens and stakeholders depending of their degree of participation. In the case of citizens, in general, the goal was to inform them through different media (articles, publications, conferences, studies, reports and others) with the object to keep the news media permanently informed about the negotiations, problems and situation of the project in general. For stakeholders in the basin there are events for agreements, socialization, and capacity building, which support their involvement, as well as the development of local capacities for effective involvement in the design and implementation of programs. These actions allow citizens and stakeholders to contribute to the sustainable and rational use of the basin resources, thereby contributing to the improvement of the conditions and quality of life.

4.3 Institutional Sustainability

There are agreements between Bolivia and Peru which made have made possible for the Binational Authority to undertake the execution of the Master Plan for Flood Prevention and Resource Management in the TDPS. The Binational Authority undertakes coordination at a variety of levels including with the states within each country (Congress), the Governments (Secretaries of State) and other government structures in the region (prefectures, municipalities), and also in a special way with the indigenous communities who are major stakeholders of the TDPS basin. In addition, the Binational Authority works with other public, private and academic institutions, as well as, the broader civil society and media.

4.4 Monitoring

The monitoring system has made it possible to compile and elaborate data during the execution of the project and to establish clear priorities with regard to the plan. Among the priorities for monitoring are: the environmental conditions of the lake; activities supporting the management goals of the TDPS basin; human activities; and natural events and their effects.

4.5 Indicators

Indicators have a fundamental role in developing and collecting information on activities of the project and external influences that have resulted in transformations in the project area such as the status of native species versus invasive species, water pollution from urban and mining related sources. Indicators concerning the rational use of the water resources and environmental indicators which permit knowledge of changes or results in the monitored systems are also important.

4.6 Previous Studies and Information Available

The Binational Master Plan was based on a wide range of studies in the area, including: geomorphology; climatologic; hydrology; hydrogeology; hydrochemistry and pollution; fluviomorphology; soils; soil cover and erosion; natural resources; and topography.

The analysis and evaluation of data from previous studies has been an important part of the work and a major source of information for development of the Binational Master Plan. These studies were divided into two main groups:

- Sector studies: climatologic, hydrology, hydro-geology, hydraulic, socio-economic, agricultural and fishing; and,
- Land-cover studies: cartography, topography and thematic maps (soils, vegetation, geology, etc).

The selection of meteorological and hydrometric sites and the development of a database were based on previous information:

- Meteorological database (precipitation, temperature, evaporation, wind speed, etc.); and,
- Hydrometric database (river flow, level of Lake Titicaca, solid transport and water quality).

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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